ORIGINAL ARTICLE

Effects of Lime, Blended Fertilizer (NPSB) and Compost on Yield and Yield Attributes of Barley (*Hordium Vulgare* L.) on Acid Soils of Wolmera District, West Showa, Ethiopia

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ABSTRACT

Soil acidity is a major yielding limiting factors in the highlands of Ethiopia where highly weathered acid soils. This in view a field experiment was executed to investigate the effect lime, blended fertilizer and compost application on productivity of barley and soil fertility at Telecho, Wolmera district, in the highlands of western Ethiopia in 2015 cropping season. The experiment consisted of nine treatments which was laid out in a randomized complete block design with 3 replicates. Lime requirement was determined based exchangeable acidity. Application of lime was dramatically improved soil pH from 3.80 to pH level ranging from 6.63 to 6.86. Yield and yield components of barley was significantly ($p<0.05$) affected by integrated use of lime, blended fertilizer and compost. Significantly higher yield 5386 kg ha^{-1} and nutrient uptake N (74), P (19.65), K (16.05) and S (15) kg $ha^{-1}$of barley were obtained with application of 611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}. Higher net return EB 30633 ha^{-1} with marginal rate of return of 667 % of barley was obtained with application of 611kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}. Thus, integrated use of 611kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1} is recommended for barley production in acid soil of Telecho, Wolmera district and similar agroecologies.

Key words: Lime, soil pH, blended fertilizer, soil test, fertilizer recommendation

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the fifth most staple food and economically important crop in Ethiopia next to teff, maize, sorghum and wheat (CSA, 2014). The main advantage of incorporating barley in diets nowadays is due to its potential health benefits among which 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 a total average of 1.04 million hectares and total annual production of about 1.7 million tons in main season (CSA, 2014), 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 cultivated lands of the Ethiopian highlands are characterized by heavy rainfall and prone to soil acidity due to removal of ample amount of exchangeable heavy cations by leaching, crop mining and runoff as compared with grazing and forest lands (Paulos, 2001; IFPRI, 2010, Temesgen, 2014). Hence, soil acidity is now becoming a serious challenge for crop production in the highlands of Ethiopia where annual precipitation exceeds evapotranspiration (Mesfin, 2007; Temesgen, 2014). 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 (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, 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 of land 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 get the best out of the input. However, the contribution of lime with blended fertilizer (NPSB) and compost on yield and yield attributes of barley in Wolmera district had not been determined. Therefore, the objective is to determine the effect of blended fertilizer (NPSB) and compost on yield and yield components of barley under acidic soil condition of in western Showa, particularly in Wolmera District.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted on acidic soils of *Welmera* District in West Showa 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. The district comprises *Dega* (41%) and *Wainadega* (59%) are the two agro climatic zones. The area receives bimodal rainfall: 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 and 3.61^0C, respectively. 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 (Woldeyesus, 2005). The soil type of the experimental site is Nitisols (Getachew *et al*., 2000).

Treatment and experimental design

The experiment was laid out in a randomized complete block design with three replications. The experiment treatments consisted of nine treatments:

1. Control
2. 5 t compost ha^{-1}
3. 0.611t lime ha^{-1}
4. 0.611t lime + 5 t compos t ha^{-1}
5. 150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}
6. 150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}
7. 0.611t lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}
8. 0.611t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}
9. 0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}

The gross plot size was 3 m x 3 m (9 m^2) and crop planted in rows. 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. The field lime requirement was estimated based on exchangeable acidity as follows

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

Thus, treatments that received lime, 611 kg ha^{-1} calcitic lime (CaCO3) was evenly broadcasted manually and mixed thoroughly in upper soils at 15 cm depth (plow depth) in the first week of June 2015 to all plots allotted to lime treatment. Compost was applied uniformly and incorporated to the plough depth in the first week of June 2015 to all plots allotted to compost treatment one month before planting.

The improved seeds of barley (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 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 Diammonium Phosphate (DAP) (18 %N, 46 % P_2O_5) 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 weeded twice by hand (at 25 and 45 days after planting) to control weeds. At physiological maturity barley, the crop was harvested sun dried for trashing purposes and collect grain yields.

