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Integrated plant nutrition system influences the productivity of wheat–aus rice–aman rice cropping pattern in the Old Himalayan Piedmont Plain of Bangladesh

MD. MAHFUZ BAZZAZ[1], AKBAR HOSSAIN[2], MD. PARVEZ KABIR[3], ANNIKA JAHAN AONTI[4] AND V. VISHA KUMARI[5]

Bangladesh Wheat and Maize Research Institute, Dinajpur 5200, Bangladesh

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ABSTRACT

Integrated nutrient management maximizes energy efficiency, improves soil health, and enhances crop yield. The experiment was conducted at the Bangladesh Wheat and Maize Research Institute (BWMRI) in Nashipur, Bangladesh, over three consecutive years: 2017–20. The main aim of this study was to determine the optimal combination of vermicompost and chemical fertilizers required to improve wheat growth and yield while maintaining soil fertility sustainably. Seven treatments were utilized in the study: T_1, chemical fertilizers formulated according to soil test results (STB); T_2, integrated plant nutrition systems (IPNS) utilizing 5 t/ha of cow manure (based on T_1); T_3, IPNS (1.0 t/ha) combined with vermicompost (derived from T_1); T_4, (IPNS utilizing 2.0 t/ha of vermicompost on T_1); T_5, IPNS - 4.0 t/ha of vermicompost in conjunction with T_1; T_6, IPNS utilizing 0.750 t/ha of Farha in comparison to T_1, and T_7, indigenous reproductive capacity (control). The application of vermicompost and other organic fertilizers significantly improved the yields of wheat, T. Aus, and T. Aman rice across the three cropping seasons. Treatment T_3 was deemed the most effective, producing the highest rice equivalent of 18.28 t/ha, followed by T_2 and T_4. The control treatment resulted in the lowest yields. The gross margin is largest in the case of Tk. The T_2 utilized 5 t/ha cow dung, yielded a gross margin of Tk. 246,477 /ha, which was the second-highest amount recorded. The maximum density of 239,242 per ha was recorded in T_3 (1 t/ha of vermicompost). The increased effectiveness of organic treatments is associated with increased soil health due to improvements in the physical and chemical properties of the soil. To increase soil fertility and production, a combination of 5 t/ha cow dung, 1 t/ha vermicompost, and STB chemical fertilizers is recommended to increase crop output.

Key words: Cropping system, Equivalent yield, Rice, Wheat, Yield

Bangladesh's soils are generally very poor in organic matter content; most soils contain less than 1.5% organic matter, and some even contain less than 1% organic matter (FRG 2024). The perfect soil would contain at least 2.5% organic matter. Gradually, the amount of organic matter in the soil decreases.

In the long-term fertilizer experiments, the soil organic matter content remained unchanged (or slightly increased) in the ricerice cropping system, whereas it slightly decreased in the wheatrice cropping system. Owing to the increasing scarcity of land and water, agricultural strategies are based on chemical fertilizers and the development of new high-yielding crop varieties. Fertilizer prices increase from season to season (Selim, 2020) because the second- and third-season fertilizer rates are much greater than those in the first season, making it imperative to maintain yield production at a profitable level. In addition, the excessive utilization of chemical fertilizers in traditional agricultural systems leads to the deterioration of food and soil quality (Melero *et al.,* 2008; Liu *et al.,* 2009). Therefore, alternative sources of fertilizers that increase the soil nutrient content and physicochemical properties may be solutions (Kochaki *et al.,* 2008). One method involves the use of vermicompost as an organic fertilizer. Vermicomposts are poorly carbon, plant-based organic substances that are decomposed by the action of earthworms and microorganisms. The vermicompost N, P, and K contents are approximately 1.5% - 2.2%, 1.8% - 2.2%, and 1.0% - 1.5%, respectively. With organic carbon contents ranging between 9.5% and 17.98%, micronutrient elements, such as sodium (Na), calcium (Ca), zinc

