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Effect of integrated nutrient management on the growth and productivity of four high-yielding rice varieties of Eastern India

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Abstract

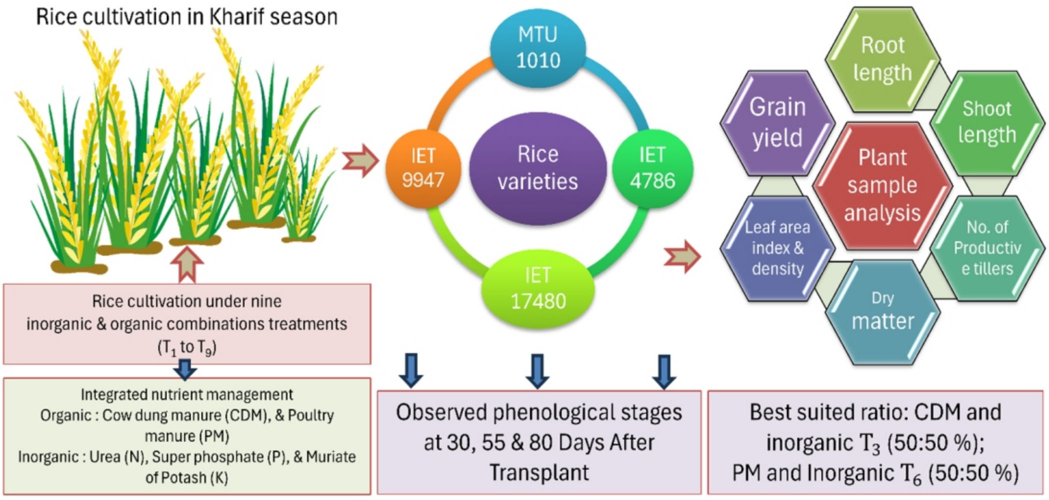
Aim: To investigate the integrated nutrient management in agricultural fields using cow dung manure and poultry manure as organic, and NPK as inorganic fertilizer at varied ratios.

Methodology: Four rice varieties were selected for the experiment viz., MTU 1010, IET 4786, IET 17430, and IET 9947 under nine organic manure and inorganic fertilizer combinations in different ratios with one control treatment. The cultivation was carried out in three replications in a randomized complete block design. The biometric observations were noted at 30, 55, and 80 days after transplant (DAT). Leaf Area Index (LAI), Crop Growth Rate (CGR), and grain yield were calculated for the varieties under varied treatments.

Results: Biometric observation and growth indices confirmed that the treatment T$_3$ showed the highest value among all other treatments for shoot length, dry matter, LAI and LAD for all varieties. Treatment T$_7$ recorded the maximum root length. For CGR treatment T$_2$ and T$_3$ recorded highest value for different varieties. Soil nutrient results suggest that treatment T$_2$-T$_4$ and T$_6$-T$_8$ showed the highest N, P and K content. The results showed significant difference ($p<0.05$) in grain yield for all the treatments in all varieties, where T$_3$ recorded the highest value.

Interpretation: The year experiment revealed that integrated nutrient application resulted in considerably greater growth and productivity compared to the control and 100% inorganic fertilizer-treated cultivation.

Key words: Cow dung, Integrated nutrient management, Poultry manure, Plant growth indices, Rice productivity



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Introduction

The world's population has crossed 7 billion and is expected to reach 9.3 billion by 2050 (Pathak *et al.,* 2014; Semenov and Stratonovitch, 2015). The global food security is heavily reliant on the agricultural sector which is expected to provide food, nutritional, and energy security to the growing population. Rice (*Oryza sativa* L.) is a staple food crop for more than 50% of the world's population (Birla *et al.,* 2017). The current demand for rice, which is 25.1 million tons, is expected to increase by 56% by the year 2050 as a result of the pace of population growth (Wassmann *et al.,* 2009). One important aspect of Green Revolution was to promote the use of high-yielding variety seeds for cereal crops. The seeds of high-yielding varieties of commonly cultivated crops are usually characterized by a combination of an array of superior traits (viz. increased productivity per unit area, improved quality, early maturation, and resistance to many diseases) in contrast to the conventional varieties. Crop, especially rice production is essential for addressing the rising food demand of the growing population. However, a trade-off arose with the use of high-yielding cultivars and the application of chemical fertilizers. To increase the productivity, these high-yielding varieties have higher nutrient requirements than traditional varieties. This has led to the considerable usage of inorganic fertilizers with a significant decline in the use of organic manure.

Manures play an important role in improving the plant growth and crop yield (Chatterjee *et al.,* 2019; Jin *et al.,* 2021). However, over the past few years, this excessive reliance on these chemical inorganic fertilizers to increase crop cultivation has raised a serious concern owing to its negative influence on the physio-chemical and biological properties of the soil and the environment (Aktar *et al.,* 2018). This includes degradation of soil quality and structure (Guo *et al.,* 2017), increased greenhouse gas emissions (Gangopadhyay *et al.,* 2022), groundwater pollution and surface water eutrophication (Cai *et al.,* 2018).

Maintenance of soil fertility is essential for long-term sustainable crop productivity. To avoid aggravated soil degradation in the upcoming years, various organic amendments have been championed as viable substitutes for chemical fertilizers as it is both an eco-friendly and cost-effective option (Du *et al.,* 2020). Application of organic amendments to the soils holds the potential for improving the physico-chemical and biological properties of the soil, by storing higher amounts of water and nutrients, enhancing the enzymatic activity of soil microbes (Hou *et al.,* 2022), and improving the carbon sequestration potential of the soil (Aktar *et al.,* 2019). Being a by-product derived from animal waste, organic manure has multiple benefits as it is a balanced supply of both macro and micronutrients and satisfies the nutrient requirement of the plants (Loh *et al.,* 2019).

