CHAPTER 6

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EFFECT OF FARMYARD MANURE AND INORGANIC FERTILIZER ON SORGHUM GROWTH AND YIELD AND SOIL PROPERTIES IN A SEMI-ARID AREA IN ETHIOPIA. II. SOIL PROPERTIES

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ABSTRACT

A field experiment was conducted to assess the effect of the integrated use of farmyard manure and inorganic fertilizers on the growth and yield of sorghum and on soil chemical properties in a semi-arid area in NE Ethiopia. Twelve treatments comprising the factorial combinations of four levels of FYM (0, 5, 10 and 15 t ha^{-1} $annum^{-1}$) and three levels of inorganic fertilizers (0, 50 and 100% of the recommended fertilizer rates) were compared for six years in a randomised complete block trial with three replications. The results revealed substantial increases in total N, available P, exchangeable K, organic carbon (OC) and organic matter (OM) contents of the soil with the application of 5 to 15 t FYM ha^{-1}. Increase in these soil parameters increased with the level of FYM application. The inorganic fertilizer treatments made no impact on fertility build up. The application of FYM and inorganic fertilizer did not affect exchangeable Na^{+}, Ca^{2+}, Mg^{2+}, cation exchange capacity, base saturation or soil pH. Significant increases in soil N balance and soil water holding capacity were observed with FYM application. It can be concluded that with the application FYM at 5, 10 and 15 t ha^{-1} soil degradation under continuous cultivation can be reversed within a relatively short period of time.

INTRODUCTION

The soils in the semi-arid sorghum growing areas of NE Ethiopia are predominantly shallow, low in organic matter content and poor in water holding capacity and plant nutrients (1, 2). Soil organic matter and nutrients have been severely depleted owing to continuous cultivation without nutrient inputs, absence of fallowing and prevalence of severe erosion (1, 3). The productivity of these soils has consequently declined (4). The enhancement of the soil organic matter status by regular addition of organic material is essential if adequate soil productivity is to be maintained. Farmyard manure is readily available in NE Ethiopia as a source of multiple nutrients and to improve soil characteristics.

Exclusive dependence on mineral fertilizers is often criticized because of the potential damage it causes to soil quality and soil life. It has been suggested that good soil fertility management needs to include organic material, which can improve the chemical and physical conditions of the soil (5). FYM is a valuable fertilizer and soil amendment in crop production. The addition of FYM is known to change the physical and chemical properties of soils. It increases soil pH in acidic soils, organic matter content, water holding capacity, infiltration rate, and the availability of N, P and K (6, 7).

Little or no research concerning the effect of FYM application on soil chemical properties has been conducted in NE Ethiopia. This paper reports on the effect of the combined application of FYM and inorganic fertilizer (N and P) on selected soil properties.

MATERIALS AND METHODS

Study Site

This experiment was conducted on the same plots for six years (1997-2002) on a Eutric fluvisol at Kobo research site of the Sirinka Agricultural Research Centre in Ethiopia. The site is situated at 12^0 9'N, 39^0 38'E at an altitude of 1470 m above sea level, has a semi-arid climate with mean annual maximum and minimum air temperatures of 29^0 C and 15^0 C (1976-2002) and mean annual rainfall of 649 mm (1973-2002). The rainfall is characterized by an uneven and unpredictable distribution. The soil in the 0-23 cm horizon contains on average 34% clay, 52% silt and 14% sand, with a pH of 7.5 (1:2.5 in water), 1.20% organic C, 0.08% total N, 12.5 mg kg^{-1} available P (Olsen), 2.3 meq 100 g^{-1} K, 34.2 meq 100 g^{-1} Ca, 11.4 meq 100 g^{-1} Mg, 1.58 meq 100 g^{-1} Na, and has a CEC of 50.6 meq 100 g^{-1}.

