Original Research Article

Influence of INM on biochemical properties of *Inceptisol* under Surguja District of Chhattisgarh

Abstract

The present experiment entitled "Influence of integrated nutrient management on biochemical properties of Inceptisol under Surguja district of Chhattisgarh" was conducted during the 2021-22 at village Sonwahi, Dist. Surguja. Field experiment laid out in Randomized Block Design (RBD) with four replications 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 Vermicompost . The pH and EC (dSm^{-1}) of soil doesn't show any significant effect with different INM treatments. The higher SOC (5.69 g kg^{-1}) was recorded under applied treatment 100% RDF + 5t/ha FYM, The available nitrogen (220.36 kg ha^{-1}) in 100% RDF + 5t/ha FYM, available phosphorus and available potassium (45.81 kg ha^{-1}, 245.42 kg ha^{-1},) in 150% RDF, field experiment shown 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}) was recorded under @100% RDF + 5t/ha FYM over control.

Keywords: Integrated nutrient management, biological, farm yard manure, Vermicompost, rice, organic manure

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 (Babu et al., 2007), and maintains crop productivity (Mondal et al., 2016). 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 (Mahajan and Gupta 2009). 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 (DeForest et al.,2012). The integration of various sources of nutrients, such as organic, inorganic, and biological, is encouraged by an

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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. (Sharma et al., 2013).

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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 a 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 (Jenkinson 1988).

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 (Katkar et al., 2011) Microbial activity has a substantial impact on ecosystem processes since microorganisms mediate roughly 80% to 90% of soil activities (Nannipieri and Badalucco, 2003).

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 catalyses 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 hydrolyse 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 other 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. (Tarafdar et al., 2001). Phosphatases are important in the accumulation of phosphorus by plants and microbes, and consequently in its cycling within the soil (Schneider et al., 2001) Phosphatase, which is obtained by root exudates and microorganisms, breaks down phosphate from the organic substrate and thereby contributes to the soil phosphorus cycle. (Huang et al., 2011).

Urease is an amidohydrolase enzyme that hydrolases straight amides with nonpeptide carbon-nitrogen linkages ("Bremner and Mulvaney 1978," Karaca et al., 1999). 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 (Pattnaik et al., 1999). Urease activity is reduced when soil bioavailability is compromised. Saliha et al., (2006) 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". (Byrnes and Amberger, 1989). 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.

Materials and Methods

The experimental site was located at a farmer's field at village Sonwahi around 10 km away from Ambikapur, Surguja. Field experiment was carried out during the Kharif season, 2021 on rice crop and studied the effect on soil properties with applied different levels of N, P, K and FYM & Vermicompost. Soil samples were collected from respective treatments and lab work was conducted in laboratory of department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. 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 experimental site is sandy loam with the local name "Matasi" and is categorised as an *Inceptisol*, having low pH, EC (dSm-1) and water holding capacity.

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Soil pH was determined in 2.5:1 water-soil suspension (by Piper, 1966) than soil suspension after pH determination was stored overnight and EC of the supernatant liquid was determined by Solu-bridge as described by Black (1965). The organic carbon was determined by Walkley and Black rapid titration method (1934). Available nitrogen was estimate by alkaline potassium permanganate method (Subbiah and Asija. 1956), available phosphorus by Bray and Kurtz (1945) method and available potassium was determined by neutral normal ammonium acetate extractant and detected by Flame photometer as described by Hanway and Heidal (1952). Soil dehydrogenase activity was determined by the method as described by Cassida et al., (1964). Urease activity was measured by the protocol given by Douglas[1] and Bremner (1970). Acid and alkaline phosphatase activities were assayed by the method given by Tabatabai and Bremner (1969)

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Calculation for microbial analysis of soil

I. Calculation of enzyme activity

Concentration = Y value x Sample reading

$$\text{Enzyme Activity} = \frac{\text{Concentration x D}}{\text{It x W}}$$

Y = Value taken from 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 dilution

RESULTS AND DISCUSSION

Soil chemical properties

The application of inorganic fertilizer alone or in combination with FYM and Vermicompost were found to have no significant effect on soil pH and EC (Table 1). This might be caused by "high 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., (2020) and Patel et al., (2018).

