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Original Article

Influence of *Azadirachta indica* and *Tagetes erecta*-Based Organic Amendments on Crop Growth

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Abstract *- Excessive dependence on inorganic fertilizers in vegetable cultivation has raised serious issues such as soil degradation, declining microbial activity, and long-term sustainability. This study examined the potential of neem seed cake (Azadirachta indica) and marigold (Tagetes erecta) whole-plant powder, applied singly and in combination, as organic soil amendments to enhance the growth, flowering, and physiological performance of Solanum melongena L. (brinjal). The experimental layout followed a completely randomized design (CRD) with five treatment levels: untreated control (T0), recommended NPK fertilizer (T1), marigold powder (T2), neem seed cake (T3), and a combined marigold–neem amendment (T4). Measurements of vegetative growth, flowering characteristics, relative water content (RWC), chlorophyll content, net photosynthetic rate and fruiting were performed following standard protocols. The NPK treatment produced the greatest improvement across most measured traits, recording the maximum plant height (84.7 cm), biomass (91.6 g plant^{-1}), chlorophyll content (2.92 mg g^{-1} FW), and net photosynthetic rate (19.6 µmol CO_2 m^{-2} s^{-1}). Among the organic treatments, the combined marigold–neem amendment consistently outperformed the individual amendments, producing plant growth, flowering performance, chlorophyll accumulation, and photosynthetic activity that closely approached those obtained with inorganic fertilization. The study revealed that integration of marigold biomass and neem seed cake can be a sustainable alternative to synthetic fertilizers, contributing effectively to plant growth and soil health.*

Keywords *- Azadirachta indica, Botanical soil amendments, Integrated nutrient management, Solanum melongena, Tagetes erecta.*

1. Introduction

Vegetable production systems worldwide are experiencing great pressure to supply high-quality food to an increasing population while reducing the environmental impacts arising from intensive agricultural practices. Brinjal (*Solanum melongena* L.) is one of the most extensively cultivated Solanaceous species among vegetable crops, predominantly in the South and Southeast Asian region due to its nutritional and economic significance, as well as its ability to adapt to diverse agro-climatic conditions [1][2].

Achieving optimum productivity in brinjal cultivation, however, largely depends on effective nutrient management without compromising long-term soil health. Conventional vegetable production systems have relied primarily on the extensive use of chemical fertilizers to maximize yield; nonetheless, their constant and excessive application has led to deteriorated soil quality, nutrient imbalance, decreased soil-microbial diversity, increased production cost and depleted groundwater resources. These challenges have become the basis for the search for an alternative environmentally sustainable strategy for nutrient management.

Sustainable agricultural methods efficiently integrate organic amendments as they help to maintain soil characteristics, stimulate beneficial microbial activity, augment nutrient use-efficiency, and provide a gradual, consistent supply of required macro- and micronutrients throughout the crop life cycle. As compared to inorganic chemical fertilizers, plant-derived organic nutrient sources decompose progressively, hence synchronising nutrient availability with crop demand, simultaneously improving soil structure, water-holding capacity and thus rhizosphere functioning. Hence, there is more stress on the utilization of locally available botanical residues as nutrient sources since they are cost-effective and can limit the use of synthetic fertilizers without compromising crop performance [3].

Among plant-derived organic amendments, neem (*Azadirachta indica* A. Juss.) seed cake has drawn significant interest for its dual role as a nutrient source and a natural bioprotectant [4]. After extraction of oil from neem seeds, residual neem seed cake is obtained, which contains appreciable amounts of nitrogen, phosphorus, potassium, calcium, sulfur, and several micronutrients that are gradually

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mineralized following soil incorporation [5]. Unlike readily soluble inorganic fertilizers, the slow decomposition of neem cake ensures a sustained nutrient supply throughout crop development and reduces loss of nutrients through leaching [6][7]. In addition to its fertilizing value, neem seed cake contains biologically active limonoids, including azadirachtin, nimbin, and salannin, which exhibit insecticidal, nematicidal, and antifungal properties. These bioactive constituents contribute to healthier rhizosphere conditions by suppressing several soil-borne pests and pathogens, thereby indirectly improving root growth, nutrient acquisition, and overall crop performance.

