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Research Article

Effects of Organic and Inorganic Fertilizers on Soil Properties of Lowland Rice on Vertisols of Fogera District, Northwestern Ethiopia

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Abstract

Declining land productivity due to low soil fertility status as a result of continuous cultivation, inadequate use of organic and inorganic fertilizers is a major cause for decline crop productivity. Hence, a field experiment was conducted at Fogera National Rice Research and Training Center (FNRRTC) during the 2021 cropping season to determine the effects of integrated use of farmyard manure (FYM) and nitrogen fertilizer on soil properties and yield of lowland rice on the vertisols of Fogera district. The treatments were factorial combination of three levels of FYM (0, 5, and 7.5 t ha^{-1}) and four levels of Nitrogen (0, 46, 92, and 184 kg ha^{-1}). The experiment was arranged in a randomized complete block design (RCBD) with three replications. Representative soil samples were collected at a depth of 0-20 cm before treatment application and after crop harvest, and analyzed following the standard laboratory procedures. All collected soil data were analyzed by using SAS software (version 9.4). After crop harvest the results showed that soil pH, OC, TN, CEC, Exc. K, Ca, Mg and Av.P were significantly ($p<0.01$) affected by the main effects of FYM. The combined applications of FYM and N fertilizer also significantly ($p<0.01$) affected CEC, OC and Exc.Mg. The highest soil CEC, OC and Exc.Mg were recorded from the combine effects of 7.5 t/kg with 92 kg/ha. From the results of this experiment, it could be concluded that combined application of FYM and inorganic N fertilizers improved the chemical and physical properties, which may lead to enhanced and sustainable production of rice in the study area.

Keywords

Farmyard Manure, Integrated, Nitrogen Fertilizer, Soil Properties, Vertisols

1. Introduction

Agricultural sector in Ethiopia is the major factor in sustaining growth and reducing poverty. However, inadequate nutrient levels, loss of organic matter in the soil, and soil erosion are the main challenges to continued agricultural production [50]. Hence, agricultural productivity has been seriously threatened by nutrient depletion and soil deteriora-

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tion. Soil nutrient depletion in smallholder farming systems is recognized as a causal force leading to food insecurity and rural poverty in Africa [19]. The rate of annual soil macronutrient depletion in Africa was estimated at 22 kg N ha^{-1}, 2.5 kg P ha^{-1} and 15 kg K ha^{-1} [45]. Declining soil fertility has also been stressed to be the fundamental impediment to agricultural development and the major reason for the slow growth of food production in Ethiopia. The depletion rate of macronutrients in Ethiopia was estimated to be high, with 122 kg N ha^{-1} $year^{-1}$, 13 kg P ha^{-1} $year^{-1}$ and 82 kg K ha^{-1} $year^{-1}$. The loss of soil nutrients in Ethiopia is related to cultural practices such as low fertilizer use, removal of vegetative cover (such as straw or stubble) and burning plant residues or the annual burning of vegetation on grazing land.

Decline soil fertility due to long-term cultivation with little or no fertilizer addition is the major limiting factor for rice production in Ethiopia [34]. The use of chemical fertilizers is essential for obtaining high yields in the weathered soils of the humid tropics and can overcome the shortcomings of organic fertilizers. However, many small holders and resource poor farmers cannot afford the costly fertilizers needed to apply the recommended amount, [1]. In addition to this, inorganic fertilizers available in Ethiopia do not replace trace mineral elements in the soil, which become gradually depleted by crop removal and cannot maintain desirable soil physical properties such as water holding capacity and congenial conditions for microbial activity [1]. On the other hand, the application of organic fertilizers such as animal manure, farmyard manure, compost, and other organic sources has been suggested as a means of addressing the decline in soil fertility and improving crop productivity. In comparison to inorganic fertilizers, organic fertilizers, maintain soil quality, increase soil organic matter, and improve soil physical and chemical properties through the decomposition of its substances [37]. However, the sole application of organic matter is constrained by access to sufficient organic inputs, low nutrient content, and high labor demand for preparation and transport. Thus, improved fertility management through the combination of organic and inorganic fertilizers can allow for more efficient use of the inputs applied while increasing overall system productivity [52].

An integrated nutrient management system improves soil quality, yield, and grain quality. Hence, there is a pressing need to use a variation of organic fertilizer sources as a substitute to reduce the utilization rate of inorganic fertilizers. Therefore, integrated nutrient management, in which both organic and inorganic fertilizers are used simultaneously, is the most effective method to maintain fertile and long-lasting productive soil [13]. According to Waseem *et al*. [56] `s long-term experiment, the integrated use of FYM and inorganic N has significantly enhanced grain yield of maize, water use efficiency and soil chemical properties as compared to the use of only inorganic N and P fertilizers. Integrated use of organic residues and inorganic fertilizers can sustain soil fertility and soil organic matter required for sustainable high yields and maximum benefits for smallholder farming in the tropics [48]. There for in this study to conduct Effects of organic and inorganic fertilizers on soil properties of lowland rice on vertisols of fogera district, northwestern Ethiopia. and to determine optimum rates of combined FYM and nitrogen fertilizers for increase rice productivity.