Experimental Design and Procedure

Treatments comprised factorial combinations of four rates of farmyard manure (0, 5, 10 and 15 t ha^{-1} $annum^{-1}$ on dry weight basis) and three rates of inorganic fertilizers (0, 50 and 100% of the recommended rate). The locally recommended rate for a sorghum yield potential of 3 t ha^{-1} is 41 kg N ha^{-1} and 20 kg P ha^{-1}. The experimental layout was a randomised complete block design with three replications. Treatments were applied to the same plot every year. Crop residues were removed from the plots after harvest. FYM was collected from neighbouring farmers' kraals, mixed thoroughly, weighed for each plot, spread evenly, and incorporated into the soil a month before planting. The N, P and K contents of the FYM determined before application are presented in Table 1.

Table 1. Total N, P and K composition of FYM and resulting annual addition of N, P and K to the soil.

Year	N, P, K content of FYM (%)			Addition of N, P, and K to the soil (kg ha^{-1})								
				5 t			10 t			15 t		
	N	P	K	N	P	K	N	P	K	N	P	K
1997	0.21	0.78	Nd	10.3	39.0	Nd	20.6	78.0	Nd	30.9	117.0	Nd
1998	0.21	0.44	Nd	10.4	22.2	Nd	20.8	44.4	Nd	31.2	66.6	Nd
1999	0.19	0.52	Nd	9.7	25.9	Nd	19.3	51.8	Nd	29.0	77.7	Nd
2000	0.19	0.14	Nd	9.5	6.9	Nd	18.9	13.7	Nd	28.4	20.6	Nd
2001	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd
2002	1.38	0.41	2.87	69	20.5	143.5	138	41.0	287.0	207	61.5	430.5

Nd = Not determined

Urea and diammonium phosphate (DAP) were used as inorganic fertilizer sources. Half of the urea and all the DAP were applied in rows prior to planting and incorporated into the soil. The remainder of the urea was side dressed at the six to eight leaf stage. Sorghum cultivar 76 T1 #23 was hand drilled in 75 cm rows and thinned to an interplant spacing of 15 cm to obtain a plant population of 88 888 plants ha^{-1}. Gross plot size was 5.25 m wide by 6 m long. In each plot soil samples from nine random positions were taken from the 0-15 cm depth prior to planting and again after harvest in the sixth year. The samples were mixed, homogenised, air dried in shade, ground and passed through a 2 mm sieve. Soil samples were analysed for total N, available P, exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), organic C, cation exchange capacity, base saturation and pH. Organic carbon was determined by the rapid titration method (8). Total N and Olsen P were determined according to the procedures outlined by Page et al. (9). Soil pH was measured in 1:2.5 soil:water suspension. Exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) were determined in an ammonium acetate extract at pH 7 using an atomic absorption spectrophotometer. Soil N balance was computed, according to Hegde (10), as the difference between N added (FYM and fertilizer) and N removed by plants (uptake). Soil water holding capacity was determined by the gravimetric method at crop harvest.

Analyses of variance for all data were performed using the SAS statistical program (SAS V8.2, SAS Institute Inc., Cary, NC, USA). Whenever treatment differences were found to be significant, based on results of the *F*-test, critical differences were calculated at 5% level of probability using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Changes in Soil Chemical Properties

FYM applications substantially increased total N, available P, and exchangeable K contents of the soil after five and six years of application. FYM application was the major source of variation for all elements (Table 2). Variations, amounting to 90-98% in total N, 92% in P and 79% in exchangeable K, were largely accounted for by FYM applications (Table 2). Application of FYM increased the total N content of the soil by up to 59%, available P by up to 158%, and exchangeable K by up to 70% over the soil that received no FYM (Table 3).

Table 2. Analysis of variance of changes in total N, P, and K in soil resulting from the combined use of FYM and inorganic fertilizers (Fert).

Sources of variation	Nitrogen				Phosphorus		Potassium	
	5 Year$^{\phi}$	%	6 Year$^{\delta}$	%	6 Year$^{\delta}$	%	6 Year$^{\delta}$	%
FYM	0.0036**	90.0	0.0017**	98.0	699.82**	91.7	1.083**	78.8
Fert	0.0001ns	2.5	0.00003ns	1.7	58.77**	7.7	0.068ns	4.9
FYM * Fert	0.0003ns	7.5	0.000004ns	0.2	4.38ns	0.6	0.224*	16.3

$^{\phi}$ & $^{\delta}$ Indicate residuals from five and six years of FYM application, respectively. % Indicates percentage of the total variation accounted for by treatments.

