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Influence of Integrated Nutrient Management (INM) on Biochemical Properties of *Inceptisol* of Surguja District of Chhattisgarh, 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

The present experiment entitled "Influence of Integrated nutrient management (INM) on biochemical properties of Inceptisol of Surguja District of Chhattisgarh, India" was conducted during 2021-22 at village Sonwahi, Dist. Surguja. experiment out in a RBD with seven treatments i.e. T_1-control, T_2-50% RDF, T_3-100% RDF, T_4-150% RDF, T_5-100% RDF + 5t/ha FYM, T_6-50% RDF + 5t/ha FYM, and T_7-50% RDF + 1.5t/ha The pH and EC (dSm^{-1}) of soil doesn't show any significant effect with different INM treatments. SOC (5.69 g kg^{-1}) nitrogen (220.36 kg ha^{-1}) available phosphorus and available potassium (45.81 kg ha^{-1}, 245.42 kg ha^{-1},) 50% RD Field experiment that INM technique significantly influenced the activity of soil enzyme viz. dehydrogenase (48.34 µg TPF 24 hr^{-1} g^{-1}), urease (40.07 µg NH4+- N g^{-1} soil h^{-1}), acid phosphatase (72.93 µg p-nitrophenol g^{-1} hr^{-1}) and alkaline phosphatase (45.14 µg p-nitrophenol g^{-1} hr^{-1}) in 100% RDF + 5t/ha FYM (T5). The maximum bacterial load (201.00 x 107 CFU g^{-1}) and fungal load (19.20 x 104 CFU g^{-1}) recorded under 100% RDF + 5t/ha FYM.

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1. INTRODUCTION

Rice production has proven difficult to maintain, especially in locations where rice output has declined despite adopting suggested nutrient management measures. Nutrient management that incorporates organic and inorganic sources of nutrients helps to improve the physical and microbial health of the soil, improves fertilizers use efficiency [1], and maintains crop productivity [2]. Furthermore, under intensive cropping systems, chemical fertilizers will play a significant role and will remain the most integral aspect of the INM system, since they provide around 50% of the growth in food grain production for our country's growing population [3]. Soil biological features are intimately linked to soil productivity and sustainability since they provide strength and buffering capabilities to minimize stress. The biological ecosystem of soils benefits from coordinated nutrient management. This is accomplished by maximizing the advantages of all possible plant nutrient sources in a holistic way [4]. The integration of various sources of nutrients, such as organic, inorganic, and biological, is encouraged by an integrated plant nutrition supply system. Organic manures like farmyard manure, which is a storehouse of major nutrients apart from containing a considerable amount of macro and micronutrients Furthermore, the application of organic manures enhances the organic matter content of the soil by improving the water holding capacity [5].

Microorganisms in the soil, especially the microbiota, are crucial to the stability of soil structure and the cycling of elements. They also serve as a source and sink for C and labile nutrients. A huge colony of microbes performs the mineralization of organic materials, which involves a variety of metabolic activities. Only 1-3 percent of Soil's Organic Carbon (SOC) comes from the microbial population, which is a tiny population that all organic matter entering the soil must pass through [6].

Microorganisms control soil nutrient flow by absorbing nutrients and creating soil biomass. Changes in soil organic carbon content are also closely related to changes in soil microbial biomass carbon and biological activity [7]. Microbial activity has a substantial impact on ecosystem processes since microorganisms mediate roughly 80% to 90% of soil activities [8].

Soil enzymes are essential for the breakdown of organic materials as well as the decomposition of hazardous waste and other contaminants. Soil enzymes govern the transformation of components needed for plant development in soil. The activity of soil enzymes, whether extracellular or intracellular depends on crop rotation, amendments, tillage, and agricultural management.

