MITIGATION OF SOIL ACIDITY AND FERTILITY DECLINE CHALLENGES FOR SUSTAINABLE LIVELIHOOD IMPROVEMENT: RESEARCH FINDINGS FROM SOUTHER REGION OF ETHIOPIA AND ITS POLICY IMPLICATIONS

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ABSTRACT

Soil acidity and soil fertility decline are forms of soil degradation adversely affecting sustainable crop production in Ethiopia in general and in SNNPR in particular. Soil acidity affects root development leading to reduced nutrient and water uptake and also acidic soils are deficient in essential plant nutrients such as K, Ca, Mg so on. Some of the causes of soil acidity could be type of parent material, use of acid forming fertilizers (Urea and DAP) and leaching of base forming materials from soils in high rainfall areas. Currently, highland areas of Gamugofa, Sidam, Hadya, Kembata, Guragie and South western areas are affected by soils acidity seriously limiting crop production. This paper explores copping mechanisms employed by farmers in the south. Decline in soil fertility is another critical problem to crop production in SNNPR. In an effort to solve the problem and improve crop productivity, research experiments were conducted by Awassa Agricultural research center on liming, integrated soil fertility, organic nutrient sources and fertilizer types and rate on potato, wheat and barely. The result revealed that there was no significant difference between NP treatments and control on the yield of potato. However, application of NPK significantly increased the yield of potato from 6.3t/ha in the control and 8.6t/ha in NP treatment to 30.9t/ha at acid soils of Chencha. In terms of percentage, NPK application increased the yield by 392% and 363% over the control and NP treatment respectively suggesting that Application of Potassium is very critical in acidic areas. Liming of acid soil improved soil acidity but the best result is obtained provided either organic or inorganic fertilizers are applied together. Integrated application of farm yard manure and inorganic fertilizers have significantly and positively improved the yield of potato, barely and wheat. The result of an other experiment on organic nutrient sources showed that, Erythrina bruci, an indigenous, nitrogen fixing tree to Ethiopia is identified to be rich in nutrients content (N= 4.83%, P = 0.38% and 2.24%) and has ample potential to serve as organic fertilizer. Application of its biomass at 10t/ha increased the yield of wheat by 189%.The implications of the results are discussed and policy recommendations are suggested.

Keywords: Soil acidity, soil fertility, integrated soil fertility management, Potassium, lime

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INTRODUCTION

Soil Acidity

Soil acidity is now a serious threat to crop production in most highland of Ethiopia in general and in SNNPR in particular. Currently, it is estimated that about 40% of the total arable land of Ethiopia is affected by soil acidity (Abdenna et. al., 2007; Taye, 2007; Desta, 1988). Soil acidity affects the growth crop because acidic soil contain toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P, Ca, K, Mg, and Mo (Wang et. al., 2006; Tisdale *et. al*., 1985). The cause of soil acidity could be the type of parent materials from which the soil are formed, leaching of base forming cations, continuous use of acid forming fertilizers such as Urea and DAP (Cook, 1982). In the tropics the soil acidity is aggravated by leaching or/and continuous removal of basic cations through crop harvest. At pH below 5, aluminum is soluble in water and becomes the dominant ion in the soil solution. In acid soils, excess aluminum primarily injures the root apex and inhibits root elongation (Sivaguru and Horst 1998). The poor root growth leads to reduced water and nutrient uptake, and consequently crops grown on acid soils are confronted with poor nutrients and water availability. The net effect of which is reduced growth and yield of crops (Wang et. al., 2006; Tisdale *et. al*., 1985). Soil acidity is expanding both in scope and magnitude in Ethiopia severely limiting crop production. In some barley and wheat growing areas of central and southern Ethiopia, farmers have shifted to producing oats which is more tolerant to soil acidity than wheat and barley. The increasing trend of soil acidity and exchangeable Al in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid forming inorganic fertilizers (Abdenna et. al., 2007). In SNNPR, the highlands of Gamugofa, Sidama, Kembata, Hadya, Guragie areas are severely affected by soil acidity.

Some of the approaches to address soil acidity are liming, applications of organic matter such as FMY and use of acid tolerant varieties each of them have their own merits and limitation. In the recent past there was a massive campaign to demonstrate the beneficial effect of liming in ameliorating soil acidity on several crops and locations on farmers' field and encouraging results were obtained. But its cost and availability are the main limitation for its wider use. Application of organic matter is another option to mitigate soil acidity. Soil organic matter sequesters Al^{3+} there by avoid the toxic effect of the later on crops growing in acidic soil (Rowell, 1994). In the past few years, experiments were conducted by Awassa agricultural research to find viable solution to soil acidity in areas affected by soil acidity. Encouraging results were obtained and are briefed in this paper

Soil fertility Decline

The fertility of most Ethiopian soils has already declined and continued to decline posing an other challenge to crop production. Mining of nutriments due to continuous cropping, abandoning of fallowing, reduced manure application, crop rotation, removal of crop residues to be used as fuel and erosion coupled with low inherent fertility are among the main causes decreasing soil (Tilahun et. al., 2007; Taye et. al., 1996; Yonannes, 1994).

