



# Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.289>

## EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF BASMATI RICE (*ORYZA SATIVA* L.) UNDER DOON VALLEY CONDITION

Prince Kumar<sup>1</sup>, Roop Kishore Sharma<sup>1</sup>, Vipin Negi<sup>1</sup>, Mukesh Kumar<sup>2\*</sup>, Neha Kumari<sup>3</sup>, Sonal Kumari<sup>4</sup>

<sup>1</sup>Department of Agriculture, Doon (PG), College of Agriculture Science and Technology, Camp Road Selaqui, Dehradun - 248011 (Uttarakhand), India.

<sup>2</sup>Department of Agronomy, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan - 731236, West Bengal, India.

<sup>3</sup>Bihar Agricultural University, Sabour, Bhagalpur-813210, Bihar, India

<sup>4</sup>ICAR-Research Complex for Eastern Region, Patna-800014, Bihar, India

\*Corresponding author E-mail: [ymukeshkr.61@gmail.com](mailto:ymukeshkr.61@gmail.com)

(Date of Receiving : 21-01-2026; Date of Revision : 26-03-2026; Date of Acceptance : 08-04-2026)

One of the most important cereal crops in the world is rice (*Oryza sativa* L.). It is a staple for nearly half of the world's population, especially in East and Southeast Asia, where rice is deeply woven into daily life and culture. Among the many varieties of rice, Basmati holds a distinguished place known for its delightful aroma, and unique cooking quality. Azolla in basmati paddies enhances biological N inputs, moderates nutrient losses, and suppresses early weed growth. Subsequent incorporation improves soil carbon turnover and microbial-mediated nutrient availability, enabling stable or improved yields with lower fertilizer dependence. Vermicompost enhances SOC, microbial biomass, enzymatic activity and NUE. Slow nutrient release also resists from the excessive vegetative growth and by this mechanism plants have better lodging resistance and grain quality in aromatic rice system.

A field investigation was conducted during the Kharif season of 2024 at the Research Farm of Doon (P.G.) College of Agriculture Science and Technology, situated in Selaqui, Dehradun, within the Doon Valley of Uttarakhand to assess the effect of integrated nutrient management on growth and yield of basmati rice. The treatments replicated thrice with Eight treatments combinations.

The results revealed that the application of 100% NPK applied with the combination of Azolla significantly increase plant height, plant dry matter, number of tillers/hill, and yield indices viz number of panicles/hill, grains/panicle, filled grains/panicle, test weight (23.10gm), but was at par with 100% NPK. In context of benefit cost ratio treatment of 100% NPK among with Azolla achieved the highest gross and net returns, showing that integrated use of chemical and biological sources is highly profitable. T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK along with Vermicompost) also performed very well in terms of economic returns and B:C ratio.

**Keywords** : Basmati Rice (*Oryza sativa* L.), Azolla, Vermicompost, NPK, INM.

### ABSTRACT

### Introduction

One of the most important cereal crops in the world is rice (*Oryza sativa* L.). It is a staple for nearly half of the world's population, especially in East and Southeast Asia, where rice is deeply woven into daily life and culture. Remarkably, people consume over 95% of the world's rice output directly. Asia alone accounts for approximately 85% of the global rice cultivation area, highlighting the crop's regional significance. To meet the demands of a growing

population, rice production needed to increase by at least 65% between 1990 and 2020 (Fageria, 2007). In India, the world's largest rice-cultivating country, rice is grown on around 43.79 million hectares, producing a record 116.42 million tonnes during 2018–19 (Directorate of Economics and Statistics, 2018–19).

Among the many varieties of rice, Basmati holds a distinguished place. Known for its long, slender grains, delightful aroma, and unique cooking quality, Basmati rice expands up to two to three times its

original length when cooked, releasing a nutty fragrance. Its dry, fluffy texture makes it particularly desirable in global cuisines.

