



Integrated Nutrient Management: Effect on Soil Properties and Crop Yields on Sandy Clay Loam Soil under Maize-wheat Cropping System

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ABSTRACT

Background: Constant use of chemical fertilizer in agriculture field, degrade overall soil quality and increases the environmental pollution. Integrated nutrient management is an eco-friendly and cost-effective method that involves the combined application of organic amendment and inorganic fertilizer resulting in upgrading soil health, crop productivity, carbon sequestration and mitigating climate change. The current study aimed to examine the combined effects of organic amendment and inorganic fertilizer on soil quality and crop productivity in maize-wheat cropping systems.

Methods: A two-year field experiment was conducted in the month of June-October (2021-2022) for maize and Nov-April (2021-2022 and 2022-2023) for wheat crop. Fertilizer treatments, viz., control (zero fertilizer), NPK (recommended fertilizer), 50% NPK + *A. chroococum*, 50% NPK + green manure, 50% NPK + karanja cake, 50% NPK + poultry waste, 50% NPK + wheat residue, 50% NPK + maize residue were applied in a randomized block design with four replications.

Result: Application of 50% NPK+ poultry waste showed higher soil organic carbon (0.91% and 0.92%) and microbial biomass carbon (353.42 mg kg⁻¹ and 394.35 mg kg⁻¹) followed by 50% NPK+ karanja cake. Application of 50% NPK + poultry waste increased grain yield by 48.5% and 23.25% in maize and wheat respectively over control. Poultry waste, as a replacement for sole NPK, could be a promising strategy for the management of soil health as well as crop productivity.

Key words: Carbon sequestration, Organic amendment, Poultry waste, Soil organic carbon.

INTRODUCTION

Maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) are important cereal crops after rice cultivated widely throughout the world and adopted in uplands area of Jharkhand. In the state of Jharkhand, maize is cultivated on an area of 286.23 ha (2016-2017) with an annual production of 578.06 tonnes and productivity of 2.02 t ha⁻¹ and wheat grown on an area of 1.7 Mha with an annual production of 3.36 MT and productivity of 1.98 t ha⁻¹.

Inorganic or commercial nitrogenous fertilizers are increasingly being used to meet the food demand for the ever-expanding population. But the continuous use of chemical fertilizer decreases the overall soil quality as well as increases the environmental pollution (Selim, 2018). Integrated nutrient management (INM) encourages the application of both organic and inorganic fertilizer sources and help in understanding the relationship between soil, crop and climate (Mohan *et al.*, 2024). Combine application of organic and inorganic fertilizer provides a balanced supply of mineral nutrients to the plants and provides a favorable environment for rapid microbial growth which enhances crop growth and productivity (Sankhyan *et al.*, 2024).

Organic amendment like, green manure (GM) is a renewable source of on farm biological nitrogen fertilizer, which boosts soil nitrogen use efficiency and improves nutrient retention and is beneficial for crop production (Bharali *et al.*, 2017). After mineralization of GM it releases

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available nitrogen for subsequent crop and increase nutrient status of the soil. Continuous addition of crop residue increases the status of organic matter in soil and favour carbon sequestration. The integrated use of organic waste with the biofertilizer and chemical fertilizer act as a best alternative of sole use of chemical fertilizer. Nutrient accumulation within the crop residue increases crop yield. Incorporating legumes plant residue play an important role in improving soil fertility and crop productivity (Abera and Gerkabo, 2021).

Azotobacter as a biofertilizer, used in combination with inorganic fertilizer, increases crop growth, economic and biological yield (Mahato and Kafle, 2018). Poultry manure is carbon based manure, easily available and eco-friendly (Fiyyaz *et al.*, 2021). It imparts surplus amount of nitrogen as well as increase the potential of cation exchange in soil

that, helps in the crop development. Combine application of poultry waste and inorganic fertilizer is the finest way for optimum nutrient utilization, increases the crop productivity and soil quality. Application of karanja cake on soil makes soil acidic, by producing organic acids and humus during the process of decomposition. Organic amendments help in the formation of soil aggregation with large soil micropores. This leads to decrease in bulk density of the soil with increase porosity as well as water holding capacity provide enough space for air and water retention in soil. The combine effect of karanja cake with inorganic fertilizer slow down the process of conversion of nitrogenous compound into ammonia, nitrates, nitrogen and upgrade nutrient use efficiency (NUE) (Sarwar *et al.*, 2020).

