



# Impact of Combinations of Organic and Inorganic Fertilizers on Soil Health and Yield of Rice: A Comprehensive Review

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## Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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## ABSTRACT

As a cereal grain, rice is the staple diet of more than half of the world's population, especially in Asia and Africa. The grass species *oryza sativa*, also known as Asian rice, and, less frequently, *oryza glaberrima*, sometimes known as African rice, are the seeds of rice. African rice was domesticated in Africa approximately 3,000 years ago, while Asian rice was domesticated in China between 13,500 and 8,200 years ago. A staple in many cultures around the world, rice ranked fourth in terms of production in 2021 (787 million tons), behind wheat, maize, and sugarcane. The amount of rice traded worldwide is only about 8 percent. The three countries that consume the

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most rice are China, India, and Indonesia. Various rice cultivars have been developed to increase crop yield and quality. Green Revolution rice, made possible by biotechnology, can yield large amounts of grain when given nitrogen fertilizer and carefully tended. Additional products include flood-tolerant or deep-water rice, drought-tolerant and salt-tolerant rice, and rice that may express human proteins for therapeutic purposes. In biology, rice is utilized as a model organism.

**Keywords:** Rice; deep-water; fertilizer; cereal grain; soil health.

## 1. INTRODUCTION

“One of the most significant cereal crops in the world is rice (*Oryza sativa* L.). Over 70 percent of the world's population eats it as a staple diet. Around 155.62 million hectares of land are used to grow rice worldwide, with yields of 461 million tons and 4.09 t ha<sup>-1</sup> respectively. Drought and water scarcity are two major factors restricting rice production globally as a result of ongoing climate change. Iron (Fe) and aluminum (Al) toxicity, phosphate (P) shortage, reduced biological activity, poor base saturation, and other acidity-induced issues with soil plant nutrition and fertility are the key factors limiting Odisha soil productivity. One of the primary factors influencing rice production is nitrogen (N), and low crop nitrogen recovery in these troublesome soils necessitates a sustainable nitrogen management strategy to boost yield and improve use efficiency. Therefore, a combination of both inorganic and organic fertilizers is the ideal way to regulate soil fertility, with the inorganic fertilizer providing nutrients and the organic fertilizer primarily increasing soil organic matter, improving soil structure, and increasing the soil's buffering ability”, (Jobe, 2003). “The major components of INM framework are fertilizers, farmyard manure/compost, green fertilizer, trim residues/recyclable squanders and bio fertilizers” (Kumar et al., 2023). “4.18 million hectares of rice are grown in Odisha, with an average yield of 1815 kg ha<sup>-1</sup> and an annual production of 7.58 million tons. Odisha accounts for 8.51% of the nation's total gross area under rice cultivation. However, compared to the national productivity, its productivity is 33.55% lower”, (GOI, 2014). “The state economy is directly linked with improvements in production and productivity of rice in the state” (Das, 2010). Although this is typically relatively modest, a significant amount of nitrogen in rice soils occurs in the organic pool. Conclusive research suggests that increasing the soil's organic carbon content, initial soil nitrogen concentration, and applied fertilizer efficiency are more crucial for the development of irrigated rice.

Although rice consumes a lot of nitrogen, its fertilizer N efficiency in tropical climates is extremely low, seldom exceeding 50% and typically falling between 15% and 35% (De Datta et al.1983). Without applying organic amendments, the years-long use of inorganic fertilizers in rice fields changed the structure of the soil and reduced its fertility, (Sannathimappa et al., 2015).

## 2. EFFECT OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON GROWTH PARAMETERS AND YIELD OF RICE

Dutta and Sangtam (2014) revealed that “plant height, numbers of tillers and productive tillers increased significantly in all the treatments whereas, grain yield increased significantly in all the treatments”. Kumar et al., (2017) revealed that “using poultry manure in combination with urea, zinc, and other nutrients increased the amount of organic carbon, accessible N, P, K, and S in the soil beneath rice plants considerably more than using chemical fertilizer alone. The residual soil fertility significantly improved in the plots that had been treated with chemical fertilizers and poultry manure. It is also possible to draw the conclusion that using poultry manure performs better than applying manure alone. The combination of chemical fertilizers and organic manure increased the uptake of N, P, and K compared to the control. Similar finding was reported by” (Pandey et al.,2023). “Integrated nutrient management practice including FYM and recommended dose of NPK showed as best treatment with respect to growth and yield parameters like plant height, panicle length number of tillers and effective tillers, and grain test weight as compare to other treatments. The grain (46 q ha<sup>-1</sup>) and straw (51.3 q ha<sup>-1</sup>) yield of rice was registered higher in treatment (100% NPK+5 t FYM+ ZnSO<sub>4</sub>@25kg ha<sup>-1</sup> + Lime 3 q ha<sup>-1</sup>), followed by treatment (100% NPK+5 t FYM+ ZnSO<sub>4</sub>@25kg ha<sup>-1</sup>) with 44.8 and 50.2 q ha<sup>-1</sup> yield and lowest in control treatment (24.5 and 37.5q ha<sup>-1</sup>) (Sahu P, 2017). (Manimaran and

