

Effect of various organic on growth and yield of cabbage (*Brassica oleracea* L.)

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Abstract. This study evaluates the effects of organic manures and biofertilizers on the growth and yield of cabbage (*Brassica oleracea* var. *capitata*). A field experiment was conducted using a randomized block design to assess the impact of farmyard manure, vermicompost, poultry manure, and their combinations with biofertilizers on cabbage production. Growth parameters such as plant height, number of outer leaves, and head diameter were measured at different stages, while yield parameters were recorded at harvest. The results indicated that organic fertilizers significantly improved cabbage growth and productivity compared to the control. Treatments incorporating farmyard manure and vermicompost combined with biofertilizers exhibited superior performance in plant growth and yield. These treatments enhanced soil fertility, promoted better nutrient uptake, and supported healthy plant development. The study suggests that the use of organic amendments can reduce the dependency on chemical fertilizers, minimizing their adverse environmental effects while maintaining agricultural sustainability. Furthermore, organic fertilizers contribute to improved soil health by increasing microbial activity, enhancing water retention, and maintaining soil structure. The findings highlight the importance of integrating organic manures and biofertilizers into farming practices to achieve better crop performance while ensuring long-term soil productivity. This study reinforces the role of organic farming in sustainable agriculture, offering an eco-friendly alternative to conventional chemical-based cultivation methods. Future research can focus on optimizing organic fertilizer application rates and assessing their long-term impact on different crop varieties.

KEYWORDS: Organic manures, biofertilizers, soil fertility, yield improvement, sustainable agriculture.

1. INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is commonly grown as an annual crop, though it is naturally a biennial plant characterized by dense foliage. It has a somatic chromosome number of $2n = 18$, making it a secondary polyploid with six basic chromosomes. As a subspecies of *Brassica oleracea*, cabbage is closely related to other vegetables such as cauliflower and broccoli, all of which have wild cabbage as their common ancestor. The term "capitata" comes from Latin and translates to "having a head," highlighting the plant's unique, tightly formed head structure. Cabbage is a valuable source of essential vitamins such as A, B, and C, along with vital minerals like calcium, potassium, phosphorus, and iron, making it an important component of diets around the world [1]. Native to the Mediterranean region, cabbage was domesticated from wild cabbage (*Brassica oleracea*) and has been cultivated for over two millennia [2].

Cabbage grows best in cool climates and is most suited for temperate regions, although tropical and subtropical varieties have been developed to expand

its cultivation range [3]. The ideal temperature for cabbage growth is between 15°C and 21°C, and it requires loamy, well-drained soils enriched with organic matter and a pH range of 6.0 to 6.8 for optimal growth. Effective soil preparation and nutrient management are vital for cabbage cultivation, as it is a heavy feeder requiring constant nutrient availability [4].

Cabbage is grown on all continents except Antarctica, with China, India, Russia, and the United States being the top producers. China is the largest global producer, accounting for more than 40% of the total cabbage output [5]. In recent years, global cabbage trade has expanded significantly, driven by the rising demand for fresh and processed vegetables. The export of fresh cabbage and related products has become a vital segment of global agricultural trade, with the European Union and the United States being major importers and Asian countries dominating exports. The growing consumer demand for organic and sustainably produced vegetables has further propelled the international cabbage trade [6].

Cabbage was initially introduced as an exotic crop; it has adapted well to local growing conditions and

is now widely cultivated. Major producers include southern states like Karnataka, Tamil Nadu, and Andhra Pradesh, where favourable climates allow for year-round cultivation. In northern states like Punjab, Haryana, and Uttar Pradesh, cabbage is grown mainly during the cooler months, contributing significantly to production [3]. The development of tropical varieties and hybrids has extended the cabbage growing season, improving its availability in markets.

Cabbage is a rich source of antioxidants such as vitamin C, beta-carotene, flavonoids, anthocyanins, and glucosinolates. These substances are crucial for neutralizing free radicals, minimizing oxidative stress, and protecting cells from damage. Glucosinolates, unique to cruciferous vegetables, are known for their detoxifying properties and their potential role in cancer prevention. Anthocyanins, which give certain cabbage varieties their red or purple color, possess strong anti-inflammatory and heart-protective effects. Regular consumption of cabbage has been linked to better digestion, improved cardiovascular health, and a decreased risk of chronic diseases such as cancer, diabetes, and neurodegenerative disorders [3].

