Integrated Soil Fertility Management Options for Sustainable Crop Production: Review of Research Findings from Southern Regional State of Ethiopia

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ABSTRACT

Declining of soil fertility and soil acidity are the major challenges to crop production in Ethiopia. Applications of chemical fertilizers mainly Urea and DAP have been started some four decades ago to improve soil fertility for enhanced crop production. Dramatic increases in the yields of several crops were obtained due to this practice. However, because of untenable increase in the price of fertilizers coupled with their adverse effects on the soil and reduced recovery efficiency of fertilizers by crops are some of the bottlenecks that prohibit the indiscriminate use of this technology. Therefore, these problems entail the development and use of integrated, cheap, available, sustainable and environmentally friendly ways of soil fertility management techniques. The effects of transferred biomass of Erythrina bruci biomass alone and integrated with chemical fertilizers effect on wheat, integrated application of organic-inorganic fertilizers on different crops, green manuring and liming experiments were conducted in different location of southern Ethiopia. The results revealed that application of 5 tha^{-1} and 10 tha^{-1} of Erythrina biomass increased the grain yield of wheat by 86% and 134% over the control respectively. And application of 10 tha^{-1} of Erythrina biomass and 23/20 kg N/P ha^{-1} increased the grain yield by 189% over the control and by 11% over that obtained with the application of 46/40 kg NP ha^{-1} implying that the recommended rate of chemical fertilizer for wheat can be reduced by half by using Erythrina biomass as organic supplement. Similarly the result of green manuring with Delicos lablab experiment over two years showed that the grain yield of wheat was increased by 97 and 63% at Hossana and Kokate over the control, respectively. There was a significant and positive response of barely and potato to the application of potassium. There were also significant and positive responses of different crops to liming and integrated application of farmyard manure (FYM) and inorganic fertilizers. The implications of the results are discussed and future research directions are indicated.

Key word: Soil fertility, Soil acidity, Integrated Soil management, Liming, Organic Nutrient sources

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INTRODUCTION

Being in the tropics, most Ethiopian soils are very poor in their inherent soil fertility (Okalebo *et al*., 2003). However, they were able to sustain crop production in the far past due to useful tradition soil fertility restoring practices such as fallowing, crop rotation, manuring, maintenance of forest cover, shifting cultivation so on (Wondimagegne Chekol and Engida Mersha, 2000; Yonannes Uloro, 1994). However, some four decades back these traditional and natural ways of soil fertility restoration practices have been abandoned adversely affecting crop production. The unlimited rise in population size is the core cause of the problem that to satisfy the growing demand for more and more food and fuel led to continuous cropping, removal of crop residues to be used as energy source which otherwise been incorporated back in to the soil, forests were cleared aggravating soil erosion (Tilahun Amede *et. al*., 2007; Hailessilassie Amare *et. al*., 2005).

In an effort to overcome soil fertility decline and improve crop yield applications of industrial fertilizers containing mainly N and P have been started some four decades ago. There was enormous increase in the yield of several crops due to application of fertilizers (Amsal Tarkegne and Tanner, 2001; Taye Bekele *et. al*., 1996; Desta Beyene, 1988). For Instance, Kelsa Kena *et. al*.(2001) reported that the yield of cereals could be increased by more than 100%. In general there were only few occasions where there was no positive response of crops to fertilizer applications. Due to highly significant and visible impact of fertilizers on crops its adoption by farmers was very fast (Redy, 1996) compared to any other technology probably except that of improved crop varieties. 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 Bekele *et al*., 2002). However, the price of fertilizers is increasing from time to time prohibiting subsistent farmers from using this invaluable input. Moreover, continuous use of fertilizers containing only few essential elements like those being used in Ethiopia, Urea and DAP, aggravate the depletion of other essential nutrients in soil (Rasmussen and Rohde, 1989), acidify soil (Rowell, 1994) and have adverse effect on the environment and generally they are unsustainable. Reduced 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. In the case of N-fertilizers leaching and denitrification are the main causes which reduce recovery efficiency (Sahrawat *et. al*., 1977). However, we can not void the use of chemical fertilizers for crop production for the plenty of beneficial effect of these inputs (Lindqvist, 2005). Thus, there is need to mitigate the adverse effects of fertilizers and maximize the fertilizer use efficiency of crops.