Prakash, 2018) found that, in comparison to other treatments, the 100% recommended dose of NPK kg ha<sup>-1</sup> (120:38:38) with soil application of 25 kg ha<sup>-1</sup> of Beema green granules at 20 DAT, foliar spray of pancha-gavya 3 percent at 30 DAT, and foliar spray of 750 ml ha<sup>-1</sup> of Nitrobenzene at 45 DAT increased the growth parameters of rice, including plant height, number of tillers per hill, LAI, and DMP. When compared to other treatments, the optimum treatment for growth and yield characteristics such as plant height, panicle length, number of tillers and effective tillers, and test weight was an integrated nutrition management strategy that included FYM and the recommended dosage of NPK. The grain (46 q/ha) and straw (51.3 q ha<sup>-1</sup>) yield of rice was registered higher in treatment (100% NPK (100:60:40 kg ha<sup>-1</sup>) +5 t FYM+ ZnSO<sub>4</sub>@25kg ha<sup>-1</sup> + Lime 3 q ha<sup>-1</sup>) followed by treatment (100% NPK+5 t FYM+ ZnSO<sub>4</sub>@25kg ha<sup>-1</sup>) with yield 44.8 and 50.2 q ha<sup>-1</sup> respectively and lowest in control treatment (24.5 and 37.5 q ha<sup>-1</sup>). Additionally, the findings imply that the rice production, soil fertility, and soil physical and chemical environment were all improved by the addition of organic manure (FYM) to inorganic fertilizer”, (Sahu et al.,2018).

### **3. EFFECT OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON N, P, K UPTAKE IN GRAIN AND STRAW OF RICE**

“The application of 50 percent of the recommended dose of nitrogen (through urea) and the remaining 50% of RDN through vermi-compost led to significantly higher grain (5520.8 kg ha<sup>-1</sup>) and straw yield (6264.9 kg ha<sup>-1</sup>) in addition to nutrient uptake (157.9, 30.7, and 166 N, P, and K kg ha<sup>-1</sup>, respectively) (Ranjitha et al., 2013). This was observed when the various nutrient management options were examined”. Bahadur et al., (2012) revealed that, “in comparison to RDF alone and its organic mixtures, rice's uptake of N, P, and K was higher when a higher nitrogen dose was applied together with zinc and RDF in conjunction with farm yard manure and bio fertilizers. The application of 1/3 N each of chemical fertilizer, FYM, and Azolla produced the maximum rice yield; however, 50% N of chemical fertilizer and 50% N of dhaincha were shown to increase K uptake” (Mohanty et al.,2013). “When combined, the use of both organic and inorganic nutrition sources

significantly improved rice yield, yield characteristics, and nutrient uptake. When compared to other treatments, yields, yield characteristics, and nutrient uptake were significantly greater for 125% RDF + 5 tha<sup>-1</sup> vermi-compost, followed by 100% RDF + 5 tha<sup>-1</sup> vermi-compost. The number of panicles (20.50%), panicle length (23.12%), panicle weight (13.02%), 1000 grain weight (12.90%), grain yield (31.15%), straw yield (37.12%), protein content (18.77%), N uptake in grain (36.81%) and straw (42.81%), P uptake in grain (32.62%) and straw (31.56%), and K uptake in grain (35.46%) and straw (25.39%) were all higher than the control group when 125% RDF + 5 tha<sup>-1</sup> vermi-compost was added. The control group had a poorer yield, yield characteristics, gross return, and nutrient uptake” (Kumar et al., 2014; Puli et al., 2017). “The results of experimentation revealed that significantly higher nitrogen phosphorus and potassium uptake (131.32, 26.95 and 113.07 kg ha<sup>-1</sup> respectively) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and also higher available nitrogen (269.40 kg ha<sup>-1</sup>) available phosphorus (86.95 kg ha<sup>-1</sup>) was observed with the application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, it was followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (262.62 kg ha<sup>-1</sup>)” (Kumar et al., 2018).

