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Long term evaluation of organic and inorganic amendments in suppressing soil acidity and enhancing soil fertility for field pea productivity in acidic soils of Shambu Sub-site, Western Oromia, Ethiopia

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Abstract
A field experiment was conducted for five consecutive main cropping seasons (2016-2020) in Horro district of Shambu sub-site for field pea, Western Oromia. The aim is to determine long-term effect of organic and inorganic fertilizers on soil physico-chemical properties, plant nutrient availability and crop productivity for sustainable agricultural development. Moreover, to compare the performance of organic materials with inorganic counterpart (FYM, lime and NPS) and to examine their combined effect in alleviating aluminum toxicity in acidic soils. Treatments (NPS, Farm Yard Manure, Lime and the control) were integrated to evaluate their performance on crop yield and soil fertility dynamics. Treatments were designed in RCBD replicated three times on an area of 2.8 x 2.4m for each plot of the experimental site. Field layout and fine seed bed was prepared according to the design. FYM and lime were applied in three different levels 0, 2 tha^{-1}, 4 $tha^{-1}$and 0, 2.23 tha^{-1} 4.46 tha^{-1} respectively. 0, 60.5 $kgha^{-1}$, and 121 $kgha^{-1}$ NPS was applied for field pea at Shambu sub-site. Lime was incorporated to the soil on plots which receives the treatment a month before sowing to buffer the soil while the experiment was started (2016) and a full dose of FYM also applied once in the first year during planting according to its levels. Then, NPS was applied year after year for the crop until the experiment was terminated. Field pea was sown in Horro district of Shambu sub site; the interaction of 4 tha^{-1} FYM+4.46 tha^{-1} Lime+121 $kgha^{-1}$ NPS and the control gave the highest pooled mean grain yield 1.84 tha^{-1} and the lowest 0.86 tha^{-1} respectively. Eventually, the collected and analyzed post-harvest soil results revealed that there is a progressive change on soil physico-chemical properties in the experimental sites for consecutive years as compared to composite pre-sowing soil samples collected while the experiment was launched (2016). Partial budget analysis indicated that integrated application of NPS, FYM and lime at justifiable rate is economically feasible for field pea production in the study area and in similar agro ecologies.

Keywords: FYM, Field Pea, Lime, NPS, Yield

1. Introduction

Field pea (*Pisum sativum* L.) is one self-pollinated diploid (2n=14) annual of the most important annual cool season pulse crop and is valued as high protein food (K. McKay *et al*, 2003) [7]. It is widely grown in the cooler temperate zones and in the highlands of tropical regions of the world. The crop is cultivated in a wide range of soil types from light sandy loams to heavy clays but it does not tolerate to saline and waterlogged soil conditions (FAO, 2012) [4]. In Ethiopia field pea is produced in various regions and is widely grown in north, south, west and central parts of the country including, pocket areas in highland and mid highlands with altitude ranging from 1800-3000 m.a.s.l.

The soil pH optimum is 5.5-6.5. Field pea is one of the most important pulse crops in Ethiopia which is produced for a long time in high- and mid-altitude areas by smallholder farmers. It covers an area of about 25147.69 hectares with an annual production volume of 21406364 kg (CSA, 2015) [3]. Field pea is nutritious food staff when fully matures and they are valuable food legume, often being ground into flour and used extensively in the manufacture of soups. Fresh green peas are almost universally accepted as a nutritious vegetable (R. Yayis, *et al*, 2015) [14]. Nutritionally, field peas contain all the essential amino acids and are rich in high-quality vegetable protein (H. Kandel *et al*, 2016) [5]. Therefore, this crop can substitute high protein containing animal meat products in the developing countries including Ethiopia. The crop has an important role in the highlands of Ethiopia by playing a significant role in soil fertility improvement occupying a unique position in cereal-based cropping systems (Fikere M., 2014) [10]. The crop is considered environmentally friendly and economical feasible from soil improvement point of view. Despite its importance, the average national productivity (0.85 tha^{-1}) is very low (CSA, 2015) [3]. It is below the potential as compared to the research findings that ranged from 0.82 $tha^{-1}$to 4.6 tha^{-1}in Ethiopia (Tolessa T., 2013) [17]. and the higher yield reported about 7 tha^{-1} to 8 tha^{-1}in Europe (P. Smykal *et al*, 2012) [12] The major yield-limiting constraints in field pea production in Ethiopia in general specifically in western parts of Oromia is/are soil fertility decline and acidity problem, low yielding local varieties, lodging, diseases etc.