2. Materials and Methods

2.1. Description of the Study Site

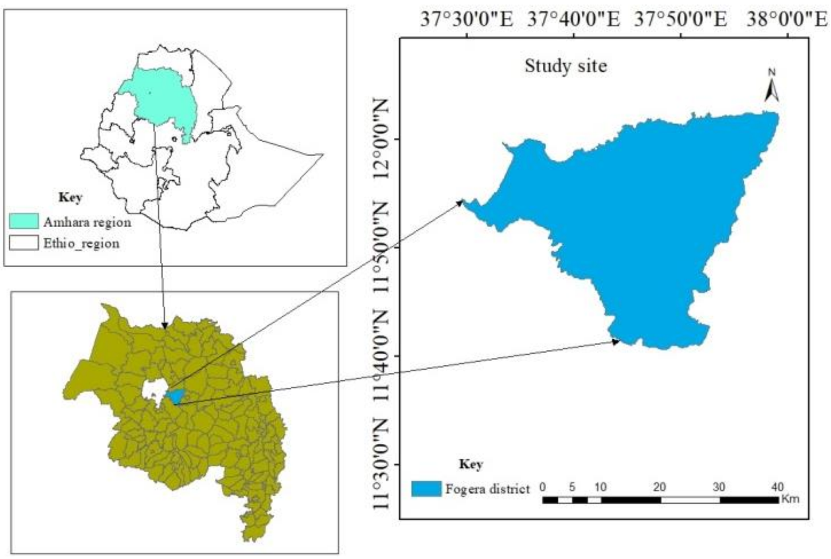

Figure 1. *Location map of the study area.*

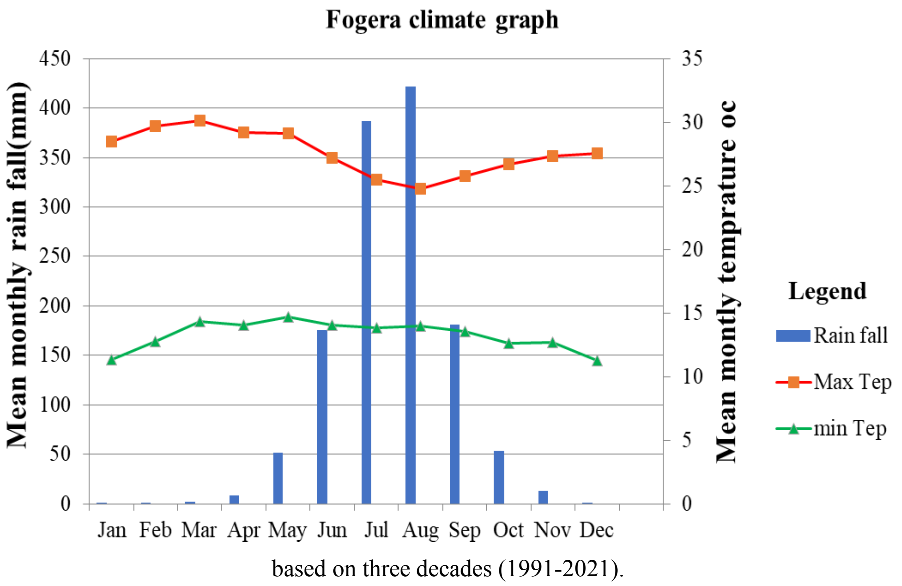

Figure 2. *Mean monthly rainfall, minimum and maximum temperature of the study area.*

The experiment was conducted at research station of Fogera National Rice Research and Training Center (FNRRTC) during the rainy season (June-December) of 2021. FNRRTC is located in Fogera district, South Gondar zone, Amhara National Regional State, Northwestern Ethiopia. Geographically, the experimental site is found at an altitude of 11° 54′ 26.4″ N and longitude of 37° 41′ 08.2″E, at an altitude of 1815 meters above sea level. It is far around 625 km from Addis Ababa in northwest direction [12]. A thirty-year period (1991 to 2021) of data collected from Bahir Dar meteorological station at Fogera district indicated that the mean annual minimum, maximum, and mean temperatures of the area are 14.2 ℃, 27.81 ℃ and 21 ℃, respectively. The rainfall pattern of the study area is uni-modal, occurring from June to October with a mean annual rainfall of 1446.62 mm (Figure 2) The dominant soil type on the Fogera plains is black clay soil (Eutric Vertisols). This soil type is locally known as Walka or Tikurafer with clayey in texture, dark brown to black. It has a high-water holding capacity and therefore considerable potential for different crop production. Most part of Fogera district is swampy areas which are ideal for lowland rice-ecosystem cultivation [14].

2.2. Experimental Materials and Methods

2.2.1. Description of Experimental Materials

A recently released high-yielding improved rice *(Oryza sativa L.) Shaga* variety was used as a test crop. The recommended seed rate of 100 kg ha^{-1} was used and sown by hand drilling at each row. Farm yard manure (cattle manure) was collected from Woreta Agricultural College, Livestock Research Center. It was air-dried, weighed on a dry weight basis, and applied by broadcasting method as per each FYM rate one month before planting. A full dose of the recommended P fertilizer (46 kg P_2O_5 ha^{-1}) in the form of TSP was applied at planting time. Nitrogen fertilizer in the form of urea was applied three times; 1/3 at planting, 1/3 at tillering, and the remaining 1/3 at panicle initiation stages. All other cultural practices were applied uniformly to all plots as per recommendations for rice production in the study area.

