RESEARCH ARTICLE

Effect of integrated use of lime, blended fertilizer and compost on productivity, nutrient removal and economics of barley (*Hordeum vulgare* L.) on acid soils of high lands in West Showa Zone of Ethiopia

Woubshet Demissie[1], Selamyihun Kidanu[2] and Cherukuri V Raghavaiah[3]*

[1]Soil fertility expert, Ministry of Agriculture, Addis Ababa, Ethiopia.
[3]Professor of Agronomy, Department of Plant Science, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia, East Africa.
*Corresponding author: Cherukuri V Raghavaiah, Email: cheruraghav@yahoo.in

Manuscript details:

Received: 28.02.2017
Accepted: 04.05.2017
Published : 09.09.2017

Editor:
Dr. Arvind Chavhan

Cite this article as:
Woubshet Demissie, Selamyihun Kidanu and Cherukuri V Raghavaiah (2017) Effect of integrated use of lime, blended fertilizer and compost on productivity, nutrient removal and economics of barley (*Hordeum vulgare* L.) on acid soils of high lands in West Showa Zone of Ethiopia; *International J. of Life Sciences*, 5 (3): 311-322.

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ABSTRACT

A field experiment was conducted during 2015 rainy season to investigate the effect of integrated nutrient and lime application on soil fertility and productivity of barley at Telecho, Wolmera district in the highlands of Western Ethiopia. The experiment comprised 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} and urea 72 kg ha^{-1}research recommendation (60 kg n $ha^{-1}$and 69 kg p2o5 ha^{-1}), (t6):site specific fertilizer recommendation (npsb at 150 kg ha^{-1}, kcl at 100 kg ha^{-1}, n at 33 kg ha^{-1}), (t7): lime at 611kg ha^{-1} + npsb at 150 kg ha^{-1}, kcl at 100 kg ha^{-1}, n at 33 kg 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}, n at 33 kg ha^{-1}, (t9): lime at 611kg ha^{-1} + 2.5 t ha^{-1} compost with 50 % of site specific fertilizer recommendation (npsb at 75 kg ha^{-1}, kcl at 50 kg ha^{-1}, n at 16 kg ha^{-1}) laid out in a randomized complete block design with 3 replicates. Lime requirement was determined based on exchangeable acidity. Soil analysis revealed that lime application raised soil pH from 3.80 to the pH level ranging from 6.63 to 6.86. Yield and yield components of barley was significantly affected by the treatments. The highest and significant crop yield response was obtained with t8 (5385.6 kg ha^{-1}). Likewise nutrient uptake (n, p, k, s) was significantly higher in plots treated with t8 compared to t1, t2, t3, t4, t6. However, in most cases the difference in yield and yield attributes, nutrient uptake, and soil parameters due to t1, t2, t3,t4, t6, were not discernible suggesting that all elements of soil health and fertility issues should be addressed together. The highest net return (30633 birr ha^{-1}) with MRR (666.81) was obtained with t9. Thus, integrated use of lime at 611kg ha^{-1} + 2.5 t ha^{-1} compost together with 50 % of soil test based fertilizer recommendation (npsb at 75 kg ha^{-1}, kcl at 50 kg ha^{-1}, n at 16 kg ha^{-1}) for barley is advocated in the study area and other locations with similar agro-ecologies to maximize barley grain productivity ha^{-1} and higher economic return.

Key words: Lime, compost, soil pH, blended fertilizer, soil test based fertilizer recommendation, barley yield, nutrient uptake, economics.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fifth staple food and economically important crop in Ethiopia next to teff (*Eragrostis teff*), maize (*Zea mays* L.), sorghum (*Sorghum bicolor*) and wheat (*Triticum aestivum*) (CSA, 2009). The main advantage of incorporating barley in diets oflate is due to its potential health benefits such as lowering of blood cholesterol, with b-glucans (Behall *et al*., 2004), and the glycemic index (Cavallero *et al*., 2002) by barley has been reported widely (Pins and Kaur, 2006).