As of 2018–19, India dominated the global Basmati trade, exporting 65% of the total Basmati rice internationally, followed by Pakistan with 35% (Wikipedia, 2020). Grown mainly in the north-western states of India over 1.6 million hectares, Basmati fetches premium prices in both domestic and international markets. Prominent varieties include Basmati-370, Basmati386, Type-3 (Dehraduni), Taraori Basmati, Ranbir Basmati, Pusa Basmati-1121, Pusa Basmati-1, and Pusa-1509. Because it requires very few nutrients, basmati rice is a good choice for organic farming. Studies suggest that organic practices can improve soil and grain quality, reduce pest and disease outbreaks, and even enhance the aromatic quality of Basmati rice (Prasad, 2005; Stockdale, 2001). Basmati cultivation thrives best in the Indo-Gangetic plains, where climate and soil support its superior quality traits, making it a highly valuable export product.

India remains a key player in the global rice trade, exporting both Basmati and non-Basmati rice to over 130 countries. In 2018–19, India exported around 11.9 million metric tonnes (MT) of rice, consisting of 4.4 million MT of Basmati and 7.5 million MT of non-Basmati rice, with major destinations being Saudi Arabia, the United Arab Emirates, Iran, and Iraq (NCML, 2019).

Rice makes up more than 54% of the cereal area in the Indian state of Uttarakhand, making it a vital crop. The state produces about 550,000 tonnes annually from approximately 280,000 hectares. Although rice is grown in all 13 districts, Udham Singh Nagar emerges as the leading contributor—accounting for 33% of the cultivated area and 48% of total production—earning it the nickname "Chawal ki Nagari" (Rice City). As per a 2019 survey by NCML, paddy cultivation in Uttarakhand during the kharif season increased by 19% over the previous year, with Basmati acreage growing by 18%. Pusa Basmati-1121, Pusa-1509, and Type-3 are important Basmati cultivars.

One of the critical challenges facing rice cultivation today is the decline in soil health, especially under intensive cropping systems. Excessive reliance on chemical fertilizers has led to imbalanced nutrient use, reduced soil organic matter, and diminishing crop yields (Kang *et al.*, 2005). The long-term impact includes poor soil structure, lower microbial activity, and environmental pollution from fertilizer runoff and

residue burning. To address these challenges, Integrated Nutrient Management (INM) offers a balanced, environmentally friendly solution. INM involves the combined use of chemical fertilizers, organic manures (such as FYM, vermicompost, neem cake, green manure), and biofertilizers (e.g., *Azotobacter*, *Rhizobium*). This approach improves soil fertility, enhances crop productivity, and sustains soil health over time (Kundu & Pillai, 1991).

Biofertilizers, in particular, play a key role by fixing atmospheric nitrogen and mobilizing phosphorus, making nutrients more available to crops. Studies show that INM enhances plant growth, yield, and quality more effectively than either chemical or organic sources used alone.

Vermicompost is an organic material produced through the decomposition of organic waste by earthworms. It improves soil porosity, water retention, and cation exchange capacity, while providing readily available nutrients like phosphorus, potassium, calcium, and magnesium (Garg & Gupta, 2006). Vermicompost also supports root development and enhances microbial activity, making it a valuable component of INM.

Likewise, the water fern *Azolla*, which coexists with the nitrogen-fixing *Anabaena azollae*, is an effective biofertilizer. It enriches soil with nitrogen, reduces ammonia volatilization, suppresses weeds, and supports water conservation. *Azolla* application has been shown to reduce chemical nitrogen needs by 25% without compromising yield (Malyan *et al.*, 2019).

INM maintains soil structure, boosts microbial activity, and replenishes essential nutrients. Environmental Sustainability: Reduces dependence on chemical fertilizers and mitigates pollution. Economic Viability: Long-term soil fertility translates into reduced input costs and improved profitability.