2.2.2. Experimental Design and Treatments

The treatments were comprised of factorial combinations of four levels of N fertilizer (0, 46, 92, and 184 kg ha^{-1}) and three levels of farmyard manure (0, 5, and 7.5 t ha^{-1}) (Table 1). The treatments were laid out in a randomized complete block design (RCBD) with three replications. The total experimental area was 14*41.5 m. Gross plot area was 3*4 m (12 m^2). The spacing between each row was 25 cm, so the gross plot was consisted of 16 rows. Two rows (0.5 m).

Table 1. *The experimental treatment arrangements.*

Treatment No.	Treatment combination	N fertilizer (Kg/ha)	FYM (t/ha)
T1	N0FYM0	0	0
T2	N0FYM1	0	5
T3	N0FYM2	0	7.5
T4	N1FYM0	46	0
T5	N1FYM1	46	5
T6	N1FYM2	46	7.5
T7	N2FYM0	92	0
T8	N2FYM1	92	5
T9	N2FYM2	92	7.5

Treatment No.	Treatment combination	N fertilizer (Kg/ha)	FYM (t/ha)
T10	N3FYM0	184	0
T11	N3FYM1	184	5
T12	N3FYM2	184	7.5

Note; FYM=farm yard manure, N=nitrogen fertilizers.

2.3. Soil Sampling and Laboratory Analysis

Before the application of treatments and seeding, surface soil samples at a depth of 0-20 cm were collected at six locations of the experimental field and composited as one sample. In addition, undisturbed core samples were collected to determine soil bulk density. Similarly, after crop harvest, soil samples were collected at a depth of 0-20 cm by soil auger from each treated plot to determine the effects of farmyard manure and mineral fertilizer on selected soil physico-chemical properties. Undisturbed soil sample from each plot was also collected by core sampler for bulk density analysis. These soil samples were analyzed to determine soil texture, bulk density, soil pH, organic carbon (OC), total nitrogen (TN), available P, cation exchange capacity (CEC), and exchangeable Ca, Mg, and K.

Texture was determined by Hydrometer method [7]. Bulk density was examined according to the procedure described in Okalebo *et al*., [38]. The pH was measured potentiometrically in 1: 2.5 (soil to water) ratio using a glass calomel combination electrode [41]. Soil organic carbon was determined following the modified method of Walkley and Black [55], and the organic matter content was calculated by multiplying the percent organic carbon by 1.724. Total nitrogen was also determined by Kjeldahl digestion method [24]. Available phosphorus was determined by the Olsen method [39]. Exchangeable bases (Ca, Mg, and K) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while exchangeable K was analyzed by flame photometer [42]. To determine the cation exchange capacity (CEC), the soil samples were first leached with 1 M ammonium acetate, washed with ethanol to replace Na by the adsorbed ammonium. Then, the CEC was measured titrimetrically by distillation of the ammonia that was displaced by sodium [10].

2.4. Farmyard Manure (FYM) Analysis

The FYM sample was first air dried, grounded, and sieved through a 2 mm sieve for the analysis of selected chemical properties and to determine its quality. The pH of FYM was determined using a glass electrode attached to a pH digital meter at a 1: 2.5 FYM: water ratio. Organic carbon was determined by using the Walklay and Black wet oxidation method as described by Walkley and Black [55]. Total nitrogen analysis was done using the Kjeldahl method [9]. exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer methods. While, K were analyzed by a flame photometer [42]. Cation exchange capacity was there after estimated titrimetriccally by distillation of ammonium that was displaced by sodium after leaching with NaCl solution [10].

3. Results and Discussion

3.1. Physical and Chemical Properties of the Soil Before Treatment Application

The physico-chemical properties of soil analysis before treatment application are presented in Table 2. According to Hazelton and Murphy [22], the textural class of experimental soils was clay, with medium soil bulk density (1.35 g cm^{-3}). The pH of the soil was 5.95, which is moderately acidic as per the ratings of Landon [31]. The total nitrogen was 0.097%, which is very low for crop production Landon, [31]. So, the experimental site needed optimum N fertilizer level to fulfill the N requirement of the crop. The low contents of total N could be attributed to the effects of intensive cultivation and the lower content of soil organic matter in the study area. The available P content of the study area (20.5 mg kg^{-1}) was very high, but the OC (1.60%) was very low. The value of soil cation exchange capacity (CEC), exchangeable potassium (Exc. K), exchangeable calcium (Exc. Ca) and exchangeable magnesium (Exc. Mg) were 42.34 Cmol (+) Kg^{-1}, 0.51 Cmol (+) Kg^{-1}, 31.53 Cmol (+) Kg^{-1} and 15.5 Cmol (+) Kg^{-1}) respectively.