Data collection

Soil sampling and analysis

The soil samples were collected two times. First three-representative soil sample was collected at the depth of 0-20 cm with auger before application of the treatment. Second after harvesting of the treatments nine composite soil samples were collected from each experimental plot to investigate the effect of liming on pH of the soil. The collected soil samples were prepared and analyzed using standard soil laboratory procedures. 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); using EC meter Van Reeuwijk, (2002) and buffered with KCl., soil texture was determined by hydrometer method (Day, 1965). The organic carbon was determined following wet digestion methods as described by Walkley (1947); whereas kjeldahl procedure was used for the determination of total N as described by Bremner and Mulvaney (1982). 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). Samples were analyzed at National Soil Testing Center (NTSC). The compost sample was collected and analyzed for pH, organic carbon (OC), total N, available P and C/N and exchangeable cations (Ca, Mg, K, Na).

Plant parameters

The measurements of yield attributing factors were taken at physiological maturity of the crops prior to harvest. Plant height, number of tillers (effective tillers and total tillers) per plant, spike length and number of kernels per spike of barley was recorded from each plot. The test 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 10 % 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 seeds weight were determined by using seed counter and weighting 1000 seeds sample taken from each barley plots.

Grain sampling and analysis

Barley grain samples were collected at physiological maturity from each plot for determination nitrogen, phosphorus, potassium and Sulphur concentration. The measurement of N was carried out according to the Kjeldahl procedure by transforming organic N in to ammonium N by digesting with H_2SO_4 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 NH_3. The measurement of P concentrations of grain was carried out through calcinations of both grain and straw separately at 450 °C. After calcinations, wet destruction of plant substances with strong acids was carried out, and then P was measured using dry ashing, (flame Photometer) as described by Chapman (1965). The measurement of K and S grain concentration 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 by the respective N, P, K and S percentage.

Economic analysis

For economic evaluation, partial budget, values to cost ratio (VCR) and marginal analyses were used. The cost of barley seed was 8.50 Ethiopian Birr (EB) kg^{-1}. The prices for Blended fertilizer (NPSB), KCl, N and P from DAP and urea were taken as 13.65 EB kg^{-1}, 14.50 EB kg^{-1}, 14.00 EB kg^{-1} and 11.50 EB kg^{-1} of each nutrient, respectively. The field price of lime and compost were to be 1.35 EB kg^{-1} and 0.50 EB kg^{-1}, respectively. The costs of harvesting and bagging were taken at 22 EB 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 EB 100 kg^{-1}. The cost of other production practices like seed cost and weeding cost were assumed to remain the same or insignificant among the treatments. The average yield was adjusted downward by 10% was used to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments (CIMMYT, 1988; Getachew and Rezene, 2006).

Statistical analysis

The collected data were subjected to statistical Analysis of variance (ANOVA) using SAS statistical package program version 9.1.3. (SAS, 2002). Mean separation was done using Least significance difference Test procedure at 5% probability level. 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 clayey which is similarly with Getachew *et al.*, (2003). The soil pH and exchangeable acidity 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 ranged in extremely acidic (Landon,1991) which suggests the presence of substantial quantity of exchangeable hydrogen and aluminum ions which is associated with The organic carbon and total nitrogen percentage of the experimental field was 1.26 and 0.14 % found in low range Sahlemedhin (1999); Landon (1991) and Bruce and Rayment, (1982). For soil to be productive, it needs to have organic carbon content in range of 1.8-3.0 % to achieve a good soil structural condition and structural stability (Charman and Roper, 2007). The result is agreement with Zelleke *et al.* (2010) 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) soil 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, soil fertility status is sub-optimal for the production of barley.

Table 1. Selected Soil physico-chemical properties of surfaces soils collected before lime application

Soil properties	Values
Clay	58.47%
Silt	25.42%
Sand	16.11%
Textural class	Clay
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

Chemical properties of compost

The organic carbon and total nitrogen contents 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 such as 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 The average pH (1:2.5 H_2O) was 6.8 where most essential plant nutrients are available for the crop. Likewise, Getachew *et al.*, (2012) reported similar result.

