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Rice yield under long-term soil fertility management & correlation co-efficient analysis of soil properties

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Abstract
The excessive application of chemical fertilisers poses a significant threat to soil health and undermines the sustainability of agricultural practices over time. A research investigation entitled "Carbon Sequestration and Soil Health under Long-Term Soil Fertility Management in a Rice–Rice Cropping System" was carried out across the *Kharif* growing seasons of 2016–2017 and 2017–2018. The study was conducted at the Sultanpur District, as part of the farmers trials with KVK, Kushinagar experts. The primary objective of this research was to examine the relationship between rice yield and a range of soil properties, encompassing physical, chemical, and biological dimensions. The study's outcomes demonstrated that most soil parameters were positively correlated with both grain and straw yields. These results highlight the advantage of integrating organic manures with a well-balanced use of inorganic fertilisers, reinforcing the case for a combined nutrient management approach in sustaining soil health and agricultural productivity.

Keywords: Correlation analysis, soil pH, nitrogen, and rice yield

Introduction

The inappropriate and overuse of fertilizers frequently contributes to reduced crop production and the gradual degradation of soil quality. Achieving a proper nutrient equilibrium plays a crucial role in enhancing overall agricultural output. The persistent extraction of nutrients from the soil without sufficient restoration has progressively led to a decline in soil fertility over extended periods was reported by Nambiar and Abrol (1989) [1]. The integration of organic matter alongside chemical fertilizers has demonstrated notable improvements in both the condition of the soil and the overall performance of crops.

Continuous rice–rice cropping systems are increasingly confronting serious challenges related to long-term agricultural sustainability (Akbari, 2011) [2]. The primary driver behind this concern is the growing dependence on synthetic chemical fertilisers and pesticides that characterise contemporary farming methods. The prolonged use of such agricultural inputs tends to deteriorate soil structure, disrupt microbial communities, and compromise the overall quality of farm produce (Lal *et al*., 2007) [3].

Several critical issues have emerged as a consequence of intensive rice cultivation, including declining crop productivity, progressive loss of soil organic carbon, and growing imbalances in essential nutrient levels. These problems collectively threaten the productive potential of rice-based farming systems over time (Paul *et al*., 1997).

In this context, long-term fertilizer experiments serve as indispensable tools for evaluating how sustained and repeated nutrient applications shape both soil characteristics and crop output. Such research endeavours offer a meaningful and evidence-based understanding of the incremental transformations occurring in the physical, chemical, and biological attributes of soil (Sharma *et al.,* 2010; Katkar *et al.,* 2011). This accumulated knowledge plays a foundational role in formulating effective and environmentally responsible nutrient management strategies that can ensure the continued viability of rice cultivation systems.

Effective nutrient management is a cornerstone of achieving sustainable and productive rice cultivation. Since the decade of the 1960s, Indian agriculture has witnessed a remarkable transformation, predominantly propelled by the widespread adoption of high-yielding crop varieties and a substantial increase in fertilizer consumption. The use of fertilizers has undeniably emerged as one of the most influential factors in boosting overall agricultural output. Nevertheless, preserving soil quality and arresting the progressive decline in crop yields have surfaced as pressing concerns in contemporary farming.

Soil quality is broadly understood as the inherent capacity of soil to sustain healthy plant growth without undergoing structural or functional degradation. This capacity is collectively determined by the soil's physical, chemical, and biological characteristics, all of which must be maintained in a balanced state for long-term agricultural productivity. Against this backdrop, the present investigation was carried out with the following specific objectives:

Objectives

- To examine the influence of various organic amendments when integrated with inorganic fertilizers on the overall productivity of the rice–rice cropping system.

- To evaluate selected physical, chemical, and biological properties of the soil under different nutrient management treatments.
- To determine the most appropriate nutrient management practices capable of enhancing soil fertility and improving the overall quality of agricultural soil.

Materials and Methods

A long-term field experiment was originally initiated during the *Kharif* season of 2019, established under a continuous rice–rice cropping framework at the Sultanpur the current investigation (Dr. N. Goutami *et al*., 2018) [4] was carried out over the *Kharif* and *Rabi* cropping seasons spanning 2016–2017 and 2017–2018. This research was conducted as an integral component of the KVK, Kushinagar.

The experimental design encompassed a total of twelve treatment combinations, incorporating varying proportions of inorganic fertilizers alongside organic nutrient sources, including farmyard manure (FYM) and green manures. All treatments were laid out following a randomised block design (RBD) with three replications, maintained consistently across both cropping seasons over the two-year study period. Nitrogen was delivered through urea, divided into three equal split applications corresponding to the basal stage, tillering stage, and panicle initiation stage. Phosphorus was administered via di-ammonium phosphate (DAP), with appropriate adjustments made to account for its inherent nitrogen contribution. Potassium was supplied through muriate of potash, while zinc was provided in the form of zinc sulphate. Phosphorus, potassium, and zinc were uniformly applied as basal doses before crop establishment.

