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RESEARCH ARTICLE

PRODUCTIVITY AND ECONOMICS OF FABA BEAN (*Vicia faba* L.) IN RELATION TO INTEGRATED USE OF LIME, BLENDED FERTILIZER, BIOFERTILIZER AND COMPOST ON ACID SOILS OF HIGH LANDS IN WEST SHOWA ZONE OF ETHIOPIA

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ABSTRACT

Faba bean (*Vicia faba* L.) is the most important legume crop being grown predominantly in the Ethiopian highlands of Oromia region where soil acidity and nutrient depletion pose serious limitation to land productivity. Field experiment was conducted during 2015 rainy season (July-Sept.) to investigate the effect of integrated nutrient and lime application on soil fertility and productivity of faba bean at Telecho, Wolmera district, in the highlands of Western Ethiopia. The investigation consisted of nine treatments namely- (t1):control, (t2): compost at 5t ha^{-1},(t3) :lime at 611kg ha^{-1}, (t4): compost at 5t ha^{-1} + lime at 611kg ha^{-1},(t5): lime at 611kg ha^{-1} + DAP 150 kg ha^{-1} research recommendation (69 kg p2o5 ha^{-1}) and biofertilizer (500 g ha^{-1}), (t6):site specific recommendation (npsb at 150 kg ha^{-1}, kcl at 100 kg ha^{-1})+ biofertilizer (500 g ha^{-1}), (t7): lime at 611kg ha^{-1} + npsb at 150 kg ha^{-1}, kcl at 100 kg ha^{-1} and biofertilizer (500 g ha^{-1}, (t8): lime at 611kg ha^{-1} + compost at 5t ha^{-1} + npsb at 150 kg ha^{-1}, kcl at 100 kg ha^{-1}) and biofertilizer (500 g ha^{-1}) (t9): lime at 611kg ha^{-1} + 2.5 t ha^{-1} compost and biofertilizer (500 g ha^{-1})with 50 % of soil test based fertilizer recommendation (npsb at 75 kg ha^{-1}, kcl at 50 kg ha$^{-1,}$). The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. Soil samples were collected before and after lime application and analyzed for selected soil properties. Lime requirement was determined based on exchangeable acidity. Soil analysis result revealed that lime application raised soil pH from 3.80 to pH level ranging from 6.70 to 6.86.Yield and yield components of faba bean were significantly ($p<0.05$) affected by imposed treatments where in the highest and significant crop yield response was obtained with t8 (2882.9 kg ha^{-1}). However, in most cases the difference in yield and yield attributes, and soil parameters due to t1, t2, t3,t4, t6, were not discernible suggesting that all elements of soil health and fertility issues need to be addressed together. The economic analysis indicated that the highest net return (38833.50 birr ha^{-1}) and MRR (1333.94) was obtained with t9. Hence, it can be concluded that integrated use of lime at 611kg ha^{-1}, bio fertilizer 500 g ha^{-1} + 2.5 t ha^{-1} compost along with 50 % of soil test based fertilizer recommendation (npsb at 75 kg ha^{-1}, kcl at 50 kg ha$^{-1,}$) for faba bean is advisable for farmers in the study area and locations with similar agro-ecologies to maximize faba bean yield and economic return.

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INTRODUCTION

Faba bean (*Vicia faba L.*) belonging to Fabaceae family, is among the major grain food legumes in the world. Ethiopia is one of the largest faba bean producing countries in the world only second to China (Hawitin and Hebblewaite, 1993). Faba bean is grown as field crop ranging from 1800-3000 m and with annual rainfall of 700-1000 mm (Mussa *et al*., 2003) throughout the highlands and is most common in *Wayena Dega.* It serves as a daily food and as cash crop in many parts of the country (Hawitin and Hebblewaite, 1993). It produces maximum dry matter between 7 and soil pH (Jessop and Mahoney, 1998). Faba bean ranks first among cool season food legumes based on area of production and foreign exchange earnings in Ethiopia (CSA, 2010). Currently, it is among the leading pulses which have attracted great attention in the country due to its demand as an export crop. It has also a great contribution for sustainable soil fertility management due to its ability to fix atmospheric N_2 (Beck *et al*., 1991). However, the average national productivity is 1.5 tons ha^{-1}, while the world average yield of faba bean is around 1.8 tons

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ha^{-1} (ICARDA, 2008). This is mainly attributed to poor soil fertility, acidity of the soil in high rain fall areas and low existence of effective indigenous rhizobium population (Carter *et al*., 1998). Whereas in developed world, excess applications of fertilizer and manure have damaged the environment, low use of inorganic fertilizer is one of the main causes of environmental degradation in Africa (Bationo *et al*., 2006). Thus, soil fertility maintenance is a major concern in tropical Africa, particularly with the rapid population increase, which has occurred in the past few decades. In traditional farming systems, farmers use bush fallow, plant residues, household refuse, animal manures and other organic nutrient sources to maintain soil fertility and soil organic matter. Although the reliance on biological nutrient sources for soil fertility regeneration is adequate with low cropping intensity, it becomes unsustainable with more intensive cropping unless fertilizers are applied (Mulongey and Merck, 1993).

