PLANT SCIENCE TODAY
Vol 12(sp1): 01–07
https://doi.org/10.14719/pst.8396

eISSN 2348-1900

RESEARCH ARTICLE

Effect of mineral nitrogen and organics on growth and yield of rice (*Oryza sativa* L.) in Typic Ustifluvents soil

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Received: 19 March 2025; Accepted: 26 July 2025; Available online: Version 1.0: 08 September 2025; Version 2.0: 29 September 2025

Cite this article: Kaviya R, Manivannan R, Senthilvalavan P, Kalaisudarson S. Effect of mineral nitrogen and organics on growth and yield of rice (*Oryza sativa* L.) in Typic Ustifluvents soil. Plant Science Today. 2025;12(sp1):01–07. https:/doi.org/10.14719/pst.8396

Abstract

Rice (*Oryza sativa* L.) is a staple food for nearly half of the world's population. To meet the global demand of growing population, rice production must be substantially increased with the adoption of Integrated Nutrient Management (INM). With this background, present field study was conducted in 2023 at a farmer's holding in Kuttalam to evaluate the effect of organics alone or mineral nitrogen alone or in combination tested on an N-equivalent basis on sandy clay loam soil (Padugai series- *Typic Ustifluvents*). The research was conducted during Samba season (Oct- Feb. 2023) using a randomized block design with three replications. Rice variety was used as the test crop, with ten treatments consisting of Nitrogen applied on an equivalent basis with organic manures, inorganic fertilizers and a control. Based on N equivalent basis, the required quantities of organic manures were applied to rice. Observations on growth parameters *viz.* (plant height, tiller count, leaf area index, chlorophyll content, crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), grain and straw yield were recorded and the data were analysed using LSD at 5 % probability level for significant differences. The results revealed that the application of 75 % RDN (urea) combined with 25 % N (poultry manure) (T_7) achieved the highest growth parameters grain yield and straw yield in rice, Where the lowest values were recorded in the control (T_1). The findings demonstrate that a combined application of mineral nitrogen and organic fertilizers is required to achieve the maximum rice yield.

Keywords: growth parameters; mineral nitrogen; organics; rice; yield

Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in the world and serves as a staple food for more than half of the global population. Currently, over one-third of humanity relies on rice for their daily sustenance. Rice is cultivated in 114 countries, covering an area of 177.125 million hectares, with a production of 518.14 million tonnes and an average productivity of approximately 2.92 tonnes per hectare (1). In India, rice is grown over an area of 46.37 million hectares, the largest among all rice-producing countries, yielding about 135.54 million tonnes with a productivity rate of 2.92 tonnes per hectare (2). Within India, Tamil Nadu cultivates rice on 2.2 million hectares, producing 8.65 million tonnes and achieving an average productivity of around 3.93 tonnes per hectare (3). Nitrogen (N) is an essential nutrient that plays a crucial role in enhancing rice yields by promoting rapid plant growth and improving quality (4). Globally, rice cultivation consumes approximately 9 to 10 million tonnes of nitrogen fertilizer annually, accounting for about 10 % of the total nitrogen fertilizer production worldwide (5). However, the continued use of inorganic nitrogen fertilizers can lead to yield loss, poor soil health and increased environmental pollution. Organic nutrient sources offer a slower release of nutrients, making them safer for the environment (6). However, relying solely on organic sources may not sufficiently meet plant requirements, especially during critical growth stages when nutrient demand is high. A practical approach to ensuring the sustained availability of nitrogen and improving its use efficiency is balanced fertilization, which combines both organic and inorganic nutrient sources (7).

The use of organic materials such as poultry manure, paddy straw compost and coir pith compost are essential for maintaining soil fertility and maximizing crop yields while optimizing nitrogen, phosphorus and potassium (NPK) levels. This study presents a novel, region-specific approach by evaluating the combined effects of mineral nitrogen and four different organic manures, applied on an N-equivalent basis under Typic Ustifluvents soil conditions in Tamil Nadu. This specific soil type has not been widely studied for such comparisons.

Furthermore, the study includes detailed growth analyses (CGR, RGR, NAR) and explores the correlation between available nitrogen and chlorophyll content (SPAD). This comprehensive approach offers a better understanding of nutrient interactions and plant performance. The findings contribute to region specific, sustainable nutrient management strategies, aimed at enhancing rice productivity and improving soil health. Hence, this study was conducted to examine the effects of various organic and inorganic nitrogen sources on the growth and yield of rice.