Although applying organic wastes as fertilizer helps provide nutritive elements to crops at little added cost to enrich the soil, there arises a constraint associated with the fertilizer efficiency of manure (Hou *et al.,* 2023). A higher C: N ratio in cow dung and poultry litter restricts the pace at which the organic material mineralizes, hence, lowering its nutritional availability. In addition, the lower nutrient-releasing ability of organic fertilizers hinders the nutrient uptake by plants, thereby failing to meet the short-term crop requirements. Therefore, the lone use of organics has not yet been proven to meet the usual intensity of agriculture production (Iqbal *et al.,* 2019). To tackle this situation, integrated nutrient management (INM), which combines inorganic and organic fertilizers has become a promising route for the development of sustainable fertilizer-management strategies (Ismael *et al.,* 2021). In this study, it has been hypothesized that a combination of inorganic and organic fertilizers would improve and sustain soil fertility, increase crop productivity, and make cultivation more affordable for small-holder crop producers.

A balanced intake of both organic and inorganic nutrients is required for sustainable agriculture to guarantee high-quality food production (Islam *et al.,* 2013). Improved soil physical qualities and availability of vital plant nutrients for increased production requires both chemical and organic fertilizers (Islam *et al.,* 2013). According to Nguyen *et al.* (2020), cow dung manure has a greater nutritional content and its application rate may be changed to replace nutrients lost from the soil. The study conducted by Moe *et al.* (2019) examined the impact of combined organic (plant compost, cow manure, and poultry manure) and inorganic fertilizers on the development and yield characteristics of several types of rice varieties. Previous studies have shown that substituting 30–50% pig, cow, and poultry manure for artificial fertilizer has greatly enhanced growth characteristics and raised rice yields (Loh *et al.,* 2019). In view of the above, the objective of the present study was to examine the combined effect of cow dung manure and poultry manure with inorganic fertilizer at different ratios on the growth and yield of four rice varieties, var. MTU 1010, var. IET 4786, var. IET 17430, and var. IET 9947.

Materials and Methods

Experimental site and weather conditions: The field experiments were carried out at the Crop Research and Seed Multiplication Farm, The University of Burdwan, West Bengal, India, for three consecutive Kharif seasons (sowing time: July–August; harvesting time: October–November) in the cropping years 2019-20, 2020-21 and 2021-2022 at 23°15'58.04"N and 23°15'19.44"N latitude and 87°50'34.29"E and 87°50'43.95"E, longitude. Baseline soil of the experimental site was silt-loam texture with 21.5 ± 2.1% sand, 37.4 ± 3.1 % silt, and 25.1 ± 3.2 % clay. Particle density, bulk density, and porosity of the soil varied from 1.1 to 1.2 g cm^{-3}, 2.1 to 2.5 g cm^{-3}, and 50 to 60%, at an average depth of 0 -15 cm. The average soil pH and conductivity were around 6.9 and 0.3 ds m^{-1}. The average atmospheric temperature for the Kharif season of cropping year 2019-2020 was 28.25 °C with a minimum temperature of 24.42°C and a maximum temperature of 33.92°C with a relative humidity of 86.37%. In the Kharif season of cropping year 2020-2021, the mean temperature was 28.53 °C with 24.58 °C and 34 °C being the minimum and maximum temperature, respectively, with the mean relative humidity of 87.56%. In 2021-2022, the average temperature and relative humidity were 28.66°C and 83.04%, respectively. The three consecutive years received precipitation of about 0.83 mm, 0.74 mm and 0.83 mm, and the average wind speed were 8.17 ms^{-1}, 8.16 ms^{-1}, and 8.67 ms^{-1}, respectively.

Treatments design: A total of ten treatments were considered, where nine different combination of cow dung manure and poultry manure along with inorganic fertilizer based on nitrogen content were used (T_1-T_9). Besides, one control treatment with no fertilizer and manure (T_0) was used. The treatment details are as follows: T_0: Control (No fertilizer); T_1: 100% nitrogen dose from cow dung manure; T_2: 75% nitrogen dose from CDM + 25% nitrogen dose from inorganic fertilizer (NPK); T_3: 50% nitrogen dose from cow dung manure + 50% nitrogen dose from inorganic fertilizer (NPK); T_4: 25% nitrogen dose from cow dung manure + 75% nitrogen dose from inorganic fertilizer (NPK); T_5: 100% Nitrogen dose from poultry manure; T_6: 75% nitrogen dose from poultry manure + 25% nitrogen dose from inorganic fertilizer (NPK); T_7: 50% nitrogen dose from poultry manure + 50% nitrogen dose from inorganic fertilizer (NPK); T_8: 25% nitrogen dose from poultry manure + 75% nitrogen dose from inorganic fertilizer (NPK) and T_9: 100% nitrogen dose from inorganic fertilizer (NPK), were, 100% nitrogen dose from cow dung manure was 5 t ha^{-1}, 100% nitrogen dose from poultry manure was 2 t ha^{-1}. The source of inorganic fertilizer nitrogen was urea, the phosphate source was single super phosphate, and potassium was muriate of potash. The application dose was 60 N: 30 P:30 K kg ha^{-1}.