Another promising botanical resource is marigold (*Tagetes erecta* L.), a widely cultivated ornamental botanical species that has gained recognition for its potential application in sustainable crop production [8][9]. Besides contributing organic matter, marigold biomass is rich in carotenoids, flavonoids, phenolic compounds, and sulfur-containing thiophenes, showing antimicrobial, nematicidal, and allelopathic activities [10]. Following incorporation into soil, decomposing marigold residues improve soil organic carbon status, stimulate beneficial microbial communities, and provide essential nutrients necessary for plant development [11]. Existing literature has also established that marigold-based amendments can improve soil biological activity and suppress plant-parasitic nematodes, making them attractive components of integrated nutrient and soil health management strategies [12]. Nevertheless, despite these recognized benefits, the agronomic potential of marigold biomass as a direct organic amendment for vegetable crops remains comparatively underexplored.

Although neem seed cake and marigold biomass have individually demonstrated beneficial effects on crop productivity and soil quality, studies evaluating their combined application remain extremely limited, particularly in brinjal cultivation [8][9]. The complementary characteristics of these two botanical amendments suggest the possibility of synergistic interactions, whereby neem seed cake provides a sustained supply of nutrients while marigold biomass contributes additional organic matter and bioactive compounds capable of improving soil biological activity. Such integration may enhance vegetative growth, flowering behaviour, and physiological performance beyond that achieved by either amendment alone. However, experimental evidence directly comparing their individual and combined effects under identical field conditions is still scarce, thereby limiting their practical recommendation as sustainable alternatives to conventional fertilization practices.

Accordingly, the current research was carried out to analyze the impact of neem seed cake, marigold whole-plant powder, and their combined application on the vegetative growth, flowering characteristics, and physiological responses of brinjal under field conditions. The performance of these organic amendments was compared with both an untreated control and the recommended inorganic NPK fertilizer. It was postulated that the combined application of neem seed cake and marigold biomass would produce a complementary effect by improving the supply of nutrients and plant physiological performance, thereby narrowing the performance gap between organic and conventional inorganic fertilization.

To bridge the existing knowledge gap, the present investigation was undertaken to assess the effectiveness of two plant-derived organic amendments, neem seed cake and marigold whole-plant powder, applied individually and in combination, on the growth and physiological performance of brinjal under field conditions. The study compared these organic nutrient sources with both an untreated control and the recommended inorganic NPK fertilizer to determine their relative agronomic efficiency.

The specific objectives of this study were to: (i) analyse the influence of diverse organic amendments on vegetative growth parameters, such as overall plant height, root length, shoot length, leaf production, branch formation, stem diameter, and biomass accumulation; (ii) assess their influence on flowering behaviour through flowering initiation, flower production, and flowering duration; (iii) determine their effects on key physiological attributes, including chlorophyll content, relative water content, and net photosynthetic rate; and (iv) identify whether the combined application of neem seed cake and marigold biomass provides a complementary advantage over their individual application and approaches the performance achieved with conventional inorganic fertilization.

It was hypothesized that integrating neem seed cake with marigold biomass would improve nutrient accessibility and rhizosphere functioning, resulting in enhanced vegetative growth, reproductive performance, and physiological efficiency compared with individual organic amendments, while offering a sustainable alternative to sole dependence on inorganic fertilizers.

2. Materials and Methods

2.1. Study Site and Experimental Conditions

The field trials were carried out at Seemawat Krishi Farm, located in Jaipur, Rajasthan, India, during the winter season (2025). The research site is located at an elevation of 431 m above mean sea level with geographical coordinates of 27.110279 and 75.861132.

The region experiences a semi-arid climate characterized by moderate to high temperatures during the crop-growing season. Before transplanting, composite soil samples were gathered from the experimental field and analyzed following standard analytical procedures. The initial physico-chemical properties of the experimental soil are presented in Table 1.