The Ethiopian highlands have a great potential for crop production, contributing 95% of the cultivated land and 90% of the economic activities of the country (FAO, 2005). However, the potential in most of these areas is severely affected by soil degradation. Besides, the problem has been aggravated in magnitude and degree from year to year in the last three decades. Most cultivated lands of the Ethiopian highlands are characterized by heavy rainfall and prone to soil acidity due to removal of ample quantities of exchangeable heavy cations by leaching, crop mining and runoff as compared with grazing and forest lands. Hence, soil acidity of late is becoming a serious challenge for crop production in the highlands of Ethiopia (Mesfin, 2007). Currently, it is estimated that about 40% of arable lands of Ethiopia are affected by soil acidity/Al^{3+} toxicity (Taye, 2007). Soil acidity is expanding both in scope and magnitude in Ethiopia, which extend from southwestern to northwestern with east-west distribution but are concentrated in the western part of the country (Mesfin, 2007) severely limiting crop production. The increasing trend of soil acidity and exchangeable Al^{3+} in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid forming inorganic fertilizers (Wakene *et al.,* 2007). Mesfin (2007) also noted that the soil acidity problem of Ethiopia is mainly related to some of the Alfisols, and most Oxisols and Ultisols soil classes that occur in the west, north-western, south-western and southern parts of the country. Soil acidity limits or reduces crop production primarily by impairing root growth there by reducing nutrient and water uptake (Marschner, 1995). Moreover, low pH or soil acidity converts available soil nutrients in to unavailable form and also acidic soils are poor in their basic cations such as Ca, K, Mg and some micronutrients which are as essential for crop growth and development (Wang et *al*., 2006). Soil acidity and associated low nutrient availability is one of the major constraints to faba bean (*Vicia faba*) production on Nitisols of Ethiopian highlands. The extent of damage posed by soil acidity varies from place to place depending on several factors. But there are also occasions where total loss of crop occurs due to soil acidity.

Only 40 percent of the farm land receives some chemical fertilizer application (Dercon and Hill, 2009) and about 30% of the small peasant farmers apply some amount of the inorganic fertilizers on their farmlands (NFIA, 1999). Although there is a gradual increase in the total volume of fertilizers used in the country, low and unbalanced application rates mainly focusing on Urea and DAP fertilizers with low efficiency of the fertilizers (Getachew *et al.,* 2009) and limited use of improved seeds (Dercon *et al.,* 2009) have still remained major constraints for small farmers to obtain the best output for unit input. Moreover the effectiveness of soil fertility interventions in Ethiopia has historically been constrained by the lack of an integrated and locally-tailored approach. Thus, the yield of pulse crops is generally around 0.8 t ha^{-1} (CSA, 2010). The contributing factors for low yield in Ethiopia and particularly in the study area is soil acidity and poor agronomic management practices, specifically, lack of locally tailored integrated use of lime with organic and inorganic fertilizers by faba bean growers. Studies that have been conducted earlier to assess the effects of integrated use of liming with organic and inorganic fertilizers on faba bean grain yield and yield components are limited and the results may not be applicable in all acidic soils of the country, without considering the local cropping system, variation in soil condition including nutrient levels and amount of rainfall. In fact, the results were also recommended for varieties which are different from the currently cultivated high yielding varieties. Thus, meager information is available on the synergistic effect of integrated use of lime with organic and inorganic inputs (compost, biofertilizers, blended fertilizers) to reduce crop yield losses associated with acid soils in western Shewa, particularly in *Wolmera* District. Therefore the present study was conducted to evaluate the effect of integrated use of lime, blended fertilizers, compost and bio fertilizers on yield and economics of faba bean (*faba vicia*) .It was also aimed to find out the effect of liming on selected soil properties (pH and EC).

MATERIALS AND METHODS

Description of the study area

The experiment was conducted on acidic soils of *Welmera* District in West Shewa Zone, Oromia National Regional State at *Telecho kebele* Farmers Training Center (FTC) which is located at about 17 km North of the district during the main rainy season (June-November) 2015. Geographically, the district is located at 9^0 02' N Latitude and 38^0 34' E Longitude with altitude range from 2060-3380 m above sea level. *Dega* (41%) and *Wainadega* (59%) are the two agro climatic zones of the district. Rainfall is bimodal: short rains, *belg*, from March to April and long rains, *meher*, from June to September (*Welmera* Agricultural office, 2014). The annual rainfall, mean maximum temperature and mean minimum temperature recorded for the year 2015 were 483.5 mm, 22.38 ^{0}C and 3.61^{0}C, respectively. Woldeyesus (2005) reported that 85% of the total annual rainfall is received between the months of June and September and the rest from end March to mid May as a bimodal pattern. The soil type of the experimental site is Nitisols (Getachew *et al*., 2000). The experimental site was cultivated with forage crop Oat (*Avena sativa*) during the previous year. The predominant crops grown in the areas are barley (*Hordeum vulgare L*), wheat (*Triticum durum*), faba bean (*Vicia faba*), field peas (*Pisum sativum*), Ethiopian mustard or Gomenzer (*Brassica carinata*), *teff* (*Eragrostis tef*) and as homestead farming the farmers grow potato (*Solanum tubrosum).*

Treatments, Design and experimental procedures

The study comprised the following treatments:T1- control; T2 - compost (5 t ha^{-1}) ;T3-lime (611 kg ha^{-1}); T4 - lime (611 kg ha^{-1}) + compost (5 t ha^{-1}); T5 - DAP(150 kg ha^{-1}) + rhizobia (500 g ha^{-1})+ KCl (100 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ rhizobia (500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7- Lime (611 kg ha^{-1})+ rhizobia (500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}); T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia (500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD). The treatments and treatment combinations including the control were assigned randomly to the experimental plots within a block. The plot size was 3 m x 3 m (9 m^2) and the crop was planted in rows spaced at 40 cm. Leaving the two outer most rows as border, 4 central rows of faba bean excluding 0.5 m length from both ends were harvested for biomass and grain yield determination.