To this effect, integrated application of organic and inorganic nutrients sources to soil is very crucial to counteract the negative aspects of chemical fertilizers. Organic nutrients that could be applied as biomass transfer, green manure, FYM, compost etc.. serve as fertilizers. In addition they help to increase organic matter content of the soil which in turn improves the physco-chemical characteristics of the soil notably, increase water holding capacity of the soil, CEC, and basic cations. They also improve the nutrient retention property of the soil serve as reservoir of micronutrients and reduce leaching losses of nutrients (Vanlauwe *et. al*, 2005; Ravishankar *et. al*., 2002). Besides, they increase the fertilizer use efficiency of crops (Lindqvist, 2005). CIAT-TSBF (2002) states that "both organic and inorganic inputs are necessary to enhance crop yields without deteriorating the soil resource base emphasizing the integrated application of both inputs for either of them are hardly available in sufficient quantities to small scale farmers and the multiple benefits of combined applications of organic and inorganic inputs".

According to Mugwe *et. al*., (2007), sole application of organic materials at 60kg N/ha and combined application of organic material (30kg N/ha) and inorganic fertilizer (30 kg N/ha) were compared for their effect on the grain yield of maize and it was found that the later treatment gave higher yields than the recommended fertilizer. These authors stated that organic materials improved the nutrient use efficiency of fertilizer. Similarly, Abebe

Yadesa and Diriba (2002) 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 and less only by 16% from plots received the full recommended doses of fertilizers. According to the same Authors, applications of 6t/ha of *Cajanus cajan* with half of the recommended inorganic fertilizer gave significantly higher maize grain than plots received full rate. The result of experiment conducted at Kabate, Kenya, with *Macuna pruriens* and Cr*otalaria ochroleuca* incorporated it to the soil as green manure increased the grain yield of maize by 83% and 107% higher than when maize was grown without any fertilizer application respectively (Gachene *et. al*., 1999).

Soil acidity/Al toxicity is another important challenge to crop production in Ethiopia. It affects crop production by affecting root development ultimately affecting nutrient and water uptake, as a result crop yields are severely reduced. Currently about 40% of the arable lands in Ethiopia are affected by soil acidity and it is expanding both in scope and magnitude. Some of the approaches to address soil acidity are liming, applications of organic matter such as farmyard manure (FYM) 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 is the main limitation for its wider use. Application of organic matter is another option to mitigate soil acidity. Soil organic matter sequesters Al^{3+} thereby avoids the toxic effect of the later on crops growing in acidic soil (Rowell, 1994).

Considering, the multiple beneficial effects of organic nutrient sources on soil fertility and yield of crops applied either alone or in combination with inorganic fertilizers and the availability of potentially nutrient rich organic nutrient sources in Ethiopia a number of experiments viz. transferred biomass of *Erythrina bruci* applied alone or in combination with fertilizers on wheat, Organic-inorganic interaction fertilizer effects on potato wheat and barely, green manuring of *Delicos labalab* on wheat and liming effect study on different potato have been conducted in different experimental sites of Southern Agricultural Research Institute in the past five years. Thus, the objective of this review paper is to present the research findings done on integrated soil fertility and soil acidity management methods for enhanced yields of potato, wheat and barely.

Effect of Transferred Biomass of *Erythrina bruci* and NPK fertilizers on Wheat.

Erythrina bruci is an indigenous N-fixing 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. The results of chemical analysis of leaf and twig samples showed that it had 4.83% N, 0.38% P and 2.24% K. These indicate that *Erythrina bruci* has higher amount of nutrients than most green manure crops (Gachene *et. al*., 1999).

Based on these facts the effect of transferred biomass of *E. bruci* on wheat was studied for two years at Kokate, southern Ethiopia. The location has geographic position of Latitude $6^0$52'N and Longitude of 37^0 48'E. The site has an altitude of 2156masl, mean annual rain fall of 1325 mm and mean maximum temperature of 25.5^{O}C. The soil is characterized as Dystric Nitisol. The experiment consisted of factorial combinations of three levels of Erythrina biomass (0, 5 and 10 tha^{-1}) and five levels of fertilizers (NPK a rate of 0:0:, 23:20:0, 46:40:0, 23:20:50 and 46:40:50 $kgha^{-1}$ respectively). The leaves and twigs of *Erythrina* biomass were collected from around experimental site, chopped into pieces and incorporated at a depth of 15 cm in the soil one month ahead of planting. The plot size was 16 m^2. Wheat variety Simba was planted on 24/8/07 and 25/8/08. Other recommended practices were applied. Data on plant height, tiller numbers, spike length, number of spike let per spike, grain and straw yield were collected and analyzed statistically using SAS software.