A judicious use of nutrient is the best alternative for sustainable crop production and maintains soil health. Although many researchers and scientists have reported good results of INM but farmers are still unknown and not aware regarding INM which needs great efforts and assistance for adoption of INM practices. The proper use of inorganic fertilizer in combination with organic sources may increase crop growth, yield and soil health that reduces environment pollution. So, our study was done in agricultural field with objective to examine the changes in soil physical, chemical and biological characteristics of sandy clay loam soil and crop yield involving fertilizer treatments on maize-wheat cropping sequence.

MATERIALS AND METHODS

Site description

Field experiments were conducted through two consecutive years in June-Oct (2021-2022) and Nov-April (2021-2022 and 2022-2023) for *kharif* maize and *rabi* wheat respectively. Experimental site located in the agricultural site near by the Central University of Jharkhand, Brambe (23°43' N, 85°14' E), Ranchi, Jharkhand (Fig 1). During the

crop growing season, the average rainfall were recorded 57.32 mm and 23.4 mm in maize and wheat crop respectively (Fig 2). The average maximum and minimum temperatures were recorded at 30.04°C and 22.51°C in maize and 28.17°C and 15.35°C in wheat crop in both the seasons (Fig 2). The initial soil was characterized as sandy clay loam in texture. Analysis of physico-chemical and biological properties of initial soil before applying treatment is shown in Table 1. The climate of this zone is humid subtropical, dry winter climate (Shree and Kumar, 2018).

Experimental design and fertilizer management

The experiments were carried out in a randomized block design with the following treatments: Control (zero fertilizer, T_0), 100% recommended dose of inorganic fertilizer (NPK) (T_1), 50% NPK+ *A.chroococum* (AZ @ 7.5kg ha⁻¹, T_2), 50%

Table 1: Physico-chemical and biological properties of initial soil from experimental field.

Soil properties	
Bulk density (g cm ⁻³)	1.512±0.03
Water holding capacity (%)	36.163±0.12
Porosity (%)	35.34± 0.02
Moisture (%)	7.18±0.21
Sand (%)	63±0.5
Silt (%)	26.17±0.36
Clay (%)	10.83±0.57
pH	6.34±0.082
EC (mS cm ⁻¹)	0.26±0.01
Organic matter (%)	1.01±0.05
Available nitrogen (kg ha ⁻¹)	130.33±2.31
Available phosphorous (kg ha ⁻¹)	18.32±1.23
Available potassium (kg ha ⁻¹)	98.38±2.54
Cation exchange capacity (Cmolckg ⁻¹)	11.26±0.02
Microbial biomass C (mg kg ⁻¹)	186.25±3.12

Value reported mean±SE (n=4).

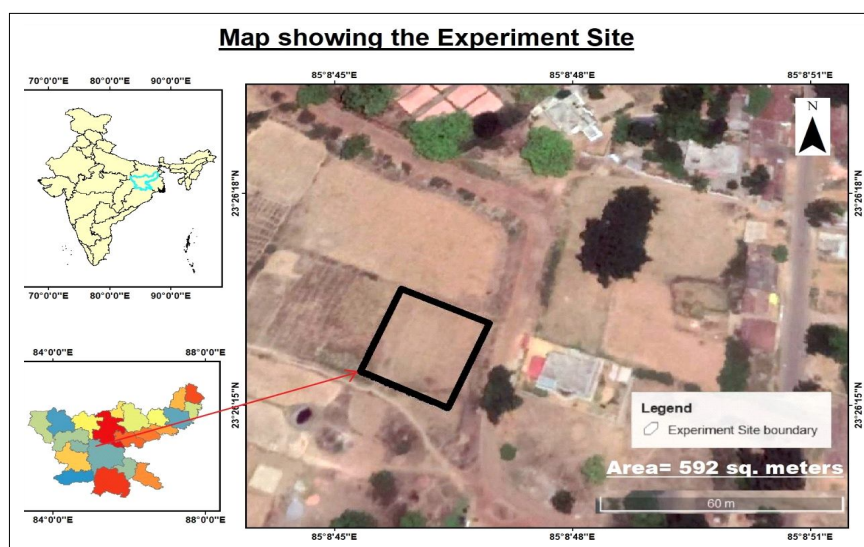


Fig 1: Map showing the experimental site.

Table 2: Effect of INM on the soil properties after harvesting of maize crop.