Table 3. Effect of FYM on soil total N, available P, K, and N balance after five and six years of application, averaged across inorganic fertilizer treatments.

FYM (t ha^{-1})	Total N (%)		Available P (mg kg^{-1})	Exchangeable K (meq/100g)	N balance (kg ha^{-1})
	5 Year$^{\phi}$	6 Year$^{\delta}$	6 Year$^{\delta}$	6 Year$^{\delta}$	
0	0.079d	0.074c	12.9d	1.2c	-80.7d
5	0.093c (18)	0.082c (11)	19.8c (53)	1.7b (44)	-15.7c
10	0.109b (38)	0.093b (26)	26.8b (107)	1.7ab (48)	65.5b
15	0.126a (59)	0.105a (42)	33.4a (158)	2.0a (70)	141.4a
CV (%)	11.1	12.5	14.1	18.0	38.5

$^{\phi}$ & $^{\delta}$ as in Table 2. Numbers in parenthesis indicate percent change over the control. Means in a column accompanied by different letters are significantly different at P≤ 0.05.

The improvement in the soil available P with FYM addition may be attributed to many factors, such as the addition of P through FYM, the improved availability of soil P as a result of the action of organic acids produced during FYM decomposition, and retardation of soil P fixation by organic anions formed during FYM decomposition (11). Increases in soil K may be attributed to the additional K applied through FYM and the solubilizing action of certain organic acids formed during FYM decomposition (11). The observed enhancement in total N, available P and K is in agreement with the reports of several researchers (6, 12, 13, 14, 15). A three fold increase in soil N and six-fold increase in soil P as a result of manure applications were reported by Powell (6) and Kaihura et al. (12), respectively. Zia et al. (16) reported a 12.7% increase in total N in the soil with the application of 5 t FYM ha^{-1}.

Inorganic fertilizer application did not affect the soil N and K content. However, application of 100% of the recommended inorganic fertilizer rate increased soil available P by 20% over the soil that did not receive inorganic fertilizer (data not shown). Exchangeable cations (Na^+, Ca^{2+} and Mg^{2+}), cation exchange capacity, base saturation and soil pH were affected neither by FYM main effects (Table 4) nor by inorganic fertilizer and interaction effects of FYM and inorganic fertilizer. The FYM x inorganic fertilizer interaction effects were not significant for any of the soil nutrients.

Table 4. Effect of FYM on exchangeable cations, base saturation, cation exchange capacity and pH, averaged across inorganic fertilizer treatments.

FYM ($t\ ha^{-1}$)	Exchangeable cations (meq/100g)			Base saturation (%)	Cation exchange capacity (meq/100g)	pH (1:2.5 H_2O)	
	Na^+	Ca^{2+}	Mg^{2+}			5 Year$^{\phi}$	6 Year$^{\delta}$
0	0.401a	19.023a	16.92a	76.662a	49.111a	7.5a	7.7a
5	0.372a	16.538a	16.442a	70.755a	49.462a	7.5a	7.6a
10	0.392a	16.921a	15.812a	73.973a	47.362a	7.5a	7.7a
15	0.399a	20.452a	16.342a	79.996a	48.864a	7.6a	7.7a
CV (%)	18.2	23.1	9.4	12.9	7.1	1.6	1.4

$^{\phi}$ & $^{\delta}$ as in Table 2. Means in a column accompanied by different letters are significantly different at $P \leq 0.05$.

Changes in Soil Organic Carbon

FYM application also influenced organic carbon (OC) and organic matter (OM) contents of the soil. Variations amounting to 75-94% in OC and 75-99% in OM were accounted for by FYM applications (Table 5). FYM application increased soil organic carbon content by up to 67% and organic matter content by up to 59% over the FYM control (Table 6). The inorganic fertilizer treatments and the interaction effects had no significant effect on the organic carbon and organic matter contents of the soil. The increase in organic carbon with FYM application can be attributed to its stable nature and slow degradability (17).