The results revealed that both grain and straw yields of wheat were significantly (P= 0.001) improved by *Erythrina bruci* biomass, inorganic fertilizers and their combinations (Fig.1). Application 5 tha^{-1} and 10 tha^{-1} of *Erythrina* biomass increased the grain yield of wheat by 86% and 134% over the control respectively. The corresponding increases in the straw yields were 81% and 150% respectively. Combined application of *Erythrina* biomass (10 tha^{-1}) + 23/20 kg N/P ha^{-1} increased the grain yield by 189% over the control and by 30% over that obtained with the application of 46/40 kg N/P ha^{-1} implying that the recommended rate of chemical fertilizer application could be reduced by half by using *Erythrina* biomass as organic supplement. The superiority of combined application of organic and inorganic fertilizers in increasing the yield of crops over that obtained from the applications of inorganic fertilizers alone have been reported by several Authors (Mugwe *et. al*., 2007; Sharma, 2006; Vanlauwe *et. al*, 2005). Nutrients applied as inorganic fertilizer along with organic sources are retained for longer period of time than applied as inorganic fertilizers alone (Ravishankar *et. al*., 2002). This argument is substantiated by the finding of Taye Bekele (1996) who reported that leaching and denitrification loss of N was very low when N-fertilizers were applied along with farmyard manure (FYM).

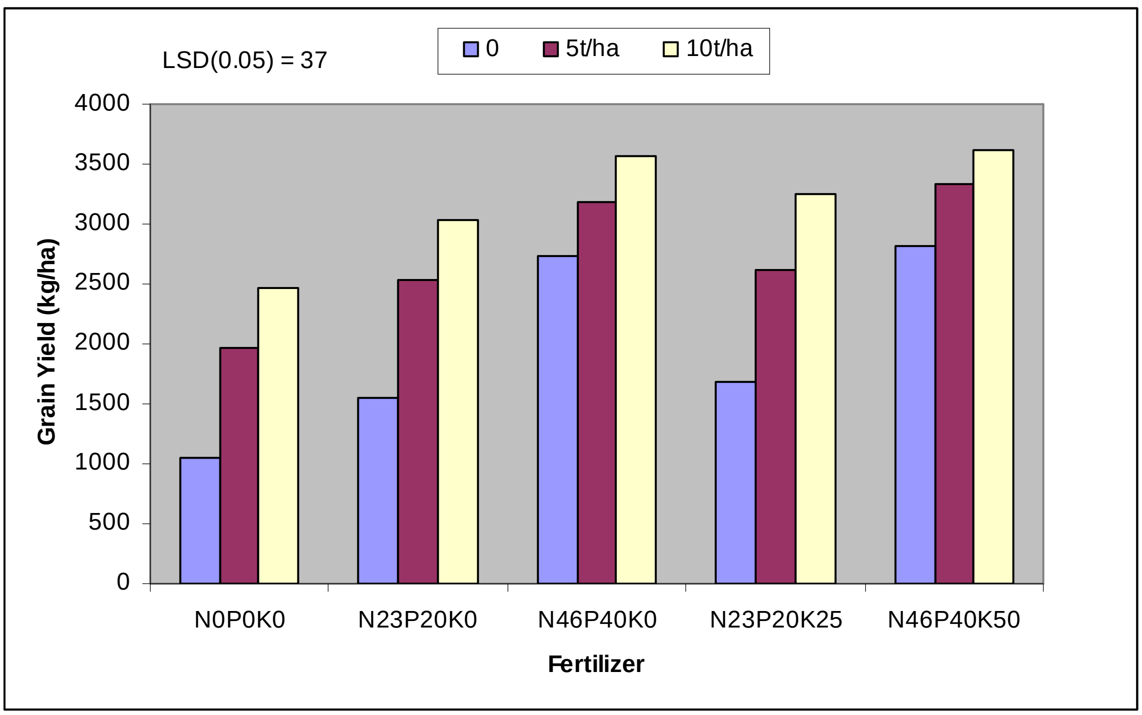

Figure 1. The effect of *Erythrina* biomass, NPK fertilizers and their combinations on the grain yield of Wheat at Kokate

Application of K fertilizer had no effect on both grain and straw yield of wheat indicating that at least at the moment soils of Kokate area have sufficient amount of K in the soil to satisfy the K requirement.

