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Integrated Nutrient Management Practices and their Effect on Soil Health in Relation of Enzyme Dynamics and Biota in a Long-Term Diverse Cropping System in Vertisols of Central India

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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

Organic farming is gaining popularity as it maintains food yields and soil health without harming the environment. However, there is a dearth of global data on enzymes involved in the carbon, nitrogen, phosphorus, and sulphur cycles; microbial elemental stoichiometry; and soil functional diversity. On the other hand, organic farming lacks the most sensitive biological components and enzyme activity based on soil quality indices. It all started in 2004 when four of India's largest

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soybean-based cropping systems participated in a trial to examine the viability of nutrient management in soybean-based cropping systems (soybean-wheat, soyabean-mustard, soybean-chickpea, and soybean-linseed). Herein, we report the findings of a soybean-wheat cropping system studied for Vertisol under six nutrient management practises. Chemical characteristics of the soil were studied before and after seeding. Enzyme activity, soil microbial biomass carbon (SMBC), and microbial count were studied in biological parameters. The chemical, biological and agronomic parameters of the soybean crop were statistically examined using the Randomized Block Design. The analysis of the various parameters from the surface soils (0–15 cm). The biological activity varied significantly between treatments. The agronomical indicators also exhibited significant values in the organically treated plot. Organic treatments improved agronomic conditions, stabilised soil, and improved its nutrient content, quality, and biological activity over time. The inorganically treated plot and the state recommended dose plot had the lowest nutritional content, as suggested by the lowest biological activity parameters. Soil fertility and nutrient availability were studied in this experiment in order to comprehend why switching from chemical to integrated nutrient application practises will be helpful towards the inception of a sustainable future.

Keywords: Nutrient management practices; integrated nutrient management; vertisols; soybean; wheat.

1. INTRODUCTION

Increased population is a serious issue all around the world. especially in countries that have a surplus of workers but a shortage of land. Food security for such a massive population would be one of the biggest obstacles. Hence, there has been a worldwide trend toward intensive agriculture, which has put substantial burden on land. There are environmental risks associated with the widespread and exclusive use of chemical fertilizers in modern, intensive agriculture, which leads to fluctuating crop yields and deteriorating soil health [1]. The decline in both soil health and crop output can be attributed to the excessive or inadequate use of fertilizers, as well as inadequate resource management practices. These issues pose significant challenges to the long-term sustainability of agriculture. Organic manures have been found to have a notable residual impact on subsequent crops, indicating their beneficial influence on both the soil and the succeeding crop. The utilization of organic manure is a prevalent practice aimed at enhancing crop yields through the augmentation of soil organic carbon (SOC) storage and the improvement of nutrient accessibility [2,3]. Even though organic manure is widely employed in the country, the supply of FYM has been dwindling due to increased demand in intensive agricultural systems and a shrinking cattle population [4]. The crop yield however cannot be substantially increased by either organic manures or chemical fertilizers alone [5]. Thus, if we want to keep improving crop productivity, sustainability, and environmental quality, we need to practice integrated nutrient management. Therefore, this creates a need to switch over to a nutrient delivery system which keeps the environmental health and food production intricate and also has the potency to deliver nutrients at a competent rate as that of chemical fertilizers. Integrated nutrition management (INM) appears to be the solution to these concerns. In addition to improving environmental protection and resource quality, INM also has the potential to increase resource efficiency and boost plant performance [6]. Crop productivity and nutrient use efficiency are both improved by the promising technology of integrated nutrient management treatments, which involve the use of both bio-fertilizer and inorganic fertilizers [7]. In integrated farming a balance between the usage of chemical fertilizers and organics is maintained and there is a significant residual effect of organic manures on subsequent crops, implying that they help the soil and the next crop as well. Many experiments have also proven that integrated utilization of organic and inorganic nutrient sources proves to be the most intuitive concept for managing and sustaining soil health and crop output [8]. Integrated nutrient management is also one of the most significant factors in preserving soil fertility and increasing crop yield. The best study of integrated nutrient management can be done on Long-term fertilizer experiments (LTFEs) which provide vital information on the impact on soil fertility and crop productivity of continuous application of various quantities of fertilizer nutrients alone or in combination with organic manure during intense cropping [9]. For exact monitoring of soil fertility changes, these studies might be of essential importance in tackling the complicated issues linked to soil fertility management [10]. Soil fertility, nutritional status, and plant nutrient usage efficiency may all be improved with the application of organic amendments [11]. Mangalassery et al. (2019) reported that supplementing mineral fertilisers with organics improved the C, N, and enzyme activity of microbial biomass in heavily worn laterite soils. Recent researches also shows that organic farming has a significant impact on protecting the environment and enhancing food quality [12], but food security still remains a challenge. Numerous researches have demonstrated the favorable effects of combining organic and inorganic fertilizers on crop yield and soil health [8]. Thus, it contemplates the use of chemical fertilizers in conjunction with organic manures and other locally accessible nutrient sources for soil health and productivity maintenance (food safety paper). In light of the foregoing, the current study was carried out under a LTFE (Long term fertilizer experiment) experiment plot in IISS Bhopal, with the objectives to examine the impact of organic, inorganic, and natural farming practices on the physio-chemical properties of soil as affected by the dynamics of soil properties and nutrient transitions, to set a distinct comparison amongst the organic, inorganic and INM practices and their impact on soil health as monitored by the biological properties of soil, and monitoring changes in the chemical, and biological properties of soil over a long period of time with the help of long-term fertilizer management in deep black vertisolic soil of Central India.