The recommended dose of fertilizers for the *Kharif* season was fixed at 90:60:60 kg ha^{-1} of N: P_2O_5: K_2O, whereas the *Rabi* season requirement was set at 180:90:60 kg ha^{-1}. Adequately decomposed farmyard manure and green leaf manure derived from *Calotropis* were incorporated into the soil approximately two weeks ahead of transplanting to ensure thorough integration.

The rice varieties selected for the study were Sarjoo-52 for the *Kharif* season and Narendra-97 for the *Rabi* season. Upon reaching maturity, both grain yield and straw yield were systematically recorded at the time of harvest for each respective season.

Soil samples were systematically collected from a depth of 0–15 cm, both following harvest and prior to transplanting operations. The collected samples were subsequently air-dried, appropriately processed, and carefully stored in preparation for laboratory analysis. All soil parameters were determined by adhering to well-established standard analytical procedures. The parameters assessed included bulk density, soil pH, electrical conductivity (EC) and a range of available nutrients comprising nitrogen, phosphorus, potassium, iron, copper, zinc, and Manganese. Bulk density was quantified employing the core sampling method, whereas soil pH was measured in a 1:2 soil-to-water suspension using a glass electrode pH meter. Available soil nutrients were assessed using the following methods: nitrogen (N) via alkaline potassium permanganate method as suggested by Subbaiah and Asija, 1956, phosphorus (P2O5) by colourimetric method using Olsen's extractant, and potassium (K2O) by flame photometry with neutral ammonium acetate extractant as described by Jackson, 1973. Statistical evaluation of the collected data was performed utilising the STPR software, developed by G.B. Pant University of Agriculture and Technology. Descriptive statistics and Pearson correlation coefficients were computed using Microsoft Excel and IBM SPSS Statistics v25. Furthermore, correlation coefficients among the studied variables were computed using SPSS software (Version 25). Photographs selected from KVK, Hardoi-II, On Farm Trials(OFT) during 2022-23.

Results and Discussion

Soil pH and EC

The data revealed that most of the physical parameters were positively and significantly correlated with grain and straw yield of rice, except pH of soil showed negative correlation with yields (Table 2) in both *kharif* and *rabi* seasons during both the years of study (2016-17 and 2017-18). The correlation values in grain and straw yields in *kharif* season in both the years of study is -0.625*, -0.577*, -0.633* and -0.567*) respectively. A significant negative correlation between soil pH and rice yield exists primarily in alkaline or saline-sodic soils (pH > 7.5–8.0), where high pH stresses the crop and reduces grain production. Research studies indicates that as soil pH increases above the optimal range (slightly acidic to neutral, pH 5.5–7.0), rice shoot weight, panicle number, and grain weight decrease significantly. In alkaline and saline-sodic soils, the high concentration of carbonate and bicarbonate ions causes alkali stress, which is a major limiting factor for rice production (Baishun Liu *et al*.,2025) [5]. The EC (electrical conductivity) values are positively significantly correlated with the rice yields in both the years of study in both the seasons. In *Kharif* season the EC values (0.592* and 0.579*) (Table 2) are high than the *rabi* season EC values (0.518* and 0.540*). Properly measured and interpreted, EC provides appositive predictive correlation with rice productivity, supporting precision agriculture interventions. Optimal management of EC related factors, along with nutrient and pH control, is essential to maximize the benefits of this correlation (Rashid Mustafa and Alauddin Ansari, 2024) [6].

Soil Nitrogen (N)

The nitrogen values demonstrated a highly positive correlation with both grain and straw yields across both seasons during the two years of study. The highest correlation values were observed in straw yields (0.971***, 0.957***) compared to grain yields (0.951***, 0.945***) in the first year of study (2016–17). Kumar *et al*. (2012 [7] also reported a positive correlation between soil nitrogen and crop yield. This strong association can be attributed to the fundamental role nitrogen plays in rice plant physiology.

As a primary macronutrient, nitrogen is directly involved in chlorophyll synthesis, which drives photosynthetic efficiency and supports vigorous vegetative growth. Sufficient nitrogen availability promotes active tillering, enhances leaf area development, and sustains overall plant biomass accumulation. In contrast, nitrogen-deficient conditions restrict cellular metabolism, leading to reduced dry matter production and ultimately lower grain yield. Since rice has a comparatively high nitrogen demand throughout its growth cycle, soils with adequate nitrogen content — particularly those receiving balanced organic and inorganic nutrient inputs — are better positioned to support higher productivity levels.