[2]**Corresponding author's Email:** akbarhossainwrc@gmail.com
[1]Principal Scientist and Head, Agronomy Division, [2]Principal Scientist and Head Soil Science Division, [3,4]Scientist, Bangladesh Wheat and Maize Research Institute, Dinajpur 5200, Bangladesh; [5]Senior Scientist (Agronomy), Department of Crop Science, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Telangana 500 059, India

(Zn), sulfur (S), magnesium (Mg), and iron (Fe), are also found. Research conducted by Ghorbani and Sabour (2021) suggested that vermicompost can create nutrients from waste products, including sewage sludge, that improve the quality of the soil. It is an organic substance that is rich in nutrients, has attracted the interest of both researchers and agriculturists, and can be used as a cultivation-enhancing agent. Przemieniecki *et al.* (2021) confirmed that treatment with vermicompost enhances the physical properties of soil, such as porosity, water-holding ability, and air permeability. Additionally, it can improve the organic matter properties of soils and effectively decompose pesticide residues from contaminated soils (Yen *et al.,* 2021). Sustainable crop production is possible with the use of vermicompost, as it ameliorates the detrimental effects of continuous cropping by enhancing the physico-chemical properties of the soil.

Integrated nutrient management is the method of utilizing the minimum effective dosage of an adequate and balanced supply of organic and inorganic manure with specific microorganisms to increase the obtainability of nutrients and productivity while maintaining native soil nutrients and avoiding environmental pollution. The interaction of all organic, inorganic, and biological components in a synergistic way to maintain the fertility of the soil and maximize nutrient availability for target production is called integrated nutrient management (Panta and Parajulee, 2021). INM looks at the most effective homogenous mixture for optimal management, as a fertilizer target for efficiency, quantity and quality balance, and adequate and assimilable capacity to improve the yield of plants (Selim, 2020). The mixing of organic manure with chemical fertilizers is a common practice in agricultural fields for crop production. Overall, independent utilization of inorganic fertilizer or organic manures does not improve soil health or productivity. Various researchers (Baishya et *al.,* 2015; Singh *et al.,* 2015; Kundu *et al.,* 2016) have recorded the favorable effects of the judicious use of organic and inorganic fertilizers on crop yield and soil fertility. However, few studies have investigated the effects of suitable combinations of vermicompost and chemical fertilizers on soil fertility, plant growth, and wheat yield. The objectives of the present study are (1) to find an ideal combination of vermicompost and chemical fertilizers to promote the growth and yield of wheat and (2) to sustain the fertility and productivity of the soil.

MATERIALS AND METHODS

Observation locations

The experiment was carried out at the BWMRI research station in Nashipur, Dinajpur, from 2017-2020. The geographic allocation of the site is between 25°13' latitude and 88°23' longitude. Site elevation (37.5 m) above sea level. The experimental area belongs to agroecological Zone-1 (Old Himalayan Piedmont Plains) (Brammer *et al.,* 1988).

Soil properties

Soil samples were taken from the experimental field before the soil was prepared and were used for laboratory analysis at depths of 0–15 cm and 15–30 cm. The soil at the experimental site was noncalcareous, acidic, or alluvial sandy loam, and the Inceptisol taxonomic order was as follows. Dinajpur had a bulk density of 1.61 g cm-3 for the topsoil (0–15 cm), with a hard plow pan at 15–30 cm (Table 1).

The pH $_{(1:5)}$ was estimated via the method described by ISO (2005); total organic carbon (TOC) and total nitrogen were estimated via the methods of Nelson and Sommers (1996); exchangeable P was calculated via the method of Colwell (1963); exchangeable K was estimated via the method of Thomas (1982); exchangeable S was estimated via the method of Fox *et al.* (1964); extractable Zn was estimated via the method described by Lindsay and Norvell (1978); exchangeable B was estimated via the method of Bingham (1982); bulk density was calculated via the method described by Dalgliesh and Foale (1998); and the USDA particle size distribution was recorded via the methods described by Sochan *et al.* (2012) and Konert and Vandenberghe (1997).