Table 1. Physico-chemical properties of soil before transplanting

S. No.	Soil Property	Observed Range	Unit
1.	Soil texture	Sandy loam	—
2.	pH	7.5–7.9	—
3.	Electrical conductivity(EC)	0.22–0.45	dS m^{-1}
4.	Organic carbon	0.32–0.45	%
5.	Available nitrogen (N)	162–234	kg ha^{-1}
6.	Available phosphorus (P)	19–30	kg ha^{-1}
7.	Available potassium (K)	220–310	kg ha^{-1}

2.2. Preparation of Organic Amendments

Neem seed cake was obtained after mechanical extraction of oil from mature neem (*Azadirachta indica* A. Juss.) seeds. The de-oiled seed cake was shade-dried, homogenised into a fine powder using a mechanical grinder, passed through a 2-mm sieve, and stored in airtight containers until application. Whole plants of marigold (*Tagetes erecta* L.), including roots, stems, leaves, and flowers, were collected after flowering. To remove adhering soil particles from plant materials, they were rinsed thoroughly with tap water, shade-dried to constant weight, pulverized into a fine powder, sieved through a 2-mm mesh, and stored in moisture-free airtight containers before field application.

2.3. Experimental Design, Crop establishment and Treatment application

The study was structured following a Randomized Complete Block Design (RCBD) consisting of five treatments, each having 3 replications. Healthy and uniform brinjal (*Solanum melongena* L.) seedlings approximately 30–35 days old were transplanted into the prepared experimental field at a spacing of 60 × 60 cm. Each seedling was established under identical field conditions to reduce variability associated with plant vigour at the time of transplantation. The experimental plots were irrigated immediately after transplanting to ensure proper establishment. The experimental treatments consisted of 5 treatment conditions detailed in Table 2.

Table 2. Experimental treatments applied to brinjal (*Solanum melongena* L.) in the field trial

Treatment	Description
T0	Control (no organic or inorganic amendment applied)
T1	NPK fertilizer applied at 5 g per plant (recommended inorganic dose)
T2	Marigold (*Tagetes erecta*) whole-plant powder applied at 100 g per plant
T3	Neem (*Azadirachta indica*) seed cake powder applied at 100 g per plant
T4	Combination treatment: 50 g marigold whole-plant powder + 50 g neem seed cake powder per plant

Organic amendments were incorporated uniformly into the rhizosphere immediately after transplanting, whereas the inorganic fertilizer was applied according to the recommended agronomic practice. The designated organic amendments were applied as a basal dose immediately after transplantation.

Neem seed cake powder and marigold whole-plant powder were incorporated uniformly into the soil approximately 5-8 cm away from the stem base at a depth of 5-8 cm to facilitate gradual nutrient release within the active root zone while preventing direct root injury. The combined treatment received equal quantities of both amendments. The inorganic NPK fertilizer was administered in accordance with the prescribed dosage for brinjal cultivation. No additional nutrient source was supplied during the experimental period.

All treatments received identical irrigation, intercultural operations, and crop protection measures throughout the experimental period to eliminate management-related variability.

2.4. Crop Management

All experimental plants were maintained under identical agronomic practices throughout the cropping season. Irrigation was provided uniformly according to crop water requirements to avoid moisture stress. Manual weeding was done whenever necessary to minimize weed competition. No chemical pesticides, insecticides, fungicides, or other plant protection chemicals were applied during the experiment. Insect pests and diseases, whenever observed, were managed through manual or non-chemical methods uniformly across all treatments. No management practice differed among treatments except for the nutrient amendments under investigation.

2.5. Growth Measurements

Vegetative growth observations were recorded at the final stage of vegetative development using randomly selected representative plants from each treatment. Plant height was determined by measuring the distance of the apical meristem from the soil surface using a graduated measuring scale. Root length was determined after carefully uprooting representative plants and measuring the longest primary root.