In Ethiopia, vast areas of land in the western, southern and even the central highlands of the country which receive high rainfall are thought to be affected by soil acidity (Mesfin, 2007) [19]. An earlier study by Mesfin (2007) [19] estimated that about 41% of arable lands of Ethiopia are affected by soil acidity/Al^{3+} toxicity. Of this land area, about 27.7% is moderately acidic (pH in KCl) 4.5 - 5.5) and about 13.2% is strongly (pH in KCl) < 4.5) acidic. The causes of soil acidification have mainly been attributed to an imbalance in the carbon and nitrogen cycles. These include (i) excretion of H^+ from plant roots to balance excess uptake of cations over anions; (ii) removal of large amounts of agricultural product, because both plant and animal produce are slightly alkaline; (iii) accumulation of organic matter, because it contains numerous acid functional groups from which these ions can dissociate (Brady and Weil (2002) (iv) mineralization and nitrification of plant N and consequent nitrate leaching and (v) input of acidifying substances as ammonium containing fertilizers. Precipitation also introduces acidity to soils, because gaseous carbon dioxide (CO2) and water (H2O) in the rain react to form a solution that is about pH 5.7 (Crawford *et al* (2008)) [2]. Application of chemical fertilizers alone can supply only one or two nutrient elements to the crop. On the other hand, supplying only organic inputs can improve soil physical and biological environment but suffers from drawback of low content of plant nutrients. Liming the soil increases soil pH with deceasing soil acidity consequently increasing nutrient availability for crop growth. However, in the modern days, when agriculture is motivated not only for production, but also accounts for the sustainability of all the resources including soil for the coming generations integration of nutrients is critical issue. The use of chemical fertilizer has been many times reported for degradation of soil and water resources.

Thus, this experiment was carried out in order to study long term effects of organic and inorganic fertilizers on soil physico-chemical properties, plant nutrient availability and crop productivity for sustainable agricultural development and as well as to examine their combined effect in alleviating aluminum toxicity in acid soil.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Horro district of Shambu sub site on field pea for the last five consecutive years (2016-2020). Shambu lies between 9°34'N latitude and 37°06'E longitude at an altitude of 2400 meter above sea level. Mean annual rainfall of 1,695 mm (Abera and Abebe, 2018). It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.15, 15.72 and 11.94°C, respectively. The soil of the sites is Black soil.

2.2. Treatments and Experimental Procedure

Field pea was used as test crop for conducting this experiment. Treatments (NPS, Farm Yard Manure, Lime and the control) were evaluated for their performance on crop yield and soil fertility dynamics. It was designed in RCBD replicated three times having an area of 2.8m x 2.4m=6.72m^2 total plot area for each plot of the experimental sites. Field layout and fine seed bed was prepared according to the design. FYM and lime were applied in three different levels 0, 2 tha^{-1}, 4 tha^{-1} and 0, 2.23 tha^{-1} 4.46 tha^{-1} respectively. Then (0, 60.50 $kgha^{-1}$, and 121 $kgha^{-1}$ NPS) levels were applied at Shambu. Lime was incorporated to the soil on plots which receives the treatment a month before sowing to buffer the soil while the experiment was started (2016) and a full dose of FYM also applied once in the first year during planting according to its levels. Remember that: NPS was applied year after year following its levels until the experiment was terminated.

2.3. Data Collected

2.3.1. Pre-Sowing Soil Samples

An initial soil sample/composite soil/ from the surface soil (0-20cm) was collected by using Auger from ten points randomly selected diagonally across the experimental fields amalgamated as one sample and analyzed at BARC soil laboratory. The samples were analyzed for important soil parameters like (pH, Ava.P, % TN, % OM, % OC) before sowing when the experiment was launched in 2016.

2.3.2. Post-harvest soil samples

Post-harvest soil samples having similar parameters with composite soil samples were collected from each plots/observations/ and analyzed to observe the progress occurred as compared to composite soil samples analyzed before sowing until the experiment was terminated (2020).

2.3.3. Yield data

Yield and yield components were collected until the termination of the experimental periods.

2.4. Data Analysis

All yield and yield components of data were collected, analyzed by using graphical methods and the soil parameters were subjected to descriptive statistics.