2. MATERIALS AND METHODS

2.1 Experimental Details

The current experimental study was conducted at the Indian Institute of Soil Science's Research Farm in Bhopal. The coordinates for the experimental site are 23° 18' N and 77° 24' E. At 495 meters above sea level, the location is quite high. With an average annual rainfall of 1208 mm and an annual mean air temperature of 25 °C, the climate is considered to be sub-humid tropical. Around 80% of yearly rainfall is obtained during the South-West monsoon (June to September), with the remainder falling during the North-East monsoon (October and November). Agroecologically speaking, the research region is located around Vindhya plateau region (Zone IV) has a humid subtropical climate. The trial was set up in the year 2004 as part of the 'Network initiative on organic farming' with four of India's largest soybean-based cropping systems (soybean-wheat, soybean-mustard, soybean-chickpea and soybean-linseed). The soil was mainly of clayey nature (Typic Haplustert). Initial characteristics of the soil and climatic parameters are given in Table 1. Since 2013, the experiment has included six management practises as stated in Table 2. Sowing and harvesting of soybean crop were done in June end and October respectively. The irrigation of the crop was done according to the package of practices. Plots were ploughed to a depth of 15 cm using a tractor-drawn disc plough before seeding. All crops were harvested at ground level first, and then the above-ground biomass was taken away. Soybean crop nutrition was maintained through the use of animal dung in organic fertilisation practises. The crops were watered only when necessary. Plots were ploughed to a depth of about 15 cm using a tractor-drawn disc plough before planting. All crops were harvested at ground level, and then the above-ground biomass was removed. Soybeans in the organic treatments received cow dung as a source of nutrients during the rainy season, and wheat in the organic treatments received a mixture of cattle dung, vermicompost, and poultry manure (one-third of each) in the colder months. At 30 and 45 days after sowing, 10% Vermiwash and 10% cow urine were sprinkled on all crops as part of an innovative technique. Manures were administered according to the N-equivalent requirements of each crop. After modifying the quantity of phosphorus given by manures, rock phosphate was employed to augment the phosphorus needs of soybean crop. Table 3 summarises the nutritional makeup of the organic manures used in the experiment. In natural farming the inputs were given through beejamrit, jeevamrit and ghanjivamrit. Treatments comprising of Natural Farming seed treatment was done with Beejamrit, application of Ghanjeevamrit was done at the rate of @ 250 kg ha^{-1}, Jeevamrit was applied at a rate of 500 litres ha^{-1} twice a month with irrigation water. Weed check was kept with the help of hand weeding. Leaf-eating caterpillar's count was kept in check with Neem oil (Azardirachtin 0.03%). *Sesbania aculata* was used as a decoy crop soybean girdle beetle. Nutrients were supplied via mineral fertilisers (urea, single superphosphate, and muriate of potash) in conventional management approaches, and prescribed pesticides were applied as needed to protect the plants. In integrated nutrient management methods,

Table 1. Initial properties of the studied soil

Soil characteristics	Soil depth (0-15cm)
Taxonomic classification	Typic Haplustert
Sand % (>2mm)	25.3
Silt % (2 - 0.05mm)	18.2
Clay % (<0.05mm)	57.6
Bulk density (Mgm^{-3})	1.46
pH	7.87
EC (ds/m)	0.53
Organic C (g/kg)	5.31
CEC (%)	44.5
Total N (mg/kg)	10.85
Avg P (mg/kg)	12.77
Avg K (mg/kg)	265.71
Iron (Fe) (mg/kg)	5.62
Manganese (Mn) (mg/kg)	9.56
Zinc (Zn) (mg/kg)	0.74
Copper (Cu) (mg/kg)	1.32
Average max. temperature ($°C$)	33.6
Average min. temperature ($°C$)	19.3
Average annual rainfall (cm)	113
Potential evapotranspiration (cm)	140

Table 2. Treatment detail

Treatments	Details of Composition
T1	100% Organic
T2	50 % Organic + NF
T3	50% Organic + 50% Inorganic
T4	25%Organic + 25% Inorganic +NF
T5	Conventional, 100% Inorganic
T6	Conventional, state recommendation on farmer package

organic manures supplied 50% or 75% of nutrients, while mineral fertilisers supplied the remaining 50% or 25%.

2.2 Soil Sample Collection and Processing

Soil samples were collected in triplicate from each plot in October, 2020 from two soil depths (0-15 and 15-30 cm) to determine the chemical parameters and biochemical properties of soil before and after soybean harvest in the plough layer (0-15 cm soil depth). The crop's aboveground biomass was dried and saved for agronomic parameters and plant-related analysis. Each sample was split into two sub-samples. One portion was air-dried, ground using mortar and pestle, sieved through a 4.75-mm sieve (bulk soil), and soil chemical parameters were analysed. The second subsample was kept in the refrigerator (at 4 °C) to analyse enzymatic activities and other microbial parameters. The soil was taken into field capacity level (60% water holding capacity) before analysis.