Table 2. Chemical composition of compost used for the experiment.

PH (H_2O)	OC (%)	TN (%)	C/N Ratio	AP(ppm)	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, AP= 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

No.	Treatments	pH	EC (ds/m)
1	Control	4.16	0.07
2	5 t compost ha^{-1}	5.54	0.11
3	0.611t lime ha^{-1}	6.63	0.14
4	0.611t lime + 5 t compos t ha^{-1}	6.78	0.14
5	150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}	6.82	0.16
6	150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}	4.68	0.1
7	0.611t lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	6.71	0.14
8	0.611 t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	6.74	0.13
9	0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}	6.86	0.11

EC = Electrical conductivity

Lime requirement and its effect on soil properties

The lime requirement of the experimental soils is 0.611t 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). Application of lime 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). Similarly, Bohn (2001) 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. Likewise, Brady and Weil (2002); 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). Therefore, application of lime to Welmera District experimental site was advisable for optimum barley production. Plant height, effective and total tillers, spike length and number of kernels per spike of barley The synergy between lime application and plant nutrition was very conspicuous on response to height increments of barley (Table 4).

Application of lime with balanced fertilization increased plant height by 24 cm compared to balanced fertilizer sole application (68 cm). Plant height which hardly exceeds 60 cm with sole application of lime improved to 90 to 95 cm when integrated with balanced fertilizer (Table 4).

Table 4. Effects of lime, blended fertilizer and compost on plant height, effective and total tillers, spike length and number of kernels, of barley in Wolmera district West Showa, Ethiopia

No.	Treatments	Plant height (cm)	Number of effective tillers	Number of tillers	Spike length	Number of kernels
1	Control	44.66[c]	2.33[e]	3.00[d]	5.70[d]	33.00[b]
2	5 t compost ha^{-1}	66.66[b]	3.66[de]	3.66[cd]	6.40[c]	34.66[b]
3	0.611t lime ha^{-1}	63.00[b]	4.00[cd]	4.00[cd]	6.03[d]	35.66[b]
4	0.611t lime + 5 t compos t ha^{-1}	70.66[b]	5.33[bc]	5.33[bc]	6.56[bc]	37.66[b]
5	150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}	90.33[a]	6.00[b]	6.00[b]	6.97a	45.66[a]
6	150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}	68.00[b]	3.66[de]	4.00[cd]	6.76[ab]	36.33[b]
7	0.611t lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	92.33[a]	9.66[a]	9.66[a]	6.90[ab]	48.33[a]
8	0.611t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	95.33[a]	10.66[a]	10.66[a]	7.03[a]	50.66[a]
9	0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}	93.33[a]	11.00[a]	11.00[a]	6.83[ab]	45.66[a]
	LSD (5%)	11.41	1.65	1.74	0.35	6.92
	CV (%)	5.24	9.22	9.55	1.89	5.92

Likewise, Mitiku *et al*. (2014) found 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*. Similarly, Getachew (2009) reported that the use of organic manures in combination with mineral fertilizers maximized the plant height than the application of inorganic fertilizers alone.

Higher number of effective tiller (11) and total tiller (11) of barley were obtained with application of 0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}. The 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 found that application of 5 t ha^{-1} farmyard manure along with 75% of recommended NP gave higher number of productive tiller m^{-2} and highest number of grains per spike at *Adiyo* and Ghimbo, respectively.

The spike length and number of kernels per spike of barley were significantly affected by integrated use of lime and nutrients. Higher mean spike length (7cm) and number of kernels per spike (51) of barley were obtained with integrated application of 611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1} (Table 4). This gave an advantage of 23 and 53% increase in spike length and number of kernels per spike of barley, 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. Similarly, Arif *et al*. (2006) reported significant increase in number of grains per spike of wheat by applying or manure and mineral fertilizer in combination as compared to inorganic fertilizer alone.

