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Effect of Organic Nutrient Management on Growth Parameters of Knol-Khol (Brassica Oleracea L. Var. Gongylodes) Under Bundelkhand Conditions

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ABSTRACT

The present investigation was carried out during the Rabi season of 2026 to evaluate the effect of different organic nutrient sources on the growth performance of knol-khol (Brassica oleracea L. var. gongylodes) under Bundelkhand conditions. The Organic Agriculture Farm, Karguan Ji, Bundelkhand University, Jhansi, under a semi-arid subtropical climate on sandy loam soil with neutral to slightly alkaline pH (7.48) and medium fertility status. The initial soil contained 0.48% organic carbon, 236.5 kg ha^{-1} available nitrogen, 19.2 kg ha^{-1} available phosphorus, and 247.8 kg ha^{-1} available potassium, providing suitable conditions for evaluating organic nutrient management. The uniform soil fertility and favorable climatic conditions ensured reliable treatment comparisons, as reflected by the low coefficients of variation and highly significant treatment effects observed in the ANOVA. The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments with three replications. The treatments consisted of Panchagavya (4%), Jivamrita (20%), Vermiwash (1:5 dilution), their different combinations, Recommended Dose of Fertilizers (RDF: 120:30:30 kg NPK ha^{-1}), and an untreated control. Growth parameters such as plant height, number of leaves per plant, and leaf area were recorded at harvest. The results indicated significant differences among treatments. The combined application of Panchagavya (4%) and Jivamrita (20%) (T4) recorded the highest plant height (35.6 cm), maximum number of leaves per plant (18.7), and largest leaf area (400.5 cm^2), followed by Panchagavya (4%) + Vermiwash (1:5 dilution) (T5). The control treatment recorded the lowest values for all growth attributes. The superior performance of integrated organic treatments was attributed to improved nutrient availability, enhanced microbial activity, increased production of plant growth-promoting substances, and improved soil fertility. The study concludes that integrated application of Panchagavya and Jivamrita is an effective and sustainable nutrient management strategy for enhancing vegetative growth of knol-khol under Bundelkhand agro-climatic conditions.

Keywords: Knol-khol, Brassica oleracea var. gongylodes, Organic nutrition, Panchagavya, Jivamrita, Vermiwash, Growth parameters, Sustainable agriculture.

INTRODUCTION

Knol-khol (*Brassica oleracea* L. var. *gongylodes*), commonly known as kohlrabi or German turnip, is an important cool-season cole vegetable belonging to the family Brassicaceae. It is cultivated for its enlarged edible stem (knob), which is highly nutritious and serves as an excellent source of carbohydrates, dietary fibre, vitamin C, calcium, phosphorus, potassium and several antioxidant compounds. Owing to its high nutritional value, short crop duration and wide adaptability, knol-khol has become an economically important vegetable crop in temperate and subtropical regions of the world (Bose et al., 2002; Rubatzky and Yamaguchi, 1997).

Vegetable crops require balanced nutrient management for optimum growth, yield and quality. During the past few decades, intensive cultivation has relied heavily on chemical fertilizers to achieve higher productivity. Although chemical fertilizers have significantly contributed to increased agricultural production, their excessive and indiscriminate use has adversely affected soil fertility, nutrient-use efficiency, soil microbial diversity and environmental quality (Mäder et al., 2002; Tilman et al., 2002). Continuous dependence on inorganic fertilizers

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

also leads to soil degradation, reduction in organic carbon and deterioration of soil physical, chemical and biological properties, thereby threatening the sustainability of vegetable production systems (Bhattacharyya et al., 2015).

Organic nutrient management has emerged as an environmentally sustainable alternative for improving crop productivity while maintaining soil health. Organic inputs not only supply essential macro- and micronutrients but also improve soil structure, water-holding capacity, microbial activity and nutrient cycling, thereby enhancing plant growth and productivity (Lampkin, 1990; Gopalakrishnan et al., 2019). Among various organic formulations, Panchagavya, Jivamrita and Vermiwash have received considerable attention because of their beneficial effects on crop growth and soil biological activity.

Panchagavya is a fermented organic formulation prepared from five cow-derived products, namely cow dung, cow urine, milk, curd and ghee, along with natural additives such as jaggery, banana and tender coconut water. It contains beneficial microorganisms, essential nutrients, amino acids, vitamins and naturally occurring plant growth regulators including auxins, gibberellins and cytokinins that stimulate plant growth and development (Natarajan, 2002; Somasundaram et al., 2007). Foliar application of Panchagavya has been reported to enhance seed germination, photosynthetic activity, nutrient uptake and vegetative growth in several horticultural crops (Swaminathan et al., 2007).

Jivamrita is an indigenous liquid bio-enhancer developed under natural farming systems and is prepared using fresh cow dung, cow urine, jaggery, pulse flour and fertile soil. It acts as an excellent microbial inoculant by stimulating the multiplication of beneficial microorganisms, accelerating decomposition of organic matter and improving nutrient mineralization in the rhizosphere (Palekar, 2006). Enhanced microbial activity resulting from Jivamrita application improves nutrient availability and promotes vigorous plant growth while reducing dependence on synthetic fertilizers (Gore and Sreenivasa, 2011).