Experimental design: The cultivation was performed using conventional method. Separate seed beds were prepared for four different varieties (MTU 1010, IET 4786, IET 17430, and IET 9947) and the seeds were spread on the soil treated with respective treatments (T_0-T_9) in standard recommended dose (5g m^{-2}) (Fertilizer Association of India). The main plots were puddled and prepared for transplantation. The Randomized Complete Block Design (RCBD) was used to arrange three replica plots (6 m × 3 m) for each rice varieties and each treatment. To provide a simple and continuous irrigation flow for every plot, 0.5 m wide irrigation canals were placed in between each plot. All agronomic practices, such as irrigation, plant protection, and fertilizer management were implemented following agronomic protocol (Chandrasekaran *et al*., 2010). At the last stage of land preparation, treatments were administered at respective plots.

A one-third dose of each treatment was administered as a baseline dosage and thoroughly absorbed into the soil. Thereafter, that seedlings between 30 and 32 days old were carefully uprooted from the seed beds and transplanted into the respective plots. Average three seedlings were transplanted per hill at a regular interval in flooded field. The remaining two-third of each dose of treatments were given in equal portions 30 and 60 days after transplant (DAT). Irrigation was applied from the transplanting stage to the maximum tillering stage. The water depth of 5-6 cm was maintained throughout the vegetative to tillering stage. The plots were inundated with a thin layer of water (2–3 cm) from panicle initiation until the hard dough stage. The plots had no water throughout the ripening phase. Crop in each plot harvested independently when 90% of the grains showed golden yellow tint. The same cultivation procedure was followed for three consecutive cropping years.

Biometric observations: The morpho-physiological traits and growth attributes of rice plants were studied. Randomly, three plant samples were collected carefully to prevent any root tearing from each plot at different phenological stages viz. active tillering, panicle initiation and maturity [30, 55, and 80 days after transplant (DAT), respectively] to measure the impact of various treatments on their growth and development. The shoot and root length of the selected plants from each plot was measured with a measuring scale. The plants were then oven-dried for 24 hr at 80 °C, and their dry weights were measured. At 80 DAT, the number of productive tillers (that bore spikelet's) were counted.

Growth Indices

Graph paper was used to measure the area of the leaf. The leaf area index was calculated by the formula given by Watson (1947). Leaf area duration was calculated following Mondal *et al.* (2017): Where, LAI_1 and LAI_2 are leaf area indices recorded at times t_1 (30 DAT) and t_2 (55 DAT), respectively. The dry weight per plant was calculated and used to estimate Crop growth rate (CGR) according to Hunt (1978). Where, W_1 and W_2 are dry weights (g m^{-2}) at first and second harvests taken at times t_1 (30 DAT) and t_2 (55 DAT), respectively.

Estimation of soil nutrients: Soil sample were collected from each plot before land preparation and after harvest in each cropping year. Soil sample were taken at a depth of approximately 0.1 m and an area of 1m^2 and immediately brought to the laboratory for further analysis. The amount of available nitrogen (N), potassium (K), and phosphorus (P) were estimated following the modified macro Kjeldahl procedure (Model KELPLUS Elite EXVA) (Jackson, 1972; Gangopadhyay *et al.,* 2022), Olsen method (Olsen, 1954), and flame photometer method (Black *et al.,* 1965), respectively.

Grain yield: Following threshing, a composite grain sample from each plot was obtained, cleaned and sun-dried, and later the total grains were weighed to determine the grain yield. The moisture content of grains during harvest was 20%.

Statistical analyses: To check any significant difference between various treatments and phenological stages for leaf area index, the values of three consecutive years were averaged and Two-way ANOVA was performed. One-way ANOVA was performed to find the significant difference of productive tillers according to various treatments by taking average of three consecutive years. Two-way ANOVA was performed to check significant difference in crop yields for various treatments between different years. All statistical tests were performed in SPSS statistical software (IBM SPSS Statistics 23).

Results and Discussion

The perusal of data showed that the treatment T_3 (50% of nitrogen dose from CDM + 50% nitrogen dose from inorganic fertilizer) showed the highest average shoot length in three consecutive cropping years for all varieties, i.e., var. MTU 1010, var. IET 4786, var. IET 17430 and var. IET 9947 (120.51±5.78, 124.74±3.51, 121.80±4.81, and 123.15±3.31 cm, respectively) at maturity (80 DAT). Plants under T_7 (50% nitrogen dose from PM +50% nitrogen dose from inorganic fertilizer) treatment showed superior root growth with root length of 33.46±1.28, 34.09±1.31, 32.88±2.09, and 37.71±2.98 cm, respectively. The plants under T_0 (control with no fertilizer) treatment had the lowest average shoot length (64.42±5.84, 63.59±5.21, 62.86±6.52, and 59.1±6.37cm) as well as root length (19.71±2.78, 18.2±2.09, 16.65±1.26, and 15.96±1.55 cm) for all varieties. The highest average dry matter biomass in the maturity stage (80 DAT) was observed in the treatment T_3 for all varieties, i.e., var. MTU 1010, var. IET 4786, var. IET 17430, and var. IET 9947 (69.29±7.26, 79.74±3.04, 76.6±4.13, and 71.56±8.02 g per plant), while the lowest average dry matter biomass was observed in the case of T_0 (23.68±3.59, 26.45±2.41, 26.17±3.72, and 27.85±3.94 g treatment per plant).

This result signifies that the treatment with organic manure and inorganic fertilizer with equal proportion helps in better plant growth. This result is in line with the deduction made by Antil *et al.* (2020); and Iqbal *et al.* (2019; 2020) where they also found better plant growth for the combination of both organic and inorganic sources of nutrients in fertilization management. According to Lanna *et al.* (2018), the ability of rice roots to uptake water and absorb nutrients is intimately linked to their shape. To some degree, the leaching of inorganic elements from topsoil layer is stopped by the integrated application of both organic and inorganic fertilizers (Geng *et al.,* 2019). Through postponed root senescence, the gradual and consistent release of nutrients from manure demonstrates a significant increase in root development. The primary source of nutrition shoots receives from the roots. The current findings are also consistent with a field experiment conducted by Moe *et al.* (2019), who found that plants grown in a mixture of manure and urea exhibited improved growth metrics compared to those grown with urea alone. The combination of both organic and inorganic sources of nutrients in the fertilization management for crops is essential to ensure sustainable agriculture with high productivity (Ding *et al.,* 2018; Iqbal *et al.,* 2021).