The unlimited rise in population is the core cause of the problem that has stressed and continued to stressing the land adversely affecting its productive capacity.

Aimed at overcoming the problem of decreasing soil fertility for enhanced crop yield, application of inorganic fertilizers mainly of Urea and DAP has been started some four decades ago. Though the response varies from place to place, in general enormous increase in the yields of several crops were obtained (Amsal and Tanner, 2001; Taye *et. al*., 1996; Desta, 1988). There were several occasion where the yield of cereals were increased by over 100% due to fertilizer application (Kelsa, et. al., 1992). Because of immediate availability of nutrients contained in inorganic fertilizer to plants, ease of application, immediately visible effect and many other beneficial effects, its adoption was very fast compared to many other technologies in Ethiopia. As a result this fact there was an increasing trend of fertilizer consumption in Ethiopia. Since they were first introduced in 1967 their consumption increased from 14000 mt in 1974/75 to 50,000 mt in 1997/98. The annual consumption surpassed 200,000 mt in 1993/94 (UNDP, 1995). This figure has grown to 446, 000 mt in 2000 (Taye *et al*., 2002).

However, the price of fertilizers is increasing from time to time becoming unaffordable to subsistent farmers. More over, some types of fertilizers such as Urea and DAP soil acidifying nature and aggravate cation losses and ultimately causes acidification of soils (Potash institute, 1979). Reduced nitrogen fertilizer use efficiency or recovery efficiency by crops is the most important problem associated with the use of chemical fertilizers. In developed country like USA, only 50% of the applied fertilizers are used by crops in the season. The situation is very severe in the tropics where only between 25 – 40% of the applied fertilizers is utilized by crops in the season and leaching and denitrification are the main cause of reduced recovery efficiency (Sahrawat *et. al*., 1977). This year we have conducted survey to identify crop production constraints in the representative zones in SNNPR and in some areas it farmers said " Even if we apply fertilizers there is no good yield of crops we planted" the most likely reason we have judge for lack of response to fertilizer is removal of top soil by erosion and very low organic matter content. In general, inorganic fertilizers not sustainable in the long term. For fertilizer application to be profitable it requires definite set of soil, environment and management condition such as balanced application of NPK together with soil conservation measures so on (Gruhn et. al., 2000).

The use of organic fertilizers such as farm yard manure, compost, green manure and transferred biomass of leguminous trees is an alternative to inorganic fertilizers to improve soil fertility. For instance Shiferaw (2005) studied the effect of green manuring of delicos lablab on the yield of wheat at Kokate and Hossana site of SNNPR, he found that the yield of wheat was increased by 63% and 97% over the control respectively. Similarly, Abebe and Diriba (2003) reported that transferred biomass of *Cajanus cajan* at a rate of 4t/ha increased the grain yield of maize by over 86% compared to the control. Organic fertilizer, in addition to being nutrient sources, they improve the physical and chemical characteristics of soil, improve the water holding capacity, CEC and biological activity of soil (Vanlauwe *et. al*, 2005; Gruhn et. al., 2000). But organic sources have also problem in that they vary in quality, availability, bulkiness, and some organic nutrient sources are very poor in a particular plant nutrient.

Therefore, integrated application of both organic and inorganic fertilizers is the best option available for sustainable soil fertility improvement for enhanced crop yield. Many research finding proved that combined application of organic and inorganic fertilizer produce superior yield of crops than either sources applied alone (CIAT-TSBF. 2002; Ravishankar et. al., 2002; Gruhn et. al., 2000). Based on this fact experiment were conducted to determine the effect of integrated applications of organic- inorganic nutrient sources on potato, wheat and barely in different location along that we have also tested the response of crops to transferred biomass of *Erythrina bruci* and potassium application. Thus, this paper narrates the key findings of the research.

I. FARMERS' COPPING STRATEGIES

Farmers living in acid areas of chencha and Hagereselam have both different and similar copping strategies soil acidity. Farmers' of Chencha area (Gamugofa) heavily relay on farm yard manure (FMY) as a remedy to soil acidity. They collect FMY, accumulate and during the rainy season, they transport it to out field on horse back where they incorporate it into the soil as fertilize. Farmers of Chencha say that they used to practice application of inorganic fertilizers many years ago but they have abandoned it recently due to none beneficial effect of fertilizers. Even some farmers say that inorganic fertilizers burn their crops. In addition, they use the falling leaf litter of *Erythrina abyssinica*, *Hagenia abyssinica*, *croton macrostachyes* locally known as ANKA as organic nutrient source for soil fertility improvement. On the other hand, farmers of Hagereselam (Sidama) when they think their land become acidic in their language became none fertile they let weeds to grow and plow it back in to the soil thinking that the decomposing weeds serves a remedy to soil acidity. After that they grow cereals (Barely and Wheat). More over, farmers at Hagereselam practice minimum tillage to reduce the adverse effect of soil acidity on crops. They also use locally selected acid tolerant variety of barely known HULLA. Common to farmers both locations is when they think that their soils have extremely unproductive, they grow, lupine, an indigenous N-fixing crop, then they leave the residue on the land and let it decompose. Such lessons and experiences show that farmers have their own indigenous knowledge built over generation as how to manage agricultural constraints. The indigenous knowledge of farmers is very diverse and specific to specific location or agro ecology and varies according to the constraint itself. As the constraints or agricultural problems are dynamic the knowledge developed through trail and error is also very dynamic. The modern science has been very reluctant and undermining the indigenous knowledge of farmers or societies due to a prejudice that the modern agricultural science was superior and farmers were ignorant. However, some two decades back many scientific communities have given due attention to indigenous knowledge of farmers and effort is being made to document and refine it for better solving agricultural constraints.

