Sustainable Agriculture

A Comparative Study of Organic and Conventional Paddy Cultivation in the Lower Gangetic Region

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EXECUTIVE SUMMARY

Introduction:

India's large population of 140.76 crores presents significant food security challenges, necessitating sustainable agricultural practices. Rice, the primary staple, is crucial for food security and nutrition. Organic farming, emphasising soil health and sustainability through natural inputs, enhances nutrient content and biodiversity. In contrast, conventional farming's synthetic fertilisers can degrade soil and introduce contaminants. India's government promotes sustainable agriculture and technology adoption to boost productivity. Integrating organic methods into conventional systems can ensure long-term soil health and environmental sustainability, balancing productivity and conservation.

Aims & Objectives:

The study aims to investigate and compare the effectiveness and outcomes of conventional and organic paddy cultivation in the Lower Gangetic plains of India. In this regard, the considered objectives of this report are to-

- Study the impact of conventional and organic farming practices of paddy on the growth attributes, yield attributes and yield.
- Determine how conventional and organic farming practices affect the nutrient value of paddy grains.
- Estimate the economics of different treatments under the conventional and organic package of practices on paddy cultivation.
- Compare disease pest surveillance capacity under these two diverse scenarios.
- Compare social adaptability and cultivation potentialities of organic practices in comparison to traditional practices.

Materials & Methods:

The study is conducted in Gopalpur at Nadia district, West Bengal, a key area of the Lower Gangetic plains, during the Kharif season of 2023. Utilising NOP-certified organic lands, a Strip Plot Design compares four rice varieties under organic and inorganic methods. The experiment includes 24 plots, with each variety replicated three times under both cultivation practices. Data are collected on climatic and edaphic conditions, with observations on plant height, dry weight, tiller density, and yield attributes recorded at specified intervals. Fertiliser application involves Urea, DAP, SSP, and MOP, with specific dosages for each treatment. Growth metrics and yield are assessed for economic analysis, including cost, gross return, net return, and benefit-cost ratio (BCR). The design aims to provide insights into the effectiveness of different paddy cultivation methods in the region.

Findings:

Key findings indicate that indigenous rice cultivars, notably Black Rice and Gobindbhog, excel under organic management practices. These varieties show resilience and consistent yields, with Black Rice producing 3.2 t/ha and Gobindbhog yielding 3.0 t/ha under organic conditions, closely mirroring their inorganic yields. In contrast, improved and hybrid varieties see significant yield reductions under organic practices, highlighting the adaptability and potential of indigenous varieties for organic farming systems. Economically, organic practices are especially viable for indigenous varieties and the hybrid cultivar CMS-2264 due to higher market prices for organic produce. While inorganic practices result in greater plant heights, tiller densities, and panicle numbers, the overall economic return favours organic practices due to lower input costs and higher market premiums for organic rice.

Conclusion:

In conclusion, this study highlights the potential of organic farming to enhance the sustainability and economic viability of rice cultivation in the Lower Gangetic plains of India. Indigenous rice varieties, like Black Rice and Gobindbhog, are particularly well-suited to organic practices, providing significant agronomic and economic benefits. These findings support the promotion of organic farming, especially for indigenous cultivars, to achieve sustainable agricultural development in the region. Future research should focus on optimising organic management strategies and exploring their broader impacts on soil health and crop productivity, aiming to foster a resilient and eco-friendly agricultural system.

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1.Introduction:

India, with a population of 140.76 crores in 2021, faces significant food security challenges due to its vast and growing population. Ensuring an adequate and nutritious food supply for such a large population involves addressing factors like population growth, agricultural practices, water scarcity, climate change, distribution challenges, and storage losses. Smallholder farmers dominate India's diverse agricultural system, but outdated practices and limited access to modern technology hinder productivity. The government has implemented policies to promote sustainable agriculture, improve water management, and enhance technology adoption, including the National Food Security Act of 2013, which provides subsidised food grains to a large section of the population.

Rice (Oryza sativa L.) is the most significant cereal crop in India and a staple food for over half of the world's population, providing essential nutrients and calories, especially in Asia. Its adaptability to diverse agro-climatic conditions makes it a reliable food source. Rice's cultural significance and role in food security underscore the importance of initiatives to improve rice-growing techniques, yields, and sustainability.

1.1. Rice Cultivation in India

India is the second-largest producer of rice in the world, following China. Rice cultivation spans five regions: Northeastern (Assam and northeastern states), Eastern (Eastern Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, and West Bengal), Northern (Punjab, Haryana, Uttarakhand, Western Uttar Pradesh, Himachal Pradesh, and Jammu and Kashmir), Western (Gujarat, Maharashtra, and Rajasthan), and Southern (Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu). In 2023-2024, India harvested about 47 million hectares of milled rice, with a total production of 1308.37 lakh tonnes in 2022-2023 (USDA, GOI).

1.2. Organic vs. Conventional Farming

Organic farming and conventional farming differ significantly in principles, practices, and outcomes. Organic farming emphasises healthy soil through natural inputs, compost, and cover cropping, enhancing soil structure, water retention, and nutrient cycling, leading to long-term sustainability. Consumers prefer organic products for their perceived health benefits and reduced environmental impact. Organic fertilisers increase soil organic matter, enhancing nutrients, plant growth regulators, and biodiversity, while reducing reliance on inorganic fertilisers, which can damage groundwater and decrease crop nutritional value (Kakar et al., 2019; Mäder et al., 2002).

Conventional farming, with its use of synthetic fertilisers, provides a quick nutrient boost but may lead to soil degradation, contamination, and disruption of microbial communities. Studies show mixed results on the efficiency of land use between organic and conventional farming, with some indicating that organic farming requires more land (Tuomisto et al., 2012). Contextual factors, such as local ecological conditions, influence the sustainability of farming practices, necessitating a nuanced evaluation of their benefits and drawbacks.

1.3. Nutritional Quality of Rice

Organic farming practices can lead to higher nutrient content in crops due to improved soil fertility and microbial activity. Organic rice may have higher levels of certain antioxidants and lower pesticide residues compared to conventionally grown rice (Banik et al., 2006; Thakur et al., 2020). However, the nutritional quality of rice is influenced by various factors, including soil management, fertiliser use, and pest control methods. Inorganic fertilisers, while boosting growth, can introduce heavy metals into plant tissues, lowering the nutritional value and grain quality of crops (Kakar et al., 2019).

1.4. Soil Health and Sustainability

Soil health and sustainability are critical in both organic and conventional farming systems. Organic farming relies on natural fertilisers and practices that enhance soil organic matter, structure, and microbial diversity, contributing to a resilient soil ecosystem. Conventional farming's use of synthetic fertilisers, though providing quick nutrients, can lead to nutrient imbalances and reduced organic matter over time, negatively impacting soil health (Bihari et al., 2015; Basak et al., 2017).

Sustainable soil management requires a holistic approach, balancing productivity with environmental conservation. Integrating organic practices into conventional systems through agroecological techniques can pave the way for more sustainable agriculture in the future, ensuring long-term soil health and environmental sustainability.

1.5. Aims & Objectives

The study aims to investigate and compare the effectiveness and outcomes of conventional and organic paddy cultivation in the Lower Gangetic plains of India. It seeks to provide evidence-based insights into the relative merits of these two farming methods. The findings are intended to assist farmers, policymakers, and other stakeholders in making informed decisions about agriculture in this specific region. In this regard, the considered objectives of this report are as follows:

- ***To study the impact of conventional and organic farming practices of paddy on the growth attributes, yield attributes and yield.***
- ***To determine how conventional and organic farming practices affect the nutrient value of paddy grains.***
- ***To estimate the economics of different treatments under the conventional and organic package of practices on paddy cultivation.***
- ***Compare disease pest surveillance capacity under these two diverse scenarios.***
- ***Compare the social-adaptability and cultivation potentialities of organic practices in comparison to traditional practices.***

2.Literature Review

2.1. Crop Yield and Quality Comparison

Research on crop yield and quality under different farming practices has yielded diverse insights. Chiranjeevi et al. (2018) conducted a field experiment to compare rice varieties and nutrient management practices. They found that the RP-BIO-226 variety consistently outperformed Tulasi and Vasumathi in grain yield and nutrient absorption when subjected to integrated nutrient management practices. Specifically, the combination of 50% vermicompost and 50% recommended dose of fertilisers (RDF) resulted in significantly higher yields compared to other treatments. This suggests that hybrid varieties and balanced nutrient management practices can optimise rice production.