Leaf area index varied significantly among different varieties at all crop growth stages throughout the study period. All the treatments exhibited lower Leaf index values at the initiation of tillering stage (30 DAT), which showed maximum values at the panicle initiation stage (55 DAT), and there was a decline in leaf area index at the end of the growth cycle, *i.e.,* at the mature stage of rice growth (80 DAT).The average values of leaf area index for all varieties and treatments ranged between 1.4±0.03 to 2.1±0.05, 2.5±0.06 to 3.9±0.05 and 2.1 ± 0.06 to 3.4 ±0.05 for 30 DAT, 55 DAT and 80 DAT, respectively. At 55 DAT, T3 treatment showed the maximum LAI values for all varieties, *i.e.,* var. MTU 1010, var. IET 4786, var. IET 17430, and var. IET 9947 (3.91±0.03, 4.03±0.04, 4.01±0.03 and 3.88±0.08) where as treatment T0 showed the minimum Leaf area index values (2.59±0.04, 2.52±0.08, 2.47±0.05 and 2.57±0.05) (Table 1).

Leaf area duration was highest in T_3 treatment at 30-55 DAT interval (0.48 ±0.02, 0.49±0.01, 0.49±0.02, and 0.48±0.01) as well as at 55-80 DAT interval (0.61 ±0.01, 0.60±0.01, 0.58±0.03 and 0.58±0.02) whereas treatment T_0 showed the lowest values of Leaf area duration at 30-55 DAT interval (0.32±0.02, 0.31±0.02, 0.31±0.02, and 0.32±0.01) as well as at 55-80 DAT interval (0.36±0.03, 0.36±0.01, 0.35±0.02, and 0.37±0.01) (Fig. 1). For all the treatments, the crop growth rate was tracked at two-time intervals viz. 30-55 DAT and 55-80 DAT. At 30-55 DAT the crop growth rate was highest for plants under treatment T_2 (75% nitrogen dose from CDM + 25% nitrogen dose from inorganic fertilizer, NPK) for var. IET 4786, var. IET 17430 and var. IET 9947 (1.15±0.08, 0.88±0.03 and 0.57±0.02) whereas for var. MTU 1010 it was highest in T3 treatment (1.28±0.05). The trend was reversed at 55-80 DAT where treatment T_3 showed the highest the crop growth rate for var. IET 4786, var. IET 17430 and var. IET 9947 (1.12±0.06, 0.67±0.02 and 0.27±0.02) and treatment T_2 for var. MTU 1010 (0.75±0.03) (Fig. 2). Leaf area index depends upon a greater amount of light interception by the crop plants, which have flourished during the vegetative stages bearing a higher number of leaves (Aduloju *et al.,* 2009). Banerjee *et al.* (2012) observed similar leaf area index variation patterns among phenological stages. They observed that plants under integrated inorganic fertilizers and biofertilizers showed the highest values of leaf area index as integrated fertilization improved nutrient availability in soil. The application of biofertilizers enhanced the availability of nutrients from the soil and also boosted their uptake by the plants. Higher values of leaf area index and Leaf area density were also influenced by the greater amount of light interception by the crop plants. Greater light interception stimulates crop growth rate or crop growth rate which is an important agricultural index for emphasizing the rate of dry matter production. The obtained results align with the outcomes of the experiment by Mondal *et al.* (2017). A direct positive correlation was observed between crop growth rate and leaf area index as higher crop growth rate values were recorded for plants with higher leaf area index values. This is because higher light interception by leaves results in higher rates of photosynthesis. This leads to the accumulation of a greater amount of photosynthates (Mondal *et al.,* 2017).

In the experimental plots, the concentration of available nitrogen, available phosphorus and available potassium were 120.8 kg ha^{-1}, 21.2 kg ha^{-1} and 168.1 kg ha^{-1}, respectively, during land preparation of cropping year 2019-20. All the treatments (T_1-T_9) showed increase in N, P and K concentration in the soil after harvesting prior to before land preparation for each respective cropping seasons where the control plot (treatment T_0) showed a decremental amount of N, P and K. At the end of all cropping seasons (2021-22) plot with T_2-T_4 and T_6-T_8 treatment recorded

Table 1: Average Leaf area index (LAI) of rice plants of three consecutive kharif seasons (2020-2022)