### Scope

Studies indicate that use of Integrated Nutrient Management (INM) in Basmati rice production sustains high productivity while preserving the superior grain quality required for high value marketing purpose. The integration of inorganic fertilizers with organic sources such as vermicompost, green manures, *azolla*, and biofertilizers improves nutrient synchrony and enhances nutrient use efficiency. In addition, INM improves the physical characteristics of the soil, increases soil organic carbon (SOC), and promotes microbial activity, all of which contribute to long-term system resilience. Providing Balanced nutrition which prevents excessive nitrogen application, reducing lodging risk and desirable aroma

and cooking characteristics. Additionally, INM also addresses the secondary and micronutrient deficiencies common in Basmati rice-growing regions. Therefore, INM offers a practical way to achieving both economic profitability and environmental sustainability in Basmati rice production systems.

### Material and Methods

A field experiment was conducted at The Rampur Farm, Doon P.G. College of Agriculture Science and Technology, Salaqui, Dehradun, Uttarakhand during the *Kharif* season of 2024 on transplanted Basmati rice under integrated nutrient management practices. The current study used a randomized block design (RBD) with three replications of eight treatments.

The location of experiment at the Research Farm of Doon (P.G.) College of Agriculture Science and Technology, situated in Selaqui, Dehradun, within the Doon Valley of Uttarakhand. The experimental site is located at an altitude of approximately 435 meters above mean sea level, with geographic coordinates of 29.96°N latitude and 77.02°E longitude. The region experiences a subtropical climate characterized by hot summers, mild winters, and a monsoon season lasting from June to November.

The experimental site's soil had a sandy loam texture, was well-drained, and had a pH that ranged from slightly acidic to neutral (pH 6.8), Organic carbon was medium (0.55%), available nitrogen was low (260 kg/ha), potassium was medium (185 kg/ha), and accessible phosphorus was extremely high (22.5 kg/ha) in the sandy loam soil that was used for the experiment. On August 3, 2024, transplanting was carried out utilizing robust seedlings. Each hill received 2–3 seedlings of Basmati rice (Pusa Basmati 1886), transplanted at a spacing of 20 cm × 15 cm to ensure an optimal plant population. The treatment combinations variables was NPK, Vermicompost and Azolla. At 25 and 45 DAT, intercultural operations repeated twice to reduce weed competition. Conversely, analysis of variance (ANOVA) for randomized block design was used to statistically assess a number of yield parameters that were measured during harvest. Number of panicles, Grains/Panicle, test weight, stover yield and harvest index were some of the parameters that were measured (Gomez and Gomez., 1984; Kavya *et al.*, 2021).

### Treatment Details

1. Control (No fertilizer application)
2. 100% NPK (120:60:60 kg/ha NPK)
3. 75% NPK
4. 100% Nitrogen through Vermicompost
5. 100% NPK + Vermicompost

6. 75% NPK + Vermicompost
7. Biofertilizer (Azolla)
8. 100% NPK + Azolla

### Soil analysis of the experiment field

#### A. Physical Characteristics

Soil characteristics	Composition
Soil texture class	Sandy loam
Sand	55.50
Silt	28.10
Clay	16.40

#### B. Chemical Analysis of the soil

Soil characteristics	Composition
pH	6.8
EC (dSm <sup>-1</sup> )	0.417
Organic matter (%)	0.55
Available N (Kg)	260
Available Phosphorus	22.50
Available Potassium	185

### Result and Discussions

#### Influence of Different Nutrient Management Practices on Plant Height (cm) of Basmati Rice

Plant height during experiment was recorded at 30, 60, 90 days after transplanting (DAT), and at harvest which was significantly influenced by different nutrient management. Application of (T<sub>8</sub>) 100% NPK along with Azolla shows maximum height of 94.80 cm at 90 DAT, 43.63% more than the control plant height of 66.0 cm, however, at 90 DAT other variable combinations T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost), were statistically similar to 100% NPK with biofertilizer (azolla) this is due to NPK fertilization increased paddy plant height by improving soil chemical properties specifically enhancing the availability of nitrogen, phosphorus, and potassium. This nutrient availability positively affected plant growth (Pirgadi & Abdurachman, 2019). Supporting this, (Purnomo, 2019) observed significant height increases in paddy plants up to the primordial phase when compound NPK fertilizers were used, attributing the growth to improved soil chemistry.