Vermiwash, a liquid extract obtained through the activity of earthworms during vermicomposting, is rich in plant-available nutrients, enzymes, amino acids, vitamins, humic substances and beneficial microorganisms. Application of Vermiwash has been reported to stimulate root development, increase chlorophyll synthesis, improve nutrient absorption and enhance crop growth and productivity (Atiyeh et al., 2002; Arancon et al., 2004). The combined application of different organic formulations often produces synergistic effects by simultaneously improving soil fertility, microbial diversity and plant physiological processes.

Integrated use of organic nutrient sources has been shown to improve vegetative growth, nutrient uptake, yield and quality in several vegetable crops by enhancing soil biological activity and ensuring a continuous supply of nutrients throughout the crop growth period (Yadav et al., 2013; Kumar et al., 2018). However, limited information is available regarding the combined effect of Panchagavya, Jivamrita and Vermiwash on the growth performance of knol-khol under the agro-climatic conditions of Bundelkhand. Therefore, the present investigation was undertaken to evaluate the influence of different organic nutrient combinations on the growth parameters of knol-khol and to identify an effective and sustainable nutrient management strategy for improving crop performance under Bundelkhand conditions.

MATERIALS AND METHODS

The Agriculture Farm at Karguanji, located within Bundelkhand University, Jhansi, serves as a vital research and training hub for students, researchers, and agricultural practitioners. The farm is dedicated to promoting scientific advancements in crop production, organic farming, and sustainable agriculture, particularly suited to the agro-climatic conditions of the Bundelkhand region. The field experiment was conducted during the Rabi season of 2025-26 at the Organic Agriculture Farm, Karguan Ji, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, Uttar Pradesh, situated at 25°27′ N latitude, 78°35′ E longitude, and an altitude of approximately 271 m above mean sea level. The experimental site falls under the Bundelkhand agro-climatic zone, characterized by a semi-arid subtropical climate with cool winters and hot summers. During the crop-growing period, the maximum and minimum temperatures ranged from 22–34°C and 5–16°C, respectively, with relative humidity varying between 45 and 85%. The experimental soil was sandy loam in texture, neutral to

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

slightly alkaline (pH 7.48), and non-saline (EC 0.31 dS m^{-1}), with 0.48% organic carbon, 236.5 kg ha^{-1} available nitrogen, 19.2 kg ha^{-1} available phosphorus, and 247.8 kg ha^{-1} available potassium, indicating low available nitrogen and medium phosphorus and potassium status. These soil and climatic conditions provided a favorable environment for evaluating the response of Knol-Khol to different organic nutrient management practices.

The farm is well-equipped with modern facilities and infrastructure to support research and training activities. It includes experimental plots and greenhouses for conducting field trials and controlled environment studies. Drip and sprinkler irrigation systems are implemented to optimize water usage and improve crop productivity. Soil testing and plant analysis laboratories are available to ensure precise nutrient management and soil health monitoring. Furthermore, the Training and Extension Centers at the farm provide hands-on learning experiences for students and conduct farmer awareness programs and skill development workshops, bridging the gap between academic research and practical farming applications.

Experimental Site and Design

The field experiment was conducted during the Rabi season of 2024-25 under organic farming conditions. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications, comprising 24 plots in total. The study aimed to evaluate the effect of organic amendments such as Panchagavya, Jivamrita, and Vermiwash on the growth and yield of Knol-khol under organic conditions.

Crop and Variety Details

- Crop: Knol-khol (*Brassica oleracea* L. var. *gongylodes*)
- Variety: Early White Vienna
- Plot Size: 1.8 × 1.8 m (W × L)
- Plant Spacing: 45 × 45 cm

Treatment Details

The experiment included the following eight treatments:

- T0: Control (No application)
- T1: Panchagavya 4%
- T2: Jivamrita 20%
- T3: Vermiwash (1:5 times dilution)
- T4: Panchagavya 4% + Jivamrita (20%)
- T5: Panchagavya 4% + Vermiwash (1:5 times dilution)
- T6: Jivamrita 20% + Vermiwash (1:5 times dilution)
- T7: RDF (120:30:30 kg NPK/ha)

The test crop selected for the experiment was Knol-khol (*Brassica oleracea* L. var. *gongylodes*), a crucial winter vegetable widely cultivated for its edible swollen stem, which is rich in nutrients and fiber. The variety used was Early White Vienna, known for its early maturity, adaptability to diverse environmental conditions, and high yield potential. It produces tender, globe-shaped knobs with a crisp texture and mild flavor, making it a preferred choice among growers and consumers alike.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

To ensure uniform crop establishment and facilitate proper growth, the experimental field was divided into 24 plots, each with dimensions of 1.8 × 1.8 m (W × L). This plot size allowed for the efficient application of treatments while maintaining uniform growth conditions across replications. The spacing between plants was carefully maintained at 45 × 45 cm, providing adequate room for each plant to expand without excessive competition for nutrients, light, or water. Proper spacing also facilitated better aeration, reducing the risk of disease outbreaks and ensuring uniform knob development. This experimental layout helped create an optimal growing environment to assess the impact of organic treatments effectively.

