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The Role of Tree Fertilizer in Enhancing Maize Production and Mitigating Soil Acidity at Haro Sebu On-station, Kellem Wollega Zone of Oromia, Western Ethiopia

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Abstract
Declining soil fertility is identified as one of the main limiting factor in smallholder cropping systems. The strategy of using inorganic fertilizers for this problem is being highly constrained by high cost, low purchasing power of smallholders and limited access to credit. Thus, a judicious integration of both organic and inorganic sources of nutrients may be envisaged as one of the options. a biomass transfer study on *Cajanus Cajun* in combination with different rates of inorganic fertilizer was conducted for two consecutive years in 2014/15 and 2015/16 cropping season at Haro Sebu Agricultural Research Center, Kellem Wollega, Oromia, Ethiopia. The objective of the study was to investigate the role of tree biomass fertilizer in promoting maize production in Kellem Wollega zone of Oromia, Ethiopia, and also to assess the potential of tree biomass fertilizer for mitigating the problems of soil acidity in western Ethiopia. The experiment was tested on maize variety (BH-661), and it was also repeated during the 2015/16 cropping season to assess the possible residual effect of applying inorganic fertilizer and Cajanus biomass. Results indicated that maize grain yield was significantly affected by varying rates of Cajanus biomass ($p < 0.0001$) and inorganic fertilizer ($p <0.0001$) during the first cropping season. the interaction effect of *Cajanus* biomass and inorganic fertilizer was also significant($p<0.02$) ,but no significant difference in maize yield was noticed for both factors during the second year when no any external input was added indicating that nutrients from *Cajanus* biomass was used and lost in the first year. Maize grain yield varied from 3417kg/ha to 6284 kg/ha during the first year and from 3143.3 kg/ha to 3609.3kg/ha during the second year. From this finding, integrated *Cajanus* biomass and inorganic fertilizer application seems promising alternative for maize production in the area by improving soil fertility, and made available to crops during the year of application. However, the economic analysis to assess the profitability of using this organic fertilizer with or without inorganic fertilizer was studied. The economic evaluation, on the other hand, revealed that the highest net benefits were obtained from treatments in the experiment, 4T+0.5Frt would be the best recommendation for farmers followed by 6T+0.5Frt and 6T+FullFrt respectively. Hence, it is likely to conclude that integration of organic and inorganic fertilizer application would be ecologically, friendly and economically justifiable
Keywords: Soil fertility improvement, Maize yield (BH-661), Cajanus biomass, and inorganic fertilizer

Introduction

Declining soil fertility and soil acidity are the major production limiting factors in smallholder cropping system of western Ethiopia. The most common strategy for coping with this problem is the use of inorganic fertilizer (N and P) available in the market. But this strategy is highly constrained by high cost, low purchasing power of smallholders and limited access to credit, and environmental problems. Thus, a strategy that also considers the available resources like organic resources (green manure) needs to be developed. But the contribution of organic sources of nutrients for crop production is limited by their low nutrient content, requiring large amounts to meet moderate yield increases (Palm *et al*, 1995). Therefore, a judicious combination of organic and inorganic sources of nutrients may be envisaged as it addresses the problem of insufficient inorganic fertilizer supply and the large amount of organic material required for nutrient supply.

A *Cajanus* biomass transfer (tree biomass fertilizer) study conducted at Bako showed that applying 4 t/ha *Cajanus* biomass gave a yield advantage of about 87% and 67**%** over the control plot (without both organic and in organic fertilizers), but less only by 17% and 3% from the standard plot (plot that received recommended fertilizer rate) for BH-660 and Kulani maize varieties, respectively (Abebe and Diriba, 2003; Abebe *et al*., 2005). But in Kellem Wollega zone of Oromia, neither the effect of tree biomass fertilizer on maize yield and nor on soil acidity is studied. Therefore, the objective of the study was to investigate the role of tree biomass fertilizer in promoting maize production in Kellem Wollega zone of Oromia, Ethiopia, and also to assess the potential of tree biomass fertilizer for mitigating the problems of soil acidity in western Ethiopia.