Taking farmers' copping strategies in to account experiments were conducted by Awassa agricultural research center aimed at developing viable and integrated solutions to soil acidity and fertility problems for enhanced crop production.

II. RESEARCH FINDINGS ON SOIL ACIDITY AND FERTILITY MANAGEMENT TECHNIQUES FROM SOUTHERN ETHIOPIA

1. Effect of integrated application of organic – inorganic on the tuber yield of potato in acid soils of Chencha

Experiment I

Chencha is located in Gamogofa zone has an altitude over 2700masl, receive high annual rainfall with a rugged terrain. The soils are very acidic (pH = 4.8) very poor in most essential nutrients especially of Potassium. Experiment was conducted to test the effect of organic-inorganic fertilizers application on tuber yield of potato for two years.

The result of organic-inorganic fertilizer application on tuber yield of potato is shown in Table 1. Accordingly, there were highly significant differences among treatments. Combined application of FYM and NPK gave significantly superior yield over two years. There was significant difference between NP treatments and control. But addition of K along NP has dramatically improved the yield of potato. NPK application increased tuber yield by 363% and 392% over the NP and control treatments respectively suggesting that potassium is critically deficient in Chench acid soils.

Table 1. Mean Potato tuber yield as affected by organic-inorganic amendments

Treatment	**Total Potato Tuber Yield (t/ha)**		**Mean**
	2006	2007	
Control	6.33 d	6.16 d	6.27 d
*NP	8.82d	8.60d	8.09 d
NPK	31.09 b	31.70b	30.88 b
NP+15t FYM	31.74 b	31.60 b	30.96 b
NPK+15tFYM	42.59a	40.55a	41.88a
15 ton FYM	16.47 c	16.38 c	16.43 c
LSD (0.05)	**6.08**	**6.56**	**4.47**
CV(%)	**21**	**24**	**23**

* N = nitrogen, P = phosphorus , K = potassium

Application of FYM at 15t/ha increased the tuber yield by 68% over the control indicating that the amount of FYM applied was not sufficient to fulfill the required amount of nutrients for maximum growth and yield of potato.

Table 2. Economic (partial budget analysis)

Partial budget	Treatment					
	Control	**NP**	**FYM**	**NPK**	**NP+FYM**	**NPK+FYM**
Average yield ton/ha	6.27	8.09	17.73	30.88	30.96	41.88
Adj. yield ton/ha	5.643	7.281	15.957	27.792	27.864	37.692
Gross benefit birr/ha	8464.5	10921.5	23935.5	41688	41796	56538
N	0	706	0	706	706	706
P	0	1866	0	1866	1866	1866
K	0	0	0	600	0	600
FYM	0	0	750	0	750	750
TVC	0	2572	750	3172	3322	3922
Net benefit birr/ha	8464.5	8349.5	23185.5	38516	38474	52616
MRR			1962.3	633		2350

Partial budget analysis data for different treatments are shown in Table 2. Balanced application of organic amendment, NPK and combined application of organic inorganic fertilizers in production of potato at Chencha acid soil is feasible. Combined of NPK and 15t/ FYM had highest net benefit (52616 ET birr) and marginal rate of return (2350). Negative net benefit was realized for NP (100:100) treatment which suggests that application NP alone for the study area is not feasible.

Experiment II

The effect of integrated application of FYM and inorganic fertilizer and their residual effect on potato on acid soils of Chencha were studied for two years (Table 3). The result revealed that in 2007, FMY applied at 10 and 20t/ha increased the tuber yield by 70% and 100% over the control respectively. Application N at 55kg/ha and small amount of P (20kg/ha) reduced the tuber yield by 10% suggesting that the probably nitrification of urea has aggravated the existing strong soil acidity at chencha severely affecting the crop (Cooke). Application of $N_{55}P_{20}K_{50}$ and $N_{110}P_{40}K_{100}$ increased the tuber yield by 64 and 123% respectively suggesting that K and P are critically deficient in the area. The soil of Chencha has 11.2 ppm of K and 3.2 ppm of P which according to Jones (2001) are classified as very low. Combined application of both sources gave superior yield than either source applied alone. But application organic-inorganic fertilizers beyond $N_{55}P_{40}K_{50}$ + 10t/ha FYM did not significantly increased the tuber yield.

Table 3. The effect of integrated application of FMY and inorganic fertilizers on tuber yield of potato at chencha.