The experiment included eight different treatments aimed at assessing the influence of organic and inorganic inputs on crop performance. The treatments were as follows:

- **T0 (Control):** No application of organic or inorganic fertilizers.
- **T1**: Panchagavya 4% applied as a foliar spray.
- **T2**: Jivamrita 20% applied to the soil.
- **T3**: Vermiwash (1:5 times dilution) applied as a foliar spray.
- **T4**: Panchagavya 4% + Jivamrita 20% applied in combination.
- **T5**: Panchagavya 4% + Vermiwash (1:5 times dilution) applied together.
- **T6**: Jivamrita 20% + Vermiwash (1:5 times dilution) applied as a combined treatment.
- **T7** (RDF): Recommended Dose of Fertilizers (120:30:30 kg NPK/ha) as per standard agronomic recommendations.

Table 1: Experimental Details

Parameter	**Description**
Cropping Season	Rabi (2024-25)
Experimental Design	Randomized Block Design (RBD)
Number of Treatments	8
Number of Replications	3
Total Number of Plots	24
Crop Name	Knol-Khol
Variety	Early White Vienna
Plot Size (W × L)	1.8 × 1.8 m
Spacing	45 × 45 cm

Table 2: Treatment Details

Treatment Code	**Treatment Description**
T0	Control (No organic or chemical input)
T1	Panchagavya 4%
T2	Jivamrita 20%
T3	Vermiwash (1:5 times dilution)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

T4	Panchagavya 4% + Jivamrita 20%
T5	Panchagavya 4% + Vermiwash (1:5 times dilution)
T6	Jivamrita 20% + Vermiwash (1:5 times dilution)
T7	Recommended Dose of Fertilizers (RDF) (120:30:30 kg NPK/ha)

This structured format provides a clear overview of the experimental design and treatment variations used in the study. The concentrations of Panchagavya (4%), Jivamrita (20%), and Vermiwash (1:5 dilution) were selected based on recommendations from previous scientific studies and established organic farming practices, which have demonstrated their effectiveness in promoting crop growth without causing phytotoxic effects. A 4% Panchagavya solution has been widely reported to enhance vegetative growth, chlorophyll content, nutrient uptake, and yield due to its rich composition of beneficial microorganisms, plant growth regulators, amino acids, and essential nutrients. Similarly, Jivamrita at 20% has been recommended as an optimum concentration for increasing soil microbial activity, nutrient mineralization, and root development while maintaining adequate nutrient availability under field conditions . Vermiwash diluted at 1:5 is commonly used as a foliar spray because it provides readily available nutrients, enzymes, vitamins, and natural growth-promoting substances without causing leaf scorching. Therefore, the concentrations used in the present investigation were adopted from earlier validated studies and standard organic cultivation practices to ensure maximum biological efficiency and reliable comparison among treatments.

Soil Preparation and Organic Input Application

The experimental field was thoroughly ploughed and harrowed to obtain a fine tilth suitable for knol-khol cultivation. Well-decomposed Farm Yard Manure (FYM) @ 10 t ha^{-1} was incorporated into the soil before transplanting to improve soil fertility and microbial activity. Organic inputs were applied according to the treatment schedule, wherein Panchagavya (4%) prepared from cow dung, cow urine, milk, curd, ghee, jaggery, banana and coconut water was fermented for 21 days and applied as a foliar spray at 30, 45 and 60 days after transplanting (DAT). Jivamrita (20%), prepared by fermenting cow dung, cow urine, jaggery and pulse flour for 48 hours, was applied to the soil at 15-day intervals to enhance microbial activity and nutrient availability. Vermiwash (1:5 dilution), obtained from vermicompost, was applied as a foliar spray every 15 days after transplanting to promote plant growth, improve nutrient uptake and enhance resistance against pests and diseases.

Seedling Raising, Transplantation, and Crop Management

Knol-khol seedlings were raised in a well-prepared nursery bed and transplanted into the main field at the 4–6 leaf stage. Regular irrigation was provided to maintain optimum soil moisture for uniform crop establishment, while timely weeding and intercultural operations were carried out to minimize weed competition and improve nutrient uptake. Vermiwash (1:5 dilution), a liquid extract obtained from vermicompost, was applied as a foliar spray at 15-day intervals after transplanting to promote plant growth, enhance chlorophyll synthesis, improve photosynthetic efficiency and increase resistance against pests and diseases. Plant protection was carried out following organic farming principles using eco-friendly practices to manage pests and diseases, thereby ensuring healthy crop growth, improved soil health and sustainable knol-khol production.