Setiawati et al. (2020) studied the performance of two paddy varieties, Bangir and Inpari 41, under various organic soil fertility strategies in Indonesia. They reported that Inpari 41 achieved a higher grain yield (4.92 t/ha) compared to Bangir (3.48 t/ha), particularly when combined with green manures such as Azolla and Sesbania. This highlights the positive impact of organic soil amendments on paddy yield and soil fertility.

Joshi et al. (2019) compared grain quality parameters of rice grown under organic and inorganic systems in India. They discovered that while organically cultivated rice had lower protein content and higher moisture, it scored better on in-vitro protein digestibility, which suggests improved nutritional quality in organic rice despite slightly lower yields.

Similarly, Sihi et al. (2012) found that organic management of basmati rice enhanced grain elongation and improved kernel quality compared to conventional practices. Their research indicates that organic systems can produce high-quality rice with better grain characteristics.

2.2. Soil Health and Nutrient Management

Soil health and nutrient management are crucial for sustainable agricultural productivity. Nakhro and Dkhar (2010) observed that organically treated paddy fields exhibited higher microbial populations and biomass carbon compared to inorganically treated plots. This suggests that organic farming enhances soil biological activity and organic carbon content, which are vital for long-term soil health.

Pal et al. (2021) assessed the impact of nitrogen levels on hybrid rice varieties in eastern Uttar Pradesh. They found that the hybrid variety Arize 6444 gold showed significant improvements in growth and yield attributes when provided with a 100% recommended nitrogen dose. This underscores the importance of precise nutrient management for optimising rice productivity.

Mondal et al. (2022) conducted a study on hybrid rice varieties and nutrient management in West Bengal. They reported that combining organic and inorganic fertilisers led to superior growth and yield attributes compared to using either alone. This finding supports the integration of diverse nutrient management strategies to enhance rice production.

In contrast, Saha et al. (2010) observed that organic fertilisation with cattle dung significantly improved grain production and nutritional quality of aromatic rice. Their results highlight the effectiveness of organic fertilisers in boosting soil fertility and crop yield.

2.3. Environmental Impact and Sustainability

The environmental impact of agricultural practices is a growing concern. Gomiero et al. (2011) conducted a comparative review of organic versus conventional farming systems and found that organic agriculture has superior water-holding capacity and better carbon sequestration potential. Organic systems tend to enhance soil biodiversity and can contribute to climate change mitigation through improved soil carbon storage.

Scialabba and Müller-Lindenlauf (2010) explored the environmental benefits of organic farming, including reduced greenhouse gas emissions and enhanced soil carbon sequestration. Their study indicates that organic farming systems can provide sustainable solutions for food security and climate adaptation.

Pimentel and Burgess (2014) evaluated the environmental and economic benefits of organic farming. They found that organic farming conserves soil and water resources, uses less fossil energy, and offers comparable yields to conventional systems. This makes organic farming a viable option for sustainable agriculture, especially in drought-prone areas.

Condron et al. (2000) compared soil and environmental quality between organic and conventional systems in New Zealand. They reported higher soil organic matter and biological activity in organic systems, although challenges related to trace element availability need addressing for long-term sustainability.

2.4. Economic Viability and Farmer Profitability

Economic considerations are pivotal in evaluating farming practices. Singh et al. (2012) assessed the impact of conventional, organic, and integrated cultivation on Pusa basmati-1 rice. They found that organic cultivation led to a 52.96% increase in yield over five years compared to conventional methods. Organic farming also improved soil bulk density and organic carbon content, enhancing overall sustainability and profitability.

Kakar et al. (2020) investigated the effects of various organic and inorganic fertilisers on rice cultivation in Afghanistan. They observed that treatments combining animal manure with reduced levels of traditional fertilisers achieved higher grain yield and better nutritional quality. This suggests that integrating organic and reduced chemical inputs can enhance economic viability and farmer profitability.

Gopalakrishnan et al. (2014) compared organic and conventional practices in rice cultivation and found that organic + inorganic systems provided better growth parameters and water-saving potential. They noted that while organic management was beneficial, it was particularly effective in saving irrigation water and enhancing soil properties.

2.5. Pest and Disease Management Strategies

Pest and disease management remains a critical challenge in agriculture. Bniggen and Termorskuizen (2003) compared pest surveillance capacity between organic and conventional systems. They found that while organic systems might face initial yield losses and pest issues, well-managed organic farms eventually maintain better soil health and pest tolerance. This suggests that long-term organic practices can be effective in managing pests and diseases.

El-Shafie (2019) explored pest and disease management in date palm crops under organic farming in Saudi Arabia. The report noted that organic methods, such as crop rotation and natural pest control, were more preventive than curative. Organic farming systems rely on maintaining natural biodiversity to manage pests effectively.

Chakraborty et al. (2011) conducted long-term research on soil quality and microbial profiles under different fertilisation practices. They found that organic supplements significantly enhanced microbial biomass and activity, which could indirectly support better pest and disease management through improved soil health.

Liu et al. (2009) investigated the effects of organic amendments on soil microbial activity and nutrient availability in China. Their findings indicate that organic amendments improve microbial biomass and soil health, which can contribute to better disease resistance and pest management in the long term.

In summary, the literature highlights the benefits of organic and integrated farming systems in enhancing crop yield and quality, improving soil health, and contributing to environmental sustainability. While organic systems may face initial challenges, their long-term benefits in terms of soil fertility, water conservation, and pest management make them a viable option for sustainable agriculture.

3.Materials & Method

The Lower Gangetic plains of India, renowned for their enormous paddy production, are chosen as in research site. This region usually includes parts of the states of West Bengal, Bihar, Jharkhand, and Odisha. The study has been carried out in the Nadia district of West Bengal, which is a significant rice-growing area and a section of the Lower Gangetic plains. All of the data has been collected from the most important research subjects.

3.1. Experimental site

Field experiments were carried out at the farmer's field (located at 23° 13 N latitude and 88°54 E longitudes and 7.5 m above MSL) in Nadia district, West Bengal comes under Lower Gangetic Plain zone (Figure 1). The experiment was set up on a field having medium topography, uniform fertility and soil texture, and was linked with electrical pump as the source of irrigation water through earthen channels. Additionally, the land used for organic cultivation comes under NOP certified land.

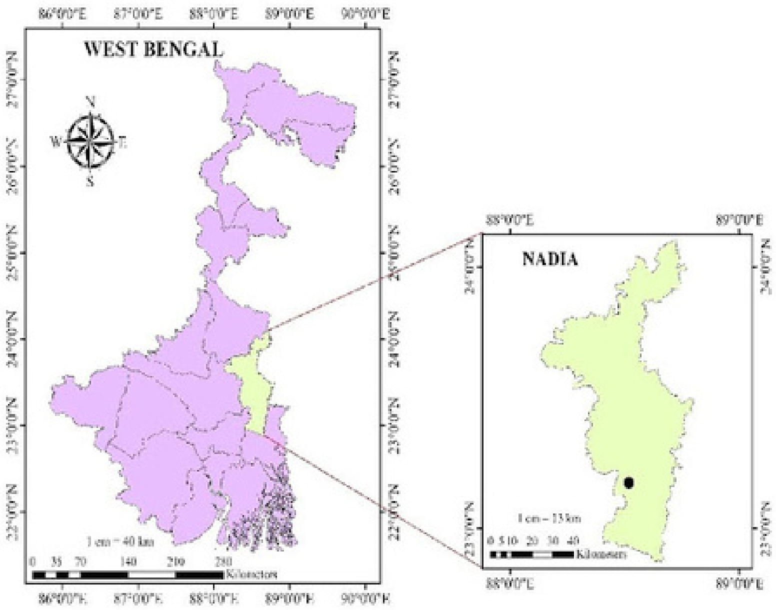

Figure 1: Experimental site

3.2. Crop season

This experimentation is during the Kharif season of 2023 (July to December).

