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Effect of Panchagavya, Jivamrita and Vermiwash on Yield of Knol-Khol (Brassica Oleracea L. Var. Gongylodes) Under Organic Conditions

Samiksha Verma[1], Dr. Harpal Singh[2], Dr. Jitendra Kumar[3], Dr. B.P. Singh[4]

Bundelkhand University, Jhansi

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ABSTRACT

A field experiment was conducted during the Rabi season of 2025-26 to evaluate the influence of different organic nutrient management practices on the yield performance of Knol-Khol (*Brassica oleracea* L. var. *gongylodes*) under Bundelkhand conditions. The experiment comprised eight treatments, including Panchagavya, Jivamrita, Vermiwash, their combinations, Recommended Dose of Fertilizer (RDF), and an untreated control, arranged in a Randomized Block Design (RBD) with three replications. 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 yield parameters recorded were knob diameter (cm), knob weight (g), and total yield (t ha^{-1}). Statistical analysis using Analysis of Variance (ANOVA) revealed significant differences among treatments for all the characters studied. The combined application of Panchagavya (4%) + Jivamrita (20%) (T_4) produced the highest knob diameter (9.20 cm), knob weight (410.30 g), and total yield (19.80 t ha^{-1}), which was significantly superior over all other treatments. The lowest values were recorded in the untreated control. The study demonstrated that integrated organic nutrient management enhanced productivity through improved nutrient availability, microbial activity, and better physiological efficiency of the crop.

Keywords: Knol-Khol, Organic nutrition, Panchagavya, Jivamrita, Vermiwash, Yield, ANOVA, RBD.

INTRODUCTION

Knol-Khol (*Brassica oleracea* L. var. *gongylodes*) is one of the important cole vegetables cultivated throughout temperate and subtropical regions. The edible swollen stem (knob) is highly nutritious and rich in vitamins, minerals, dietary fibre, and antioxidants. Excessive dependence on chemical fertilizers has adversely affected soil fertility, microbial diversity, and environmental sustainability. Consequently, organic nutrient management practices such as Panchagavya, Jivamrita, and Vermiwash have gained considerable im Knol-Khol (*Brassica oleracea* L. var. *gongylodes* L.), also known as Kohlrabi or German turnip, is an important cool-season cole vegetable belonging to the family Brassicaceae. It is cultivated extensively in temperate, subtropical, and tropical regions of the world for its edible swollen stem, commonly referred to as the knob. The crop is valued for its high nutritional quality, being a rich source of vitamin C, vitamin A, dietary fibre, calcium, phosphorus, potassium, iron, and various antioxidant compounds. Owing to its excellent nutritional profile, pleasant flavour, and short duration, Knol-Khol has become an important vegetable crop for both commercial cultivation and kitchen gardening (Bose et al., 2002; Rubatzky & Yamaguchi, 1997).

The productivity and quality of Knol-Khol largely depend on balanced nutrient management. Conventionally, farmers rely heavily on inorganic fertilizers to maximize yield. However, continuous and indiscriminate application of chemical fertilizers has resulted in deterioration of soil physical, chemical, and biological properties, reduced soil organic carbon, nutrient imbalance, decline in beneficial microbial populations, and increased environmental pollution (Mahajan et al., 2008; Das et al., 2014). These concerns have emphasized the need for sustainable nutrient management strategies that can maintain crop productivity while preserving soil health and environmental quality.

Organic nutrient management has emerged as an eco-friendly alternative that integrates organic inputs to improve soil fertility, microbial diversity, and nutrient-use efficiency. Organic formulations not only supply essential macro- and micronutrients but also stimulate biological activity in the rhizosphere, enhance nutrient mineralization, improve soil structure, and promote sustainable crop production (Palekar, 2006; Lampkin, 1999). Among the various organic formulations, Panchagavya, Jivamrita, and Vermiwash have attracted considerable attention because of their beneficial effects on plant growth and yield.