Materials and Methods

Experimental site

The field experiment was conducted on a farm in Kuttalam, located in the Mayiladuthurai district, during the Samba season (October 2023 - February 2024). The soil at the experimental site is classified as sandy clay loam (Padugai series - Typic Ustifluvents) and has a pH of 7.1, with an electrical conductivity (EC) of 0.25 dS m^{-1}. The soil exhibited low nutrient status with available nitrogen, phosphorus (medium as per Olsen P), potassium (also medium) and organic carbon (low as per Olsen P) recorded at 248.1 kg/ha, 15.2 kg/ha, 250.5 kg/ha and 4.1 g/kg.

Experimental design and treatments

The experiment was laid out in a randomized block design with 10 treatments; each replicated three times. The treatments imposed were T_1-control, T_2-RDF (150:50:50-N:P_2O_5:K_2O kg ha^{-1}), T_3-100 % N (Poultry manure), T_4-100 % N (Paddy straw compost), T_5-100 % N (Water hyacinth compost), T_6-100 % N (Composted coir pith), T_7 -75 % RDN (Urea) + 25 % N (Poultry manure), T_8-75 % RDN (Urea) +25 % N (Paddy straw compost), T_9 -75 % RDN (Urea) + 25 % N (Water hyacinth compost) and T_{10}-75 % RDN (Urea) + 25 % N (Composted coir pith). Before application, nutrient contents of organics were analysed and their application rates were determined in accordance with N equivalence (Table 1-3).

Crop management

Nitrogen was applied in three split doses: 50 % at the basal stage, followed by 25 % each at the active tillering and panicle primordial stages. Full doses of phosphorus (P_2O_5) and potassium (K_2O) were applied as basal treatments. These nutrients were provided in the form of urea, superphosphate and muriate of potash, respectively. The calculated quantities of various organic materials, based on nitrogen equivalence, were incorporated into the soil prior to fertilizer application. The variety used for this study was ADT 46. Twenty-five-day-old seedlings were transplanted into the main field, with two seedlings per hill and a spacing of 12.5 cm × 10 cm. Growth attributes were recorded at critical stages of crop growth, while yield attributes and overall yields were documented at harvest time. Experimental data were collected from a net plot size of 4.5 m × 3.5 m and were statistically analyzed as described in the relevant literature (8).

Results

Growth and yield attributes

Application of mineral nitrogen alone, organic fertilizers alone, or their combination significantly improved various growth parameters and yield attributes compared to the control (Table 4, 5). The integration of organic matter and fertilizer nitrogen resulted in higher growth than their individual applications. Among the different nutrient management strategies, the treatment comprising 75 % of the recommended dose of

Table 1. Chemical composition of different organic sources

S. No	Organic manures	Nutrients content (%)				
		N	P	K	Organic carbon	C:N ratio
1.	Poultry manure(PM)	2.48	1.01	1.68	35.3	14.2
2.	Water hyacinth compost (WHC)	1.57	0.59	1.64	31.9	20.3
3.	Composted coirpith (CCP)	0.98	0.06	1.04	23.4	23.8
4.	Paddy straw compost (PSC)	0.50	0.25	2.62	39.2	78.4

Table 2. Quantity of organics applied for different treatments based on N equivalence

S. No.	Organics	Concentration of N (%)	Quantity added to supply 100% N (t ha^{-1})	Quantity added to supply 25% N (t ha^{-1})
1.	Poultry manure	2.48	6.04	1.51
2.	Water hyacinth compost	1.57	9.55	2.38
3.	Composted coirpith	0.98	15.30	3.82
4.	Paddy straw compost	0.50	30.0	7.50

Table 3. Details of analytical methods employed in soil analysis

S. No.	Parameters	Method
1.	Mechanical analysis	International pipette method
2.	Soil reaction (pH)	1:2.5 soil water ratio using pH meter
3.	Electrical conductivity	1:2.5 soil water ratio using conductivity bridge
4.	Available nitrogen	Alkaline permanganate method
5.	Available phosphorus	Ascorbic acid method in spectrophotometer using red filter (660 nm).
6.	Available potassium	1 N NH_4OAC extraction method using flame photometer with K filter
7.	Organic carbon	Chromic acid wet oxidation method
8.	Chlorophyll	SPAD Meter