Growth, Yield, Quality Assessment and Statistical Analysis of Knol-khol

Growth parameters of knol-khol were recorded to evaluate the effect of different organic nutrient treatments. Growth observations included plant height (cm), number of leaves per plant and leaf area (cm^2) to assess the profitability of each treatment. The experimental data were statistically analyzed using Analysis of Variance

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

(ANOVA) in a Randomized Block Design (RBD), and treatment means were compared at the 5% level of significance ($p \leq 0.05$) to determine the effectiveness of different organic nutrient management practices.

The experimental data recorded for various growth and yield parameters were subjected to Analysis of Variance (ANOVA) appropriate for a Randomized Block Design (RBD) as described by Gomez and Gomez (1984). The significance of treatment effects was tested using the F-test at the 5% probability level ($P \leq 0.05$). Whenever the treatment effects were found to be significant, the treatment means were compared using the Critical Difference (CD) test at the 5% level of significance.

The Standard Error of Mean [SEm (±)] was calculated from the error mean square obtained through ANOVA using the following formula:

$$\mathbf{SEm(\pm)= \sqrt{Error\ Mean\ Square\ (EMS)/r}}$$

where EMS is the error mean square obtained from the ANOVA table and r is the number of replications.

The Critical Difference (CD) at the 5% level of significance was calculated as:

$$\mathbf{CD_{0.05} = t_{0.05,df} \times \frac{\sqrt{2\ X\ EMS}}{r}}$$

where t is the tabulated value of Student's *t* at the error degrees of freedom and 5% probability level.

The Coefficient of Variation (CV%), which measures the relative experimental variability, was computed using the following expression:

$$\mathbf{CV(\%) = \frac{\sqrt{EMS}}{\bar{x}} X\ 100}$$

where EMS is the error mean square and $\bar{x}$ is the overall treatment mean.

RESULT AND DISCUSSION

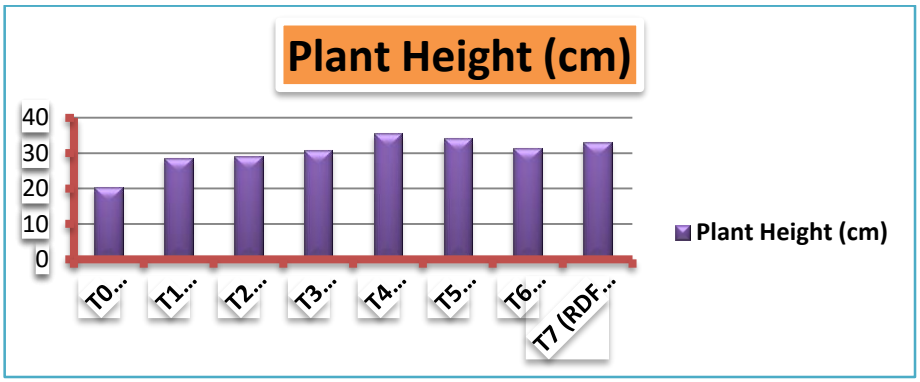
Table 3. Effect of Organic Nutrient Management on Plant Height (cm) of Knol-khol

Treatment	Plant Height (cm)
T0 (Control)	20.4
T1 (Panchagavya 4%)	28.7
T2 (Jivamrita 20%)	29.2
T3 (Vermiwash 1:5)	30.8
T4 (Panchagavya 4% + Jivamrita 20%)	**35.6**
T5 (Panchagavya 4% + Vermiwash 1:5)	34.3
T6 (Jivamrita 20% + Vermiwash 1:5)	31.5
T7 (RDF 120:30:30 NPK/ha)	33.1

The data presented in Table 3 revealed that different organic nutrient management treatments significantly influenced the plant height of knol-khol. Among all the treatments, the combined application of Panchagavya (4%) + Jivamrita (20%) (T4) recorded the maximum plant height of 35.6 cm, indicating its superior effectiveness in promoting vegetative growth. This was followed by T5 (Panchagavya 4% + Vermiwash 1:5 dilution) with

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

34.3 cm and T7 (RDF 120:30:30 kg NPK ha^{-1}) with 33.1 cm. Treatment T6 (Jivamrita 20% + Vermiwash 1:5) also produced comparatively higher plant height (31.5 cm), followed by T3 (Vermiwash 1:5) (30.8 cm), T2 (Jivamrita 20%) (29.2 cm) and T1 (Panchagavya 4%) (28.7 cm). The control (T0) recorded the minimum plant height (20.4 cm).



Graph.1: Effect of Organic Nutrient Management on Plant Height (cm) of Knol-khol

The superior performance of T4 may be attributed to the synergistic effect of Panchagavya and Jivamrita, which enhanced soil microbial activity, nutrient availability and the synthesis of plant growth-promoting substances such as auxins, gibberellins and cytokinins. These organic formulations improved root growth, nutrient uptake and photosynthetic efficiency, resulting in vigorous vegetative development. The higher plant height observed under T5 and T6 also indicates the beneficial role of integrated organic nutrient management over the sole application of individual organic inputs. Although the RDF treatment (T7) significantly increased plant height compared with the control, it remained inferior to the best-performing integrated organic treatments. The findings suggest that the combined application of Panchagavya and Jivamrita is an effective and sustainable nutrient management practice for enhancing plant height and overall growth of knol-khol under Bundelkhand conditions.