Panchagavya is a traditional organic formulation prepared from five cow-derived products, namely cow dung, cow urine, milk, curd, and ghee, along with additives such as jaggery, banana, and tender coconut water during fermentation. It contains beneficial microorganisms, essential nutrients, amino acids, vitamins, enzymes, and naturally occurring plant growth regulators such as auxins, gibberellins, and cytokinins, which collectively enhance vegetative growth, flowering, yield, and crop quality (Natarajan, 2002; Somasundaram et al., 2003). Numerous studies have demonstrated that foliar application of Panchagavya improves photosynthetic efficiency, nutrient uptake, chlorophyll synthesis, and biomass accumulation in vegetable crops.

Jivamrita, developed under Zero Budget Natural Farming (ZBNF), is another important liquid organic formulation prepared using fresh cow dung, cow urine, pulse flour, jaggery, and soil. It acts primarily as a microbial inoculant that stimulates the multiplication of beneficial microorganisms responsible for decomposition, nutrient mineralization, and biological nitrogen fixation. Enhanced microbial activity improves nutrient availability, root development, soil enzymatic activity, and overall plant vigour, thereby contributing to higher productivity (Palekar, 2006; Sreenivasa et al., 2010). Vermiwash is a liquid extract collected during the process of vermicomposting and is considered a valuable bio-liquid fertilizer. It contains readily available nutrients, humic substances, vitamins, enzymes, amino acids, beneficial microorganisms, and plant growth-promoting hormones. Foliar application of Vermiwash has been reported to stimulate cell division, chlorophyll synthesis, nutrient absorption, and photosynthetic activity, resulting in improved growth, yield, and quality of horticultural crops (Atiyeh et al., 2002; Arancon et al., 2004). In addition, Vermiwash contributes to better soil biological activity and enhances the efficiency of nutrient utilization by plants.

The combined application of different organic nutrient sources is often more effective than their individual use because of synergistic interactions among nutrients, microorganisms, and naturally occurring growth regulators. Integrated organic nutrient management improves nutrient availability throughout the crop growth period, enhances microbial diversity, promotes efficient assimilate partitioning, and ultimately increases yield and quality while maintaining long-term soil fertility (Yadav et al., 2013; Das et al., 2014).

The Bundelkhand region of Uttar Pradesh is characterized by low soil organic matter, erratic rainfall, and declining soil fertility, making sustainable nutrient management a major challenge for vegetable production. Under such agro-climatic conditions, evaluation of different organic nutrient combinations becomes essential for identifying suitable nutrient management practices that enhance productivity while maintaining soil health. However, information regarding the combined use of Panchagavya, Jivamrita, and Vermiwash for Knol-Khol cultivation under Bundelkhand conditions is limited.

Therefore, the present investigation was undertaken to evaluate the effect of different organic nutrient management treatments on the yield parameters of Knol-Khol (*Brassica oleracea* L. var. *gongylodes*) under Bundelkhand conditions and to identify an effective organic nutrient management strategy for sustainable vegetable production.

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 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 2025-26 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.

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)
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

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.

Yield Assessment and Statistical Analysis of Knol-khol

Yield parameters of knol-khol were recorded to evaluate the effect of different organic nutrient treatments. yield parameters comprised knob diameter (cm), knob weight (g) and total yield (t ha^{-1}). to assess the profitability of each treatment. The experimental data were statistically analyzed using Analysis of Variance (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:

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

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:

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

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

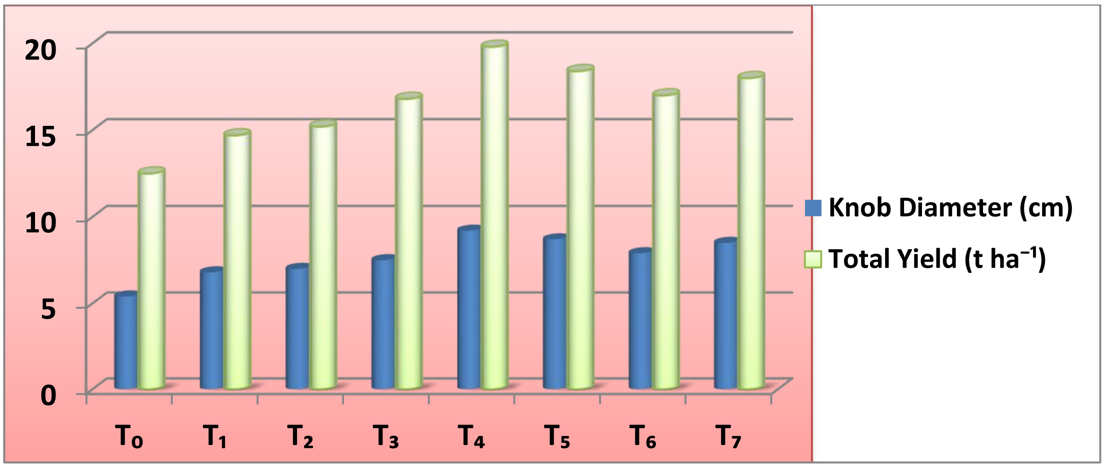
The data presented in Table 3 clearly indicate that different organic nutrient treatments significantly influenced the yield parameters of Knol-Khol.

The largest knob diameter (9.20 cm) was recorded under T_4 (Panchagavya 4% + Jivamrita 20%), followed by T_5 (8.70 cm) and T_7 (8.50 cm). The smallest knob diameter (5.40 cm) was observed in the untreated control. The improvement in knob diameter under combined organic treatments may be attributed to enhanced nutrient availability, increased microbial activity, and better photosynthetic efficiency resulting in greater cell expansion and accumulation of carbohydrates within the edible knob.

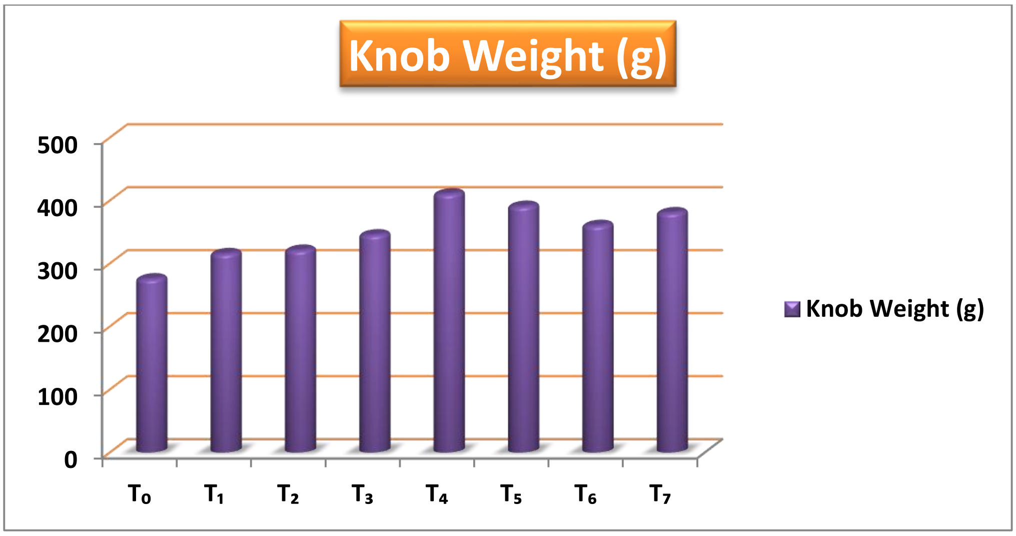
Table 3. Effect of Organic Nutrient Management on Yield Parameters of Knol-Khol

Treatment	Knob Diameter (cm)	Knob Weight (g)	Total Yield (t ha^{-1})
T_0	5.40	275.30	12.50
T_1	6.80	315.40	14.70
T_2	7.00	320.80	15.20
T_3	7.50	345.20	16.80
T_4	**9.20**	**410.30**	**19.80**
T_5	8.70	390.60	18.40
T_6	7.90	360.20	17.00
T_7	8.50	380.40	18.00

Similarly, knob weight was significantly influenced by different nutrient management practices. The highest knob weight (410.30 g) was recorded with T_4, followed by T_5 (390.60 g), T_7 (380.40 g), and T_6 (360.20 g). The untreated control recorded only 275.30 g. The increase in knob weight under integrated organic treatments can be attributed to continuous nutrient release, improved root growth, and efficient translocation of photosynthates towards the developing knob.