The soil organic carbon after post-harvest is influenced by various INM and showed that the balanced application of organics and inorganics enhanced the SOC significantly. The value of soil organic carbon varies from 5.21 g kg-1 to 5.69 g kg-1. The higher SOC (5.69 g kg-1) was recorded under applied 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 minimum value of SOC (5.21 g kg-1) was recorded in unfertilized plot. The SOC was found to be significantly higher between the different treatments due to the higher concentration of biomass to soil in the form of crop residues and higher root biomass (Dhaliwal et al., 2021). Similar results were also noticed by Patel et al., (2018), Ramesh et al., (2019). The maximum value of available nitrogen (220.36 kg ha-1) in soil was reported in the treatment received @ 100% RDF + 5t/ha FYM, followed by treatment @ 150% RDF (218.07 kg ha-1). The minimum value of available N (131.98 kg ha-1) was reported in unfertilized plot (control). The mineralization of soil N is facilitated by the application of organic matter, which helps in higher build of available nitrogen (Singh et al., 2012). The maximum value of available phosphorus (45.81 kg ha-1) and available potassium (245.42 kg ha-1) in soil was reported under applied treatment with @ 150%

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RDF followed by treatment @ 100% RDF + 5t/ha FYM, (44.38 kg ha-1) and the minimum value of available P (36.50 kg ha-1) and available K (217.06 kg ha-1) was reported in unfertilized plot (control). The organic matter creates a blanket over sesquioxide's, makes them inactive, limits the phosphate-fixing capacity of soil, and allows for the release of a large amount of phosphorus. The similar finding was observed by Tiwari et al., (2017) Lakshmi et al., (2011) and Reddy et al. (2017)

Soil enzymes microbial population

Dehydrogenase

INM technique enhanced the activity of DHA (Table 2) in soil. Significantly increase in activity of dehydrogenase in soil as the doses of fertilizer increased from 50% RDF to 100% RDF and 150% RDF kg ha-1 respectively, and varies 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 applied treatment T5 (100% RDF + 5t/ha FYM), followed by applied treatment 50% RDF + 5t/ha FYM (T6-43.43 µg TPF 24 hr-1 g -1) and 50% RDF + 1.5t/ha Vermicompost (T7- 44.53 43 µg TPF 24 hr-1 g -1) however, both the treatment (T6 and T7) is statistically at par with each other. The minimum activity of DHA was obtained from the unfertilized plot (control). The results are in line with the finding by Yadav et al. (2020) who observed that highest DHA activity (55.393 µg TPF 24 hr-1 g -1) was recorded in treatment T8 (100% NPK + FYM @ 5 t/ha) over 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 (Joychim et al., 2008). A significant increase in dehydrogenase activity in the plots with organic treatments, especially with NPK was also recorded by Saha et al. (2008) and Ingle et al. (2014).

Urease

Urease activity significantly increased in soil as the doses of fertilizer increased from 50% RDF to 100% RDF and 150% RDF kg ha-1 respectively, and varies from 23.35 to 29.60 and 31.20 µg NH4+- N g-1 soil h-1. The maximum activity of urease (40.07 µg NH4+- N g-1 soil h-1) was obtained under applied treatment T5 (100% RDF + 5t/ha FYM), followed by applied treatment 50% RDF + 5t/ha FYM (T6 – 35.64 µg NH4+- N g-1 soil h-1) and 50% RDF + 1.5t/ha Vermicompost (T7- 36.29 µg NH4+- N g-1 soil h-1The minimum 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

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biomaterials added to the soil and root exudates, stimulated the production of nitrogeneous substance, which promoted the urease activity (Elayearja and Singravel 2011). Similar results were also agreed by Mishra et al. (2008), Meshram et al. (2016) and Yadav et al. (2020).

Acid phosphatase activity

acid phosphatase activity significantly increased in soil as the doses of fertilizer increased from 50% RDF to 100% RDF and 150% RDF kg ha-1 respectively, and varies 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 applied treatment T5 (100% RDF + 5t/ha FYM), followed by treatment 50% RDF + 5t/ha FYM (T6 – 67.27 µg p-nitrophenol g-1 hr-1) and 50% RDF + 1.5t/ha Vermicompost (T7-66.67 µg p-nitrophenol g-1 hr-1) however, both the treatment (T6 and T7) is statistically at par with each other. The minimum activity of acid phosphatase (41.10 µg p-nitrophenol g-1 hr-1) was obtained from the unfertilized plot (control). Phosphatase activity was shown to be correlated with the amount of available P in a substantial and balanced manner (Rai and Yadav 2011). Significantly increased in activity of acid phosphatase enzyme is greatly influenced by low soil pH (Dick 1994). 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 (Vandana et al., 2012). Similar observations were also noted by Yadav et al. (2020), Saha et al., (2008)