Grain yield and yield components of barley

Integrated application of lime with half and full recommended rate of organic and inorganic fertilizer (NPSB, urea, KCl and compost) were gave higher grain yield of barley as compared to control plots (Table 5). Hence, the highest mean yields (5386 kg ha^{-1}) obtained over the control with 1318 kg ha^{-1} with integrated application of 0.611t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1} (Table 5) This indicates that the synergistic effect of applied lime with recommended rate of organic and inorganic fertilizers was gave highest productivity of barley. Application of integrated organic and inorganic nutrient sources was not adequate enough to increase grain yield of barley significantly without integration of lime (Table 5). 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}).

In contrary, grain yield of barley which was 1.6 t ha^{-1} with sole application of lime increased to 4.4 to 5.3 t ha^{-1} when integrated with balanced fertilization (Table 5), which indicates the positive interaction of lime with organic and inorganic fertilizers. The lower yield of barley (1670 kg ha^{-1}) was exhibited with sole application of 150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1} in the absence of lime and compost integration which is mainly attributed to adverse effect of soil acidity on the availability of plant nutrients (Merino *et al*., 2010). Furthermore, similarly Shiferaw and Anteneh (2014) found application of lime and all combinations of fertilizers, either alone or combined, significantly increased barley yield over untreated control.

Table 5. Effects of lime, blended fertilizer and compost on thousand seed weight, harvest index, grain yield, straw yield, biological yield and straw yield of barley in Wolmera district West Showa, Ethiopia.

No.	Treatments	Thousand seed weight (g)	Harvest index (%)	Grain yield (kg ha^{-1})	Biomass yield (kg ha^{-1})	Straw yield (kg ha^{-1})
1	Control	10^{c}	38^{c}	1318^{c}	3433^{c}	2116^{b}
2	5 t compost ha^{-1}	37^{b}	39^{c}	1617^{c}	4173^{c}	2556^{b}
3	611kg lime ha^{-1}	36^{b}	37^{c}	1683^{c}	4483^{c}	2801^{b}
4	611kg lime + 5 t compos t ha^{-1}	37^{b}	40^{bc}	1745^{c}	4267^{c}	2522^{b}
5	150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}	38^{b}	43^{abc}	3811^{b}	8917^{b}	5106^{a}
6	150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}	37^{b}	42^{abc}	1670^{c}	3967^{c}	2296^{b}
7	611kg lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	38^{b}	45^{ab}	4414^{ab}	9820^{ab}	5406^{a}
8	611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	44^{a}	47^{a}	5386^{a}	11500^{a}	6114^{a}
9	611kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}	42^{a}	44^{ab}	4800^{ab}	10767^{ab}	5967^{a}
	LSD (5%)	2	0.05	1099.7	2467.9	1465.3
	CV (%)	2.25	4.43	13.08	12.66	13.21

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

The synergistic effect of applied lime with organic and inorganic plant nutrient sources highly influenced ($P \leq 0.0001$) thousand seeds weight of barley (Table 5). The highest thousand seeds weight of barley (44 g) was recorded with application of 0.611 t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1} followed by (43g) with application of 611kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1} over control plots (10 g) which is attributed to better availability of nutrients. The lowest thousand seed weight could be due to shriveled seeds that have small size which contributed to the less grain weight. Increased combination of lime, organic and inorganic fertilizers, increased thousand seed weight of barley from 10 g to 44 g. Similarly, Mitiku *et al*. (2014) reported that application of 5 t FYM ha^{-1} 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. Likewise, Saidu *et al*. (2012) obtained the highest 1000 wheat grain weight, from application of 5 t FYM ha^{-1} in combination with 50% inorganic NP, while the lowest 1000 grain weight was recorded from no fertilizer application.

The harvest index of barley was significantly ($P \leq 0.0001$) influenced with integrated application of lime with recommended rate of organic and inorganic fertilizers (Table 5). The highest harvest index of barley (47 %) was obtained with 0.611 t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg Urea ha^{-1} as compared to other treatments that received less combination of applied lime and fertilizers (Table 5). Barley 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 to the seed. Similarly, Mooleki *et al*. (2002) indicated 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).