Graph-1: Effect of Organic Nutrient Management on Knob Diameter and Total Yield of Knol-Khol



Graph-1: Effect of Organic Nutrient Management on Knob weight of Knol-Khol

The highest total yield (19.80 t ha^{-1}) was also obtained under T_4, followed by T_5 (18.40 t ha^{-1}), T_7 (18.00 t ha^{-1}), and T_6 (17.00 t ha^{-1}). In contrast, the control treatment produced only 12.50 t ha^{-1}. The integrated application of Panchagavya and Jivamrita resulted in approximately 58.4% higher yield over the untreated control.

The superior performance of T_4 may be due to the synergistic action of Panchagavya and Jivamrita. Panchagavya provides naturally occurring plant growth regulators such as auxins, gibberellins, amino acids, vitamins, and beneficial microorganisms, whereas Jivamrita enhances soil microbial population, accelerates decomposition and nutrient mineralization, and improves nutrient uptake by roots. Together, these factors enhanced vegetative growth, photosynthetic activity, assimilate partitioning, and knob development, ultimately leading to higher yield.

Individual application of Vermiwash (T_3) also produced appreciable improvements over the control because Vermiwash supplies readily available nutrients, enzymes, and growth-promoting substances. However, combined organic treatments were more effective than individual applications, indicating a synergistic effect among the organic inputs.

Interestingly, the combined organic treatments (T_4 and T_5) also outperformed the recommended dose of chemical fertilizers (T_7), suggesting that integrated organic nutrient management can effectively replace or reduce dependence on inorganic fertilizers while maintaining higher productivity under organic conditions.

The present study clearly demonstrated that different organic nutrient management practices significantly affected the yield parameters of Knol-Khol. Among the treatments, the combined application of Panchagavya (4%) + Jivamrita (20%) (T_4) recorded the maximum knob diameter (9.20 cm), knob weight (410.30 g), and total yield (19.80 t ha^{-1}). The superiority of this treatment indicates that integrated application of organic nutrient sources provides a more balanced nutrient supply, improves soil biological activity, and enhances nutrient-use efficiency compared with individual organic inputs or conventional fertilization.

The significant increase in knob diameter observed under T_4 may be attributed to enhanced cell division and enlargement resulting from improved nutrient availability and better physiological activity of the plants. Organic nutrient sources stimulate microbial populations that accelerate nutrient mineralization and improve the availability of nitrogen, phosphorus, potassium, and micronutrients throughout the crop growth period. Improved nutrient availability promotes chlorophyll synthesis, photosynthetic efficiency, and carbohydrate accumulation, which ultimately contribute to greater enlargement of the edible knob. Similar findings were reported by Chatterjee et al. (2005) in cabbage, Singh et al. (2017) in cole crops, and Kansal et al. (2018) in Knol-Khol, who observed significant improvement in vegetative growth and knob development through integrated organic nutrient management.

The increase in knob weight under combined organic treatments may be due to continuous nutrient release from organic formulations together with improved root development and enhanced translocation of photosynthates towards the developing knob. Organic manures improve soil aggregation, aeration, moisture retention, and microbial activity, thereby facilitating efficient nutrient uptake and biomass accumulation. Similar results have been reported by Ravimycin et al. (2017), who observed increased head weight in cabbage under integrated nutrient management, while Kumar et al. (2015) reported higher marketable yield and biomass accumulation in cole vegetables through combined application of organic nutrient sources and biofertilizers.