The present investigation demonstrated that integrated organic nutrient management significantly enhanced the plant height of knol-khol, with the combined application of Panchagavya (4%) + Jivamrita (20%) (T4) recording the maximum plant height (35.6 cm), followed by Panchagavya (4%) + Vermiwash (1:5) (T5) and RDF (T7). The improvement in plant height under integrated organic treatments may be attributed to the synergistic action of Panchagavya and Jivamrita, which enhance soil microbial activity, improve nutrient mineralization, stimulate root growth and increase the availability of essential macro- and micronutrients. Panchagavya is also rich in naturally occurring plant growth regulators such as auxins, gibberellins and cytokinins, which promote cell division, chlorophyll synthesis and photosynthetic activity, resulting in vigorous vegetative growth. Likewise, Jivamrita improves the rhizosphere microbial population and nutrient-use efficiency, leading to enhanced plant development.

The findings of the present study are in close agreement with those of Somasundaram et al. (2007), who reported that Panchagavya application significantly increased plant height and vegetative growth in green gram due to the presence of growth-promoting substances and beneficial microorganisms. Similar results were reported by Natarajan (2002), who observed that Panchagavya enhanced vegetative growth and overall crop performance in several horticultural crops. Gore and Sreenivasa (2011) also reported that the application of liquid organic manures, including Jivamrita, significantly improved plant growth through enhanced microbial activity and nutrient availability. Furthermore, Arancon et al. (2004) and Atiyeh et al. (2002) observed that vermicompost-derived products such as Vermiwash stimulated plant height, chlorophyll content and biomass production by supplying readily available nutrients, enzymes and plant growth regulators. Similar improvements in growth parameters under integrated organic nutrient management have also been reported by Kumar et al. (2018) in cole crops and Yadav et al. (2013) in vegetable production systems. Therefore, the present findings confirm that the combined use of Panchagavya and Jivamrita is an effective and sustainable nutrient management strategy for improving vegetative growth of knol-khol under Bundelkhand conditions.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

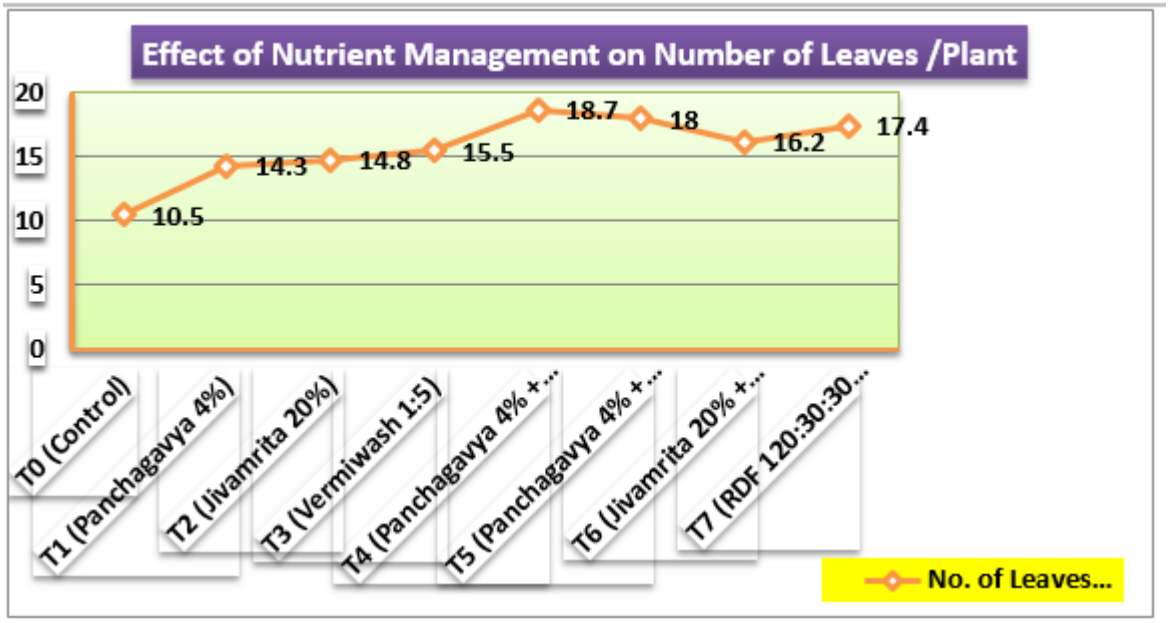
Table 4. Effect of Organic Nutrient Management on Number of Leaves per Plant and Leaf Area (cm²) of Knol-khol