Treatment	pH	EC (mS cm ⁻¹)	WHC (%)	BD (g cm ⁻³)	Porosity (%)	Moisture (%)	SOC (%)	SOM (%)	CEC (Cmolkg ⁻¹)	MBC (mg kg ⁻¹)
T ₀ : Control	6.58±0.34 ^d	0.27±0.01 ^c	40.72±2.2 ^c	1.50±0.04 ^d	36.74±2.2 ^c	7.59±2.01 ^c	0.60±0.005 ^d	1.04±0.003 ^d	13.62±1.05 ^d	187±3.03 ^c
T ₁ : NPK	6.32±0.03 ^{bc}	0.31±0.02 ^a	44.31±3.4 ^b	1.48±0.02 ^c	38.30±3.4 ^{ab}	8.22 ±1.2 ^{bc}	0.79±0.001 ^{bc}	1.38±0.005 ^c	14.87±1.1 ^{bc}	296.38±2.02 ^b
T ₂ : NPK+AZ	6.38± 0.2 ^{ab}	0.31±0.05 ^a	45.69±3.5 ^{ab}	1.43±0.03 ^b	38.39±3.5 ^a	8.43 ±2.31 ^b	0.81±0.002 ^{ab}	1.40±0.004 ^{bc}	15.12±1.3 ^b	320.53±3.07 ^a
T ₃ : NPK+GM	5.80± 0.2 ^b	0.29±0.01 ^{ab}	43.24±3.1 ^b	1.45±0.05 ^{ab}	38.09±3.2 ^{ab}	8.38 ±1.3 ^{ab}	0.78±0.001 ^c	1.43±0.002 ^b	15.2 ±1.2 ^b	327.91±2.04 ^{ab}
T ₄ : NPK+KC	6.05± 0.03 ^a	0.32±0.04 ^a	44.36±4.2 ^a	1.44±0.03 ^{ca}	38.61±3.2 ^a	8.44 ±1.4 ^a	0.86±0.002 ^{ab}	1.54±0.001 ^a	15.52±1.05 ^a	344.08±3.03 ^a
T ₅ : NPK+PW	6.09 ±0.59 ^a	0.34±0.1 ^a	46.48±3.7 ^a	1.44±0.01 ^a	39.73±2.3 ^a	8.48±1.23 ^a	0.91±0.002 ^a	1.57±0.003 ^a	16.06±1.25 ^a	353.42±3.01 ^a
T ₇ : NPK+WR	5.75±0.2 ^b	0.27±0.2 ^{ab}	42.24±3.0 ^{bc}	1.46±0.05 ^{ab}	37.15±0.4 ^{ab}	8.13±1.21 ^{bc}	0.80±0.001 ^b	1.35±0.002 ^c	15.1±1.02 ^b	289.24±32 ^{bc}
P value										
Year	0.000	0.13	0.000	0.36	0.000	0.000	0.000	0.000	0.20	0.000
Treatment	0.000	0.30	0.000	0.80	0.000	0.000	0.000	0.000	0.185	0.000
Year*treatment	0.000	0.039	0.000	0.288	0.000	0.000	0.000	0.000	0.037	0.000
LSD (0.05)	0.065	0.005	1.36	0.08	0.98	0.122	0.094	0.16	0.461	8.50

LSD-Least significant differences; NPK- Recommended inorganic fertilizer, AZ-Azotobacter, GM- Green manure, KC- Karanja cake, PW- Poultry waste, WR-Wheat residue. Values represent as mean of two years pooled data ± SE (n=4). Different letters within the same column indicate significant differences among the treatments at p<0.05 level by DMRT.

NPK+ green manure (*Vigna unguiculata*) (GM @ 2.5 t ha⁻¹, T₃), 50% NPK + karanja cake (KC @ 6 t ha⁻¹, T₄), 50% NPK + poultry waste (PW @ 4 t ha⁻¹, T₅), 50% NPK + maize residue (MR @ 5 t ha⁻¹, T₆), 50% NPK + wheat residue (WR @ 5 t ha⁻¹, T₇). Each treatment was replicated 4 times and randomly distributed in blocks with plot size of 4m × 4m.

Maize (*Zea mays* L., cv Hybrid maize Hero) seeds were sown at a spacing of 75 × 20 cm (row × plant) with seed rate of 20 kg ha⁻¹ and wheat seeds (*Triticum aestivum* L., cv Kaveri-51) were sown at the spacing of 20 × 20 cm (row × plant) with seed rate of 120 kg ha⁻¹ as per the Birsa Kishan Diary, recommended by Birsa Agriculture University, Ranchi, Jharkhand.