Table 4. Effect of organics and mineral nitrogen on growth parameters in rice in Typic Ustifluvents soil

Treatments	Plant height (cm)	No. of tillers/ hill	LAI	Chlorophyll content (SPAD value)	CGR ($gm^{-2} d^{-1}$)	RGR ($gg^{-1}d^{-1}$)	NAR ($gm^{-2} d^{-1}$)
T_1 - Control	66.3	6.5	3.83	25.3	7.3	23.8	1.02
T_2- RDF (150:50:50 N, P_2O_5, K_2O kg ha^{-1})	84.4	9.9	5.01	38.1	11.4	29.9	1.35
T_3- 100 % N (Poultry manure)	79.9	8.5	4.79	35.3	10.7	28.6	1.28
T_4 -100 % N (Paddy straw compost)	70.5	7.1	4.18	28.9	9.6	25.4	1.12
T_5-100% N (Water hyacinth compost)	76.4	8.0	4.56	32.7	10.3	27.3	1.21
T_6 - 100 % N (Composted coir pith)	72.9	7.4	4.33	29.8	9.8	26.0	1.15
T_7 -75 % RDN (Urea) + 25 % N (Poultry manure)	96.1	14.9	6.13	48.3	13.2	34.3	1.74
T_8 - 75 % RDN (Urea) + 25 % N(Paddy straw compost)	85.5	10.3	5.08	39.8	11.6	30.2	1.40
T_9 -75 % RDN (Urea) + 25% N (Water hyacinth compost)	92.6	12.8	5.35	45.1	12.6	32.9	1.58
T_{10}-75 %RDN (Urea) + 25% N (Composted coir pith)	89.1	11.6	5.11	42.5	12.1	31.6	1.49
SE_D	1.64	0.22	0.11	0.79	0.22	0.58	0.03
CD (p=0.05)	3.48	0.48	0.21	2.51	0.38	1.23	0.06

Table 5. Effect of organics and mineral nitrogen on yield parameters in rice in Typic Ustifluvents soil

Treatments	DMP (kg ha^{-1})		No. of panicles m^{-2}	No. of grains $panicle^{-1}$	Panicle length (cm)	1000 grain weight (g)
	Tillering stage	Panicle initiation				
T_1 - Control	1523	6395	180.3	117.3	14.2	28.9
T_2- RDF (150:50:50 N, P_2O_5, K_2O kg ha^{-1})	3203	6188	195.1	139.5	22.9	29.1
T_3- 100% N (Poultry manure)	3099	5629	190.8	133.2	19.2	29.2
T_4 -100 % N (Paddy straw compost)	2778	5996	183.1	122.5	17.0	29.3
T_5-100%N (Water hyacinth compost)	2994	5783	187.9	129.3	18.3	29.5
T_6 - 100 % N (Composted coir pith)	2885	7123	185.1	125.1	17.5	29.4
T_7 -75 % RDN (Urea) + 25 % N (Poultry manure)	3652	6536	205.6	156.3	25.8	30.1
T_8 - 75 % RDN (Urea) + 25 % N(Paddy straw compost)	3299	6932	197.2	142.6	23.4	30.2
T_9-75 % RDN (Urea) + 25 % N (Water hyacinth compost)	3522	6935	202.4	150.8	25.1	30.3
T_{10}-75 %RDN (Urea) + 25 % N (Composted coir pith)	3402	6764	199.6	146.2	24.2	30.4
SE_D	49.5	80.3	1.12	1.73	0.29	0.55
CD (p=0.05)	99.1	160.5	2.36	3.63	0.61	NS

nitrogen (RDN) from urea and 25% nitrogen from poultry manure (T_7) produced the highest growth parameters. These included plant height (96.1cm), no. of tillers/hill (19.9), LAI (6.13), chlorophyll content (48.3 SPAD value), CGR (13.2 g m^{-2} d^{-1}), RGR (34.3 g g^{-1} d^{-1}), NAR (1.74 g m^{-2} d^{-1}), dry matter production (7123 kg ha^{-1}). Yield attributes such as number of panicles m^{-2}(205.6), number of grains $panicle^{-1}$(156.3), panicle length (25.8 cm) and 1000-grain weight (30.1) in rice were also highest under this treatment. It was closely followed by application of 75 % RDN (urea) + 25 % N (water hyacinth compost) (T_9). This was supported by significant positive correlation between available N with plant height (r= 0.983**), tiller count (r = 0.937**), leaf area index (r= (0.956**), CGR (0.997**), RGR (0.982**) and NAR (0.965**).The chlorophyll content was confirmed by significant positive linear relationship with available N in rice (Fig. 1).