Table 2. *Some selected physico-chemical characteristics of the surface soil (0-20 cm) of the experimental site before starting the experiment at Fogera, Ethiopia, 2021.*

S/N	Soil properties	Unit	Value	Rating	Reference
1	BD	(g cm^{-3})	1.35	Medium	(Hazelton andMurphy, [22])
2	Sand	%	30	-	-
	Silt	%	10	-	-

S/N	Soil properties	Unit	Value	Rating	Reference
	Clay	%	60	-	-
	Soil textural class		-	Clay	(Hazelton and Murphy, [22])
3	pH 1: 2.5 (H_2O)		5.95	Moderately acidic	(Landon, [31])
4	OC	%	1.60	very low	(Landon, [30])
5	TN	%	0.097	Very low	(Landon, [31])
6	Av.P	mg kg^{-1}	20.5	very high	(Landon, [30])
7	Exc.K	Cmol (+) Kg^{-1}	0.51	Medium	(FAO, [18])
7	CEC	Cmol (+) kg^{-1}	42.34	very high	(Landon, [30])
9	Exc.Ca	Cmol (+) kg^{-1}	31.53	very high	(FAO [18])
10	Exc.Mg	Cmol (+) kg^{-1}	15.5	very high	(FAO [18])

Note; BD=Bulk density, pH=Power of hydrogen, OC=Organic carbon, OM=Organic matter, TN=Total nitrogen, Ava. P=Available phosphorus, CEC= Cation exchange capacity, Exc. k=Exchangeable potassium, Exc.Ca= Exchangeable calcium, Exc. Mg= Exchangeable magnesium.

3.2. Evaluation of the Chemical Quality of Farmyard Manure

Organic fertilizers such as farmyard manure are known for improving soil fertility. It is a source of several nutrients that could be robust in the soil. The laboratory result showed that the FYM used in this study was good in quality, with higher pH (7.84), OC (8%), OM (13.79), total N (1.302%), Ava. P (289.9 mg/kg), C:N ratio (6.14), CEC (46.4 cmol (+) kg^{-1}), exchangeable potassium (10.25 cmol (+) kg^{-1}), exchangeable calcium 22.5 Cmol (+) kg^{-1} and exchangeable magnesium 8.71 Cmol (+) kg^{-1} (Table 3). The experimental material's FYM was slightly alkaline, and it was used to improve soil fertility and crop yields. The result was in line with Khater [28] who found an optimum pH value, and other chemical properties for different FYM types used to amend soil fertility and increase crop production. According to Hazelton and Murphy [22], where the C:N ratio is <10, organic matter will be easy and rapidly breakdown; in contrast organic matter with a high C:N ratio (>20) also displays N as it decomposes, reducing the amount of available nitrogen for the crop. This shows that the C:N ratio of the experimental FYM was <10 (Table 3), which indicates the FYM is well decomposed and suitable to improved nitrogen availability for crop production.

Table 3. Chemical properties of FYM used in this study at Fogera in 2021.

s/n	FYM Property	Value	Unit
1	PH1: 2.5 (H_2O)	7.84	-
2	Organic carbon	8	%
3	Organic matter	13.79	%
4	Total nitrogen	1.302	%
5	Available phosphorus	289.9	mg kg^{-1}
6	C:N ratio	6.14	-
7	CEC	46.4	Cmol (+) kg^{-1}
8	Exchangeable potassium	10.25	Cmol (+) kg^{-1}
9	Exchangeable calcium	22.5	Cmol (+) kg^{-1}
10	Exchangeable magnesium	8.71	Cmol (+) kg^{-1}

Note: pH=Power of hydrogen, CEC= Cation exchange capacity, C: N ratio = carbon to nitrogen ratio.

3.3. Effect of Farmyard Manure and Nitrogen Fertilizers on Selected Soil Properties After Harvesting

Table 4. *ANOVA table showing mean square values of soil properties as affected by integrated use of organic and inorganic fertilizers.*

S.O.V	Df	BD	PH	OC	TN	Ava.P	CEC	Ex K	Ex Mg	Ex Ca
Rep	2	0.0045	0.0033	0.0038	0.0021	0.78	0.02	0.001	0.0042	0.076
FYM	2	0.028*	0.0089**	0.065**	0.0046**	60.53**	5.57**	0.079**	1.026**	3.33**
NR	3	0.0072	0.0048*	0.023**	0.0035**	1.38	3.704*	0.002**	0.13**	0.036
FYM*NR	6	0.0059	0.00052	0.0023**	0.00081	0.58	5.68**	0.0011	0.095**	0.02
Error	22	0.0045	0.0013	0.0024	0.0069	0.45	0.87	0.0032	0.0025	0.084
CV		4.52	0.61	0.92	6.14	2.58	2.07	3.2	0.32	0.90

Note; BD=Bulk density; pH=power of hydrogen; TN=Total nitrogen; Av.P=Available phosphorus; Exc. K=Exchangeable potassium; CEC=Cation Exchange capacity; OC=organic carbon, Exc. Mg=Exchangeable Magnesium And Exc.Ca=Exchangabel calcium.

3.3.1. Bulk Density (BD)

Bulk density is an indicator of soil compaction. The analysis of variance showed that soil bulk density was significantly affected (P≤0.05) by the application of sole FYM. However, it was not affected by the addition of N fertilizer as a main factor or in combination with FYM (Table 4). The lowest BD (1.21 gcm^{-3}) was recorded from plots treated with 7.5-ton ha^{-1} FYM, while the highest BD (1.28 g cm^{-3}) was recorded from no FYM addition plots (Table 5). The highest bulk density recorded in the control could result from lower organic matter content and a higher degree of soil compaction caused by intensive cultivation. While the lowest BD in the soil could be attributed to the effects of farmyard manure, which improved soil aggregation and increased soil porosity. However, based on Hazelton and Murphy [22]`s rating of soil BD, all treatments showed low BD. The result was consistent with Getachew Agegnehu *et al*. [21], who found that the application of organic fertilizer decreased the soil's BD after barley harvest compared to the control. According to Jagadeesh *et al*. [25], the use of organic sources also tends to improve the soil's bulk density when compared to the soils before crop harvesting condition. Corresponding to this study, Workineh Ejigu *et al*. [60] found that applying compost after maize collection significantly ($p < 0.01$) reduced soil bulk density as compared to solely applying mineral fertilizer and the control. However, the impact of inorganic N fertilizer on soil BD was not statistically significant ($p > 0.05$).