Weather conditions

The meteorological conditions for wheat cultivation during the rabi season in three years (2017-18, 2018-19, and 2019-20) are presented in Fig. 1.

Table 1. Initial soil properties of the experimental plot

Soil depth cm	pH	TOC %	Total N	P mg/kg	K cmol	S	Zn /kg/mg /kg	B	Bulk density g cm^{-3}	Soil texture Sand	Silt %	Clay
0-15	5.5	0.75	0.09	45.0	0.16	22	1.56	0.35	1.61	56	29	18
15-30	5.8	0.55	0.05	17.5	0.08	13	0.79	0.18	1.68	49	28	24

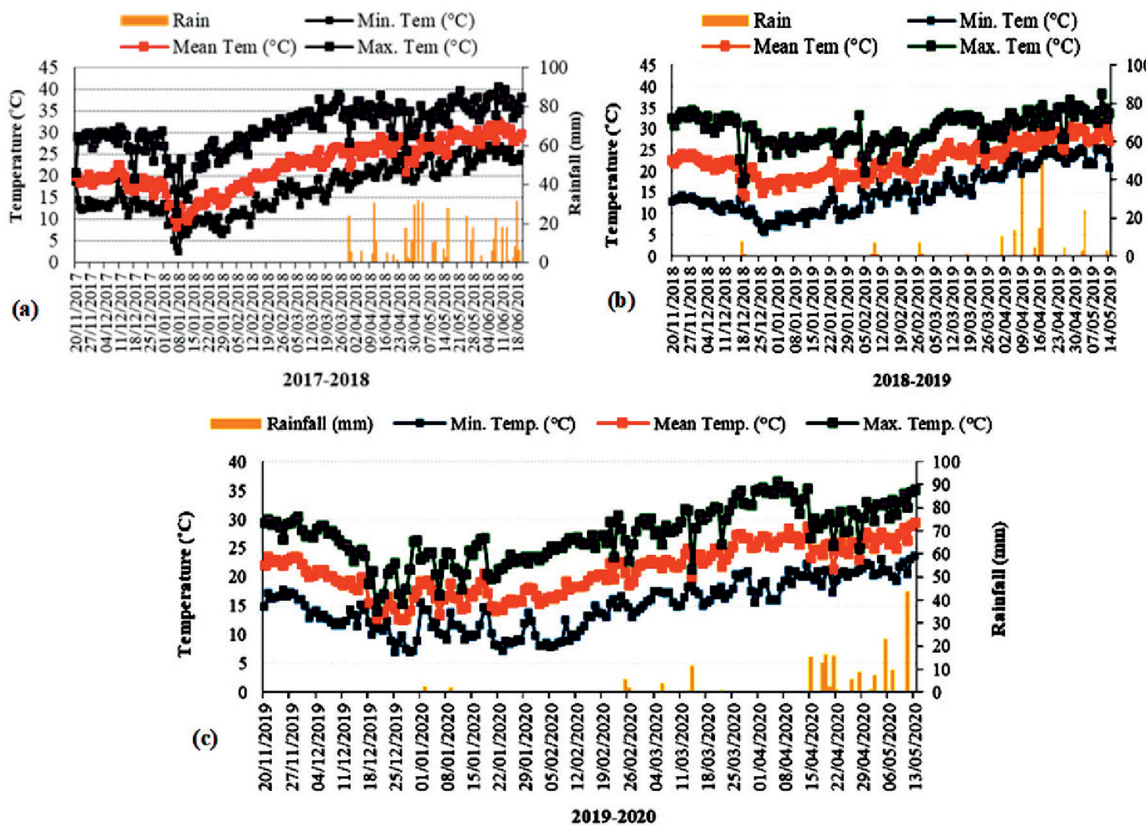

Fig. 1. Three years (2017–2018, 2018–19 and 2019–20) of climatic conditions during the wheat growth stages