Table 1: Climatic condition and Edaphic condition

Sl No.	Climatic Condition		Edaphic Condition	
1	**Maximum temp (Range)**	28-33 °C	**pH**	6.7
2	**Minimum temp (Range)**	21-27 °C	**EC**	0.23 dS.m-1
3	**Avg. rainfall**	154 mm	**OC**	0.47%
4	**Relative humidity**	51-78%	**Available N**	230 kg/ha
5	**Bright Sunshine hour (Range)**	0-10.8 hr./day	**Available P**	24 kg/ha
6	-	-	**Available K**	282 kg/ha

3.3. Study Area

Table 2. Details of the study area

Location Name	Landholder name	Type of land	Longitude & Latitude
Gopalpur (Nadia)	Chitta Biswas	Upland	23.136961, 88.545389

3.4.Details of the experiment at a glance

Table 3. Details of experiment

Particulars	Details
Test Crop	Rice
Design of Experiment	Strip Plot Design
Total number of Treatments	4 (Four)
Replication	3 (Three)
No. of Factors	2 (Two)
Total number of Plots	24
Spacing	20cm×15cm
Individual plot size	4m×5m (20m^2)
Bund	3m
Irrigation cum drainage channel	1m
Demarcation between plot	1m
Inorganic plot size	483m^2
Organic plot size	483m^2
Total area	966m^2

3.5. Varietal Details

Table 4. Varietal Details

Sl. No.	Name of the Variety	Salient characteristics	Days to Maturity
1.	Black Rice (Indigenous)	It prefers warm climates, and long growing seasons, leaves and husks are light black, and it grows up to 5 to 6.5 feet in height (Das et al., 2018).	140-160
2.	Gobindbhog (Indigenous)	It is a short, white, aromatic and sticky grain, semi-dwarf, profuse tillering,	140-160
3.	PAN-865 (Improved)	Medium, long, slender type grain, drought tolerant, 3.5ft or more height & it is suitable for raw rice and pop.	125-130
4.	GMS-2264 (Hybrid)	Extra-long slender grain, short height (80-105cm), irrigated and medium low land areas are suitable, good clustering habit, non-lodging, non-shattering, high yielder, excellent cooking quality.	135-140

3.6. Experimental design and treatment details:

The experiment is laid out in a Strip Plot Design with 4 treatments, 3 replications, and 2 factors. Four distinct rice varieties are used, each with three replications under both organic and inorganic management techniques, totalling 24 plots. Twelve plots are organic, and the remaining are inorganic.

3.7. Treatment Details:

Table 5. Treatment Details

Treatments	Particulars
T-1	Black Rice
T-2	Gobindbhog
T-3	PAN-865 (Improved)
T-4	GMS 2264 (Hybrid)

3.8. Layout plan:

Each plot measures 4 meters wide by 5 meters long, with a 1-meter-wide plant-free border separating it from neighbouring plots. The irrigation-cum-drainage canals are 1 meter wide. The experiment covers a total area of 966 m², with 483 m² allocated to both the organic and inorganic plots.

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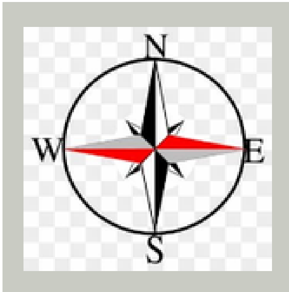
Table 6: Layout Plan

3m		1m		1m		3m
	R1T1		R2T2		R3T4	
	1m					
	R1T2		R2T4		R3T3	
	1m					
	R1T3		R2T1		R3T2	
	1m					
	R1T4		R2T3		R3T1	4m
3m			5m		5m	3m
	R1T1		R2T2		R3T4	
	1m					
	R1T2		R2T4		R3T3	
	1m					
	R1T3		R2T1		R3T2	
	1m					
	R1T4		R2T3		R3T1	4m
3m					5m	3m



3.9. Fertiliser Application:

Nitrogen, phosphorous and potassium have been supplied through Urea, DAP, SSP and MOP, respectively. N has been applied in three equal splits viz. one at basal and another two at active tillering and panicle initiation stage. Full doses of P2O5 and K2O have been applied during the basal stage.

Table 7: Fertiliser Details

Treatment	Variety	Doses (N:P:K)	fertiliser requirement		
			Urea (gm)	SSP (gm)	MOP (gm)
T-1	Black Rice	60:30:30	260	375	100
T-2	Gobindobhog	60:30:30	260	375	100
T-3	Improved (PAN-865)	120:60:60	522	750	200
T-4	Hybrid(GMS-2264)	160:40:40	670	500	134

3.10.Recorded Observations:

The second rows on either side of each plot have been designated for recording additional biometric observations and destructive sampling. Each plot includes five randomly chosen plants that are tagged for biometric data, at DAS 30, 45, 60, 75, 90,120 and Harvest time.

Table 8: Growth attributes

Sl. No.	Parameters	Units	Time Intervals
1.	Plant Height	Cm	30, 45, 60, 75, 90 and at harvest.
2.	Plant Dry Weight	Gm	30, 45, 60, 75, 90 DAT.
3.	Tiller density	No./m2	60, 75, 90 and at harvest.

Table 9: Yield attributes and yield

Sl. No.	Parameters	Units	Time Intervals
1.	No. of Effective Tillers	No.	At harvest
2.	Panicle length	Cm	
3.	No. of grains per panicle	No./m2	
4.	1000 grain weight	gm	
5.	Grain Yield	t/ha	
6.	Straw Yield	t/ha	
7.	Harvest Index	%	

TABLE 10: ECONOMICS ANALYSIS

Sl. No.	Parameters	Unit	Time
1.	Cost of cultivation	₹ ha-1₹ ha-1₹ ha-1₹ ha-1	After harvesting of the crop
2.	Gross return		
3.	Net return		
4.	B: C ratio (BCR)		

4.RESULT

4.1. Morphological Traits/ Growth Attributes

4.1.1. Plant Height Variability Among Rice Varieties

Plant height among different rice varieties demonstrates significant variability and is influenced by the management practices employed. Statistical analysis reveals significant differences ($p \leq 0.05$) in plant height across rice varieties, nutrient treatments, and their interactions, as detailed in Tables 11a and 11b. Notably, plant height is consistently greater under inorganic management compared to organic management across various growth stages.

- **Initial Growth Stage (30 Days After Transplanting - Dat):**

At 30 DAT, the improved variety PAN-865 (V3) exhibits the tallest height under both inorganic (76.5 cm) and organic (67.2 cm) management practices. This is followed by the indigenous varieties Gobindobhog (V2) and Black rice (V1). In contrast, the hybrid variety GMS-2264 (V4) shows the shortest height, measuring 54.7 cm under inorganic and 48.4 cm under organic management.

- **Mid-Growth Stage (45 and 60 Dat):**

Under inorganic management, V3 achieves the highest plant height at both 45 DAT (84.7 cm) and 60 DAT (113.2 cm). It is followed by V2 (80.0 cm and 105.4 cm) and V1 (78.57 cm and 104.4 cm), with no significant difference observed between V2 and V1 at these stages. Under organic management, V3 also has the tallest plant height at 45 DAT (74.83 cm), but at 60 DAT, V1 and V2 exhibit the highest heights (96.0 cm and 95.1 cm, respectively), with V3 at 88.2 cm. V4 records the lowest height at both stages under both inorganic (65.07 cm and 74.5 cm) and organic (55.7 cm and 66.5 cm) management practices.

- **Late-Growth Stage (75 and 90 Dat):**

At 75 DAT, there is no significant difference in plant height among V1, V2, and V3 under inorganic management (123.53 cm, 119.10 cm, and 123.73 cm, respectively). In the organic system, V1 and V2 have the highest plant heights (112.17 cm and 110.50 cm), followed by V3 (108.33 cm). V4 has the lowest height under both inorganic (82.20 cm) and organic (74.83 cm) management practices. By 90 DAT, the highest plant height under inorganic management is observed in the indigenous variety V1 (133.67 cm), followed by V3 (131.07 cm) and V2 (129.17 cm). V4 records the lowest height (86.30 cm). Under organic management, V2 and V1 have the highest plant heights (120.50 cm and 119.7 cm), followed by V3 (115.77 cm), with V4 again showing the lowest height (78.2 cm).