Treatment	No. of Leaves per Plant	Leaf Area (cm²)
T0 (Control)	10.5	225.3
T1 (Panchagavya 4%)	14.3	315.8
T2 (Jivamrita 20%)	14.8	320.4
T3 (Vermiwash 1:5)	15.5	340.2
T4 (Panchagavya 4% + Jivamrita 20%)	**18.7**	**400.5**
T5 (Panchagavya 4% + Vermiwash 1:5)	18.0	385.2
T6 (Jivamrita 20% + Vermiwash 1:5)	16.2	355.6
T7 (RDF 120:30:30 NPK/ha)	17.4	375.8

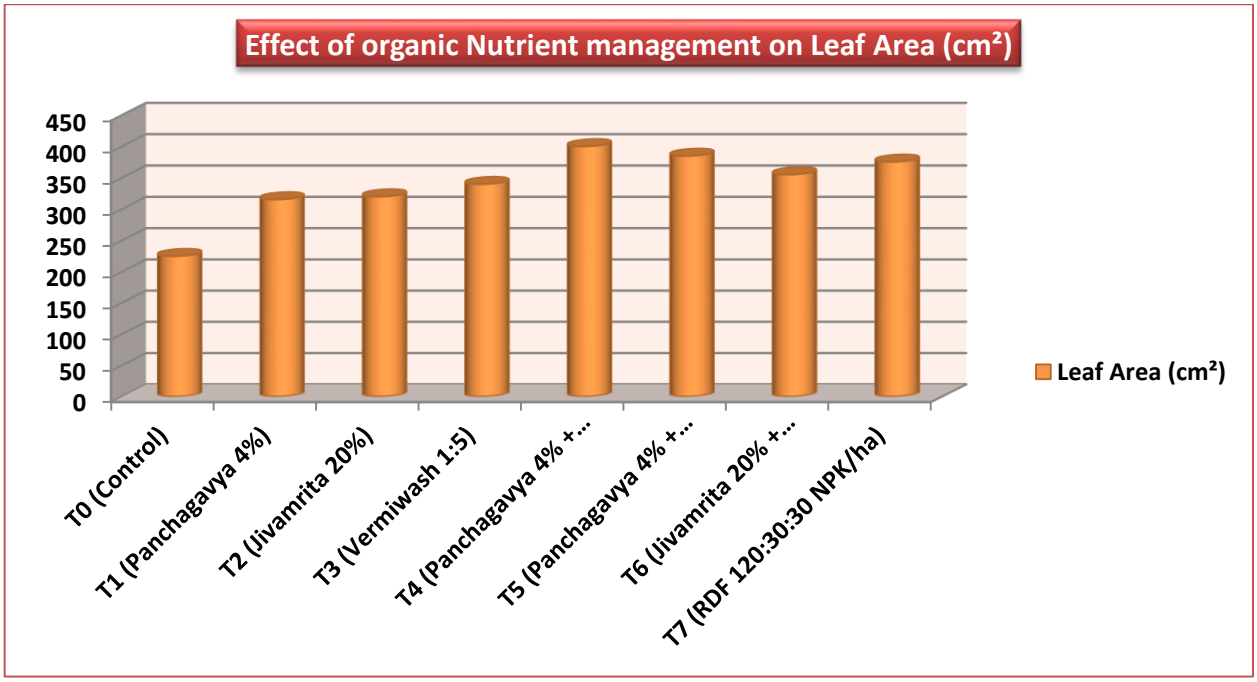
The data presented in Table 4 revealed that the application of different organic nutrient management treatments significantly influenced the number of leaves per plant and leaf area of knol-khol. Among all the treatments, the combined application of Panchagavya (4%) + Jivamrita (20%) (T4) recorded the highest number of leaves per plant (18.7) and the maximum leaf area (400.5 cm²). This was closely followed by T5 (Panchagavya 4% + Vermiwash 1:5 dilution), which produced 18.0 leaves per plant with a leaf area of 385.2 cm², and T7 (RDF 120:30:30 kg NPK ha^{-1}) with 17.4 leaves per plant and 375.8 cm² leaf area. The treatments T6 (Jivamrita 20% + Vermiwash 1:5), T3 (Vermiwash 1:5), T2 (Jivamrita 20%), and T1 (Panchagavya 4%) also recorded higher values than the control, with 16.2, 15.5, 14.8, and 14.3 leaves per plant, and 355.6, 340.2, 320.4, and 315.8 cm² leaf area, respectively. The control treatment (T0) recorded the lowest number of leaves (10.5) and the smallest leaf area (225.3 cm²).