3. Results and Discussions

3.1. Soil physicochemical properties

3.1.1. Composite Soil Results

Pre-sowing soil results showed that the experimental areas were in strongly acidic soil conditions having pH values of 4.92 at Shambu sub-site according to Tekalign ratings (1991) (Table.1.) This result showed mostly essential plant nutrients were fixed in soil colloidal particles and unavailable to plants since the majority of plant nutrients were more available and utilized by the plants from slightly to neutral soil pH. Moreover, available phosphorus, %TN, and %OC exist within low to medium ranges indicated that there is phosphate sorption/fixation/ since phosphates are negatively charged and delimited with strongly and positively charged toxic elements like Al^{+3}, Mn^{+2}, Fe^{+2} and H^{+} those elements could form a reaction to form insoluble phosphates and caused phosphate retention (Kim,2010). The result also indicated that depletion of basic cations/exchangeable bases/ like calcium, magnesium and potassium caused by crop harvest and higher microbial oxidation that produces organic acids, which provided hydrogen ion to the soil solution and lower soil pH. Soil acidity affects the growth of crops because acidic soils 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) [18].

3.1.2. Post-harvest soil results

The result of soil samples after harvest revealed that an increased phosphate availability, soil pH, %TN and %OC (Table.1).This indicated that post-harvest soil results showed progressive changes after the application of integrated treatments especially lime and FYM. The devotion of phosphate by amphoteric soil surfaces generally decreased slowly as the pH increased. Liming can increase phosphate availability by stimulating mineralization of soil organic phosphorus. Soil pH values were increased from 4.92 to 6.7 for this crop at Shambu Sub-site (Table.1). This pH result was changed from the level of strongly acidic soil to neutral for field pea at Shambu sub-site. In general, the result indicated that most essential plant nutrients were more exist in available ranges for plant growth and development after harvest. Since the change could be obtained because of the application of treatments especially agricultural lime and decomposed FYM to the experimental fields. In line with this result, Prasad (1992) [13] has reported that especially available soil phosphorus increased significantly under liming due to lowering P fixation by other elements (Al, Mn, and Fe). Sood and Bhardwaj (1992) [16] and Rahman *et al.* (2001) have also reported that available soil P was higher under limed over the none-limed plots. Tolessa (1999) also revealed that there was significant increase in total nitrogen, available phosphorus and potassium content of the soil with increases in FYM levels from 8 to 24t/ha. Selvi *et al*., (2004) [15] reported that application of FYM along with chemical fertilizers favored the microbial population in the soil whereas; sole application of nitrogenous fertilizers had detrimental effect on soil micro flora. The same authors in 2005 showed a maximum increase in soil organic carbon with the application of FYM in combination with inorganic fertilizers when compared with commercial fertilizers alone and the control treatments.

The higher content of soil Ca, Mg, and K after harvest might be occurred due to the direct addition of those elements from the liming material and/or greater availability of those elements at higher soil pH due to liming. In line with this, Prased (1992 has reported that exchangeable Ca in the soil increased significantly with higher dose of liming. Hillard *et al. (*1992) [6] have also reported that lime increased soil pH and Ca and Mg contents in the soil. Furthermore, it has reported that lime application neutralizes soil acidity, reduces toxicity levels of Al, Fe and Mn and improves physiological, chemical and biological properties of soil (Kisinyo *et al.*, 2005) [9].

Table 1: Post-harvest and pre-sowing analyzed soil results for Available Phosphorous, Soil pH, % Organic Carbon and % Total Nitrogen of the Experimental Sites (2016-2020)