The experimental site has a subtropical monsoon climate with an average annual precipitation of approximately 1938 mm, which is mainly concentrated from June to October, accounting for nearly 82% of the total. This covers the initial growing period for Aman rice (monsoon rice, *kharif*-II season rice). Pinpointing report for the *Rabi* season: Wheat is grown during the *Rabi* season (21 to 25°C), from mid-November to mid-March, with very little rainfall. In the Kharif-I season, Aus rice developed from adequate and evenly distributed rainfall that occurred from the end of March to mid-June in rainfed crops over warm summer months (30 to 33°C). The monthly average daily solar radiation ranged between 14 and 20 MJ m^{-2} d^{-1} in the Kharif season and between 14 and 22 MJ m^{-2} d^{-1} in the winter season.

Treatments and design

The experiment was conducted via a randomized complete block design with three replications. The unit plot measures 4 × 5 meters, covering an area of 20 square meters. The fertilizer dosages were determined for the different treatments based on the obtained soil test data via the formula given by BARC (FRG, 2012). Seven treatments [T_1: chemical fertilizers formulated according to soil test results (STB); T_2: integrated plant nutrition system (IPNS) utilizing 5 t/ha of cow manure (based on T_1); T_3: IPNS (1.0 t/ha) combined with vermicompost (derived from T_1); T_4: (IPNS utilizing 2.0 t/ha of vermicompost on T_1); T_5: IPNS - 4.0 t/ha of vermicompost in conjunction with T_1; T_6: IPNS utilizing 0.750 t/ha of Farha in comparison to T_1; T_7: indigenous reproductive capacity (control)]. These treatments were used to evaluate the response of the different crops to the fertilizers applied in a Wheat-T. Aus-T. Aman rice cropping system.

Experimental management

Information on management practices for wheat, T. aus, and T. aman rice is provided in Table 2. A summary of cropping patterns, including crop varieties, dates of sowing seeds on the bed, sowings/transplanting, harvestings, and yields of crops, is given in Table 2.

For wheat, all the other fertilizers and two-thirds of the nitrogen were applied in the last land preparation. At 20 DAS, irrigation and the first urea application were performed. Weeds were managed using the herbicide Affinity 50.75 WP at 1.25 kg/ha each year, which was applied 25 days after sowing. The second and third irrigations were given at 50 and 75 days after sowing, respectively. Half of the nitrogen was applied, and the other fertilizers were applied in full doses in the last field preparation for

Table 2. Management practices followed in the Wheat-T. Aus -T. Aman rice cropping pattern

Management factors	Wheat (BARI Gom 32)	T. Aus rice (BRRI dhan 48)	T. Aman rice (Binadhan 7)
Date of sowing/Transplanting	25-30 Nov.	1-7 May	1-7 August
Seedling age (days)	-	26	30
Unit plot size	5 m × 4 m	5 m × 4 m	5 m × 4 m
Spacing	20 cm× continuous sowing	20 cm × 15 cm	20 cm × 15 cm
Fertilizer rate: STB dose (N-P-K-S-Zn-B kg/ha)	133-10-45.5-5-1-1	117-5-38-3-1-1	100-5-50-4-1-1
N application method	Basal & top dress 20 DAS	Basal & top dress 35 DAP	Top dress 15, 30, 45 DAP
Pest control	2 spray	5 spray	4 spray
Irrigation (DAS/DAT)	20, 50 and 75	10, 20, 35, 50 and 60	10, 25
Date of harvest	March	July	Nov.
Crop duration (days)	94	82	88

The collected data were averaged and presented in tabular form. Economic analysis was performed on the basis of the prevailing market price of the commodities. The agronomic performances, such as field duration and rice equivalent yield, of the cropping patterns were calculated.

T. Aus. The wheat and rice grains were harvested from a 6.0 m^2 (2 m × 3 m) area. Table 2 contains further details of the management practices for wheat, T. Aus, and T. Aman rice.