Collection and analysis of soil quality parameters

Soil samples (0-30 cm) were collected after maize and wheat crop harvest and analysed for selected soil quality parameters. Soil pH and electrical conductivity (EC) were determined by pH meter and conductivity meter respectively. Soil moisture, bulk density (BD), Water holding capacity (WHC), soil porosity, soil texture, available N, P and K was determined by standard method. Soil organic carbon (SOC) and soil organic matter (SOM) were determined by the dichromate oxidation method (Walkley and Black, 1934). Cation exchange capacity (CEC) was estimated by ammonium acetate method (Norman, 1965). Microbial biomass carbon (MBC) (Cmic) content was estimated by chloroform extraction (Vance *et al.*, 1987).

Analysis of yield attributing parameters

After harvesting of the crop, yield and yield attributing parameters of maize and wheat were recorded manually (Bordoloi *et al.*, 2017). From 1 m² area of all replications of each treatment, mature plants were harvested avoiding the border rows.

Water management

Kharif maize crop required irrigation, once in a week after 20 to 30 days of sowing. There were a total of 6 irrigation events in wheat, following the recommended practices mentioned in Birsa Kishan Diary, recommended by Birsa Agriculture University, Ranchi, Jharkhand.

Statistical analysis

The effect of the combined application of organic and inorganic amendment and the differences among treatments were determined by using ANOVA followed by Duncan's multiple range test (DMRT) and least significant difference (LSD) differences are reported at p<0.05 with the help of IBM SPSS 23.0 (IBM SPSS, Inc., USA, 2011) statistical software.

RESULTS AND DISCUSSION

Soil physico chemical properties

A perusal of data in Table 2 and Table 5 showed that overall pH ranges from 5.62 to 6.58 of the soil after harvest of maize and wheat crops, whereas, EC content recorded

maximum in T_5 (NPK+PW) i.e., 0.34 and 0.41 mS cm^{-1} in maize and wheat field respectively. Minimum BD was recorded in T_5 (1.44 and 1.40 g cm^{-3}) in both the crops. The treatment NPK+PW recorded maximum porosity and water holding capacity followed by NPK+AZ > NPK+KC > NPK >

NPK+ GM > NPK+WR > control in maize crop (Table 2). A similar trend was observed in the wheat crop in the order of NPK+ PW > NPK+AZ > NPK+KC > NPK > NPK+ GM > NPK+WR > control and the treatments had significant differences among them (LSD0.05 = 1.022 and 1.545)

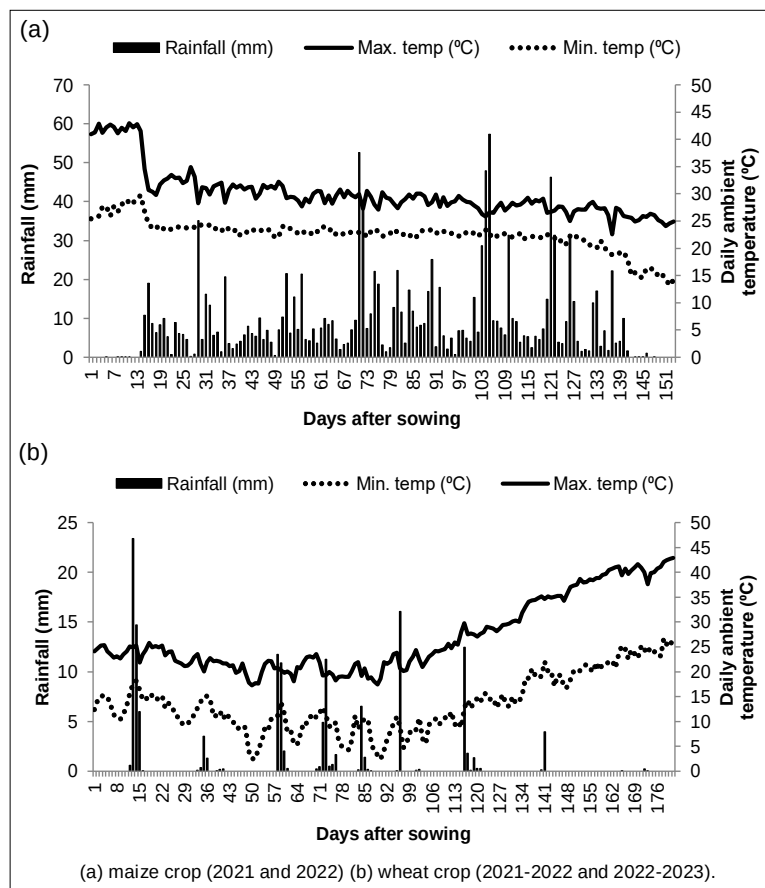


Fig 2: Daily rainfall and variation of temperature during the crop growth period.