The dehydrogenase enzyme catalyzes the dehydrogenation of organic material through the oxidation process of soil organic matter by transferring hydrogen and electrons from the source to acceptors. Phosphatase in soil refers to a collection of enzymes that hydrolytically cleave a variety of ester-phosphate bonds of organic phosphates and anhydrides of orthophosphoric acid (H_3PO_4) into inorganic phosphate. Acid and alkaline phosphatases, especially hydrolyze the ester linkages that bind P to C in organic material (C-O-P ester bonds). Inorganic P is released from organically bound P such as leaf litter, dead root systems, and another organic waste throughout the process without the simultaneous release of C. Phosphatase is abundant in the upper layers and rhizosphere, which contain the majority of the fresh and less humified organic materials [9]. Phosphatases are important in the accumulation of phosphorus by plants and microbes, and consequently in its cycling within the soil [10]. Phosphatase, which is obtained by root exudates and microorganisms, breaks down phosphate from the organic substrate and thereby contributes to the soil phosphorus cycle.

Urease is an amidohydrolase enzyme that hydrolases straight amides with nonpeptide carbon-nitrogen linkages [11], Karaca et al. [12]. Urease activity in soil proved effective in creating and maintaining nitrogen management strategies. Urease hydrolysis activity is increased under aerobic circumstances, and its hydrolysis varies with the plant growth stage when green manure is applied to the crop [13]. Urease activity is reduced when soil bioavailability is compromised. Saliha et al. [14] confirm that urease activity enhanced in soil treated with a liquid organic substrate, as increased microbial population. "The hydrolysis" reaction of urea fertilizer in the soil into NH_3 and CO_2 is performed by "urease enzyme" with the concomitant "increase in soil pH" [15]. The most

sensitive indices of soil health are microbial activities, specifically the population of bacteria, fungi, and actinomycetes, MBC, and enzyme activity such as dehydrogenase, urease, and phosphatase.

2. MATERIALS AND METHODS

The experimental site was located at a farmer's field in village Sonwahi around 10 km away from Ambikapur, Surguja. The field experiment was carried out during the *Kharif* season, 2021 on rice crops to study the effect on soil properties with applied different levels of N, P, K, and FYM & Vermicompost. The field experiment was laid out in a Randomized Block Design with seven treatments T1 - Control (N0: P0: K0), T2 - 50% RDF (60:30:20), T3-100% RDF (120:60:40), T4 - 150% RDF (180:90:60), T5-100% RDF + 5t/ha FYM, T6 -50% RDF + 5t/ha FYM and T7 - 50% RDF + 1.5 t/ha Vermicompost. The above treatments were allocated randomly with five replications. The soil of the experimental site is sandy loam with the local name "Matasi" and is categorized as an *Inceptisol*, having low pH, EC (dSm^{-1}), and water holding capacity.

The Soil pH was determined in 2.5:1 water-soil suspension (Piper, 1966) soil suspension after pH determination was stored overnight and EC of the supernatant liquid was determined by Solu-bridge as described by Black [16]. The organic carbon was determined by Walkley and Black's rapid titration method [17]. Available nitrogen was estimated by alkaline potassium permanganate method [18], available phosphorus by Bray and Kurtz [19] method, and available potassium was determined by neutral normal ammonium acetate extractant and detected by Flame photometer as described by Hanway and Heidal [20]. Soil dehydrogenase activity was determined by the method described by Casida et al. [21]. Urease activity was measured by the protocol given by Acid and alkaline phosphatase activities were assayed by the method given by Tabatabai and Bremner [22]

The calculation for microbial analysis of soil:

I. Calculation of enzyme activity = Y value x Sample reading

Enzyme Activity = (Concentration x D) / (It x W)

Y = Value taken from the standard curve
It = Incubation time
D = Dilution
W = Dry weight of soil (g)

II. Calculation of total bacterial and fungal count

CFU per gram soil = No. of colonies x reciprocal of the dilution

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties

Application of inorganic fertilizer either alone or in combination with FYM or Vermicompost significant effect on soil pH and EC (Table 1). This might be due to buffering capacity" of the soil (*Inceptisol*). Different treatments showed uneven pH change, indicating that the applied treatments had no effect on the pH of the soil. The results were in close conformity to those obtained by Yadav et al. [23] and Patel et al. (2018).