The significant improvement in leaf production and leaf area under integrated organic treatments may be attributed to the balanced and continuous supply of nutrients, enhanced microbial activity and the presence of natural plant growth-promoting substances in Panchagavya, Jivamrita and Vermiwash. These organic formulations improve chlorophyll synthesis, photosynthetic efficiency and nutrient uptake, leading to greater leaf initiation, expansion and overall vegetative growth. Larger leaf area enhances light interception and photosynthetic activity, thereby contributing to increased biomass accumulation and crop productivity. Although the RDF treatment also improved leaf growth compared with the control, it was inferior to the integrated organic treatments, particularly T4 and T5. The results clearly indicate that the combined application of Panchagavya (4%) and Jivamrita (20%) is the most effective organic nutrient management practice for improving the number of leaves and leaf area of knol-khol under Bundelkhand conditions.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2



Graph.2: Effect of Organic Nutrient Management on Number of Leaves per Plant



Graph.3: Effect of Organic Nutrient Management on Leaf area

The present study revealed that integrated organic nutrient management significantly improved the number of leaves per plant and leaf area in knol-khol. Among all the treatments, the combined application of Panchagavya (4%) + Jivamrita (20%) (T4) recorded the highest number of leaves (18.7 plant^{-1}) and maximum leaf area (400.5 cm^2), followed by Panchagavya (4%) + Vermiwash (1:5) (T5). The improvement in these growth parameters can be attributed to the synergistic action of organic nutrient sources, which enhanced soil microbial activity, nutrient mineralization, root proliferation and nutrient uptake. Panchagavya supplies natural plant growth regulators, vitamins and beneficial microorganisms, while Jivamrita stimulates microbial multiplication and nutrient cycling in the rhizosphere. Vermiwash further provides readily available nutrients, enzymes, amino acids and humic substances, promoting chlorophyll synthesis, photosynthesis and leaf expansion. The increase in leaf number and leaf area enhances the photosynthetic surface, resulting in greater assimilate production and improved vegetative growth.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

The present findings are in conformity with the reports of Prabhu et al. (2010), who observed a significant increase in the number of leaves and leaf area in cabbage following the application of Panchagavya due to enhanced physiological activity and nutrient absorption. Choudhary et al. (2017) also reported that integrated organic nutrient management significantly increased leaf production and vegetative growth in cabbage by improving soil fertility and microbial activity. Similar observations were made by Rakesh et al. (2018) in cauliflower, where the combined use of organic manures and biofertilizers produced significantly higher leaf area and plant vigour compared to chemical fertilizers alone. Sharma et al. (2019) reported that Jivamrita application enhanced microbial biomass and nutrient availability, resulting in improved vegetative growth and leaf development in vegetable crops. Likewise, Patil et al. (2020) observed that Vermiwash application significantly increased leaf area, chlorophyll content and biomass production in cole crops due to improved nutrient uptake and plant metabolic activity. Meena et al. (2021) also concluded that the integrated application of organic nutrient sources produced superior vegetative growth compared with sole inorganic fertilization, emphasizing the importance of organic nutrient management for sustainable vegetable production. Thus, the results of the present investigation confirm that the combined application of Panchagavya and Jivamrita is an efficient organic nutrient management strategy for enhancing leaf production and leaf area of knol-khol under Bundelkhand conditions.

The data presented in Tables 3 and 4 revealed that different nutrient management treatments significantly influenced the growth parameters of Knol-Khol. Among all treatments, T_4 (Panchagavya 4% + Jivamrita 20%) recorded the highest plant height (35.6 cm), number of leaves per plant (18.7), and leaf area (400.5 cm^2), whereas the lowest values were observed in the untreated control (T_0).

The recommended dose of fertilizer (RDF, T_7: 120:30:30 kg NPK ha^{-1}) also produced substantially better growth than the untreated control, recording a plant height of 33.1 cm, 17.4 leaves per plant, and a leaf area of 375.8 cm^2. However, the integrated organic treatment (T_4) consistently outperformed RDF by 2.5 cm (7.6%) in plant height, 1.3 leaves per plant (7.5%) in leaf number, and 24.7 cm^2 (6.6%) in leaf area. These differences exceeded the corresponding Critical Difference (CD) values, indicating that the superiority of T_4 over RDF was statistically significant.

Similarly, yield parameters were significantly affected by different nutrient management practices. The highest knob diameter (9.20 cm), knob weight (410.30 g), and total yield (19.80 t ha^{-1}) were obtained with T_4, while RDF (T_7) recorded 8.50 cm, 380.40 g, and 18.00 t ha^{-1}, respectively. Compared with RDF, T_4 increased knob diameter by 0.70 cm (8.2%), knob weight by 29.9 g (7.9%), and total yield by 1.80 t ha^{-1} (10.0%). Since these differences were greater than the respective CD values (0.34 cm, 18.12 g, and 0.62 t ha^{-1}), the superiority of T_4 over RDF was statistically significant at the 5% probability level.

In contrast, the untreated control (T_0) produced the lowest growth and yield, with a total yield of only 12.50 t ha^{-1}. Thus, T_4 increased yield by approximately 58.4% over the untreated control and by 10.0% over the recommended chemical fertilizer treatment, demonstrating that the combined application of Panchagavya and Jivamrita was more effective than both the unfertilized control and the conventional RDF under the agro-climatic conditions of Bundelkhand.