Among the organics treatment, application of poultry manure (100 % N) (T_3) resulted in the highest growth parameters viz., plant height (42.1 cm), no. of tillers/hill (15.0), LAI (4.79), chlorophyll content (35.3 SPAD value), CGR (10.7 g m^{-2} d^{-1}), RGR (28.6 g g^{-1} d^{-1}), NAR (1.28 g m^{-2} d^{-1}), dry matter production (6188 kg ha^{-1}).Yield attributes were also highest under T_3 with number of panicles m^{-2} (190.8), number of grains $panicle^{-1}$ (133.2), panicle length (19.2 cm) and 1000- grain weight(29.2 g) making it superior to rest of the treatments. The lowest growth parameters were recorded in control (T_1).

Rice yield

The grain and straw yield of rice (var. ADT 46) showed a significant response to the integrated use of organics and mineral N or organics alone or mineral N alone, compared to the control (Fig. 2). The combined application of mineral nitrogen and organics significantly increased the grain and straw yield over their individual application. The grain and straw yield ranged from 3095 to 5701 kg ha^{-1} and 4106 to 6993 kg ha^{-1} respectively. The highest grain yield (5701 kg ha^{-1}) and straw yield (6993 kg ha^{-1}) was recorded in 75 % RDN (urea) + 25% N (poultry manure) (T_7) which was followed by (T_9) 75 % RDN (urea) + 25 % N (water hyacinth compost). The best treatment resulted in an 84.2 % increase in grain yield and a 70.3 % increase straw yield, when compared to the control (Fig. 3). Among the organics the highest grain yield (4702 kg ha^{-1}) and straw yield (5801 kg ha^{-1}) was recorded under the application of poultry manure (100 % N) (T_3), followed by water hyacinth compost (100 % N). The best treatment resulted in 51.9 % and 41.2 % increase in grain and straw yield respectively, when compared to control. The lowest grain yield (3095 kg ha^{-1}) and straw yield (4106 kg ha^{-1}) were recorded in control treatment. This was supported by a significant positive correlation between grain yield and available nitrogen (r= 0.995**). Similarly, a positive linear relationship was observed between growth parameters and grain yield (Fig. 4) and yield parameters with grain yield (Fig. 5).

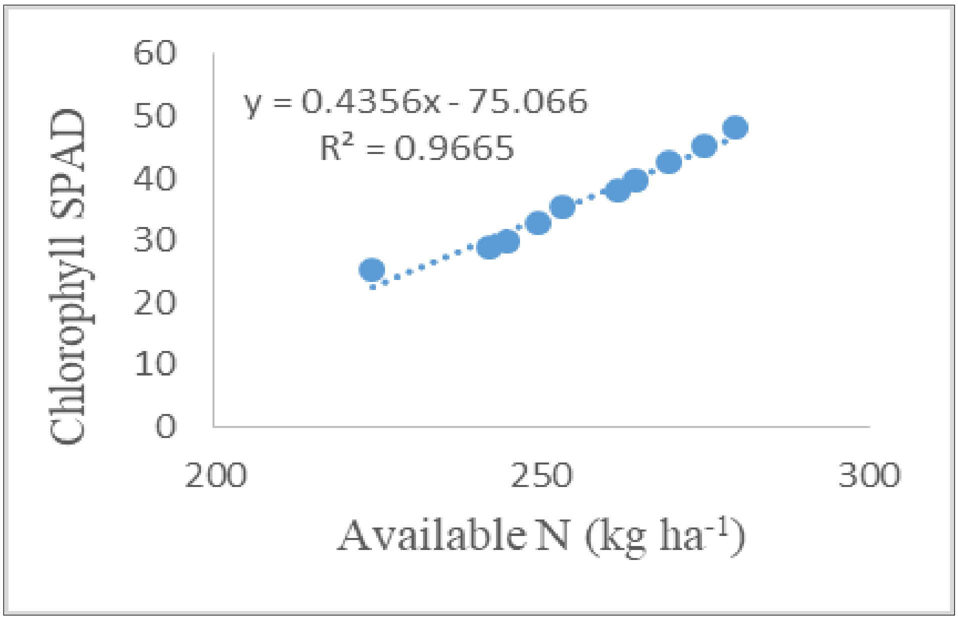

Fig.1. Linear relationship between available N with chlorophyll content (SPAD value).