### **4. EFFECT OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON PHYSICO-CHEMICAL PROPERTIES OF SOIL**

“Bulk density and pore space were found to be at their highest in INM practice, which included vermi-compost and the recommended dosage of NPK (Kannan et al.,2013). The FYM treatments had the highest reported particle density. The highest amount of organic carbon was found in the INM treatment, which included vermicompost and the suggested dosage of NPK” (Zayed et al., 2013) claimed that in terms of their capacity to raise soil organic matter content and soil nutrient availability, the applications of 7 t ha<sup>-1</sup> farmyard manure + 110 kg Nha<sup>-1</sup> and 5 t ha<sup>-1</sup> rice straw compost + 110 kg Nha<sup>-1</sup> were equivalent and both were superior to the use of chemical nitrogen fertilizer alone. Rao et al., (2013) reported that pH of soil was not influenced statistically by various treatments. The

continuous use of manures and fertilizer slightly lowered the pH. Increased dose of fertilizer decreased the pH (Yaduvanshi et al. 2013). The SOC increased in plots receiving N120 P26 K42 plus green manure (GM) and N120, P26, K42 plus farmyard manure (FYM) by 28 and 23 percent over the initial value but decreased by 31 and 24 percent in unfertilized and N120, P26, K42 treated plots, respectively. Lungmuana et al. (2013) reported "chemical fertilizers and vermi-compost furnished the highest amount of available phosphorus in the rhizosphere and produced the highest rice grain yield. These parameters were found to be significantly and positively correlated. Application of S (40 kg ha<sup>-1</sup>), Zn (5 kg ha<sup>-1</sup>) and B (1.5 kg ha<sup>-1</sup>) along with NPK (120:60:60) in rice with other treatments RDF + S, Zn, B (40:05:1.5 kg ha<sup>-1</sup>), customized fertilizer with composition of N:P:K:Zn:B:11:32:13:0.9:0.24% @ 312.5 kg ha<sup>-1</sup>, 75% RDF + 25% N through sewage sludge, 75% RDF + 25% N through vermi-compost, 75% RDF + 25% N through Sesbania indicated that application of Sesbania perhaps increased N, P, B and Zn in soil while inorganic S, B and Zn fertilizers had residual effect in post-harvest soil" (Gour et al., 2015). "Application of FYM (1/3) + vermi-compost (1/3) + green leaf manure (1/3) equivalent to 100 kg recommended N ha<sup>-1</sup> with recommended FYM (5 t ha<sup>-1</sup>) + microbial consortium with soil application of bio digester @ 2500 l ha<sup>-1</sup> at 30, 60 and 90 DAS recorded higher organic carbon (5.97 g kg<sup>-1</sup>), available soil nitrogen (310.46 kg ha<sup>-1</sup>), phosphorus (30.90 kg ha<sup>-1</sup>), potassium (328.16 kg ha<sup>-1</sup>) and sulphur (15.16 ppm) in soil after harvest of rice under aerobic cultivation" (Basha & Basavarajappa, 2015). "The results revealed that highest organic carbon, cation exchange capacity, available and total nitrogen, phosphorus, and potassium were recorded where organic, inorganic and biofertilizers were applied conjunctively" (Singh & Dubey, 2018). "The application of NPK along with organic residues increased the pH, EC, organic carbon. The content of available S and Ca improved significantly over the control. The content of S and Ca ranged from 16.87 to 30.41 ppm and 141.87 to 268.53 ppm, respectively at the surface layer and 15.07 to 22.51 ppm and 108.21 to 308.61 ppm, respectively at the sub-surface layer. The partial replacement of N through FYM, wheat straw and mung straw caused significant improvement in soil physico-chemical properties. In all the treatments of sub-subsurface layer nutrient status decreased as compared to surface layer except in case of pH, bulk density and Calcium.

The treatment where 25 percent N was applied through FYM and 75 percent through NPK fertilizer and the other treatment where 50 percent N was applied through mung straw and 50 percent through NPK were found best among all the treatments" (Bhatt et al., 2019).