Experimental field preparation

The experimental field was prepared by using oxen driven local plow *(Maresha)* in accordance with conventional farming practices followed by the farming community in the area. The field was plowed thrice before planting, between the end of March and the first week of June 2015. Lastly, the field was leveled and divided into blocks which were then divided into plots.

Lime and compost source

The lime source was calcitic lime (CaCO3) which was the product of *Guder* lime factory. The source of composting material was from farmers which was prepared from cow dung and straw of wheat at homestead.

Lime requirement determination

Lime requirement was estimated based on exchangeable acidity. Labetowicz (2004) reported measuring lime requirement and estimating level of acid saturation together with exchangeable acidity are the most common methods to alleviate soil acidity constraints to crop production and to modify soils fertility status.

$$\text{Lime requirement} = \frac{\text{EA *bulk density*0.15*area kg ha}^{-1}}{2}$$

Where EA-exchangeable acidity

Seed and *Rhizobium* source

The source of inoculants for faba bean was rhizobium strain (*Rhizobium leguminosarum* biovar viciae strain EAL-110) which was produced for 2015/2016 cropping season at National Soil Laboratory (NTSC). The recently released faba bean (variety *Gora*) was used which was obtained from *Holeta* Agricultural Research Center.

Application of treatments and field management

In treatments that received lime, 611 kg ha^{-1} calcitic lime (CaCO3) was evenly broadcast manually and mixed thoroughly in upper soil at 15 cm depth (plow depth) in the first week of June 2015 to the plots as per the treatment. Compost was applied in the first week of June 2015 to the plots as per treatment one month before planting. The seeds of faba bean was sown by hand at the rate of 275 kg ha^{-1} on July 13, 2015 just after one month of lime and compost application. A Blended fertilizer, NPSB having 18.1 N-36.1 P_2O_5-6.7 S-0.71 B nutrient ratio was applied at rate of 150 kg ha-^{1} along with 60 kg ha^{-1}K_2O and rhizobia strain @500 g ha^{-1} which represents recommended fertilization practice for faba bean based on the recent soil fertility atlas of the study area (ATA, 2013). Diammonium Phosphate (DAP) was applied at a rate 150 kg ha^{-1} along with Rhizobium strain 500 g ha^{-1} for faba beans. The DAP; blended fertilizer NPSB; K_2O were applied as basal at the time of planting. Rhizobium strain (*Rhizobium leguminosarum* biovar viciae strain EAL-110) was wetted with water containing sugar rubbed with seed in order to facilitate the adhesion of strain on the seed and dressed seed was planted immediately . Faba bean fields were weeded twice by hand (at 25 and 45 days after planting) to control weeds. At physiological maturity faba bean was harvested between 15 and 22 November, 2015, sun dried for a while, thrashed on December 7 and 8, 2015 to determine grain yields.

Data Collection

Soil and compost sample collection and analysis

Prior to conducting the experiment, three representative composite soil samples were collected from experimental site at plow depth (0-20 cm) on April 15, 2015 and analyzed using standard laboratory procedures. Compost samples were analyzed for pH, organic carbon (OC), total N, available P, C/N ratio and exchangeable cations (Ca, Mg , K, Na). The soil samples were air-dried and ground to pass through a 2 mm sieve. Soil pH (pH-H_2O) and pH KCl (pH-KCl) was determined (1:2.5 soil to solution ratio) using a glass electrode attached to a digital pH meter (Page, 1982). Soil texture was determined by hydrometer method (Day, 1965). Employing methods as described by Walkley and Black, organic carbon was determined following wet oxidation. Kjeldahl method was used to determine Total N, as described by Jackson (1967). Exchangeable bases were extracted with 1 M NH4OAc at pH 7. Exchangeable Ca and Mg were measured from the extract with atomic absorption spectrophotometer, while exchangeable K was determined from the same extract with flame photometer. Exchangeable acidity (Al and H) was determined from a neutral 1 N KCl extracted solution through titration with a standard NaOH solution based on the procedure described by McLean (1965). Available P was determined using the Olsen extraction method (Olsen and Dean, 1965). To delineate the effect of liming to a change in pH and electrical conductivity, composite soil samples were again collected from each experimental plot on August 15, 2015. Samples were analyzed at National Soil Testing Center (NTSC). The pH was measured using the same method as above, while electrical conductivity was measured (1:2.5 soil to water ratio) using EC meter Van Reeuwijk, (2002) and buffered with KCl.

