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Impact of Inorganic, Organic and Biological Sources of Nutrients on Growth and Yield of Rice in an Inceptisol Soil of Tamil Nadu (Navarai Season)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during the Navarai season (2022) using rice variety ADT - 37 to assess the impact of inorganic, organic, and biological sources of nutrients on the growth and yield of rice in an Inceptisol soil of Tamil Nadu. The experimental soil was clay loam in texture and had a pH-8.10, EC-0.7 dSm^{-1}, and available NPK of 186.20, 23.30, and 192.25 kg ha^{-1}, respectively. The experiment comprised of nine treatments viz., T_1 – Control, T_2 - 100% RDF, T_3 - 125% RDF , T_4 - 100% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_5 – 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_6 – 100% RDF + Coirpith Compost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_7 – 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_8 – 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_9 – 125% RDF + Coirpith Compost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria. The results of the experiment revealed that application of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc

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Solubilizing Bacteria (T_8) recorded higher values in growth and yield parameters viz., plant height (106.8 cm), Number of productive tillers $hill^{-1}$ (14.5), Leaf area index (8.02), chlorophyll content (1.285 mg g^{-1}) Number of panicles m^{-2} (585), Number of grains $panicle^{-1}$ (227) Dry matter production (5720 kg ha^{-1}), Grain yield (6293 kg ha^{-1}) and Straw yield (8943 kg ha^{-1}).

Keywords: Rice; RDF; vermicompost; zinc solubilizing bacteria; grain yield.

1. INTRODUCTION

"Rice occupies a pride place among the food crops cultivated and it has not only meets most of the needs on earth but also symbolizes revolution, industrialization, calorie, and earth. It is the cause of the revolution on earth in nutrition as well as on the food security front" [1]. "Rice is cultivated worldwide over an area of about 160.68 million ha^{-1} with an annual production of about 650.19 million tonnes. In India rice is cultivated over an area of about 39.16 million hectares with an annual production of about 85.59 million tonnes and a productivity of 2.20 tonnes ha^{-1} [2]. In Tamil Nadu, rice is grown predominantly among the states in India, which is cultivated in an area of 1.90 million hectares and production of 5.79 million tonnes with a productivity of 3.04 t ha^{-1}. However, yield is still lower when compared to the average productivity of rice-producing countries such as Japan (6.50 t ha^{-1}), China (6.70 t ha^{-1}), Egypt (7.50 t ha^{-1}), and Israel (5.50 t ha^{-1}). In India, during the past three decades, intensive agriculture involving high-yielding varieties of rice has led to the heavy withdrawal of nutrients from the soil. Further, the imbalanced use of chemical fertilizers by farmers has also deteriorated soil health and declined soil organic carbon content, which is a threat to sustainability. Nitrogen is commonly the most limiting nutrient for crop production in the major world's agricultural areas and therefore, adoption of good N management strategies often results in large economic benefits to farmers. The use of organic manures in present agriculture is increasing day by day, because of its utility not only in improving the physical, chemical, and biological properties of soil but also in maintaining good soil health and supplying almost all essential plant nutrients for growth and development of crop plants" [3,4,5]. "So, it is time to look for measures to stimulate sustainability in the production of rice on a long-term basis. In this context, vermicomposting of different organic wastes shows promising results in enriching the soil with organic matter, nutrients, etc., thereby maintaining soil fertility. Vermicomposting is a simple process of composting with certain species of earthworms to accelerate the process of waste conversion and to get a better end product" [6].

Research pieces of evidence clearly show that vermicompost is a potential organic input that would impart consistent environment and soil Physico-chemical properties, biological activity, and nutrient availability which ultimately improves nutrient uptake, growth and yield components, and yields of cereal crops.

"To sustain soil health and to provide adequate plant nutrients, an alternative to chemical fertilizers has to be supplied in integration instead of sudden stoppage of chemicals and total conversion to organic would lead to drastic yield gaps during the early stages of the crop" [7]. "The demand for rice is expected to rise by 1.6 percent per year due to the increasing population, while the area of rice cultivation is expected to reduce 40 million ha in the next 15 to 20 years" [8]. "Hence it is a need to increase the yield and productivity of rice cultivation using reduced inputs and resources to feed the growing population. Moreover, the increasing cost of chemical fertilizers has reduced the profitability of cultivation. Therefore, alternative use of organic manures like green manuring and crop residues along with inorganic fertilizers not only reduces the demand for inorganic fertilizers but also increases the efficiency of applied nutrients due to the favorable effect on physical, chemical, and biological properties of soil" [9].

The effectiveness of integrated nutrient management practice depends on the season, soil type, climate, water management, variety, and cropping pattern. Thus, this paper is written to discuss the impact of inorganic, organic, and biological sources of nutrients in various growth and yield parameters of rice.