Table 1. Effect of integrated nutrient management on chemical properties of soil

Treatments	pH	EC ($dS\ m^{-1}$)	Organic carbon ($g\ kg^{-1}$)	Available N of soil ($kg\ ha^{-1}$)	Available P of soil ($Kg\ ha^{-1}$)	Available K of soil ($Kg\ ha^{-1}$)
Control	4.38	0.03	5.21	131.98	36.50	217.06
50% RDF	4.36	0.03	5.39	157.25	38.96	222.88
100% RDF	4.28	0.04	5.58	201.50	41.93	236.11
150% RDF	4.52	0.04	5.56	218.07	45.81	245.42
100% RDF + 5t/ha FYM	4.44	0.04	5.69	220.36	44.38	242.85
50% RDF + 5t/ha FYM	4.44	0.04	5.48	173.38	39.67	229.62
50% RDF + 1.5t/ha Vermicompost	4.46	0.04	5.47	172.04	39.35	228.67
SEm±	0.103	0.002	0.02	4.48	0.74	1.97
CD (5%)	NS	NS	0.08	13.08	2.16	5.76

Table 2. Effect of integrated nutrient management on dehydrogenase activity, urease activity, acid phosphatase activity and alkaline phosphatase activity of soil

Treatment	Dehydrogenase activity (µg TPF 24 $hr^{-1}g^{-1}$)	Urease Activity (µg $NH4+ - N g^{-1}$ soil hr^{-1})	Acid phosphatase Activity (µg PNP g^{-1} hr^{-1})	Alkaline Phosphatase Activity (µgPNP g-1 hr^{-1})	Bacterial population (10^7 CFU g^{-1})	Fungal population (10^4 CFU g^{-1})
Control	26.96	17.59	41.10	19.73	126.80	4.60
50% RDF	32.49	23.35	48.11	25.61	116.40	7.20
100% RDF	37.19	29.60	56.56	31.31	106.40	9.00
150% RDF	39.49	31.20	61.14	33.97	103.00	12.00
100% RDF + 5t/ha FYM	48.34	40.07	72.93	45.14	201.00	19.20
50% RDF + 5t/ha FYM	43.43	35.64	67.27	40.10	178.60	15.00
50% RDF + 1.5t/ha VC	44.53	36.29	66.67	39.42	175.80	14.40
S. Em±	1.22	1.48	1.76	1.41	2.86	0.44
CD (5%)	3.56	4.32	5.51	4.12	8.37	1.28

The soil organic carbon after harvest was influenced by various INM and the balanced application of organics and inorganics enhanced the SOC significantly. Soil organic carbon content from 5.21 g kg-1 to 5.69 g kg-1. Higher SOC (5.69 g kg-1) was recorded under treatment 100% RDF + 5t/ha FYM, followed by 150% RDF (5.67 g kg^{-1} however both are statistically at par with each other, and the least content of SOC (5.21 g kg^{-1} was recorded in the unfertilized plot. The SOC was found to be significantly higher between the different treatments due to the higher concentration of biomass in the soil in the form of crop residues and higher root biomass [24]. Similar results were also noticed by Patel et al. [25], and Ramesh et al. (2019). Higher available nitrogen (220.36 kg ha^{-1}) in soil was recorded in the treatment of 100% RDF + 5t/ha FYM, followed by 150% RDF (218.07 kg ha^{-1}). The last available N (131.98 kg ha^{-1}) was recorded in an unfertilized plot (control). The mineralization of soil N facilitated by the application of organic matter might have helped in the higher build of available nitrogen [26]. Higher available phosphorus (45.81 kg ha^{-1}) and available potassium (245.42 kg ha^{-1}) in soil was recorded under 150% RDF followed by 100% RDF + 5t/ha FYM, (44.38 kg ha^{-1}) and least available P (36.50 kg ha^{-1}) and available K (217.06 kg ha^{-1}) was recorded in the unfertilized plot (control). The organic matter creates a blanket over sesquioxide, makes them inactive, limits the phosphate-fixing capacity of the soil, and allows for the release of a large amount of phosphorus. A similar finding was reported by Tiwari et al. [27], Lakshmi et al. [28] and Reddy et al. [29].