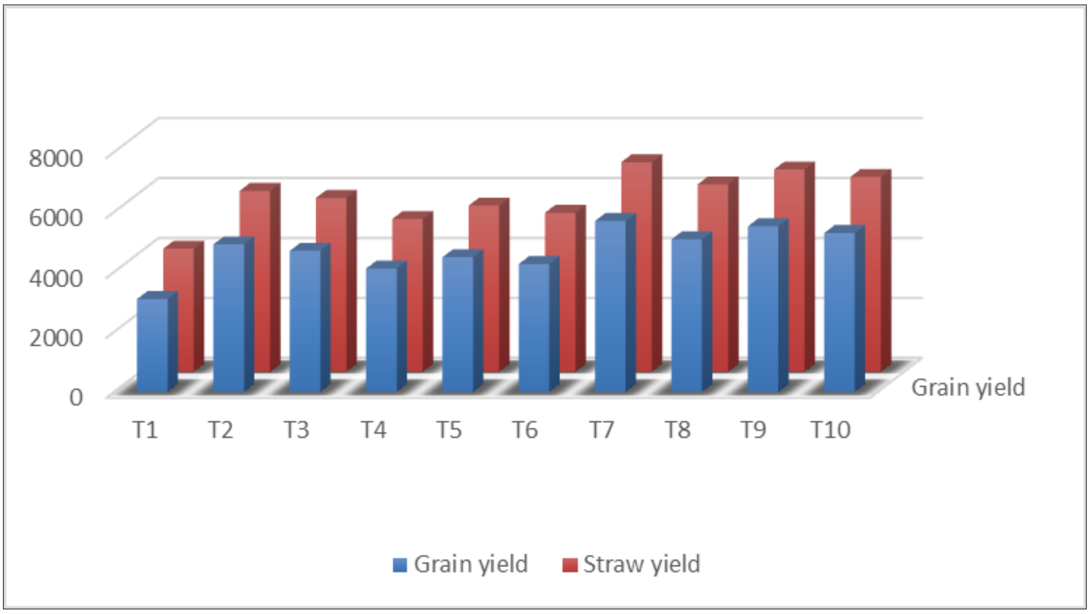

Fig. 2. Effect of organics and mineral nitrogen on rice yield (kg ha-1) in rice.