There fore, *Erythrina bruci* biomass incorporated one month ahead of planting produced significantly superior yield of wheat over the control hence it can serve as an excellent source of organic nutrient sources for soil fertility improvement. Applications of the recommended rate of commercial fertilizers could be reduced by half with combined application of *Erythrina* biomass so that equal or higher yield of wheat can be attained with the later. Potassium was not found a limiting nutrient in the study area.

Table 1. The results of partial budget analysis data for selected treatments of *Erythrina* biomass transfer experiment.

	Treatment			
Partial budget	**Control**	**Erythrina (10 tha^{-1})**	**Erythrina 10 tha^{-1} + Half NP (23/20 kgha^{-1})**	**NP (46/40 kgha^{-1})**
Average yield (kgha^{-1})	10.5	24.6	30.4	27.3
Adj. yield (kgha^{-1})	9.45	22.14	27.36	24.57
Gross benefit birr ha^{-1}	4725	11070	13680	12285
N	0	0	353	706
P	0	0	466.5	933
labor for Erythrina biomass incorporation	0	500	250	0
TVC	0	500	1069.5	1639
Net benefit birr/ha	4725	10570	12610.5	10646
MRR		1169	358	

Price of wheat = 500 Birr kg^{-1}

Table 1 shows the result of partial budget analysis data selected treatments of experiment shown in Fig. 1. Accordingly, the higher net benefit and higher marginal rate of return relative to the untreated control treatment was obtained from plot treated with 10 tha^{-1}. However, the highest net benefit and marginal rate of return was obtained from plots treated with 10 tha^{-1} *Eryhthina* biomass + half NP (23/20 kgha^{-1}) relative to plots treated with 10 tha^{-1}. Thus, it is recommended that economically marginalized farmers can get a reasonablely high yield with application of *Erythrina* biomass alone at a rate of 10 tha^{-1}. While, those farmers who can afford to apply commercial fertilizers will get maximum yield by combined application of *Erythrina* biomass with half NP fertilizer recommended for wheat production for kokate area..

Results of Green Manuring (GM) experiments

The effect of *Delicos lablab* as green manure (GM) on wheat was studied for two years at two locations namely Kokate and Hossana. Phosphorus was applied on plots at a rate of 20 $kgha^{-1}$ as TSP. The results of green manuring applied alone and in combination with inorganic fertilizers on the grain yield of wheat are shown in Table 2. Average over two years, green manure increased the grain yield of wheat by 63% and 97% over the control at Kokate and Hossan respectively. Similarly, the combined applications of GM and 23 $kgha^{-1}$ N increased the grained by 70% and 117% over the control respectively. These results showed that reasonably high yield of crops could be obtained using green manuring and of inorganic fertilizer application could be reduced by half using integrated application with GM.

Table 2. The effect of *Delicos lablab* as Green Manure (GM) on Wheat at Kokate and Hossana, Southern Ethiopia

Treatment	Mean Grain Yield ($kgha^{-1}$)	
	Kokate	**Hossana**
Control	2011c	1443b
GM + 0N	3282ab	2857a
GM0 + 23N	2926b	2956a
GM + 23N	3417ab	3141a
GM0 +46N	3329ab	3392a
GM + 46N	3529a	2954a
GM0 + 69N	3502a	3267a
GM + 69N	3630a	3130a
LSD().05)	**327**	**365**
CV(%)	**10.7**	**13.3**

Source: ARC, 2005

The effect of Farm Yard Manure (FYM) and NPK fertilizers on the yield of potato and barely.

Potato

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, FYM applied at 10 and 20 tha^{-1} increased the tuber yield by 70% and 100% over the control respectively. Application N at 55 $kgha^{-1}$ and small amount of P (20$kgha^{-1}$) 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. Further increased application of N:P at 110:40 $kgha^{-1}$ did not significantly increased the tuber yield of potato. However, applications of N and P along with potassium have significantly increased the tuber yield of potato. As can be seen from Table 3, 55-20-50 and 100-40-100 kgha-^{1} of NPK increased the tuber yield by 64 and 123% respectively suggesting that K is 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 NPK at 55-20-50 $kgha^{-1}$ sources gave superior yield than either source applied alone and increased the tuber yield by 172% over the control. But combined application of NPK and FYM beyond the above rate did not significantly increase the tuber yield. Regarding this experiment it can be concluded that if only inorganic fertilizers are to be applied balanced application of NPK is necessary to get superior yield of potato. Other wise if combined application of inorganic-organic sources is to be practiced, application of half of both half of the maximum amount of NPK at a rate of 55:20:50 $kgha^{-1}$) + 10 tha^{-1} FYM applied in this experiment will give the optimum yield.

