Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs

Integrated Use of Organic and Inorganic Fertilizers for Maize Production

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ABSTRACT

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. Anthropogenic factors such as inappropriate land use systems, monocropping, nutrient mining and inadequate supply of nutrients are aggravated the situation. Integrated nutrient management (INM) is an option to alleviate soil fertility problem as it utilizes available organic and inorganic nutrients for sustainable agricultural production and productivity. Thus, to this effect, study of INM techniques to increase maize production and improve soil fertility was conducted for three consecutive years (2001 to 2003) on acidic Alfisols of Bako Agricultural Research Center, western Ethiopia. The treatments of the experiment were control (0), mucuna [*Mucuna pruriens* (L) DC] as improved fallow (IF), IF + 55/10 kg N/P ha^{-1}, IF + 37/7 kg N/P ha^{-1}, IF + 4 t farmyard manure (FYM) ha^{-1}, IF + 2.7 t FYM ha^{-1}, and the recommended rate of NP fertilizers (110/20 kg N/P ha^{-1}). The treatments were arranged in randomized complete block design with three replications. The results showed significant differences among the treatments on maize grain yield and plant height in all cropping seasons except in 2002. The sole use of IF increased maize grain yield by 75, 56 and 244% in 2001, 2002 and 2003 cropping seasons, respectively, over the control treatment. The integrated use of IF along with FYM also improved important soil chemical properties, and the uptake of nitrogen, phosphorus, and potassium. Therefore, the use of IF along with FYM or low dose of NP fertilizers could improve both maize yield and soil fertility in western Ethiopia. Despite mucuna used in improved fallow and has greatly improved yield and restore soil fertility, farmers may be reluctant to adopt the technology in short run, as it is recently introduced to the country. Hence, we recommend follow up research and extension to be done in maize based farming system of western Ethiopian to demonstrate and verify the use of mucuna as IF for soil fertility restoration, food and/or feed to accelerate its adoption.

Key Words/Phrases**:** Improved fallow, Farmyard manure, NP fertilizers, *Mucuna*, Western Ethiopian,

1. INTRODUCTION

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. Anthropogenic factors such as inappropriate land use systems, monocropping, nutrient mining and inadequate supply of nutrients are aggravated the situation. To alleviate the problem, INM is an option as it utilizes available organic and inorganic nutrients to build ecologically sound and economically viable farming system (Gruhn et al., 2000). Sub-humid agroecosystem of western Ethiopia is the major maize producing belt in the country where the highest maize grain yield (11 t ha^{-1}) was record under the farmers' field by using improved maize technologies (variety and inorganic fertilizer) for the first time in the history of Ethiopian agriculture in 1993 when SG 2000 started to operate in the country. 1235The SG 2000 extension systems were soon adopted at national level that enhanced the dissemination of maize technology in all parts of the country. As a result, average maize grain yield under farmers' condition maintained between 6 -8 t ha^{-1} in Bako area from 1993 to the end of 1990's. As farmers practiced maize monocropping for decade, and maize yield was significantly declined to below 3 t ha^{-1}, regardless of using the similarly

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technologies. The technology dissemination based only on improved hybrid maize varieties and inorganic fertilizers such as urea and diammonium phosphate. Appropriate copping patterns and soil fertility management were over looked in the process.

Palm et al. (1997) emphasized the effects of organic materials on nutrient availability and acquisition. According to these authors, organic inputs influence nutrient availability by the total nutrients added by controlling the net mineralization-immobilization patterns. Organic materials are also precursors to soil organic matter fractions that interact with soil minerals in complexing phosphorus (P) fixing cations thereby reducing P sorption capacity. Similarly, Negassa et al (2002a, 2002b, 2003) demonstrated that the integrated use of farmyard manure (FYM), compost, and bone meal with low dose of NP fertilizers gave comparable maize grain when compared to the yield obtained under the recommended rate of NP fertilizers (110/20 kg ha^{-1}) in Bako area. The sole application of either the organic fertilizer mentioned above doubled maize grain yield on relatively fertile soil as compared with the control treatment.