Treatments	Mean yield (t/ha)	
	2007	2008
$N_0P_0K_0$ +0FYM	17..8g	4.1g
[1]$N_{55}P_{20}K_0$ + 0FYM	15.38g	5.4fg
$N_{110}P_{40}K_0$+ 0FYM	20.47fg	6.4fg
$N_{55}P_{20}K_{50}$+ 0FYM	28.2ef	18.3cd
$N_{110}P_{40}K_{100}$+ 0FYM	38.2bc	23.4bc
N0PK0 +10/FYM	29.2.3e	7.9efg
$N_{55}P_{20}K_0$ + 10FYM	37.2cd	9.3efg
$N_{110}P_{40}K_0$+ 10FYM	36.4cde	10.9ef
$N_{55}P_{20}K_{50}$+ 10FYM	46.5ab	21.5.c
$N_{110}P_{40}K_{100}$+ 10FYM	45.9ab	28.2b
$N_0P_0K_0$ + 20t/haFYM	34.3cde	13.2de
$N_{55}P_{20}K_0$ + 20FYM	46.7ab	21.6c
$N_{110}P_{40}K_0$ + 20FYM	39.1bc	11.8ef
$N_{55}P_{20}K_{50}$ + 20FYM	52.80a	21.9bc
$N_{110}P_{40}K_{100}$ + 20FYM	53.90a	34.76a
LSD (0.05)	**8.6**	
CV (%)	**14.0**	**24.0**

[1]N55P20K50 = 80kg UREA + 100kg DAP + 192.3kg KCl

From results presented in Table 1 and 3 it could be concluded that if only inorganic fertilizers to be applied for enhanced crop yield, balanced application of NPK is a must. In line with this a long term experiment was conducted with yearly application of N, NP and NPK on wheat from 1970-88 and it was found that the yield wheat was uneconomical after five years however with NPK there was a decreasing tread of wheat yield but was not as drastic as it was with N and NPK.

The residual effect of FYM was studied on the same plot in 2008 and it was observed the tuber yield has been reduced by more than half in all treatments. However plots received 10 and 20t/ha have produced significantly higher yield of potato than plots received N and NP and control.

2. The effect of integrated applications of organic-inorganic fertilizers on the yield of barley at acid soils of Chencha

The effect of FYM and inorganic fertilizers on the yield of barely on acid soils of Chench is shown in Figure 1. There was almost a liner increase in the yield of barely when inorganic fertilizers were applied with 10t/ha and 20t/ha of FYM than applied alone. Application of FYM at 10 and 20t/ha increased the grain yield by 100 and 160%

respectively. The increase was further augmented with combined application with inorganic fertilizers.

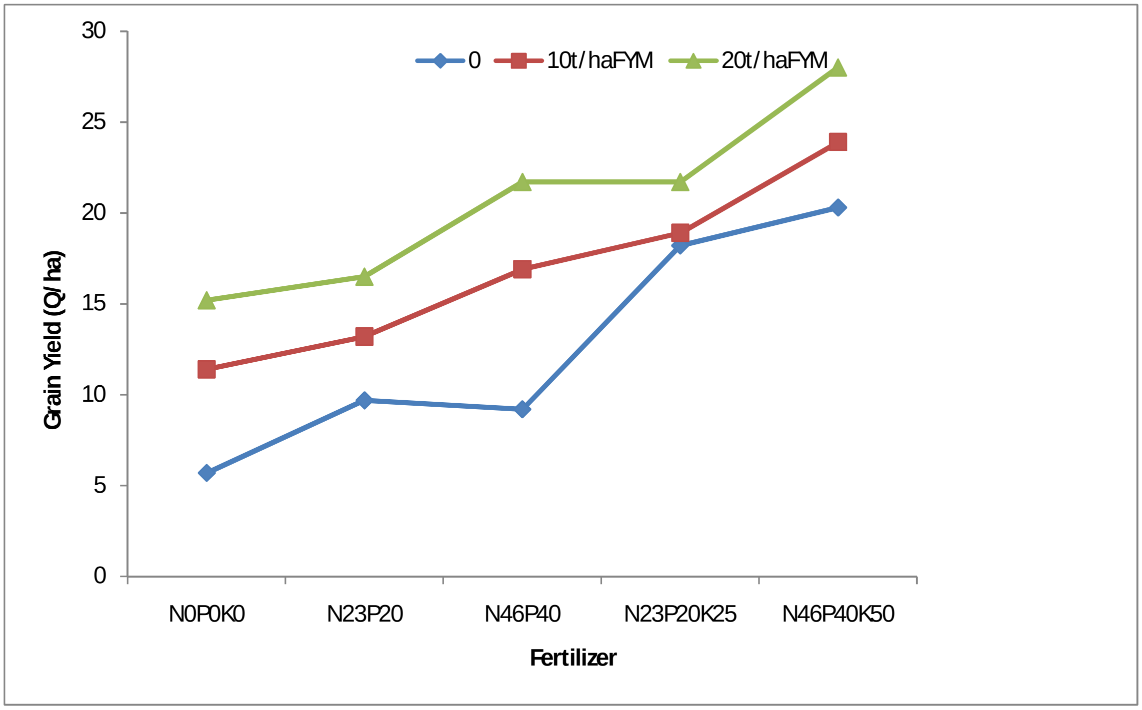

Figure 1. The effect of FYM and Inorganic fertilizers on the grain yield of barely at Chencha.