- **At Harvest:**

At harvest, the indigenous Black rice (V1) has the tallest plant height (130.87 cm under organic and 142.7 cm under inorganic management). This is followed by Gobindobhog (V2) (137.7 cm under inorganic and 126.3 cm under organic) and the improved variety PAN-865 (V3) (132.47 cm under inorganic and 122.9 cm under organic). The hybrid variety GMS-2264 (V4) has the shortest plant height at harvest, measuring 87.53 cm under inorganic and 80.1 cm under organic management practices.

This thematic organisation of plant height variability provides a clear view of how different rice varieties respond to inorganic and organic management practices across various growth stages.

Table 11a: Effect of nutrient management practices on plant height of different rice varieties

Treatment	Plant height					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At Harvest**
Nutrient Management (N)						
Inorganic (N1)	66.0	77.1	99.4	112.1	120.1	125.1
Organic (N2)	56.7	67.4	86.5	101.5	108.5	115.0
SEm±	0.76	0.891	2.06	1.359	0.721	0.611
CD (p≤0.05)	2.31	2.701	6.25	4.122	2.188	1.853
Variety (V)						
V1	60.1	73.93	100.2	117.85	126.68	136.78
V2	61.9	74.83	100.3	114.8	124.83	132
V3	71.8	79.80	100.7	116.03	123.42	127.68
V4	51.5	60.38	70.5	78.52	82.25	83.82
SEm±	1.08	1.259	2.91	1.922	1.02	0.864
CD (p≤0.05)	3.27	3.820	8.83	5.829	3.095	2.621

**DAT: DAYS AFTER TRANSPLANTING*

Table 11b: Interaction effect of nutrient management and varieties on plant height of rice

Treatment Combinations	Plant height					
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At Harvest
N1xV1	64.5	78.5	104.4	123.53	133.67	142.7
N1xV2	68.2	80	105.4	119.10	129.17	137.7
N1xV3	76.5	84.7	113.2	123.73	131.07	132.47
N1xV4	54.7	65.0	74.5	82.20	86.30	87.53
N2xV1	55.7	69.3	96	112.17	119.7	130.87
N2xV2	55.6	69.6	95.1	110.50	120.50	126.3
N2xV3	67.2	74.8	88.2	108.33	115.77	122.9
N2xV4	48.4	55.7	66.5	74.83	78.2	80.1
SEm±	1.08	1.7	4.12	1.922	1.443	1.222
CD ($p \leq 0.05$)	4.62	5.4	12.49	8.244	4.376	3.706

*DAT: DAYS AFTER TRANSPLANTING

4.1.2. Tillering Density

The number of tillers per hill increases gradually up to 75 DAT, after which it reduces by 90 DAT, as shown in Table 12a & Table 12b. Tiller density is slightly higher under inorganic management compared to organic management.

- **Initial Growth Stage (30 Days After Transplanting - DAT)**

At 30 DAT, the hybrid variety GMS-2264 (V4) has the highest tiller density under inorganic management (164.46 tillers/hill), followed by V2 (151.17 tillers/hill). Under organic management, V4 has the lowest tiller density (131.73 tillers/hill). The highest tiller density under organic management is observed in the Gobindobhog variety V2 (142.30 tillers/hill), followed by the Black rice variety V1 (135.03 tillers/hill under organic and 144.83 tillers/hill under inorganic management). The improved variety V3 shows a tiller density of 135.07 tillers/hill under organic and 130.17 tillers/hill under inorganic management.

- **Mid-Growth Stage (45 and 60 DAT)**

At 45 DAT, V4 maintains the highest number of tillers per hill under inorganic management (184.4 tillers/hill), followed by V2 (169.6 tillers/hill) and V1 (166.4 tillers/hill). Under organic management, the highest tiller density is observed in V2 (159.4 tillers/hill) and V3 (158.3 tillers/hill). The lowest tiller density under inorganic management is recorded for V3 (149.4 tillers/hill), while under organic management, the lowest densities are observed in V4 (155.1 tillers/hill) and V1 (155.9 tillers/hill).

At 60 DAT, under inorganic management, V4 has the highest tiller density (229.1 tillers/hill), followed by V2 (191.3 tillers/hill) and V1 (186.8 tillers/hill), with V3 showing the lowest density (170.7 tillers/hill). Under organic management, V2 has the highest tiller density (190.7 tillers/hill), followed by V1 (182.9 tillers/hill), with V3 and V4 having the lowest densities (177.8 tillers/hill and 177.1 tillers/hill, respectively).

- **Peak Growth Stage (75 DAT)**

At 75 DAT, the peak tiller density is observed for all rice varieties. Under inorganic management, V4 and V2 have the highest tiller densities (278.2 tillers/hill and 277.7 tillers/hill, respectively). Under organic management, V2 and V3 have the highest densities (250.2 tillers/hill and 246.6 tillers/hill, respectively), followed by V1 (226.9 tillers/hill). The lowest tiller density under organic management is recorded in V4 (209.1 tillers/hill).

- **Late-Growth Stage and Harvest (90 DAT and Harvest)**

After 75 DAT, tiller numbers reduce. At 90 DAT, under inorganic management, V4 has the maximum tiller density (228.5 tillers/hill), followed by V2 (182.3 tillers/hill) and V1 (175.7 tillers/hill). The lowest density is observed in V3 (158.4 tillers/hill). Under organic management, V2 and V1 have the highest densities (187.9 tillers/hill and 184.4 tillers/hill, respectively), with V4 having the lowest density (158.8 tillers/hill).

At harvest, V4 demonstrates the maximum tillering capacity (219.67 tillers/hill), followed by V2 (179 tillers/hill) and V1.

Table 12a: Effect of nutrient management practices on tillering density of different rice varieties

Treatment	Tiller Density				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Nutrient Management (N)					
Inorganic (N1)	147.7	167.5	194.5	266.1	186.2
Organic (N2)	136.0	157.2	182.1	233.2	173.8
SEm±	1.1	1.6	1.5	2.5	1.9
CD (p≤0.05)	3.2	4.9	4.5	7.6	5.6
Variety (V)					
V1	139.9	161.2	184.8	245.7	180.0
V2	146.7	164.5	191.0	264.0	185.1
V3	132.6	153.9	174.2	245.4	161.3
V4	148.1	169.7	203.1	243.7	193.6
SEm±	1.507	2.29	2.09	3.52	2.62
CD (p≤0.05)	4.572	6.95	6.34	10.68	7.94

*DAT: Days after transplanting

Table 12b: Interaction effect of nutrient management and varieties on the tillering density of rice

Treatment Combinations	Tiller Density				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
N1xV1	144.8	166.4	186.8	264.4	175.7
N1xV2	151.2	169.6	191.3	277.7	182.3
N1xV3	130.2	149.4	170.7	244.1	158.4
N1xV4	164.5	184.4	229.1	278.2	228.5
N2xV1	135.0	155.9	182.9	226.9	184.4
N2xV2	142.3	159.4	190.7	250.2	187.9
N2xV3	135.1	158.3	177.8	246.6	164.1
N2xV4	131.7	155.1	177.1	209.1	158.8
SEm±	2.132	3.24	2.96	4.98	3.7
CD (p≤0.05)	6.466	9.83	8.97	15.1	11.24

**DAT: Days after transplanting*

4.1.3. Plant Dry Weight

The influence of different nutrient management practices on the plant dry weight of various rice varieties is assessed, with details provided in Table 13a. Additionally, the interaction effects of nutrient management and varieties on plant dry weight are elaborated in Table 13b. Inorganic nutrient management (N1) consistently results in slightly higher plant dry weights compared to organic management (N2) across multiple observation stages (30, 45, 60, 75, and 90 days after transplanting - DAT).