Table 3: Effect of INM on the soil nutrients after harvesting of maize and wheat crop.

Treatment	Maize (kg ha^{-1})			Wheat (kg ha^{-1})		
	Available N	Available P	Available K	Available N	Available P	Available K
Control	133.31 $\pm$ 2.3 ^d	20.45 $\pm$ 2.8 ^c	104.6 $\pm$ 1.21 ^d	134.7 $\pm$ 3.2 ^d	21.26 $\pm$ 2.2 ^c	103.4 $\pm$ 3.21 ^d
T_1 :NPK	335.2 $\pm$ 3.4 ^{ab}	24.8 $\pm$ 2.14 ^{bc}	168.9 $\pm$ 1.2 ^{bc}	332.3 $\pm$ 3.3 ^{ab}	25.75 $\pm$ 2.4 ^{bc}	176.45 $\pm$ 3.52 ^c
T_2 :NPK+AZ	337.2 $\pm$ 2.31 ^{ab}	27.5 $\pm$ 2.36 ^b	187.25 $\pm$ 2.5 ^b	343.2 $\pm$ 3.12 ^b	29.2 $\pm$ 2.3 ^b	206.7 $\pm$ 3.45 ^{ab}
T_3 :NPK+GM	321.05 $\pm$ 2.14 ^c	31.7 $\pm$ 2.58 ^b	202.7 $\pm$ 2.12 ^{ab}	323.1 $\pm$ 2.4 ^c	30.55 $\pm$ 2.42 ^b	195.75 $\pm$ 3.67 ^b
T_4 :NPK+KC	337.35 $\pm$ 3.0 ^{ab}	32.45 $\pm$ 2.24 ^{ab}	204.65 $\pm$ 2.3 ^a	338.7 $\pm$ 2.3 ^{ab}	35.2 $\pm$ 2.1 ^a	217.3 $\pm$ 3.61 ^a
T_5 :NPK+PW	355.25 $\pm$ 2.16 ^a	36.55 $\pm$ 2.57 ^a	218.45 $\pm$ 2.8 ^a	357.3 $\pm$ 2.3 ^a	37.95 $\pm$ 2.3 ^a	235.7 $\pm$ 3.58 ^a
T_6 :NPK+MR				330.45 $\pm$ 2.61 ^c	29.95 $\pm$ 2.5 ^b	202.8 $\pm$ 3.81 ^{ab}
T_7 :NPK+WR	329.35 $\pm$ 2.3 ^{bc}	26.25 $\pm$ 1.2 ^b	161.4 $\pm$ 1.9 ^{bc}			
P value						
Year	0.000	0.1	0.000	0.000	0.000	0.000
Treatment	0.000	0.39	0.000	0.000	0.000	0.000
Year*treatment	0.000	0.039	0.000	0.000	0.000	0.000
LSD (0.05)	2.51	0.84	1.65	2.77	2.87	1.56

LSD-Least significant differences; NPK- Recommended inorganic fertilizer, AZ-Azotobacter, GM- Green manure, KC- Karanja cake, PW- Poultry waste, WR-Wheat residue, MR- Maize residue. Values represent as mean of two years pooled data $\pm$ SE (n=4). Different letters within the same column indicate significant differences among the treatments at $p<0.05$ level by DMRT.

(Table 5). The application of NPK+ PW increased CEC value by 17% and 14% over control in maize and wheat crop respectively.

Soil organic carbon, soil organic matter and microbial biomass carbon

The pooled data of 2 years showed that, application of NPK in combination with the organic enriches the SOC over control in both the crop (Table 2 and 5). SOC was found to be significantly higher in NPK+PW (0.91%) over control (0.60%) followed by NPK+KC (0.86%) in maize crop. Similar pattern was also observed in wheat crop (Table 5). IN both the crop, soil organic matter was significantly higher in NPK+PW (1.57% and 1.58%) and lowest in NPK+WR (1.35%) in maize and NPK+MR (1.40%) in wheat crop. The MBC recorded maximum values in NPK+PW *i.e.*, 353.42 mg kg⁻¹ and 394.35 mg kg⁻¹ in maize and wheat crop respectively.