Chemical fertilizers, including nitrogen (N), phosphorus (P), and potassium (K), are frequently applied to enhance plant growth and improve crop yields. Nitrogen supports vigorous vegetative growth, phosphorus promotes root establishment, and potassium helps in head formation and improves disease resistance [7]. However, excessive use of chemical fertilizers can result in various negative environmental impacts, including soil degradation, reduced microbial activity, and water contamination [4, 8]. There is also concern about fertilizer residue accumulation in crops, raising potential health risks. While chemical fertilizers can enhance productivity, their usage needs to be carefully controlled to avoid environmental and health issues. Although chemical fertilizers are commonly used, excessive application can lead to several significant drawbacks. These fertilizers typically contain high levels of soluble salts, which can lead to soil salinization, adversely affecting plant growth and reducing soil fertility over time [9]. Continued reliance on chemical fertilizers can deplete beneficial soil microorganisms, disrupting the balance of soil ecosystems and making crops more vulnerable to pests and diseases [10]. Moreover, excess nitrogen and phosphorus can leach into water bodies, contributing to eutrophication and the destruction of aquatic ecosystems through harmful algae blooms [11]. Fertilizer chemicals can also leave harmful residues in the soil, which may reduce crop quality and pose health risks to humans [12].

Organic fertilizers, which come from natural sources such as plants, animals, or minerals, are being used more frequently in farming to enhance soil health and supply vital nutrients to crops. Examples of organic fertilizers include farmyard manure (FYM), compost, vermicompost, bone meal, and green manure [13]. In contrast to chemical fertilizers, organic fertilizers release nutrients slowly, enhancing soil structure, boosting water retention, and promoting microbial activity. The growing use of organic fertilizers reflects the need for more sustainable farming practices, as they help reduce dependence on synthetic chemicals and support ecological balance [3, 14]. Organic fertilizers not only promote healthy plant growth but also contribute to the long-term health of the soil, making it more resilient to erosion and degradation [15].

Organic fertilizers are essential for sustainable cabbage cultivation, improving soil health and providing the nutrients necessary for optimal growth. Organic amendments such as FYM, compost, and vermicompost enhance soil structure and nutrient availability, resulting in healthier plants and higher yields [14]. They also promote the activity of beneficial microorganisms that support plant health and improve nutrient uptake. In contrast to chemical fertilizers, organic fertilizers pose less risk to the environment and human health, making them a preferred option for organic farming [3]. Furthermore, the use of organic fertilizers has been shown to enhance the nutritional quality of cabbage, boosting its antioxidant content and overall health benefits.

2. MATERIAL AND METHODS

The research was conducted at the Amity University Organic Farm in Noida, Uttar Pradesh (28.5441° N latitude, 77.3332° E longitude) during the Rabi season of 2024-2025. The study site, situated at an elevation of 200 meters above sea level, falls within the Trans-Gangetic plains agroclimatic zone and experiences a semi-arid, subtropical climate. Noida exhibits significant seasonal fluctuations, with summer temperatures peaking at 42.5°C and winter temperatures dropping as low as 9.1°C. The monsoon season contributes an average rainfall of 141.26 mm, accompanied by a relative humidity of 60.5%.

Based on existing data, the soil in the study area is classified as sandy loam, comprising 62.18% sand, 11.02% silt, and 24.19% clay. The levels of organic carbon (0.60%) and total nitrogen (0.045%) are relatively low, while phosphorus availability is poor, and potassium content is moderate. The soil has a slightly alkaline pH of 8.40 and an electrical conductivity of 0.98 dS/m at 25°C, indicating

moderate salinity. The experimental site is flat, well-drained, and slightly elevated, providing optimal conditions for conducting field trials.

The objective of this study was to evaluate the effects of organic farming practices on soil fertility and crop productivity under the given agroclimatic conditions. A **Randomized Block Design (RBD)** was employed to reduce variability and enhance the reliability of treatment comparisons. The research methodology encompassed a comprehensive soil analysis, systematic field layout, and the application of agronomic practices adapted to the specific soil and climatic characteristics of the site.