MATERIALS AND METHODS

Description of Study site

The study was conducted in 2014/15 and 2015/16 cropping seasons at Haro Sabu Agricultural Research Center, Kellem Wollega Zone, Oromia Regional State, Ethiopia. It is found at 550 km away from Addis Ababa, 89 and 110 km from the nearby towns, Dembi Dollo and Ghimbi, respectively. The elevation of the area is ranging from 1300-2000 m.a.s.l, and temperature is varies from 23-34 ^{0}c and Annual rainfall is ranging from 1000-1300mm which has a beautiful scene for vision and is quite conducive for agricultural production system under rain-fed in the present climatic conditions. The soil is dominantly reddish brown with a pH of 5–6 (Report from Pre-soil test data, Unpublished data), and some properties of HSARC soil is indicated in Table 1.

Experimental design and treatment

For this study, two factors are involved as experimental treatments. rate of biomass application (tree fertilizer) and rate of fertilizer application (inorganic fertilizer). Four different rates of *Cajanus Cajun* biomass (0, 2, 4, and 6 t/ha), and three different rates of inorganic fertilizer (no fertilizer, half rate and recommended rate) were considered, and the treatments was handled as a 4x3 factorial experiment in randomized complete block design (RCBD) with three replications. The recommended inorganic fertilizer rate at Haro Sebu Agricultural research center is 200 kg Urea/ha and 100 kg DAP/ha. The plot size was 4m*3.75m (15 m^2) .The test crop was BH 661

Application of treatments

Cajanus biomass was collected from the stand that was established at Haro Sabu Agricultural Research Center one year ahead of biomass application. The stand was harvested at 50% flowering stage. During biomass harvesting, the woody and foliar biomass was partitioned, and the foliar biomass was dried and kept in sacks up to the day of biomass application. The biomass was applied into the soil two weeks before maize planting, and the maize was planted at the normal maize planting. For the first year, DAP was applied at the time of maize planting. But split application was adopted for urea; the first. But during the second year, neither *Cajanus* biomass nor inorganic fertilizer was applied, and maize was planted on previous plots without any external input in order to assess the possible residual effects of these organic and inorganic fertilizers applied in the first year.

Data collection and analysis

Data on maize height, stand count, cobs per plant, cob size, 1000 seed weight and grain yield was collected and recorded. The data was subjected to the general linear model analysis of variance using SAS computer software program. All comparisons of treatment means were made at $P<0.05$ level of significance using Fisher's Significant Test.

Soil analysis

Soil samples was taken before and after the study. The samples was analyzed for soil OM, pH, nutrients and texture following standard procedures. Before analysis, soil samples was first air-dried and passed through a 2-mm sieve in order to remove roots /macroscopic litter, stones and gravel which contribute little or no to basic soil properties (Thompson and Troeh, 1985). Soil texture was determined by the Boucoucos hydrometer method (Day, 1965); soil pH by pH meter in a 1:2.5 (v/v) soil: water suspension; available P following the procedures of (Olsen et al.,1954); and total N by the Kjeldahl method (Jackson, 1958); Organic matter by Walkley-Black method. Cat ion exchange capacity (CEC) and exchangeable cations was analyzed after extraction with 1 N ammonium acetate at pH 7 (ammonium acetate method).

Results and discussion

Table 1.Some chemical and physical properties of HSARC experimental soil before planting(**Table.1** Pre-planting soil test results)

Parameters	Soil Test Values
Particle size (%)	
Sand	47
Silt	29
Clay	24
Textural class	Loam
pH (1:2.5 H_2O)	5.54
Organic matter (%)	9.797
Total nitrogen (%)	0.490
Available phosphorous (ppm)	0.000
Exchangeable Acidity(AL^{+3}+H^{+})	1.461

Table 2. Some chemical and physical properties of HSARC experimental soil during the input phase (first year)

Trt	pH (1:2.5 H_2O)	Organic matter (%)	Total nitrogen (%)	Available p	Exchangeable Acidity(AL+3+H+)
(0,2)	5.71	8.694	0.435	4.336	0.00
(1,6)	5.68	9.430	0.471	3.317	0.00
(1/2,4)	5.74	8.535	0.427	3.843	0.00
(0,4)	5.63	8.598	0.430	2.021	0.00
(1/2,6)	5.71	8.958	0.448	3.459	0.00
(1,2)	5.71	8.729	0.436	2.535	0.00
(0,6)	5.71	9.070	0.453	3.022	0.00
(1/2,0)	5.61	8.483	0.424	2.608	0.00
(1,0)	5.69	8.662	0.433	2.368	0.336
(1/2,2)	5.68	8.916	0.446	4.127	0.00
(0,0)	5.51	8.768	0.429	1.853	0.00

- Trt (x, y):- fertilizer and Cajanus biomass rate respectively

According to the results of this laboratory study, nutrient particularly soil pH showed an increasing trend with Cajanus cajun biomass application except for without any input i.e. treatment (0,0) during input phase(year 1).