Soil nutrient contents

In the soil layer (0-30 cm), plot treated with NPK+PW recorded highest AN *i.e.*, 355.25 and 357.3 kg ha⁻¹ in maize and wheat field respectively. AP was also greater in plots treated poultry waste (36.55 kg ha⁻¹) and (37.95 kg ha⁻¹) than other fertilizer in both the cropping systems. AK ranged from 104.6 -218.45 kg ha⁻¹ in maize while 103.4-235.7 kg ha⁻¹ in wheat in both year of cropping system. Plot incorporated with NPK+PW showed 1.08% higher AK in maize and 1.27% in wheat over control (Table 3).

Yield and yield related parameters

Table 4 and Table 6 showed the differences in yield and yield related parameters of the crops in response to different treatments ($P<0.05$). In maize crop, parameters like ear weight, cob length, tassel length, 1000 kernel weight, number of kernalrow⁻¹, yield, stover yield and harvest index were recorded highest in NPK+PW treated plots (Table 4). In NPK+PW treated plots, the yield of maize increased by 49% (Table 4) whereas in wheat value increased by 23% as compared to control (Table 6). In wheat crop, maximum viable tillers during two consecutive years were recorded in NPK+PW followed by NPK+KC> NPK+AZ> NPK> NPK+MR> NPK+GM> control (Table 6). The spike weight of wheat crop recorded highest in NPK+KC over control. The straw yield was recorded higher in NPK+PW followed by NPK+AZ. Harvest index was recorded maximum in NPK+PW (43.03%) in wheat crop (Table 6).

At crop harvest, soil pH decreased in treated plots compared to the control, likely due to nitrification and organic acid release during decomposition. EC increased with organic amendments, as microbial activity mineralized nutrients into more soluble forms, raising EC levels. Plot treated with organic amendments (PW and KC) improved soil structure, porosity, WHC and maintaining higher SOC than others treatments (Table 2 and Table 5). PW treatment reduced BD, likely due to increased root biomass and soil aggregation, consistent with findings by Sachan *et al.*

Table 4: Effects of INM on yield and yield attributing parameters of the maize crop harvest.

Treatment	Ear weight (g)	Cob length (cm)	Tassel length (cm)	No. of grains cob ⁻¹	1000 grain weight (g)	Yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest Index (%)
T ₀ : Control	147.4±2.32 ^d	15.37±2.7 ^c	28.35 ± 1 ^b	332.5±4.2 ^c	346±0.04 ^{bc}	2.65±0.2 ^c	3.93±0.2 ^c	40.21±2 ^c
T ₁ : NPK	286.95±5.6 ^{ab}	17.74±2.9 ^{ab}	31.35± 1.8 ^a	442.5±3.4 ^b	419±0.02 ^{ab}	3.7±0.4 ^{ab}	5.23±1.3 ^a	41.41±3 ^{bc}
T ₂ : NPK+AZ	321.5±6.2 ^a	18.5±3.05 ^a	31.03 ± 0.07 ^{ab}	481±4.5 ^{ab}	437±0.03 ^a	3.75±0.5 ^a	5.07±1.7 ^a	42.49±2 ^a
T ₃ : NPK+GM	279.35±4.7 ^{bc}	17.65±3.01 ^{ab}	24.7± 1.2 ^c	468±3.1 ^b	376.5±0.05 ^{bc}	3.63±0.2 ^{ab}	4.82±0.4 ^b	42.91±3 ^b
T ₄ : NPK+KC	280.62±4.1 ^{bc}	19.27±3.01 ^a	31.9 ± 0.2 ^a	490±4.2 ^a	428±0.03 ^{ab}	3.90±0.2 ^a	5.11±0.32 ^a	43.27±2 ^a
T ₅ : NPK+PW	243.9±2.5 ^b	20.1±3.1 ^a	32.15 ± 0.1 ^a	499±3.7 ^a	442±0.1 ^a	3.97±0.3 ^a	5.02±0.54 ^{ab}	44.13±3 ^a
T ₇ : NPK+WR	172.05±1.64 ^c	17.52±2.7 ^{abc}	28.67 ± 1.55 ^{bc}	350.1±4.0 ^{bc}	360±0.05 ^{bc}	3.43±0.4 ^{ab}	4.84±0.21 ^{ab}	42.21±2 ^{ab}
P value								
Year	0.000	0.5	0.000	0.000	0.37	0.000	0.000	0.000
Treatment	0.000	0.078	0.000	0.000	0.403	0.000	0.000	0.000
Year*treatment	0.000	0.039	0.000	0.000	0.149	0.000	0.000	0.000
LSD (0.05)	10.13	0.71	0.79	14.57	171.3	0.07	0.08	0.21