2.1 EXPERIMENTAL DETAILS

The experiment carried out during the 2024–2025 period included the following details:

Sr. No.	Treatment details
1.	FYM
2.	VERMICOMPOST
3.	POULTRY MANURE
4.	VERMICOMPOST + AZOTOBACTER
5.	POULTRY MANURE + AZOTOBACTER
6.	CONTROL

PLANT GROWTH STUDIES

Gaining insight into the processes that drive plant growth and development required careful observation of how the plants responded to different treatments. Vigorous plants were chosen at random and labelled with identification tags. These tagged plants were systematically monitored and data was collected every fifteen days. Various indicators, including plant count, branching patterns, height, and dry matter accumulation, were used to evaluate the impact of the treatments on plant growth.

Plant Height

- To accurately gauge plant height, hold a measuring tape upright alongside the cabbage plant.
- Record the length from the ground level to the tallest point of the plant to obtain an accurate height.

Number of Outer Leaves

- Select a mature cabbage plant for measurement, making sure that none of its outer leaves have been removed.
- Carefully pluck the outer leaves one by one, starting from the outermost layer and working inward.
- Once all the outer leaves have been removed, count the remaining leaves, taking care not to damage them during the process.

Leaf Area

- Select healthy cabbage plants for sampling, prioritizing those with similar size and growth stage.
- Place the leaves flat and create digital scans or photocopies to precisely capture their dimensions and form.
- The total leaf area of cabbage leaves can be precisely calculated using an image analysis program or a leaf area meter.

Head Diameter

- Use a measuring tape or ruler marked in millimetres or centimetres for accuracy.
- Place the cabbage head on a flat surface, like a cutting board, and measure its diameter.

Total Yield

- Collect all harvested cabbage heads as the first step in the yield assessment process.
- Measure the size of each cabbage head by weighing them individually on a scale to determine their total weight.

Statistical Analysis

The gathered data was analysed statistically using Analysis of Variance (ANOVA) to determine significant variations among treatments. The Least Significant Difference (LSD) test was employed for mean comparisons at a significance level of $p < 0.05$. Both field and laboratory data were processed using the statistical methods described by Gomez and Gomez (1984). A Critical Difference (CD) was calculated for variables where treatment effects were statistically significant at the 5% probability level.

3. RESULT AND DISCUSSION

The findings from a 2024–2025 Rabi season study conducted at Amity University's Organic Agriculture Farm in Noida, Uttar Pradesh, are

presented below. The study, titled "Effect of Organic Manures on Cabbage Growth and Yield," investigates the effects of various organic fertilizers on cabbage production and its economic viability.

3.1 Growth Parameters

Data on key growth parameters, including plant height, the number of outer leaves, and head

Treatments	30 DAT	60 DAT	90 DAT
T1- FYM	10.4	18.8	21.56
T2- VERMICOMPOST	9.23	16.3	20.1
T3- POULTRY MANURE	10.6	19.23	22.1
T4- VERMICOMPOST+ AZOTOBACTER	12.1	21.5	22.76
T5- POULTRY MANURE+ AZOTOBACTER	11.4	19.4	22.56
T6- CONTROL	9.6	14.3	19.6
C.D at 5%	0.5	0.5	0.6
SEm	0.40	0.96	0.54

diameter, were collected throughout the crop's life cycle. These measurements were taken at multiple stages of growth, including the period just before harvest.

3.1.1 Plant height (cm)

Plant height is an important determinant of plant health and growth, especially in relation to various organic treatments. Measurement at 30, 60, and 90 days after transplanting (DAT) indicated significant differences between the treatments, indicating how varied inputs affect the development of the plant over time.

At 30 DAT, the maximum plant height was recorded in T4 (Vermicompost + Azotobacter) with a mean of 12.1 cm, followed by T5 (Poultry manure + Azotobacter, 11.4 cm) and T3 (Poultry manure, 10.6 cm). T6 (Control) gave the minimum plant height (9.6 cm), indicating that poultry manure with the addition of biofertilizers such as Azotobacter can greatly enhance early growth, perhaps due to increased nutrient release and microbial interaction, as reported in previous research.