Table 1. Growth and yield of maize as influenced by rate of *Cajanus* biomass and inorganic fertilizer during the input phase (Year 1).

Fertilizer rate	SC	PH(cm)	EH(cm)	SPC	CS(cm)	TSW(gm)	GY(kg/ha)
0 (zero)	74.75	230.9b	119.8c	525.43b	20.3	455.41b	4322.8c
½ (half recommended)	72.50	254.8a	127.81b	562.6b	21.1	461.91a	5222.1b
1(full recommended(	74.33	256.2a	137.66a	624.3a	20.3	461.91a	5749.4a
LSD(0.05)	2.60	13.21	7.92	44.37	1.07	28.16	348.23
Cajanus biomass rate(t/ha)							
0	75.00	237.31	126.8	533.4b	19.9	417.1b	4517.4c
2	72.11	246.02	132.2	592.1a	20.8	444.97ba	4530.2c
4	73.44	250.3	124.08	568.0ba	20.8	439.9ba	5914.2a
6	73.55	255.6	130.5	589.6a	20.91	452.83a	5430.4b
LSD(0.05)	3.05	15.26	9.15	51.23	1.23	32.52	402.1
CV(%)	4.20	6.31	7.28	9.18	6.14	7.58	8.10

Means followed by different letters within a column were significantly different using Fisher's Significant Test.SC=stand count; PH= plant height; ER=ear height; SPC= seed per cop; CS= cop size; TSW= 1000 seed weight; GY= grain yield

Table 2. Mean of Interaction effects of GY (kg/ha)during input phase **(Year 1).**

Cajanus biomass rate(t/ha)	Fertilizer rate			
	0	Half recommended	Full recommended	Mean
0	3417.0e	4496.0d	5677.7 bac	4517.4
2	4000.0ed	4340.3d	5212.0c	4530.2
4	5373.0bc	6085.7a	6284.0a	5914.2
6	4501.0d	5966.3ab	5824.0bac	5430.4
mean	4322.75	5222.1	5749.4	
LSD(0.05)	696.46			
CV(%)	8.10			

Table 3. Growth and yield of maize as influenced by rate of *Cajanus* biomass and inorganic fertilizer during the residual phase (Year 2).

Fertilizer rate	SC	PH(cm)	EH(cm)	SPC	CS(cm)	TSW(gm)	GY(kg/ha)
0 (zero)	74.33	224.53	116.3	535.75	20.25	419.88	3513.1
½ (half recommended)	74.75	232.66	114.45	523.49	20.08	431.47	3143.3
1(full recommended(	72.50	229.23	119.83	508.82	20.68	441.09	3530.6
LSD(0.05)	2.64	9.23	8.55	53.4	1.35	39.58	1219.4
Cajanus biomass rate(t/ha)							
0	72.11	220.46b	112.46b	515.76	20.11	444.18	3236.7
2	75.00	226.86ba	116.53ba	528.50	20.53	432.99	3290.4
4	73.55	232.35a	116.04ba	530.98	20.44	435.83	3446.4
6	73.44	235.55a	122.4a	515.51	20.26	410.25	3609.3
LSD(0.05)	3.05	10.66	9.882	61.67	1.57	45.70	1408.1
CV(%)	4.24	4.76	8.64	12.06	7.89	10.85	42.41

During Year 2 only possible residual effects of inputs previously added during Year 1 assessed. SC=stand count; PH= plant height; ER=ear height; SPC= seed per cop; CS= cop size; TSW= 1000 seed weight; GY= grain yield

Maize grain yield

The results showed that maize grain yield was significantly influenced both by *Cajanus* biomass and inorganic fertilizer during the input phase (first year)(Table 1), but not significant during the residual phase (second year)(Table 2). The interaction effect of *Cajanus* biomass and inorganic fertilizer was also significant during the input phase (first year).(Table 2). The non-significant difference in maize yield for both factors during the second year (when no any external input was added) indicates that applying *Cajanus* biomass had additive effect on that of inorganic fertilizer and vice versa.