2.3 Soil Analysis

Standard procedures were used to ascertain soil chemical parameters [13]. Using a potentiometer, we measured the soil's acidity and electrical conductivity (1:2 soil: water suspension). For organic carbon status of soil (Soil-SOC) 1 g of soil was dissolved in 20 mL of sulfuric acid, 10 mL of potassium dichromate was added as an oxidising agent, and 10 mL of ferrous ammonium sulphate as a titrating agent to measure the carbon status of soil [14]. The percentage of available N was determined using the alkaline permanganate technique and a Kjeldahl distillation apparatus [15]. In a nutshell, 20 g of soil was put into the distillation flask together with 20 mL of water, 100 mL of 0.32% potassium permanganate, and 100 mL of 2.5% sodium hydroxide. Subsequently, a beaker was filled with 20 mL of 2% boric acid and two to three drops of methyl red indicator. Ammonia gas was collected into boric acid solution followed the distillation of the soil solution mixture in a distillation apparatus. 0.02 N sulphuric acid was used to titrate the distillate. Blue colour intensity was measured on a spectrophotometer at an intensity at 660 nm with Olsen's extractant (pH 8.5) to estimate available P. Soil sample weighing 2.5 grams was immersed in 50 mL of 0.5 M sodium bicarbonate along with a pinch of activated charcoal and was agitated for 30 minutes. A 25 mL volumetric flask was filled halfway with the solution, and then 5 mL of the clear filtrate was placed there after being filtered through Whatman No. 1 filter paper. Last but not least, 5 mL of 1.5% ammonium molybdate solution was added, bringing the total amount to 25 mL for colour intensity readings, Soil samples weighing about 5 grams were mixed with 25 mL of 1 N ammonium acetate (pH 7.0) to measure the amount of available potassium [13]. After filtering the solution, the flame photometer was used to determine the K concentration. Soil - microbial biomass carbon (Soil-MBC) and microbial biomass nitrogen (SMBN) were analyzed using the chloroform-fumigation extraction method and were expressed as µg g^{-1} of dry soil each [16]. The microbial biomass carbon extraction efficiency value i.e. (kEC) value was 0.45. [17]. TTC-Dehydrogenase activity (DHA) of soil was calculated for an indirect estimation of microorganism by measuring microbial respiration in-situ determined by calculating the rate of production of tri-phenyl formazon (TPF) from triphenyl tetrazolium chloride (TTC), using the method given by [18], soil alkaline phosphatase (Alk–P) was assayed by the amount of p-nitrophenyl phosphate produced given as micrograms of p-nitrophenol per gram of soil per hour (µg p-np g^{-1} soil h^{-1}) by utilizing 16 millimoles of para (p)-nitrophenyl phosphate as the substrate and estimation was done at visible wavelength of 490 nm and was measured with the help of spectrophotometer. Similarly, β-glucosidase activity was calculated by using 25 mM p-nitrophenol β-d glucopyranoside as a substrate, and the results were represented as units of p-nitrophenol production per unit of dry soil per hour at a wavelength of 490nm 1 [19]. (FDA) Fluorescein di-acetate or (-diacetyl-fluorescein) is a fluorescein-conjugated to two acetate radicals and end product absorbs strongly in the visible wavelength (490 nm) and the intensity of yellow colour can be measured with the use of spectrophotometry. The hydrolysis of FDA by soil enzymes was estimated by methods of Adam and Duncan [20]. In order to find out how many bacteria, fungi, and actinomycetes were in soil samples, we used a technique proposed by Halvorson & Ziegler [21]. Various groups of microorganisms were counted in soil samples using various growth mediums and methodologies. Following the dilution plating viable count method, heterotrophic aerobic bacteria, fungus, and actinobacteria were counted on soil extract agar medium, including potato dextrose agar medium, Bengal rose medium and Ken knight's agar medium, respectively. After the requisite incubation period, the number of colony forming units was determined and expressed as cfu g^{-1} of soil. Serial dilution pour plate method was used to calculate the cfu g^{-1} of soil bacteria, fungi, and actinomycetes in their respective media.

2.4 Statistical Analysis

Web Agri Stat Package 2.0 (WASP 2.0) developed by ICAR-Central Coastal Agricultural Research Institute, Goa, India, was used to compile, pool, and statistically analyse the primary data collected during the investigation and to test the significance ($P < 0.05$) of variations between the treatments studied here.

Table 3. Nutrient content of manures applied in the experiment (mean over 5 years)

Nutrients manure	Cow dung manure	Vermicompost	Poultry
Organic C (mg g^{-1})	201.5	203.6	252.9
N (mg g^{-1})	8.8	12.7	19.6
P (mg g^{-1})	5.9	7.4	16.8
K (mg g^{-1})	14.2	8.0	15.1
Fe (mg g^{-1})	1.06	1.03	1.49
Mn (mg kg^{-1})	357.0	406.9	553
Zn (mg kg^{-1})	53.2	53.4	82
Cu (mg kg^{-1})	36.6	46.1	73

3. RESULTS AND DISCUSSION

In this piece of work, we look at the results of our investigation into the impact of different nutrient management practices on soybean growth, yield attributes, and soil properties.

3.1 Soil Biological Properties

Soil biological properties varied according to the different treatments applied. The study of biological parameters involved the microbial count and the enzymatic activity of the soil as follow:

Soil microbial population: Table 4 and Fig. 1, show the microbial population of bacteria, fungi, and actinomycetes in terms of colony forming unit per gram soil (cfu g^{-1} soil). In the given experiment it was seen that the colony forming unit (cfu) of bacteria, fungi, and actinomycetes were significantly higher in organically treated plots than in plots with chemical treatments. Treatment T1 represented by a bacterial count of 9.4 $x10^6$ cfu g^{-1} soil had the highest bacterial population, followed by T3 percent; 8.7 $x10^6$ cfu g^{-1}, T2 7.9 $x10^6$cfu g^{-1} and T4 7.4 $x10^6$cfu g^{-1}. T5 with 6.2 $x10^6$cfu g^{-1} and T6 were found to be statistically superior (state recommendations; 5.6 $x10^6$cfu g^{-1}. Fungi and actinomycetes populations showed similar trends to the bacterial population in all treatments. Soil microbial population was found to be higher in organic manure plots and/or combination plots than in inorganic fertilizer plots.