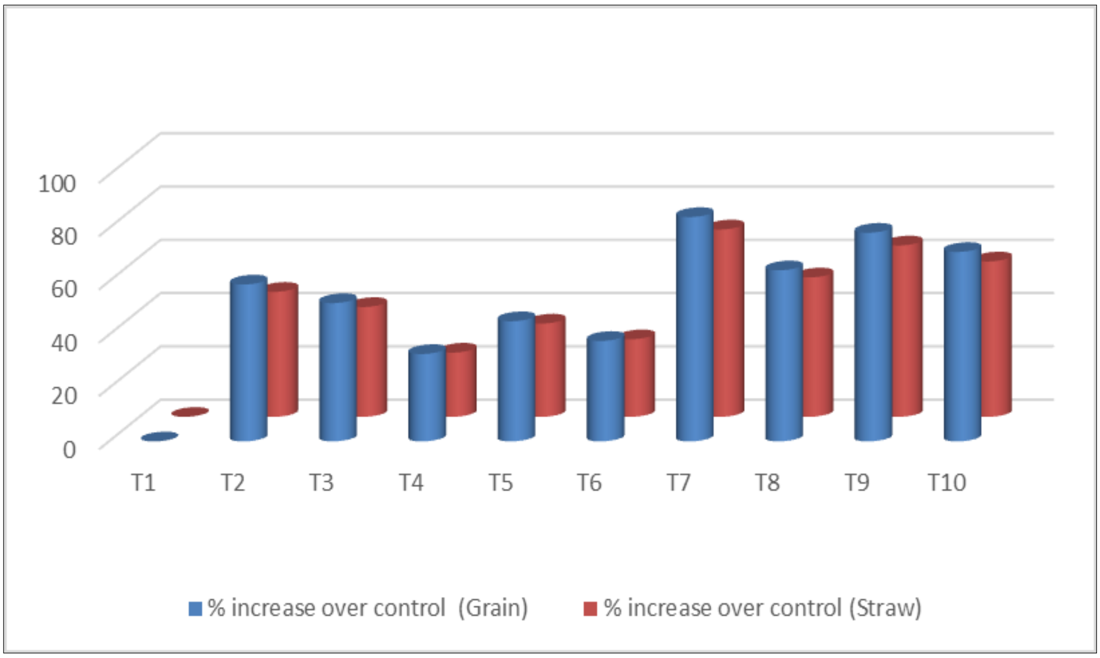

Fig. 3. Effect of organics and mineral nitrogen on rice yield % increase over control in rice.

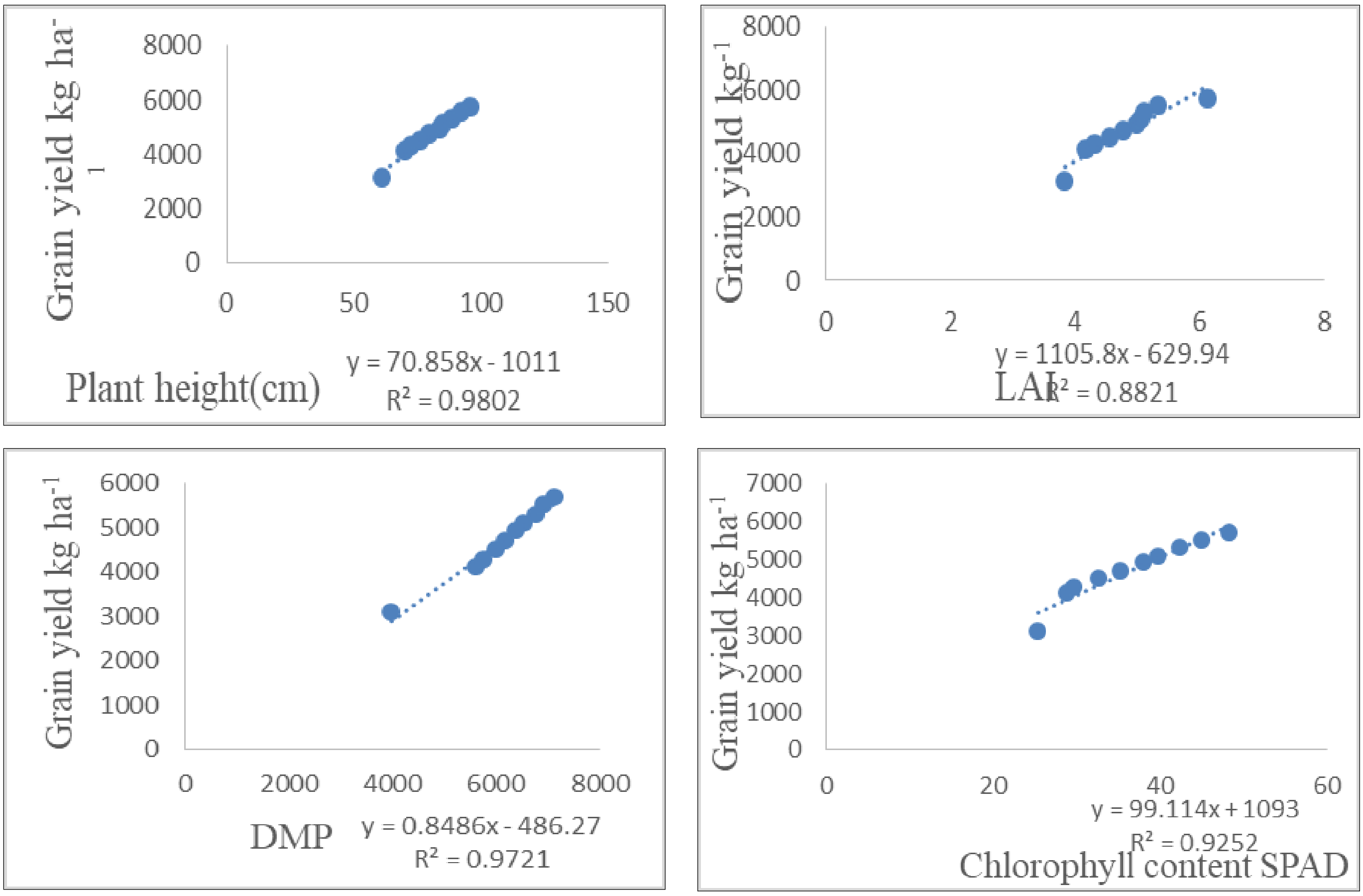

Fig. 4. Linear relationship between growth parameters with grain yield.