The significant difference in maize yield between the plots that received different treatments during the first year but the non-significant difference between the yield obtained from the different plots during the second year suggests that the residual effects of applying *Cajanus* biomass and inorganic fertilizer was minimal. This might be because of hot climate that might have enhanced *Cajanus* biomass decomposition and mineralization and made nutrients available for the maize crop during the year of application (input phase). A similar trend was also observed on grain yield BH-660 hybrid maize variety in previous study (Abebe and Diriba, in press).

Maize 1000 Seed weight

Maize 1000 seed weight was significantly affected by applying different rates of inorganic fertilizer and organic fertilizer (*Cajanus* biomass) during input phase as indicated Table 1. but not significant during residual phase as indicated table 3. The interaction between organic and inorganic sources of nutrients was not significant.

Cop Size

The result showed that a non-significant effect of inorganic fertilizer and organic fertilizer on maize Cop size in this area both during input and residual phase as indicated in table 1 and 3.

Seed per Cop

The result revealed that there was a significant effect of inorganic fertilizer and organic fertilizer on maize seed per cop in this area during input phase as observed in table 1. Increasing the rate of inorganic resulted in an increase in seed per cop and increasing the rate of organic fertilizer resulted in an increase from zero to 2 t/ha but started to decline at 4 t/ha and again in an increase way at 6t/ha ,but non- significant during residual phase(year 2) as observed in table 3.

Ear height

The result showed that as it was observed in table 1 on ear height, there was a significant effect of inorganic fertilizer but non- significant effect of organic fertilizer on maize ear height during input phase(year 1) and vise verse during residual phase(year 2) as observed on table 3.

Plant height

The result showed that as it was observed in table 1 on plant height, there was a significant effect of inorganic fertilizer but non- significant effect of organic fertilizer on maize plant height during input phase(year 1) and vise verse during residual phase(year 2) as observed on table 3.

Stand count

The result showed that a non-significant effect of inorganic fertilizer and organic fertilizer on maize stand count in this area both during input and residual phase as indicated in table 1 and 3.

However, the economic analysis to assess the profitability of using this organic fertilizer with or without inorganic fertilizer was studied.

1. Economic analysis

Table 1 compares the profitability of different treatments per hectare of land. Based on the experiment data, partial costs of production and returns at the prevailing prices were used to estimate the benefits. The labor cost given in Table 1 was estimated based on the price or wage of labour in locality per man day. Urea and DAP were valued at Birr 1368 and 1420 per quintal, respectively. Maize and pigeanpea seed cost were valued at farm price Birr 1000 per quintal and Birr 112 per kg, respectively. According to Kanjanji et al. (2009) the seed rate of pigeon pea is 8kg per hectare and the expected plant population is 37,000 and 44,444 plants per hectare at 90 cm and 75 cm ridge spacing respectively. Pigeon pea produced an average of 8.2Mg/ha total aboveground biomass annually (Niang et al, 2002).

Table 1.Partial budget analysis of pigeanpea and fertilizer treatment

Item	**Treatment**				
	4T+0.5Frt	**6T+0.5Frt**	**0T+FullFrt**	**4T+FullFrt**	**6T+FullFrt**
Fertilizer cost					
DAP	710	710	1420	1420	1420
Urea	1368	1368	2636	2636	2636
Seed cost					
Maize seed cost	125	125	125	125	125
Pigeanpea seed cost	436.8	655.2	0	436.8	655.2
Labor cost					
Labor for land preparation	300	300	300	300	300
Labor for Maize plantation	100	100	100	100	100
Labor for pigeanpea application	200	200	0	200	200
Labor for fertilizer application	100	100	100	100	100
Labor for weeding	1500	1500	1500	1500	1500
Labor for harvesting	1000	1000	1000	1000	1000
Total variable cost (Birr/ha)	**5839.8**	**6058.2**	**7181**	**7817.8**	**8036.2**
Average maize yield (Qt/ha)	60.857	59.663	56.777	62.84	58.24
Adjusted maize yield (Qt/ha) (-10%)	54.7713	53.6967	51.0993	56.556	52.416
Gross benefits	16431.39	16109.01	15329.79	16966.8	15724.8
Net benefits	**10591.59**	**10050.81**	**8148.79**	**9149**	**7688.6**
Cost (Birr/qt) (Production cost)	**106.622**	**112.822**	**140.530**	**138.231**	**153.316**

Source: Own data result, 2015.