Alkaline phosphatase activity

Alkaline phosphatase activity significantly increased in soil as the doses of fertilizer increased from 50% RDF (25.61 µg p-nitrophenol g-1 hr-1), 100% RDF (31.31 µg p-nitrophenol g-1 hr-1) and 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 applied treatment T5 (100% RDF + 5t/ha FYM), followed by treatment 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 T7) is statistically 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). Activity of alkaline phosphatase enzyme is greatly influenced by high soil pH (Dick 1994). The significantly higher activity of alkaline phosphatase in the INM treated plots

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might be associated with greater microbial activity and diversity of phosphate solubilizing bacteria over time as a result of manure input (Mandal et al. 2007). Similar results were reported by Kanchikerimath and Dhyan Singh (2001) and Meshram et al. (2016)

Bacterial population

The maximum bacterial load (201.00 x 107 CFU g-1) was recorded in 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 are statistically at par with each other. Significantly decrease in bacterial population in 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 due to the acidic nature of fertilizers. The unfertilized plot (126.80 x 107 CFU g-1) recorded the higher bacterial population as compared to the 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. Significantly increase in bacterial population might be due to supply of FYM along with chemical fertilizer, enhance the content of organic carbon which act as a sole source for the multiplication of bacteria (Rajannan and Oblisami 1979; Vishwanath et al., 2020). Incorporation of organics increase microbial population because it improved hydrothermal regime and supply of large amount of carbon, a major food source for several bacteria involved in decomposition (Kumar et al., 2013; Goutami et al., 2015). Similar results were also agreed by Ingle et al. (2014) and Mandal et al. (2018).

Fungal population

Significantly increase in fungal population in soil as the increased recommended doses of fertilizer from 50% RDF (T2 – 7.20 x 104 CFU g-1), 100% RDF (T3 - 9.00 x 104 CFU g-1) and 150% RDF (T4 - 12.00 x 104 CFU g-1) respectively; probably due to low pH is preferred by fungi. Among all the treatments maximum fungal load (19.20 x 104 CFU g-1) was recorded in 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 are 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 – 100% RDF + FYM > 50% RDF + FYM >50% RDF + VC > 150% RDF >100% RDF >50% RDF > control. Application of NPK alone resulted in

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higher fungal population due to low soil pH preferred by the fungi for survival. The results are in agreement with the findings of Vineela et al. (2008) and Tao et al. (2015).

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. Soil enzymes and microbial population were both slowed down when inorganic fertilizer is 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. Maximum load of microbial population was found with applied 50% RDF + 5t/ha FYM and 50% RDF + 1.5t/ha Vermicompost.

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REFERENCE

1) Babu, M.V.S., Reddy, C.M., Subramanyam, A. and Balaguravaiah, D. 2007. Effects of integrated use of organic and inorganic fartilisers on soil properties and yield of sugarcane. Journal of the Indian Society of Soil Science 55, 161-166.
2) Black, C.A. and Evans, D.D. 1965. Method of soil analysis. American Society of Agronomy, Madison, Wisconsin, USA, 131-137.Society of Soil Science; 54 (1): 24- 29.
3) Bray, R.H. and Kurtz, L.T. (1945) Determination of Total Organic and Available Forms of Phosphorus in Soils. Soil Science, 59, 39-45.
4) Bremner, J.M., Mulvaney, R.L. 1978. Urease activity in soils. In: Bums R G (ed) Soil Enzymes. Academic Press, London, 149-96.
5) Byrnes, B.H., Amberger, A. 1989. Fate of broadcast urea in a flooded soil when treated with N-(n-butyl) thiophospheric triamide, a urease inhibitor Fertile Research; 18:221-31.
6) Casida, L.E., Klein, D., A.K. and Santoro, T. 1964. Soil dehydrogenase activity, Soil biochem; 1: 301-07.
7) Deforest, J.L., Smemo, K.A., Burke, D.J., Elliott, H.L. and Becker, J.C. 2012. Soil microbial responses to elevated phosphorus and pH in acidic temperate deciduous forests. Biogeochemistry 109, 189-202.
8) Dick, R.P. 1994. Soil enzyme activities as indicators of soil quality. In De Wning Soil Quality for a Sustainable Environment (J.W. Doran, D.C. Coleman, D.F. Bezdicek and B.A. Stewart, Eds.), SSSA Special Publication No. 35, ASA and SSSA, Madison; WI, pp. 104-124
9) Dick, R.P. 1994. Soil enzyme activities as indicators of soil quality. In De Wning Soil Quality for a Sustainable Environment (J.W. Doran, D.C. Coleman, D.F. Bezdicek and B.A. Stewart, Eds.), SSSA Special Publication No. 35, ASA and SSSA, Madison; WI, pp. 104-124
10) Elayeraja, D. and Singaravel, R. 2011. Influence of organics and various levels of NPK on soil nutrient availability, enzyme activity and yield of groundnut in coastal sandy soil. Journal of the Indian Society of Soil Science; 59, 300-303.
11) Goutami, N., Rani, P.P., Pathy, R.L. and Babu, P.R. 2015.Soil properties and biological activity as influenced by nutrient management in rice-fallow sorghum. International Journal of Agricultural Research, Innovation and Technology; 5, 10- 14
12) Hanway, J.J., Heidal, H., 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. Iowa State College of Agriculture Bulletin, 57, 1-31.
13) Hu, W., Jiao, Z., Wu, F., Liu, Y., Dong, M., Ma, T., Fan, T., An, l. and Feng, H. 2014. Long-term effects of fertilizer on soil enzymatic activity of wheat field soil in Loess Plateau, China. Ecotoxicology; 23(10) :2069-80
14) Ingle, S. S., Jadhao, S. D., Kharche, V. K., Sonune, B. A. And Mali, D. V. 2014. Soil biological properties as influenced by long-term manuring and fertilization under sorghum (Sorghum bicolor) -wheat (Triticum aestivum) sequence in Vertisols. Indian Journal of Agricultural Sciences; 84 (4): 452–7
15) Jenkinson, D.S. and Ladd, J.N. 1981. Microbial biomass in soil measurement and turnover. In Soil Biochemistry, E.A. Paul and J.N. Ladd (Eds.). Marcel Dekker, New York, USA; pp. 415-71.
16) Joychim, H.J., Makoi, R., Patrick, A. and Dakidemin, N. 2008. Selected soil enzymes: examples of their potential roles in the ecosystem. African Journal of Biochemistry; 7, 181-191.
17) Kanchikerimatha, M. and Singh, D. 2001. Soil organic matter and biological properties after 26 years of maize-wheat-cowpea cropping as affected by manure and fertilization in semi and region of India. Agric Ecosyst Environ; 86: 155-63