At 60 days after transplanting (DAT), the T4 treatment (Vermicompost + Azotobacter) recorded the highest average plant height of 21.5 cm. It was trailed by T3 (Poultry Manure, 19.23 cm) and T5 (Poultry Manure + Azotobacter, 19.4 cm). Opposite to it were T2 (vermicompost, 16.8 cm) and T6 (Control, 14.3 cm) with least

values. The findings point to biofertilizer-enriched treatments yielding superior mid-stage growth as a result of enhanced nutrient assimilation.

At the end measurement (90 DAT), T4 still recorded higher values for other treatments with an average value of 22.76 cm, followed by T5 (22.56 cm) and T3 (22.1 cm). The control treatment (T6) once more had the lowest plant height (19.6 cm), highlighting the significance of organic amendments in facilitating growth over subsequent stages. T1 (21.56 cm) and T2 (20.1 cm) had moderate values, indicating that their efficacy over time may be lost without microbial augmentation.

Overall, T4 (Vermicompost + Azotobacter) had the most stable and beneficial impact on plant growth at all time points, testifying to the potential of organic amendments being blended with beneficial microbes. T5 also registered optimistic results, particularly at initial and terminal levels. These findings affirm existing research that has demonstrated that integrated organic methods can have a considerable impact on plant performance by optimizing soil health and nutrient uptake.

Table 2: The impact of different treatments on plant height (cm).

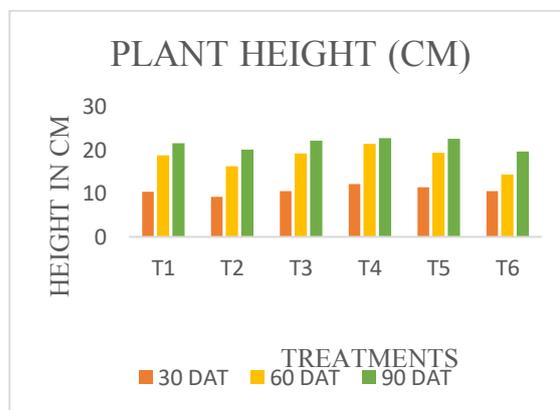


Figure 1: Impact of different treatments on plant height (cm)

3.1.2 Number of outer leaves per plant

Outer leaves growth is a critical indicator of the vegetative development and general health of a plant. During this research, the impact of different organic treatments on the production of outer leaves was measured at 30, 60, and 90 DAT. Observations demonstrated obvious differences in leaf development between the treatments.

30 DAT recorded the maximum number of outer leaves from T4 (Azotobacter + Vermicompost) with a mean of 8.3 leaves, followed by T5 (Azotobacter + Poultry Manure) at 8.0, T3 (Poultry Manure) at 7.6, and then the control treatment (T6) with the

least number of leaves at 5.6, which reflected lesser early development in the control treatment in the absence of organic supplementation. These results suggest that combining organic materials with beneficial microbes like Azotobacter may stimulate faster early leaf formation by improving nutrient availability and root-zone microbial activity.

At 60 DAT, T4 still performed best with the most number of outer leaves (15), while T5 (Poultry Manure + Azotobacter) was still strong at 14.6 leaves. Both T2 (Vermicompost) and T3 (Poultry Manure) had 13.6 leaves. The control had the lowest at 11 leaves. The enhanced leaf growth in organically treated plants in this stage may be attributed to improved nutrient release patterns and increased microbial support, favouring consistent vegetative growth.

At 90 DAT, T4 again possessed the maximum number of leaves (20.6), indicating its performance throughout the growth cycle. T5 had 18.3 leaves, followed by T1 (FYM), T2 (Vermicompost), and T3 (Poultry Manure) with 17.6 leaves each. T6 (Control) still exhibited the minimum growth with 16 leaves. These results indicate the long-term advantage of using vermicompost in combination with microbial inoculants, which presumably facilitate sustained nutrient supply and activate plant metabolism, resulting in enhanced foliage production.

Overall, T4 (Vermicompost + Azotobacter) performed best to increase the number of outer leaves at all growth stages. T5 (Poultry Manure + Azotobacter) also performed well, especially at the start and end of the observation period. These results highlight the need to combine organic fertilizers with beneficial microbes to induce healthy vegetative growth and general plant performance.

Table 3: The impact of different treatments on the number of outer leaves.