Many researchers stated that unavailability and low quality of organic materials, and shortage of labour constrained the use of organic materials for soil fertility management in the tropics. However, considerable amounts of organic materials are wasted without proper use especially in humid and sub-humid agroecosystem of western Ethiopia. If these locally available organic materials such compost, crop residues, FYM, appropriate crop rotation, and improved fallow are used based on socio-economic circumstances of farming communities, the investment in organic fertilizers processing and application is not more than the cost of inorganic fertilizers. The sole application of either organic or inorganic fertilizers on degraded soils can hardly increased crop yield in the tropics (Palm et al., 1997).

So long as agriculture remains a soil-based industry, there is no way that required yield increases of the major crops can be attained without ensuring that plants have an adequate and balanced supply of nutrients (Gruhn et al., 2000). This call for alternative cropping systems that address key aspects of nutrient management such as increasing plant-available nutrients and soil organic matter. Mucuna [*Mucuna pruriens* (L) DC] is one of the legume cover crops currently introduced to Ethiopia. A preliminary study conducted in western Ethiopia showed that mucuna provided high biomass production and significantly improved maize grain yield when used as improved fallow (Negassa, unpublished data). Moreover, a participatory evaluation of different legume cover crops in southern Ethiopia showed that farmers selected Mucuna as number one because of its firm rooting systems, soil conservation, and drought resistance (Amede and Kirkby, 2004). This indicated that mucuna could be one of the potential cover crop to be used as improved fallow in maize based farming system of western Ethiopia. Therefore, the objective of the study was to investigate the effect of integrated use of mucuna as improved fallow with different fertilizer sources to improve maize grain yield and soil fertility.

2. **MATERIALS AND METHODS**

2.1. Description of the Study Area

Geographically, the study site is located in Oromia National Regional State, western Ethiopia, in the sub humid agro-ecology (9^0 6' N and 37^0 09' E), at 1650 meter above sea level. The long-term weather information (1961-2003) at Bako Agricultural Research Center revealed that the study area has a unimodal rainfall pattern and total annual rainfall is 1243 mm. The rainy season covers April to December and maximum rain is received in June, July and August. Minimum, maximum and average air temperature is 13.3, 27.9 and 20.6 ^{0} C, respectively. Soil type of the study area is Alfisols, which is clay in texture and acidic in reaction.

2.2. Soil Sampling and laboratory analysis

Composite soil samples were collected from the plough layers of each plot before planting and after incorporating the improved fallow, and after harvesting of maize crop to examine the residual effect of INM on selected soil chemical properties. Standard laboratory procedures were followed in soil samples preparation. The samples were transported to International Livestock Research Institute (ILRI), Addis Ababa for analysis. Accordingly, soil pH was measured using a soil to water ratio of 1:2.5 (w/v). The exchangeable bases were extracted with 1 *M* ammonium acetate (NH_4OAC) at pH 7. The exchangeable Ca and Mg were measured from the extract with atomic adsorption spectrophotometer while the exchangeable K and Na were determined by flame photometer. The cation exchange capacity of the soil was determined from 1 *M* NH_4OAC saturated samples (Chapman, 1965). Exchangeable acidity was determined by saturating the soil samples with 1 *M* KCl solution and titrated with sodium hydroxide as described by McLean (1965). Total organic carbon was determined following the wet digestion method as described by Walkley and Black (1934), whereas Kjeldahl procedure was used for the determination of total nitrogen as described by Jackson (1958). The available phosphorus was extracted by Bray II procedures (Bray and Kurtz, 1945) and was determined colorimeterically following the procedures described by Murphy and Riley (1962).

