12. Improvement of Barley Productivity and Soil Physico-Chemical Properties through Farmyard Manure and Lime Application in Acidic Hot Spot Areas in Northwestern Ethiopia

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Abstract

The experiment was conducted to determine the optimum rates of farmyard manure and lime to increase barley yield and improve soil Physico-chemical properties in Machakel and Guagusa shikudad Districts. The experiment comprised three levels of farmyard manure (0, 2 & 4 tha^{-1}) and four levels of lime (0, 25%, 50% &100%) with one pilot (92N, 69P_2O_5) treatment which was laid out in RBD design with three replications. Data on soil Physico-chemical properties, yield and yield components of barley were collected and subjected to ANOVA using SAS (9.4 version) software. The results revealed that the individual application of farmyard manure and lime significantly affected yield and yield components of barley. Similarly, soil property after planting slightly changed across treatments as compared to before planting. Sole Application of farmyard manure (4 tha^{-1}) and 100% *(8, 8 tha^{-1})* lime *gives the highest grain and above-ground biomass yield (1.7&3.5 tha^{-1}) and (1.6&3.1tha^{-1}) respectively as compared to control and a pilot treatments. Similarly, the application of sole 4 that-1scored the highest plant height (72.9cm) than both control and pilot treatments. On the other hand, the individual supplement of both farmyard manure and lime scored the highest net benefit with acceptable marginal return than control (note receive organic fertilizer). In general, the application of farmyard manure and lime improved yield and yield components of barley and soil properties in the study area. To attain the highest net benefit, within a short period of time application of 4 tha^{-1} and 25% (2.2tha^{-1}) can be preferable for yield improvement in the study area and similar agro-ecological environments.*

Key Words: Lime, Farmyard manure, soil properties, Barley

Introduction

Globally, soil acidity has been known as an important problem, which adversely affects crop production, directly or indirectly, especially in temperate and tropical regions of the world (Brady and Weil 2002). It covers about 30% or 3950 million ha of the land area and occurs mainly in two global belts, the northern belt (cold and temperate climate) dominated by Spodosols, Al*fi*sols, Inceptisols, and Histosols, and the southern tropical belt consisting largely of Ultisols and Oxisols (Sumner and Noble 2003). Acid soils in Ethiopia are widely distributed in highlands under varying climatic and environmental conditions. It covers nearly 40.9 % of the area under cultivation (Geremew et al., 2020). From this 2*7.7*% is moderately acidic (pH 4.5–5.5) and 13.2% is strongly acidic (pH < 4.5) (Taye, 2007). The problem is more expected in areas thathave high rainfall that enable leach exchangeable bases from the soil surface (Achalu *et al*., 2012).

In the case of the Amhara region, about 24% of the cultivated land is affected by acidity (ANRIO, 2006). The severity of soil-related problems affects the agricultural sustainability of cultivated lands. Its problem is known to exert an adverse effect on crop growth directly and indirectly through its effect on nutrient availability. The problem is very acute at Machakel and Guagusa Shikudad woredas, where most of the soils are predominantly acidic in nature with 3.33-5.6 exchangeable acidity. That forced most farmers to grow acid-tolerant crops at the expense of economically important crops or to allocate their cultivated lands to eucalyptus, Acacia decurrens and oat cultivation for the last many years.

Soil acidification is one of the major causes of soil degeneration that come from different sources like addition of acid-forming fertilizers, intensive cultivation, precipitation, and heavy irrigation also result in the development of acidity in these soils. Hence, these soils are poor in basic cations. Poor growth of crops on these soils is attributed to the presence of toxic amounts of iron (Fe), Al, and manganese (Mn), de*fi*ciency of Phosphorus (P), and molybdenum (Mo), and less activity of soil microorganisms (Dhananjaya and Ananthanarayana, 2010). This leads to a decrease in the pH value by increasing exchangeable acidity, which consequently results in a decrease in crop yield. The productivity losses of soils with pH range 5.5– 6.5, 4.5–5.5, and less than 4.5 are up to 10%, 10–25%, and more than 50%, respectively (Jehangir et al., 2013).