Agronomic parameters

The days to 50% crop emergence, days to 50% flowering and days to 50% physiological maturity were recorded when 50% of faba bean stands reached the respective phenological stages. Phenological data were collected from the net plot area 2 m x 2 m (4 m^2) from randomly selected five plants. Measurements of yield attributing characters were made at physiological maturity of the crop prior to harvest. Plant height was recorded at physiological maturity from each plot. Nodules per plant were collected at 50% flowering from five plants randomly selected from inner border rows of each plot. Undisturbed soil core containing entire rooting system of each sampled plants were safely wrapped in plastic bag and the soil clods were carefully removed leaving the nodule on the root. The remaining soil on the root was washed using pure water on sieve and then nodule number and nodule fresh weight was recorded. Nodule dry weight per plant was recorded after oven drying the samples at 105^0C for 24 hours. Number of pods per plant was recorded by counting the total number of pods of a plant, whereas number of seeds per pod was recorded by counting the total number of seeds in a pod from five randomly sampled plants at physiological maturity. Harvesting from the net plot areas was done when most stems were defoliated and the lower pods were matured and the upper ones fully developed, but still have some green tinge in them . Grain, straw and total biomass yields were determined by harvesting the crop of the entire net plot area and converted in to hectare basis. Grain moisture content was determined and grain yield was adjusted to 12.5 % moisture content as follows:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \text{Yield obtained (kg ha}^{-1}\text{)} * \frac{(100\text{-\% moisture content})}{(100-12.5)}$$

Haulm yield was determined as the difference between the total above ground biomass (straw plus grain) which was recorded after uniform air drying of harvest for 3 weeks and the grain yield of the respective treatments. Harvest index was calculated as the percentage ratio of grain yield to the total above ground biomass yield. Hundred seed weight was determined by using seed counter and weighing 100 seeds sample taken from faba bean plots.

Economic analysis

Economic analysis of treatments using input and output data of faba beans was carried out using CIMMYT methodology (CIMMYT, 1988). In this method partial budget was calculated. Cost of faba bean was 18.00 Ethiopian Birr (ETB) kg^{-1}. Field prices for Blended fertilizer (NPSB), KCl, biofertilizer, N and P from DAP were taken as 13.65 ETB kg^{-1}, 14.50 ETB kg^{-1}, 128.00 EB 500 gm^{-1}.and 14.00 ETB kg^{-1} of nutrient, respectively. The field price of lime and compost were taken as 1.35 ETB kg^{-1} and 0.50 EB kg^{-1}, respectively. The costs of harvesting and bagging were taken as 22 ETB 100 kg^{-1} of grain harvest. The cost of spreading and transportation of lime and compost were taken as 20 EB 100 kg^{-1}. The cost of application and transport for fertilizer was taken to be 15 ETB 100 kg^{-1}.The average yield adjusted downward by 10% was used to reflect the difference between the experimental field and the expected yield at farmers fields and with farmers practices from the same treatments (Getachew and Rezene, 2006). Analysis of marginal rate of return (MRR) was carried out for non-dominated treatments, and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% in order to select the optimum treatment.

Statistical Analysis

The data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS statistical package program version 9.1.3. (SAS, 2002). Tukey's Test ($P< 0.05$) was used to assess differences among treatment means where significant differences were obtained by the analysis of variance.

RESULTS AND DISCUSSION

Soil physical and chemical properties

The particle size distribution of the soil was dominated by clay fraction (58.47%) with 25.42 % silt and 16.11% sand. Thus the soil texture of the experimental site in *Wolmera wereda* prior to conducting the experiment was clayey in texture (Getachew *et al*., 2003). The soil pH and exchangeable acidity (EA) of the experimental site were 3.80 (pH-H_2O) and 0.82, respectively. In most cases soils with pH values less than 5.5 are deficient in Ca and/or Mg and also P (Marschner, 1995; Getachew and Sommer, 2000). The soil reaction of the experimental site is extremely acidic (Landon, 1991). The low soil pH suggests the presence of substantial quantities of exchangeable hydrogen and aluminum ions which are associated with exchangeable acidity. This was also explained by Sivaguru and Horst (1997) who stated that acidic soil solutions especially when the pH drops below 4.5 are dominated by aluminum (Al) ion which has a phytotoxic effect on the root which ultimately leads to reduced growth and yield of crops. Smith *et al*., (1998) further pointed out the effect of low pH on the limitation of concentration and supply of most basic plant nutrients which has an adverse effect on productivity. The organic carbon and total nitrogen percentage of the experimental field was 1.26 and 0.14, respectively found in low range (Sahlemedhin,1999 and Bruce and Rayment, 1982). For soil to be productive, it needs to have organic carbon content in the range of 1.8-3.0% to achieve a good soil structural condition and structural stability (Charman and Roper, 2007).

This result is agreement with that of Zelleke *et al.* (2010) who noted that the organic matter depletion is a wide spread problem in Ethiopian soils. Soil available P was 3.85 ppm, considered as low (Berhanu, 1980). Available P of *Alfisols* (*Nitisols*) is low (Mesfin, 1998). Also Marschner (1995) stated in most cases, soils with pH values less than 5.5 are deficient in Ca and/or Mg, and also P. The soil fertility status is sub-optimal for the production of faba bean.