2.3. Treatments and Experimental Design

The experiment was conducted for three consecutive years (2001 to 2003). Mucuna planted in July, and allowed to decay on the plots until land preparation was stared at the beginning of April in each season. The dried above ground biomass was incorporated into the soil. The treatments of the experiment was control (zero), *Mucuna pruriens* as improved fallow (IF), IF + 55/10 kg N/P ha^{-1}, IF + 37/7 kg N/P ha^{-1}, IF + 4 t FYM ha^{-1}, IF + 2.7 t FYM ha^{-1}, and the recommended rate of NP fertilizers (110/20 kg N/P ha^{-1}). Plots of the control and the recommended NP were left bare while mucuna was grown on the other plots. The FYM used for the experiment was collected under shade and allowed for well decomposition. The treatments laid out in randomized complete block design with three replications. Full dose of fertilizer P, FYM, and half of N fertiliser was applied at spot in 50 cm interval within row, and 80 cm interval between rows. Three seeds of the hybrid maize variety (BH-660) was placed 3-5 cm away from the fertilizer spots. The remaining N fertiliser was applied at knee height. The N and P fertiliser sources were urea and di-ammonium phosphate, respectively. All the recommended cultural practices were used for the management of the experiment.

2.4. Plant Tissue Sampling and Analysis

Normal and matured maize leaves were collected at grain filling stages randomly from 20 plants per plot. The collected plant samples were washed by distilled water and subjected to air drying. The dried plant tissues were ground into 0.25 mm size and transported to ILRI for N, P, and K analyses. The plant tissues were subjected to wet digestion. The N content of the plant tissue was determined by Kjeldahl procedure, whereas the P content was determined by colorimeterically according to Murphy and Riley (1962), and the K content of the plant tissue was determined by flame photometer.

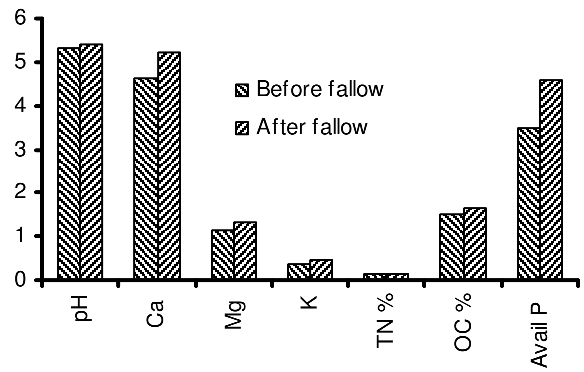
2.5. Statistical Analysis

The selected soil chemical properties, maize grain yield, plant height, N, P, and the K uptake at grain filling stage were subjected to analysis of variance. The least significant differences were calculated for the significantly different means among the treatments.

3. RESULTS AND DISCUSSION

3.1. Soil Chemical Properties

The use of mucuna as improved fallow (IF) increased the soil pH (H_2O), exchangeable bases (Ca^{++}, Mg^{++}, and K^{+}), organic matter (OM), and the available P (Fig. 1). The results showed that mucuna could be one of the alternative legume cover crops to be used as improved fallow to improve the important soil chemical properties. Moreover, the residual effects of IF after maize crop harvesting showed improving trends of the selected soil chemical properties (Fig. 2).



(pH (H_2O) 1:2.5, Unit for exchangeable bases (cmol$_c$ kg^{-1}), Avail P ; available P (Bray II): mg kg^{-1}

Fig. 1. Effects of mucuna as improved fallow on selected soil chemical properties