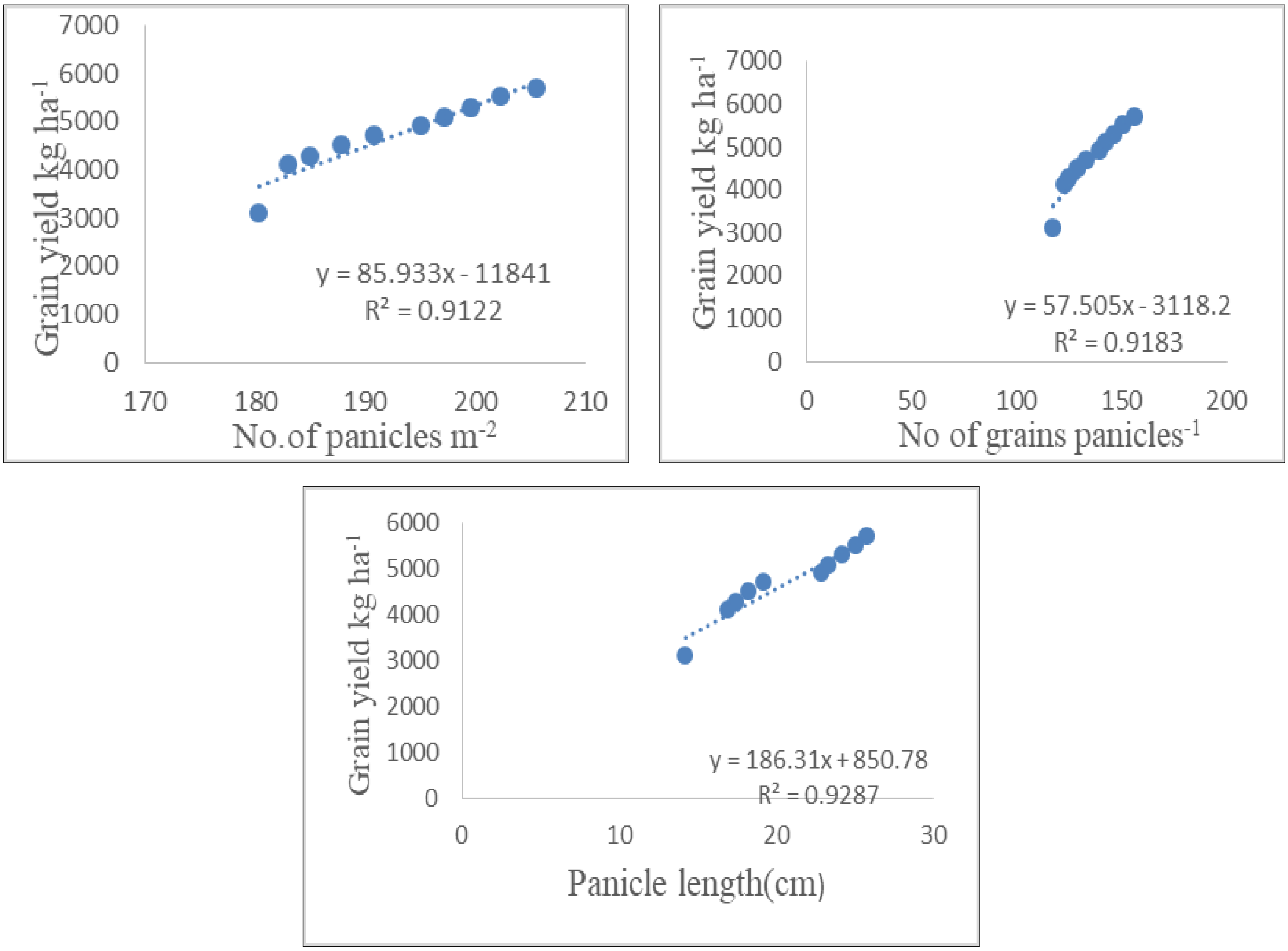

Fig. 5. Linear relationship between yield parameters with grain yield.