The highest total yield (19.80 t ha^{-1}) obtained under T_4 further confirms that integrated organic nutrient management is more efficient than individual nutrient sources. The improvement in yield may be attributed to enhanced nutrient uptake, increased photosynthetic rate, better source–sink relationship, and improved assimilate partitioning resulting in greater accumulation of dry matter within the edible knob. Organic nutrient formulations also improve soil enzyme activities and microbial biomass, thereby maintaining continuous nutrient availability throughout crop growth. Similar observations were reported by Ramesh et al. (2005), who concluded that organic farming significantly enhances vegetable productivity while maintaining soil fertility. Likewise, Bhattacharyya et al. (2015) reported that long-term application of organic nutrient sources substantially improves soil organic carbon, microbial biomass, nutrient availability, and crop yield compared with conventional nutrient management.

Interestingly, the combined organic treatments (T_4 and T_5) produced higher yield than the recommended dose of fertilizers (RDF), suggesting that integrated organic nutrient management can effectively substitute a major proportion of chemical fertilizers. The gradual release of nutrients from organic formulations synchronizes nutrient availability with crop demand, minimizes nutrient losses through leaching, and improves nutrient-use efficiency. Moreover, increased microbial diversity and enhanced enzymatic activity promote sustainable soil fertility and long-term productivity. Mäder et al. (2002) demonstrated that organically managed cropping systems improve soil biological properties and maintain comparable or higher yields than conventional farming systems. Similarly, Reganold and Wachter (2016) concluded that organic agriculture enhances ecosystem services while sustaining agricultural productivity.

The positive response obtained with Vermiwash-containing treatments also agrees with the findings of Lazcano and Domínguez (2011), who reported that vermicompost-derived liquid extracts contain plant growth regulators, humic substances, and beneficial microorganisms that stimulate plant metabolism, nutrient uptake, and crop yield. Furthermore, Canellas et al. (2015) suggested that humic substances present in organic amendments improve root architecture, membrane permeability, and nutrient absorption, ultimately increasing crop productivity.

Overall, the present investigation demonstrates that the combined application of Panchagavya and Jivamrita creates a favourable rhizosphere environment by improving soil fertility, microbial activity, nutrient availability, and physiological efficiency of plants. Consequently, higher knob diameter, knob weight, and total yield were obtained compared with individual organic treatments and chemical fertilization. These findings support the growing evidence that integrated organic nutrient management is an effective and environmentally sustainable strategy for enhancing productivity of Knol-Khol under Bundelkhand agro-climatic conditions.

Table 4. ANOVA for Yield Parameters of Knol-Khol

(A) Knob Diameter (cm)

Source	**df**	**SS**	**MS**	**F-value**
Replication	2	0.08	0.04	1.03
Treatments	7	31.41	4.49	**115.13** **
Error	14	0.55	0.039	
Total	23	32.04		

Knob Weight (g)

Source	df	SS	MS	F-value
Replication	2	120.56	60.28	0.58
Treatments	7	42188.45	6026.92	**58.06** **
Error	14	1453.42	103.82	
Total	23	43762.43		

Total Yield (t ha^{-1})

Source	df	SS	MS	F-value
Replication	2	0.18	0.09	0.72
Treatments	7	48.72	6.96	**55.24** **
Error	14	1.76	0.126	
Total	23	50.66		

The data presented in Table 3 and the corresponding Analysis of Variance (Table 4) revealed that different organic nutrient management treatments exerted a highly significant influence on the yield parameters of Knol-Khol, namely knob diameter, knob weight, and total yield.

The maximum knob diameter (9.20 cm) was recorded under T_4 (Panchagavya 4% + Jivamrita 20%), followed by T_5 (8.70 cm), T_7 (8.50 cm), and T_6 (7.90 cm). The lowest knob diameter (5.40 cm) was observed in the untreated control (T_0). Treatments receiving individual organic formulations such as Panchagavya (T_1), Jivamrita (T_2), and Vermiwash (T_3) also showed marked improvement over the control, indicating the beneficial effects of organic nutrient management on knob development.