3.2 Soil Enzymes Microbial Population

3.2.1 Dehydrogenase

Integrated nutrient management techniques enhanced the activity of DHA (Table 2) in soil. The activity of dehydrogenase in the soil the doses of fertilizer were increased from 50% RDF to 100% RDF and 150% RDF kg ha^{-1} respectively, and from 32.49 to 37.19 and 39.49 µg TPF 24 hr^{-1} g^{-1}. The maximum activity of DHA (48.34 µg TPF 24 hr^{-1} g^{-1}) was obtained under the treatment T5 (100% RDF + 5t/ha FYM), followed by 50% RDF + 5t/ha FYM 43.43 µg TPF 24 hr^{-1} g^{-1}) and 50% RDF + 1.5t/ha Vermicompost 44.53 43 µg TPF 24 hr^{-1} g^{-1}) however, the treatment at par with each other. The minimum activity of DHA was obtained from the unfertilized plot (control). Results are in line with the finding of Yadav et al. (2021) who observed higher DHA activity (55.393 µg TPF 24 hr^{-1} g^{-1}) with T8 (100% NPK + FYM @ 5 t/ha) over the other treatments. The activities of dehydrogenase, an enzyme in the soil system, are especially notable because they may indicate the soil's ability to sustain biochemical processes that are necessary for soil fertility maintenance [30]. A significant increase in dehydrogenase activity in the plots with organic treatments, especially with NPK was also recorded by Saha et al. [31] and Ingle et al. [32].

3.2.2 Urease

Urease activity significantly increased in the soil as the doses of fertilizer increased from 50% RDF to 150% RDF kg ha^{-1}respectively, and the value ranged from 23.35 to 29.60 and 31.20 µg NH4+- N g^{-1} soil h^{-1}. Higher activity of urease (40.07 µg NH4+- N g^{-1} soil h^{-1}) was obtained under the treatment T5 (100% RDF + 5t/ha FYM), followed by 50% RDF + 5t/ha FYM (T6 – 35.64 µg NH4+- N g-1 soil h^{-1}) and 50% RDF + 1.5t/ha Vermicompost (36.29 µg NH4+- N g^{-1} soil ha^{-1}.The last activity of urease was obtained from the unfertilized plot (control). The activity of urease was greatly influenced by the use of inorganic fertilizers and diverse organic sources. The increased rate of nitrogen application, as well as numerous biomaterials added to the soil and root exudates, stimulated the production of nitrogenous substances, which promoted urease activity [33]. Similar results were also recorded by Mishra et al. [34], Meshram et al. [35] and Yadav et al. [23].

3.2.3 Acid phosphatase activity

Acid phosphatase activity significantly increased in the soil as the doses of fertilizer increased from 50% RDF to 150% RDF kg ha^{-1} respectively, and the value ranged from 48.11 to 56.56 and 61.14 µg p-nitrophenol g^{-1} hr^{-1}. The maximum activity of acid phosphatase (72.93 µg p-nitrophenol g-1 hr^{-1}) was obtained under the treatment T5 (100% RDF + 5t/ha FYM), followed by 50% RDF + 5t/ha FYM (67.27 µg p-nitrophenol g-1 hr^{-1}) and 50% RDF + 1.5t/ha Vermicompost 66.67 µg p-nitrophenol g^{-1} hr^{-1}) however, both the treatment was at par with each other. The minimum activity of acid phosphatase (41.10 µg p-nitrophenol g-1 hr^{-1}) was obtained from an unfertilized plot (control). Phosphatase activity was shown to be correlated with the amount of available P in a substantial and balanced manner [36]. Significantly increased

activity of acid phosphatase enzyme is greatly influenced by low soil pH [37]. Higher acid phosphatase enzyme activity might be attributed to the use of inorganic fertilizers in combination with organics, which resulted in higher levels of organic carbon, humus content, and root biomass in the soil, all of which increased microbial activity and phosphatase enzyme activity [38]. Similar observations were also noted by Yadav et al. [23] and Saha et al. [31].