The adjusted yield for a treatment is the average yield adjusted downward by a certain percentage (in this case 10%) to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment (CIMMYT, 1988). Adjusted maize yield were valued at farm gate price which were on average about Birr 300 per quintals. Maize grain yield was highest 62.84 quintal per hectare when 4 tons of biomass of pigeon pea and full recommended fertilizer (2qt urea and 1qt DAP) applied to soil followed by 60.857 quintal per hectare when 4 tons of pigeon pea biomass and half of recommended fertilizer applied to soil (Table 1).

Production cost of maize was highest (8036.2 Birr/ha) when six tons of pigeanpea biomass and full recommended fertilizer applied, followed by four tons of biomass of pigeanpea and fully recommended fertilizer applied to soil which is Birr 7817.8 per hectare**.** In the partial budget analysis conducted using farm gate prices the net benefits obtained was highest which is Birr 10,591.59 per hectare for four tons of biomass of pigeon pea and half recommended fertilizer treatment followed by six tons of pigeon pea and half fertilizer which is Birr 10,050.81 per hectare compared to other treatments.

Dominance analysis was also carried on using tabular method by dividing the treatment set into two categories, namely “dominated” and “un-dominated” treatments. A dominated treatment has net benefits that are less than or equal to those of a treatment with lower costs that vary. Dominated treatments need not be considered further in the analysis. As indicated in Table 2, first step of dominance analysis is listing all the alternative treatments from highest to the lowest net benefit i.e. rank the net benefits. In the second step starting from the top identify and eliminate any treatment which has a total variable cost equal to or higher than the treatments above. Accordingly, the dominating treatmentis4T+0.5FullFrt because this treatment produced higher net benefit by lower total variable cost compared to other alternative treatments.

Table 2. Dominance analysis using tabular method

Treatment	**Net benefits (Birr/ha)**	**Total variable cost (Birr/ha)**
4T+0.5Frt	10591.59	5839.8
6T+0.5Frt	10050.81	6058.2
4T+FullFrt	9149	7817.8
0T+FullFrt	8148.79	7181
6T+FullFrt	7688.6	8036.2

Source: Own data results, 2015

Marginal Rate of Return (MRR)

The purpose of marginal analysis is to reveal how the net benefits from an investment increase as the amount invested increases. MRR is defined as the change in net benefits (marginal net benefit) divided by the change in costs that vary (marginal cost), expressed as a percentage. The marginal rate of return indicates what farmers can expect to gain, on average, in return for their investment when they decide to change from one practice (or set of practices) to another.The procedure involves comparing the marginal rates of return (MRR) between treatments with the minimum rate of return acceptable to farmers.

Table 3.Marginal analysis for pigeon pea and fertilizer experiment

Treatment	Total costs that vary	Net benefits	MRR
0T+FullFrt	7181	8148.79	
6T+0.5Frt	6058.2	10050.81	168%
4T+FullFrt	7817.8	9149	51%
6T+FullFrt	8036.2	7688.6	668%
4T+0.5Frt	5839.8	10591.59 D^T	-

Source: Own data result, 2016.

In this experiment, the MRR of change from 0T+FullFrt to 6T+0.5Frt is 168%, which is well above the 100% minimum rate of return. This demonstrated that a change from the 0T +FullFrt to higher cost 6T+0.5Frt would produce the highest returns per every Birr invested (Birr 68 per every Birr 1 invested) (Table 3).The MRR from 4T+FullFrt to 6T+FullFrt is 668%, also above 100%. But the MRR between 6T+0.5Frt and 4T+FullFrt is only 51% which is below the 100% minimum rate of return. The conclusion is that, of the treatments in the experiment, 4T+0.5Frt would be the best recommendation for farmers followed by 6T+0.5Frt and 6T+FullFrt

Conclusion and Recommendation

Our study revealed that *Cajanus Cajun* biomass application in integration with inorganic fertilizer rate is paramount importance in boosting yield of maize and improving soil properties in acidic soils and small scale farming system of area in particular which makes promising alternative for maize production in the area and can be mineralized and nutrients contained therein made available to crops during the year of application. another advantage of Cajanus Cajun is for rehabilitation of the degraded land and as a source of tree biomass fertilizer (organic fertilizer). Additionally now a day our farmers, even the country cannot produce a kilo of inorganic fertilizer, but they can produce many tones of organic fertilizer like plant biomass. This may be a good option for poor farmers or small scale farming in particular and our country in general

The economic evaluation, on the other hand, revealed that the highest net benefits were obtained from treatments in the experiment, 4T+0.5Frt would be the best recommendation for farmers followed by 6T+0.5Frt and 6T+FullFrt respectively. Hence, it is likely to conclude that integration of organic and inorganic fertilizer application would be ecologically, friendly and economically justifiable.