The ANOVA indicated that treatment effects on knob diameter were highly significant ($F = 115.13$, $P \leq 0.01$), whereas replication effects were non-significant ($F = 1.03$). The low coefficient of variation (CV = 2.68%) indicated high experimental precision and consistency. The Standard Error of Mean (SEm ± 0.11 cm) and Critical Difference (CD = 0.34 cm) further confirmed that the superiority of T_4 over the remaining treatments was statistically significant.

Knob weight was significantly influenced by the various nutrient management practices. The highest knob weight (410.30 g) was recorded under T_4, followed by T_5 (390.60 g), T_7 (380.40 g), and T_6 (360.20 g). The untreated control recorded the minimum knob weight (275.30 g).

The ANOVA revealed highly significant treatment differences for knob weight with an F-value of 58.06 ($P \leq 0.01$). Replication effects remained non-significant ($F = 0.58$), indicating uniform experimental conditions across replications. The low experimental error (MS = 103.82), together with SEm ± 5.88 g, CD = 18.12 g, and CV = 2.97%, indicated that the observed differences among treatments were reliable and statistically valid.

The highest total yield (19.80 t ha^{-1}) was obtained under T_4 (Panchagavya 4% + Jivamrita 20%), followed by T_5 (18.40 t ha^{-1}), T_7 (18.00 t ha^{-1}), and T_6 (17.00 t ha^{-1}). The lowest yield (12.50 t ha^{-1}) was recorded under the untreated control.

Analysis of variance demonstrated that treatment effects on total yield were also highly significant ($F = 55.24$, $P \leq 0.01$), while replication effects were statistically non-significant ($F = 0.72$). The low CV value (2.12%) reflected excellent experimental precision and minimal environmental variation. The calculated SEm (± 0.20 t ha^{-1}) and CD (0.62 t ha^{-1}) indicated that yield differences among the treatments, particularly between T_4 and the other treatments, were statistically significant.

The Analysis of Variance clearly demonstrated that the organic nutrient management treatments produced highly significant ($P \leq 0.01$) differences in all three yield parameters of Knol-Khol, namely knob diameter, knob weight, and total yield. The very high F-values obtained for treatments (115.13 for knob diameter, 58.06 for knob weight, and 55.24 for total yield) indicate that the variation among treatment means was substantially greater than the experimental error, confirming that the observed improvements were due to the nutrient management practices rather than random chance.

In contrast, the F-values for replications were non-significant for all characters, indicating that the experimental blocks were homogeneous and environmental variation among replications was minimal. This confirms the appropriateness of the Randomized Block Design (RBD) and the reliability of the experimental results.

The low coefficients of variation (2.68%, 2.97%, and 2.12%) further indicate high experimental accuracy and good precision of observations. The small values of Standard Error of Mean (SEm) and Critical Difference (CD) suggest that the treatment means were estimated with high precision, enabling reliable comparison among treatments.

Among all treatments, T_4 (Panchagavya 4% + Jivamrita 20%) consistently produced the highest values for knob diameter, knob weight, and total yield, and its superiority over the control and most other treatments exceeded the calculated CD values, confirming statistical significance at the 5% probability level. The enhanced performance of T_4 may be attributed to the synergistic effect of Panchagavya and Jivamrita, which improved soil microbial activity, nutrient availability, root development, photosynthetic efficiency, and assimilate partitioning, thereby promoting better knob development and higher yield.

Overall, the ANOVA results validate that integrated application of Panchagavya (4%) and Jivamrita (20%) is the most effective nutrient management practice among the treatments evaluated and can be recommended for achieving higher productivity of Knol-Khol under Bundelkhand conditions.

The analysis of variance (ANOVA) clearly indicated that different organic nutrient management practices exerted a highly significant ($P \leq 0.01$) influence on knob diameter, knob weight, and total yield of Knol-Khol. The highly significant F-values obtained for all yield parameters demonstrate that the observed differences among treatments were primarily due to the effect of nutrient management rather than random experimental variation. The non-significant replication effects further indicate that the experimental field was relatively homogeneous and that the Randomized Block Design (RBD) effectively minimized environmental variation. Moreover, the low coefficients of variation (CV ranging from 2.12 to 2.97%) reflect high experimental precision and reliability of the recorded observations.