#### Influence of Different Nutrient Management Practices on Number of Tillers per Hill of Basmati Rice

T<sub>8</sub> (100% NPK + Azolla) produced the highest number of tillers per hill (10.80) at 60 DAT, and T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost) were statistically similar. Treatments T<sub>4</sub> (100% N through Vermicompost) and T<sub>7</sub> (Azolla) showed moderate tiller production. Maximum tillering was observed in T<sub>8</sub> (100% NPK + Azolla), indicating that

the integration of chemical fertilizers with biofertilizer (Azolla) promotes vegetative branching and enhances nutrient availability. T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost) also performed significantly better than treatments relying solely on organic or chemical inputs. The data suggest that integrated nutrient management practices enhance crop vigour and tiller development more effectively than alone approaches.

### **Influence of Different Nutrient Management Practices on Dry Matter Accumulation of Basmati Rice**

Dry Matter Accumulation during experiment was recorded at 30, 60, 90 days after transplanting (DAT), and at harvest which was significantly influenced by different nutrient management. Application of (T<sub>8</sub>) 100% NPK along with Azolla shows highest dry matter accumulation of (37.30 g/hill) at 90 DAT, 72.68 % more than the dry matter accumulation of control (21.60 g/hill), however, at 90 DAT other variable combinations T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost), were statistically similar to 100% NPK with biofertilizer (azolla).

### **Influence of Different Nutrient Management Practices on Yield attributes of Basmati Rice**

Table 2. displays data regarding the characters that contribute to yield. Treatment 8 (100%NPK with Biofertilizer) produced highest panicles (14.10) which was statistically equivalent to T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost). 100% NPK in conjunction with biofertilizer resulted in a noticeably increased grain per panicle (120.30) and also in number of filled grains per panicle (109.20). Statistically Treatment 8-100% NPK along with Azolla was surpassed by T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost). 100 % NPK with Azolla had highest test weight this is due to NPK influence number of grains per panicle in Bapatla's sandy clay soils with the application of 120 kg/ha nitrogen through urea compared to other organic and inorganic nutrient combinations (Hari Prasad, 2016). Similarly, (Alok Kumar and Yadav, 2018) found that in the initial years of their study, 100% recommended NPK fertilizer application alone resulted in higher rice yields than its combination with organic manures. However, in subsequent years, 25–50% of the recommended chemical fertilizers could be effectively substituted with organic manures to improve soil fertility and condition.

### **Influence of Different Nutrient Management Practices on Yield of Basmati Rice**

Applying NPK with biofertilizer had a substantial impact on seed and stover yield. Treatment including 100% NPK with Azolla at 90 DAT shows highest result in grain yield (53.70 q/ha). Out-forming all other treatments except treatment 2(51.20 q/ha) and treatment 6- (75% NPK along with Vermicompost) (50.60 q/ha) at 90 DAT. Similarly, 100% NPK with Azolla at 90 DAT resulted in a maximum stover production of (77.60 q/ha), a (51.26 %) improvement over the control treatment of (51.30 q/ha). Venkateswarulu (2022) suggested that long-term sustainability in crop yields is achievable only when nutrient inputs include organic manures or a combination of organic and chemical fertilizers. Sole reliance on chemical fertilizers, in contrast, fails to support sustainable productivity. The combined application of organic manures and chemical fertilizers helps in maintaining yield stability. This approach addresses marginal deficiencies in secondary and micronutrients, enhances nutrient use efficiency, and improves soil physical properties and it is demonstrated by (Gill and Walia, 2022).

### **Influence of Different Nutrient Management Practices on Harvest Index of Basmati Rice**

T<sub>8</sub> exhibited the highest grain yield, biological yield, and harvest index, confirming the beneficial impact of integrated nutrient management (chemical + biofertilizer). Treatments with vermicompost or FYM in combination with reduced chemical fertilizer (T<sub>6</sub>-75% NPK + Vermicompost & T<sub>4</sub>-100% Nitrogen through vermicompost) also performed well, showing that partial substitution can maintain high yields. The control plot (T<sub>1</sub>) was significantly inferior in all yield components, proving the necessity of nutrient application in Basmati rice.