Soil microbial population was found to be higher in organic manure plots and/or combination plots than in inorganic fertilizer plots. It could be because organic manure provides more substrate. These findings are consistent with previous research findings [22, 23,24]. Thus, using organic N sources or combining them with chemical fertilisers has a greater positive impact on soil microbial activity than using only chemical fertilisers [25]. Another reason for the higher count in treatment T1 could be the moisture content, which has long been recognized as an important environmental factor in promoting microbial growth and activity [26, 27,28]. Previous research has found that using organic sources of nutrients increases microbial population, which supports the current study's findings (bacteria, fungus, and actinomycetes).

Soil enzymatic activity: Soil enzyme activity is a direct indicator of soil microbial dynamics and an indirect indicator of microbial activity. The level of enzyme activity in the soil can be used to infer the dynamics of soil microorganisms. Enzyme activity in the soil environment is thought to have a significant influence on overall soil microbial activity. In soil, the activity of enzymes such as fluorescein diacetate (FDA), dehydrogenase, alkaline phosphatase, and β-Glucosidase was measured as a function of nutrient management practices. Fluorescein diacetate hydrolysis activity in soybean was found to be highest in the 100 percent organic plot (T1), which was closely similar to T3 and T5 as stated in Table 4 and Fig. 2. Organic management had the highest dehydrogenase activity when compared to inorganic and integrated nutrient management Table 4 and Fig 2. Similarly, the highest levels of alkaline phosphatase and β-Glucosidase enzyme activity were found in T1 > T3 > T2 > T4 > T5 and T6. Treatments T5 and T6 were found to be statistically at par with each other.

Organic management had the highest dehydrogenase activity when compared to inorganic and integrated nutrient management. Mangalassery et al. (2019) and Ghosh et al. [29] supported this by indicating that an increase in DHA activity for organic management over mineral fertilized plots could be due to higher microbial biomass carbon and nitrogen in those plots. The DHA in rice and wheat-cultivated soils was improved after the application of FYM and other organic sources (sewage sludge, biofertilizers, crop residues, and combinations of these) due to the synergistic effect of microbial growth stimulation and improved soil moisture retention [22]. The activities of alkaline phosphatase and glucosidase enzymes were also highest in 100 percent organic, followed by 50 percent organic + 50 percent inorganic, as opposed to 100 percent inorganic and state recommendations.

Manure application is known to increase enzyme activities in soil, which could account for the higher organic carbon content in the organically applied plot, as reported by Aher et al [30]. Soil enzymatic activities were found to increase after organic manure was added, according to research by Okur et al [31]. Whereas a reduced soil enzyme activity as seen under RDF and sole inorganic treatment might be because of reduced substrate availability [32]. Also, higher levels of phosphatase and other soil enzyme activity were maintained after organic matter was added. This was likely the result of an increase in the soil microbial biomass and a greater degree of enzyme stabilization in humic substances [33].

Table 4. Soil microbe diversity and enzyme activity as a result of various nutrient management practices

Treatments	Microbial count (CFU g^{-1} soil)			Enzymatic activity				
	Bacteria (X 10^6 CFU g^{-1} soil)	Fungi (X 10^4 CFU g^{-1} soil)	Actinomycetes (X 10^5 CFU g^{-1} soil)	FDA* (µg fluorescein g^{-1} soil h^{-1})	DHA# (µg TPF g^{-1} soil d^{-1})	β-Glucosidase (µg PNP g^{-1} soil h^{-1})	Alkaline phosphatase (µg PNP g^{-1} soil h^{-1})	SMBC^ (µg g^{-1})
T1	9.4	4.7	5.6	59.5	50.1	281	304	318
T2	7.9	3.6	4.0	39.5	41.2	240	260	292
T3	8.7	4.2	4.5	43.5	45.6	270	287	304
T4	7.4	2.9	3.8	37.6	32.2	228	247	283
T5	6.2	2.0	2.7	30.9	16.5	213	229	268
T6	5.6	1.7	2.2	25.0	13.4	213	220	264
CD (P=0.05)	1.0	0.5	0.9	7	4	17	9	12