Treatments	30 DAT	60 DAT	90 DAT
T1- FYM	7.3	12.6	17.6
T2- VERMICOMPOST	6.3	13.6	17.6
T3- POULTRY MANURE	7.6	13.6	17.6
T4- VERMICOMPOST+ AZOTOBACTER	8.3	15	20.6
T5- POULTRY MANURE+ AZOTOBACTER	8.0	14.6	18.3
T6- CONTROL	5.6	11	16
C.D at 5%	0.3	0.4	0.5
SEm	0.45	0.59	0.61

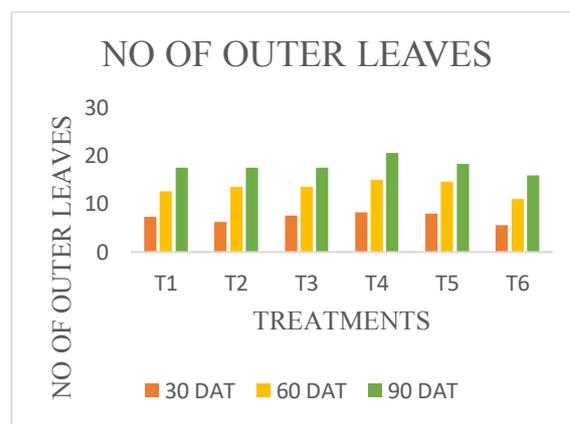


Figure 2: The impact of different treatments on the number of outer leaves.

3.1.3 Head Diameters in (cm)

Head diameter is an important characteristic in determining the yield potential and market value of head-forming crops. In this research, the influence of various organic treatments on plant head diameter was quantified at 60 and 90 days after transplanting (DAT). The results indicated a high degree of variation among the treatments, demonstrating that both

nutrient type and microbial additions impacted head development.

At 60 DAT, maximum head diameter was found in T4 (Vermicompost + Azotobacter) with a mean value of 13.8 cm, followed by T5 (Poultry Manure + Azotobacter, 11.4 cm) and T3 (Poultry Manure, 11.3 cm). Minimum head diameters were found in T6 (Control, 9.0 cm) and T2 (Vermicompost, 9.3 cm), indicating that the lack of microbial inoculants or suboptimal nutrient supply could have limited initial head development. These findings indicate that the combination of biofertilizers with organic manure can greatly improve plant growth during the mid-growth phase, probably by enhancing nutrient uptake and stimulating hormonal activity in the plant.

At 90 DAT, T4 was still the best treatment, with the biggest head diameter (23.0 cm). T5 was also highly rated with 22.5 cm average, followed by T3 (Poultry Manure, 18.5 cm) and T1 (FYM, 18.2 cm). T6 (Control) still recorded the lowest head diameter (13.3 cm), showing that without organic input, head growth was greatly diminished. The significant increase in head diameter in T4 and T5 implies that the synergistic effect of organic nutrients and useful microbes allows for continued growth, apparently because nitrogen fixation was enhanced and enzymatic activity led to bigger biomass production.

Overall, T4 (Vermicompost + Azotobacter) was the most superior in maximizing plant head diameter at both measurement periods, and it was very closely followed by T5 (Poultry Manure + Azotobacter). These results reinforce the necessity for utilizing integrated organic methods which combine nutrient-sufficient compost and microbial inoculants to maximize crop structure and yield potential.

Table 4: The impact of different treatments on each plant head diameter

Treatments	60 DAT	90 DAT
T1- FYM	10.8	18.2
T2- VERMICOMPOST	9.3	16.3
T3- POULTRY MANURE	11.3	18.5
T4- VERMICOMPOST+ AZOTOBACTER	13.8	23.0
T5- POULTRY MANURE+ AZOTOBACTER	11.4	22.5
T6- CONTROL	9.0	13.3
C.D at 5%	0.9	1.00
SEm	0.73	1.52

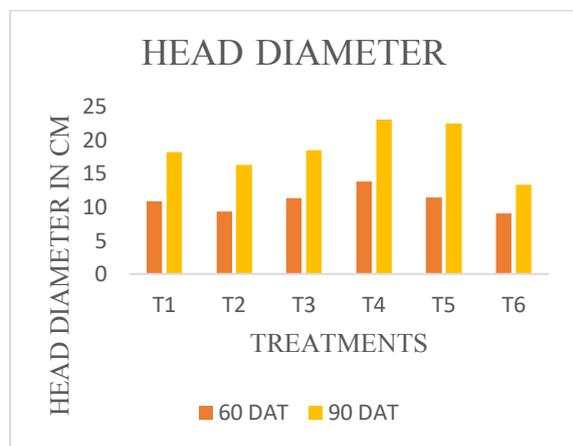


Figure 3: The impact of different treatments on the head diameter of each plant.