LSD-Least significant differences; NPK- Recommended inorganic fertilizer, AZ-Azotobacter, GM- Green manure, KC- Karanja cake, PW- Poultry waste, WR-Wheat residue. Values represent as mean of two years pooled data±SE (n=4). Different letters within the same column indicate significant differences among the treatments at $p<0.05$ level by DMRT.

Table 5: Effect of INM on the soil properties after harvesting of wheat crop.

Treatment	pH	EC (mS cm ⁻¹)	WHC (%)	BD (g cm ⁻³)	Porosity (%)	Moisture (%)	SOC (%)	SOM (%)	CEC (Cmol/kg ⁻¹)	MBC (mg kg ⁻¹)
T ₀ : Control	6.55±0.01 ^c	0.34±0.02 ^c	40.45±2.5 ^c	1.48±0.03 ^a	34.21±2.2 ^c	8.50±1.10 ^c	0.65±0.002 ^d	1.11±0.002 ^{bc}	13.68±1.03 ^d	197.62±3.51 ^c
T ₁ : NPK	5.75±0.002 ^{bc}	0.38±0.03 ^a	42.66±2.3 ^b	1.43±0.01 ^b	37.63±3.4 ^{ab}	8.42 ±1.3 ^{bc}	0.82±0.002 ^{bc}	1.41±0.001 ^{ab}	15.33±1.02 ^b	310.41±3.11 ^{ab}
T ₂ : NPK+AZ	5.86±0.02 ^{ab}	0.37±0.04 ^b	45.91±2.3 ^{ab}	1.40±0.02 ^{bc}	36.4±3.5 ^a	8.51 ±1.31 ^b	0.86±0.001 ^{ab}	1.48±0.002 ^{bc}	15.11±1.31 ^b	388.57±3.32 ^a
T ₃ : NPK+GM	5.75±0.04 ^{bc}	0.39 ±0.02 ^a	42.73±2.1 ^b	1.41±0.03 ^{ab}	38.1±3.2 ^{ab}	8.64 ±1.5 ^{ab}	0.80±0.002 ^c	1.41±0.001 ^c	14.98±1.21 ^{bc}	356.42±2.04 ^{ab}
T ₄ : NPK+KC	5.84±0.01 ^a	0.39±0.001 ^a	43.60±2.8 ^a	1.41±0.02 ^c	38.37±3.2 ^a	8.74 ±1.02 ^a	0.90±0.001 ^{ab}	1.55±0.003 ^a	15.89±1.13 ^a	389.97±3.03 ^a
T ₅ : NPK+PW	5.77±0.02 ^a	0.41±0.01 ^a	45.24±2.4 ^a	1.40±0.01 ^c	40.05±2.3 ^a	8.98±1.03 ^a	0.92±0.001 ^a	1.58±0.001 ^{ab}	15.67±1.31 ^a	394.35±2.01 ^a
T ₆ : NPK+MR	5.62±0.02 ^{ab}	0.37±0.02 ^b	41.99±2.8 ^{bc}	1.41±0.03 ^{ab}	35.56±0.4 ^{ab}	8.47±1.01 ^{bc}	0.83±0.002 ^b	1.40±0.001 ^{ab}	14.73±1.20 ^{bc}	298.16±3.2 ^{bc}
P value										
Year	0.000	0.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Year*treatment	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LSD (0.05)	0.12	0.034	1.545	0.001	1.022	0.416	0.052	0.113	0.643	0.81

LSD- Least significant differences; NPK- Recommended inorganic fertilizer, AZ-Azotobacter, GM- Green manure, KC- Karanja cake, PW- Poultry waste, MR- Maize residue. Values represent as mean of two years pooled data±SE (n=4). Different letters within the same column indicate significant differences among the treatments at p<0.05 level by DMRT.

Table 6: Effects of INM on yield and yield attributing parameters of the wheat during harvest.