## 5. EFFECT OF ORGANIC AND INORGANIC NUTRIENT SOURCES ON AVAILABLE NUTRIENT CONTENT OF SOIL

Singh et al. (2006) found that applying vermi-compost had the largest amount of accessible phosphorus, followed by FYM, green manuring, and residue incorporation. Due to the production of CO<sub>2</sub> and organic acids during decomposition, which assisted in solubilizing the native soil P, the soil's accessible p content rose. Urkurkar et al. (2010) claimed that using farmyard manure, composted rice straw, and green manure along with 50 percent of the prescribed fertilizer dosage greatly raised the soil's accessible P content compared to the starting value and control. Shilpashree et al. (2012) studied the effect of different nitrogen sources on yield and revealed that lower available nitrogen status was recorded in the treatments which received nitrogen only through fertilizers and without any organic matter application (196.00-200.50 kg ha<sup>-1</sup>) including absolute control compared to all other treatments (238.00-243.60 kg ha<sup>-1</sup>). Kumar et al., 2018 observed that higher available nitrogen (269.40 kg ha<sup>-1</sup>) available phosphorus (86.95 kg ha<sup>-1</sup>) was observed with the application of RDF + Vermi-compost + PSB + 25% Nitrogen through Glyricidia. However, it was followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (262.62 kg ha<sup>-1</sup>).

## 6. EFFECT OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON MICROBIAL ACTIVITIES AND POPULATION IN SOIL

Basha et al. (2016) reported higher soil microbial population viz., N fixers, PSB, spp. and soil enzyme activity of dehydrogenase and phosphatase at flowering and harvest with the application of FYM (1/3) + vermi-compost (1/3) + green leaf manure (1/3) equivalent to RDN of 100 kg ha with recommended FYM (5 t ha<sup>-1</sup>) and microbial consortium (+ PSB) with soil application of bio-digester in aerobic

rice. Liu et al. (2017) described that organic amendments (NPK + pig manure) produced more favorable effects on soil productivity and exhibited the highest levels of nutrient availability, microbial biomass carbon (MBC), activities of most enzymes and the microbial community. This resulted in the highest soil quality index (SQI) and rice yield, indicating better soil fertility and quality. Significant differences in enzyme activities and the microbial community were observed among the treatments also. Goutami et al. (2018) reported "highest enzyme activity was observed with application of 100 % NPK + ZnSO<sub>4</sub> +FYM (both Kharif and Rabi) which was significantly superior over remaining treatments. The application of zinc did not show any significant effect on enzyme activity". Raghavendra et al. (2018) reported "highest phosphatase activity (14.91 µg PNP g<sup>-1</sup> soil hr<sup>-1</sup>) of soil with application of nutrients as per targeted yield approach as compared to absolute control (9.47 µg PNP g<sup>-1</sup> soil hr<sup>-1</sup>). Application of nutrients as per site specific nutrient management (SSNM) approach for targeted yield of 55 q ha<sup>-1</sup> for dry Direct Seeded Rice (DSR) registered significantly higher soil microbial population viz., bacterial (25.73×10<sup>6</sup> cfu g<sup>-1</sup> of soil), fungal (8.62 × 10<sup>3</sup> cfu g<sup>-1</sup> of soil) and actinomycetes (10.14 × 10<sup>4</sup> cfu g<sup>-1</sup> of soil) over farmers practice and other soil test methods". Upadhyay et al., (2019) stated that "combined application of organic source of nutrient and inorganic fertilizers increases nutrient synchrony and reduces losses leading to sustainable productivity. They observed that application of panchagavya (blend of five cow products i.e. dung, ghee, curd, urine and milk) at seedling root dip + one spray at 30 days after transplanting-DAT @ 6% + application through irrigation water at 60 DAT produced higher soil bacterial and fungal population, and dehydrogenase activity". Rajput et al., (2019) showed that "significantly higher magnitude of soil organic carbon, microbial biomass carbon, microbial quotient, available nitrogen, and enzymatic activities (dehydrogenase, alkaline phosphatase and urease) was obtained in T6 (mix of wheat + rice compost) and T7 (green manure) than biochar T2(rice compost) and T5(wheat compost) and crop residue amendments. The experimental results imply that composting of crop residues could be the most reliable practice to improve soil nutritional quality as well as crop growth for sustainable rice–wheat cropping system in the hilly area".

## 7. CONCLUSION

Several types of rice found in India have therapeutic qualities and meet the criteria for a health food according to both contemporary and traditional ideas. Due to pressure from high-yielding cultivars and other cash crops, these varieties are rapidly going extinct, hence conservation is desperately needed. It is imperative that these types be vigorously marketed and promoted by raising public knowledge of their significance, particularly among the younger population. Establishing a niche in the global market requires clinical evidence of their medicinal benefits (just how China sells red rice yeast worldwide). Promoting and preserving this national treasure as a nutritious food is essential to halting the rise of diseases linked to a poor lifestyle.

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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 writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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