3.2 Yield Parameters

During the crop harvest, data were recorded on yield parameters, including head weight and overall yield.

3.2.1 Head weight

Head weight is directly a measure of yield and marketable quality in head-forming crops. Various

organic treatments were tested in this research for their effect on head weight, and the results varied significantly based on the nature and combination of amendments used.

Among all the treatments, T4 (Vermicompost + Azotobacter) registered the maximum head weight at 1.20 kg, which proves its better efficacy in enhancing biomass development. This was followed closely by T5 (Poultry Manure + Azotobacter) with head weight at 1.16 kg and T3 (Poultry Manure) with 0.98 kg. These results indicate that the use of biofertilizers like Azotobacter in combination with organic manure has a beneficial impact on nutrient absorption and metabolic processes, leading to heavier and more developed heads.

T1 (FYM) was also satisfactory in terms of average head weight at 0.95 kg, followed by T2 (Vermicompost) at 0.85 kg. The lowest head weight belonged to the control treatment (T6), which was not given any organic input, at 0.70 kg, indicating the minimal productivity of plants with no additional nutrients.

Generally, the integrated treatment T4 (Vermicompost + Azotobacter) was found to be most effective in enhancing head weight, possibly because of the synergistic action of gradual nutrient release from vermicompost and improved nitrogen fixation by Azotobacter. T5 also showed significant promise, affirming the worth of holistic organic and microbial strategies in achieving maximum crop yield.

Table 5: The impact of different treatments on the weight of the head.

Treatments	Head weight in kg
T1- FYM	0.95
T2- VERMICOMPOST	0.85
T3- POULTRY MANURE	0.98
T4- VERMICOMPOST+ AZOTOBACTER	1.20
T5- POULTRY MANURE+ AZOTOBACTER	1.16
T6- CONTROL	0.70
C.D at 5%	0.05
SEm	0.08

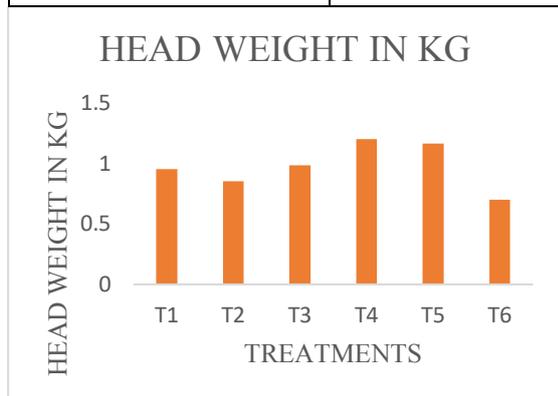


Figure 4: Impact of various treatment methods on head weight.

3.2.2 Yield per plot

Total yield per plot is among the most important parameters to consider when assessing overall productivity and agronomic practice efficiency. In this research, the influence of various organic treatments on total yield per plot was measured, demonstrating considerable differences depending on the nature and combination of amendments used.

Maximum yield was obtained from T4 (Azotobacter + Vermicompost), averaging 15.50 kg per plot. This was followed by T5 (Azotobacter + Poultry Manure) with 14.20 kg, and T3 (Poultry Manure) with 13.50 kg. These findings suggest that the addition of Azotobacter to organic treatments significantly boosted productivity due to improved nutrient availability, better root development, and increased microbial activity in the rhizosphere.

T1 (FYM) also worked fairly well with a yield of 13.33 kg, whereas T2 (Vermicompost) recorded a slightly lower yield at 12.17 kg. The control treatment (T6) that did not receive any organic amendment gave the least yield of 10.88 kg per plot. This comparison highlights the significance of organic inputs in enhancing crop performance under field conditions.

Generally, T4 (Vermicompost + Azotobacter) was the best treatment in regard to maximizing the yield, in support of the fact that integration of nutrient-surplus compost with biofertilizers can increase crop yields drastically. These results reveal the promising role that integrated organic management methods have to offer in increasing yield without harming the soil health and sustainability.