- **Late-Growth Stage and Harvest (90 DAT and Harvest)**

At 30 DAT, the overall plant dry weight under inorganic management (N1) reaches 3.01 g, while organic management (N2) yields 2.35 g. Notably, the combination of N1 with V2 and V3 demonstrates the highest plant dry weights at 3.33 g and 3.17 g, respectively. Conversely, under organic management, indigenous rice cultivars Black rice (V1) and Gobindobhog (V2) exhibit the highest plant dry weights (V1-2.57 g & V2-2.5 g). After V1 and V2, V3, an improved variety, displays the highest plant dry weight (2.33 g) under organic management. The hybrid rice cultivar V4 has the lowest plant dry weight (Inorganic-2.47 g & Organic-2 g).

- **Mid-Growth Stage (45 and 60 DAT)**

At 45 DAT, the plant dry weight under N1 is 10.16 g compared to 8.01 g under N2. Notably, the combinations of N1 with V1 and V2 (Black rice and Gobindobhog) demonstrate the highest plant dry weights in both conditions (N1: 10.6 g & 11.53 g, and N2: 8.17 g & 8.83 g, respectively). The V3 rice variety weighs 10.33 g and 7.77 g, respectively, under inorganic and organic practices. The V4 rice cultivar has the lowest plant dry weight (8.17 g for inorganic condition and 6.97 g for organic).

By 60 DAT, the plant dry weight under N1 reaches 20.18 g, significantly higher than the 16.68 g under N2. Indigenous rice cultivars Black rice (V1) and Gobindobhog (V2) consistently show high plant dry weights under both organic and inorganic management practices. For the 60 DAT growth stage, the plant dry weight under inorganic management practices is 22.2 g to 29.43 g for V1 and 22.8 g to 29.43 g for V2. Under organic management practices, for the indigenous rice cultivars V1 (Black rice) and V2 (Gobindobhog), it is 19.1 g to 25.2 g and 18.3 g to 23.97 g, respectively. The V4 rice cultivar shows the lowest plant dry weight, ranging from 15.5 g to 20.13 g in inorganic condition and 11.3 g to 16.1 g in organic condition for 60 DAT.

- **Peak Growth Stage (75 DAT)**

At 75 DAT, N1 exhibits a plant dry weight of 26.33 g, while N2 yields 22.2 g. Indigenous rice cultivars Black rice (V1) and Gobindobhog (V2) continue to show high plant dry weights under both organic and inorganic management practices. The plant dry weight under inorganic management practices is 29.43 g for both V1 and V2. Under organic management practices, for the indigenous rice cultivars V1 (Black rice) and V2 (Gobindobhog), it is 25.2 g and 23.97 g, respectively. The V4 rice cultivar continues to show the lowest plant dry weight, ranging from 20.13 g in inorganic condition to 16.1 g in organic condition at 75 DAT.

- **Late Growth Stage and Harvest (90 DAT and Harvest)**

By 90 DAT, plant dry weights are 29.38 g for N1 and 27.26 g for N2. V1 (Black rice) consistently displays high plant dry weights, reaching 31.53 g at 90 DAT. V2 (Gobindobhog) exhibits similar performance to V1, with slightly lower weights (30.82 g). V3, an improved rice variety, presents moderate weights, peaking at 28.55 g at 90 DAT. V4, hybrid rice consistently has the lowest weight among the varieties, reaching only 22.37 g at 90 DAT. The highest plant dry weights are observed in the combination of N1 with V1 and V2, with V2 showing a peak weight of 32.53 g at 90 DAT. The combination of N1 with V3 and V4 shows lower weights, with N1xV4 being the lowest among the N1 combinations (24.23 g at 90 DAT). Organic combinations (N2) display lower weights overall, with N2xV1 and N2xV2 performing relatively well (30.53 g and 29.9 g at 90 DAT, respectively). The N2xV4 combination has the lowest plant dry weight at 90 DAT (20.5 g).

Table 13a: Effect of nutrient management practices on Plant Dry Weight of different rice varieties

Treatment	**Plant Dry Weight**				
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
Nutrient Management (N)					
Inorganic (N1)	3.01	10.16	20.18	26.33	29.38
Organic (N2)	2.35	8.01	16.68	22.2	27.26
SEm±	0.077	0.108	0.104	0.169	0.13
CD (p≤0.05)	0.234	0.327	0.315	0.514	0.394
Variety (V)					
V1	2.82	9.72	20.62	27.32	31.53
V2	2.92	10	20.5	26.7	30.82
V3	2.75	9.05	19.23	24.93	28.55
V4	2.23	7.57	13.37	18.12	22.37
SEm±	0.109	0.153	0.147	0.24	0.18
CD (p≤0.05)	0.33	0.463	0.446	0.727	0.557

**DAT: Days after transplanting*

Table 13b: Interaction effect of nutrient management and varieties on Plant Dry Weight of rice

Treatment Combinations	Plant Dry Weight				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
N1xV1	3.07	10.6	22.2	29.43	32.53
N1xV2	3.33	11.53	22.8	29.43	31.73
N1xV3	3.17	10.33	20.3	26.33	29
N1xV4	2.47	8.17	15.5	20.13	24.23
N2xV1	2.57	8.83	19.1	25.2	30.53
N2xV2	2.5	8.47	18.3	23.97	29.9
N2xV3	2.33	7.77	18.2	23.53	28.1
N2xV4	2	6.97	11.3	16.1	20.5
SEm±	0.154	0.216	0.208	0.339	0.26
CD (p≤0.05)	0.467	0.654	0.63	1.027	0.789

**DAT: Days after transplanting*

4.2. Yield and Yield Attributes:

Plant height among different rice varieties demonstrates significant variability and is influenced by the management practices employed. Statistical analysis reveals significant differences ($p \leq 0.05$) in plant height across rice varieties, nutrient treatments, and their interactions, as detailed in Tables 11a and 11b. Notably, plant height is consistently greater under inorganic management compared to organic management across various growth stages.

4.2.1. No. of Effective Tillers

At harvest, a higher number of effective tillers are observed under inorganic practice (24.5) compared to organic management practice (21.2). Significant variations are also noted among different rice varieties under different management practices. The combination of N1 (Inorganic) x V3 (Improved rice variety) exhibited the highest number of effective tillers (27.1), followed by indigenous rice cultivars V1 and V2 (26 and 24.1, respectively). Conversely, under organic management practice, the highest number of effective tillers was observed in V1 (24.1), followed by V2 and V3 (23.7 and 20.4, respectively). Notably, V4 (hybrid rice cultivar) displayed a more pronounced difference in the number of effective tillers between organic and inorganic management practices, with 20.8 under inorganic and 18.7 under organic management.

4.2.2. Length of Panicle

The longest panicles are observed in V3 (30.4 cm) and V2 (30.2 cm) under inorganic practice, followed closely by V1 (29.5 cm). In contrast, under organic practice, V1 and V2 exhibited similar panicle lengths (25.2 cm and 25 cm, respectively). Additionally, V3 had the longest panicles (26.3 cm), while V4 had the shortest in both management practices (26.2 cm under inorganic and 24 cm under organic).

4.2.3. Grain Yield & Biological Yield

Inorganic (N1) nutrient management showed a slightly higher number of effective tillers (24.5) and longer panicle length (29.1 cm) compared to organic (N2) management (21.2 and 25.1 cm, respectively). However, differences in grain yield and biological yield between the two nutrient management practices are negligible, with N1 slightly outperforming N2 in both parameters. Variations in grain yield and biological yield are primarily attributed to rice varieties, with V1 exhibiting the highest grain yield (3.3 t/ha) and biological yield (11.4 t/ha).

The interaction between nutrient management practices and rice varieties also influenced the agronomic parameters studied. For instance, among all treatment combinations, the combination of N1 with V1 and N2 with V1 produced the maximum grain and biological yield: 3.4 t/ha for grain and 11.9 t/ha for biological yield in the case of inorganic practice (N1), and 3.2 t/ha and 10.8 t/ha in the case of organic practice (N2). On the other hand, the combination of N2 & N1 with V4 displayed the lowest values for these metrics, suggesting that rice variety and nutrient management may interact. The hybrid rice cultivar V4 had a grain yield and biological yield of 2.6 t/ha & 7 t/ha respectively, in organic practice. Although that is good, in inorganic practice, it is, respectively, 3.2 t/ha and 8 t/ha.