Shoot length was recorded from the collar region to the shoot apex. To determine the total leaf number and number of primary branches per plant, direct counting was performed. Stem diameter was measured at the collar region using a digital Vernier calliper. Fresh biomass was determined immediately after harvesting, and total plant biomass was reported in grams per plant.

2.6. Flowering Measurements

Flowering characteristics were monitored throughout the reproductive phase of crop development. Days to flowering were calculated as the number of days after transplanting until

the appearance of the first fully opened flower. The total number of flowers produced by each plant was recorded during the observation period. Flowering duration was calculated as the interval between the appearance of the first flower and the cessation of flowering for each experimental plant.

2.7. Physiological Measurements

Physiological parameters were assessed from the fully expanded youngest leaves collected from representative plants of each treatment. Chlorophyll *a*, chlorophyll *b*, and total chlorophyll contents were estimated spectrophotometrically following Arnon's acetone extraction method and expressed as mg g^{-1} fresh weight. Relative water content (RWC) was determined from fresh, turgid, and dry leaf weights using the standard gravimetric method.

2.8. Statistical Analysis

All experimental observations were expressed as mean ± standard deviation (SD). Descriptive statistical analysis was performed to summarize the experimental observations.

3. Results and Discussion

3.1. Physicochemical Analysis of Post-Treatment Soil

At the end of the experimental period, soil samples were collected from the rhizosphere of brinjal plants representing each treatment, i.e., from T0 (control), T1 (NPK), T2 (marigold), T3 (neem cake), and T4 (marigold + neem cake) treatments. The collected soil samples were processed and analyzed for pH, electrical conductivity (EC), organic carbon, available nitrogen (N), available phosphorus (P), and available potassium (K) using standard soil analytical procedures. The application of T4 treatment in soil enhanced the organic carbon, available nitrogen, available phosphorus, and available potassium content as compared to other treatments (Table 3). Several studies have shown that the addition of organic amendments enhances the nutrient profile of soil [12][13]. Neem and Marigold biomass is a potent source of soil organic carbon and due to its low C/N ratio, it augments mineralisation of carbon. Furthermore, it is proposed that INM enhances nutrient-use efficiency and physiological performance by improving soil physical and biological properties [16].

Table 3. Effect of different organic and inorganic amendments on physicochemical properties of post-treatment soil

Treatment	pH	EC (dS m^{-1})	Organic C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T0	7.5–7.8	0.25–0.40	0.34-0.46	163-219	18-27	221-307
T1	7.4–7.7	0.34–0.53	0.35–0.45	217-281	29-38	266-357
T2	7.3–7.6	0.29–0.48	0.42–0.55	186-245	22-33	244-328
T3	7.4–7.8	0.30–0.50	0.43–0.57	199-264	26-35	243-336
T4	7.4–7.8	0.35–0.52	0.48–0.62	212-278	29-41	277-361

Note: Values represent the observed ranges of post-treatment soil physicochemical properties. T0 = control; T1 = NPK; T2 = marigold; T3 = neem cake; T4 = marigold + neem cake.

Table 4. Effect of organic and inorganic amendments on vegetative growth parameters of brinjal

Treatment	Plant Height (cm)	Root Length (cm)	Shoot Length (cm)	No. of Leaves	No. of Branches	Stem Diameter (mm)	Total Biomass (g $plant^{-1}$)
T0	56.3±0.63	18.4±0.61	37.9±0.50	34±1.41	5±0.81	7.2±0.29	42.8±0.57
T1	84.7±0.80	28.9±0.96	55.8±0.57	63±1.22	10±1.63	11.8±0.69	91.6±1.06
T2	68.5±0.42	22.6±0.85	45.9±1.07	46±0.70	7±0.81	8.9±0.43	61.4±0.61
T3	74.2±0.94	25.3±0.69	48.9±0.94	53±1.22	8±0.81	9.8±0.64	71.8±0.63
T4	82.4±1.17	28.1±0.58	54.3±0.56	60±1.22	10±1.63	11.2±0.61	87.5±0.43

Note: Values are mean ± SD. Treatments significantly affected all growth parameters ($p < 0.001$). T0 = control; T1 = NPK; T2 = marigold; T3 = neem cake; T4 = marigold + neem cake.