Table 1. Selected Soil physico-chemical properties of surface soil collected before lime application

Soil properties	Values
Clay (%)	58.47
Silt (%)	25.42
Sand (%)	16.11
Textural class	Clay loam
pH(H_2O)	3.8
Organic carbon (%)	1.26
Total N (%)	0.14
Exchangeable acidity (cmolc kg^{-1})	0.82
Available P (ppm)	3.85

Selected chemical properties of compost

The organic carbon and total nitrogen content of the compost is 8.47 and 0.78 %, respectively with resultant narrow C:N ratio of about 10.85. This indicates the compost applied to experimental field is well decomposed. Brady and Weil (2002) recommends C:N ratio of below 20 to have expected impact from application of compost. The concentration of available phosphorus was 51.32 ppm. The average concentrations of basic cations, viz . K, Ca, Mg and Na were 819.56, 7245.6, 806.69, and 52.91 ppm, respectively, while the CEC was 44.62 cmol (+) kg $^{-1}$. of compost (Table 2). The average pH (1:2.5

H_2O) of compost was 6.8 where most essential plant nutrients are available for the crop. Getachew *et al*. (2012) also reported similar result. Besides, compost is expected to supply the soil with appreciable amounts of micronutrients such as manganese (Mn), copper (Cu), zinc (Zn) and other micronutrients as noted by Wakene *et al*. (2001) and Getachew *et al*. (2012). Shrivastava *et al*., (1992) who reported plants depend mostly on stored food than on external nutrients for germination.

Days to 50% Flowering

Days to 50% flowering showed markedly significant differences due to treatments .The shortest days (63 days) to flowering was observed with T5- DAP(150 kg ha^{-1}) + rhizobia (500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7-Lime (611 kg ha^{-1})+ rhizobia (500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}); T8 - Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) and T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia(500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}). Control plots took the more days to flowering which was delayed by 7 days in comparison with above treatments. Synergistic effect of integrated use of lime, bio fertilizer, organic and inorganic fertilizers substantially reduced days to flowering. The result is in agreement with Brady and Weil (2002) who reported the presence of positive relationship between N and P in reducing days to flowering because of their synergistic effects.

Table 2. Chemical composition of compost used in the experiment

PH (H_2O)	OC (%)	TN (%)	C/N Ratio	Avail. P(ppm)	Basic cations (ppm kg^{-1})				CEC (cmol(+)kg^{-1})
					Ca	Mg	K	Na	
6.8	8.47	0.78	10.86	51.32	7245.6	806.69	819.56	52.91	44.62

OM= Organic matter, TN = Total nitrogen, C/N= Carbon to nitrogen ratio, P= Available phosphorus and CEC= Cation exchange capacity, ppm = parts per million

Lime requirement and its effect on soil properties

Table 3. Effect of liming on soil pH and electrical conductivity after two months of lime incorporation

Treatments	Soil	
	pH	EC(ds /m)
T1	4.23	0.06
T2	5.62	0.15
T3	6.7	0.15
T4	6.84	0.14
T5	6.85	0.16
T6	4.6	0.11
T7	6.86	0.15
T8	6.85	0.15
T9	6.82	0.14

EC = Electrical conductivity, T1- control; T2 - compost (5 t ha^{-1}) ;T3-lime (611 kg ha^{-1}); T4 - lime (611 kg ha^{-1}) + compost(5 t ha^{-1}); T5 - DAP(150 kg ha^{-1}) + rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) ;T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia(500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1})

The lime requirement of the experimental soils was 611kg ha^{-1} and its effect on soil pH and EC measured after two months of incorporation is presented in Table 3. Application of lime effectively increased the soil pH from extremely acidic to medium and neutral range (pH 6.63 to 6.86). Crop response to lime is principally a response to pH and the related secondary benefits (Haynes and Ludecke 1981). The results clearly showed that liming visibly raised the pH value of the experimental soils when lime requirement is estimated based on exchangeable acidity, and thus indirectly favor the creation of more suitable medium for nutrient uptake by plants (Coventry *et al*., 1987). The result is in agreement with Bohn (2001) who stated that for agricultural purposes, soils with pH values within the range of 5.8 to 7.5 are apt to be more trouble free than those with higher or lower pH values. Brady and Weil (2002) and Rowell (1994) stated that lime application to acidic soils is one of the solutions to address soil acidity problem. Liming acid soil has been suggested as the best method to attain a suitable pH for growth of a variety of crops (Slattery and Coventry, 1993).

Days to 50% Emergence

About 98% seedling emergence was achieved within 14 days of planting in all plots regardless of treatment differences (Table 4). This suggests that the effect of imposed treatments on seed germination and seedling emergence is not important as seeds of most plants use their own stored food initially for germination and emergence. This result corraborates with

Crop Phenology

Table 4. Integrated use of lime, bio fertilizer, blended fertilizer and compost on phenology of faba bean

Treatments	Faba bean		
	DE	DF	DPM
T1	14.00	70.00^{a}	134.00^{a}
T2	14.00	68.00^{c}	134.0^{a}
T3	14.00	68.00^{c}	134.0^{a}
T4	14.00	68.33^{c}	134.0^{a}
T5	14.00	65.00^{d}	127.0^{b}
T6	14.00	69.00^{b}	134.0^{a}
T7	14.00	63.00^{e}	127.0^{b}
T8	14.00	63.00^{e}	127.0^{b}
T9	14.00	63.00^{e}	127.0^{b}
LSD (5%)	NS	0.55	NS
CV (%)	0	0.28	0
Grand mean	14.00	66.37	130.88