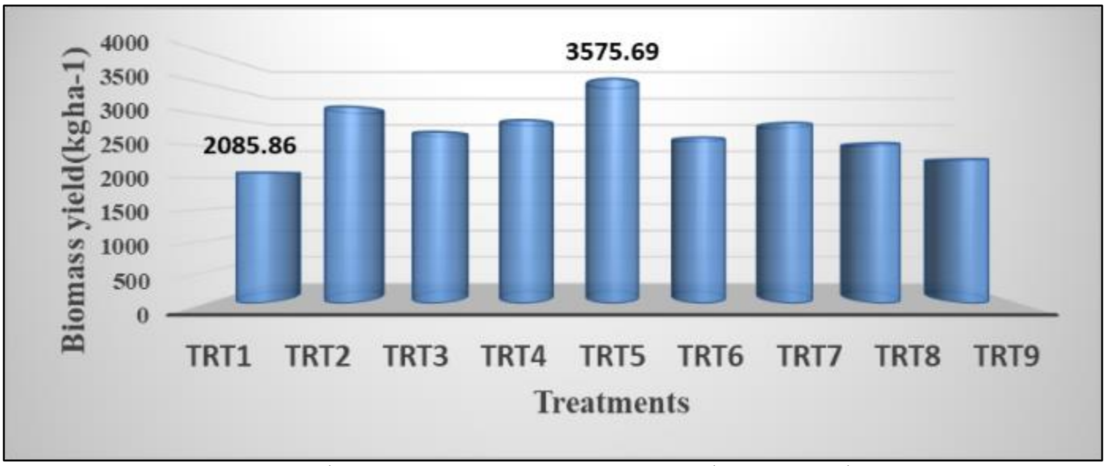
Parameters	**Location**	**Crop type**	**Pre-sowing**	**Post-harvest**	**Descriptions**
Analyzed			soil results	soil results	
	Shambu	Field Pea			
	Sub-Site				
pH(1:2.5 H_2O)			4.92	6.7	
Av.P (ppm)			8.00	14.9	
% OC			-	4.6	
% OM			-	7.5	
% TN			-	0.22	

Source: BARC Soil lab. Result

3.2, Yield and Yield Components

3.2.1. Biomass yield (kgha^{-1})

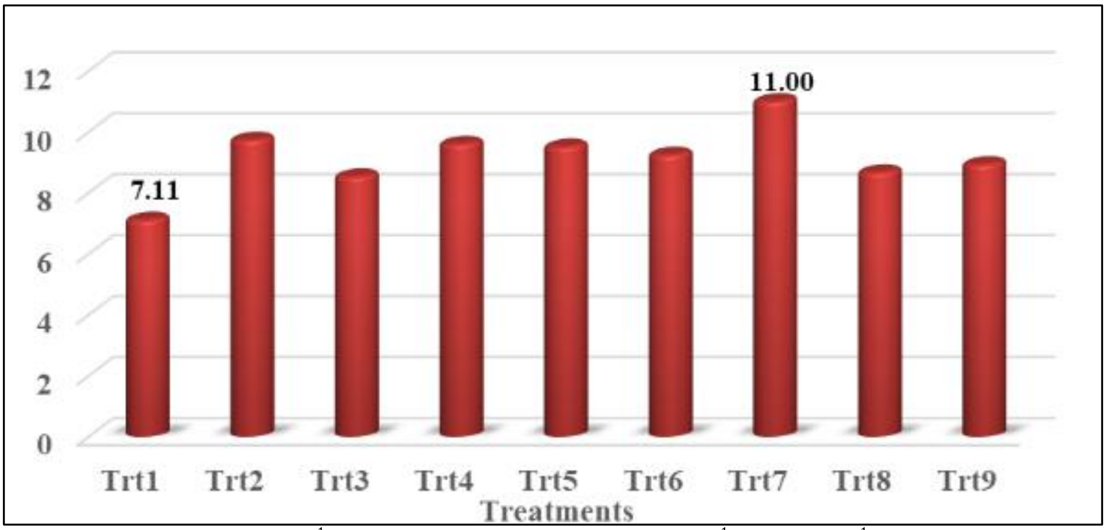
Biomass yields were significantly higher in the case of treatment T5 (121 kgha^{-1} NPS + 4 tha^{-1} FYM + 4.46 tha^{-1} Lime) as compared relatively to the other treatment combinations. This result indicated that the combination of NPS, FYM and Lime contributes more for the growth of above ground biomass of field pea than other treatment combinations.



KEY:T1(Control), T2(121 kgha^{-1}NPS+ 0 Lime +0 FYM), T3(121 kgha^{-1}NPS + 4 tha^{-1}FYM + 0 Lime, T4(121 kgha^{-1}NPS+0FYM +4.46 tha^{-1}Lime),**T5(121 kgha^{-1} NPS + 4 tha^{-1} FYM + 4.46 tha^{-1} Lime),** T6(121 kgha^{-1}NPS +0 FYM + 2.23 tha^{-1}Lime), T7(121 kgha^{-1}NPS + 4 tha^{-1}FYM + 2.23 tha^{-1}Lime),T8 (60.5 kgha^{-1}NPS + 2 tha^{-1}FYM + 4.46 tha^{-1}Lime), T9 (60.5 kgha^{-1}NPS + 0 FYM + 4.46 tha^{-1}Lime)