2. MATERIALS AND METHODS

The present investigation was carried out in rice variety ADT -37 in farmers field near Gingee taluk, Villupuram district, Tamil Nadu. It represented clay loam texture, and had a pH-8.10, EC-0.7 dSm^{-1}. The experiment carried out to find out the response of rice (*Oryza sativa*) to different sources of nutrients.

2.1 Experimental Design

The experimental design was used was a randomized block design with three replications. The treatments were different levels of inorganic, organic, and biological nutrients applied to the soil. Treatments details are given below:

T_1 - Control
T_2 - 100 % RDF
T_3 - 125% RDF
T_4 - 100% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria
T_5 - 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria
T_6 - 100% RDF + Coir pith compost @ 6 t ha^{-1}+ 2% Zinc Solubilizing Bacteria
T_7 - 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria
T_8 - 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria
T_9 - 125% RDF + Coir pith compost @ 6 t ha^{-1}+ 2% Zinc Solubilizing Bacteria

Plot size	: 5 x 4 m
Design	: Randomized Block Design
Replications	: Three

3. RESULTS AND DISCUSSION

3.1 Plant Height

Among the various treatments, application of 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) recorded higher plant height over control and other treatments at tillering stage (54.1 cm), panicle initiation stage (88.3 cm) and harvest stage (106.8 cm). The increase in plant height in response with favorable effect of vermicompost on plant height could be attributed to the sustained availability of major and micronutrients resulting in increased plant height. This was also confirmed by Murali and Setty [10], Kavitha and Subramanian [11]. The least plant height were reported in control plots (T_1).

3.2 Number of Productive Tillers Hill^{-1}

Among the various treatments, the application of 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) recorded the highest number of productive tillers $hill^{-1}$ of 14.50 significantly higher than other treatments. "This may be due to better growth and enhanced photosynthesis in presence of required nutrients in sufficient amount and also owing to better translocation of photosynthesis to sink because of balance nutrients of NPK in vermicompost" [12]. "Higher tiller count might be ascribed to adequate supply of zinc that might have increased the uptake and availability of other essential nutrients which resulted in improvement of plant metabolic process" [13]. This result is corroborating with the reports of Kamaleshwaran and Elayaraja [14]. The lowest number of productive tillers $hill^{-1}$ was recorded in the absolute control T_1 of (6.55) respectively.

3.3 Leaf Area Index

Among the various combinations experimented with, the maximum leaf area index of 8.02 was recorded in the treatment T_8 (125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria) and it was on par with T_7 (125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) of 7.77. Meena et al., [15], Dipankar Kar et al., [16], Mirza et al., [17], Morteza Siavoshi et al., [18] reported increase in LAI on addition of organics. Higher LAI could be attributed to an increase in metabolic activity in the plant which could have promoted meristematic activities causing apical growth. Hence, increase N utilization by plants in response to vermicompost application has increased photosynthesis and ultimately leaf area index. The lowest leaf area index was recorded in the absolute control T_1 of 5.30 respectively.

3.4 Chlorophyll Content

Among the various treatments, the application of 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) recorded the highest chlorophyll content of 1.285 mg g^{-1} and was on par with the application of 125% RDF + Press mud at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_7) of 1.240 mg g^{-1} and significantly higher than other treatments. Vermicompost stimulates the plant growth possibly through supplying nutrients and increasing chlorophyll which consequently improves the photosynthesis [19]. These results are also confirmed by the reports of Ramesh et al., [20]. The lowest chlorophyll content was recorded in the absolute control T_1 of 0.650 mg g^{-1} respectively.

Table 1. Impact of inorganic, organic, and biological sources of nutrients on growth and yield parameters of rice