Means within a column followed by the same letter are not significantly different at 5% probability level. DE-Days to emergence, DF-Days to 50% flowering, DPM- Days to physiological maturity. T1- control; T2 - compost (5 t ha^{-1}) ;T3-lime (611 kg ha^{-1}); T4 - lime (611 kg ha^{-1}) + compost(5 t ha^{-1}); T5 - DAP(150 kg ha^{-1}) + rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) ;T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia (500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1})

Days to physiological maturity

The least number of days (127) to maturity of the crop was observed with T5- DAP(150 kg ha^{-1}) + rhizobia (500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7-Lime (611 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}); T8 - Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) and T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia(500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) compared to the control which took 134 days

(Table 4). Thus, the control took longer days to maturity by 7 days. The integrated use of lime with organic and inorganic fertilizer showed a significant effect in reducing number of days to maturity as compared with sole application of lime, organic or inorganic fertilizers. This could be attributed to amelioration of aluminum toxicity due to the effect of liming thereby creating conducive environment for root system development in which efficient uptake of nutrients achieved from both organic and inorganic plant nutrient sources that ultimately lead to earliness in crop maturity.

Yield and yield components

Table 5. Effect of Integrated use of lime, bio fertilizer, blended fertilizer and compost on crop growth, yield components, and harvest index of faba bean

Treatments	PH	NN	NFW	NDW	NPP	NSPP	HSW	HI
T1	63.00^{c}	23.33^{d}	8.67^{d}	3.31^{d}	2.66^{c}	2.00^{b}	270.43	29^{c}
T2	68.00^{c}	39.66^{bc}	15.31^{bc}	5.32^{bc}	3.33^{bc}	2.33^{ab}	272.68	33^{bc}
T3	66.33^{c}	35.66^{c}	13.46^{c}	4.86^{c}	4.33^{bc}	2.33^{ab}	269.68	32^{bc}
T4	81.00^{b}	36.33^{c}	13.92^{c}	4.90^{c}	4.33^{bc}	3.00^{ab}	272.31	42^{a}
T5	87.00^{ab}	34.00^{c}	13.20^{c}	4.82^{c}	4.66^{bc}	3.33^{ab}	278.06	41^{a}
T6	66.33^{c}	34.33^{c}	13.08^{c}	4.87^{c}	4.66^{bc}	2.33^{ab}	270.11	40^{ab}
T7	91.00^{ab}	42.33^{ab}	16.71^{ab}	5.98^{ab}	6.00^{b}	3.33^{ab}	270.18	43^{b}
T8	94.33^{a}	45.00^{a}	17.71^{ab}	6.32^{a}	9.66^{a}	3.66^{a}	269.1	46^{a}
T9	95.33^{a}	47.33^{a}	18.76^{a}	6.45^{a}	9.66^{a}	3.66^{a}	268.83	44^{a}
LSD (5%)	12.18	5.98	2.49	0.88	2.8	1.45	NS	0.07
CV (%)	5.38	5.56	5.99	5.91	17.9	17.85	2.09	6.89
Grand mean	79.14	37.55	14.53	5.2	5.48	2.85	271.26	39

Means within a column followed by the same letter are not significantly different at 5% probability level. PH-Plant height, NN-Number of nodules, NFW-Nodule fresh weight, NDW-Nodule dry weight. T1- control; T2 - compost (5 t ha^{-1}) ;T3-lime (611 kg ha^{-1}); T4 - lime (611 kg ha^{-1}) + compost(5 t ha^{-1}); T5 - DAP(150 kg ha^{-1}) + rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}); T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia(500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}).
NPP-no of pods /pl; NSPP-no of seeds /pod; HSW-100 seeds weight; HI-Harvest index.

Plant height

The highest mean height of 95 cm was recorded in with T9-Lime (611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB (75 kg ha^{-1})+ KCl (50kg ha^{-1}) +rhizobia (500 g ha^{-1}) which was comparable with t5,t7,t8. In contrast, control plots exhibited significantly lower plant height compared to all other treatments. The synergy between lime application and plant nutrition was very conspicuous on response to height increments. Plant height which was 66 cm with sole application of lime jumped within a range of 91 to 95 cm when integrated with balanced fertilizer (Table 5). This result is in line with Thomas and Hargrove (1984) who stated that the increase in plant height due to application of lime on acidic soils is likely related to the increase in soil fertility and reduction of the toxic concentration of acidic cations. The inorganic fertilizer sources fulfilled the NPK requirements at early growth stages, while the organic source compost provided the crop with nutrients in the later stage.

Number of nodules, nodule fresh weight and nodule dry weight

The highest number of nodules (47), nodule fresh weight (18.46 g) and nodule dry weight (6.45 g) was obtained with T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia (500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) which increased by 102, 116 and 94%, respectively as compared with the control, though it was at par with T8 and T7. This might be due to integrated use of lime and rhizobia with organic and inorganic fertilizers. Significant increment in NN, NFW and NDW was due to increased soil pH by applied lime which ultimately neutralized the effects of Al^{3+} and H^{+} ions in the soil solution thereby creating conducive environment for biological activity, and efficiency of fertilization with macronutrients. This result is consistent with the findings of Abebe and Tolera (2014). The biofertilizer (Rhizobium strain EAL-110) integration either with organic or inorganic nutrient sources and lime did not produce any significant differences in nodulation (Table 4). This result is in conformity with the findings of Tolera and Zerihun (2014) who reported ineffectiveness of rhizobia might be due to competition with effective indigenous bacteria or probably poor adaptability of the inoculated strains in the soil environment.