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18) Karaca. A, Haggblomb, M.M., Tate, R.L. 1993. Effects of the land application of sewage sludge on soil heavy metal concentrations and soil microbial communities. Soil Biol Biochem; 31:1467-70

19) Katkar, R.N., Sonune, B.A. and Kadu, P.R. 2011. Longterm effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (Sorghum bicolor)-wheat (Triticum aestivum) system in Vertisol. Indian Journal of Agricultural Sciences; 81, 734-739.

20) Kumar, S., Patra, A.K., Singh, D., Purakayastha, T.J., Rosin, K.G. and Kumar, M. 2013. Balanced fertilization along with farmyard manures enhances abundance of microbial groups and their resistance and resilience against heat stress in a semiarid Inceptisol. Communications in Soil Science and Plant Analysis; 44, 2299-2313

21) Lakshmi, C. S., Sreelatha, R.T., Rani, T.U., Rao, S.R.K., and Naidu N.V. 2011. Effect of organic manures on soil fertility and productivity of sugarcane in north coastal zone of Andhra Pradesh. Indian Journal of Agriculture Research; 45 (4): 307 – 313

22) Mahajan A and Gupta R D. 2009. Integrated nutrient management (INM) in a sustainable rice-wheat cropping system. Springer Science & Business Media; pp 140.

23) Mandal, B., Majumdar, B., Bandopadhyay, P.K., Hazre, G.C., Gangopadhyay, A., Samantaroy, R.N., Misra, A.K., Chowdhuri, J., Saha, M.N. and Kundu, S. 2007. The potential of cropping as affected by manure and fertilization in cambisol in semiarid region of India. Agriculture, Ecosystems and Environment; 86, 155-62.

24) Meshram, N. A., Ismail, S., & Patil, V. D. 2016. Long-term effect of organic manuring and inorganic fertilization on humus fractionation, microbial community and enzymes assay in Vertisol. Journal of Pure and Applied Microbiology; 10(1), 139- 150.

25) Mishra, B., Sharma, A., Singh, S. K., Prasad, J., & Singh, B. P. 2008. Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. Journal of the Indian Society of Soil Science; 56(1), 71-75.