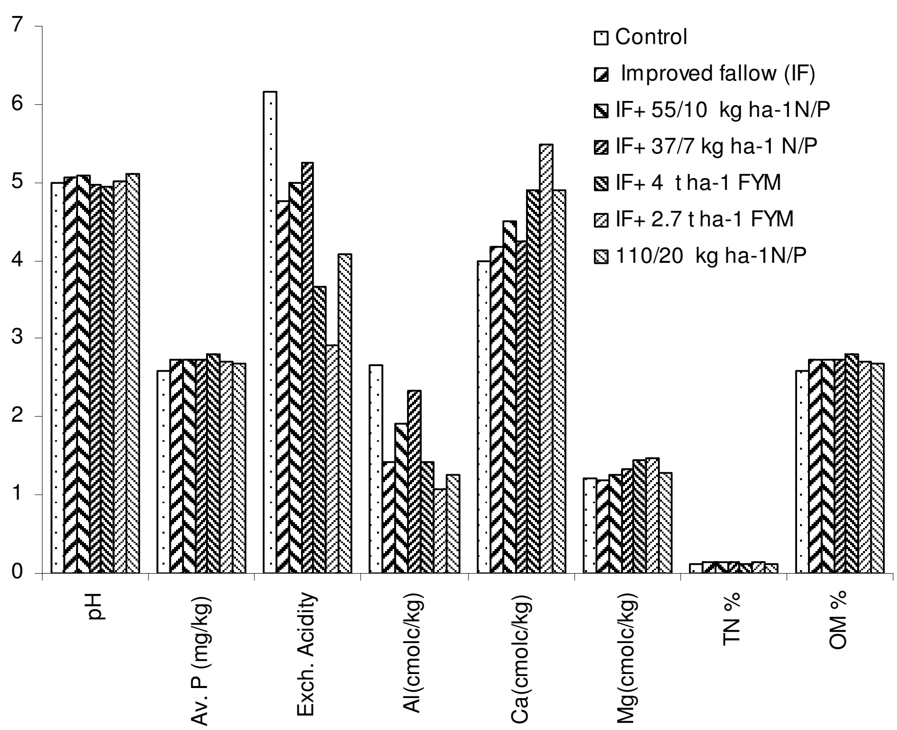


Fig. 2. Residual effects of integrated use of mucuna as improved fallow along with different fertilizer sources

The results indicated that including IF of mucuna and supplementing with low dose of inorganic or organic fertilizers could gradually improve plant nutrients and related soil properties. The improvement of the selected soil chemical properties under IF related to mucuna above and below ground biomass incorporation and decomposition. This result is in agreement with the work done in different parts of tropics (Pypers et al., 2005; Lee et al., 2006) where the application of crop residues, green manure and compost increased available nutrients, organic matter content, and reduced exchangeable acidity.

3.2. Maize Grain Yield and Plant Height

The integrated use of IF along with low dose of NP fertilizers or FYM increased maize grain yield, and plant height (Table 1). The sole use of IF increased maize grain yield by 75, 56 and 244% in 2001, 2002 and 2003 cropping seasons, respectively, over the control treatment. The three years average maize grain yield showed that IF alone doubled the yield as compared with the control treatment. Supplementing the IF with low doses of NP fertilizers or FYM also further increased grain yield. Maize grain yield among the supplemented IF with NP or FYM ranged between 5.91 to 6.06 t ha^{-1} which were statistically non significant (P>0.05) among each other. The lowest grain yield was recorded from the control treatment followed by recommended NP fertilizers. Similar trends were also observed for the plant height.

Table. 1. Effects of integrated nutrient management on plant height and maize grain yield

Treatment	2001		2002		2003		Mean	
	Plant H	Yield	Plant H	Yield	Plant H	Yield	Plant H	Yield
	cm	(t ha^{-1})	(cm)	(t ha^{-1})	cm	(t ha^{-1})	cm	(t ha^{-1})
Control	250	2.29	277	2.72	2001	1.720	242	2.24c
IF	295	4.00	3123	4.31	248	5.920	285	4.74b
IF+55/10 N/P	347	7.89	304	4.01	269	5.837	311	5.91a
IF+37/7 N/P	339	7.66	319	3.808	248	5.870	297	5.78a
IF+4 tha^{-1} FYM	340	7.42	317	4.91	274	6.387	312	6.25a
IF+2.7tha^{-1} FYM	341	6.31	318	4.55	270	7.320	309	6.06a
110/20 kg ha^{-1}N/P	336	5.52	318	3.25	251	4.45	301	4.41b
LSD (5%)	39.25	1.37	NS	NS	34.76	1.81	18.86	0.85
CV%	12.49	12.72	5.84	23.82	8.06	18.02	6.69	17.02

Plant H; plant height

Many studies were conducted on the integrated use of inorganic and organic fertilizers in western Ethiopia, where encouraging results were reported. For instance, the integrated use of low dose of NP fertilizers with different organic fertilizers such FYM (Negassa et al., 2002a), compost (Negassa et al., 2002b), *Cajanus cajan* (Yadessa and Bekere, 2003), and bon meal (Negassa et al, 2003) significantly increased maize grain yield in Bako area. The high prices of inorganic fertilizers together with the limited supply of organic input calls for a closer integration or combined use of these two sources of plant nutrients. Fertilizer prices at the farm gate are very expensive because of lack of domestic production capacity, poorly developed infrastructure, and inefficient production systems (Gruhn et al., 2000). Our results show that not only the integrated use of organic and inorganic fertilizers but also the integrated use of different organic fertilizers such as IF and FYM could be the potential alternative to be used in improving crop yield and soil fertility. So far little work has been done on this line may be due to nutrient immobilization when different organic materials applied at the same time. But our pervious studies showed that the well decomposed organic materials at the time of application rarely immobilized plant nutrients (Negassa et al, 2002b).