Treatments	Rice Varieties											
	MTU 1010			IET 4786			IET 17430			IET 9947		
	30 DAT	55 DAT	80 DAT	30 DAT	55 DAT	80 DAT	30 DAT	55 DAT	80 DAT	30 DAT	55 DAT	80 DAT
T_0	1.44±0.02	2.59±0.04	2.16±0.07	1.39±0.02	2.47±0.05	2.1±0.04	1.49±0.05	2.57±0.05	2.16±0.08	1.4±0.04	2.52±0.08	2.11±0.06
T_1	1.81±0.03	3.29±0.05	2.88±0.04	1.84±0.04	3.31±0.03	2.82±0.03	1.86±0.03	3.21±0.03	2.77±0.04	1.83±0.05	3.19±0.06	2.72±0.05
T_2	2.05±0.05	3.96±0.03	3.39±0.06	2.1±0.03	3.94±0.06	3.42±0.07	2.07±0.05	3.77±0.05	3.35±0.05	2.03±0.04	3.72±0.05	3.23±0.09
T_3	2.1±0.04	4.03±0.04	3.62±0.05	2.15±0.07	4.01±0.03	3.55±0.04	2.12±0.04	3.91±0.03	3.42±0.06	2.17±0.05	3.88±0.08	3.37±0.04
T_4	1.89±0.05	3.54±0.02	3.27±0.04	1.92±0.04	3.61±0.05	3.22±0.05	1.9±0.05	3.43±0.02	3.02±0.07	1.86±0.03	3.4±0.05	2.85±0.07
T_5	1.72±0.04	3.08±0.04	2.85±0.05	1.75±0.03	3.17±0.03	2.97±0.04	1.76±0.02	3.09±0.03	2.73±0.02	1.79±0.02	3.01±0.05	2.73±0.05
T_6	2.06±0.03	3.62±0.02	3.25±0.04	2.02±0.05	3.67±0.05	3.31±0.04	2.07±0.07	3.54±0.07	3.11±0.06	2.16±0.05	3.51±0.08	3.16±0.07
T_7	2.08±0.02	3.58±0.04	2.96±0.03	2.01±0.03	3.6±0.03	3.13±0.03	2.12±0.04	3.62±0.04	3.29±0.04	2.05±0.04	3.66±0.05	3.31±0.05
T_8	1.83±0.05	3.27±0.03	2.44±0.06	1.86±0.05	3.35±0.05	2.72±0.02	1.82±0.05	3.31±0.03	2.87±0.05	1.85±0.06	3.37±0.05	2.96±0.04
T_9	2±0.02	3.98±0.02	3.32±0.05	1.87±0.04	3.96±0.02	3.38±0.04	1.89±0.02	3.96±0.02	3.42±0.02	1.97±0.03	3.86±0.04	3.48±0.03
Treatments	*	*	*	*	*	*	*	*	*	*	*	*
DAT		*			*			*			*	
Treatments X DAT		*			*			*			*	

*= statistically significance ($p<0.05$)

Table 2: Available nutrient status of the soil before land preparation and after harvest in three-cropping season 2019-2020, 2020-2021 and 2021-2022 during Kharif season

Treatments	Nitrogen (kg ha^{-1})						Phosphorus (kg ha^{-1})						Potassium (kg ha^{-1})					
	2019-20		2020-21		2021-22		2019-20		2020-21		2021-22		2019-20		2020-21		2021-22	
	BLP	AH	BLP	AH	BLP	AH	BLP	AH	BLP	AH	BLP	AH	BLP	AH	BLP	AH	BLP	AH
T_0	102.8	88.14	87.03	80.23	79.12	71.91	21.2	15.08	12.75	12.12	11.66	11.19	168.1	119.31	107.75	103.55	103.55	87.79
T_1	102.8	218.34	222.2	229.14	233	241.25	21.2	37.89	39.34	39.55	40.9	44.23	168.1	394.47	394.47	391.51	409.94	412.23
T_2	102.8	256.66	262.61	268.63	274.58	285.95	21.2	44.11	45.34	47.33	48.21	52.85	168.1	443.2	443.2	435.98	455.54	458.87
T_3	102.8	267.74	274.28	278.08	284.62	294.4	21.2	52.01	55.57	52.5	58.78	58.3	168.1	447.21	447.21	450.74	463.19	466.12
T_4	102.8	210.1	209.01	219.81	218.72	232.48	21.2	38.47	40.92	42.61	42.59	47.95	168.1	408.28	408.28	412.87	428.37	429.26
T_5	102.8	188.55	193.09	200.11	204.65	217.43	21.2	46.07	48.16	49.56	51.72	53.38	168.1	359.8	359.8	374	379.23	376.5
T_6	102.8	251.2	254.96	263.76	267.52	276.97	21.2	43.73	45.7	45.18	48.04	49.14	168.1	419.03	419.03	424.33	437.51	436.34
T_7	102.8	254.33	262.26	266.09	274.02	280.78	21.2	50.65	52.43	52.98	55.03	55.7	168.1	405.65	405.65	402.08	414.86	423.43
T_8	102.8	179.99	187.07	193.14	200.22	208.45	21.2	44.3	46.43	45.32	49.08	48.92	168.1	312.9	312.9	311.92	325.46	332.21
T_9	102.8	214.54	219.25	224.32	229.03	239.41	21.2	39.01	40.68	41.31	43.07	44.49	168.1	381.23	381.23	382.23	398.66	400.04

