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Effect of integrated application of FYM and zinc on nutrient availability in soil-plant system of Rice (*Oryza* *Sativa* L.)

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Abstract

Continuous intensive cropping and micronutrient deficiencies degrade soil health and reduce nutrient use efficiency. The study evaluated the effect of farmyard manure (FYM) and zinc on post-harvest soil properties and nutrient uptake in rice under western Uttar Pradesh conditions. A field experiment was conducted during the *Kharif* season of 2023 in a randomized block design with seven treatments and three replications using rice variety Pusa Basmati 1718. Integrated nutrient management improved soil fertility and nutrient content in plants compared with the control. The treatment with 90% of recommended fertilizer dose, FYM at 2.5 t ha⁻¹ and zinc at 12.5 kg ha⁻¹ produced the highest available nitrogen, phosphorus and potassium in soil, as well as the highest N, P and K content in grain and straw. Zinc at 25 kg ha⁻¹ recorded the highest DTPA-extractable soil zinc and the highest zinc content in grain and straw. FYM also increased soil organic carbon and slightly lowered soil pH. Combined application of 90% recommended dose of fertilizer (RDF) + 2.5 t ha⁻¹ FYM + 12.5 kg ha⁻¹ Zn (T₇) optimized nutrient availability, yielding the highest post-harvest available nitrogen (216 kg ha⁻¹), phosphorus (16.50 kg ha⁻¹) and potassium (220.6 kg ha⁻¹), while 100% RDF + 25.0 kg ha⁻¹ Zn (T₆) maximized DTPA-extractable soil zinc (0.86 mg kg⁻¹). Integrated application of organic manure and zinc fertilizers significantly improves nutrient content and maintains soil fertility, statistically non-significant change as observed for soil pH or electrical conductivity. The combined application of FYM and zinc application improved soil health, nutrient availability and nutrient content in crop. The results suggest that using organic manure with RDF and zinc can support more sustainable rice production in similar agro-ecological conditions.

Keywords: FYM, productivity, soil health, zinc

Introduction

Soil fertility decline in intensive agricultural systems has become a matter of great concern across the world. Continuous cropping, high nutrient removal and inadequate addition of organic residues gradually reduce soil organic carbon and decrease the soil ability to supply nutrient. In cereal-based production systems, such deterioration presents a serious challenge to sustainable productivity and long-term resource conservation. Indian soils are deficit in organic matter and increasingly affected by micronutrient deficiencies. Among micronutrients, zinc deficiency has become a widespread constraint in rice-based systems. Rice is especially sensitive to zinc imbalance due to soil submergence, alkaline reaction and low organic carbon. As a result, nutrient uptake, crop growth and soil fertility maintenance are adversely affected in many rice-growing areas.

In western Uttar Pradesh, rice is grown under intensive management and is an important component of the regional production system. The soils are often slightly alkaline and low in organic carbon and available zinc, conditions that can restrict nutrient availability and uptake by rice. Nutrient application significantly influences nutrient content, uptake and residual soil fertility in rice grown on clay loam soils. Therefore, strategies that improve both soil properties and crop nutrient uptake are of considerable importance.

Among the available nutrient management options, farmyard manure (FYM) and zinc deserve special attention because of their complementary roles in soil and plant nutrition. FYM is an important source of organic matter and improves soil physical condition, microbial activity and

nutrient retention (Alvarez *et al.*, 2023) ^[1]. Zinc is an essential micronutrient for several physiological and biochemical processes that regulate plant growth and nutrient metabolism (Tabassum *et al.*, 2014) ^[9]. Previous studies have shown positive effects of zinc and organic inputs on rice productivity and soil health, particularly under Zn-deficient conditions. However, most available studies have focused mainly on growth and yield response, while fewer reports have examined the combined influence of FYM and zinc on post-harvest soil properties and nutrient content under the specific agro-ecological conditions of western Uttar Pradesh. Therefore, an experiment was conducted to study the effect of FYM and zinc application on soil properties and nutrient content of rice under western Uttar Pradesh conditions. The study was aimed at assessing the changes in soil fertility status and nutrient content of rice under different FYM and zinc treatments for developing an efficient and sustainable nutrient management approach.

Methods and Materials

A field experiment was conducted during the *Kharif* season of 2023 at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, India. The experimental site is located in the Upper Gangetic Plains of western Uttar Pradesh at 29°40' N latitude, 77°42' E longitude and 237 m above mean sea level. The site had a uniform topography, assured irrigation and adequate drainage facilities.