3.3.2. Soil pH

The analysis of variances showed that the application of N and FYM had a significant effect on soil pH at (p≤0.05) and (p≤0.01) respectively (Table 4). Although there were numerical changes between experimental treatments attributable to the interaction of the treatments. The highest soil pH (5.98) was recorded from treatments applied with 7.5-ton ha^{-1} FYM. However, the unilateral application of 184 kg N ha^{-1} and control had the lowest soil pH (5.92) (Table 5). Hence, in comparison to treatments using 184 kg ha^{-1} N, the application of 7.5 t ha^{-1} FYM raised soil pH by 0.98%. This indicated that as nitrogen fertilizer rates increase soil pH was decrease and vice versa. On the other hand, the increase in the level of application of FYM caused a corresponding increase in soil pH. This could be attributed to the increased microbial activity during the process of organic matter decomposition, which could have led to the release of more exchangeable cations or bases that might have increased the soil pH. The decrease in pH at N fertilized treatments may have been due to the nitrification of ammonium (NH_4^+) to nitrate (NO_3^-) or the acid creating nature of urea application, which can release considerable H^+ ions to the soil through nitrification [27]. Therefore, the long-term application of chemical fertilizers may reduce the soil pH value with subsequent increments of soil acidity. Based on Landon [31]`s rating, all treated plots of the experimental sites showed moderately to slightly acidic soil pH.

The sole application of FYM and its combination with N fertilizer increased soil pH, which might be attributed to increased microbial activity in the decomposition of organic matter and the subsequent release of more exchangeable cations and enriched the soil with basic cations which increased the soil pH. Based on this study result, the application of organic fertilizer is a good option as compared to the application of inorganic fertilizer for soil character amendment through an increment of the soil pH value. In line with this result Iqbal *et al*. [23] verified that the use of organic fertilizer considerably enhanced soil pH in rice-cultivated plots while unilateral urea application dramatically decreased soil pH. Schroder *et al.* [47] also reported the acid-producing properties of urea application, which can release a significant amount of H^+ ions to the soil through nitrification, have been responsible for the reduction in soil pH from treatments received with only mineral N fertilizer. According to Widowati *et al*. [58], compost releases cations and alkaline chemicals including Ca^{2+}, Mg^{2+}, K^+ that raise CEC and pH levels and counteract soil acidification.

3.3.3. Available Phosphorus (Av. P)

Phosphorus is the second most limiting nutrient next to N for the production of healthy plants with profitable yields [8]. The analysis of variance showed that soil Av. P was affected significantly ($p \leq 0.01$) by the sole application of FYM rates. However, it was not affected by the interaction effect of FYM and N fertilizer as well as the main effect of N fertilizers (Table 4). Although there were numerical changes between experimental treatments attributable to the interaction effects of the treatments.

After crop harvest, the value of Av. P for all treatments was higher than the Av. P before planting due to the residual effect of applications of recommended TSP and FYM during planting for all plots. The highest Av. P (28.38 mg kg^{-1}) was recorded from plots treated with 7.5 t ha^{-1} FYM. In contrast, no FYM addition plots yielded the lowest available P (23.89 mg kg^{-1}) (Table 5). Therefore, the application of 7.5-ton ha^{-1} FYM increased Av. P by 18.79% as compared to the treatment with the lowest value. Thus, the availability of phosphorus may rise when the application rate of FYM fertilizers increases. The increase in available P using FYM might be attributed to the high phosphorus content of the experimental material FYM as confirmed by the sample analysis of FYM (Table 3). This might be attributed to the release of soluble humic material or organic acids from the decomposing of the organic residues and manures, which contribute greatly to the decrease in phosphorus adsorption capacity and increase in Av. P that occur in soils [16]. This idea was agreed with [29], who reported that the increase in Av.P receiving from FYM applied either alone or in combination with NPK compared to control due to the release of organically bound phosphorus, during decomposition of organic matter and solubilization of soil phosphorus by organic acids. The improvement in organic matter (OM) content in the soil also increases the amount of available P in the soil. This indicates that continuous application of FYM helps to reduce soil P-fixation [4]. According to Alem Redda and Fassil Kebede [2], both the main factors (FYM and inorganic fertilizer) had a highly significant positive influence on the content of available phosphorous after harvesting of rice. similarly, Aruna *et al.* [4] reported that animal manures and green manure increased soil available phosphorus, OM, total nitrogen, and cation exchange capacity (CEC) of the soil and this was attributed to the availability and adequate supply of organic matter. According to Jagadeesha *et al.* [25] the application of organic sources tended to improve available NPK, soil bulk density, and the organic carbon content of soil compared to their initial status after harvesting of crops. Similar to this, Apriyani *et al*. [3] reported that the applying of farmyard manure can increase the amount of available P due to the phosphorus concentration in cow manure alone.