The observed increase in soil organic carbon and organic matter in this study is in agreement with the results of Shirani et al. (18) who reported a three fold increase in soil organic matter with the application of FYM at 3 and 6 $t\ ha^{-1}$. Mokwunye (19) reported a two-fold increase with the application of FYM at 5 and 20 $t\ ha^{-1}$. Many other studies (10, 20, 21, 22) have also reported increased soil organic matter content after the application of FYM.

Table 5. Analysis of variance of change in soil organic carbon and organic matter from the combined use of FYM and inorganic fertilizers (Fert).

Sources of variation	Organic Carbon				Organic Matter			
	5 Year$^{\phi}$	%	6 Year$^{\delta}$	%	5 Year$^{\phi}$	%	6 Year$^{\delta}$	%
FYM	0.461**	94.0	0.099**	75.0	1.093**	98.6	0.293**	74.7
Fert	0.014ns	2.9	0.016ns	12.1	0.0007ns	0.1	0.049ns	12.5
FYM * Fert	0.015ns	3.1	0.017*	12.9	0.0146ns	16.3	0.050*	12.8

$^{\phi}$ & $^{\delta}$ as in Table 2. % Indicates percentage of the total variation accounted for by treatments.

Table 6. Effect of FYM applications on soil organic carbon and organic matter content and water holding capacity (SWHC), averaged across inorganic fertilizer treatments.

FYM (t ha^{-1})	Organic carbon (%)		Organic matter (%)		SWHC (%)
	5 Year$^{\phi}$	6 Year$^{\delta}$	5 Year	6 Year	
0	0.784d	0.869c	1.349c	1.499c	45.8b
5	0.943c (20)	0.991b (14)	1.626b (21)	1.708b (14)	45.4b (-0.9)
10	1.129b (44)	1.007b (15)	1.939a (44)	1.737b (16)	46.4ab (1.3)
15	1.307a (67)	1.125a (29)	2.141a (59)	1.910a (27)	47.4a (3.5)
CV (%)	9.5	7.2	14.6	7.2	2.4

$^{\phi}$ & $^{\delta}$ as in Table 2. Numbers in parenthesis indicate percent change over the control. Means in a column accompanied by different letters are significantly different at $P \leq 0.05$.

Data in Fig. 1 illustrate the relationship between the change in soil organic matter content with the change in soil total N and available P content and soil water holding capacity. Changes in total soil N and available P were linearly and significantly ($P<0.01$) related to the change in soil organic matter content. Between 40 to 65% of the variability in total soil N and 37% of available P were explained by the variance in OM content. However, the change in exchangeable K explained by the change in OM was small and insignificant ($r^2 = 0.09$ns).