The application of K has significantly improved the grain yield of barely than NP, FYM and NP + FYM suggesting that K is the limiting nutrient at Chernacha in the same was as was witnessed in other experiment too.

3. Exploitation of locally available Organic nutrient sources for soil fertility improvement

These days a there are varieties of leguminous cover crops and trees that can be used as fertilizers as compost, green manure and biomass transfer so on. The notable examples are Delicos lablab, vetch, crotalaria, macuna, luceanae, susbania, Cajanus cajan and Titonia and there are a multitude of research results proving that such plants are rich in their nutrient contents essential for soil fertility improvement. Organic nutrient source of such types could be used alone or in combination with inorganic fertilizers for enhanced crop. However, most of leguminous cover crops and trees that are identified to be best as organic fertilizer sources are exotic species and their dissemination and use in Ethiopia is very limited. This may due to limited efforts on the part of researchers, extension personnel and all other concerned stake holders to demonstrate the importance of these exotic species for soil fertility improvement. There are also only limited research finding indicating which of the leguminous crops grows best where from ecological and social point of view.

Thus, While making an effort to introduce and disseminate exotic leguminous crops to different agro ecological zone for soil fertility management, there is a need identify locally available organic nutrient sources that can serve as organic fertilizers. One such locally available organic fertilizer recently identified is *Erythrina bruci*. It is an indigenous N-fixing (Fassil, 1993) nutrient rich organic nutrient source adapted to growing in mid altitude areas of Southern region. It is a fast growing tree that produces abundant biomass in a short period of time and grown as live fence, inside farmlands and on communal lands (Demil, T. 1990). The results of chemical analysis of leave and twig samples showed that it has 4.83%N, 0.38%P and 2.24% K (Wassie et. al., 2009). These indicate that Erythrina has higher amount of nutrients than most green manure crops (Gachene et. al., 1999). Further experiments were conducted to test the effect of transferred biomass of Erythrina applied alone or in combination with inorganic fertilizer on the yield of wheat for two years at Kokate testing site located at wolaita. Erythrina biomass was applied at 5 and 10t/ha one month ahead of planting of wheat to allow time for decomposition.

The result of transferred biomass of Erythrina applied alone or in combination with inorganic fertilizers on the grain yield of wheat is presented in Fig. 2.

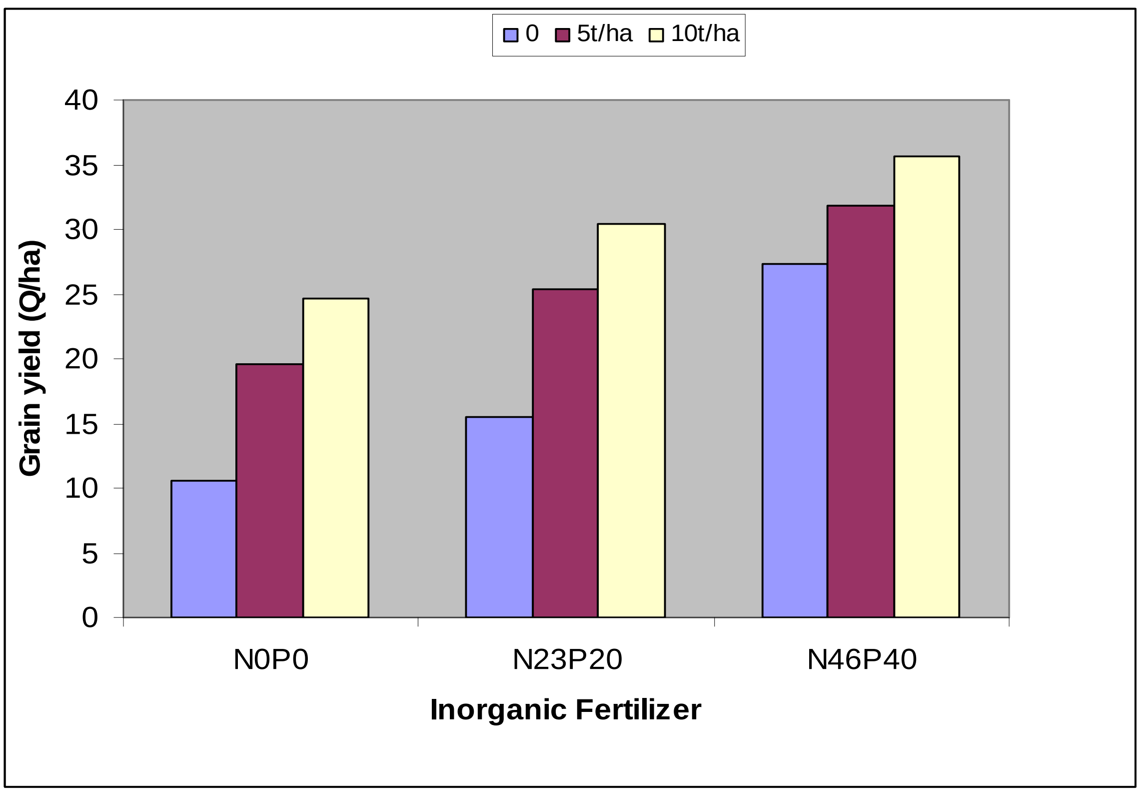

Figure 2. The effect of transferred biomass of Erythrina biomass applied alone and in combination with inorganic fertilizers on the grain yield of wheat at wheat

Application of 5 and 10t/ha of biomass increased the grain yield by 86 and 134% respectively over the control. Application rate of Erythrina biomass at 10t/ha + half of the recommended rate of NP ($N_{23}P_{20}$) for wheat at kokate area increased the grain yield by 189% suggesting that the cost of inorganic fertilizer could be reduced by half using erythrina biomass as organic supplement while obtaining superior yield of wheat than either source applied alone.