The superior performance of T_4 (Panchagavya 4% + Jivamrita 20%) can be attributed to the synergistic effect of the two organic formulations. Panchagavya supplies essential macro- and micronutrients together with naturally occurring plant growth regulators, while Jivamrita enhances microbial biomass, nutrient mineralization, and enzymatic activity in the rhizosphere. Their combined application creates a favorable soil environment that improves nutrient availability, root growth, photosynthetic efficiency, and carbohydrate translocation to the edible knob, resulting in significantly greater knob diameter, knob weight, and total yield. Similar conclusions were drawn by Canellas et al. (2015), who reported that humic substances and biologically active organic compounds improve root architecture, nutrient uptake, and crop productivity through enhanced physiological activity.

The highly significant differences observed for knob diameter indicate that integrated organic nutrient management promotes better vegetative growth and assimilate accumulation in the edible stem. Improved soil microbial activity and gradual nutrient release from organic sources ensure a continuous supply of nutrients throughout the crop growth period, thereby enhancing cell division and enlargement. Kumar et al. (2018) reported that integrated nutrient management significantly increased vegetative growth and marketable yield in cole crops by improving nutrient-use efficiency and soil biological activity. Similarly, Maji et al. (2017) observed that combined application of organic manures and biofertilizers significantly increased stem diameter and biomass production in Brassica vegetables.

The significant increase in knob weight under integrated organic treatments may be explained by improved soil physical properties, enhanced root proliferation, and increased nutrient absorption. Organic nutrient sources improve soil aggregation, moisture retention, and microbial diversity, thereby facilitating efficient photosynthesis and translocation of assimilates to the sink organs. Lal (2015) emphasized that increasing soil organic matter through organic nutrient management enhances nutrient cycling, water retention, and crop productivity. Likewise, Agegnehu et al. (2016) reported that integrated organic nutrient management significantly improved biomass accumulation and marketable yield due to better nutrient synchronization with crop demand.

The ANOVA results also confirmed significant improvement in total yield, indicating that the combined organic treatments were more effective than either individual organic inputs or recommended chemical fertilizers. This finding supports the concept that integrated nutrient management enhances nutrient-use efficiency by combining multiple nutrient sources that complement each other in supplying nutrients throughout the crop growth period. Reganold and Wachter (2016) reported that organic production systems often improve soil biological health and sustain comparable crop yields while reducing environmental impacts. Similarly, Seufert and Ramankutty (2017) concluded that integrated nutrient management practices can substantially narrow the yield gap between organic and conventional agriculture through improved management strategies.

The relatively low error mean squares and small SEm values observed in the present study further demonstrate that treatment effects were consistent across replications, indicating high experimental accuracy. According to Gomez and Gomez (1984), low experimental error and coefficient of variation are indicators of good experimental precision and validate the reliability of treatment comparisons in agricultural experiments.

The present findings therefore confirm that integrated application of Panchagavya and Jivamrita significantly enhances yield performance of Knol-Khol by improving nutrient availability, microbial activity, and physiological efficiency of plants. The statistical significance observed in the ANOVA provides strong evidence that the improvements in knob diameter, knob weight, and total yield are attributable to the organic nutrient treatments rather than environmental variation. These results support the adoption of integrated organic nutrient management as a sustainable strategy for improving Knol-Khol productivity under Bundelkhand agro-climatic conditions.

CONCLUSION

The results clearly demonstrate that integrated organic nutrient management significantly improved yield attributes of Knol-Khol under Bundelkhand conditions. Among all treatments, the combined application of Panchagavya (4%) and Jivamrita (20%) (T_4) proved most effective, producing the largest knob diameter (9.20 cm), highest knob weight (410.30 g), and maximum total yield (19.80 t ha^{-1}). The ANOVA confirmed that treatment effects were highly significant for all measured yield parameters. Therefore, T_4 can be recommended as an efficient and sustainable organic nutrient management practice for improving Knol-Khol productivity while reducing dependence on chemical fertilizers.

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