*BLP = Before land preparation, AH = After harvesting

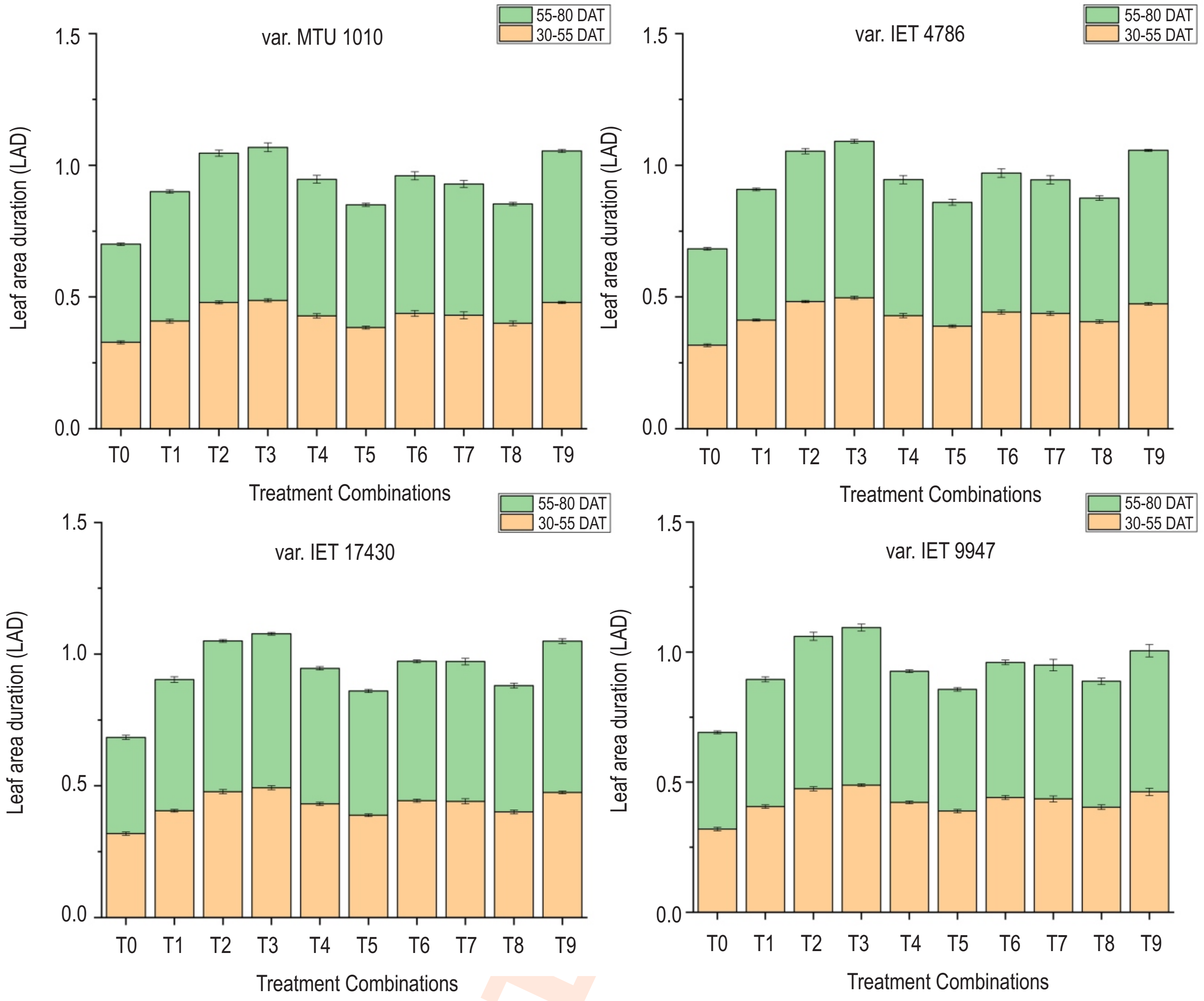

Fig. 1: Average variations of Leaf area duration (LAD) of different rice varieties in different organic and inorganic manure combinations of three consecutive kharif seasons (2020-2022).

higher average concentration of N, P, and K (263.17, 52.14, and 424.37 kg ha^{-1}) *i.e.,* an increment of 156, 146, and 152.5% from the the land preparation of cropping year 2019-20 compared to T$_9$ treatment (239.41, 44.49, and 400.04 kg ha^{-1}) an increment of 132, 109, and 137% respectively. Treatment T$_1$ and T$_5$ showed lower average values for N and K than treatment T$_9$ (229.34 and 394.36 kg ha^{-1}) increament 1.5 times, whereas for P, treatment T$_1$ and T$_5$ showed higher average values than T$_9$ but lower from the average of T$_2$-T$_4$ and T$_6$-T$_8$ treatment (48.8 kg ha^{-1}) *i.e.,* 130% increment. On the other hand, the plot with T$_0$ treatment recorded the lowest concentration of N, P and K (71.91, 11.19, and 87.79 kg ha^{-1}) *i.e.,* 30, 47, and 47.7 % reduction (Table 2).

This result indicates that the treatments (T$_2$-T$_4$ and T$_6$-T$_8$) with a combination of organic manure and inorganic fertilizer leads to better soil nutrient quality in comparison with treatments (T$_1$ and T$_5$) with fully organic manure and treatment (T$_9$) with 100% inorganic fertilizer. Reddy and Reddy (2011) and Kumar *et al.* (2023) observed that the efficiency of applied chemical fertilizers increases when organics are added. The use of both organic and inorganic fertilizers have proved to be more effective in improving macronutrients content of the soil as well as the absorption of these nutrients by plants, as compared to the use of only inorganic fertilizers (Reddy and Ahmed, 2009; Ibrahim *et al.* 2020). The combined application of inorganic fertilizer and organic manures increased the soil's NPK status, as reported by Sharma *et al.* (2009) and Peng *et al.* (2023). Fertilizer experiments conducted over an extended period have demonstrated that the continuous application of chemical fertilizers at suboptimal doses to soil led to a decline in soil health, which in turn caused environment pollution and a stagnation in