### **Influence of Different Nutrient Management Practices on Economics of Basmati Rice**

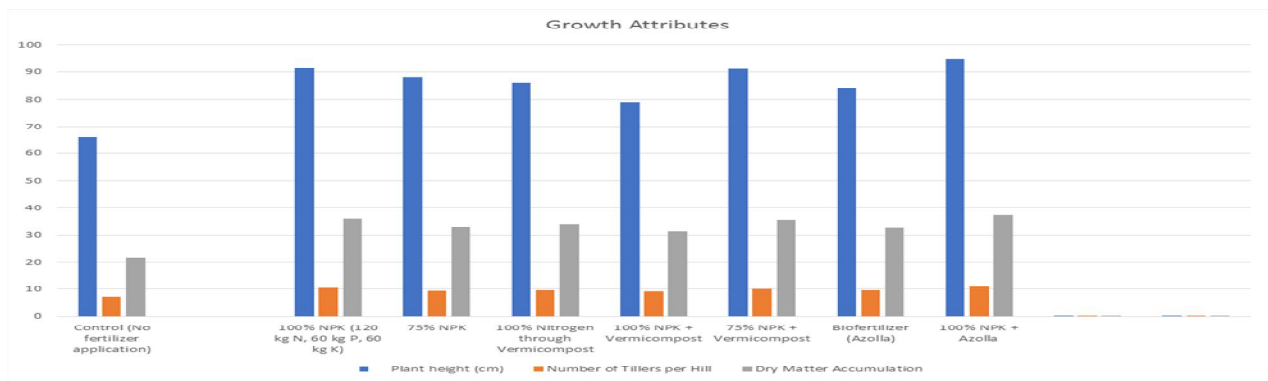
Economic evaluation was carried out to determine the profitability of different nutrient management treatments in Pusa Basmati 1886 cultivation. Parameters such as Total Cost of Cultivation, Gross Return, Net Return, and Benefit: Cost (B:C) Ratio were calculated based on prevailing input costs and market prices. T<sub>8</sub> (100% NPK + Azolla) achieved the highest gross and net returns, showing that integrated use of chemical and biological sources is highly profitable. T<sub>2</sub> (100% NPK) and T<sub>6</sub> (75% NPK + Vermicompost) also performed very well in terms of economic returns and B:C ratio. Even though T<sub>1</sub> (Control) had the lowest input cost, it also produced

the least net return, underscoring the importance of nutrient management in Basmati rice profitability. Treatments that partially replaced chemical fertilizers with vermicompost or Azolla maintained high profitability, emphasizing the role of sustainable INM practices.