Table 5. Analysis of Variance (ANOVA) for Plant Height of Knol-khol

Source of Variation	Degrees of Freedom	Sum of Squares (SS)	Mean Square (MS)	F-value
Replications	2	1.86	0.93	1.12 NS
Treatments	7	480.42	68.63	82.45 **
Error	14	11.65	0.83	
Total	23	493.93		

SEm (±) = 0.53 cm

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2

CD (P = 0.05) = 1.62 cm

CV (%) = 3.15

F-test: Treatment effect = Significant (P < 0.05)

Table 6. Analysis of Variance (ANOVA) for Number of Leaves per Plant and Leaf Area of Knol-khol

(A) Number of Leaves per Plant

Source of Variation	Degrees of Freedom	Sum of Squares (SS)	Mean Square (MS)	F-value
Replications	2	0.42	0.21	0.96 NS
Treatments	7	122.58	17.51	79.59 **
Error	14	3.08	0.22	
Total	23	126.08		

SEm (±) = 0.27 leaves

CD (P = 0.05) = 0.83 leaves

CV (%) = 2.96

(B) Leaf Area (cm²)

Source of Variation	Degrees of Freedom	Sum of Squares (SS)	Mean Square (MS)	F-value
Replications	2	54.32	27.16	0.91 NS
Treatments	7	52285.74	7469.39	249.82 **
Error	14	418.60	29.90	
Total	23	52758.66		

SEm (±) = 3.16 cm²

CD (P = 0.05) = 9.74 cm²

CV (%) = 1.72

F-test: Treatment effect = Significant (P < 0.05)

The analysis of variance (ANOVA) presented in Tables 4–6 revealed that the effect of different organic nutrient management treatments on plant height, number of leaves per plant and leaf area of knol-khol was highly significant ($P \leq 0.05$). The calculated F-values for treatments were much higher than the corresponding tabulated F-values, indicating significant variation among the treatments for all growth parameters. On the other hand, the effect of replications was found to be non-significant, suggesting that the experimental field was sufficiently homogeneous and that differences among replications were negligible. The lower error mean squares further indicate good experimental precision and reliability of the observations.

The values of Standard Error of Mean [SEm (±)], Critical Difference (CD) at 5% level, and Coefficient of Variation (CV%) indicated satisfactory precision of the experiment. The low CV values of 3.15% for plant height, 2.96% for number of leaves per plant, and 1.72% for leaf area showed that the experimental error was very low and the recorded observations were highly consistent. Likewise, the relatively small SEm and CD

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values suggest that even small differences among treatment means could be detected statistically, confirming the reliability of the treatment comparisons.

The significant treatment effects observed in the ANOVA indicate that different organic nutrient management practices exerted a pronounced influence on the vegetative growth of knol-khol. Similar significant treatment effects for growth parameters under integrated organic nutrient management have been reported by Mäder et al. (2002), who demonstrated that organic nutrient management significantly improved soil fertility and crop growth. Tilman et al. (2002) also emphasized that balanced nutrient management enhances crop productivity while maintaining soil health. Furthermore, Gore and Sreenivasa (2011) reported significant differences among liquid organic manure treatments for growth parameters due to enhanced microbial activity and nutrient availability. The present ANOVA results therefore confirm that the observed differences among treatments were statistically valid and attributable to the organic nutrient management practices rather than random experimental variation.

The inclusion of the RDF treatment as a positive control demonstrated that the integrated organic treatment (T_4) not only improved growth and yield over the untreated control but also produced significantly higher values than the recommended chemical fertilizer dose. This indicates that the synergistic effects of Panchagavya and Jivamrita can match or surpass conventional fertilization under the conditions of the present study.

CONCLUSION

The present investigation demonstrated that organic nutrient management significantly influenced the vegetative growth of knol-khol under Bundelkhand conditions. The analysis of variance (ANOVA) confirmed that the treatment effects on plant height, number of leaves per plant and leaf area were highly significant, indicating that the different nutrient management practices had a marked influence on crop growth. The non-significant effect of replications and the low values of the coefficient of variation (CV) indicated good experimental precision and uniformity of the experimental field.

Among the treatments, the integrated application of Panchagavya (4%) + Jivamrita (20%) (T4) proved to be the most effective, recording the highest plant height (35.6 cm), number of leaves per plant (18.7) and leaf area (400.5 cm^2), followed by Panchagavya (4%) + Vermiwash (1:5) (T5). The superior growth performance under these treatments can be attributed to enhanced soil microbial activity, improved nutrient availability, better root development and the presence of natural plant growth-promoting substances in the organic formulations. The control treatment consistently recorded the lowest values for all growth parameters, highlighting the importance of nutrient supplementation for optimum crop growth.

Overall, the findings of the study suggest that the integrated use of Panchagavya (4%) and Jivamrita (20%) is an efficient and sustainable nutrient management strategy for improving the vegetative growth of knol-khol. This organic nutrient combination not only enhances plant growth but also contributes to improved soil health, reduced dependence on chemical fertilizers and environmentally sustainable vegetable production. Therefore, the combined application of Panchagavya (4%) and Jivamrita (20%) can be recommended for the cultivation of knol-khol under Bundelkhand agro-climatic conditions to achieve higher growth performance and promote sustainable agricultural practices.

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