Even though barley represents about 13% of the total national cereal production with an area of 1.04 million hectares with an annual production of 1.7 million tons in main season (CSA, 2011), the problems of soil acidity and diseases decrease productivity of barley and national average yield to as low as 1 ton ha^{-1} under farmers' condition in Ethiopia (Berhane *et al*., 1996; CSA, 2009). Besides, major production of barley still largely depends on the traditional varieties and farming practices, which is also assumed to be one of the constraints accounting for its low yield.

Most of the Ethiopian highlands are characterized by heavy rainfall and prone to soil acidity due to removal of ample amount of exchangeable heavy cations through leaching, crop mining and runoff as compared with grazing and forest lands. Hence, soil acidity is now becoming a serious challenge for crop production in the highlands of Ethiopia (Mesfin, 2007). According to the same author, soil acidity problem in 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. 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, severely limiting crop production which extend from southwestern to northwestern with east-west distribution but are concentrated in the western part of the country (Mesfin, 2007). Hence, Soil fertility maintenance is a major concern in Ethiopia. Although there is a gradual increase in the total volume of fertilizers used in the country, low and unbalanced application rates per unit area mainly focusing on Urea and DAP fertilizers with low use efficiency of the fertilizers (Getachew *et al.,* 2009) and limited use of improved seeds (Dercon *et al.,* 2009) have remained major constraints for small farmers to get the best out of the 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 current study was designed to assess the influence of integrated use of lime, compost and blended fertilizers on productivity of barley under acidic soil condition of West Shewa zone of Ethiopia.

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 *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*, (March to April) and long rains, *meher*, (June to September) (*Welmera* Agricultural office, 2014).

The annual rainfall, mean maximum and mean minimum temperatures recorded for the year 2015 were 483.5 mm, 22.38 ^{0}C and 3.61^{0}C, respectively. Woldeyesus (2005) reported, 85% of the total annual rainfall is received between the months of June and September and the rest from the end of March to the mid of May as a bimodal pattern. The soil type of the experimental site is Nitisols (Getachew *et al*., 2000).

Treatments and experimental design

The experiment was laid out in a randomized complete block design (RCBD). Treatments and treatment combinations including the control treatment 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 with three replications. The experiment 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} plus lime at 611kg ha^{-1},(T5): lime at 611kg ha^{-1} plus DAP 150 kg ha^{-1} and urea 72 kg ha^{-1}research recommendation (60 kg N $ha^{-1}$and 69 kg P2O5 ha^{-1}), (T6):site specific recommendation (NPSB at 150 kg ha^{-1}, KCl at 100 kg ha^{-1}, N at 33 kg ha^{-1}), (T7): lime at 611kg ha^{-1} plus NPSB at 150 kg ha^{-1}, KCl at 100 kg ha^{-1}, N at 33 kg ha^{-1}, (T8): lime at 611kg ha^{-1} plus compost at 5t ha^{-1} plus NPSB at 150 kg ha^{-1}, KCl at 100 kg ha^{-1}, N at 33 kg ha^{-1}, (T9): lime at 611kg 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}, N at 16 kg ha^{-1}) laid out in a randomized complete block design (RCBD) with 3 replications.

Application of treatments and field management

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 three times 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.

The field lime requirement was estimated based on exchangeable acidity as follows

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

Thus, treatments that received lime, 611 kg ha^{-1} calcitic lime ($CaCO_3$) was evenly broadcast manually and mixed thoroughly in upper soils at 15 cm depth (plow depth) in the first week of June 2015 as per the treatments. Compost was applied in the first week of June 2015 to all plots as per the treatments one month before planting.