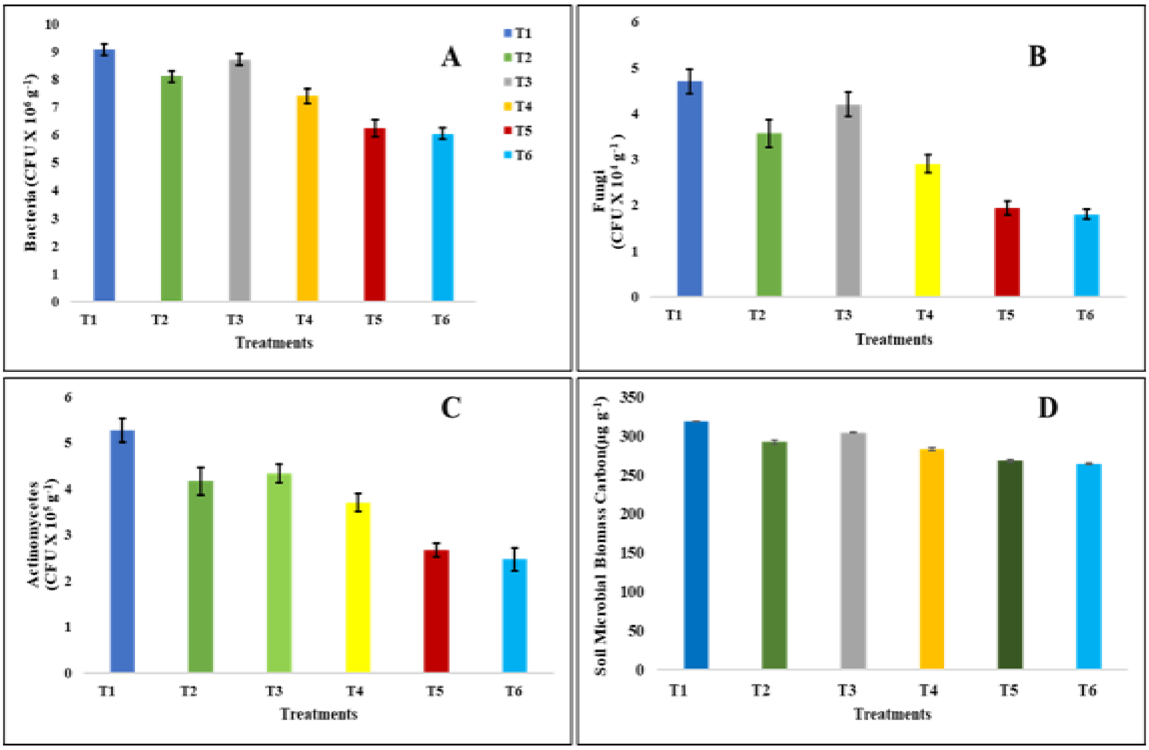

Fig. 1. Soil Microbial count (CFU g^{-1}soil) Bacteria (A), Fungi (B), Actinomycetes (C) and Soil Microbial Biomass Carbon (D) as affected by various nutrient management practices

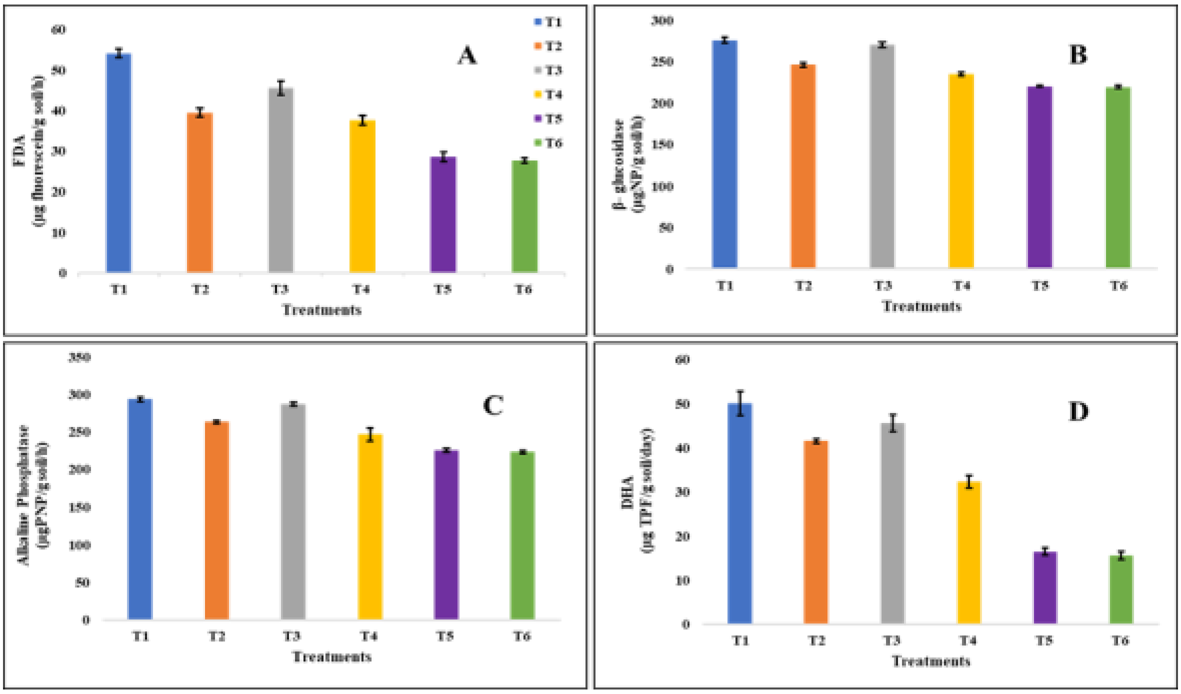

Fig. 2. Soil Enzymatic activity as affected by various nutrient management practices:(A) FDA, (B)β-glucosidase, (C) Alkaline Phosphatase and (D) DHA

***Soil microbial biomass carbon**:* Table 4 and Fig. 1 show that the highest value of soil microbial biomass carbon i.e., 318 g g^{-1} of soil, was recorded with 100% organic treatment. The state recommendations treatment had the lowest carbon content in soil microbial biomass (264 g g^{-1} of soil). These results were consistent with those reported by Tao et al. [34] in their research on cotton crops, where they found that the use of mineral fertilizers in combination with organic ones increased soil microbial biomass, enzyme activity, and resource utility of carbon. In treatments where organic manure was applied alone or in combination with inorganic fertilizer and natural farming product, the SMBC was found to be significantly higher than in treatments where inorganic fertilizer was applied alone (cattle manure and bio-organic fertilizer). Soil MBC increased when organic manure was applied due to an increase in root biomass, root exudates, and metabolizable carbon Manna et al. [35]; Ghosh et al. [36]. Possibly, a reduced soil enzyme activity (β-glucosidase and alkaline phosphatase) and SMBC under RDF and CT was because of reduced substrate availability [32]. According to Ghosh et al. [29], the carbon content of microbial biomass is increased when it is supplemented from the outside with organic manure and microorganisms are activated.