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

Treatments*	Mean yield (tha^{-1})	
	2007	2008
$N_0P_0K_0$ +0FYM	17.08g	4.05g
$N_{55}P_{20}K_0$ + 0FYM	15.38g	5.45fg
$N_{110}P_{40}K_0$+ 0FYM	20.47fg	6.42fg
$N_{55}P_{20}K_{50}$+ 0FYM	28.18ef	18.34cd
$N_{110}P_{40}K_{100}$+ 0FYM	38.15bc	23.39bc
N0PK0 +10 tha^{-1}FYM	29.23e	7.97efg
$N_{55}P_{20}K_0$ + 10 tha^{-1} FYM	37.21cd	9.30efg
$N_{110}P_{40}K_0$+ 10 tha^{-1} FYM	36.26cde	10.90ef
$N_{55}P_{20}K_{50}$+ 10 tha^{-1} FYM	46.51ab	21.53c
$N_{110}P_{40}K_{100}$+ 10 tha^{-1} FYM	45.94ab	28.19b
$N_0P_0K_0$ + 20 tha^{-1} FYM	34.17cde	13.15de
$N_{55}P_{20}K_0$ + 20 tha^{-1} FYM	46.66ab	21.63c
$N_{110}P_{40}K_0$ + 20 tha^{-1} FYM	39.11bc	11.81ef
$N_{55}P_{20}K_{50}$ + 20 tha^{-1}FYM	52.77a	21.91bc
$N_{110}P_{40}K_{100}$ + 20 tha^{-1}FYM	53.91a	34.66a
LSD	**8.6**	**6.4**
CV (%)	**14.0**	**24.0**

* $N_0P_0K_0$, $N_{55}P_{20}K_0$, $N_{110}P_{40}K_0$, $N_{55}P_{20}K_{50}$ and $N_{110}P_{40}K_{100}$ = 0:0:0, 55:20: 0, 110:40:0, 55:20:50 and 110:40:100 $kgha^{-1}$ of NPK respectively

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 20 tha^{-1} have produced significantly higher yield of potato than plots received N, NP and control.

Table 4. Economic (Partial budget analysis of data)

Partial budget	**Treatment***					
	Control	**NP**	**FYM**	**NPK**	**Half NPK + Half FYM**	**NPK+FYM**
Average yield (tha^{-1})	17.08	15	34.17	38.15	46.51	53.91
Adj. yield (tha^{-1})	15.37	13.5	30.75	34.34	41.86	48.52
Gross benefit $birrha^{-1}$	30740	27000	61500	68680	83720	97040
N	0	1687.34	0	1687.34	843.67	1687.34
P	0	1866	0	1866	1866	1866
K	0	0	0	860	430	860
FYM	0	0	750	0	375	750
TVC	0	3553.34	750	4413.34	3514.67	5163.34
Net benefit birr/ha	30740	23446.66	60750	64266.66	80205.33	91876.66
MRR			1330	96	1773	708

Price of potato = 2 birr/kg

*NP = 55:20 $kgha^{-1}$, FYM = 20tha^{-1}, NPK = 110:40:100 $kgha^{-1}$, Half NPK + Half FYM = 55:20 :50 $kgha^{-1}$ NPK + 10 tha^{-1} FYM, NPK + FYM = 110:40:100 $kgha^{-1}$ + 20tha^{-1}

The economic analysis data for selected treatments of experiment of the effect of integrated application of FYM and inorganic fertilizers on potato is shown in Table 4. Accordingly, the net benefit for NP treatments was negative relative to the control. Otherwise, it was positive for the remaining treatments. The highest marginal rate of return was obtained from treatments that received half NPK + half FMY application. There fore, it is recommended that in situation where only inorganic fertilizers are to be applied at Chencha, it is a must to apply balanced application of NPK. However, if both inorganic – organic fertilizers are available, integrated application of both sources at half of the highest rate of NPK and FYM (55:20: 100 $kgha^{-1}$ NPK + 10 tha^{-1} FYM) is recommended.