The seeds of barley variety *HB 1307* were sown by hand at the rate of 100 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) applied at a rate of 150 kg ha^{-1} along with 60 kg K_2O and 33 kg N ha^{-1} represents balanced nutrition recommended for barley production in the study area (EthioSIS, 2014). While treatments which receive Di ammonium Phosphate (DAP) applied at a rate 150 kg ha^{-1} along with 33 kg N . DAP, blended fertilizer NPSB; K_2O were applied as basal at time of planting. Nitrogen in the form of urea was applied at tillering stage of barley 35 days after planting. The experimental field was hand weeded twice at 25 and 45 days after planting to control weeds. At physiological maturity barley crop was harvested on 22 November 2015, sun dried for a while and threshed on December 7 and 8, 2015 to determine grain yields.

Data Collection

Soil sampling and analysis

Prior to conducting the experiment, three representative composite soil samples were collected from experimental site at plow depth of 0-20 cm on April 15, 2015 and analyzed using standard laboratory procedures. Well decomposed compost sample was 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). Methods as described by Walkley and Black for organic carbon, and wet oxidation Kjeldahl method was used to determine Total N, as described by Jackson (1967). Exchangeable bases were extracted with 1 M NH4O Ac 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). In order to investigate 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 and 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

Data on days to 50% crop emergence, days to 50% flowering and days to 50% physiological maturity were recorded when 50% of barley stands reached the respective phenological stages. Phenological data were collected from the net plot area 2 m x 2 m (4 m^2) of randomly selected five plants. Measurements of yield attributes were taken at physiological maturity of the crop prior to harvest. Plant height, number of tillers (effective tillers and total tillers) per plant, spike length and number of kernels per spike was recorded from each plot. Plant height was recorded from ground level to the top of the spike excluding awns.

The crop was harvested from the net plot areas manually using sickle at the ground level and dry mater yield of the above ground biomass was determined. Grain moisture content was determined and grain yield was adjusted to 12.5 % moisture content. Straw yield was recorded after uniform air drying of harvest for 3 weeks. Harvest index was calculated as the percentage ratio of grain yield to the total above ground biomass yield. Thousand seed weight was determined by using seed counter and weighting 1000 seeds sample taken from each plot.

Plant Tissue Sampling and Analysis

Grain samples at physiological maturity were collected from each plot for determination of nitrogen, phosphorus, potassium and sulphur concentration. The measurement of N was carried out according to the Kjeldahl procedure by transforming organic N into ammonium N by digesting with H2SO4 and a catalyst (Chapman,1965). Nitrates and nitrites are initially bounded by salicylic acid as nitro compounds and then reduced by sodium thiosulfate. After digestion, the solution was made alkaline by the addition of NaOH, which allows the formation of volatile NH3. The measurement of P concentration of grain was carried out through calcinations of both grain and straw separately at 450 °C. After calcination, wet destruction of plant substances with strong acids was carried out, and then P was measured using dry ashing , Black, C.A (flame Photometer) as described by Chapman (1965). The measurement of K and S in grain was carried out through Wet ashing-turbidity. The grain concentrations of N, P, K and S were used to estimate the N, P , K and S uptake which was calculated by multiplying grain yields on hectare basis with the respective N, P , K and S percentage .

Economic analysis

The market cost of barley was 8.50 Ethiopian Birr (ETB) $kg^{-1.}$ Field prices for Blended fertilizer (NPSB), KCl , N and P from DAP and urea were taken as 13.65 ETB kg^{-1} , 14.50 ETB kg^{-1},. 14.00 ETB kg^{-1} and 11.50 ETB kg^{-1} of nutrient, respectively. The field price of lime and compost were taken to be 1.35 ETB kg^{-1} and 0.50 EB kg^{-1}, respectively. The costs of harvesting and bagging were taken at 22 ETB 100 kg^{-1} of grain harvest. The cost of spreading and transportation of lime and compost were taken as 20 ETB 100 kg^{-1}. The cost of application and transport for fertilizer was taken to be 15 ETB 100 kg^{-1}.
The average yield was adjusted downward by 10% and was used to reflect the difference between the experimental field and the expected yield from farmers fields 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. Correlation analyses were determined through simple correlation coefficient between yield and yield components.