3.2 Summary

This chapter displays and explains the results of the study "Soybean yield as affected by organic, inorganic, and integrated nutrient management practises in Vertisols of Madhya Pradesh" regarding the impact of different nutrient management practises on soybean growth, yield attributes, yield, and soil properties. Different data were statistically analysed. Soybean yield as affected by organic, inorganic, and integrated nutrient management practises in Vertisols of Madhya Pradesh was studied during the Rabi (winter) seasons of 2020-21 at ICAR-Indian Institute of Soil Science Bhopal, Madhya Pradesh. The trial had six randomised treatments. T1=100% Organic; T2=50% Organic + Natural Farming; T3=50% Organic + 50% Inorganic; T4=25% Organic + 25% Inorganic + Natural Farming; T5=100% Inorganic; T6=100% Inorganic (State recommendation). During the study parameters including soil macro and micronutrients, microbial population, and enzyme activity were analysed recorded. Before sowing and after harvesting, soil pH ranged from 7.59 to 7.64 and 7.61 to 7.66, respectively, with no significant difference between treatments. T1 (100 percent organic) had the highest pH, while T6 had the lowest. Electrical conductivity (EC), expressing total soluble salt content, was not significantly affected by different treatments, and ranged between 0.263 – 0.297 and 0.272 – 306 dS m^{-1} "before sowing" and "after harvesting." Treatments affected soil organic carbon. Before sowing, treatment T1 had the most soil organic carbon, while T6 had the least. After crop harvesting, treatment T1 had the highest soil organic carbon content (0.96 percent), followed by T3. Natural farming treatments (T2 and T4) had similar soil organic carbon content. Inorganic treatment produced the least organic carbon.

Different treatments affected soil NPK content. Available nitrogen in soil was significantly higher in treatment T1 (263 kg ha-1) followed by T3 (242 kg ha-1), T5 (232 kg ha-1) and T6 (225 kg ha-1) compared to T4 (216 kg ha-1) where nitrogen was lowest after soybean harvest. Similar trends were seen before sowing soybean. T4 was less than T5 and T6, which were at par. After crop harvest, available P in soil increased from 39 kg ha^{-1} (T4) to 58 and 65 kg ha^{-1} (50 percent organic + 50 percent inorganic and 100 percent organic treatments, respectively). 100% organic yielded 65 kg ha^{-1}. P content in 100% inorganic (54 kg ha^{-1}) and state recommendations was almost equal (52 kg ha^{-1}). T4 had the lowest P levels of all treatments. Before sowing, T4 (25 percent organic + 25 percent inorganic + natural farming) and T1 (100 percent inorganic) treatments had the least and most available P, respectively. Soil K followed the same trend as nitrogen and phosphorus. Full dose nitrogen from organic manure increased available potassium by 587 kg ha^{-1}. Different treatments affected DTPA-extractable micronutrients (Zn, Fe, Mn, Cu). T1 had the most Zn, Fe, Mn, and Cu, followed by T3, and T4 had the least. T5 and T6 were equal. Bacteria, fungi, and actinomycetes were measured in soil in (cfu g^{-1}). T1 had the highest bacterial population (9.4 $x10^6$ cfu g^{-1}), followed by T3 (8.7 $x10^6$cfu g^{-1}), T2 (7.9 $x10^6$cfu g^{-1}) and T4 (7.4 $x10^6$cfu g^{-1}). These treatments were statistically superior to T5 and T6 (5.6 $x10^6$cfu g^{-1}). Fungi and actinomycetes showed similar trends to bacteria in all treatments. Organic manure and/or combination plots had higher soil microbial populations than inorganic fertilisers plots. Fluorescein diacetate (FDA), dehydrogenase, alkaline phosphatase, and β-Glucosidase activity in soil was affected by nutrient management. T1 had the highest fluorescein diacetate hydrolysis activity, followed by T3 and T5. Organically managed soil had higher dehydrogenase activity than inorganic and integrated soils. T1 had the most alkaline phosphatase and β-glucosidase activity, followed by T3, T2, T4, and T5. T5 and T6 were equal. 100% organic soil had the highest microbial biomass carbon (318µg g^{-1}). State recommendation treatment had the least soil microbial biomass carbon (264 µg g^{-1}). Organic manure alone or in combination with inorganic fertiliser and natural farming product increased SMBC over inorganic fertiliser alone.

