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Soil Tailored Fertilizers Boost Rice Yield & Profit in NICRA Village Farmers in Tamil Nadu, India

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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

Knowledge on soil fertility is crucial for managing the nutrients in a particular soil. Deterioration of soil fertility may be due to imbalanced fertilizer application without soil testing and continuous high-yield cropping. Under the National Innovation and Climate Change for Agriculture (NICRA) project, this study was conducted to assess the village's soil fertility status and suggest the ideal fertilizer dosage. A total of 50 soil samples were collected and analyzed for different soil parameters in the Naduvananthal village of Mailam block, Villupuram district. The soil pH, available potassium, phosphorus, and nitrogen, organic carbon, and electrical conductivity (EC) were analyzed. The Electrical Conductivity shows a neutral to alkaline response in the soils. The soil had low to moderate levels of organic carbon and low to moderate levels of available nitrogen, phosphorus and potassium. The recommendations for rice nutrients were determined by taking into account the

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various soil properties that were observed. Given that soil fertility is low in available nitrogen, medium in available phosphorus, and high in available potassium, this ensures that rice will absorb nutrients in a balanced manner. The recommendation for the rice crop according to the farmer's practice was 130:58:75 kg NPK hectare^{-1} the recommendation for fertilizer based on soil testing was 150:50:50kg NPK hectare^{-1}. This results in a reduction of up to Rs. 890 ha-1 in cultivation costs, while also maintaining balanced nutrition and increasing rice productivity with additional returns of 530 kg ha^{-1}.

Keywords: Paddy; recommended fertilizer dose; NICRA; balanced nutrition; supplementary returns.

1. INTRODUCTION

In agricultural systems, one of the most crucial aspects of soil fertility that determines productivity is the soil capacity to support crop development for maximum crop-output. Numerous processes that impact soil fertility and output are determined by a range of soil characteristics. A detailed knowledge of the physical, chemical, and biological characteristics of these soils can help us better understand their dynamics**.** The inherent potential of these soils for crop production as well as the challenges associated with effectively managing them to achieve higher production may be easily understood by characterizing them. Fertility of the soil constitutes one of the key elements influencing crop yield. Intensive agriculture has drastically decreased the chemical fertilizer nutrients' response in recent years (Yadav & Meena, 2009, Sathish et al., 2017).

It is crucial to understand soil fertility in order to regulate nutrients for a site specific soil. The decline in soil fertility may be caused by continuous high-yield cropping, unbalanced fertilizing and a lack of soil testing (Satish Gaikwad, 2025). The "National Innovations in Climate Resilient Agriculture (NICRA)" project involved the collection of 50 soil samples from Naduvananthal village, Mailam block, Villupuram district. The soil parameters, including soil pH, EC, organic carbon, available nitrogen, available phosphorus, and available potassium, were examined in these samples in order to determine the best fertilizer recommendations for rice.

2. METHODS AND MATERIALS

2.1 Location of the Study

The Naduvananthal village, which is situated in the North Eastern Zone (NEZ) of Tamil Nadu at 11.94596° N Latitude, 79.49741° E Longitude, is under the Mailam talukof Villupuram district. The sandy loamy soil type was found in the area under demonstration. The study area receives 850–900 mm of rain on average annually, and the relative humidity falls between 45 and 85 percent.

2.2 Soil Sample Collection and Analysis

A single sample of soil (0–30 cm) was taken from 5–6 hectares of the village's cultivated area in 2024 prior to the NICRA demonstrations. For every soil sample taken in the research area, the coordinates were entered using GPS (Mullick, *et al*, 2022). Before being processed for analysis, the soil samples were allowed to air dry. Standard analytical procedures were used to analyse the nutrient availability in processed samples**.** Soil samples were tested for pH and electrical conductivity using a 1:2.5 Soil: Water suspension (Jackson, 1973). Following the fine grinding of the soil and its passage through a 0.2 mm sieve, the amount of organic carbon was measured using the wet oxidation method as outlined by Jackson (1973) and expressed as a percentage by Walkely and Black (1934). To determine how much nitrogen was available, Subbiah and Asija's (1956) potassium permanganate method was applied. According to standard protocols, the amount of available potassium and phosphorus was estimated, (Jackson, 1973) (Table 1).