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Table 14a: Effect of nutrient management practices on No. of effective tillers, Length of Panicle, Grain Yield & Biological Yield of different rice varieties

Treatment	No. of Effective Tillers	Length of Panicle	Grain Yield	Biological Yield
	At Harvest	At Harvest	At Harvest	At Harvest
Nutrient Management (N)				
Inorganic (N1)	24.5	29.1	3.2	10.4
Organic (N2)	21.2	25.1	2.9	9.3
SEm±	0.220	0.183	0.04	0.09
CD (p≤0.05)	0.669	0.556	0.12	0.27
Variety (V)				
V1	23.8	27.3	3.3	11.4
V2	22.3	27.6	3.0	10.5
V3	25.6	28.4	2.9	9.9
V4	19.7	25.1	2.9	7.5
SEm±	0.312	0.259	0.06	0.12
CD (p≤0.05)	0.946	0.787	0.17	0.38

**DAT: Days after transplanting*

Table 14b: Interaction effect of nutrient management and varieties on No. of effective tillers, Length of Panicle, Grain Yield & Biological Yield of rice

Treatment Combinations	No. of Effective Tillers	Length of Panicle	Grain Yield	Biological Yield
	At Harvest	At Harvest	At Harvest	At Harvest
N1xV1	26	29.5	3.4	11.9
N1xV2	24.1	30.2	3.0	11.1
N1xV3	27.1	30.4	3.1	10.6
N1xV4	20.8	26.2	3.2	8.0
N2xV1	24.1	25.2	3.2	10.8
N2xV2	23.7	25.0	3.0	10.0
N2xV3	20.4	26.3	2.8	9.3
N2xV4	18.7	24.0	2.6	7.0
SEm±	0.441	0.367	0.08	0.18
CD (p≤0.05)	1.337	1.113	0.24	0.53

**DAT: Days after transplanting*

4.3. Economics

The economic analysis of different rice varieties under inorganic and organic nutrient management practices reveals significant variations in the cost of cultivation, gross return, net return, and benefit-cost (BC) ratio. The detailed results for each treatment are summarised in Table 15.

Black Rice Indigenous Variety (V1)

Inorganic Management

- **BC Ratio:** 1.01
- **Net Return:** ₹51,168
- **Gross Return**: ₹1,02,000
- **Cost of Cultivation:** ₹1,00,000

Under inorganic management, the BC ratio for V1 is 1.01, indicating that the net return of ₹51,168 slightly exceeds the gross return. This implies that although V1 has a reasonable profit margin, it is not highly economically feasible.

Organic Management

- **BC Ratio:** 1.65
- **Net Return:** ₹80,200
- **Gross Return:** ₹1,22,000
- **Cost of Cultivation:** ₹41,800

In contrast, under organic management, V1 shows a very favourable BC ratio of 1.65. The net return of ₹80,200 indicates this variety's great economic sustainability under organic management.

Gobindobhog Indigenous Variety (V2)

Inorganic Management

- **BC Ratio:** 0.67
- **Net Return:** ₹34,101
- **Gross Return:** ₹84,000
- **Cost of Cultivation:** ₹50,000

Under inorganic management, V2 exhibits a BC ratio of 0.67, meaning that the net return of ₹34,101 does not cover the cultivation costs. This variety is less economically viable with inorganic management techniques.

Organic Management

- **BC Ratio**: 1.06
- **Net Return**: ₹51,540
- **Gross Return**: ₹92,000
- **Cost of Cultivation**: ₹40,460

Under organic management, V2 achieves a BC ratio of 1.06, indicating mild profitability with a net return of ₹51,540. This suggests that using organic methods can be moderately profitable.

Improved Rice Variety (V3)

Inorganic Management

- **BC Ratio:** 0.16
- **Net Return:** ₹9,394
- **Gross Return:** ₹43,000
- **Cost of Cultivation:** ₹60,000

For V3, the BC ratio of 0.16 under inorganic management indicates a serious economic disadvantage, as the net return is only ₹9,394, much less than the cultivation cost.

Organic Management

- **BC Ratio:** 0.40
- **Net Return:** ₹20,410
- **Gross Return:** ₹48,000
- **Cost of Cultivation:** ₹50,000

Under organic management, V3 shows a BC ratio of 0.40, suggesting poor economic performance with a net return of ₹20,410. The gross return is not high enough to cover the cost of cultivation, reducing the variety's economic suitability for organic farming.

Hybrid Rice Variety (V4)

Inorganic Management

- **BC Ratio:** 0.19
- **Net Return:** ₹10,931
- **Gross Return:** ₹58,000
- **Cost of Cultivation:** ₹70,000

The BC ratio of 0.19 for V4 under inorganic management indicates low economic return, as evidenced by the net return of ₹10,931. This variety is not economically viable under inorganic nutrient management.

Organic Management

- **BC Ratio:** 0.25
- **Net Return:** ₹13,100
- **Gross Return:** ₹63,000
- **Cost of Cultivation:** ₹52,000

Under organic management, V4 also exhibits economic inefficiency with a BC ratio of 0.25 and a net return of ₹13,100. The low BC ratio shows that the gross return is less than the production costs, making this variety economically unviable when using organic nutrient management.

Table 15: Effect of nutrient management practices on economic analysis of different rice varieties

Treatment	Economic analysis			
	Cost of Cultivation	Gross Return	Net Return	BC Ratio
Inorganic Management (N)				
V1	50832	102000	51168	1.01
V2	50832	84934	34101	0.67
V3	57816	67210	9394	0.16
V4	58736	69667	10931	0.19
Organic Management (N)				
V1	48560	128760	80200	1.65
V2	48560	100100	51540	1.06
V3	50990	71400	20410	0.40
V4	53200	66300	13100	0.25


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5. DISCUSSION

The study provides a comprehensive analysis of the impact of different nutrient management practices, specifically inorganic and organic, on the growth attributes, yield attributes and yield of various rice varieties. The data indicates significant differences in plant height, tillering density, plant dry weight, and yield attributes among the rice varieties under different management practices. Additionally, the interaction between nutrient management and rice varieties is analyzed to understand any synergistic or antagonistic effects on growth and yield.

5.1. Morphological Traits and Growth Attributes

Plant height among different rice varieties demonstrates significant variability and is influenced by the management practices employed. Statistical analysis reveals significant differences ($p \leq 0.05$) in plant height across rice varieties, nutrient treatments, and their interactions, as detailed in Tables 11a and 11b. Notably, plant height is consistently greater under inorganic management compared to organic management across various growth stages.

5.1.1. Effect of Nutrient on Morphological Traits/ Growth Attributes

Inorganic nutrient management generally promotes greater plant height, tiller density, and slightly higher plant dry weight compared to organic management. For example, at 30 days after transplanting (DAT), plants with inorganic fertilisers (N1) averaged 66.0 cm in height, versus 56.7 cm with organic fertilisers (N2). This trend persisted to harvest, with N1-treated plants reaching 125.1 cm compared to 115.0 cm for N2. Similarly, tiller density was 147.7 for N1 versus 136.0 for N2. Inorganic fertilisers provide nutrients in readily available forms, supporting rapid growth, while organic fertilisers release nutrients gradually, which benefits long-term soil health and reduces leaching risks (Chaturvedi, 2005; Timsina, 2018). Despite the initially higher growth attributes under inorganic management, organic fertilisers offer a broader nutrient spectrum and improve soil structure and microbial activity (Tilman et al., 2002; Babu et al., 2020).

5.1.2. Effect of Rice Varieties on Morphological Traits/ Growth Attributes

Rice varieties showed variability in growth parameters. Indigenous varieties V1 (Black rice) and V2 (Gobindbhog) consistently displayed the tallest plants and highest tillering density across nutrient management practices. Hybrid V4 exhibited shorter plant height and lower tillering density, particularly under organic management, likely due to slower nutrient release. While inorganic fertilisers resulted in better growth metrics, organic farming can achieve satisfactory results with its nutrient release and soil improvement benefits (Dhaliwal et al., 2023; Prasad, 2022).