4. CONCLUSION

Integrated nutrient management (INM) refers to the strategic integration of conventional and innovative techniques in nutrient management. This approach aims to establish a farming system that is environmentally and economically sustainable by effectively utilizing all available organic, inorganic, and biological components and substances [37] (Wu & Ma (2015)). Maximizing yields and enhancing nutrient use efficiency are dependent on INM's fertilizer administration volume and timing being in sync with the crop's nutrient needs [38]. The current study involves analysis of yield and nutrient dynamics of Soybean crop as affected by organic, inorganic, and integrated nutrient management practises in Madhya Pradesh was studied during the Rabi (winter) seasons of 2020-21. During the study, crop growth, yield, and yield attributing parameters and analysed soil macro and micronutrients, microbial population, and enzyme activity were recorded. The data showed that Continuous addition organic manure alone or in combination with inorganic fertilizer resulted in improved soybean growth, yield and yield attributes. Further the organic manure application alone or in combination with inorganic fertilizer also improved the soil health in term of soil organic carbon and soil biological activity.100 percent organic soil had the highest microbial biomass carbon (318 g g^{-1}). Organic manure alone or in combination with inorganic fertiliser increased SMBC over inorganic alone. Soil enzymatic activity *viz.*, Fluorescein diacetate (FDA), dehydrogenase, alkaline phosphatase, and β-Glucosidase activity in soil was positively affected by the use of organic hybrid treatments. The primary significance of the current study lies in the fundamental observation that a prudent application of both organic and inorganic amendments has the potential to foster a sustainable soybean crop yield. Furthermore, the prudent utilization of inorganic fertilizer in conjunction with organic amendments results in a notable augmentation of soil nutritional well-being, accompanied by a substantial improvement in the diversity of microbial flora and enzymatic activity within the soil. The soil's available nutrition and nutrient distribution are greatly impacted by the consistent usage of manure from farms and mineral fertilizer in a balanced way [39]. Researchers found that compared to standard farming practices, INM increased crop yields by 8-150% while also improving soil health, grain quality, and financial benefits to farmers [6]. Consequently, INM composed of farmyard manure and crop residues may improve soil quality (soil aggregation, physical characteristics, and accessible nutrients) over sole chemical fertilization in the long term [40-43]. The purpose of this study was to make soybean cropping system in the Indo-Gangetic plain a greener as well as sustainable process with least amount of carbon footprint generated (using predominant inorganic fertilizer input).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Roy R, Sultana S, Wang J, Mostofa MG, Sarker T, Rahman Shah MM et al. Revegetation of coal mine degraded arid areas: the role of a native woody species under optimum water and nutrient resources. Environ Res. 2022;204(A):111921.
2. Manna MC, Ghosh PK, Ganguly TK. Comparative performance of four sources of enriched phosphocompost and inorganic fertilizer application on yield, uptake of nutrients and biological activity of soil under soybean–wheat rotation. J Food Agric Environ. 2003;1(2):203-8.
3. Meena BP, Kumar A, Lal B, Sinha NK, Tiwari PK, Dotaniya ML, Jat NK, Meena VD. Soil microbial, chemical properties and crop productivity as affected by organic manure application in popcorn (Zea mays

L. Var. everta). African J. Microbio. Res. 2015;9(21):1402–1418.

4. Jat RA, Jain NK, Yadav RS, Reddy KK, Choudhary RR, Zala PV et al. System-based integrated nutrient management improves productivity, profitability, energy use efficiency and soil quality in peanut-wheat cropping sequence in light Black soils. Sustainability. 2023;15(2):1361.
5. Prasad R, Power JF. Soil Fertility Management for Sustainable Agriculture. CRC Lewis, Bota Raton, Fl., USA. 1997;356.
6. Tarfeen N, Hassan S, Manzoor A, Sultan Z. Integrated nutrient management strategies for improving crop yield. In Sustainable Plant Nutrition. Academic Press. 2023;283-297.
7. Ahmed M, Hyder SI, Ullah A, Khan RU, Ahmad MA, Hayat A et al. Response of integrated nutrient management (INM) on growth, yield, and nutrient use efficiency of wheat under irrigated conditions. J Appl Res Plant Sci. 2023;4(1):363-9.
8. Meena BP, Biswas AK, Singh M, Chaudhary RS, Singh AB, Das H et al. Long-term sustaining crop productivity and soil health in maize–chickpea system through integrated nutrient management practices in vertisols of central India. Field Crops Res. 2019;232:62-76.
9. Bairwa J, Dwivedi BS, Rawat A, Thakur RK, Mahawar N. Long-term effect of nutrient management on soil microbial properties and nitrogen fixation in a vertisol under soybean–wheat cropping sequence. J Indian Soc Soil Sci. 2021; 69(2):171-8.
10. Dwivedi AK, Dwivedi BS. Impact of long-term fertilizer management for sustainable soil health and crop productivity: issues and challenges. JNKVV Res J. 2015;49:387-97.
11. Diacono M, Montemurro F. Long-term effects of organic amendments on soil fertility. J Sustain Agric. 2011;2:761-86.
12. Scialabba N, Hattam C. (Eds.). Organic agriculture, environment and food security (No. 4). Food & Agriculture Org; 2002.
13. Jackosn ML. Soil chemical analysis Prentice Halla of India Private Limited. New Delhi, Indian. 1973;8:21-9.
14. Walkley A, Black IA. An examination of the Degtijariff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37(1):29-38.