26) Mondal, S., Mallikarjun, M., Ghosh, M., Ghosh, D.C. and Timsina, J. 2016. Influence of integrated nutrient management (INM) on nutrient use efficiency, soil fertility and productivity of hybrid rice. Archives of Agronomy and Soil Science 62(11): 1521- 1529

27) Nannipieri, P. and Badalucco, L. 2003. Biological processes. In: Benbi, D. K., Nieder, R. (Eds.), Handbook of Processes and Modeling in the SoilPlant System. Haworth Press, Binghamton, NY; pp. 57-82

28) Patel, G., Dwivedi, B. S., Dwivedi, A. K., Thakur, R. and Singh, M. 2018. Long-term Effect of Nutrient Management on Soil Biochemical Properties in a Vertisol under Soybean–Wheat Cropping Sequence. Journal of the Indian Society of Soil Science; 66(2): 215-221

29) Pattnaik, P., Mallick, K., Ramakrishnan, B., Adhya, T.K. and Sethunathan, N. 1999. Urease activity and urea hydrolysis in tropical flooded soil unplanted or planted to rice. Journal of the Science of Food and Agriculture. 79: 227-231.

30) Rajannan, G. and Oblisami, G. 1979. Effect of paper factory effluents on soil and crop plants. Indian Journal of Environmental Health; 21, 120-130.

31) Reddy, B.G.M., Hebbara, M., Patil, V.C. and Patil, S.G. 2017. Nitrogen use efficiency of transplanted rice as influenced by N, P and K levels. Journal of the Indian Society of Soil Science, 57(3): 345-351

32) Saha, S., Prakash, V., Kundu, S., Kumar, N., Lal Mina, B. 2008. Soil enzymatic activity as affected by long term application of farm yard manure and mineral fertilizer under a rainfed soybean–wheat system in N-W Himalaya. European Journal of Soil Biology; 44: 309–315

Comment [m156]: Not available in the text

33) Saliha, B.B., Krishnakumar, S., Saravanan, A. and Natarajan, S.K. 2006. Microbial and enzyme dynamics in distillery spentwash treated soil. Research Journal of Agriculture and Biological Sciences. 1(2): 166-169.

34) Schneider K., Turrion M-B., Grierson B. F. and Gallardo J.F. 2001. Phosphatase activity, microbial phosphorus, and fine root growth in forest soil in the Sierra de Gata, western central Spain. Biol. Fertil. Soils; 34: 151-155. Science; 98: 37176

35) Sharma, A., Wali, V. K., Bakshi, P. and Jasrotia, A. 2013. Effect of organic and inorganic fertilizers on quality and shelf life of guava (Psidium guajava L.) cv. Sardar. The Bioscan, 8(4): 1247-1250

36) Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils. Current Science, 25: 259-260.

37) Tabatabai, M.A. and Bremner, J. M. 1969. Use of p-nitrophenyl phosphate for assay of soil phosphatase enzyme. Soil Biochemical; 108: 20-46

38) Tandon, H.L.S. 1987. Phosphorus research and agricultural production in India, Fertilizer Development and Consultation Organization (FDCO), New Delhi.

39) Tao, R., Liang, Y., Wakelin, S.A., Chu, G. 2015. Supplementary chemical fertilizer with an organic component increases soil biological function and quality. Applied Soil Ecology; 96:42-51.

40) Tarafdar, J.C, Yadav, R.S. and Meena S.C. 2001. Comparative efficiency of acid phosphatase originated from plant and fungal source. Journal of Plant Nutritional and Soil Science; 164(3): 279-282

41) Tiwari, A., Tiwari, A., Singh, N.B. and Kumar, A. 2017. Effect of Integrated nutrient management (INM) on soil properties, yield and economics of rice (Oryza sativa L.). Research in Environment and Life Sciences; 10(7): 640-644

42) Vandana, L. J., Rao, P. C. and Padmaja. G 2012. Effect of cover on soil enzyme activity. ANGRAU organically managed rice (Oryza sativa) wheat Journal of Research; 40: 1-5

43) Vineela, C., Wani S.P., Srinivasarao, C. H., Padmaja, B., Vittal, K. P. R. 2008. Microbial properties of soils as affected by cropping and nutrient management practices in several long-term manurial experiments in the semi-arid tropics of India. Applied Soil Ecology; 40 (1): 165–173

44) Vishwanath, Kumar, S., Purakayastha, T.J., Datta, S.P., Rosin, K.G., Mahapatra, P., Sinha, S.K. and Yadav, S.P. 2020. Impact of forty-seven years of long-term fertilization and liming on soil health, yield of soybean and wheat in an acidic Alfisol. Archives of Agronomy and Soil Science; 18: 430- 23

45) Walkley, A. and Black, C.A. 1934. An examination of wet acid method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science; 37: 29-38

46) Yadav, S., Bachkaiya, V., Tiwari, A., Mandal, M.K., and Ray, D. 2021. Soil nutrient status and biological environment as influenced by nutrient management practices under rice-wheat cropping system. The Pharma Innovation Journal; 10(10): 890-896

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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

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