2.3 Fertilizer Dose Information

Prior to the rice demonstrations, the selected farmers were given recommendations regarding the fertilizer dosage based on the findings of the soil test. Yield observation was recorded during crop harvest in order to examine the effects of fertilizer use based on soil tests in maintaining the yield and reducing the cost of cultivating rice crops.

Table 1. Critical limits for various soil parameters (Anuratha *et al*., 2019)

S. No	Parameters	Ratings		
1	Soil pH	<6.5(Acidic)	6.5-8.5 (Neutral)	>8.5 (Alkaline)
2	Soil EC (dSm^{-1})	< 1.0 Non-saline)	1.1-3.0 (Slightly saline)	> 3.0 (Saline)
		Low	Medium	High
3	Soil Organic carbon	<0.5	0.5 - 0.75	>0.75
4	Soil Available Nitrogen (kg/ha)	<280	280 – 450	>450
5	Soil Available Phosphorus (kg/ha)	<11	11 -22	>22
6	Soil Available Potassium (kg/ha)	<118	118-280	>280

3. RESULTS AND DISCUSSION

3.1 Soil pH

Table 2 results indicated that the P^H of soils in Naduvananthal village ranging from 6.5 to 8.5. The findings demonstrated that the soil reacted neutrally to alkalinity, with 70% of the area being alkaline (pH 7.5-8.5) and 30% being neutral (pH 6.5-7.5).

3.2 Soil EC

Average electrical conductivity of soil samples in the village of Naduvananthalwas 0.40 dSm^{-1}, with a range of 0.08 to 0.80 dSm^1. According to the results, the soil's electrical conductivity was normal, and 95 percent of the area was normal (less than 1 dSm^{-1}), while 5 percent had a hint of saline. (1.5-3.0 dS m^{-1}).

3.3 Organic Carbon

In Naduvananthal village, the average organic carbon content of the soils was 0.20 percent, with a range of 0.04 to 0.30 percent (Table 2). It was roughly 100% of the area. Low levels of organic carbon in the soil were caused by low levels of FYM and crop residues supplemented by high temperatures, as well as the fast rate of decomposition brought on by these ingredients. Many farmers may be monocropping cereals, which contributes to the low levels of organic carbon in these regions. These outcomes were consistent with those published by Waikar et al. (2006).

Table 2. Major nutrient status in soil samples taken from the village of Naduvananthal

	Soil pH	Soil EC (dSm^{-1})	Soil OC (%)	Soil Available N	Soil Available P_2O_5	Soil Available K_2O
Range	6.5 to 8.5	0.08 - 0.80	0.04 - 0.30	100-210	17-30	120-250
Mean	7.5	0.40	0.20	110	14	130

Table 3. Comparisons between general guidelines and fertilizer recommendations based on soil tests.

Crop	Parameters	Fertilizer quantity (NPK kg ha^{-1})	Yield (Kg/ha)	Net returns	B:C Ratio
Paddy	Based on Soil test (NPK kg ha^{-1})	150:50:50	5480	57,500	2.70
	Farmers practice-fertilizer recommendations (NPK kg ha^{-1})	130:58:75	4859	52,600	2.48

Table 4. Comparisons between fertilizer recommendations based on soil tests and those based on general recommendations in terms of both quantity and cost

Fertilizers	Paddy			
	NPK quantity per hectare (Farmers practice)	Cost of fertilizer for 1 ha	NPK quantity per hectare (Soil test based recommendations)	Cost of fertilizer for 1 ha
Urea	350 kg/ha	2177	325 kg/ha	2021
SSP	330 kg/ha	2970	312 kg/ha	2808
MOP	100 kg/ha	3000	83 kg/ha	2500
Total	780 kg/ha	8,147	720kg/ha	7,329

Note: Urea – Rs.6.22/kg; SSP-Rs. 9/kg; MOP- Rs.30/kg.

3.4 Available Nitrogen

The available nitrogen content in soil samples from Naduvananthal village in the study area varied between 100 and 210 kg ha-1. About 80% of the area was low, and 20% of the area was medium. Like the amount of organic carbon, these soils had little available nitrogen. The application of FYM, fertilizer to the prior crop, and soil management were all factors in the variation in N content. (Priyadarsini & Prasad, 2003; Meena & Rakshit, 2017).