Rice equivalent yield (REY)

The yields of eachcrop were converted into rice equivalents based on the prevailing market price of each crop (Verma and Modgal, 1983) for comparison among different crop sequences. The rice equivalent yield (REY) was computed by multiplying the yield of aspecific crop by its market price and dividing the product by the rice market price.

$$\text{Rice equivalent yield (t/ha/yr)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{Market price of rice}}$$

Statistical analysis

Data analysis was performed via STARsoftware (IRRI, 2014). The treatment meanswere compared via the least significant difference test at p≤0.05.

RESULTS AND DISCUSSION

Yield and yield attributes of wheat as influenced by an integrated plant nutrition system

Analysisof variance confirmed the significant effects of inorganic and organic fertilizers on spikelets per spike, grains per spike, plant height, number of spikes per m^2, and grain yield (Fig. 2 and Table 3). T_5 and T_4 recorded the maximum density of spikesm^{-2}, which was statistically similar to T_6, T_3, and T_2, whereas the minimum density was recorded in the control treatment (T_7). The maximum plant height was measured in the T_2 treatment, followed by the T_6, T_5, T_3, and T_4 treatments, whereas the minimum height was notedin the control (T_7) and T_1 treatments. The spike/spike values for each treatment were statistically equivalentto those of the control. The maximum number of grains per spike occurred in the T_2 and T_5 treatments, and the minimum number occurred in the control and T_1 treatments. The highest wheat grain yields were 4231.7 kg/ha in2018—2019, 4139.3 kg/ha in 2019–2020, and 4101.79 kg/ha in 2020–2021, which were also observed in the T_5 treatment, followed by the T_4, T_2, and T_3 treatments. The traditional STB chemical fertilizer treatment (T_1) resulted in the second highest grain yield (T_1) in 2018–19 and 2020–21over the 3 years.

The greater wheat grain yield in the T_5 vermicompost treatment could be attributedto the cumulative impact of the number of grains per spike and spikes per square meter. The control treatment resulted in the minimum yield for each year, followed by the T_1 treatment, forthe periods of 2018–2019 and 2020–2021 (Fig. 2).

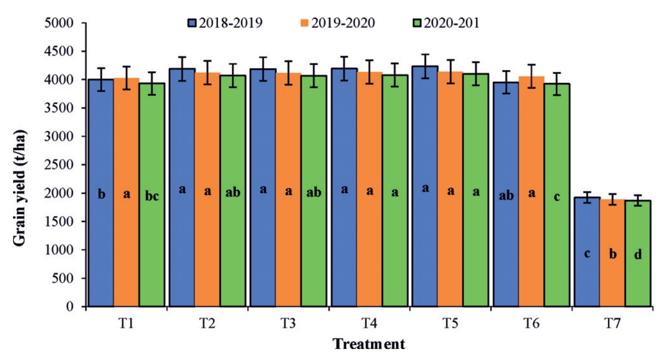

Fig. 2. Yield of wheat is influenced by organic and inorganic fertilizers. T_1, STB chemical fertilizers; T_2 = IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control.

Table 3. Yield and yield attributes of wheat as influenced by organic and inorganic fertilizers

Treatment	Spikes/m² (no.)	Spike length (cm)	Spikelets/spike (no.)	Grain/spike (no.)	TGW (g)
T_1	353 b	7.97	14.00 ab	37.00 b	45.33
T_2	383 a	8.30	15.00 a	43.00 a	46.91
T_3	383 a	8.04	15.00 a	42.00 a	47.50
T_4	386 a	8.38	15.00 a	42.00 a	46.27
T_5	386 a	8.36	15.00 a	43.00 a	45.18
T_6	382 a	7.64	12.00b b	41.00 a	47.38
T_7	298 b	7.75	14.00 ab	33.00 c	46.49
F test (0.05)	**	NS	**	**	NS
CV (%)	4.83	5.44	7.18	5.04	4.81

T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control.

Fazily *et al.* (2021) also observed the same kind of findings. Similarly, another study conducted by Ramanandan *et al.* (2020) and Patyal *et al.* (2022) revealed that integrated nutrients affect the growth and yield attributes of wheat and grain yield and its components.