Fig1: Graphical representations of field pea mean Biomass Yield (kgha^{-1}) (Shambu sub-site)

3.2.2. Pod number per plant



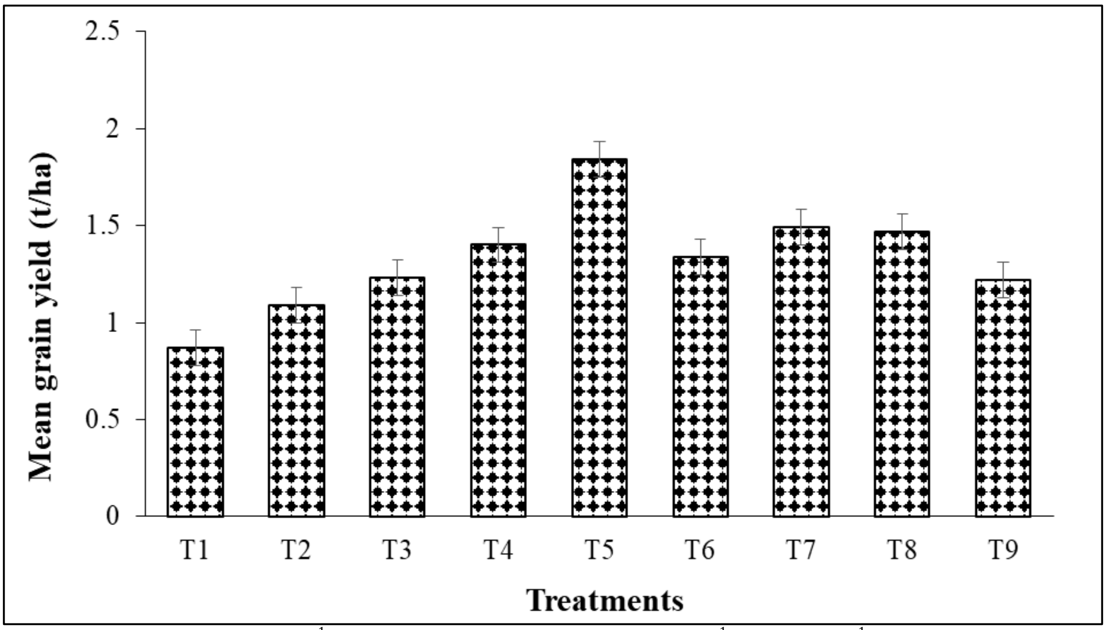
KEY:T1(Control), T2(121 kgha^{-1} NPS + 0 Lime + 0 FYM), T3(121 kgha^{-1} NPS + 4 tha^{-1}FYM + 0 Lime, T4(121 kgha^{-1} NPS + 0 FYM + 4.46 tha^{-1} Lime),T5(121 kgha^{-1} NPS + 4 tha^{-1} FYM + 4.46 tha^{-1} Lime), T6(121 kgha^{-1} NPS + 0 FYM + 2.23 tha^{-1} Lime), T7(121 kgha^{-1} NPS + 4 tha^{-1} FYM + 2.23 tha^{-1} Lime),T8 (60.5 kgha^{-1} NPS + 2 tha^{-1} FYM + 4.46 tha^{-1} Lime), T9 (60.5 kgha^{-1} NPS + 0 FYM + 4.46 tha^{-1} Lime).

Fig 2: Graphical representation of field pea mean of pod number per plant (Shambu subsite)

3.2.3. Field Pea Pooled Mean Grain Yield

Significant differences were observed between treatments. The combined/interaction/ of 4 tha^{-1} FYM + 4.46 tha^{-1} Lime + 121 kgha^{-1} NPS and the control treatments showed significant on mean grain yield of field pea and obtained the highest (1.84 tha^{-1}) and the lowest (0.86 tha^{-1}) grain yield respectively. This result indicated that combined application of organic and inorganic fertilizers have great importance in increasing pooled mean yield of field pea over the control.

In line with this result (Bhaskarrao *et al*., 2015) indicated that agronomic performances of both faba bean (*Vicia faba* L.) and field pea (*Pisum sativum* L.) were significantly influenced by the combined application of organic and inorganic fertilizers over the control.