Barely

The effect of FYM and inorganic fertilizers on the yield of barely on acid soils of Chench is shown in Figure 2. There was almost a linear 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 20 tha^{-1} increased the grain yield by 100 and 160% respectively. The increase was further augmented when applied along with inorganic fertilizers.

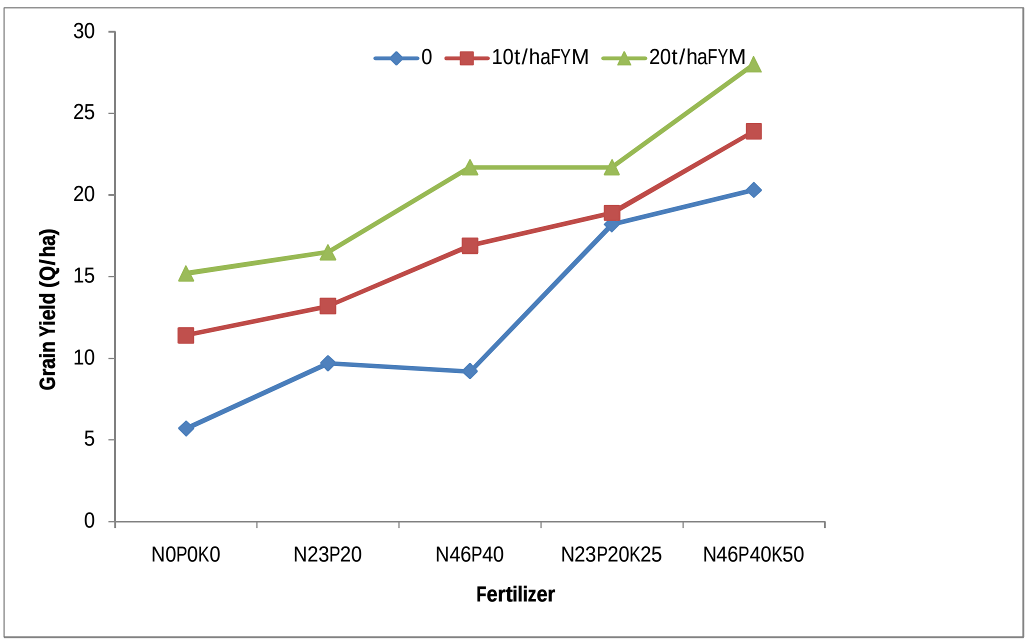

Figure 2. The effect of FYM and Inorganic fertilizers on the grain yield of barely at Chencha.

The application of potassium along with NP, FYM and NP + FYM has significantly increased the grain yield of barely suggesting that potassium is becoming a limiting nutrient at Chernacha as that witnessed on the results of other experiment.

The Effect of Liming and Fertilizers on tuber yield of Potato in 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 pH of soil in the testing site of Chencha ranges from 4.8 to 5.0, P is 3.2 ppm and K is 11.2. (Shiferaw, B., 2005). As one possible means of intervention application of lime and fertilizer were studied on potato in the area for two years.

Table 5. The effect of liming and fertilizer and residual effect on tuber yield of potato in acid soils of Chencha.

	Mean yield (tha^{-1})	
***Treatments**	**2007**	**2008**
$N_0P_0K_0$ + 0 Lime	7.96h	4.06f
$N_{110}P_{40}K_0$ + 0 lime	11.77efg	4.02f
$N_{110}P_0K_{100}$ + 0 lime	10.82fgh	4.21f
$N_0P_{40}K_{100}$ + 0 lime	22.72c	161c
$N_{110}P_{40}K_{100}$ + 0 lime	34.93b	26.88b
N_0PK_0 + 1.75 tha^{-1}	9.12gh	3.8f
$N_{110}P_{40}$ + 1.75 tha^{-1}	14.25def	6.38ef
$N_{110}P_0K_{100}$ + 1.75 tha^{-1}	14.43de	12.58cd
$N_0P_{40}K_{100}$ + 1.75 tha^{-1}	28.85c	15.8c
$N_{110}P_{40}K_{100}$ + 1.75 tha^{-1}	37.21b	28.02b
$N_0P_0K_0$ + 3.5 tha^{-1}	10. 25gh	5.20f
$N_{110}P_{40}$ + 3.5 tha^{-1}	14.81de	7.40def
$N_{110}P_0K_{100}$ + 3.5 tha^{-1}	15.95d	11.78cde
$N_0P_{40}K_{100}$ + 3.5 tha^{-1}	27.72c	24.72b
$N_{110}P_{40}K_{100}$ + 3.5 tha^{-1}	41.00a	34.62a
LSD	**8.6**	**5.4**
CV (%)	**10.5**	**24**