Yield and yield attributes of T. Aus rice

The yield and yield-related traits of T. aus rice significantly influenced the specific treatments except for panicle length (Table 4 & Fig. 3).

In terms of the maximum number of tillers per hill, the T_2 treatment resulted in more (9.00) tiller counts than did all the other treatments except for the control (T_7), which resulted in the lowest number of tillers. The maximum number of filled grains was recorded in T_3, which was statistically similar to T_2 andT_6 and T_1, and the minimum number was recorded in the control/T_7. The most unfilled grains were counted for T_5, 4 tons/ha of vermicompost, which was probably due to the imbalanced use of organic and inorganic fertilizers (Table 4 and Fig. 3). The maximum yield of grain (4399.9 and 4289.49 kg/ha/year for 2018–19 and 2019–20, respectively) was observed in T_2 (cow dung@ 5 t/ha), which was statistically comparable to that in T_3, T_4, and T_6 (Fig. 3). From 2020–2021, the maxi-

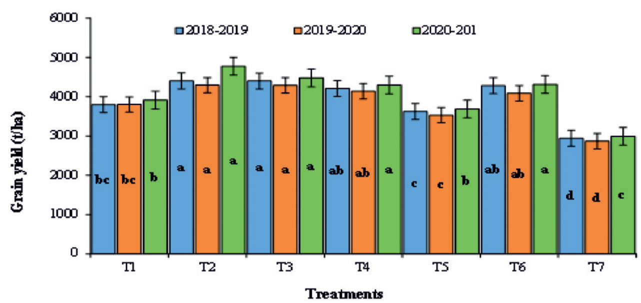

Fig. 3. Yield of T. flavus as influenced by organic and inorganic fertilizers. T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control

Table 4. Yield and yield attributes of T. Aus as influenced by organic and inorganic fertilizers

Treatment	Tiller/hill (no.)	Panicle length (cm)	Filled grain (no.)	Unfilled grain (no.)	TGW (g)
T1	9.00 a	20.95	99.00 abc	47.00 cd	22.08 a
T_2	9.00 a	24.85	108.00 ab	51.00 c	21.25 ab
T_3	9.00 a	24.13	110.00 a	43.00 d	21.35 ab
T_4	9.00 a	21.49	96.00 bc	64.00 b	21.44 ab
T_5	9.00 a	20.71	97.00 bc	75.00 a	20.65 ab
T_6	9.00 a	24.39	107.00 ab	46.00 cd	20.88 ab
T_7	6.00 b	23.91	91.00 c	43.60 cd	20.03 b
F test (0.05)	**	NS	**	**	**
CV (%)	11.00	12.56	6.0	8.00	4.38

T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control mum yield was obtained in T_3 (vermicompost at 1 t/ha), followed by T_2, T_6, and T_4. The higher yields in T_2 and T_3 were probably due toadditive positive effects on yield-contributing traits. In the 2018-2019 and 2019-2020 seasons, the second-highest grain yields of T_3 were4398.5 kg/ha and 4288.43 kg/ha, respectively, while 1.0 t/ha vermicompost was applied. On the other hand, an increase in vermicompost application decreased the grain yield by graduallyincreasing the plant biomass, resulting in lodging and a greater proportion of unfilled grains. The lowest grain yield (2940.5, 2867.05, and 2990.89 kg/ha) was attained in the control treatment (T_7), followed by the T_5 and T_1treatments, possibly because of imbalances in organic and inorganic fertilizers (Fig. 3). In the present research, the results regarding the yield and yield components of aus rice were consistent with some reports (Ullah *et al.,* 2019; Sarker *et al.,* 2019) that the combination of organic and inorganic fertilizers was useful for improving the growth and yield attributes ofrice and ultimately resulted in higher yields in rice cropping systems. Mondal *et al.* (2015) also reported that hybrid rice productivity could be improved throughintegrated nutrition management, which influences growth and production characteristics. Similar findings were also reported by several workers in different crops (Nallagatla and Patil, 2024; Verma *et al.,* 2023; Pathak *et al.,* 2023)

Yield and yield attributes of T. Aman rice

The experimental treatments had significant effects on the yield and yield-associated characteristics of T. Aman rice, with the exceptions of panicle length and 1000-grain weight (Table 5 and Fig. 4).