Most mid and high altitude areas of SNNPR are densely inhabited with average land holding of less that 0.5ha which is highly depleted of nutrients and organic matter content. Farmers in these are very poor and cannot afford to buy inorganic fertilizers. even if they can apply there is limited response of crops organic matter depletion which is very important to increase fertilizers use efficiency of crops. There fore subsistent farmers buy inorganic fertilizers can get reasonably higher yield of wheat using erythrina biomass as organic nutrient sources. Whereas few farmers who are applying inorganic fertilizer for crops currently could reduce the fertilizer rate by half using integrated application with Erythrina biomass. Thus, as the tree is familiar to farmers where it exist as multipurpose tree (as animal feed, making house hold material, fence, perceived as friendly to crops and fertility improving agent by farmers) (Eyasu, 2002) further demonstration of the technology is critical.

The current research finding further implies that further research to identify additional locally available organic nutrient sources than *Eythrina burci* is needed as Ethiopia is rich in its biodiversity there will be a high probability to tree and shrubs that can be exploited for soil fertility improvement.

4. The effect of liming and fertilizers on tuber yield of Potato at acidic soils of Chencha

Soil acidity and deficiency of nutrients particularly P and K are identified to be the key soil related problems that account for low yield of crops in Chencha area of southern Ethiopia. The soil in the testing site of Chencha ranges from 4.8 to 5.0, P is 3.2ppm and K is 11.2. (Shiferaw, B., 2005). As one possible means of intervention application of lime and fertilizer (organic and inorganic fertilizers) were studied on potato in the area for two years.

Table 4. The effect of liming and fertilizer and residual effect on the tuber yield of potato at acid soils of Chencha.

Treatments	Mean yield (q/ha) 2007	2008
$N_0P_0K_0$ + 0 Lime	79.6h	40.6f
$N_{110}P_{40}K_0$ + 0 lime	117.7efg	40.2f
$N_{110}P_0K_{100}$ + 0 lime	108.2fgh	42.1f
$N_0P_{40}K_{100}$ + 0 lime	227.2c	161c
$N_{110}P_{40}K_{100}$ + 0 lime	349.3b	268.8b
N_0PK_0 + 1.75t/ha	91.2gh	38f
$N_{110}P_{40}$ + 1.75	142.5def	63.8ef
$N_{110}P_0K_{100}$ + 1.75	144.3de	125.8cd
$N_0P_{40}K_{100}$ + 1.75	288.5c	158c
$N_{110}P_{40}K_{100}$ + 1.75	372.1b	280.2b
$N_0P_0K_0$ + 3.5t/ha	102.5gh	52.0f
$N_{110}P_{40}$ + 3.5t/ha	148.1de	74.0def
N110P0K100 + 3.5t/ha	159.5d	117.8cde
$N_0P_{40}K_{100}$ + 3.5t/ha	277.2c	247.2b
$N_{110}P_{40}K_{100}$ + 3.5t/ha	410.0a	346.2a
LSD(0.05)	**8.6**	**6.4**
CV (%)	**10.5**	**24**

The result of liming and fertilizer and their residual effect on tuber yield of potato are shown in Table 4. Lime application at both half and full rate has significantly ($P< 0.0001$) increased the tuber yield of potato in 2007. Half and full rate of lime have increased the tuber yield from 79.6 q/ha in the control to 92.2q/ha (14.5%) and 102.5q/ha (28.7%) respectively. However, the yield increment due to liming was very low suggesting that the soils of chencha not constrained by nutrient unavailability by soil acidity but they are depleted of nutrients. $N_{110}P_{40}K_0$ and $N_{110}P_0K_{100}$ treatments have significantly increased the yield of potato but no significant difference was observed between these fertilizer treatments. The yield was further increased in plots that received $N_{110}P_{40}K_{100}$ (Yield increase by 338% over the control) indicating that application of N will be more effective provided that P and K are applied together. Integrated application of lime and fertilizer gave the highest yield only when $N_{110}P_{40}K_{100}$ and full rate of lime are applied. There fore if lime application sought to bring significantly appreciable improvement in the yield of crops it has to be with applied balanced application of NPK is a must.

The residual effect was seen in 2008 and it was found that neither fertilizer application nor lime have significantly increased the yield of potato compared with control except plots that received $N_{110}P_{40}K_{100}$ treatment. This is due to the fact that the only function of lime applied to the soil is to raise the pH and as a result essential nutrients rendered unavailable will be come available. Thus, lime application or its residual effect is beneficial as far as the nutrients held unviable are not exhausted (Potash insititute, 1979).