5.1.3. Interaction Effect of Nutrient Management and Varieties

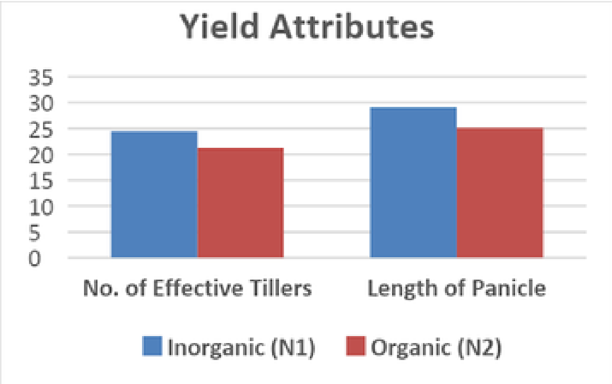
Rice varieties showed variability in growth parameters. Indigenous varieties V1 (Black rice) and V2 (Gobindbhog) consistently displayed the tallest plants and highest tillering density across nutrient management practices. Hybrid V4 exhibited shorter plant height and lower tillering density, particularly under organic management, likely due to slower nutrient release. While inorganic fertilisers resulted in better growth metrics, organic farming can achieve satisfactory results with its nutrient release and soil improvement benefits (Dhaliwal et al., 2023; Prasad, 2022).

Figure 2:
Effect of Nutrient Management and Varieties Source: field data

5.2. Yield Attributes & Yield

5.2.1. Effect of Nutrient on Yield Attributes & Yield

The results reveal that inorganic fertilisation generally led to slightly higher numbers of effective tillers, longer panicle length, and increased grain and biological yield compared to organic fertilisation. This observation aligns with the typical attributes of inorganic fertilisers, which provide readily available nutrients for immediate uptake by plants. However, it's noteworthy that organic fertilisation still resulted in respectable growth and yield outcomes, indicating its potential to support sustainable rice production. Furthermore, organic farming contributes to environmental conservation by minimising the use of synthetic chemicals, thereby reducing pollution and preserving biodiversity. Organic farming also aligns with consumer preferences for sustainably produced food, potentially offering premium prices for organic rice products (Reganold and Wachter, 2016).



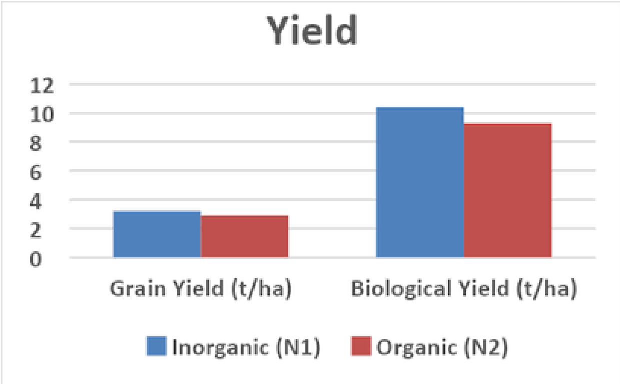


Figure 4: Nutrient Management and Varieties on Yield Attributes & Yield
Source: Field Data

5.2.2. Varietal Response to Nutrient Management on Yield Attributes & Yield

Among the rice varieties studied, V1 and V2, indigenous rice varieties, generally exhibited better performance across various yield parameters under both nutrient management practices. V3 showed comparable performance, while V4 appeared to be more sensitive to nutrient management, particularly under organic fertilisation, where its performance is slightly diminished. Moreover, the study's findings suggest that certain rice varieties perform well under organic management, indicating the potential for optimising organic farming systems through appropriate variety selection and agronomic practices.

5.2.3. Interaction between Nutrient Management and Varieties on Yield Attributes & Yield

This suggests the importance of considering both nutrient management practices and rice variety selection for maximising yield potential. The interaction analysis highlighted specific combinations of nutrient management and rice varieties that resulted in optimal growth and yield. For instance, the N1xV1 combination resulted in the highest number of effective tillers, longest panicle length, and highest grain and biological yield among all treatment combinations. Similarly, under organic management, N2xV1 and N2xV2 combinations performed well across all yield parameters, suggesting their effectiveness in promoting robust growth and yield. While the length of the panicle and the number of effective tillers are highest under inorganic management practices, there is no significant difference in yield or yield parameters when two different nutrient management and variety combinations are combined. Considering that the majority of chaffy or empty grains are produced via inorganic practices. Because of this, there is no significant difference in yield and yield attributes when two distinct nutrient management and variety combinations are combined.

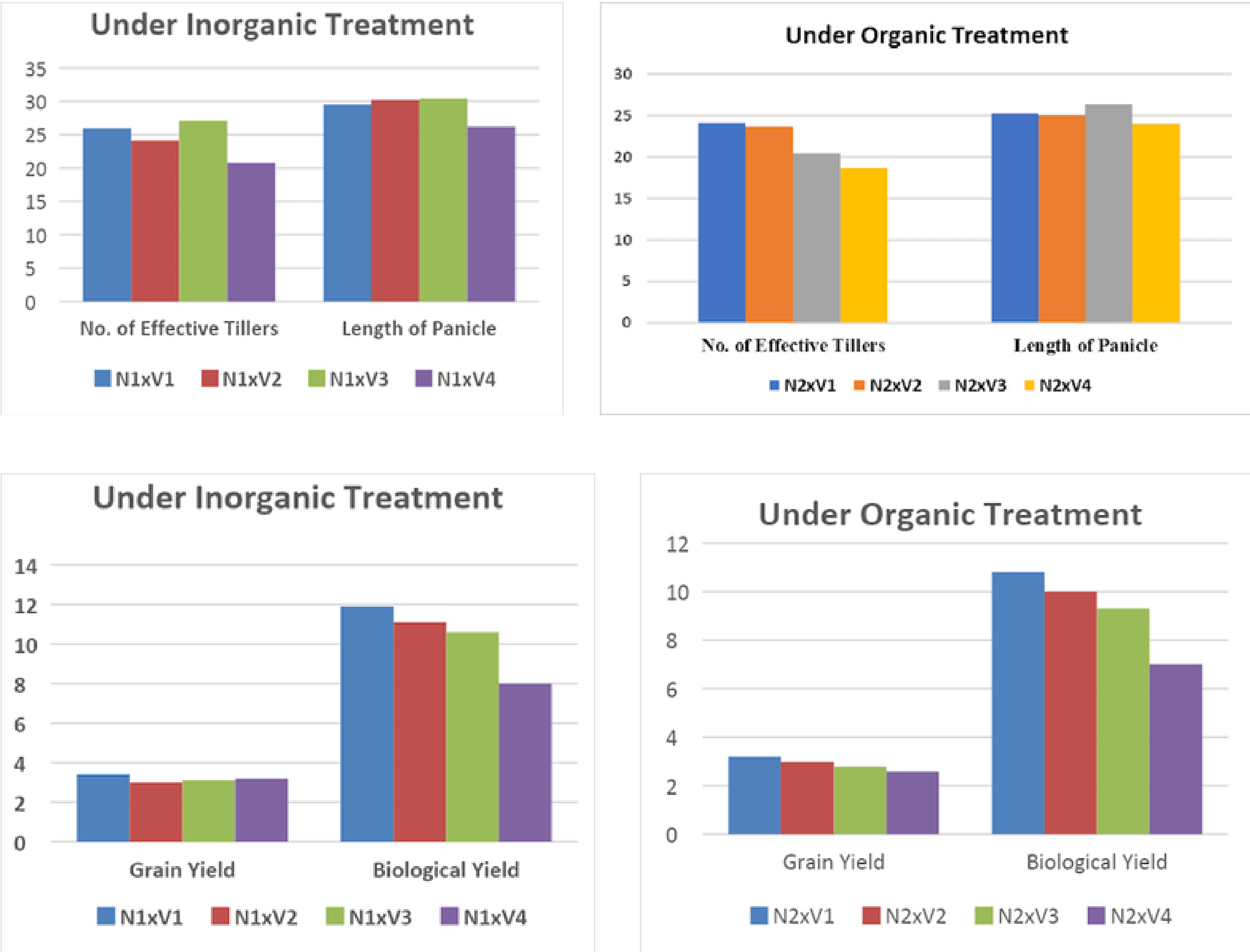


Figure 4: Nutrient Management and Varieties on Yield Attributes & Yield
Source: Field Data