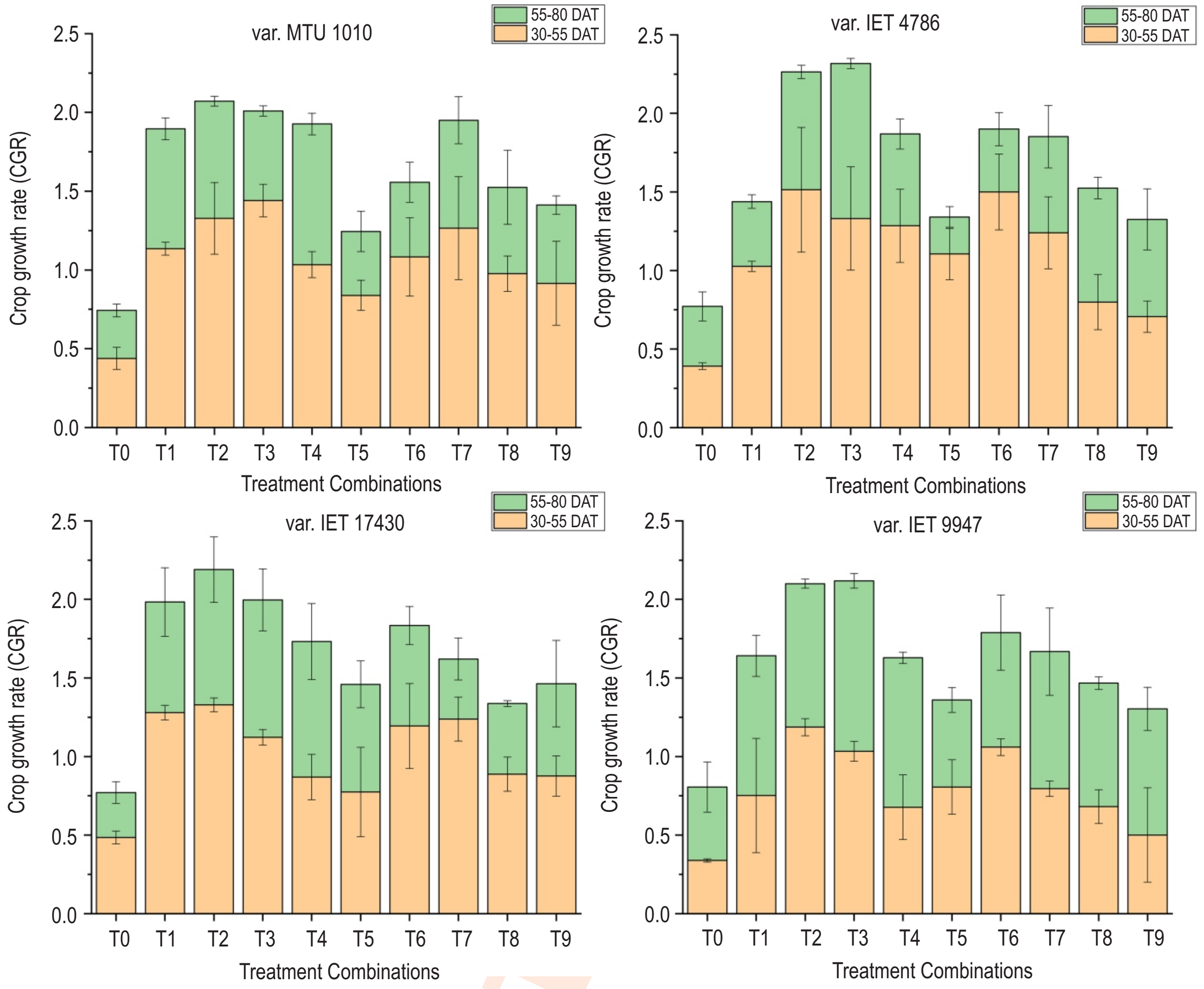

Fig. 2: Average variations of Crop growth rate of different rice varieties in different organic and inorganic manure combinations of three consecutive kharif seasons (2020-2022)

Table 3: Average number of productive tillers from year 2020-2022 per plant of three consecutive kharif seasons (2020-2022)

Treatments	**Rice varieties**			
	MTU 1010	**IET 4786**	**IET 17430**	**IET 9947**
T_0	13.08±1.71	10.71±1.3	9.17±2.43	9.19±2.3
T_1	27.4±2.5	26.59±2.86	25.97±2.22	24.48±2.86
T_2	37.71±2.64	38±2.92	36.67±2.33	36.75±2.7
T_3	42.08±2.85	40.4±2.67	41.42±2.47	41.8±2.6
T_4	27.31±3.24	23.96±3.03	25.92±2.12	26.11±2.81
T_5	29.71±2.68	26.56±2.48	25.78±2.32	24.51±3.11
T_6	38.52±2.37	35.78±2.9	33.44±2.92	35.97±2.83
T_7	37.56±3	35.18±3.18	35.32±2.34	35.83±3.56
T_8	25.06±2.91	24.07±2.74	24.31±2.65	23.89±3.58
T_9	21.03±3.06	21.33±3.05	21.18±2.7	19.74±2.93
Treatments	*	*	*	*

*= statistically significance ($p<0.05$)

Table 4: Yield of different rice varieties from year 2020 to 2022 in different organic and inorganic manure combinations of three consecutive kharif seasons (2020-2022)