III. POLICY IMPLICATIONS

Soil acidity

It is now well understood by the government and a number of stakeholders that soil acidity is a serious threat to agriculture in more than 40% of the arable lands of Ethiopia. Due to this fact, there was a massive campaign in the recent past to solve the problem by lime application. Appreciable increases in the yields of crops such as barely and wheat were recorded. However, the current research finding in this paper revealed that lime application alone is a temporary solution to soil acidity and unsustainable due to very high depletion of nutrients in acidic areas. Thus, if liming is continued to be applied it has to be supplemented with organic and inorganic fertilizers or both. The current research finding has also shown that the ammonia based fertilizers (UREA and DAP) have negative effect on crops growing in acidic soils due to acidifying nature of these fertilizers, therefore none acidifying, alternative sources of fertilizers should be tested and demonstrated. Thus, mitigation of soil acidity and transforming acidic soils in to sustainable productive status requires long term integrated solutions as a result it requires the attention of policy makers and other stake holders.

On the other hand, based on the research conclusions of Murphy (1968), some 40 years ago, Ethiopian soils were considered to be rich in potassium (K) and hence there was no need for application of K fertilizers. However, the current finding showed that K is critically deficient in acidic soils of highland areas of SNNPR disproving the long standing conclusion that Ethiopian soil are rich in potassium. Thus, consideration should be given to importing and using potassium fertilizers in acidic areas.

Soil fertility decline

Declining soil fertility is an other critical challenge adversely affecting crop production continued threatening the food security and self sufficiency of the population of Ethiopia. Application of inorganic fertilizers was taken as a main route to solve the problem for increased crop production in Ethiopia. However, the cost of fertilizers is increasing unprecedentely, fertilizers have reduced recovery efficiency, creates imbalance other essential nutrients in the soil, acidifies soil and in general unsustainable. On the other hand organic fertilizers besides being nutrient sources they improve the soil physical and chemical characteristics, improves the water holding capacity so on. But organic nutrient sources have their own shortcomings such as bulkiness availability, very low in some important nutrients and variable quality. There fore, most research findings in literature and findings in this paper showed that integrated application of inorganic and organic nutrient sources provides a balanced nutrition to crop, avoid the negative effect of each other and provide superior yield of crops. However, integrated soil fertility management technology requires identification high quality, available and cheap source of organic nutrient sources like Erythrina species reported in this paper is of paramount importance. Thus, land management policies existing currently or formulated in the future should consider methods that accelerates the dissemination and use of integrated soil fertility management technologies by farmers.

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REFRENCES

Abdenna, D., Negassa, C.W. and Tilahun, G. 2007. Inventory of Soil Acidity Status in Crop Lands of Central and Western Ethiopia. "Utilisation of diversity in land use systems: Sustainable and organic approaches to meet human needs" Tropentag, October 9-11, 2007, Witzenhausen.

Abebe, Y. and Diriba B. 2003. Effect of biomass transfer of *Cajanus cajan* with or with out inorganic fertilizer on BH-600 hybrid variety at Bako, Western Oromia. Pp. 41-50. In: Tilahun Amede and Eylachew Zewde (eds). Challenges of Land Degradation of Agriculture in Ethiopia. Proceedings of the 6th ESSS Conference, Feb 28- March 1, 2002, Ethiopian Society of Soil Science, Addis Ababa.

Amsal, T. and Tanner, D. 2001. Effect of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat grown on two soil types in central Ethiopia. *Ethiopian Journal of Natural Resources*. 3(2): 219-244.

Cooke, G.W. 1982. Fertilizer for maximum yield. Third edition. Collins Professional and Technical Books. London, UK.

CIAT-TSBF. 2002. Output 1. Biophysical and socioeconomic constraints to integrated soil fertility management (ISMF) identified and knowledge on soil process improved. Pp. 42-66. Challenge program- Biological nitrogen fixation: Position paper presented CIAT-TSBF working group for International Workshop on Biological Nitrogen Fixation for increased crop productivity, enhanced Human Health and Sustained soil fertility.v10-14, June 2002, Montpellier, France.

Demil, T. 1990. Germination ecology of two endemic multipurpose species of *Erythrina* from Ethiopia. *Forest Ecology and management* 65: 80-87.

Desta, B.1987. Soil Science Research in Ethiopia: A Review . Proceedings of the first Soil Science Research Review Workshop, 11-14 February 1986, Addis Ababa, IAR, Addis Ababa. pp

Eyasu, E. 2002. Farmer's perception of soil fertility change and management. SOS-SAHEL and Institute of sustainable development, Addis Ababa, 225p.

Fassil, A. 1993. Nodulation nitrogen fixation by *Rhizobium* and *Bradyrhizobium* species of some indigenous tree legumes of Ethiopia. Dissertation, University of Bayreuth, Germany. 93p.

Gachene, C.K. K, Palm, C.A, and Mureith, J.G. 1999. Legume cover crops for Soil fertility Improvement in the East African Region. Report of an AHI Workshop, TSBF, Nairobi, 18-19th February, 1999.