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 (Table 1). Getachew *et al*. (2003) found that the soil texture of the experimental site in *Wolmera wereda* prior to conducting the experiment was clayey in texture. 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 can be considered as extremely acidic (Landon,1991) which suggests the presence of substantial quantity of exchangeable hydrogen and aluminum ions which is associated with acidity.

The organic carbon and total nitrogen percentage of the experimental field was 1.26 and 0.14, respectively and rated as low as per 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).

Table 1. Selected 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

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.

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

Treatments	pH	EC (ds/m)
T1	4.16	0.07
T2	5.54	0.11
T3	6.63	0.14
T4	6.78	0.14
T5	6.82	0.16
T6	4.68	0.1
T7	6.71	0.14
T8	6.74	0.13
T9	6.86	0.11

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}) +KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1});T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}); T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1});

The result is agreement with the findings 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. Thus, the fertility status of the experimental soil is sub-optimal for the production of barley.

Chemical properties of compost

The organic carbon and total nitrogen contents of the compost is 8.47 and 0.78 %, respectively with the resultant narrow C:N ratio of about 10.85, indicating that the compost applied to experimental field is well decomposed. Brady and Weil (2002) recommends a 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) was 6.8 where most essential plant nutrients are available for the crop. Getachew *et al.*, (2012) reported similar result.

Lime requirement and its effect on soil properties

The lime requirement of the experimental soil is 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 raise 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) also stated that lime application to acidic soils is one of the solutions to address soil acidity problem. Liming acid soils has been suggested as the best method to attain a suitable pH for growth of a variety of crops (Slattery and Coventry ,1993).

Table 4. Effect of Integrated use of lime, blended fertilizer and compost on plant height, effective and total tillers, spike length, number of kernels, Thousand seed weight, harvest index, grain yield, straw yield, biological yield and straw yield of barley.

Treatments	PH	ET	TT	SL	NK	TSW	HI	GY (kg ha-1)	BY (kg ha-1)	SY (kg ha-1)
T1	44.66^{c}	2.33^{e}	3.00^{d}	5.70^{d}	33.00^{b}	9.92^{c}	38^{c}	1317.8^{c}	3433.3^{c}	2115.6^{b}
T2	66.66^{b}	3.66^{de}	3.66^{cd}	6.40^{c}	34.66^{b}	36.89^{b}	39^{c}	1617.0^{c}	4173.3^{c}	2556.3^{b}
T3	63.00^{b}	4.00^{cd}	4.00^{cd}	6.03^{d}	35.66^{b}	36.52^{b}	37^{c}	1682.7^{c}	4483.3^{c}	2800.6^{b}
T4	70.66^{b}	5.33^{bc}	5.33^{bc}	6.56^{bc}	37.66^{b}	36.83^{b}	40^{bc}	1744.8^{c}	4266.7^{c}	2521.8^{b}
T5	90.33^{a}	6.00^{b}	6.00^{b}	6.97a	45.66^{a}	38.44^{b}	43^{abc}	3810.7^{b}	8916.7^{b}	5106.0^{a}
T6	68.00^{b}	3.66^{de}	4.00^{cd}	6.76^{ab}	36.33^{b}	36.59^{b}	42^{abc}	1670.2^{c}	3966.7^{c}	2296.5^{b}
T7	92.33^{a}	9.66^{a}	9.66^{a}	6.90^{ab}	48.33^{a}	37.69^{b}	45^{ab}	4414.2^{ab}	9820.0^{ab}	5405.8^{a}
T8	95.33^{a}	10.66^{a}	10.66^{a}	7.03^{a}	50.66^{a}	44.02^{a}	47^{a}	5385.6^{a}	11500.0^{a}	6114.4^{a}
T9	93.33^{a}	11.00^{a}	11.00^{a}	6.83^{ab}	45.66^{a}	42.52^{a}	44^{ab}	4799.6^{ab}	10766.7^{ab}	5967.0^{a}
LSD (5%)	11.41	1.65	1.74	0.35	6.92	2	0.05	1099.7	2467.9	1465.3
CV (%)	5.24	9.22	9.55	1.89	5.92	2.25	4.43	13.08	12.66	13.21
Grand mean	76.03	6.25	6.37	6.57	40.85	35.42	42	2938.06	6814.07	3876

Means within a column followed by the same letter are not significantly different at 5% probability level.