5.3. Economic Analysis

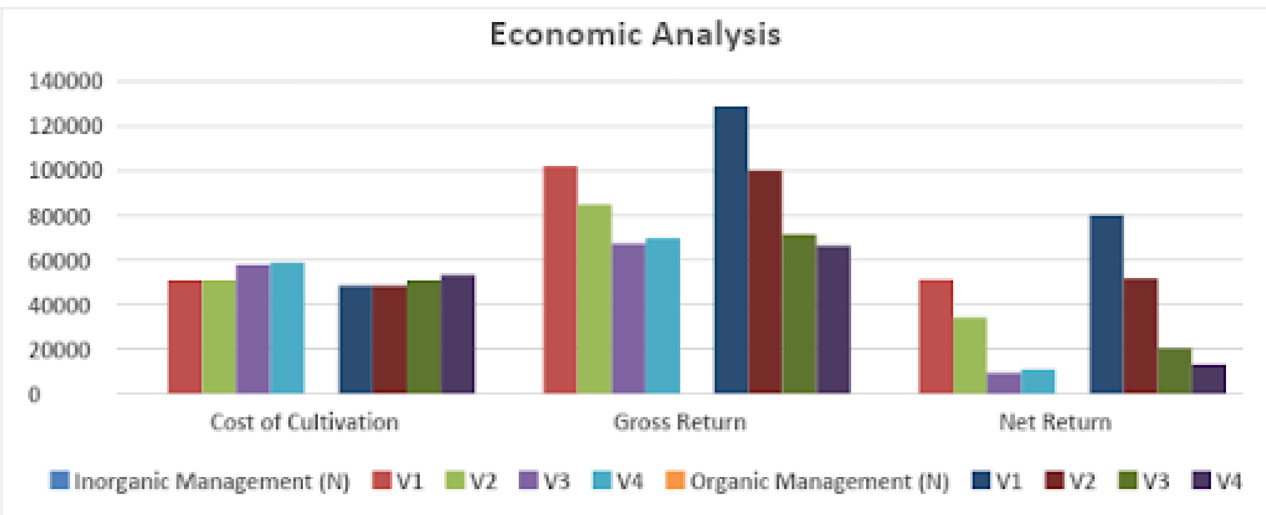
A comparison of economic outcomes between inorganic and organic nutrient management practices reveals notable differences for the tested rice varieties.

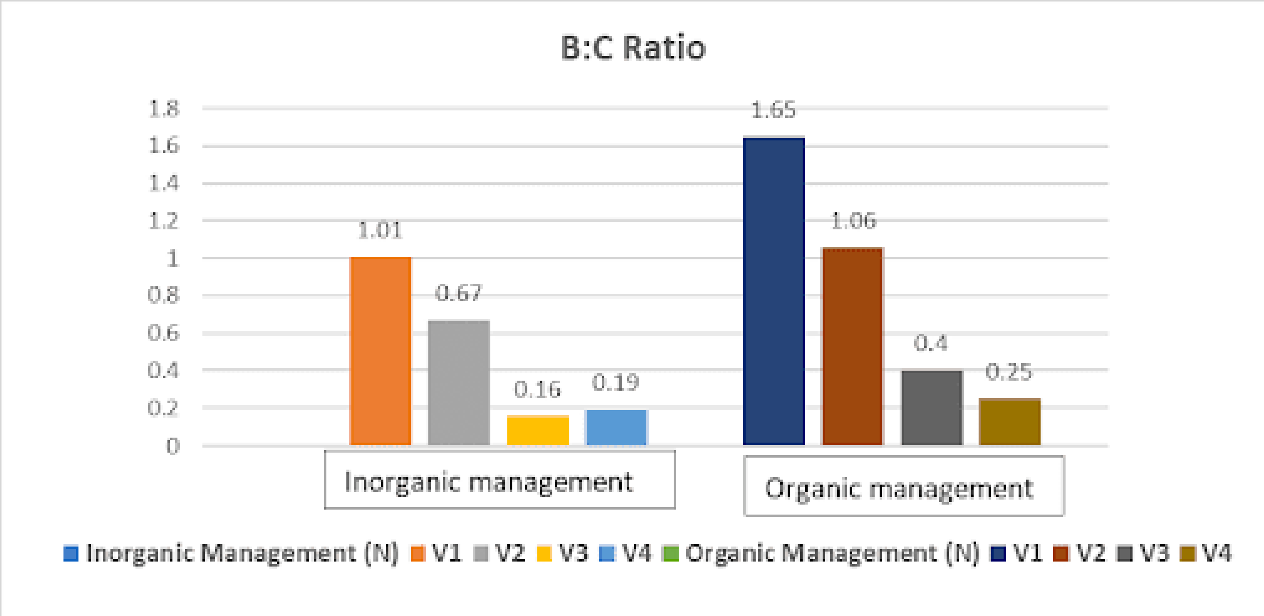
Variety V1 (Black Rice) consistently demonstrated superior economic performance under both management practices, with a benefit-cost (BC) ratio of 1.65 under organic management compared to 1.01 under inorganic management. This indicates that organic practices enhance the economic viability of this variety, likely due to improved soil health and reduced input costs (Shende et al., 2022).

Gobindbhog (V2) also showed moderate economic viability under both systems, with a better BC ratio of 1.06 under organic management versus 0.67 under inorganic management. The higher net return from organic practices suggests that V2 is well-suited for organic farming systems (Ghosh et al., 2013).

Variety V3 (Improved Rice) and V4 (Hybrid Rice) exhibited poor economic performance under both nutrient management practices. V3 had a notably low BC ratio, and V4's performance is particularly weak under organic management, with a BC ratio of 0.19. However, V4 performed better under inorganic management. Despite these challenges, the high market price of organic products and lower total cultivation costs under organic practices could make these varieties more viable if adapted to organic systems. Their current poor performance indicates that either agronomic practices need refinement or these varieties might not be well-suited to the prevailing conditions.

Overall, nutrient management practices significantly impact the economic viability of different rice varieties. Organic management generally enhances economic returns for varieties like V1 and V2, while inorganic management offers limited benefits for most varieties. This suggests that transitioning to organic practices could improve sustainability and profitability for certain varieties. Future research can be focused on optimising organic practices and evaluating their long-term benefits on soil health and productivity. Additionally, investigating the reasons behind the poor performance of certain varieties could identify areas for improvement or alternative strategies for better economic outcomes.





6. CONCLUSION

The field experiment conducted in the Nadia district of the lower Gangetic zone in West Bengal from 2023 to 2024 offers valuable insights into the comparative efficacy of conventional (inorganic) and organic cultivation practices for paddy (Oryza sativa L.). This study evaluated four rice varieties, including two indigenous (Black rice and Gobindbhog), one improved (PAN-865), and one hybrid (CMS-2264).

Key findings reveal that indigenous rice cultivars, particularly Black rice and Gobindbhog, exhibit superior performance under organic management practices. These varieties demonstrate resilience and consistent yields, with Black rice yielding 3.2 t/ha and Gobindbhog yielding 3.0 t/ha under organic management, closely matching their inorganic yields. In contrast, the improved and hybrid varieties show notable yield reductions under organic practices, highlighting the adaptability and potential of indigenous varieties for organic farming systems.

Economically, organic management practices prove particularly viable for indigenous varieties, followed by the hybrid cultivar CMS-2264, primarily due to the higher market prices of organic produce. Although inorganic practices result in higher plant heights, tiller densities, and panicle numbers, the overall economic return favours organic practices due to lower input costs and higher market premiums for organic rice.

In conclusion, this study underscores the potential of organic farming in enhancing the sustainability and economic viability of rice cultivation in the Lower Gangetic plains of India. Indigenous rice varieties, such as Black rice and Gobindbhog, are particularly well-suited to organic practices, offering substantial agronomic and economic benefits. These findings advocate for the promotion of organic farming practices, especially for indigenous rice cultivars, to achieve sustainable agricultural development in the region. Future research should focus on optimising organic management strategies and exploring their broader benefits on soil health and crop productivity, thereby promoting a resilient and eco-friendly agricultural system.

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