Number of pods per plant and seeds per pod

The highest number of pods/plant (10) and seeds /pod (4) were obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) and T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia(500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) over control (Table 5). Integrated application of lime and rhizobia with inorganic plant nutrient sources was not adequate enough to increase NPP and NSPP without integration of organic manure. This result is in agreement with Bhattarai *et al*., (2003) who reported that application of poultry manure along with full dose of nutrients recorded highest pods plant^{-1}, seeds pod^{-1} and seed yield.

Thousand seed weight and harvest index

There was no significant difference in hundred seed weight among different treatments in faba bean crop (Table 5). This might be due to faba bean seed weight is mainly affected by genetic makeup rather than imposed treatments. Harvest index was influenced significantly with integrated application of lime with recommended rate of organic and inorganic fertilizers (Table 7). The highest harvest index (46) was obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150kg ha^{-1})+ KCl (100 kg ha^{-1}) +rhizobia (500 g ha^{-1}) as compared to plots that received combination of applied lime and lower doses of fertilizers (Table 7). In this study, faba bean harvest indices ranged from 29 to 46 that showed an increasing trend with increased combination of applied lime, organic and inorganic plant nutrient sources. The possible reason could be that application of lime with increased rate of compost and inorganic fertilizers might have increased the efficiency of faba bean to partition the dry matter into the seed. Mooleki *et al*., (2002) also indicated that increased rate of either FYM or inorganic NP has increased the harvest index of rice.

Bean yield, total biomass yield and haulm Yield

Integrated application of lime and rhizobia with half and full recommended rate of organic and inorganic fertilizer (NPSB, KCl and compost) gave many fold enhancement in bean yield over control plots. Substantially higher bean yield of 2882.9 kg ha^{-1} was obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) over the control (283.5 kg ha^{-1}) (Table 6). This indicates that the synergistic effect of applied lime together with recommended rate of organic and inorganic fertilizers gave highest productivity. Application of integrated organic and inorganic nutrient sources was not adequate enough to increase grain yield of faba bean significantly without application of lime. The synergistic effect of lime and plant nutrition made a significant difference in terms of grain yield increment. Application of lime with balanced fertilization increased faba bean yield by 2344 kg ha^{-1} compared with sole application of balanced fertilizer (1457 kg ha^{-1}).

acidity on the availability of plant nutrients (Merino *et al*., 2010). In line with this, Ivarson (1997) noted that effect of liming attributed to a reduction in aluminum toxicity and an increase in soil pH that can both result in an increase of microbial activity and release of labile organic matter (Anderson, 1999). By and large, substantial increase in bean yield may be due to more availability of nutrients from synergistic effect of lime application, organic and inorganic fertilizers which ultimately lead to continuous supply of nutrients throughout the developmental stages of crop. Significantly higher total biomass yield of faba bean was obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia (500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) (6303 kg ha^{-1}) as compared with control (953 kg ha^{-1}) (Table 6). This may be probably due to stimulated biological activities in the presence of balanced nutrient supply (Zafar, 2003). This implies that application of lime and rhizobia with both organic and inorganic fertilizers responded better to increase faba bean productivity as compared to other treatment combinations. This result is in line with Getachew *et al*. (2003) who revealed that farmyard manure and P fertilizer had a highly significant effect on plant height, number of pods per plant, total biomass and seed yield of faba bean. Faba bean highest straw yield

Table 6. Effect of Integrated use of lime, bio fertilizer, blended fertilizer and compost on bean yield, biomass yield and haulm yield of faba bean

Treatments	Faba bean		
	BY (kg ha^{-1})	BioY (kg ha^{-1})	HY (kg ha^{-1})
T1	283.5^{d}	953.3^{d}	669.9^{c}
T2	1375.0^{c}	4238.0^{bc}	2863.0^{ab}
T3	1327.2^{c}	4148.3^{bc}	2821.1^{ab}
T4	2338.4^{ab}	5548.7^{ab}	3210.3^{ab}
T5	1754.4^{bc}	4183.3^{bc}	2428.9^{ab}
T6	1457.0^{c}	3620.0^{c}	2163.0^{b}
T7	2344.0^{ab}	5413.7^{ab}	3069.7^{ab}
T8	2882.9^{a}	6303.3^{a}	3420.5^{a}
T9	2694.2^{a}	6066.7^{a}	3372.5^{a}
LSD (5%)	731.81	1787.7	1206.8
CV (%)	13.98	13.89	15.81
Grand mean	1828.49	4497.26	2668.77

Means within a column followed by the same letter are not significantly different (P>0.05).BY-Bean Yield, BioY- Biomass Yield, HY-haulm Yield, T1- control; T2 - compost (5 t ha^{-1}) ;T3-lime (611 kg ha^{-1}); T4 - lime (611 kg ha^{-1}) + compost(5 t ha^{-1});T5 - DAP(150 kg ha^{-1}) + rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia(500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) ;T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia (500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1})

Table 7. Integrated use of lime, organic and inorganic fertilizer effects on partial budget and marginal rate of return (MRR) in faba bean production