3.2. Effect of Various Amendments on Vegetative Growth of Brinjal

The vegetative growth of brinjal plants was significantly influenced by the use of different organic and inorganic nutrient amendments (Table 4). Plant height varied markedly among treatments, ranging from 56.3 cm in the untreated control (T0) to 84.7 cm in the NPK-treated plants (T1). Among the organic treatments, the combined application of marigold and neem cake (T4) produced the greatest plant height (82.4 cm), followed by neem cake alone (T3; 74.2 cm) and marigold alone (T2; 68.5 cm).

A similar trend was observed for root and shoot development. Root length increased from 18.4 cm in the control to 28.9 cm under NPK application, while the combined organic treatment (T4) recorded a comparable root length of 28.1 cm. Shoot length also showed progressive improvement across treatments, with values increasing from 37.9 cm in the control to 55.8 cm under NPK fertilization and 54.3 cm under the combined treatment. Leaf production and branch formation followed a comparable pattern. Plants grown under NPK yielded the greatest number of leaves (63) and branches (10), closely followed by the combined amendment treatment

(60 leaves and 10 branches) per plant. The untreated control recorded the lowest leaf (34) and branch (5) numbers.

Stem diameter and total biomass also responded positively to nutrient amendments. Stem diameter increased from 7.2 mm in the control to 11.8 mm under NPK fertilization, while the combined organic treatment recorded 11.2 mm. Likewise, total biomass increased from 42.8 g plant^{-1} in untreated plants to 91.6 g plant^{-1} under NPK application. Among the organic treatments, the highest biomass (87.5 g plant^{-1}) was observed in T4. Overall, the combined application of marigold and neem cake consistently performed better than either amendment applied individually and produced vegetative growth characteristics that closely approached those obtained with the recommended NPK fertilizer (Table 4).

The findings of the present study revealed that both inorganic fertilization and botanical organic amendments improved the growth, flowering, and physiological performance of brinjal. The combined application of neem (*Azadirachta indica*) seed cake and marigold (*Tagetes erecta*) biomass consistently outperformed the individual organic amendments and produced responses comparable to those obtained with the recommended NPK fertilizer. These findings demonstrate the potential benefits of combining complementary plant-derived amendments for enhancing crop growth while decreasing dependence on synthetic fertilizers [12]. Comparable enhancements in vegetative growth and biomass production have been observed with integrated nutrient management (INM) in other studies [14][15].

The superior performance of the combined organic treatment may be associated with the complementary characteristics of neem seed cake and marigold biomass. Neem seed cake acts as a slow-release source of nutrients while improving nutrient-use efficiency and soil biological activity, whereas marigold biomass contributes organic matter that enhances microbial activity, nutrient cycling, and soil physical properties. Their joint application therefore provides a more favourable rhizosphere environment than either amendment applied individually. Similar conclusions were reported by Thingujam et al. [16], who highlighted the role of INM in enhancing soil fertility and supporting balanced crop growth through the combined effects of multiple nutrient sources. Likewise, Saravaiya et al. [15] highlighted that integrating different organic amendments enhances nutrient availability and promotes overall crop productivity relative to the application of a single organic input.

3.3. Effect of various Amendments on Flowering Parameters

The flowering behaviour of brinjal plants was markedly influenced by the different nutrient amendment treatments (Table 5). Plants receiving the recommended NPK fertilizer (T1) showed the earliest flowering, initiating at 44 days after transplanting. The combined application of marigold and neem cake (T4) also promoted early flowering, with the first flowers appearing at 45 days. However, the untreated control plants (T0) took 56 days to reach the flowering stage.

As shown in Table 5, there was a considerable increase in the number of flowers produced (per plant) on application of organic and inorganic amendments. Plants receiving NPK treatment (T1; 58 flowers per plant) recorded the highest flower production, followed closely by the combined marigold-neem treatment (T4; 55 flowers per plant). The maximum flowering duration was observed in the T1 treatment (67 days), while the T4 treatment maintained flowering for 65 days, demonstrating a response comparable to that of the T1 treatment (inorganic fertilizer). The shortest flowering period (42 days) was recorded in the untreated control.