Gruhn, P., Goletti, F. and Yudelman, M. 2000. Integrated Nutrient management, soil fertility and sustainable agriculture: Current issues and future challenges. International Food Policy Research Institute, Washington, D.C.

Jones, B. J. Jr. 2001. Laboratory guides for conducting soil tests and plant analysis, CRC press, London.

Kelsa, K., Yohannes, and T. Bogale, T. 1992. Influence of fertilizer and its related management practice on maize grain yield in major maize producing areas of Ethiopia. In: Benti, T. and J. K. Ramsom (eds.). Proceedings of the first national maize workshop of Ethiopia. 5-7 may 1992, Addis Ababa, Ethiopia.

Murphy, H. F. 1968. A report on fertility status and other data on some soils of Ethiopia. Experimental Station Bulletin No. 44. Hailesilassie College of Agriculture, Oklahoma State University, 551P.

Potash and Phosphate Institute. 1979. Soil Fertility Manual. Atlanta,Georgia.

Ravishankar, H., Tekaligne, T. and Habtamu, Z. 2002 Sustainable approaches towards organic management and intensification in coffeee soils of Ethiopia-some suggestions. Pp. 69-74. In : Wodimagegne Chekol and Engida Mersha (eds). Proceedings of the Fifth Conference of Ethiopian Society of Soil Sciences, March 30-31, Addis Ababa, Ethiopia.

Rowell, D. L. 1994. Soil Science: Methods and Applications. Longman, Singapore.

Sahrawat, K. L. and S. K. Mukerjee and K. C. Gulati. 1977. Nitrification inhibitors. I. Studies with karanajin, a furano flaviniod from karanaja *(Pongamia glabra* vet.). *Plant and Soil*. 47:27-36.

Shiferaw, B. 2005. Progress Report of the natural resources Department, Awassa Agricultural Research Center, Awassa

Sivaguru M and Horst, W. J. 1998. The distal part of the transition zones is the most aluminum-sensitive apical root zone of maize. *Plant Physiology*. 116, 155–163.

Taye, B. 2007. An overview of acid soils their management in Ethiopia paper presented in the third International W0rkshop on water management (Wterman) project, September, 19-21, 2007, Haramaya, Ethiopia.

Taye, B., H. Yesuf, S. Sahlemedhin, G. Amanuel, H. Hassena, D. G. Tanner, T. Tesfaye and G. Takele. 2002. Optimizing Fertilizer Use in Ethiopia: Correlation of Soil Analysis with Fertilizer Response in Hetosa Woreda, Arsi zone. Addis Ababa, Sasakawa-Global 2000.

Taye, B. 1996. Utilization of organic residues in Ethiopia. A Review. Pp. 162-183. In: Teshome Yizengaw, Eyasu Mekonen and Mintesnot Behailu (eds.). Proceedings of the third Conference of Ethiopian Society of Soil Sciences, Feb. 28-29, 1996, Addis Ababa, Ethiopia

Taye B., Yeshanew, A., Balesh, T. and Girma, K. 1996. Soil fertility management in Barley. Pp. 92-103. In: Hailu Gebre and Joop van Leur (eds). Barely Research in Ethiopia past works and Future prospects. Proceedings of the First barely Research Review Workshop, 16-19 October 1993, Addis Ababa: IAR/ICARDA. Addis Ababa, Ethiopia.

Tilahune, A., Endrias, G. and Takele, B. 2007. Reversing the degradation of arable land in Ethiopian highlands, Managing Africa's soil. No. 23, IIED-London.

Tisdale, S. T., Nelson, W. L. and J. D. Beaton, J. D. 1985. Soil Fertility and Fertilizers. 4th ed. Macmillan Publishing Company, New York. 499p.

Yohannes, U . 1994. The effect of nitrogen, phosphorus, potassium, and sulphur on the yield and yield components of Ensete (*Ensete ventricosum* W.) in Southwest of Ethiopia. Ph.D. dissertation, Gießen, Germany. 93p.

UNDP-Emergency unit for Ethiopia. 1995. Country information in brief. Food and Agricultural Organization of the United Nations, Draft, June 1995.

Vanlauwe, B., J., Diels, J., Sanginga1, N and Merckx, R. 2005. Long-term integrated soil fertility management in South-western Nigeria: Crop performance and impact on the soil fertility status. *Plant and Soil* 273: 337-354.

Wang, J., Raman, H., Zhang, G. Mendham, N. and Zou, M. 2006. Aluminum tolerance in barely (*Horidium vulgarie* L.): Physiological mechanisms, genetics and screening methods. *Journal of Zhejiang University Science*. 7: 769-787.

Wassie, H., Shiferaw, B. and Kelsa, K. 2009. Integrated soil fertility management options for Sustainable Crop Production: Review of Research Findings from Southern Regional State of Ethiopia. Paper presented on the 10th anniversary conference of Ethiopian Society of Soil Science (ESSS), 26-27 March 2009, Addis Ababa, Ethiopia.

Yohannes, U . 1994. The effect of nitrogen, phosphorus, potassium, and sulphur on the yield and yield components of Ensete (*Ensete ventricosum* W.) in Southwest of Ethiopia. Ph.D. dissertation, Gießen, Germany.