Table 5. *The main effect of organic (FYM) and mineral (N) fertilizer rates on some soil physico-chemical properties after harvesting of rice at Fogera in 2021.*

FYM (t ha^{-1})	BD (gcm^{-3})	pH (1: 2.5) H_2O	TN (%)	Av.P (mg kg^{-1})	Exc.K (cmol kg^{-1})	Exc.Ca (cmol kg^{-1})
0	1.28a	5.92b	0.11c	23.89c	0.50c	31.47c
5	1.26ab	5.95ab	0.14b	26.13b	0.53b	32.28b
7.5	1.21b	5.98a	0.15a	28.38a	0.65a	32.45a
LSD (0.05)	0.057*	0.031**	0.007**	0.57**	0.02**	0.25**
N (kg ha^{-1})						
0	1.27	5.96ba	0.12c	26.24	0.57a	32.13
46	1.21	5.97a	0.12c	26.36	0.56ab	32.07
92	1.24	5.93b	0.14b	26.37	0.55bc	32.04
184	1.27	5.92b	0.16a	25.55	0.54c	31.98
LSD (0.05)	0.066ns	0.036*	0.0081**	0.66ns	0.012**	0.28ns
CV%	4.5	0.61	6.14	2.58	3.26	0.91

BD=Bulk density; TN=Total nitrogen; Av.P=Available phosphorus; Exc. K=Exchangeable potassium; Mg=Exchangeable magnesium, Exc.K = Exchangeable calcium; Means along the column with the same letter are not significantly different at $p \leq 0.05$.

3.3.4. Total Nitrogen (TN)

Nitrogen is one of the most limiting nutrients in plant growth and is the most critical element obtained by plants from the soil, and its deficiency is a bottleneck in plant growth [20]. The analysis of variance after rice harvest showed that soil total nitrogen (TN) was significantly affected ($p \leq 0.01$) by the main effects of FYM and N fertilizer rates. However, it was not affected by the interaction effect of FYM and N fertilizers (Table 4). This result agreed with Dragan *et al.* *[15]* that evaluated the content of soil TN was constantly increasing corresponding to the applied urea fertilizer rate and there is statistical significance difference between four nitrogen fertilizer rates of treated plots. Accordingly, the highest TN (0.16%) was recorded from the addition of 184 kg ha^{-1} N followed by 7.5 ton/ha FYM (0.15%), while the lowest (0.11%) was recorded from no FYM addition plots (Table 5). Therefore, the addition of 184 kg ha^{-1} N increase TN by 42.82% compared to the smallest TN. In line with this, Oluwaseyi *et al.* [40] noted that application of nitrogen fertilizer increased soil N and P compared with the control at two experiment sites. Wisa *et al.* [59] reported plots receiving crop residue and inorganic fertilizer have more TN content than controls. Similarly, Aruna *et al*. [5] reported that urea fertilizer alone increased the amounts of soil elements, such as N and P contents in comparison to the non-fertilized control plots in his experimental sites.

The increase in soil TN from treatments received sole mineral N fertilizer may attributed to low urea volatilization due to organic matter content, CEC, clay content, pH and temperature of the experimental soils. Urea volatilization influenced by pH of the soil and temperatures above 45°C [6]. However, the temperature of this experiment area was below 45°C hence; high nitrogen content was obtained in the experimental plots treated with urea fertilizers an increment in soil N after nitrogen fertilizers and FYM applications might be due to the addition of organic N through the decay of the FYM added to the soil and urea fertilizers. According to EthioSIS [17], the optimum N level needed for crop production under most soils in Ethiopia was reported to be less than 0.2%. Based on the ratings of Landon [30], the soils of the experimental plots after treatment with different rates of FYM and nitrogen, and rice crop harvest showed low and medium levels of nitrogen (Table 5). The lowest soil N content of the study area might be related to intensive cultivation and the application of inadequate fertilizers below the recommended rates. Concerning the effect of FYM rates, the highest soil residual TN (0.15%) was recorded at a rate of 7.5 t ha^{-1}, while the lowest TN (0.11%) was recorded at the rate of 0 FYN ha^{-1} (Table 5). The findings were consistent with those of Sajal and Abul [44] who examined as the application of organic materials significantly increases soil total nitrogen and available phosphorus content. And discovered that the TN increased when compost and mineral fertilizer were used together, which they attributed to the direct addition of nitrogen from inorganic fertilizers and the decomposition of compost added to the soil. Similar to this, Tilahun Tadesse *et al.* [53] reported the main effect of FYM treatment considerably changed the TN and accessible phosphorus contents of the soil; the TN and available phosphorus contents of the soil responded significantly to the main effect of FYM application.