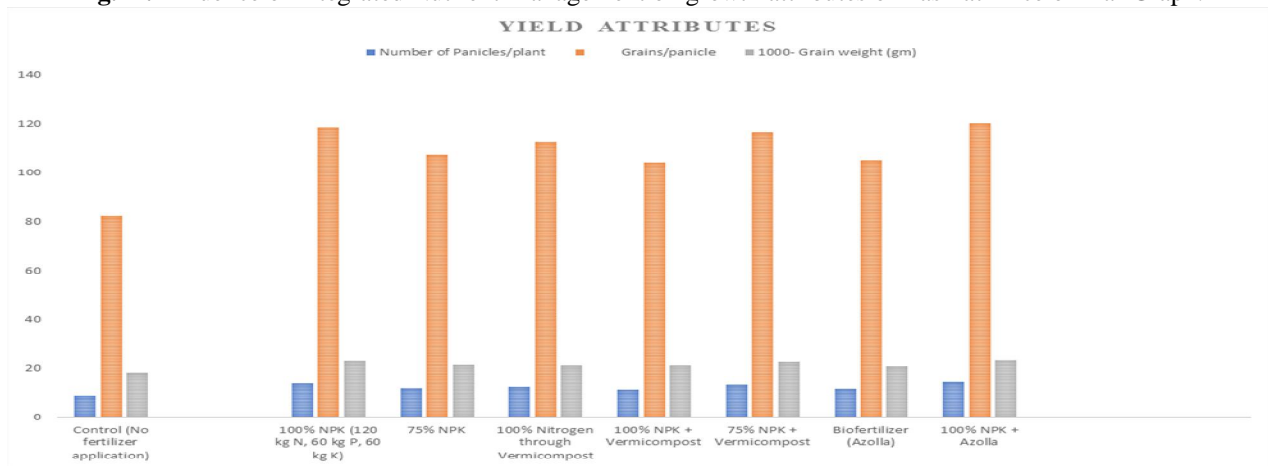
**Conclusion**

The study concludes that integrated nutrient management involving balanced application of inorganic fertilizers combined with organic sources and biofertilizers significantly improves the growth,

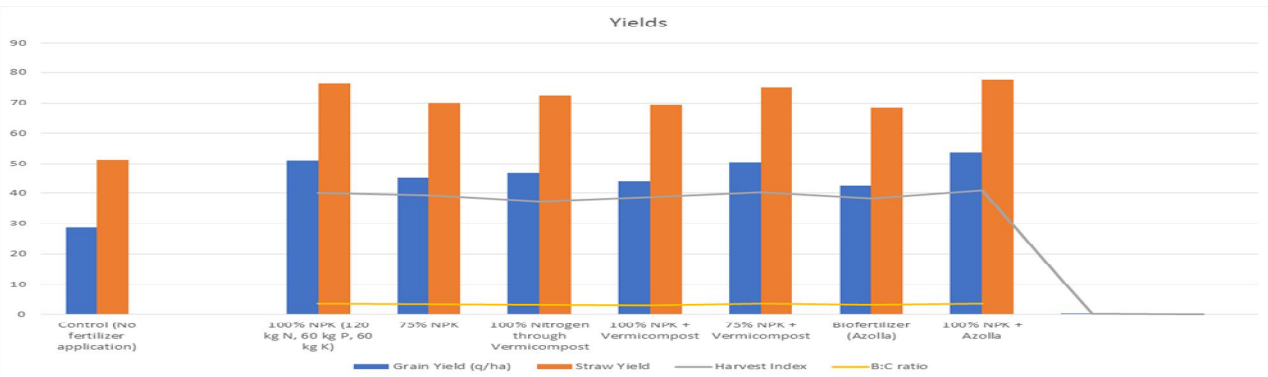
yield, nutrient uptake, and economic returns of Pusa Basmati 1886 rice under rainfed conditions in Uttarakhand. This approach not only enhances crop productivity but also promotes soil health and environmental sustainability. Farmers cultivating basmati rice in the Doon valley and similar agro-climatic zones are recommended to adopt integrated nutrient management practices, particularly the use of 50% RDF combined with farmyard manure and biofertilizers, to achieve higher yields and economic benefits.



**Fig. 1 :** Influence of Integrated Nutrient Management on growth attributes of Basmati Rice on Bar Graph.



**Fig. 2 :** Influence of Integrated Nutrient Management on yield attributes of Basmati Rice on Bar Graph.



**Fig. 3 :** Influence of Integrated Nutrient Management on yield and Economics of Basmati Rice on Combo Line Graph.

**Table 1 :** Influence of Integrated Nutrient Management on growth attributes of Basmati Rice

Treatment Code	Treatment Description	Plant height (cm) 90 DAT	Number of Tillers per Hill (60DAT)	Dry Matter Accumulation 90DAT (g/hill)
1	Control (No fertilizer application)	66.00	7.10	21.60
2	100% NPK (120 kg N, 60 kg P, 60 kg K)	91.60	10.40	36.10
3	75% NPK	88.10	9.30	33.00
4	100% Nitrogen through Vermicompost	86.10	9.60	34.20
5	100% NPK + Vermicompost	79.00	9.10	31.40
6	75% NPK + Vermicompost	91.20	10.10	35.60
7	Biofertilizer (Azolla)	84.00	9.50	32.70
8	100% NPK + Azolla	94.80	10.80	37.30
C.D.		0.052	0.082	0.11
SE(m)		0.017	0.027	0.03