* $N_0P_0K_0$ = 0:0:0, $N_{110}P_{40}K_0$ =110:40:0, $N_{110}P_0K_{100}$ = 110:0:100, $N_{110}P_{40}K_{100}$ = 110: 40:100 $kgha^{-1}$ of NPK respectively

The result of liming and fertilizer and their residual effect on tuber yield of potato at Chencha is shown in Table 5. Application of lime alone at both half and full rate did not significantly ($P< 0.001$) increased the tuber yield of potato in compared to the control in both 2007. However, application of lime along with NPK fertilizers has significantly increased the tuber yield of potato. Application of 110:40:100 $kgtha^{-1}$ NPK and 110:40:100 $kgtha^{-1}$ NPK + 3.5 lime tha^{-1} increased the tuber by 338 and 415% over the control respectively. This suggests that the soils of Chencha are not only acidic but also severely deficient of nutrients. The purpose of lime application on acidic soils is to raise the pH as a result nutrients rendered unavailable by soil acidity become available to plants as a result the yield of crops are increased. However, if soil is already depleted of nutrients by several factors, application of lime alone could not have beneficial effect. Application of PK produced significantly higher yield of potato over NP, NK treatments. This implies that phosphorus and potassium are more deficient than nitrogen at Chencha. As opposed to the longstanding notion based on the conclusion of Murphy (1968) that Ethiopian soils are rich in potassium and that there is no need for application of K fertilizers is disproved for acidic soil like at chencha as was revealed by the result of this experiment.

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 110:40:100 $kgha^{-1}$ NPK + 3.5 tha^{-1} of lime.

The results of economic analysis date of lime and fertilizer application is presented in Table 6. The highest mariginal rate of return (2323%) was obtained from NPK treatments.

Table 6. The result of partial budget analysis data of selected treatments of lime and fertilizer application experiment on Potato

Partial budget	Treatment*			
	Control	**NP**	**NPK**	**NPK + 3.5 lime tha^{-1}**
Average yield (tha^{-1})	7.96	11.77	34.93	41
Adj. yield (tha^{-1})	716	10.59	31.44	36.9
Gross benefit $birrha^{-1}$	14328	21186	62874	73800
N	0	1816	1816	1816
P	0	933	933	933
K	0	0	1720	1720
Lime	0	0	0	3850
Transportation	0	0	0	1500
Labor for lime application	0	0	0	350
TVC	0	2749	4469	10169
Net benefit $birrha^{-1}$	14328	18437	58405	63631
MRR		149	2323	91

*NP = 110:40 $kgha^{-1}$, NPK = 110:40:100 $kgha^{-1}$

From this experiment it is concluded that of application of lime alone did not improve the productivity of acid soils of Chencha. However, lime application along with NPK fertilizers have significantly higher tuber yield of potato. Application of K fertilizer along with NP is critical for crop production at Chencha. Thus, balanced application of NPK with out lime gave the highest economical and the second highest tuber yield of potato. Therefore application of NPK at a rate of 110:40:100 $kgha^{-1}$ is recommended for potato production at Chencha

FUTURE RESEARCH DIRECTIONS

- Soil organic matter dynamics needs to be investigated.
- How organic matter amendments improve the fertilizer use efficiency should be Studied.
- Synchronization of nutrient released from decomposing organic matter with the crop demand should be investigated in different agro ecologies.
- As Ethiopia is rich in its plant biodiversity, there is a need for exploration identification and characterization of organic nutrient sources that can be exploited for soil fertility improvement.
- The existing soil fertility improvement technologies and those that are going to be obtained shall be disseminated to farmers, the ultimate users.
- In this review work, it has been shown that application of commonly used fertilizers such as Urea have adverse effect when used in acid soils. Thus, testing alternative N sources for future use will be relevant.

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