3.5 Available Phosphorus

In Naduvananthal village, the available P_2O_5 varied between 17 and 30 kg ha^{-1} (Table 2). About 65% of the area had a medium amount of available phosphorus, and 35% had a high amount. SSP (Single Super Phosphate) is the most widely used phosphorus fertilizer in the region.Without understanding the crop needs and soil availability; farmers frequently apply excessive amounts of SSP fertilizer. Thus, medium-available phosphorus was found in the majority of the regions. The degree of soil weathering or disturbance, the degree of P-fixation with Fe and Ca, and the continuous use of mineral P fertilizer sources are also associated with variations in the amount of P that is readily available in soils, according to Paulos Dubale (1993).

3.6 Available Potassium

The soil samples in Naduvananthal village had a potassium content ranging from 120 to 250 K_2O kg ha^{-1}, as indicated in Table 2. There were about 14 percent of the area with low potassium availability, 62 percent with medium potassium availability, and 24 percent with high potassium availability. As Patiram and Prasad (2003) previously reported, the presence of K-rich minerals in the soil is associated with the high K status in these soils.

4. MANAGEMENT OF NUTRIENTS AND FERTILIZER RECOMMENDATIONS

Applying fertilizer according to the results of soil tests would help crops get balanced nutrients, reduce over application, stop too much nutrient mining from the soil, and save cultivation costs. Based on the soil test results, recommendations for fertilizer and soil management were made for various crops. The amount of organic carbon in the soil in the village of Naduvanandhal is low to medium. Applying organic matter, such as FYM, vermicompost, green manuring, and crop residues, is advised to preserve a sufficient amount of organic carbon in the soil and enhance its physical, chemical, and biological properties.

In addition to the recommended fertilizer dosage for rice, 25 kg ha-1 of additional nitrogen fertilizer is recommended wherever there is low nitrogen availability, as the soils in the project area had low to medium levels of nitrogen availability (Chaudhary et al., 2025) (Table 2).It was suggested that the P_2O_5 dosage be reduced by 5 kg ha^{-1} in comparison to the recommended fertilizer for rice because phosphorus fertilizer (SSP) is very expensive and nearly 42% of the land is medium in P_2O_5. Since the village's soil had a medium available potassium content of 24%, it was advised to reduce potassium (K_2O) by 10 kg ha^{-1} in order to cut down on luxury consumption.

4.1 Fertilizer Recommendation based on Soil Test

Based on site-specific nutrient status, fertilizer recommendations were given to all of the farmers who benefited from the operational research project that was conducted in this area. When this strategy is used, only the necessary nutrients are given to a particular crop and land compared to the Tamil Nadu agricultural production guide's recommended fertilizer. All of the nutrients required by the crop and the soil's capacity to supply them are provided by site-specific nutrition. As a result, only the necessary amounts of nutrients have been provided, nutrition has been balanced, and fertilizer costs have occasionally decreased.

4.2 Recommended Fertilizer for Rice

The available nitrogen and soil organic carbon in the farmer's field were low, while the available potassium and phosphorus were medium to high. Fertilizer recommendations based on farmers' practices were 138:58:75kg NPK, while soil test results for rice crops indicated 160:50:50 kg NPK per hectare. The cost of cultivation is reduced by up to Rs 890 ha^{-1}, balanced nutrition is preserved, and rice productivity is raised by an additional 530 kg ha^{-1}. The overall fertilizer cost was lowered by up to Rs.818 ha^{-1}. The benefit of providing balanced nutrition, which aided in the availability of nutrients to crops for improved growth and yield, was evident from the comparison with farmer practices and site-specific nutrient recommendations. (Smaling & Braun, 1996; Jat et al., 2013; Anuratha *et al*., 2019).

5. CONCLUSION

Based on the fertility status, balanced and location-specific fertilizer recommendations have been formulated for rice cultivation to optimize higher yield and maintain soil health. These recommendations emphasize the judicious use of NPK fertilizers, along with the application of deficient micronutrients and organic matter to ensure sustainable productivity. Overall, the study highlights the importance of regular soil testing and proper nutrient management for improving the productivity of rice in NICRA villages. Adoption of the recommended practices will not only enhance crop yields but also contribute to long-term soil sustainability and climate resilience in the NICRA implemented villages.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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