Trt No	Bean yield (kg/ha)	Adjusted yield-10% (kg/ha)	Gross return (ETB ha^{-1})	Total variable cost (ETB/ha)	Net return (ETB ha-1)	MRR (%)
1	283.45	255.11	4591.91	56.12	4535.79	
3	1327.18	1194.47	21500.4	1209.83	20290.5	1365.56
2	1374.99	1237.49	22274.9	3272.25	19002.6^{D}	-
5	1754.42	1578.98	28421.6	3555.73	24865.9	195.03
6	1456.99	1311.29	23603.3	3962.28	19641.00^{D}	-
4	2338.38	2104.54	37881.7	4410.05	33471.7	1007.32
9	2694.16	2424.75	43645.5	4812.00	38833.5	1333.94
7	2343.99	2109.59	37972.6	5084.96	32887.7^{D}	-
8	2882.87	2594.59	46702.6	8180.86	38521.7^{D}	-

D: Stands for dominated treatment. Field price of faba bean, lime and compost were 18.00 birr kg^{-1}, 1.35 birr kg^{-1} and 0.50 birr kg^{-1} ,respectively while field price of Biofertilizer, DAP, NPSB and KCl were 128 ha^{-1}, 14.00 birr kg^{-1},13.65 birr kg^{-1}and 14.50 birr kg^{-1} respectively. The cost of harvesting and bagging were taken as 22 birr 100 kg^{-1}. . The cost of incorporation and transportation of lime taken as 20 birr 100 kg^{-1}.The cost of incorporation and transportation of compost taken as 10 birr 100 kg^{-1} (the cost of transport for compost was minimum since it was purchased in the vicinity of farm), the cost of application and transport for fertilizer was taken to be 15 birr 100 kg^{-1}.

Bean yield which was 1.3 t ha^{-1}with sole application of lime jumped to 2.2 to 2.8 t ha^{-1} when integrated with balanced fertilization. The lower yield exhibited in T6-NPSB (150 kg ha^{-1})+ rhizobia(500 g ha^{-1})+ KCl (100 kg ha^{-1}) in the absence of lime integration is mainly attributed to adverse effect of soil

(3420 kg ha^{-1}) was obtained with T8 - Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+ rhizobia (500 g ha^{-1})+ NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) as compared with control (670 kg ha^{-1}). Thus, this condition is quite important that by increasing straw and total biomass yield without affecting the grain yield, farmers in the highlands of Ethiopia could be benefited as to alleviate food and animal feed security problems (Woldeyesus *et al*., 2004).

Economic evaluation of lime integrated with organic and inorganic fertilizer in production of faba bean

In terms of economic feasibility, treatment 9 – Lime (611 kg ha^{-1})+ compost (2.5 t ha^{-1}) rhizobia (500 g ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) accrued the highest net return (38834 ETB) and appropriate MRR (1334%) for faba bean (Table 7). This means on an average for each Birr ha^{-1} invested, the return was 1 Birr, plus 13.34 birr ha^{-1} as compared to T3-lime (611 kg ha^{-1}) and T4 - lime (611 kg ha^{-1}) + compost(5 t ha^{-1}) and T5 - DAP(150 kg ha^{-1}) + rhizobia (500 g ha^{-1})+ KCl (100 kg ha^{-1}) which gave lower net return and MRR (Table 10). Integrated application of lime at 611kg ha^{-1}, rhizobia 500g ha^{-1} plus 2.5 t ha^{-1} compost with 50 % of soil test based fertilizer recommendation (NPSB at 75 kg ha^{-1}, KCl at 50 kg $ha^{-1,}$) is economically feasible in faba bean production in the study area. This result is in consonance with Mitiku *et al*. (2014) who indicated that application of 5 t ha^{-1} FYM + 75% inorganic NP gave the highest net return of barley in Keffa zone, south western Ethiopia.

Conclusion

Application of lime (611 kg ha^{-1}) increased the soil pH from initial extremely acidic soil pH (3.8) to medium and neutral range (pH 6.63 to 6.86), and thus indirectly favoured creation of more suitable medium for nutrient uptake by faba bean. This condition creates a conducive soil environment for the crops that enables efficient use of both organic and inorganic nutrients which ultimately resulted in better performance of yield and yield components of faba bean crop. Integrated use of lime together with recommended rate of organic and inorganic fertilizer significantly affected agronomic parameters (days to 50% flowering, days to 50% physiological maturity, plant height, number of pods, number of nodules , grain yield, straw yield, total biomass yield, and harvest index), though no significant difference was observed in parameters such as number of nodules, nodule fresh weight and nodule dry weight among treatments due to integrated use of biofertilizer (rhizobium strain EAL-110) either with organic or inorganic nutrient sources and lime. The findings of the study revealed that the growth, and yield of faba bean responded significantly to the integrated application of lime with organic and inorganic fertilizers, where in the highest yield (2882.87 Kg ha^{-1}) was obtained with integrated use of lime together with full recommended dose of organic and inorganic nutrients. In terms of economics , application of lime at 611 kg ha^{-1}, rhizobia 500 g ha^{-1} plus 2.5 t ha^{-1} compost with 50 % of soil test based fertilizer recommendation (75 kg ha^{-1}NPSB, 50 kg ha^{-1}KCl) accrued the highest net return of 38834 ETB $ha^{-1}$with MRR of 1334 in faba bean.

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