3.2.4 Alkaline phosphatase activity

Alkaline phosphatase activity significantly increased in the soil as the doses of fertilizer increased from 50% RDF (25.61 µg p-nitrophenol g^{-1} hr^{-1}), to 100% RDF (31.31 µg p-nitrophenol g^{-1} hr^{-1}) 150% RDF (33.97 µg p-nitrophenol g^{-1} hr^{-1}) respectively. The maximum activity of alkaline phosphatase (45.14 µg p-nitrophenol g^{-1} hr^{-1}) was obtained under treatment T5 (100% RDF + 5t/ha FYM), followed by the 50% RDF + 5t/ha FYM (T6 – 40.10 µg p-nitrophenol g-1 hr^{-1}) and 50% RDF + 1.5t/ha Vermicompost (T7-39.42 µg p-nitrophenol g^{-1} hr^{-1}) however, both the treatment (T6 and T7were at par with each other. The minimum activity of alkaline phosphatase (19.73 µg p-nitrophenol g^{-1} hr^{-1}) was obtained from the unfertilized plot (control). The activity of the alkaline phosphatase enzyme is greatly influenced by high soil pH [37]. The higher activity of alkaline phosphatase in the INM treated plots might be associated with greater microbial activity and diversity of phosphate solubilizing bacteria over time as a result of manure input [39]. Similar results were reported by Kanchikerimath and Singh [40] and Meshram et al. [35].

3.2.5 Bacterial population

Higher bacterial load (201.00 x 107 CFU g^{-1}) was recorded 100% RDF + 5t/ha FYM followed by 50% RDF + 5t/ha FYM (T6 - 178.60 x 107 CFU g^{-1}) and 50% RDF + 1.5t/ha Vermicompost (T7 - 175.80 x 107 CFU g^{-1}), however both T6 and T7 were at par with each other. A significant decrease in bacterial population in the soil as the doses of fertilizer increased from 50% RDF (116.40 x 107 CFU g^{-1}), 100% RDF (106.40 x 107 CFU g^{-1}), and 150% RDF (103.00 x 107 CFU g-1) respectively probably be due to the acidic nature of fertilizers. The unfertilized plot (126.80 x 107 CFU g-1) recorded a higher bacterial population as compared to 150% RDF. Decreased order of bacterial population in rice soil 100% RDF + FYM > 50% RDF + FYM > 50% RDF + VC > control >50 % RDF >100 % RDF > 150 % RDF. The increase in bacterial population might be due to the supply of FYM along with chemical fertilizer, which enhanced the content of organic carbon which act as a sole source for the multiplication of bacteria [41,42]. The incorporation of organics increases the microbial population because it improved the hydrothermal regime and supply of a large amount of carbon, a major food source for several bacteria involved in decomposition [43,44]. Similar results were also reported by Ingle et al. [32] and Mandal et al. [45].

3.2.6 Fungal population

Significantly increase in fungal population in the soil as the increased recommended doses of fertilizer from 50% RDF (T2 – 7.20 x 104 CFU g^{-1}), 150% RDF (T4 - 12.00 x 104 CFU g^{-1}) respectively which as probably be due to low pH as preferred by fungi. Among all the treatments maximum fungal load (19.20 x 104 CFU g^{-1}) was recorded under 100% RDF + 5t/ha FYM (T5) followed by 50% RDF + 5t/ha FYM (T6 – 15.00 x 104 CFU g^{-1}) and 50% RDF + 1.5t/ha Vermicompost (T7 – 14.40 x 104 CFU g^{-1}), however both T6 and T7 were statistically at par with each other. The minimum count of fungi (4.60 x 104 CFU g^{-1}) was registered in control (T1). Decreased order of fungal population in rice soil were 100% RDF + FYM > 50% RDF + FYM >50% RDF + VC > 150% RDF >100% RDF >50% RDF > control. The application of NPK alone resulted in a higher fungal population due to the low soil pH preferred by the fungi for survival. The results are in agreement with the findings of Vineela et al. [46] and Tao et al. [47].

4. CONCLUSION

Application of fertilizer alone and or in combination with FYM and Vermicompost significantly influenced soil organic carbon, available N, P, and K content, and non-significant effect on soil pH and EC. Soil biochemical properties enzymes and microbial population were slowed down when inorganic fertilizer was applied alone. The INM treated plots with 100% RDF + 5t/ha FYM exhibited considerably higher activity of dehydrogenase, urease, acid, and alkaline phosphatase enzymes as compared to fertilizer alone. A maximum load of the microbial population was found with 50% RDF + 5t/ha FYM and 50% RDF + 1.5t/ha Vermicompost [48,49].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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