The mean dry biomass of barley is indicated in Table 5. Higher dry biomass yield (11500 kg ha^{-1}) and straw yield (6114 kg ha^{-1}) were obtained with 611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1} as compared to control for biomass yield (3433 kg ha^{-1}) and straw yield (2115 kg ha^{-1}). Similarly, Getachew *et al*. (2014) found 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, increasing both parameters (straw and total biomass yield) without affecting the grain yield through lodging effect of barley, farmers in the highlands of Ethiopia could be benefited by increasing grain yield and straws to alleviate food and animal feed shortage problems (Woldeyesus *et al*., 2004).

Nutrient concentrations and uptake in barley

Integrated application of lime with organic and inorganic fertilizers significantly increased the concentration of total nitrogen, phosphorus, potassium and Sulfur in barley grain.

Table 6. Integrated use of lime, blended fertilizer and compost on total nitrogen, phosphorus, potassium and Sulphur concentrations and uptake (Kg ha^{-1}) of barley grain in Wolmera district West Showa, Ethiopia.

No.	Treatments	Nutrient concentrations				Nutrient uptake(kg/ha)			
		TN %	P (ppm)	K (meq/100g)	S %	N	P	K	S
1	Control	1.16^{f}	0.18^{d}	0.19^{c}	0.17^{d}	15.29^{c}	2.46^{c}	2.59^{b}	2.25^{c}
2	5 t compost ha^{-1}	1.21^{e}	0.22^{c}	0.21^{bc}	0.18^{cd}	19.67^{c}	3.55^{c}	3.52^{b}	2.95^{c}
3	0.611 t lime ha^{-1}	1.22^{e}	0.22^{c}	0.22^{bc}	0.18^{cd}	20.53^{c}	3.69^{c}	3.70^{b}	3.01^{c}
4	0.611t lime + 5 t compos t ha^{-1}	1.25^{d}	0.23^{c}	0.24^{b}	0.19^{cd}	21.91^{c}	4.04^{c}	4.18^{b}	3.36^{c}
5	150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}	1.28^{cd}	0.32^{b}	0.27^{a}	0.20^{c}	60.91^{a}	15.34^{b}	12.95^{a}	9.82^{b}
6	150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}	1.22^{e}	0.23^{c}	0.23^{b}	0.18^{cd}	20.37^{c}	3.83^{c}	3.84^{b}	3.12^{c}
7	0.611t lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	1.32^{b}	0.33^{b}	0.28^{a}	0.26^{ab}	58.56^{b}	14.56^{b}	12.70^{a}	11.47^{b}
8	0.611t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	1.37^{a}	0.36^{a}	0.28^{a}	0.27^{a}	74.15^{a}	19.65^{a}	16.05^{a}	15.13^{a}
9	0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}	1.31^{bc}	0.32^{b}	0.27^{a}	0.25^{b}	63.19^{ab}	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

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

The combined effect of applied lime with organic and inorganic plant nutrient sources significantly increased the nutrient concentrations of total nitrogen, phosphorus, potassium and sulfur from 1.16 %, 0.18 ppm, 0.19 meq 100g soil^{-1}, 0.17 % to 1.37%, 0.36 ppm, 0.28 meq 100g soil^{-1}, 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 with organic and inorganic nutrients in grain of barley might 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.