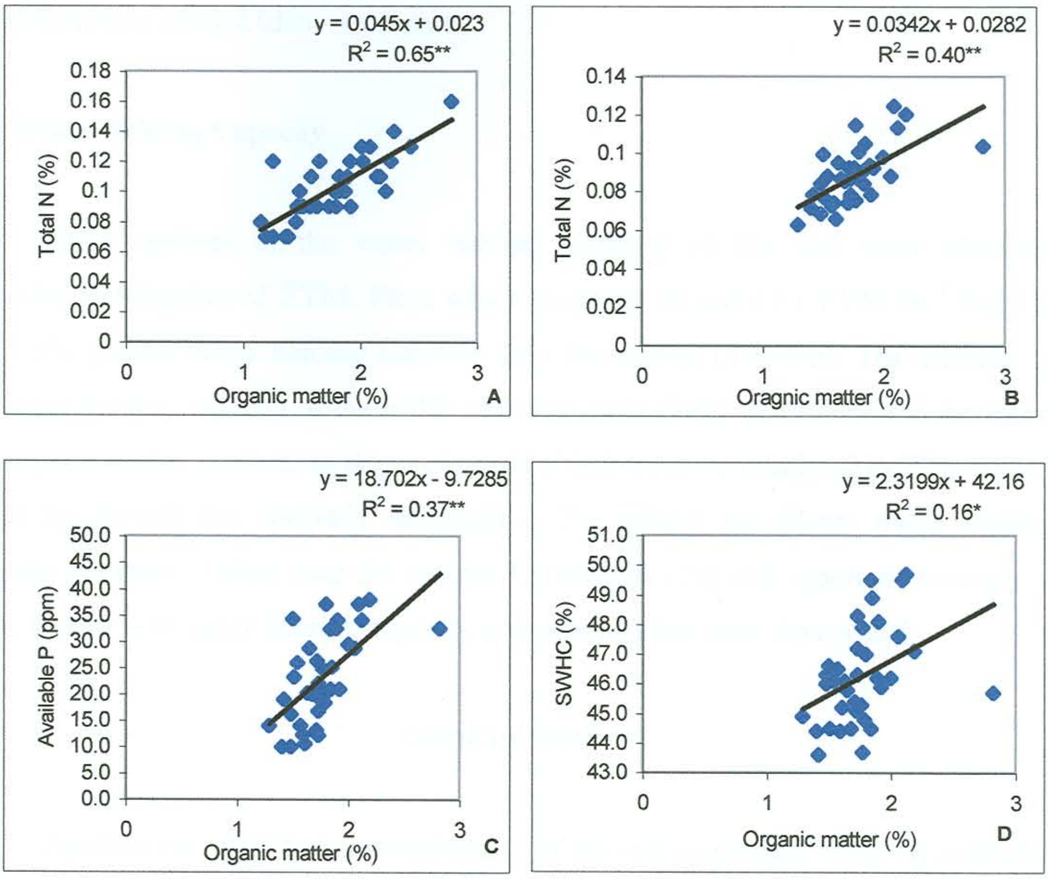

Figure 1. Relationship between soil organic matter and total nitrogen (A & B after 5 and 6 years, respectively), available P (C after 6 years) and soil water holding capacity (D after 6 years) as affected by the combined use of FYM and inorganic fertilizer. n=36.

Nitrogen Balance in Soil

The apparent N balance, computed as the difference between N addition (through fertilizer and FYM) and plant removal (uptake), was positively affected by the main effects of FYM and inorganic fertilizer applications. Cropping without addition of FYM and inorganic fertilizer resulted in a negative N balance amounting to –99 kg ha^{-1} (data not shown). Whereas FYM application at rates of 10 and 15 t ha^{-1}resulted in positive soil N balances amounting to 66 kg ha^{-1} and 141 kg ha^{-1} respectively (Table 3). Averaged across inorganic fertilizer treatments, plots that did not receive FYM had a negative N balance (–81 kg N ha^{-1}). Application of FYM at the lower rate (5 t ha^{-1}) led to a negative N balance (-16 kg ha^{-1}). This was still an improvement of 81% over the plot that received no FYM. Inorganic fertilizer application at 100% of the recommended rate increased soil N balance by 95% over the no fertilizer control (data not shown).

Soil Water Holding Capacity

Improvements in the water holding capacity of the soil were observed following application of FYM. Plots which received 10 and 15 t FYM ha^{-1} had 1.3 and 3.5% greater water holding capacity than the control (Table 6). The increase in the water holding capacity of the soil in manured plots could be attributed to increased soil organic matter content, as demonstrated by their positive relationship (Fig. 1D). A report by Powell (6) similarly indicated a 2% greater maximum water holding capacity in manured plots over the control. Carter et al. (23) also reported increases of 4, 19, and 27% in water holding capacity in manured plots over the control.

CONCLUSION

Application of FYM improved many of the soil properties. Total N, available P, exchangeable K, OC and OM contents of the soil and soil water holding capacity were substantially improved with FYM application compared to soil receiving no FYM. FYM applications also resulted in a positive soil N balance. The build-up of soil nutrients through repeated application of FYM was quite considerable for an area with a hot tropical climate like NE Ethiopia where organic matter decomposition and loss were expected to be high.

The results revealed that the integrated use of FYM with inorganic fertilizers, besides the immediate benefit of increasing crop yields could improve the chemical and physical properties of the soil within a reasonably short period of time. Thus, the possibility of sustaining the productivity of the soil through the addition of inexpensive organic amendments, such as FYM, may be an attractive strategy to the resource poor farmers. Sustainable soil management practices and the maintenance of soil quality are central to agricultural productivity.

The results of this study highlighted the positive effect of continual applications of FYM on soil organic matter content and soil physical conditions to improve the productivity of soils in NE Ethiopia.

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