3.3.5. Exchangeable Potassium (K^+)

The analysis of variance revealed that exchangeable K exhibited a highly significant difference ($p \leq 0.01$) by the main effects of FYM and nitrogen fertilizers, (Table 4). The highest exchangeable K (0.65 cmol kg^{-1}) was recorded from the sole application of 7.5-ton ha^{-1} FYM. While the lowest (0.50 cmol kg^{-1}) was obtained from no FYM addition plots (Table 5). Hence, application of 7.5-ton ha^{-1} FYM increased soil exchangeable K by 30.66% as compared to no FYM addition. The decrease in soil exchangeable K from treatments received from sole mineral N fertilizer has attributed to at the highest mineral nitrogen fertilizer the crop growth increases and might have taken more nutrients from the soil and might resulted in lower content of k nutrients in the soil than the control and the initial soil nutrients. Similar results obtained by Jianbo *et al*. [26] indicated that the high rates of N fertilization treatments significantly decreased the soil`s available K and available P content. According to FAO [18] classification of Exc. K the soil of the experimental site after the rice was harvested from most treatments showed a medium level of K, while the treatments with a high level of FYM contained high level of exchangeable K. This finding was also consistent with the findings of Gebremedhn Gebrtsadkan and Dereje Assefa [20], who discovered that all FYM and urea fertilized treatments significantly ($P<0.01$) affect the available potassium content when compared to the control treatments. The study of Alem Redda and Fassil Kebede [2] agreed with this result that the use of farmyard manure either alone or in combination with inorganic fertilizers (urea) had increased the available potassium (K) content of the soil. The buildup of available K in the soil due to the application of FYM may be due to the additional K applied through it and also the solubilizing action of certain organic acids produced during FYM decomposition and the soil's greater capacity to hold K in the available form.

3.3.6. Exchangeable Calcium (Ca^{2+})

The analysis of variance showed that the exchangeable Ca after rice harvesting was significantly ($p \leq 0.01$) affected by the sole application of FYM (Table 4). The maximum soil exchangeable Ca (32.45 cmol kg^{-1}) was recorded from the sole application of 7.5- ton ha^{-1} FYM. However, no FYM addition plots yielded the lowest exchangeable Ca (31.47 cmolc kg^{-1}) (Table 5). The result was in agreement with Munyabarenzi [36] report that exchangeable Ca increased in plots treated with organic fertilizer alone compared to inorganic fertilizer alone and control treatments after maize harvest. According to Saha *et al*. [43] there is a benefit using organic manures alongside inorganic fertilizers frequently result in increased exchangeable cations (Ca, Mg, and K), soil organic matter (SOM), CEC and soils biological activity. This improves nutrient cycling and helps to maintain the status of the soil's nutrients.

3.3.7. Soil Organic Carbon (OC)

Organic carbon in the soil is an imperative indicator of soil fertility, which can improve soil structure, nutrient exchange, and maintain soil physical conditions. The addition of organic matter enhances soil organic carbon content, which is an important indicator of soil quality and crop productivity [35]. Soil OC after rice harvest showed a significant difference ($p \leq 0.01$) in plots treated with the applications of both combinations and sole application of FYM and N fertilizer rates (Table 4). The highest soil OC (1.82%) was recorded from the combined application of 92 kg ha^{-1} N with 7.5-ton ha^{-1} of FYM, which was statically similar with the combined effect of 184 kg ha^{-1} N and 7.5-ton ha^{-1} of FYM. However, the lowest soil OC (1.59%) was obtained from the control treatments which was statistically at par with sole applications of 46 kg ha^{-1} N (Table 6). The combined application of 92 kg ha^{-1} N with 7.5-ton ha^{-1} of FYM significantly increased the soil OC by 14.45% over the control treatment, and combined application of 7.5 t ha^{-1} FYM with 184 kg ha^{-1} N significantly increased SOC by 13.85 % as compared to the control.

The plots that received organic manure alone (7.5 t ha^{-1}) and integrated with different rates of N fertilizer had higher OC than the control plots and the N fertilizer alone. This could be attributed to the decomposition and mineralization of FYM by soil microorganisms. The increase in soil organic carbon by enhancement of sole FYM and mixed fertilized plots might be due to the added FYM because all organic manures, especially FYM, contain a significant amount of organic carbon. This result was consistent with Aruna *et al.* [4] who claimed that animal manures and green manures increased soil OM, N, P, and CEC, this might have happened because of an appropriate supply of organic matter. Similar findings were found by Singh *et al.,* [49] who explained that the conjunctive use of organic and inorganic source of nutrients significantly improved the carbon content of a soil. According to Tamado Tana and Mitiku Woldesenbet [51] evaluation, applying 5 t ha^{-1} FYM along with 75% inorganic NP increased by 36% soil organic carbon content as compared from the control following the harvest of food barley. Corresponding to this, Weihua *et al.* [57] reported that, when chemical fertilizer was used in combination with organic fertilizer, the levels of SOM, total N, P, and accessible K were much higher than chemical fertilizer used alone.

3.3.8. Cation Exchange Capacity (CEC)

After crop harvest, the analysis of variance showed that the main effect of N at $p<0.05$, the main effect of FYM as well as the interactions of N with FYM at $p<0.01$ had a significant effect on total nitrogen (Table 4). The plots treated with 7.5 t ha^{-1} of FYM and 92 kg of nitrogen per hectare had the greatest CEC (46.33 cmol kg^{-1}). Nonetheless, the control plot had the lowest CEC (41.33 cmol kg^{-1}) (Table 6). In comparison to the control plots, applications of 7.5 t ha^{-1} FYM with 92 kg ha^{-1} N enhanced soil CEC by 12.1%, and applications of 7.5 t ha^{-1} farmyard manure alone significantly raised CEC by 11.30%. It was also observed that the sole application of 5 t ha^{-1} FYM significantly maximized CEC by 8.47 % following rice harvest compared to the control.