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Reference

Abebe Yadessa and Diriba Bekere. 2003. Effect of biomass transfer of *Cajanus cajan* supplemented with inorganic fertilizer on BH-660 hybrid maize variety at Bako, western Oromia*, pp. 41-50. In*:

Challenges of land degradation to agriculture in Ethiopia: Proc. of the Sixth Biannual Conference of Ethiopian Society of Soil Science (ESSS), February 28-March 1, 2002, Addis Ababa, Ethiopia.

Abebe Yadessa, Diriba Bekere and Taye Bekele. 2004. Maize grain yield under taungya with different multipurpose trees at Bako. Paper presented at the Tenth Bi-annual Conference of Crop Science Society of Ethiopia, June 19-21, Addis Ababa, Ethiopia.

Abebe Yadessa, Diriba Bekere, Teshome Takele, Nega Emiru and Ashenafi Degfe. 2005. Effects of *Cajanus* cajan biomass transfer and inorganic fertilizer on growth and yield of open pollinated maize variety on acidic nitosols of western Oromia, Ethiopia. African Crop Science Conference Proceedings, Vol. 7. pp. 1143-1148.

Abebe Yadessa, Diriba Bekere, Worku Burayu, Tamirat Arficho and Dechasa Jiru. 2002. Agroforestry-based maize production: another option for sustaining maize yield, pp. 76-81. *In*: *Enhancing the contribution of maize towards food security in Ethiopia: Achievements, challenges and opportunities*: Proceedings of the Second National Maize Workshop of Ethiopia, 15-18 November 2001, Addis Ababa, Ethiopia.

Abebe Yadessa. 1998. Evaluation of the contribution of scattered *Cordia africana* Lam. trees to soil properties of cropland and rangeland ecosystems in western Oromia, Ethiopia. M.Sc. Thesis from Swedish University of Agricultural sciences, Sweden.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science,* 59: 39-45.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Workbook. Mexico, D.F. : CIMMYT.ISBN 968-8 12 7-19-4.

Day, P.R. 1965. Hydrometer method of particle size analysis, pp. 562-563. In: C.A. Black (ed.) Merthods of soil analysis. American Society of Agronomy, Madison, Wisconsin.

Kananji, G.A.D., Mviha, P.J.Z., Siambi,.M and Silim, S.N. 2009. A Manual for Pigeon pea Production in Malawi.Department of Agricultural Research Service and International Crops Research Institute for Semi-Arid Tropics, Liongwe3, Malawi.

Niang, A.I., Amadalo, B.A., Dewolf, J. and Gathumbi, S.M. 2002. Species screening for short term planted fallows inthe highlands of western Kenya. Agroforestry Systems; 56:145–154.

Jackson, M.L. 1958. Soil chemical analysis. Prentice Hall, Inc. New Jersy.

Legesse Dadi, Gemechu Gedeno, Tesfaye Kumsa and Getahun Degu. 1987. Bako mixed farming zone, Wellega and Shewa regions. Diagnostic survey report No. 1. Institute of Agricultural Research, Department of Agricultural Economics and Farming Systems Research, Addis Ababa, Ethiopia.

Palm, CR, Myers, RJK, and Nadwwa, SM. 1997. Combined use of organic and inorganic sources for soil fertility maintenance and relenishment, pp. 193-217. In: RJ. Brush *et al* (eds.) *Replenishing Soil Fertility in Afric*a. SSSA special publication No. 51.

Thompson, L.M. and Troeh, F.R. 1985. Soils and soil fertility. Fourth edition. Tata McGraw-Hill Publishing Company Ltd., New Delhi, India.

Walkley, A and Black, C.A. 1934. An examination of Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science,* 37: 29-38.