    DOI: 10.1097/00010694-193401000-00003.
15. Subbiah BV, Asija GL. A rapid procedure for assessment of available nitrogen in soils. Curr Sci. 1956;31:196-260.
16. Vance ED, Brookes PC, Jenkinson DS. Microbial biomass measurements in forest soils: the use of the chloroform fumigation-incubation method in strongly acid soils. Soil Biol Biochem. 1987;19(6):697-702.
17. Jenkinson DS, Powolson DS, Weddreburn RWM. The effects of biocidal treatments on metabolism in soil. 3. The relationship between soil biovolume, measured by optical microscopy and the flush of decomposition caused by fumigation. Soil Biol Biochem. 1976;8:189-202.
18. Casida LE. Microbial metabolic activity in soil as measured by dehydrogenase determinations. Appl Environ Microbiol. 1977;34(6):630-6.
19. Eivazi F, Tabatabai MA. Glucosidases and galactosidases in soils. Soil Biol Biochem. 1988;20(5):601-6.
20. Adam G, Duncan H. Development of a sensitive and rapid method for the measurement of total microbial activity using fluorescein diacetate (FDA) in a range of soils. Soil Biol Biochem. 2001;33(7-8):943-51.
21. Halvorson HO, Ziegler NR. Application of statistics to problems in bacteriology: I. A means of determining bacterial population by the dilution method. J Bacteriol. 1933;25(2):101-21.
22. Kumari S, Chattopadhyay N, Mandal J, Singh M. Integrated Nutrient Management boost the soil biological properties in rice rhizosphere. J Crop Weed. 2017;13(1):116-24.
23. Kuttimani R, Somasundaram E, Velayudham K. Effect of integrated nutrient management on soil microorganisms under irrigated banana. Int J Curr Microbiol Appl Sci. 2017;6(11):2342-50.
24. Mallikarjun M, Maity SK. Effect of integrated nutrient management on soil biological properties in kharif rice. Int J Curr Microbiol Appl Sci. 2018;7(11):1531-7.

25. Sharma P, Singh G, Singh RP. Conservation tillage and optimal water supply enhance microbial enzyme (glucosidase, urease and phosphatase) activities in fields under wheat cultivation during various nitrogen management practices. Arch Agron Soil Sci. 2013; 59(7):911-28.
26. Feng X, Simpson MJ. Temperature and substrate controls on microbial phospholipid fatty acid composition during incubation of grassland soils contrasting in organic matter quality. Soil Biol Biochem. 2009;41(4):804-12.
27. Singh G, Kumar D, Marwaha TS, Singh AK, Srinivasmurthy K. Conservation tillage and integrated nitrogen management stimulates soil microbial properties under varying water regimes in maize-wheat cropping system in northern India. Arch Agron Soil Sci. 2011;57(5):507-21.
28. Bhaduri D, Purakayastha TJ, Patra AK, Singh M, Wilson BR. Biological indicators of soil quality in a long-term rice–wheat system on the Indo-Gangetic plain: combined effect of tillage–water–nutrient management. Environ Earth Sci. 2017;76(5):202.
29. Ghosh A, Singh AB, Kumar RV, Manna MC, Bhattacharyya R, Rahman MM et al. Soil enzymes and microbial elemental stoichiometry as bio-indicators of soil quality in diverse cropping systems and nutrient management practices of Indian vertisols. Appl Soil Ecol. 2020;145.
30. Aher SB, Lakaria BL, Swami K, Singh AB, Ramana S, Thakur JK et al. Soil microbial population and enzyme activities under organic, biodynamic and conventional agriculture in semi-arid tropical conditions of central India. J Exp Biol Agric Sci. 2018b;6(5):763-73.
31. Okur N, AltindİşlĬ A, Çengel M, Göçmez S, Kayikçioğlu HH. Microbial biomass and enzyme activity in vineyard soils under organic and conventional farming systems. Turk J Agric For. 2009;33:413-23.
32. Borase DN, Nath CP, Hazra KK, Senthilkumar M, Singh SS, Praharaj CS et al. Long-term impact of diversified crop rotations and nutrient management practices on soil microbial functions and soil enzymes activity. Ecol Indic. 2020;114:106322.
33. Martens DA, Johanson JB, Frankenberger WT. Production and persistence of soil enzymes with repeated addition of organic residues. Soil Sci. 1992;153(1):53-61.
34. Tao R, Liang Y, Wakelin SA, Chu G. Supplementing chemical fertilizer with an organic component increases soil biological function and quality. Appl Soil Ecol. 2015;96:42-51.
35. Manna MC, Swarup A, Wanjari RH, Ravankar HN. Long-term effects of NPK fertiliser and manure on soil fertility and a sorghum–wheat farming system. Aust J Exp Agric. 2007;47(6):700-11.
36. Ghosh A, Bhattacharyya R, Meena MC, Dwivedi BS, Singh G, Agnihotri R et al. Long-term fertilization effects on soil organic carbon sequestration in an inceptisol. Soil Till Res. 2018a;177:134-44.
37. Janssen BH. Integrated nutrient management: the use of organic and mineral fertilizers. In: van Reuler, H., Prins, W.H. (Eds.), The Role of Plant Nutrients for Sustainable Crop Production in Sub-Saharan Africa. Ponsen and Looijen, Wageningen, The Netherlands. 1993;89–105.
38. Cassman KG, Dobermann A, Walters DT. Agroecosystems, nitrogen use efficiency, and nitrogen management. Ambio. 2002;31(2):132-40.
39. Jayanthi D, Gokila B. Continuous cropping and fertilization on vertical distribution of major nutrients; 2023. Jayanthi D, Gokila B. Continuous Cropping and Fertilization on Vertical Distribution of Major Nutrients, SOC Dynamics through FT-IR spectroscopy and developing soil quality indices under sandy clay loam soil. Commun Soil Sci Plant Anal. 2023;54(3):356-77.
40. Nath CP, Kumar N, Dutta A, Hazra KK, Praharaj CS, Singh SS et al. Pulse crop and organic amendments in cropping system improve soil quality in rice ecology: evidence from a long–term experiment of 16 years. Geoderma. 2023;430:116334.
41. Adriano DC. Trace elements in terrestrial environments. Springer- Verlag, New York. 2001;29-59.

42. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circ. U.S. Deptt. Agriculturists. 1954;939:19.

43. Hanway JJ, Heidel H. Soil analysis methods as used in Iowa state college soil testing laboratory. Natl Agric Libr United States. 1952;57:1-31.

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