PH-Plant height, ET-Effective tillers, TT- Total tillers SL-Spike length, NK-Number of kernels, TSW-Thousand seed weight, HI-Harvest index, GY-Grain yield, BY-Biological yield, SY-Straw 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}) +KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1});T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}); T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1})

Yield and yield components

Barley growth parameters

In the present study, plant height, measured at physiological maturity, was significantly affected by imposed treatments (Table 4). The highest mean height of 95 cm was recorded in barley plots received T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) . 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 of barley. Addition of lime with balanced fertilization increased plant height by 24 cm compared to balanced fertilizer sole application (68 cm). Plant height which was 60 cm with sole application of lime increased to 90 to 95 cm when integrated with balanced fertilizer. The result agrees with Mitiku *et al*., (2014) who showed a significant effect of combined application of organic and inorganic fertilizers on plant height where the tallest barley plants were obtained with application of 5 t ha^{-1} farmyard manure +75% of recommended NP at *Adiyo* and from the application of 5 t ha^{-1} vermicompost and 75% of recommended NP at *Ghimbo*. Getachew (2009) also reported that the use of organic manures in combination with mineral fertilizers maximized the plant height than the application of inorganic fertilizers alone.

The highest number of effective tillers (11) and total tillers (11) was obtained with T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1}) which was comparable with T7- Lime (611 kg ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) and T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}). The attainment of higher number of effective tillers might be due to the synergetic effect of lime, organic and inorganic fertilizers combinations that contributed to increased availability of NPKS. This result is consistent with Mitiku *et al.* (2014) who observed that application of 5 t ha^{-1} farmyard manure along with 75% of recommended NP gave highest number of productive tillers m^{-2} and highest number of grains per spike at *Adiyo* and *Ghimbo* ,respectively.

Spike length (SL) and number of kernels per spike (NK) of barley responded significantly to integrated use of lime and nutrients. The highest mean SL (7) and KS (51) were obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) (Table 8). This showed an advantage of 23% and 53% increase in SL and KS, respectively as compared to control plots (Table 4). The possible reason for increased number of kernels per spike could be that mineral fertilizer and mineralization of organic nutrient sources availability due to effect of liming didn't put the plants to nutrient stress at any stage throughout the growing season. In agreement with this result Arif *et al* ., (2006) reported significant increase in number of grains per spike of wheat by applying manure and mineral fertilizer in combination as compared to inorganic fertilizer alone.

Barley grain productivity

Integrated application of lime with half and full recommended rate of organic and inorganic fertilizer (NPSB, urea, KCl and compost) gave many fold enhancement in grain yield over control plots. Hence, the highest mean yield of 5385.6 kg ha^{-1} was obtained over the control (1317.8 kg ha^{-1}) with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}). This indicates that the synergistic effect of applied lime in ameliorating soil acidity along with recommended rate of organic and inorganic fertilizers which gave greater productivity. Integrated application of organic and inorganic nutrient sources was not adequate enough to increase grain yield of barley significantly without integration of lime (Table 4). Thus, 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 barley grain yield by 2744 kg ha^{-1} compared to sole application of balanced fertilizer (1670 kg ha^{-1}). On the contrary, grain yield which was 1.6 t $ha^{-1}$with sole application of lime enhanced to 4.4 to 5.3 t ha^{-1} when integrated with balanced fertilization. The lower yield exhibited in T6- NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}) (1670.2 kg ha^{-1}) in the absence of lime integration was mainly due to adverse effect of soil acidity on the availability of plant nutrients (Merino *et al*., 2010) .