Training & Awareness on green manuring and management of rice nursery at KVK, Hardoi-II

Soil Phosphorus (P_2O_5)

The Phosphorus values shown that positive correlation with both grain and straw yields during both seasons in the two years of the study. The highest correlation value (0.883***) observed in grain yield during *kharif* season in 2017 and lowest correlation value observed in *rabi* grain yield in 2017 (Table 2) in the first year of study (2016-17). Positive Correlation is significant at the 0.01 level (2-tailed). According to Meena *et al*. (2017 [8] a rise in grain and straw output may be the result of increased photosynthetic activity brought on by an increase in leaf area index, which in turn stimulated the generation of dry matter and increased grain and straw yield. The availability of P influenced the uptake of other essential plant nutrients due to the role of P in the rice plant roots.

Soil Potassium (K20)

The Potassium values shown that highly positive correlation ($P<0.05$) with both grain and straw yields during both seasons in the two years of the study. The highest correlation value (0.873***) observed in grain yield during *kharif* season in 2017 and lowest correlation value (0.746**) observed in *rabi* straw yield in 2017 (Table 2) in the first year of study (2016-17). The second year studies (2017-18) showed the highest correlation values than the first year study (2016-17). Increased potassium uptake by rice plants is directly linked to higher biomass accumulation and grain yield, particularly up to a certain saturation point (Liu Shu-jun *et al*., 2025) [5]. A close relationship has been found between potassium accumulation in the plant internodes and the translocation of carbohydrates, directly supporting higher grain filling in high-yielding cultivars (Junko Ishikawa *et al*., 2023) [10].

Conclusion

Among the soil parameters evaluated, key macronutrients — Nitrogen, Phosphorus, and Potassium — exhibited a significant positive relationship with both grain and straw yield of rice. The combined application of compost, green manures, and chemical fertilisers enhanced nutrient availability through measurable improvements in the physical, chemical, and biological characteristics of the soil, ultimately contributing to higher rice productivity across both *Kharif* and *Rabi* cropping seasons.

With respect to soil chemical properties assessed at the time of harvest, the most notable improvements were recorded under the treatment comprising 100% RDF + $ZnSO_4$ + FYM @ 5 t ha^{-1}, with the next best response observed under the 50% NPK + 50% N through FYM treatment. These findings suggest that farmyard manure holds considerable potential as a partial substitute for synthetic fertilizers, thereby reducing dependence on inorganic nutrient inputs.

The incorporation of FYM @ 5 t ha^{-1} in combination with inorganic fertilizers not only supported sustained and economically viable crop productivity for smallholder farmers within a sensitive agro-ecosystem, but also contributed to the restoration of inherent soil fertility. Furthermore, this integrated approach enhanced both the nutritional profile and biological activity of the soil, reinforcing its long-term capacity to support productive and resilient rice-based farming systems.

Table 1: Initial properties of the experimental soil before starting of experiment in 1989

Particulars	VI Block
I. Mechanical analysis	
1. Sand (%)	42
2. Silt (%)	30
3. Clay (%)	28
Bulk density (Mg m^{-3})	1.35
pH (1:2.5)	7.55
EC (dS m^{-1})	0.89
Organic carbon (%)	0.57
Available N (kg ha^{-1})	302
Available P_2O_5 (kg ha^{-1})	16.0
Available K_2O (kg ha^{-1})	374.0

Table 2: Relationship of soil physical parameters with grain and straw yield of rice

Soil physical parameters	*Kharif,* 2016		*Kharif,*2017	
	Grain yield	Straw yield	Grain yield	Straw yield
pH	-0.625*	-0.577*	-0.633*	-0.547*
EC	0.592*	0.579*	0.518	0.540

*. Correlation is significant at the 0.05 level (2-tailed). (pH values)

Soil physical parameters	*Kharif,* 2017		*Kharif,* 2018	
	Grain yield	Straw yield	Grain yield	Straw yield
pH	-0.633*	-0.567*	-0.624*	-0.501*
EC	0.327	0.381	0.350	0.364

*. Correlation is significant at the 0.05 level (2-tailed). (pHvalues)

Table 3 Relationship of soil chemical parameters with grain and straw yield of rice

Soil physical parameters	*Kharif,* 2016		*Kharif,*2017	
	Grain yield	Straw yield	Grain yield	Straw yield
Nitrogen (N)	0.951***	0.971***	0.945***	0.957***
Phosphorus (P)	0.765**	0.763**	0.761**	0.780**
Potassium (K)	0.756**	0.765**	0.778**	0.746**

Soil physical parameters	*Kharif,* 2017		*Kharif,* 2018	
	Grain yield	Straw yield	Grain yield	Straw yield
Nitrogen (N)	0.956***	0.977***	0.958***	0.969***
Phosphorus (P)	0.883***	0.869***	0.817**	0.829***
Potassium (K)	0.873***	0.861***	0.802**	0.801**

***. Correlation is significant at the 0.001 level (2-tailed). (Nitrogen)

Competing interests disclaimer

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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