KEY:T1(Control), T2(121 kgha^{-1} NPS + 0 Lime + 0 FYM), T3(121 kgha^{-1} NPS + 4 tha^{-1}FYM + 0 Lime, T4(121 kgha^{-1} NPS + 0 FYM + 4.46 tha^{-1} Lime),T5(121 kgha^{-1} NPS + 4 tha^{-1} FYM + 4.46 tha^{-1} Lime), T6(121 kgha^{-1} NPS + 0 FYM + 2.23 tha^{-1} Lime), T7(121 kgha^{-1} NPS + 4 tha^{-1} FYM + 2.23 tha^{-1} Lime),T8 (60.5 kgha^{-1} NPS + 2 tha^{-1} FYM + 4.46 tha^{-1} Lime), T9 (60.5 kgha^{-1} NPS + 0 FYM + 4.46 tha^{-1} Lime).

Fig 2: Graphical representation of field pea pooled mean grain yield (tha^{-1}) (Shambu subsite)

Table 2: Economic (partial budget analysis) for field pea

Treatment Combinations				Fer. cost	Tra. And Lab. Cost	TVC	TYPH kgha^{-1}	Adj. Yield 10%	T. Gross benefit yield*36	Net benefit	MRR ratio
	NPS	LIME	FYM								
T1	0	0	0	0	0	0	870	783	28188	28188	-
T2	121	0	0	1089	100	1189	1090	981	35316	34127	4.99
T3	121	0	4	1089	900	1989	1230	1107	39852	37863	4.67
T4	121	4.46	0	1089	4700	5789	1400	1260	45360	39571	0.4
T5	121	4.46	4	1089	5500	6589	1840	1656	59616	53027	16.82
T6	121	2.23	0	1089	2400	3489	1340	1206	43416	39927	D
T7	121	2.23	4	1089	3200	4289	1490	1341	48276	43987	5.08
T8	60.5	4.46	2	544.5	5050	5594.5	1470	1323	47628	42033.5	D
T9	60.5	4.46	0	544.5	4650	5194.5	1220	1098	39528	34333.5	D

Partial budget analysis data for different treatments are shown in (Table. 2).In general, balanced application of organic amendments, NPS, organic fertilizers and lime in production of field pea in acidic soil at Shambu sub-site was economically feasible. The interaction of 121 kgha^{-1} + 4.46 tha^{-1} Lime + 4 tha^{-1} FYM had the highest net benefit of (53,027 ET birr) and marginal rate of return (16.82) for field pea.

4. Conclusions and Recommendations

Integrated soil fertility management is the best option to solve the existed soil nutrient problems. It is important to analyze the complex interactions and effects of the agro-climate, soil, and the environment with the various agronomic practices. Integrated soil fertility management plays a critical role in both short-term nutrient availability and longer-term maintenance of soil organic matter and sustainability of crop productivity in most smallholder farming systems in the country. Even though from the beginning of the experiment until the third year field pea pooled mean grain yield showed an increasing tendency but on fourth and fifth years it showed sharply a decreasing order even the performance of the crop on the field was poor, soil fertility status of the experimental site showed declined and it is an indication of the experimental site requires re-liming and application of FYM even after the soil comes to the desired level of reaction after the third year to keep the productive and sustainability of the experimental sites. The results showed that integrated application of organic and inorganic fertilizers improve crop production as well as the fertility status of the soil. Generally, it is understood that the positive impacts of organic sources application on crop yield and soil properties can be realized after long term applications. In addition improving the long term productivity of the soil, this soil fertility management approach has resulted to a large cost saving of mineral fertilizers.

Laboratory analysis results of the overall post-harvest soil results showed that for most soil parameters such as available phosphorous, soil pH, %organic carbon, and %total nitrogen, considerably increased while compared with pre-sowing soil conditions. This change could be due to the application of FYM and Lime treatments. Therefore, there is a significant increase in soil and yield parameters of the crop. The highest field pea grain yield (1.84 tha^{-1}) was obtained from the interaction of 4 tha^{-1} FYM + 4.46 tha^{-1} Lime + 121 kgha^{-1} NPS applications at Shambu sub-site while the lowest yield

(0.86 tha^{-1}) was obtained from the control treatment. Therefore, application of integrated lime, FYM and NPS to acidic soils increases availability of nutrients, especially phosphates, exchangeable bases, %total nitrogen as well as %organic matter and % organic carbon in the soil which is very crucial for betterment of crop performance and yield. Finally, it is recommended that using organic fertilizers, liming in combination with inorganic fertilizers is a good strategy for the country in general and specifically for the study areas for crop production. Thus, considering the poor soil fertility management by resource poor smallholder farmers and the high cost of mineral fertilizers, combined use/application/ of organic and mineral fertilizers together with lime application at justifiable rates is pertinent to enhance the productive capacity of the soil and improve crop production.