Table 6: The impact of different treatments on the yield per plot.

Treatments	Yield per plot (kg)
T1- FYM	13.33
T2- VERMICOMPOST	12.17
T3- POULTRY MANURE	13.50
T4- VERMICOMPOST+ AZOTOBACTER	15.50
T5- POULTRY MANURE+ AZOTOBACTER	14.20
T6- CONTROL	10.88
C.D at 5%	0.7
SEm	0.65

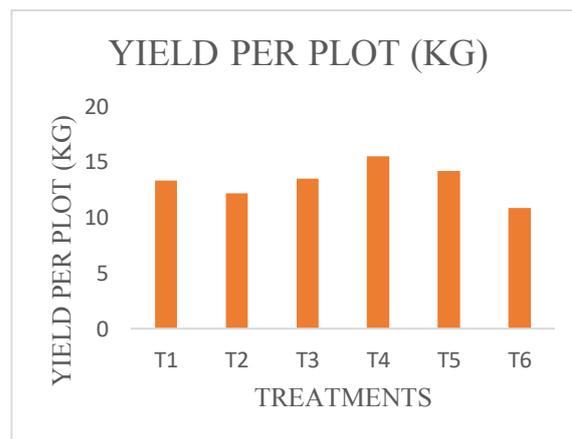


Figure 5: The impact of various treatment on the yield per plot

3.2.3 Total Yield (t/ha)

Yield per hectare is a general measure of overall crop productivity and indicates the efficacy of cultivation practices under field conditions. The current results show evident differences in yield among the different organic treatments, further highlighting the contribution of organic inputs and biofertilizers to improving crop performance.

Of the treatments, T4 (Vermicompost + Azotobacter) yielded the highest, averaging 22.59 t/ha. This was then followed by T5 (Poultry Manure + Azotobacter) with a yield of 19.88 t/ha and T3 (Poultry Manure) with a yield of 18.60 t/ha. The findings show that the integration of organic matter with microbial inoculants greatly improves crop

yield. The higher yield in T4 is due to the synergistic action of vermicompost and Azotobacter, which enhance soil structure, nutrient release, and microbial activity, leading to enhanced plant health and productivity.

T1 (FYM) also demonstrated encouraging performance with a yield of 17.72 t/ha, and T2 (Vermicompost) reported slightly less at 16.48 t/ha. The control plot (T6) where no organic amendment was given gave the least with a yield of 14.62 t/ha. Such a great disparity proves how much organic nutrient management plays in bringing the maximum yield.

In short, T4 (Vermicompost + Azotobacter) was the best treatment for enhancing per hectare yield, demonstrating the worth of combining compost with useful microbes. The findings imply that such organic combinations can play an integral role in improving crop productivity while supporting sustainable agriculture.

Table 7: The impact of different treatments on crop yield.

Treatments	Yield (t/ha)
T1- FYM	17.72
T2- VERMICOMPOST	16.48
T3- POULTRY MANURE	18.60
T4- VERMICOMPOST+ AZOTOBACTER	22.59
T5- POULTRY MANURE+ AZOTOBACTER	19.88
T6- CONTROL	14.62
C.D at 5%	0.9
SEm	1.13

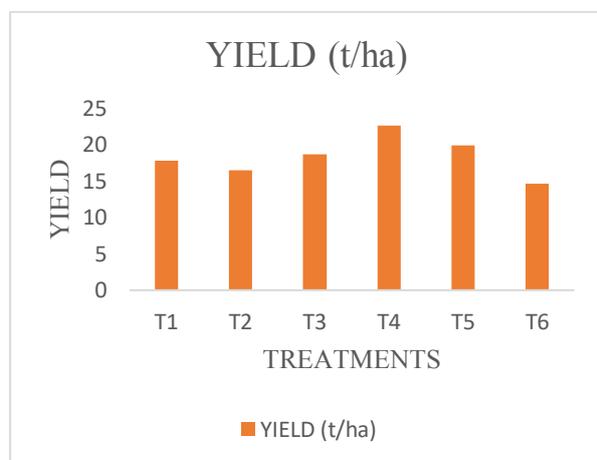


Figure 6: The impact of various treatments on the total yield(t/ha)

4. DISCUSSION

The findings of this research suggest conclusively that applying organic manures—alone or in combination with biofertilizers like Azotobacter—produces positive effects on cabbage growth, development, and yield under the particular environmental conditions of Noida, Uttar Pradesh. Carried out during the Rabi season of 2024–2025 at Amity University's Organic Agriculture Farm, this research assessed the performance of various organic inputs such as Farmyard Manure (FYM), Vermicompost, Poultry Manure, and their combination with Azotobacter to determine their effect on vegetative and yield-related parameters.