The synergistic effect of applied lime with organic and inorganic plant nutrient sources highly influenced thousand seed weight of barley (Table 4). The highest thousand seed weight was recorded with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) (44 g) followed by T9- Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1}) (43g) over control plots (10 g) which is attributed to better availability of nutrients and grain filling. The lowest thousand seed weight in control plots could be due to shriveled seeds that have small size which contributed to the less grain weight. A combination of lime, organic and inorganic fertilizers, increased thousand seed weight from 10 g to 44 g. Mitiku *et al.* (2014) also reported that application of 5 t ha^{-1} FYM in combination with 75% recommended rate of inorganic NP , the highest thousand barley grain weight was obtained at Adiyo as compared to application of 100%

recommended rate of inorganic NP which scored lower thousand grain weight. Similarly, Saidu *et al*., (2012) obtained the highest 1000 wheat grain weight, from application of 5 t ha^{-1} FYM in combination with 50% inorganic NP, while the lowest 1000 grain weight was recorded from no fertilizer application.

Harvest index was influenced significantly with integrated application of lime together with recommended rate of organic and inorganic fertilizers . The highest harvest index (47) was obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) as compared to plots that received applied lime and lower doses of fertilizers (Table 4). In this study, harvest indices ranged from 37 to 47 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 barley to partition the dry matter into the reproductive seed sinks. Mooleki *et al*., (2002) too reported that the increased rate of either FYM or inorganic NP has increased the harvest index of rice.

In line with this, Ivarson (1997) noted that effect of liming attributed to a reduction of 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). Furthermore, Shiferaw and Anteneh, (2014) found that application of lime and all combinations of fertilizers, either alone or combined, significantly increased barley yield over untreated control.

The highest total biomass yield (11500 kg ha^{-1}) and straw yield (6114 kg ha^{-1}) were obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) as compared to control (biomass3433 kg ha^{-1}.and straw yield 2115 kg ha^{-1}). This is in agreement with Agegnehu *et al*., (2014) who found that application of half the recommended NP rate and half recommended rate of manure and compost as inorganic N equivalence resulted in wheat grain and total biomass yield advantages of about 129% and 194% compared to the control. Therefore, this condition is quite important that increasing both parameters (straw and total biomass yield) without affecting the grain yield through lodging effect, farmers in the highlands of Ethiopia could be benefited by increasing grain yield and straws to alleviate food and animal feed security problems (Woldeyesus *et al*., 2004).

Nutrient concentration and uptake in barley

Integrated application of lime with organic and inorganic fertilizers significantly increased the concentration of TN %, P %, K meq/100 g and S % in barley grain (Table 5). The combined effect of applied lime with organic and inorganic plant nutrient sources significantly increased the nutrient concentrations of TN %, P %, K meq /100 g and S % from 1.16, 0.18, 0.19, 0.17 to 1.37, 0.36, 0.28, 0.27, respectively as compared to the control plots (Table 5). The linear increment in N, P, K and S concentration with increased combination of applied lime along with organic and inorganic nutrients in grain of barley could be due to the effect of lime in ameliorating Al toxicity and promoting root growth for nutrient uptake coupled with nutrient availability from the synergistic effect of both applied organic and inorganic nutrient sources.

Likewise, a distinct variation in TN, P, K and S uptake in grain was observed due to different integrated use of lime with organic and inorganic fertilizers. The highest removal of N (74 kg ha^{-1}), P (19.65 kg ha^{-1}) , K (16.05 kg ha^{-1}) and S (15 kg ha^{-1}) in grain was obtained with T8- Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}) as compared with control . The nutrient uptake increased through application of lime and compost with blended macronutrients and micronutrients in appropriate form of fertilizer to nutrient deficient soil. Hence, the complimentary effects of applied lime, organic and inorganic fertilizer (NPSB, urea and KCl and compost) ultimately lead to more nutrient uptake. The N losses due to leaching or denitrification might have been reduced in soil by mixing N fertilizer with organic compost, resulting in better utilization of N by plants. Composted organic materials enhanced fertilizer use efficiency by releasing nutrients slowly and thus reducing losses, particularly of N (Ramos and Marttinez –Casasnovas,2006). This may be attributed to the improvement of soil physical properties by organic nutrient sources in addition to contributing to nutrient availability (Laila and Ali, 2011). This result corroborates with the findings of Nasreen and Farid (2003) who demonstrated that the application of