**Table 2 :** Influence of Integrated Nutrient Management on yield attributes of Basmati Rice

Treatment Code	Treatment Description	Number of Panicles/plant	Grains/panicle	1000-Grain weight (gm)
1	Control (No fertilizer application)	8.60	82.10	18.30
2	100% NPK (120 kg N, 60 kg P, 60 kg K)	13.70	118.60	22.70
3	75% NPK	11.80	107.40	21.40
4	100% Nitrogen through Vermicompost	12.30	112.70	20.90
5	100% NPK + Vermicompost	11.00	104.30	21.00
6	75% NPK + Vermicompost	13.20	116.20	22.30
7	Biofertilizer (Azolla)	11.50	105.10	20.60
8	100% NPK + Azolla	14.10	120.30	23.10
C.D.		0.046	0.279	0.225
SE(m)		0.015	0.091	0.074

**Table 3.** Influence of Integrated Nutrient Management on yield and Economics of Basmati Rice

Treatment Code	Treatment Description	Grain Yield (q/ha)	Straw Yield	Harvest Index (%)	B:C ratio
1	Control (No fertilizer application)	28.60	51.30	35.80	2.50
2	100% NPK (120 kg N, 60 kg P, 60 kg K)	51.20	76.40	40.10	3.63
3	75% NPK	45.30	70.00	39.30	3.35
4	100% Nitrogen through Vermicompost	46.80	72.30	37.30	3.17
5	100% NPK + Vermicompost	44.10	69.50	38.80	2.95
6	75% NPK + Vermicompost	50.60	74.90	40.30	3.49
7	Biofertilizer (Azolla)	42.30	68.20	38.30	3.20
8	100% NPK + Azolla	53.70	77.60	40.90	3.57
C.D.		0.35	0.270	0.21	
SE(m)		0.11	0.080	0.06	

## References

- Alok Kumar, & Yadav, P. (2018). Effect of integrated nutrient management on rice yield and soil fertility under long-term fertilizer use. *Indian Journal of Agronomy*, **63**(2), 215–222.
- Anchal Dass, Mishra, B., Patel, N., & Sahoo, K. C. (2019). Impact of integrated nutrient management on tomato yield and soil health under farm conditions in Eastern Ghats of Orissa. *Journal of Soil and Crops*, **29**(1), 45–53.
- Ansari, A. A., & Ismail, S. A. (2018). Biofertilizers and vermicompost: Effects on soil fertility and crop productivity. *International Journal of Agricultural Sciences*, **14** (10), 259–266.
- Aruna, P., & Shaik, M. (2023). Influence of vermicompost on crop yield and soil physical properties. *Journal of Environmental Biology*, **44**(3), 421–428.
- Bano, K., Kale, R. D., Sreenivas, M. N., & Satish, P. (1993). Vermicompost application for ornamental plant cultivation. *Indian Journal of Horticulture*, **50**(2), 159–164.
- Bhawalkar, U. S., & Bhawalkar, K. A. (2016). Role of earthworms in deodorizing and stabilizing compost through vermicomposting. *Compost Science and Utilization*, **24**(3), 127–133.