Largely, the application of T4 treatment (combination of marigold biomass and neem-seed cake) steadily improved flowering performance as compared to the application of individual organic amendments (T2 and T3), while all the studied flowering attributes showed better results as compared to control (T0). For all flowering parameters, treatment performance followed the order: T1 > T4 > T3 > T2 > T0 (Table 5). Improved flowering recorded in the current investigation further reflects the beneficial effects of sustained supply of nutrients throughout all stages of crop development. Earlier flowering, increased flower production, and prolonged flowering duration under the combined amendment suggested that optimal nutrient availability supported reproductive development more effectively than the individual organic treatments. Improved flowering and reproductive performance in brinjal under INM were reported in several studies [14][17]. Neem seed cake acts as a source of organic matter and nutrients, while marigold exerts a nematicidal effect and contributes essential plant nutrients [10].

Table 5. Effect of organic and inorganic amendments on flowering attributes of brinjal (*mean* ± *SD*)

Treatment	Days to Flowering	No. of Flowers per Plant	Flowering Duration (days)
T0	56±0.81	29±1.63	42±2.16
T1	44±0.81	58±1.41	67±0.81
T2	51±2.44	40±2.94	53±2.16
T3	48±2.16	47±2.94	59±2.94
T4	45±0.00	55±1.63	65±0.81

Treatments significantly affected all flowering parameters ($p < 0.001$).

3.4. Effect of Organic Amendments on Fruit Production

Fruit production varied across the experimental treatments, with all amendment treatments showing higher fruit numbers than the untreated control (Table 6). The control plants (T0) produced 9- 13 fruits plant^{-1}, whereas the NPK treatment (T1) recorded the highest fruit production of 21-26 fruits plant^{-1}. Among the organic amendments, the combined

marigold + neem cake treatment (T4) produced 19–23 fruits plant^{-1}, representing the highest fruit production among the botanical treatments and approaching the range observed under NPK. Neem cake alone (T3) resulted in 16- 19 fruits plant^{-1}, while marigold alone (T2) produced 13- 17 fruits plant^{-1}. Thus, the combined application of marigold biomass and neem cake showed a stronger reproductive response than either amendment applied individually, indicating a potential complementary effect of the two botanical amendments on fruit production.

Table 6. Effect of different organic and inorganic amendments on fruit production of brinjal

Treatment	Range of fruit number plant^{-1}
T0 - Control	9-13
T1 - NPK	21-26
T2 - Marigold	13-17
T3 - Neem cake	16-19
T4 - Marigold + Neem cake	19-23

The improved flowering and greater fruit production observed in T4 indicate that there was improved vegetative and reproductive performance under the combined treatment as a result of enhanced soil quality. Comparable responses have been reported in brinjal under integrated nutrient management, where combined organic and inorganic nutrient sources enhanced the number of fruits per plant and overall productivity compared with the control [18][19].

3.5. Effect of various Amendments on Chlorophyll Content and Physiological Parameters

The use of different nutrient amendments substantially influenced the physiological performance of brinjal plants, as reflected by chlorophyll content, relative water content (RWC), and net photosynthetic rate. The highest chlorophyll *a*, chlorophyll *b* and total chlorophyll content was recorded in plants receiving the recommended NPK fertilizer (T1), followed closely by the combined marigold–neem treatment (T4), whereas the untreated control (T0) exhibited the lowest value (Table 7). Relative water content (RWC) also improved across all amendment treatments compared with the untreated control (Table 7). The highest RWC (91.3%) was observed in plants supplied with NPK fertilizer, followed by the combined marigold–neem treatment (89.8%), whereas the control plants recorded the lowest RWC (72.4%).