The increase in CEC might be due to the addition of organic manure that increases the negative surface charges on the soil colloids. In general, soils with larger amounts of organic matter have more negative charges and therefore a higher CEC than ones with lower amounts. High CEC might have more nutrients held on the soil, and diminishing their mobility and contributing to slow release [8]. According to Landon [31] classification of soil CEC, the soil of the experimental site after the rice was harvested, most treatments showed high level of CEC. In conformity with this result, Tolanur [54] obtained that CEC significantly increased with increased organic manure in combination with mineral NPK fertilizers than when mineral NPK fertilizers were applied alone. According to Alem Redda and Fassil Kebede [2], the CEC of the soil was greatly raised by FYM's primary effect as well as its interactional effect with inorganic fertilizers. Similar findings were made by Schoebitz and Vidal [46] who found that the application of an optimum level of organic and inorganic fertilizer improved the organic matter and CEC content, and made the soil fertile. Corresponding to this, Getachew Agegnehua *et al*. [21] confirmed that the values of CEC increased after the integrated applications of organic and inorganic fertilizers on wheat and *tef* crop cultivated soils in the highland environment of Ethiopia.

Table 6. *The interaction effect of N and FYM fertilizer rates on selected soil properties after harvesting of rice at Fogera, Ethiopia during 2021.*

FYM t/ha	NR kg/ha	OC%	CEC (cmol kg^{-1})	Exc. Mg (cmol kg^{-1})
0	0	1.59f	41.33d	15.49de
5		1.65de	44.83abc	15.57cd
7.5		1.68c	46ab	16.05b
0	46	1.60f	45.66abc	15.45ef
5		1.67cd	44.5bc	15.61c
7.5		1.69c	45.33abc	16.06b
0	92	1.63e	44.33c	15.4fg
5		1.76b	44.86abc	15.63c
7.5		1.82a	46.33a	16.31a

FYM t/ha	NR kg/ha	OC%	CEC (cmol kg^{-1})	Exc. Mg (cmol kg^{-1})
0	184	1.63e	46ab	15.35g
5		1.75b	45.5abc	15.61c
7.5		1.81a	45.1abc	15.55cd
Mean		1.69	44.98	15.67
LSD (0.05)		0.026**	1.58**	0.08**
CV (%)		0.92	2.07	0.32

Means along the column with the same letter are not significantly different at p≤0.05, FYM t/ha = Farm yard manure ton per hectare, NRkg/ha = nitrogen rate kilogram per hectare, OC= Organic carbon; CEC= Cation exchange capacity; Ex. Mg= Exchangeable Mg, ** Significant at P<0.01, * significant at P<0.05, NS= no significant difference.

3.3.9. Exchangeable Magnesium (Mg^{2+})

The main effect of FYM, N, and their interaction had a significant (p ≤0.01) impact on exchangeable Mg (Table 4). The highest soil exc. Mg (16.31 cmol kg^{-1}) was recorded from the combined effect of 7.5-ton ha^{-1} FYM with 92 kg ha^{-1} N. While the lowest soil exc. Mg (15.35 cmol kg^{-1}) was recorded from sole application of 184 kg ha^{-1} N fertilizer. Hence, the application of 7.5-ton ha^{-1} FYM with 92 kg ha^{-1} N increased exchangeable Mg by 6.25% as compared to the highest sole N fertilizer rates, while the application of 7.5-ton ha^{-1} FYM alone and 46 kg ha^{-1} N with 7.5-tons ha^{-1} FYM increased by 4.63% as compared to the sole application of 184 kg ha^{-1} N fertilizer, which had the lowest soil Mg concentration (15.35 cmol kg^{-1} (Table 6).

According to FAO [18] classification, all treated plots showed high levels of magnesium, but numerically the highest level of Mg was recorded from the highest application of FYM with 92 kg ha^{-1} N rates. The result was in line with Mclintock and Diop [33] who reported compost application increased the exchangeable bases (Mg, Ca and K) and CEC of the soil. Concerning the sole application of chemical fertilizers, the exc. Mg significantly affected by nitrogen fertilizer treatments. In line with this Dania *et al*. [11] reported that application of urea alone significantly affects that soil Mg, Ca and K than the control. According to Lungu and Dynoodt [32] there were significant effects of urea on the exchangeable bases (Ca and Mg) in the soil, and exchangeable Ca and Mg were lower at higher rates of urea application (>120 kg N ha^{-1}) compared to zero and 60 kg N ha^{-1}.

4. Conclusion

The combined use of FYM and N fertilizers result in this study was significantly improved the soil OC, CEC, and exchangeable magnesium. More over sole application of FYM significantly improved soil`s pH, organic carbon, total nitrogen, available phosphorus, cation exchange capacity, and exchangeable calcium, magnesium and potassium, while minimize soil BD, which created a good environment for the growth and development of the rice crop. Based on the findings of this study, it was determined that applying 7.5-ton ha^{-1} FYM with 92 kg ha^{-1} N fertilizer was increase rice yield and improve soil fertility. while providing the greatest economic advantage. Generally, soil productivity and health may be more sustainable with the combine use of farmyard manure and inorganic fertilizers than with the use of inorganic fertilizers alone. From the current experiment results, it could be concluded that the application of 7.5 t ha^{-1} FYM with 92 kg ha^{-1} N fertilizer improve soil physico-chemical properties and sustained production of rice crop development on the vertisols of Fogera district and other similar agro-ecologies.

Abbreviations

ANOVA	Analysis of Variance
C/N	Carbon to N Trogen Ratio
CEC	Cation Exchange Capacity
CV	Coefficient of Variance

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Conflicts of Interest

The authors declare no conflicts of interest.

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