Table 5. Effect of Integrated use of lime, blended fertilizer and compost on total nitrogen, phosphorus, potassium and sulphur concentrations and uptake (Kg ha^{-1}) in barley grain

Treatments	Nutrient concentration				Nutrient uptake(kg/ha)			
	TN%	P%	K(meq/100g)	S%	TN	P	K	S
T1	1.16^{f}	0.18^{d}	0.19^{c}	0.17^{d}	15.29^{b}	2.46^{c}	2.59^{b}	2.25^{c}
T2	1.21^{e}	0.22^{c}	0.21^{bc}	0.18^{cd}	19.67^{b}	3.55^{c}	3.52^{b}	2.95^{c}
T3	1.22^{e}	0.22^{c}	0.22^{bc}	0.18^{cd}	20.53^{b}	3.69^{c}	3.70^{b}	3.01^{c}
T4	1.25^{d}	0.23^{c}	0.24^{b}	0.19^{cd}	21.91^{b}	4.04^{c}	4.18^{b}	3.36^{c}
T5	1.28^{cd}	0.32^{b}	0.27^{a}	0.20^{c}	60.91^{a}	15.34^{b}	12.95^{a}	9.82^{b}
T6	1.22^{e}	0.23^{c}	0.23^{b}	0.18^{cd}	20.37^{b}	3.83^{c}	3.84^{b}	3.12^{c}
T7	1.32^{b}	0.33^{b}	0.28^{a}	0.26^{ab}	58.56^{a}	14.56^{b}	12.70^{a}	11.47^{b}
T8	1.37^{a}	0.36^{a}	0.28^{a}	0.27^{a}	74.15^{a}	19.65^{a}	16.05^{a}	15.13^{a}
T9	1.31^{bc}	0.32^{b}	0.27^{a}	0.25^{b}	63.19^{a}	15.51^{b}	13.27^{a}	12.00^{ab}
LSD (5%)	0.034	0.03	0.03	0.02	15.994	3.39	4.25	3.62
CV (%)	0.95	4.38	4.44	4.53	14.18	12.9	18.38	18.06
Grand mean	1.26	0.27	0.24	0.21	39.4	9.18	8.09	7.01

Means within a column followed by the same letter are not significantly different at 5% probability level.
TN-Total nitrogen, P- Phosphorus, K-Potassium ,S = Sulphur
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}) +KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T6-NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}); T7 Lime (611 kg ha^{-1})+ NPSB(150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1});T8 Lime (611 kg ha^{-1})+ compost (5 t ha^{-1})+NPSB (150 kg ha^{-1})+ KCl (100 kg ha^{-1}) +Urea (72 kg ha^{-1}); T9 Lime(611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB(75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1}).

different nutrients caused significant increase in nutrient uptake by pea. Uptake of N, P, K, S and Zn by shoot and seed was highest with the treatment 30 kg N, 50 kg P, 40 kg K and 20 kg S ha^{-1}. Furthermore Sawer *et al.* (2009) stated that the nutritional status of plants was further strengthened when chemical fertilizer was combined with compost.