Treatments details	Plant height			No. of Productive tillers hill^{-1}	Leaf area index	Chlorophyll Content (mg g^{-1})	No. of Panicles m^{-2}	No. of Grains Panicle^{-1}	Dry matter Production (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw yield (kg ha^{-1})
	TS	**PIS**	**HS**								
T_1 – Control	41.1	58.2	73.4	6.55	5.30	0.650	423.0	140.0	4480	3904	5750
T_2 – 100% RDF	42.5	64.2	80.3	8.70	6.05	0.879	464.0	162.0	4728	4260	6262
T_3 – 125% RDF	42.8	72.6	88.2	9.44	6.32	0.913	481.0	171.0	4874	4552	6607
T_4 – 100% RDF + Press mud at 10 t ha^{-1} + 2% ZSB	45.1	74.8	91.7	11.14	6.85	1.102	519.0	197.0	5163	5143	7471
T_5 – 100% RDF + Vermicompost at 6 t ha^{-1} + 2% ZSB	45.9	76.0	92.7	12.08	7.14	1.141	534.0	205.0	5302	5430	7863
T_6 – 100% RDF + Coirpith compost at 6 t ha^{-1} + 2% ZSB	41.5	69.8	86.5	10.13	6.53	1.069	501.0	186.0	5024	4864	7059
T_7 – 125% RDF + Press mud at 10 t ha^{-1} + 2% ZSB	53.2	86.8	105.2	13.72	7.77	1.240	568.0	219.0	5584	6012	8598
T_8 – 125% RDF + Vermicompost at 6 t ha^{-1} + 2% ZSB	54.1	88.3	106.8	14.50	8.02	1.285	585.0	227.0	5720	6293	8943
T_9 – 125% RDF + Coirpith compost at 6 t ha^{-1} + 2% ZSB	50.1	82.1	99.4	12.94	7.45	1.183	552.0	213.0	5444	5715	8237
S.Ed	**0.92**	**1.55**	**1.87**	**0.23**	**0.13**	**0.02**	**10.19**	**3.88**	**98.25**	**105.10**	**150.74**
CD (p=0.05)	**1.96**	**3.28**	**3.97**	**0.50**	**0.29**	**0.04**	**21.60**	**8.22**	**208.28**	**222.81**	**319.56**

Note: ZSB – Zinc Solubilizing Bacteria, TS – Tillering stage, PIS – Panicle initiation stage, HS – Harvest stage

3.5 Number of Panicles m^{-2}

Among the various combinations experimented with, the maximum number of panicles m^{-2} of 585 was recorded in the treatment T_8 (125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria) and it was on par with T_7 (125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) of 568. Highest number of panicle m^{-2} may be due to enhanced and continuous supply of nutrients by the vermicompost. This was also confirmed by Bejbaruah et al., [21]. The lowest number of panicles m^{-2} was recorded in the absolute control T_1 of 423 respectively.

3.6 Number of Grains Panicle^{-1}

Among the various combinations experimented with, the maximum number of grains panicle^{-1} of 227 was recorded in the treatment T_8 (125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria) of 227 and it was on par with T_8 (125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) of 219. Enhanced and continuous supply of nutrients by the addition of organics leading to better number of grains panicle^{-1} [22]. This result is similar to the reports of Deytarafder et al., [23]. The lowest number of grains panicle^{-1} was recorded in the absolute control T_1 of 140 respectively.

3.7 Dry Matter Production

Among the various treatments, the application of 125% RDF + + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) significantly recorded the highest dry matter production of 5720 kg ha^{-1} and was on par with the application of 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) of 5584 kg ha^{-1}. "Increase in DMP due to zinc and organic manures might be due to intermediates / metabolites of decomposing organic manures that hold zinc in the form available to plant or release of Zn mobilizing compounds such as phytosiderophores from roots and induction of polypeptide involved in Zn uptake and translocation to shoot" [24], Cakmak and Braun, [25]; Ahmad et al., [26]). The higher DMP might be due to increased leaf area due to sustained and enhanced availability of nutrients from the combined source of vermicompost and inorganic fertilizer till the maturity that would have enhanced better biomass production. The lowest dry matter production was recorded in the absolute control T_1 of 4480 kg ha^{-1} respectively.

3.8 Grain Yield and Straw Yield

In respect of grain yield and straw yield, among the various treatments observed, application of 125% RDF + + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) recorded significantly highest value of 6293 kg ha^{-1} and 8943 kg ha^{-1}. This might be due to the higher amount of nutrients supplied through vermicompost along with inorganic fertilizer, which has increased the availability of nutrients in the soil, thus more uptake of nutrients and increased photosynthetic efficiency as evident from increased LAI resulted in higher grain yield and straw yield. This result is similar to the reports of Ramalakshmi et al., [27] and Kumar et al., [28]. The control plot recorded the lowest grain yield and straw yield.

The combined use of organic fertilizers and microorganisms that promote plant growth are two strategies that contribute to soil biodiversity [3,29]. There are works in which microorganisms with properties to promote plant growth have been incorporated into the substrates used as fertilizers with satisfactory results. Similarly, Chirinos and Olivares [30] mention outstanding effects on growth and productivity in crops, when using biofertilizers, significantly reducing the use of chemical fertilizers. State-of-the-art technologies must focus on the sustainable maintenance of a system, in such a way that the use and application of resources must be conceived to conserve the environment [31,32,33].

4. CONCLUSION

Based on the above experimental results, it could be concluded that the cultivation of rice with an application of 125% RDF + Vermicompost at 6t ha^{-1} + 2% Zinc Solubilizing Bacteria was found to be agronomically and economically viable, practice for augmenting higher production. Hence this can be recommended by the rice-growing farmers in Tamil Nadu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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