The maximum number of tillers/hill (10.00) wasobserved in the T_3 and T_5 treatments, while all the other treatments (except the control) produced fewer tillers than the control (T_7). T_6 had the maximum number of full grains, whichwas comparable to those of T_1, T_2, and T_3, and the minimum count was observed in the control/ T_7. The maximum number of unfilled grains was recorded at T_5 (4 tons/ha of vermicompost), whereas the minimum number was observed at T_3 and T_7/control, whichmay have been due to the uneven application of organic and inorganic fertilizers (Table 5). However, from 2019–20 and 2020–21, the highest grain production (4939.56, 4840.77, and 4904.84 kg/ha)was recorded in T_3 (1 t/ha of applied vermicompost), which was statistically similar to all the other treatments except T_1 (Fig. 4). The treatments with the highest results may have had a compound effect on yield-contributing traits. LikeT. aus, the yield of T. aman gradually decreased with increasing vermicompost, which led to vigorous growth of the plant, causing lodgings and more emptied seeds. The grain yieldwas significantly greater in T_1, where STB chemical fertilizer was applied, with the second-highest grain yield from 2019-20 and 2020-21. The lowest grain output over the years was observed inthe control treatment (T7) (Fig. 4).

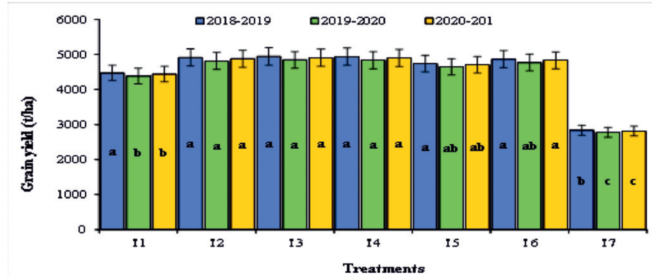

Fig. 4. Yield and yield attributes of T. Aman rice as influenced by organic and inorganic fertilizers. T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control

Table 5. Yield and yield attributes of T. Aman rice as influenced by organic and inorganic fertilizers

Treatment	Tiller/hill (no.)	Panicle length (cm)	Filled grain (no.)	Unfilled grain (no.)	TGW (g)
T1	9.00 a	19.91	94.00 abc	42.00cd	23.41
T_2	9.00 a	23.61	103.00 ab	45.00 c	22.53
T_3	10.00 a	22.93	102.00 ab	38.00 d	22.63
T_4	9.00 a	20.41	92.00 bc	57.00 b	22.73
T_5	10.00 a	19.67	92.00 bc	67.00 a	21.88
T_6	9.00 a	23.17	104.00 a	41.00 cd	22.13
T_7	6.00 b	22.71	87.00 c	38.00 cd	21.69
F test (0.05)	**	NS	**	**	NS
CV (%)	11.00	12.55	6.0	8.00	4.38

T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T_1; T_3, IPNS with 1.0 t/ha vermicompost based on T_1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control.

The results of the present study, regarding the yield and yield attributes of T. Aman rice, which are influenced by an integrated plant nutrition system, are supported by several previous studies (Ali *et al.,* 2018; Anisuzzaman *et al.,* 2022; Quddus *et al.,* 2022), which reported that when organic and inorganic fertilizers areintegrated into plant nutrition systems, they improve the productivity of rice in rice-based cropping systems. Yadav *et al.* (2019) demonstrated that the application of organic and inorganic nutrients improved rice yields, grain quality, and soil health in the northwestern IGP of South Asia. Udhaya *et al.* (2024) demonstrated how integrated nutrient management practices affect the growth and physiology of traditional rice varieties (Black Kavuni), leading to improved grainyield.