There was a wide variation of total nitrogen, phosphorus, potassium and sulfur uptake in grain observed due to different integrated use of lime with organic and inorganic fertilizers (Table 6). Higher N (74 kg ha^{-1}), P (19.65 kg ha^{-1}), K (16.05 kg ha^{-1}) and S (15 kg ha^{-1}) were obtained with 0.611 t lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1} as compared to control (Table 6). 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 of barley. 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 Martinez–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). Likewise, Nasreen and Farid (2003) who demonstrated that the application of 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 of lime integrated with compost and blended fertilizer (NPSB) on production of barley

Application of lime integrated with compost and blended fertilizer (NPSB) indicated that the highest net return of EB 30633 with highest marginal rate return of 667 % with values to cost ratio of EB 5.49 profit per unit investment for barley production as obtained from application of 0.611 t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1} followed by net return of EB 24489 and marginal rate return of 381 % with values to cost ratio of EB 5.25 profit per unit investment for barley production was obtained from application of as 150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1} (Table 7). 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. Therefore, it would be advisable for farmers in the study area to apply integrated lime at 0.611 t 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 36 kg ha^{-1}) for better barley production and economic return in acid soils of *Wolmera* District, west Showa.

Table 7. Integrated use of lime, organic and inorganic fertilizer effects on partial budget and marginal rate of return (MRR) analysis for barley production

No	Treatments	Mean grain yield (kg ha^{-1}) barley	Adjusted yield (kg ha^{-1}) barley	Gross benefit (EB ha^{-1})	Total variable cost (EB ha^{-1})	Net benefit (EB ha^{-1})	Marginal rate return (%)
1.	Control	1317.77	1185.99	10080.9	260.92	9820.02	
2.	611kg lime ha^{-1}	1682.69	1514.42	12872.6	1280.22	11592.4	174
3.	5 t compost ha^{-1}	1616.99	1455.29	12370	3320.16	9049.79^{D}	-
4.	611kg lime + 5 t compos t ha^{-1}	1744.82	1570.34	13347.9	4292.52	9055.36^{D}	-
5.	150 kg DAP +100 kg KCl + 72 kg N kg ha^{-1}	3810.67	3429.61	29151.7	4662.86	24488.8	381
6.	150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1}	1670.2	1503.18	12777.1	4704.5	8072.55^{D}	-
7.	611kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}	4799.64	4319.67	36717.2	5584.28	30633.00	667
8.	611kg lime + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	4414.24	3972.81	33768.9	6194.87	27574.00^{D}	-
9.	611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}	5385.59	4847.03	41199.8	9387.2	31812.6	31

D: dominated treatment, Field price of barley, lime and compost 8.50, 1.35 and 0.50 EB kg^{-1}, Field price of DAP, Urea, NPSB and KCl were 14.00 11.50, 13.65 and 14.50 EB kg $^{-1}$, Labour cost for harvesting and bagging 22 EB 100 kg $^{-1}$, Labour cost of incorporation and transportation of lime 20 EB 100 kg $^{-1}$, Labour cost of incorporation and transportation of compost 10 EB 100 kg $^{-1}$, (the cost of transport for compost was minimum since it was purchased in the vicinity of farm), Labour cost of application and transport of fertilizer 15 EB 100 kg^{--1}

CONCLUSION

Applications of lime (0.611 t 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 favor the creation of more suitable medium for nutrient uptake of barley. Application of lime creates a favorable soil environment that enables efficient use of both organic and inorganic nutrients which ultimately resulted in better performance of yield and yield components of barley. Integrated use of lime with recommended rate of organic and inorganic fertilizer significantly affected yield and yield components of barley. The growth, yield and yield components of barley and responded significantly to the integrated application of lime with organic and inorganic fertilizers. Nutrient concentrations and uptake of N, P, K and S were significantly increased with full combination of lime, organic and inorganic nutrient sources. Thus, highest yield of barley (5386 Kg $ha^{-1)}$) was obtained with integrated use of lime together with full recommended dose of organic and inorganic nutrients. Application of 0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1} gave the highest net return EB 30633 $ha^{-1}$with marginal rate return of 667 % which is advisable for farmers to maximize barley grain yield ha^{-1} and highest economic return. Therefore, in central high lands of Ethiopia where acid soils are a major production constraint (*Holetta* District especially at *Telecho kebele)*, application of 0.611 t ha^{-1} lime+ 2.5 t ha^{-1} compost + 75 kg ha^{-1} NPSB + 50 kg ha^{-1} KCl and 36 kg ha^{-1} N were recommended for optimum grain yield and economical profitable barley production.

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