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References
1. Chinthapalli B, Dibar DTT, Chitra DSV, Leta MB. A Comparative Study on the Effect of Organic and Inorganic Fertilizers on Agronomic Performance of Faba Bean (*Vicia faba L.*) and Pea (*Pisum sativum L.*). Agriculture, Forestry and Fisheries. 2015;4(6):263-268. doi:10.11648/j.aff.20150406.15.
2. Crawford TW, Singh U, Berman H. Solving Agricultural Problems Related to Soil Acidity in Central Africa's Great Lakes Region. An international center for soil fertility and agricultural development. CATALIST project report; 2008.
3. Central Statistical Agency (CSA). Agricultural Sample Survey. 2015/2016 Volume I Report on Area and Production of Major Crops. Statistical Bulletin, Addis Ababa, Ethiopia; 2015.
4. Food and Agricultural Organization (FAO) of the United Nations. Rome, Italy; 2012.
5. Kandel H, McPhee K, Akyüz A, *et al*. North Dakota Dry Pea Variety Trial Results for 2016 and Selection Guide. NDSU Extension Service; 2016.
6. Hillard JB, Haby VA, Hons FM. Annual ryegrass response to limestone and phosphorus on an Ultisol. Journal of Plant Nutrition. 1992;15(8):1253-1268.
7. McKay K, Schatz B, Endres G. Field pea production. In: Production. 2003;1166:1-8.
8. Kim HT. Principles of Soil Environmental Chemistry. CRC Press; 2010.
9. Kisinyo PO, Othieno CO, Okalebo JR, Kipsat MJ, Serem AK, Obiero DO. Effects of lime, phosphorus, and rhizobia on Sesbania sesban performance in a Western Kenyan acid soil. African Crop Science Conference Proceedings. 2005;7:1109-1115.
10. Fikere M, Bing DJ, Tadele T, Amsalu A. Comparison of Biometrical Methods to Describe Yield Stability in Field Pea (*Pisum Sativum L.*) under South Eastern Ethiopian Conditions. African Journal of Agricultural Research. 2014;9(33):2574-2583.
11. Abebe M. Nature and Management of Acid Soil in Ethiopia. Haramaya University, Haramaya, Ethiopia; 2007.
12. Smykal P, Aubert G, Burstin J, *et al*. Pea (*Pisum Sativum L.*) in the Genomic Era. Agronomy. 2012;2(4):74-115.
13. Prasad R. Effect of liming on yield of soybean and nutrient availability in acidic soil. J Indian Soc Soil Sci. 1992;40:377-379.
14. Yayis R, Fitsum Alemayehu F, Gurmu F, *et al*. Registration of 'AMBERICHO' a newly released field pea (*Pisum sativum L.*) variety for the Southern Highlands of Ethiopia. Journal of Plant Studies. 2015;4(2):42-43.
15. Selvi D, Santhy P, Dhakshinamoorthy M, Maheshwari M. Microbial population and biomass in rhizosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol. Journal of the Indian Society of Soil Science. 2004;52(3):254-257.
16. Sood RD, Bhardwaji RK. Effect of liming and phosphorus fertilization on P fractions in an acid Alfisol. Journal of the Indian Society of Soil Science. 1992;40:299-301.
17. Tolessa TT, Bekele Y, Sefera T, Jarso M, Keneni G. Genotype × Environment Interaction and Performance Stability for Grain Yield in Field Pea (*Pisum sativum L.*) Genotypes. International Journal of Plant Breeding. 2013;7(2):116-123.
18. Wang J, Raman H, Zhang G, Mendham N, Zou M. Aluminum tolerance in barley (*Hordeum vulgare L.*): Physiological mechanisms, genetics and screening methods. Journal of Zhejiang University-Science. 2006;7:769-787.
19. Mesfin T, Giorgis GW. Impact of farmers' selected idm options on potato late blight control and yield. In8th African Crop Science Society Conference, El-Minia, Egypt; 2007;2091-2094. African Crop Science Society.