Discussion

A significant increase in plant height might be attributed to the greater availability and steady release of nutrients from organic sources, which perhaps enabled enhanced growth during the reproductive stage (9). Poultry manure has shown potential in enhancing plant growth by improving the physicochemical properties of soil, improving microbial activity and increasing the production of plant growth regulators by microorganisms. These factors might have contributed to higher number of tillers/hill. The variation in the number of productive tillers/hills was primarily influenced by the variations in availability of N from various organic sources. Application of organic sources resulted in balanced nutrition to crops, especially micronutrients that favoured the number of productive tillers/ hill (10). The increase in the leaf area index might be due to improved nutrition and increased nutrition absorption capacity of plant, which resulted in better root development and increased translocation of carbohydrates from source to growing points (11). Nitrogen increases the chlorophyll content at all growth stages, as it is a fundamental component and may have enhanced photosynthesis, thereby contributing to increased plant height (12). The combination of chemical nitrogen and poultry manure could be associated with higher leaf area and greater photosynthate production which favoured higher growth crop growth rate, relative growth rate and net assimilation rate in rice. Higher dry matter production was likely due to increased leaf and stem dry weights recorded at different stages. This provided more photosynthetically active leaf area, resulting in higher dry matter accumulation. The rise in dry matter production might also be attributed to nitrogen fertilization, which likely improved plant's photosynthetic activity, enhancing carbohydrate metabolism and ultimately promoting dry matter accumulation (13). The increase in the grain yield components with the application of organics and mineral N sources may be due to increased nitrogen availability, along with enhanced absorption of other macro and micronutrients from source to sink (13).

Rice yield

The higher grain and straw yield might be due to the balanced supply of nutrients and steady rate of nutrient release, which enables rice plants to assimilate sufficient photosynthetic products. The increase in grain yield might be due to enhanced yield attributes, improved morphological and biological characters and efficient translocation of photosynthates from source to sink (14). These improvements in growth and yield components may have contributed to the increased rice yields observed with the application of N sources in organic form (15). In this study, the application of organic manures when supplied in sufficient quantity provided all essential nutrients in adequate amounts for plant growth and development, ultimately resulting in higher yield. This effect could be ascribed to the slow release of nutrients after decomposition, ensuring continued availability in contrast to the inorganic fertilizer alone (14). The addition of poultry manure enriched the soil by increasing nutrient availability, which enhanced cell division, cell elongation as well as various metabolic processes ultimately contributing to higher yield. The superiority of poultry manure can also be attributed to its slow and steady decomposition, which probably released nutrients slowly and in higher quantities compared to other organic materials which ultimately, resulting superior grain and straw yield (16). The application of fertilizer nitrogen alone recorded higher yield than organics alone, possibly because nitrogen application encourages vegetative growth due to cell elongation and cell division with improved vegetative growth and increased yield attributes (17). Integration of organic sources viz., poultry manure and mineral nitrogen over organics alone or mineral N alone recorded higher yield. This may be attributed to the short -term nutrient availability from mineral nitrogen through rapid mineralization, although it is subject to losses via volatilization and leaching (17). Due to the slow release and continuous supply of nutrients in balanced quantities throughout various growth stages, rice plants can assimilate sufficient photosynthetic products. This leads to an increase in dry matter and source capacity, producing more panicles with a higher number of fertile grains, increased test weight and higher grain and straw yield (18).

Conclusion

This study concluded that the application of different organics sources alone, mineral N alone or their combination significantly increased growth parameters and yield in rice. The application of poultry manure supplementing 25 % N + 75 % N through mineral fertilizer, recorded the highest growth parameters and rice productivity, indicating the potential sustainable agriculture. This INM approach is beneficial in recycling agricultural waste and poultry droppings, thereby enhancing soil health and boosting productivity in an eco-friendly manner.

Acknowledgements

The authors express their gratitude to Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University for furnishing the necessary facilities for conducting the research on integrated nitrogen management in rice, which will culminate in this research.

Authors' contributions

RK wrote the first draft of the paper, RM conceptualized, reviewed and edited the research paper holistically. PS and SK reviewed the paper and shared their inputs for upscaling. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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