Not only farmers and extension agents, but also most researchers over looked as the highest yield is the highest exploitation of native plant nutrients; resulting in demands of sustainable supply of nutrients to the soil. On the contrary, even the crop residues rarely returned to soil in Ethiopian cropping systems as utilized for many purposes such fuel, construction and animal feeds. On the other hands, the only plant nutrients currently used in the country are N and P; regardless of plants need at least 16 essential nutrients. Acid soils of western Ethiopia are also deficient in trace elements such as boron, molybdenum, copper and zinc (Negassa et al., 2003). As there are no other fertilizer sources for these micronutrients currently used in the country, the integrated use of organic and inorganic fertilizers in Ethiopian agriculture has paramount importance.

Table 2. Effect of integrated nutrient management on up take of N, P, and K of maize at grain filling stage

Treatment	N	P	K	Ash	Crude Protein
	%				
Control	1.48b	0.16c	1.71a	6.97	9.23b
IF	1.92a	0.19b	1.59ab	7.65	12.02a
IF+55/10 N/P	1.90a	0.18b	1.61a	8.19	11.87a
IF+37/7 N/P	1.88a	0.18b	1.71a	7.42	11.75a
IF+4 tha^{-1} FYM	2.12a	0.22a	1.75a	8.10	13.23a
IF+2.7tha^{-1} FYM	2.15a	0.22a	1.75a	8.06	13.46a
110/20 kg ha^{-1}N/P	2.07a	0.17bc	1.42a	7.69	13.17a
LSD (5%)	0.33	0.02	0.21b	NS	2.07
CV%	9.66	11.27	7.09	6.80	9.63

Means followed by the same letters within the column were statistically at par.

3.3. Uptake of Nitrogen, Phosphorus and Potassium

The up take of N, P, and K at grain filling stage is presented in Table 2. The results showed that the uptake of N and P was significantly improved in IF, and IF supplemented with low dose of NP fertilizers, and FYM. Similarly, the crude protein content was significantly increased as compared with the control treatment. The uptake of K was significantly low only in treatment received the recommended NP fertilizers (110/20 kg ha^{-1}). The improvement in nutrients uptake in IF, and IF supplemented with different fertilizers sources could be associated with the decomposition of mucuna, nutrient pump from the subsurface horizon as mucuna is deep rooted annual legume, and biological N fixation ability of the mucuna plant. The findings are in agreement with similar studies conducted elsewhere. For instance, study conducted in Uganda, showed that sorghum yield was significantly improved in mucuna IF over the control treatment (Kiazzi et al, 2006). Moreover, some legume plants have ability to access sparingly soluble nutrient specially P due to root induced process (Pypers et al., 2006). This implies that improved fallow along with FYM or low dose of NP fertilizers not only conserves nutrients in the soil, but makes nutrient uptake more efficient.

4. CONCLUSION

The integrated use of mucuna as improved IF and low doses of inorganic fertilizers increased maize grain yield and yield components, and improved important soil chemical properties. Moreover, the integrated use of different organic fertilizers such as improved fallow and FYM provided encouraging results in increasing maize grain yield and improving soil chemical properties. The up take of N, P, and K was improved over the control and the sole application of high dose of NP fertilizers. This implies that INM could play significant role in replenishing the depleted nutrients and sustaining the production and productivity of major crops in western Ethiopia. Hence, we recommend follow up research and extension to be done in maize based farming system to demonstrate and verify the use of mucuna as IF for soil fertility restoration, food and/or feed to accelerate its adoption.

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