System productivity and economics

It was defined as the rice equivalent yield (REY) ofsystem productivity. After three years of monitoring, the REY system showed nosignificant differences among the fertilizer treatments. The system productivity, rice equivalent yield, and economic analysis are described in Table 6. In general, the REY values from all the IPNS-based-patterns outperformed those observed within the inorganic fertilization treatments. On average, T_3 produced more REY (1.825 t/ha), followed by T_2 and $T_{4,}$ than did the control (1.94 t/ha), whichproduced the lowest (9.40 t/ha) REY at 18.28 t/ha. The superior efficacy of organic-based treatments maybe a result of improved soil health, which is a direct consequence of enhanced soil physical and chemical properties.

Theupper grossing to economic analysis is Tk. The highest grain yield was also found inthe T_3 treatment (246,477/ha$^)$, followed by the T_2, T_4, and T_6 treatments. However, the maximum gross marginis Tk. Among the treatments, T_2 (5 t/ha cow dung) had a clear advantage (246477 kg/ha). The T_3 application, where vermicompost was applied at a rate of 1 t/ha, resulted inthe second-highest gross margin of Tk. 239,242/ha. Tkis the minimum gross return. 222,500/ha for grossmargin Tk. The control treatment resulted in a total yield of 117,899/ha (Table 6).

Compared with other nutrient management practices, integrated nutrient management had a positiveeffect on soil parameters. The improved productivity, along with soil health, caused by INM practices over other nutrient management methodsin RWCSs is considered a possible nutrient management method for the Indian subcontinent (Sharma *et al.,* 2019). Paul *et al.,* (2013) performed a studythat concluded that nutrient management in an integrated way in long-term rice-wheat cropping systems improved system productivity, which in turn improved economic income. In the current climate change scenario, rice-wheat cropping systems are considered environmentally sustainable and economically viable strategies, and long-term integrated nutrient management (36 years) has affected the soil carbon sequestration, environmental footprint, and agronomic productivity of these systems (Ranjan *et al.,* 2023).

The results of this study revealed that the application of vermicompost and other organic fertilizers had a significant positive effect on improving wheat, T. Aus, and T. Aman rice yields significantly, with the highest vermicompost and other organic fertilizers occurring in all three crop cycles. Therefore, applying cow dung at a rate of 5 t/ha or vermicompost at a rate of 1 t/ha along with STB chemical fertilizer may be recommended for higher crop production by improving soil fertility and productivity.

Table 6. System productivity/rice equivalent yield and economic analysis as influenced by organic and inorganic fertilizers (average of 3 years)

Treatments	Yield of crops (kg/ha)			REY (t/ha/yr)	Gross return (tk/ha)	TVC (tk/ha)	Gross margin (tk/ha)
	Wheat	T. Aus	T. Aman				
T_1	3984.37	3835.71	4428.20	15.40	357591	132000	225591
T_2	4126.87	4388.14	4864.60	18.25	388727	142250	246477
T_3	4123.81	4386.90	4895.06	18.28	391242	152000	239242
T_4	4133.87	4212.00	4888.88	18.11	386288	182000	204288
T_5	4157.60	3612.22	4695.02	17.54	363975	202000	161975
T_6	3977.08	4225.27	4822.82	17.62	380116	154500	225616
T_7	1892.63	2932.81	2807.81	9.40	222500	104601	117899

Input price: Wheat grain, Seed Tk. 48 /kg and grain Tk. 28/kg, rice grain, Seed Tk. 48/kg and grain Tk. 28/kg, Straw Tk. 1/kg, Cowdung Tk. 1500 /t and vermicompost Tk. 8 /kg. T_1, STB chemical fertilizers; T_2, IPNS with 5 t/ha cow dung based on T1; T_3, IPNS with 1.0 t/ha vermicompost based on T1; T_4, IPNS with 2.0 t/ha vermicompost based on T_1; T_5, IPNS with 4.0 t/ha vermicompost based on T_1; T_6, IPNS with 0.750 t/ha Farha based on T_1; and T_7, Native fertility/control.

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