Net photosynthetic rate followed a trend comparable to that of chlorophyll content and RWC. The highest photosynthetic rate (19.6 µmol CO_2 m^{-2} s^{-1}) was recorded in the NPK-treated plants, followed closely by the combined organic treatment (18.9 µmol CO_2 m^{-2} s^{-1}). Neem cake alone and marigold alone recorded intermediate values of 16.9 and 14.8 µmol CO_2 m^{-2} s^{-1}, respectively, while the untreated control exhibited the lowest photosynthetic rate (10.8 µmol CO_2 m^{-2} s^{-1}).

Overall, both inorganic fertilization and organic amendments improved the physiological status of brinjal plants compared with the untreated control. Among the organic treatments, the combined application of marigold biomass and neem seed cake consistently produced the highest chlorophyll content, relative water content, and photosynthetic activity, with values approaching those obtained under the recommended NPK fertilizer. Organic amendments gradually release nutrients required for chlorophyll biosynthesis while simultaneously improving soil moisture retention and microbial activity, thereby maintaining favourable physiological conditions throughout crop growth. Improvements in physiological efficiency following INM have been reported in some studies, where improved nutrient availability and enhanced soil biological activity contribute directly to increased photosynthetic efficiency and plant productivity[13][16]. Although the recommended NPK fertilizer produced the highest values for most measured parameters, the comparatively small differences between NPK and the combined neem–marigold treatment demonstrate the considerable potential of botanical organic amendments as sustainable alternatives for vegetable production. Thus, INM represents an environmentally sustainable strategy capable of maintaining crop productivity while reducing dependence on synthetic fertilizers [15][16][18][19]. Overall, the current research provides experimental proof supporting that the joint application of neem seed cake and marigold biomass represents a promising botanical nutrient management strategy for sustainable brinjal cultivation.

Table 7. Effect of organic and inorganic amendments on chlorophyll content and physiological parameters of brinjal (mean ± SD; $p < 0.001$)

Treatment	Chl a (mg g^{-1} FW)	Chl b (mg g^{-1} FW)	Total Chl (mg g^{-1} FW)	RWC (%)	Net Photosynthetic Rate (µmol CO_2 m^{-2} s^{-1})
T0	1.21±0.03	0.48±0.02	1.69±0.07	72.4±0.44	10.8±0.84
T1	2.08±019	0.84±0.03	2.92±0.04	91.3±0.32	19.6±1.11
T2	1.56±0.08	0.63±0.03	2.19±0.05	81.7±1.49	14.8±1.00
T3	1.78±0.06	0.71±0.03	2.49±0.09	86.5±1.33	16.9±1.11
T4	2.00±0.14	0.81±0.04	2.81±0.04	89.8±1.34	18.9±1.34

4. Conclusion

The present study demonstrates that plant-derived organic amendments can substantially improve the growth, flowering, and physiological performance of brinjal (*Solanum melongena* L.). Among the studied amendments, the application of combined neem seed cake and marigold biomass consistently outperformed the individual organic amendments and produced responses approaching those obtained with inorganic NPK fertilizers. Enhanced vegetative growth, increased flower production, higher chlorophyll content, improved relative water content, and greater photosynthetic activity collectively indicate the effectiveness of integrated organic nutrient management in promoting crop performance.

The findings further suggest that a combination of plant-based organic amendments offers a sustainable, environmentally friendly and economical nutrient management strategy that reduces reliance on synthetic fertilisers while maintaining high plant productivity. The complementary effects of these two organic amendments emphasize their capacity to enhance soil fertility and assist balanced crop development under field conditions. Overall, this study provides experimental evidence supporting the use of integrated botanical organic amendments as a practical alternative for sustainable brinjal cultivation. Further multi-season and multi-location investigations incorporating fruit yield, quality attributes, plant responses and pathogen suppression are required to validate these findings and assess the potential of plant-based organic amendments as components of an integrated organic nutrient management strategy. Future research should evaluate the long-term effects of these amendments on soil health, nutrient cycling, soil microbial dynamics, and economic feasibility across diverse agro-climatic conditions to facilitate their wider adoption in sustainable vegetable production.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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