- Chaoui, H. I., Edwards, C. A., Arancon, N. Q., & Shelto, P.J. (2003). Effects of vermicompost on plant growth: Mechanisms and benefits. *Pedobiologia*, **47**(5–6), 736–740.
- Devi, S., & Agarwal, N. (2021). Effect of vermicompost application on sunflower growth and yield. *Journal of Oilseeds Research*, **38**(1), 120–125.
- Devi, S., Sharma, P., & Agarwal, N. (2021). Nutrient dynamics under vermicompost based nutrition in sunflower cultivation. *Crop Research*, **62**(2), 166–172.
- Dey, S. K., & Sannigrahi, S. (1991). Effect of Azolla application on nitrogen-fixing bacteria and rhizosphere chemistry in rice. *Plant and Soil*, **138**(2), 287–293.
- Edwards, C. A. (2022). Vermicompost: Properties, benefits, and applications in sustainable agriculture. *Advances in Organic Farming*, **18**(1), 25–41.
- Farouque, A. M., & Takeya, H. (2020). Integrated nutrient management strategies for sustainable agriculture. *Asian Journal of Agriculture and Biology*, **8**(2), 151–158.
- Gandhi, S., Patel, R., & Verma, A. (2020). Efficiency of vermicomposting on nutrient retention and waste management. *Compost Science and Technology*, **35**(4), 290–298.
- Gill, M. S., & Walia, S. S. (2022). Role of integrated nutrient management in maintaining yield stability and soil health. *Indian Journal of Fertilizers*, **18**(7), 635–642.
- Gomez, K. A., and Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*. John Wiley and Sons.
- Guerrero, R. D. (2010). Vermicompost and sustainable soil management. *Philippine Agricultural Scientist*, **93**(1), 67–72.
- Hari Prasad, G. (2016). Effect of nitrogen levels and sources on rice yield under Bapatla sandy clay soils. *Andhra Agricultural Journal*, **63**(3), 295–302.
- Jadhav, R. B., Patil, S. D., & Rane, D. B. (2021). Nutrient uptake in rice as influenced by vermicompost and chemical fertilizer combinations. *Journal of Plant Nutrition*, **44**(12), 1758–1767.
- Kale, R. D. (2021). Earthworms: The Cinderella of organic farming. *Indian Farming*, **71**(4), 45–48.
- Kaur, R., Bhardwaj, D., & Babbar, N. (2023). Influence of vermicompost on soil physico-chemical and biological properties: A review. *International Journal of Biotechnology and Bioengineering*, **39**(1), 55–63.
- Kavya Pochampally, Shikha Singh, Narreddy Hinduja, Dhananjay Tiwari, Saivasavi Sruthi. (2021). Effect of Foliar Application of Micronutrients on Growth and Yield of Greengram (*Vigna radiata* L.). *Legume Research- An International Journal*, **44** (12), 1460-1464
- Mitchell, A., & Edward, R. (2021). Environmental benefits of vermicompost: Reduction in leach loss and soil pollution. *Environmental Sustainability Journal*, **11**(2), 102–109.
- Pirngadi, K., & Abdurachman, S. (2019). Effect of NPK fertilization on rice growth and soil chemical properties. *Indonesian Journal of Agricultural Science*, **20**(3), 201–208.
- Purnomo, E. (2019). Influence of compound NPK fertilizers on paddy plant growth up to the primordial phase. *Journal of Agronomy*, **36**(1), 74–81.
- Ramesh, P., Rao, S., & Nagaraj, R. (2020). Role of organic manures in soybean – wheat cropping system on vertisols. *Indian Journal of Agronomy*, **65**(2), 225–232.
- Talukdar, T., & Goswami, M. (2019). Vermicomposting of municipal solid waste : Nutrient enrichment and waste utilization. *Environmental Technology & Innovation*, **13**(4), 283–290.
- Tomati, U., & Galli, E. (2020). Phytohormones and microbial activity in vermicompost promoting plant development. *European Journal of Soil Biology*, **51**(1), 135–142.
- Venkatesh, R., Kumar, D., & Swamy, M. (2021). Impact of vermicompost on micronutrient availability and grape yield. *Journal of Horticultural Sciences*, **16**(2), 189–195.
- Venkateswarulu, B. (2022). Sustainable nutrient management for long-term crop productivity. *Indian Journal of Agricultural Sciences*, **92**(5), 523–530.
- White, R., & Frunkel, B. (2017). Ecological role of earthworms in soil quality improvement and plant growth. *Soil Ecology Letters*, **4**(3), 192–199.