Treatment	Viable tillers m ²	Spike weight(g)	Spike length (cm)	No. of spikelet spike ⁻¹	1000 grain weight (g)	Yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Control	134.99±0.75 ^d	3.85±0.23 ^{bc}	10.22±0.17 ^{cd}	16.26±0.4 ^{ab}	595±2.05 ^d	1.77±0.03 ^{bc}	2.64±0.04 ^{bc}	40.23±1.15 ^{bc}
T ₁ :NPK	186.06±0.40 ^{bc}	4.26±0.35 ^{ab}	11.95±0.2 ^{ab}	16.73±0.28 ^{ab}	720.5±5.1 ^b	1.87±0.02 ^{ab}	2.61±0.02 ^c	42.17±0.36 ^{ab}
T ₂ :NPK+AZ	207.94±2.07 ^{ab}	4.07±0.04 ^{bc}	11.91±0.28 ^{bc}	17.81±0.25 ^b	763±1.3 ^{ab}	2.06±0.07 ^a	2.76±0.04 ^{ab}	42.68±2.81 ^{ab}
T ₃ :NPK+GM	183.96±0.28 ^c	3.77±0.10 ^c	10.7±0.17 ^c	15.86±0.4 ^c	668.5±1.2 ^{bc}	2.03±0.4 ^{ab}	2.76±0.03 ^a	41.71±1.26 ^b
T ₄ :NPK+KC	210.63±0.70 ^{ab}	5.37±0.30 ^a	12.26±0.46 ^a	17.97±0.5 ^b	787.5±1.75 ^a	2.09±0.03 ^a	2.74 ±0.06 ^{ab}	42.84±1.92 ^a
T ₅ : NPK+ PW	213.85±0.40 ^a	4.53±0.35 ^{ab}	12.38±0.46 ^{ab}	18.65±0.70 ^a	826±1.25 ^a	2.19±0.01 ^a	2.91 ±0.01 ^a	43.03±2 ^a
T ₆ :NPK+MR	185.56±0.25 ^{bc}	4.66±0.04 ^{ab}	11.20±0.24 ^b	16.25±0.80 ^{ab}	651 ±1.23 ^c	1.83±0.06 ^{bc}	2.62±0.07 ^{bc}	41.35±1.32 ^b
P value								
Year	0.000	0.000	0.000	0.000	0.5	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.35	0.000	0.000	0.000
Year*treatment	0.000	0.000	0.000	0.000	0.175	0.000	0.000	0.000
LSD (0.05)	12.4	0.29	1.04	1.0424	8.24	0.18	0.123	0.2

LSD- Least significant differences; NPK- Recommended inorganic fertilizer, AZ-Azotobacter, GM- Green manure, KC- Karanja cake, PW- Poultry waste, MR- Maize residue. Values represent as mean of two years pooled data±SE (n=4). Different letters within the same column indicate significant differences among the treatments at p<0.05 level by DMRT.

(2021); Disa *et al.* (2023). Slight decreases in AN were observed, possibly due to mineralization. Organic matter applications increased AP due to decreases phosphorus insolubilization, particularly in PW and KC treatments (Kantwa *et al.*, 2023; Rahman *et al.*, 2024). The application of PW and KC showed maximum water retention with more pore size distribution. PW had showed high moisture content in both maize and wheat based cropping systems (Table 2 and Table 5). The combination of inorganic fertilizers with organic amendments enhanced SOC and nutrient levels, resulting in higher grain yields (Kalyanasundaram and Augustine, 2021) (Table 4 and Table 6). PW, with its low C:N ratio and rich nutrient content, significantly improved soil biochemical properties and microbial activity (Cairo *et al.*, 2023), over other treatments. This treatment also showed the highest microbial biomass carbon, aligning with previous studies (Bharali *et al.*, 2017; Abera *et al.*, 2021).

Overall, integrating organic amendment and inorganic fertilizers, particularly PW, led to significant improvement in crop yield and soil health, with PW and KC treatments being the most effective. Conversely, maize residues with a higher C:N ratio were less effective in boosting the productivity.

CONCLUSION

Combined use of organic and inorganic fertilizers, particularly poultry waste and karanja cake significantly enhances soil quality and crop productivity. Poultry waste, when used with 50% inorganic fertilizer, improves soil's physical, chemical and biological properties, leading to better yields. This type of study may improve soil health of local farmer's field and aid carbon sequestration and useful to mitigate future climate change without sacrificing the crop productivity.

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Conflict of interest

The authors declare no conflict of interest.

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