During the crop season, weather data were recorded from the SVPUAT meteorological observatory. The total rainfall received during the crop growth period was 925.6 mm. Before transplanting, composite soil samples were collected from the 0–15 cm depth and analyzed for initial physico-chemical properties. The experimental soil was clay loam in texture and soil pH was 7.85.

Table 1: Soil chemical properties of experimental field

Parameters	Value
Electrical Conductivity	0.20 dS m ⁻¹
Organic Carbon	0.40%
Available Nitrogen	190 kg ha ⁻¹
Available Phosphorus	13.6 kg ha ⁻¹
Available Potassium	196 kg ha ⁻¹
DTPA extractable Zinc	0.51 mg kg ⁻¹

The experiment was laid out in a randomized block design with seven treatments and three replications. Rice variety Pusa Basmati 1718 was used as the test crop. The treatments were: T₁, control; T₂, 100% RDF; T₃, 90% RDF + FYM @ 2.5 t ha⁻¹; T₄, 100% RDF + Zn @ 5.0 kg ha⁻¹; T₅, 80% RDF + FYM @ 5.0 t ha⁻¹; T₆, 100% RDF + Zn @ 25.0 kg ha⁻¹; and T₇, 90% RDF + FYM @ 2.5 t ha⁻¹ + Zn @ 12.5 kg ha⁻¹.

Results and Discussion

Effect on pH, E.C. and O.C.

The combined application of FYM and zinc significantly influenced organic carbon, but soil pH and EC remained statistically unaffected. Soil pH decreased with the increase in FYM application (Table 2). The highest soil pH value (7.84) was observed in T₁ (control), and the lowest value of 7.64 was recorded with FYM at the rate of 5.0 t ha⁻¹. No statistically significant differences in soil electrical conductivity were observed among the treatments. The organic carbon content of soil was significantly increased with FYM incorporation. The maximum carbon content (0.58%) was observed with the application of 80% of RDF along with FYM @ 5.0 t ha⁻¹ (T₅), which was significantly superior to the other treatment and was

followed by T₇. On the other hand, the control treatment (T₁) recorded the lowest organic carbon content of 0.38%.

The increase in soil organic carbon and reduction in soil pH was mainly due to the decomposition of FYM which adds stable organic matter to the soil and release organic acids that temporarily acidify the soil environment. Similar improvements in soil organic carbon and reductions in soil pH following FYM application have also been reported by Rangaswamy *et al.* (2023) ^[7], Meena *et al.* (2018) ^[5] and Sanwal *et al.* (2023) ^[8].

Effect on Available N, P, K and zinc

Application of FYM @ 2.5 t ha⁻¹ along with 12.5 Zn kg ha⁻¹ and 90% RDF recorded highest available N, P, K content in the soil (Table 2). The available Nitrogen, P and K content in the soil ranged from 185.3 kg ha⁻¹ to 216.0 kg ha⁻¹, 12.30 to 16.50 kg ha⁻¹ and 185.6 kg ha⁻¹ to 220.6 kg ha⁻¹ respectively. The highest zinc content was observed with the application of treatment T₆. The minimum soil available N, P, K and zinc was observed with the control T₁.

The improvement in the availability of N, P, K and Zn under integrated nutrient management may be attributed to the gradual mineralization of FYM, which enhances microbial activity and ensures a continuous release of nutrients into the soil solution. The application of zinc, the formation of soluble organic complexes during the decomposition of FYM and a slight reduction in soil pH support the increased availability of Zn. These findings agree with Aziz *et al.* (2010) ^[2], Meena *et al.* (2018) ^[5] and Khaliq *et al.* (2018) ^[4].

Effect on NPK and Zn content of Rice

The highest concentration of N, P and K in grain and straw was recorded in treatment T₇ (90% RDF + FYM @ 2.5 t ha⁻¹ + zinc @ 12.5 kg ha⁻¹). The grain N, P and K contents under T₇ were 1.56%, 0.43% and 0.39%, respectively and in straw were 0.68%, 0.32%, and 1.26%, respectively (Table 3). Whereas, the control plot recorded the lowest nutrient concentrations, with grain N, P and K contents of 1.16%, 0.15% and 0.15%, respectively, and straw contents of 0.29%, 0.06% and 1.11%, respectively. The maximum Zn concentration in both grain (32.40 ppm) and straw (26.60 ppm) was recorded under T₆ (100% RDF + zinc @ 25.0 kg ha⁻¹), which was statistically at par with T₇ and significantly superior to the remaining treatments.

The higher N, P and K concentrations observed under T₇ may be attributed to the integrated application of FYM, zinc and mineral fertilizers, which improved nutrient availability and content. These results agree with the finding of Meena *et al.* (2018) ^[5] and Rangaswamy *et al.* (2023) ^[7], who reported that integrated nutrient management improves nutrient uptake, translocation and grain nutritional quality.