Growth Parameters

Plant Height

Plant height, a critical measure of growth, was significantly greater in Azotobacter-supplemented treatments. The most improved plants were found in Vermicompost + Azotobacter (T4) at 90 DAT with a mean plant height of 22.76 cm, which was followed very closely by the Poultry Manure + Azotobacter (T5). These findings correspond with earlier works, indicating the synergistic results of organic additives and microbial supplementations promote denser plant development through increased microbial activity and uptake of nutrients. The control (T6), where no organic amendments were supplied, had the lowest plant growth, affirming the role played by organic fertilizer in promoting adequate plant growth.

Outer Leaf Number

Outer leaf number, which is an indicator of the vegetative growth stage, was maximum in T4 (Vermicompost + Azotobacter) at every stage. At 90 DAT, T4 had maximum number of leaves (20.6), followed by T5 having 18.3 leaves. This is an indication that biofertilizers like Azotobacter have a significant role in speeding up leaf growth through increasing nutrient availability and root-zone microbial activities. The control treatment had notably fewer leaves, once again highlighting the importance of organic and microbial inputs for developing healthy vegetative growth.

Head Diameter

Head diameter, a significant characteristic for cabbage quality and yield potential determination, was also significantly impacted by organic treatments. At 90 days after transplanting (DAT), the largest head diameter was observed in treatment T4 (23.0 cm), with T5 (22.5 cm) ranking next. These findings emphasize the beneficial effect of integrated organic treatments on head growth since both vermicompost and Azotobacter improve soil

structure, release of nutrients, and microbial relations, all contributing to bigger and healthier cabbage heads. The control treatment produced the smallest head diameter (13.3 cm), indicating the shortfalls of growth without organic supplement.

Yield Parameters

Head Weight

Head weight, directly related to yield and market value, was also maximum in T4 (1.20 kg), followed by T5 (1.16 kg). This indicates that the integration of *Azotobacter* with organic manures facilitates better nutrient acquisition, resulting in heavier and well-developed cabbage heads. The control check produced the lightest heads (0.70 kg), indicating again the advantage of organic inputs in the promotion of crop quality.

Yield per Plot

The overall yield per plot was much higher in the T4 treatment (15.50 kg), while T5 (14.20 kg) and T3 (13.50 kg) also did well. The inclusion of *Azotobacter* in these treatments would have added to increased microbial activity and better nutrient cycling in the soil, which promoted overall productivity. The control treatment gave the least at 10.88 kg per plot, once again underscoring the importance of organic amendments in promoting crop yield.

Total Yield (t/ha)

The most yield per hectare was recorded in T4 (22.59 t/ha), followed by T5 (19.88 t/ha) and T3 (18.60 t/ha). This supports the notion that using organic fertilizers combined with microbial inoculants yields substantial increases in yields because these treatments enhance soil fertility, nutrient provision, and microbial status. The control treatment (14.62 t/ha) yielded the lowest, highlighting the need for organic inputs to improve crop performance.

5. CONCLUSION

This research explicitly shows that mixing *Azotobacter* with organic fertilizers, specifically Vermicompost, brings about great enhancements in cabbage growth and production. Treatments such as T4 (Vermicompost + *Azotobacter*) uniformly outshone all other treatments in stimulating plant height, leaf formation, head size, and total yield. These findings align with other research, which posits that the synergistic action of organic fertilizers and beneficial microbes can maximize crop performance by enhancing soil quality and nutrient availability.

The results point towards the ability of integrated organic farming methods to raise crop yield and

sustainability. Integrating organic manures with biofertilizers can help farmers minimize their dependence on chemical inputs, increase soil fertility, and enhance crop yields in a green way. Additional studies on the long-term implications of these organic treatments may bring even greater depth of understanding about their advantages in sustainable agriculture.

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