Economic feasibility analysis

Field price of barley, lime and compost were 8.50 birr kg $^{-1}$, 1.35 birr kg^{-1} and 0.50 birr kg^{-1}, respectively, while field price of DAP, Urea, NPSB and KCl were 14.00 birr kg $^{-1}$ 11.50 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$^{—1}$

The highest net return of 30633.00 Ethiopian Birr with highest MRR value of 666.81 was obtained from T9- Lime (611 kg ha^{-1})+ compost (2.5 t ha^{-1})+NPSB (75 kg ha^{-1})+ KCl (50 kg ha^{-1}) +Urea (36 kg ha^{-1}) as compared to T5 - DAP(150 kg ha^{-1}) +KCl (100 kg ha^{-1})+ Urea (72 kg ha^{-1}) with net return of 24488.00 ETB and MRR 381.00 (Table 6). This means for T9 on an average for each l Birr ha^{-1} invested, the return was 1 Birr, plus 6.00 birr ha^{-1} in net benefit which is economically feasible as compared to T5 that showed 1 birr recovery plus 3.81 birr ha^{-1} net benefits. This recommendation is also supported by CIMMYT (1988) which stated that farmers should be willing to change from one treatment to another if the marginal rate of return of that change is greater than the minimum acceptable rate of return. The current study suggests that it would be advisable for farmers in the study area to apply integrated lime at 611kg 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$^{-1,}$ urea at 36 kg ha^{-1}) for enhancing barley grain yield ha^{-1} and accruing highest economic return.

Table 6: Economic analysis of Integrated use of lime, organic and inorganic fertilizer in terms of partial budget and marginal rate of return (MRR) for barley production

Trt . No	Grain yield(kg/ha)	Adjusted yield-10%	Gross return (ETB ha^{-1})	Total variable cost (ETB	Net return (ETB ha-1)	MRR (%)
1	1317.77	1185.99	10080.9	260.92	9820.02	
3	1682.69	1514.42	12872.6	1280.22	11592.4	173.92
2	1616.99	1455.29	12370	3320.16	9049.79^{D}	-
4	1744.82	1570.34	13347.9	4292.52	9055.36^{D}	-
5	3810.67	3429.61	29151.7	4662.86	24488.8	381.25
6	1670.2	1503.18	12777.1	4704.5	8072.55^{D}	-
9	4799.64	4319.67	36717.2	5584.28	30633.00	666.81
7	4414.24	3972.81	33768.9	6194.87	27574.00^{D}	-
8	5385.59	4847.03	41199.8	9387.2	31812.6	31.01

D: Stands for dominated treatment.

CONCLUSION

From the foregoing account it could be concluded that application of lime (611 kg ha^{-1}) increased the soil pH of extremely acidic soil (pH 3.8) to medium and neutral range (pH 6.63 to 6.86) through its ameliorating effect and thus indirectly favouring the creation of more suitable medium for nutrient uptake by the crop. This condition creates a favorable soil environment that enables efficient use of both organic and inorganic nutrients which ultimately resulted in better performance in terms of yield and yield components of the crop. Integrated use of lime along with recommended rate of organic and inorganic fertilizer significantly influenced agronomic parameters (days to 50% flowering, days to 50% physiological maturity, plant height, effective tillers, total tillers, spike length, number of kernels per spike, grain yield, straw yield, total biomass yield, thousand seed weight and harvest index) of barley. Likewise Nutrient concentration and uptake of N, P, K and S were significantly increased with full combination of organic and inorganic nutrient sources.

The findings of the study revealed that the growth, yield and yield components of barley responded positively and significantly to the integrated application of lime with organic and inorganic fertilizers. Thus, the highest grain yield of barley (5385.59 Kg $ha^{-1)}$) was obtained with integrated use of lime together with full recommended dose of organic and inorganic nutrients.

In terms of economic feasibility, application of lime at 611kg 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, 36 kg ha^{-1} urea) accrued the highest net return of 30633.00 ETB $ha^{-1}$with MRR of 667% which is advisable for farmers to maximize barley grain yield ha^{-1} and economic return on acid soils of central high lands of Ethiopia where soil acidity is a major production constraint.

Conflicts of interest: The authors stated that no conflicts of interest.

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