Effect on NPK and Zn uptake

Application of treatment resulted in a significant change in the N, P, K and zinc uptake (Table 4). The highest N, P, K uptake was recorded with the combined application of FYM and zinc at the rate of 2.5 t ha⁻¹ and 12.5 kg ha⁻¹ along with 90 per cent of RDF in grain as well as in straw. The treatment T₇ recorded a 15 per cent higher uptake than the control. The highest zinc uptake was recorded in the treatment T₆. The lowest uptake was observed in the control plot.

The enhanced nutrient uptake under T₇ can be attributed to the integrated effect of organic manure and zinc, which improved nutrient availability, root growth, microbial activity and nutrient use efficiency. Similar improvements in nutrient uptake following the combined application of FYM, zinc and inorganic fertilizers have been reported by Puli *et al.* (2017) ^[6], Tiwari *et al.* (2017) ^[10], Yassen *et al.* (2010) ^[11], and Goswami *et al.* (2018) ^[3].

Table 2: Effect of FYM and Zn treatment on chemical properties of soil

Treatment	pH	EC (dSm ⁻¹)	Organic Carbon (%)	Avail. N (kg ha ⁻¹)	Avail. P (kg ha ⁻¹)	Avail. K (kg ha ⁻¹)	DTPA- Zn (mg kg ⁻¹)
T ₁	7.84	0.20	0.38	185.3	12.30	185.6	0.30
T ₂	7.80	0.22	0.40	210.6	15.0	202.2	0.60
T ₃	7.71	0.23	0.49	212.7	15.80	206.4	0.64
T ₄	7.74	0.22	0.42	214.3	15.20	205.7	0.70
T ₅	7.64	0.23	0.58	215.2	16.20	210.9	0.68
T ₆	7.76	0.22	0.43	213.0	15.50	212.4	0.86
T ₇	7.68	0.24	0.51	216.0	16.50	220.6	0.80
S.Em.±	0.06	0.07	0.007	1.54	0.59	1.37	0.01
CD at 5%	NS	NS	0.024	4.73	1.82	4.25	0.03

Table 3: Impact of FYM and Zn combinations on nutrient content of Rice

Treatment	N Content (%)		P Content (%)		K content (%)		Zn Content (ppm)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁	1.16	0.29	0.15	0.06	0.15	1.11	18.30	12.70
T ₂	1.33	0.53	0.33	0.22	0.23	1.19	22.10	20.20
T ₃	1.42	0.57	0.37	0.28	0.23	1.20	23.40	21.80
T ₄	1.37	0.56	0.35	0.25	0.30	1.21	26.00	23.40
T ₅	1.41	0.6	0.40	0.30	0.24	1.23	23.90	22.00
T ₆	1.47	0.62	0.37	0.29	0.32	1.24	32.40	26.60
T ₇	1.56	0.68	0.43	0.32	0.39	1.26	30.80	25.40
S.E(m)±	0.02	0.02	0.02	0.01	0.01	0.08	0.93	0.90
CD at 5%	0.06	0.04	0.04	0.02	0.04	0.24	2.86	2.79

Table 4: Impact of FYM and Zn combinations on nutrient uptake by Rice

Treatment	N Uptake (kg ha ⁻¹)		P Uptake (kg ha ⁻¹)		K uptake (kg ha ⁻¹)		Zn Uptake (mg kg ⁻¹)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁	32.48	14.85	4.2	3.07	4.11	59.90	51.24	65.03
T ₂	54.80	58.40	13.59	15.18	9.47	82.11	91.05	139.38
T ₃	61.69	66.29	16.06	20.17	9.98	90.39	101.55	158.92
T ₄	61.51	67.93	15.71	18.84	13.47	92.19	116.7	178.77
T ₅	61.48	70.02	17.44	21.93	10.46	92.59	104.20	160.82
T ₆	68.26	78.00	17.54	22.74	15.17	102.18	153.57	208.54
T ₇	73.16	84.25	20.17	24.38	18.29	102.92	144.4	195.58
S.E(m)±	0.47	1.37	0.57	0.58	0.68	0.58	4.46	6.49
CD at 5%	1.43	4.23	1.75	1.79	2.10	1.79	13.74	20.01

Conclusion

The integrated application of 90% RDF + FYM @ 2.5 t ha⁻¹ + Zn@ 12.5 kg ha⁻¹ improved nutrient availability, nutrient content and uptake in rice. Therefore, it can be recommended as an efficient and sustainable nutrient management strategy for rice cultivation.

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