Treatments	**Rice Varieties**											
	MTU 1010			**IET 4786**			**IET 17430**			**IET 9947**		
	2020	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
T_0	1.09±0.15	1.05±0.18	1.08±0.13	1.1±0.22	1.21±0.28	1.14±0.12	1.25±0.24	1.21±0.09	1.37±0.15	1.25±0.12	1.46±0.07	1.34±0.14
T_1	2.84±0.98	2.15±0.36	2.67±0.86	3.1±0.43	3.44±0.54	2.53±0.79	2.89±0.47	3.45±0.6	4.07±0.31	2.95±0.25	3.14±0.49	3.83±0.29
T_2	6.4±1.06	4.76±1.26	6.37±0.93	7.69±0.98	6.61±1.22	5.56±0.85	7.2±1.07	8.02±0.98	6.84±1.1	6.39±0.9	8.05±0.8	8.38±1.02
T_3	8.55±1.14	4.88±1.38	5.92±1	8.24±0.51	8.81±0.64	5.09±0.92	7.01±0.56	8.97±1.31	9.11±1.21	5.33±0.99	8.13±1.08	9.74±1.11
T_4	1.98±1.06	1.51±0.48	2.06±0.93	2.86±0.34	3.08±0.43	1.96±0.85	3.06±0.37	3.3±1.16	4.21±0.42	2.44±0.34	4.1±0.95	3.78±0.38
T_5	2.93±1.11	2.14±0.58	2.81±0.97	3.36±0.51	3.08±0.64	2.92±0.89	3.26±0.56	4.01±0.65	3.27±0.51	3.73±0.41	3.74±0.53	4.68±0.47
T_6	3.06±0.97	6.4±1.29	4.81±0.85	6.59±0.96	3.96±1.19	6.57±0.78	5.16±1.04	6.99±1.45	4.88±1.13	6.78±0.93	5.54±1.18	7.41±1.04
T_7	5.49±1.15	3.79±1.21	6.16±1.01	5.02±1.18	5.95±1.46	4.95±0.93	6.31±1.28	7±1.02	6.45±1.06	6.14±0.87	6.5±0.83	9.01±0.98
T_8	1.78±0.8	1.58±0.34	3.25±0.7	3.27±0.43	2.54±0.54	2.23±0.64	3.47±0.47	3.3±0.48	3.33±0.29	2.9±0.24	3.72±0.39	3.37±0.27
T_9	3.61±1.1	2.19±0.46	3.35±0.96	4.51±0.43	4.22±0.54	2.93±0.89	4.23±0.47	5.37±0.49	4.87±0.4	3.71±0.33	5.15±0.4	6.25±0.37
Treatments	*	*	*	*	*	*	*	*	*	*	*	*
Year		Ns			ns			ns			ns	
Treatments X Year		Ns			ns			ns			ns	

*= statistically significance (p<0.05); ns = statistically not significant (p>0.05)

crop productivity. This highlights the need for the integrated use of organic manures with optimal levels of NPK fertilizers to maintain soil health and crop yield (Mahajan *et al.,* 2008). The perusal of data for grain yield showed a significant ($p<0.05$) difference between treatments in each variety for the number of productive tillers. Treatment T_3 produced the maximum number of productive tillers for all varieties, *i.e.,* var. MTU 1010, var. IET 4786, var. IET 17430, and var. IET 9947 (42.08±2.85, 40.4±2.67, 41.42±2.47 and 41.8±2.6) whereas treatment T_0 showed the minimum number of productive tillers (13.08±1.71, 10.71±1.3, 9.17±2.43, and 9.19±2.3, respectively) (Table 3). Grain yield is a major determinant in the performance of crops under various fertilizer amendments. Spanning over a period of three-year study, the results showed that the grain yield was significantly ($p<0.05$) different for various treatments but no significant difference was observed ($p>0.05$) for three cropping seasons which signifies that the yield for the respective treatments was constant throughout the years. The average highest yield for three croppings was recorded in treatment T_3 for all varieties, *i.e.,* var. MTU 1010, var. IET 4786, var. IET 17430, and var. IET 9947 (6.45±1.17, 7.38±0.69, 8.36±1.02 and 7.73±1.06) whereas T0 treatment showed the lowest grain yield (1.07±0.15, 1.15±0.2, 1.28±0.16, and 1.35±0.11) (Table 4).

The improvements in growth and yield components of rice were mainly due to the improved soil fertility under combined treatment which ultimately improved root growth, nutrient uptake and leaf photosynthetic capacity by providing sufficient macro- and micronutrients from manure and chemical fertilizer throughout the growth period (Iqbal *et al*., 2023). Photosynthesis is one of the major drivers of crop production which enhances plant growth and biomass production. The increase in the photosynthetic area due to increased number of leaves is directly interlinked with the tillering capacity of the plants. Tillering is an important trait for grain production and thereby, an important aspect of rice growth improvement. The results of the present study is in line with the study of Siavoshi *et al.* (2011) and Ramesh *et al.* (2009), who reported that different fertilizer mixtures boosted the number of tillers in rice plants. This can be justified by the process of release of micronutrients from organic sources and their uptake by the plants which provided them with a well-balanced nourishment that positively boosted the number of tillers in plants (Yadav *et al.,* 2017).

Chemical fertilizers release nutrients rapidly, which makes them easily available to plants at early growth stages (Gangopadhyay *et al*., 2022), while the slow and steady release of nutrients from organic manure provides sufficient nutrients throughout growth, particularly at the grain-filling stage (Islam *et al*., 2024). The present results are in line with Mangalassery *et al.* (2019) and Qiong *et al.* (2023), who pointed out that the use of manure integrated with chemical fertilizer increased the growth and yield of rice significantly compared to the sole use of chemical fertilizer. The combination of organic manure and inorganic fertilizer had a significant influence on the physico-chemical characteristics of the soil, growth, and also on the physiology of rice, grain production, and quality parameters of rice. Treatment T_3, a combination of cow dung manure and organic fertilizers in a ratio of 1:1, is an effective approach for enhancing the rice grain output, simultaneously improving the root growth and soil characteristics. Eventhough application of organic amendments in the form of manure presents certain challenges in maintaining crop yields, however, it can help mitigate some of the negative effects of intensive fertilization systems by increasing the amount of soil microbial biomass and the ecosystem functions associated with it. The findings of this study could be helpful to policymakers who are entrusted with enhancing the recovery of fertilizer and developing sustainable crop production techniques for paddy soils.

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