Barley is a cool-season crop that is adapted to high altitudes. It is grown in a wide range of agro-climatic ranges between 2200–3000 m a.s.l (Asmare *et al*., 1998). The area allocated to barley reached about 1 million hectares in 2015/16, (CSA, 2016). It is one of the most important crops for food, feed, and income generation for many smallholder farmers in the highlands of Ethiopia (Bayeh and Berhane, 2011) However, the productivity of barley in production fields has remained very low (about 1.3 tha^{-1}) as compared with the world average of 2.4 tha^{-1} (CSA. 2005). Acidity-related soil fertility problem is one of the constraints that contribute to low yield levels of the crop. From our experience, AARC (Adet Agricultural Research Center) was successful with the production of wheat in these acidic hot spot areas (Machakel and Guagusashikudad) through acid soil management by applying only 25% of the lime in rows at planting that was calculated by using exchangeable acidity.

Even if, this method is highly successful for wheat it is not able to achieve for barley production until we add 10.8 tha^{-1} (125% LR). This might be due to the soil being out of production or non-responsiveness related to the severe depletion of soil organic matter beyond the high sensitivity of barley for acidity as compared to wheat (Tigist,2022). Because of this barely yield was low beyond its biological yield potential. Based on this we suggest that in order to produce barley it is important to recover this nonresponsive soil as soil through the addition of organic matter that is the building block of soil.

Liming of acid soils increases soil pH and availability of P, Mo, and N nutrients while it reduces exchangeable acidity (Cairs *et al*., 2005, Nekesa, 2007). Similarly, the application of manure on acidic soils reduces Al^{3+} toxicity and increases the nutrient content of the soils (Hati *et al.*, 2006, Whalen, 2000). But the application of manure is not a complete substitute for lime (Mesfin, 2007). So, it was important to quantify the optimum amount of lime and farmyard manure rate for barely production with the following objectives.

Objective

To assess the economical and biological optimum level of lime and farmyard manure for barley in the highly acidic areas of the Western Amhara region

Materials and Methods

The experiment was conducted in Guagusashikudad and Machakel districts of Amhara Region on farmer’s field for two consecutive years 2020/21-2021/22 cropping seasons at Guagusa shinkurta and Debrekelemo Kebles in Awi and East Gojjam zones respectively, Ethiopia. Guagusa shikudad district is located 129km from Bahirdar the capital city of Amhara region and geographically the area lies at 10^0 36' 22" N and 36^0 25' 15" E (Figure 1) with a mean altitude of 2204 m above sea level. It receives a mean annual rainfall of 1356 mm with mean minimum and maximum temperatures of 10 and 28°C, respectively (BoA). Based on the district bureau of Agriculture, the major land use comprises cultivated land (62.6%), forest and bushes (14.6%), grazing land (22.2%), and others (0.6%). Major crops grown in the study area are barley, wheat, potato, and fababean taking the lions share. The major soil types include Andisols, Nitosols, and Cambisols. Generally, the soil types of the study area are characterized by shallow, moderate to deep, and very deep in-depth and sandy clay to clay texture types (Alemayehu, 2015).

Machakel district is located 235 km away from Bahir Dar. Geographically the area lies at 10˚51'40" latitude and 37^{0}61'66"longitude E (Figure 1) with a mean altitude of 2600 m.a.s.l. It receives a mean annual rainfall of 1350 mm with mean annual temperatures of 25°C, respectively (BoA). Based on the district bureau of Agriculture (BoA), the major land use comprises cultivated land (52.3%), and others (47.7%). Major crops grown in the study area includes wheat, potato, barley, tef, triticale, and oat. The major soil types include Andisols and Nitosols

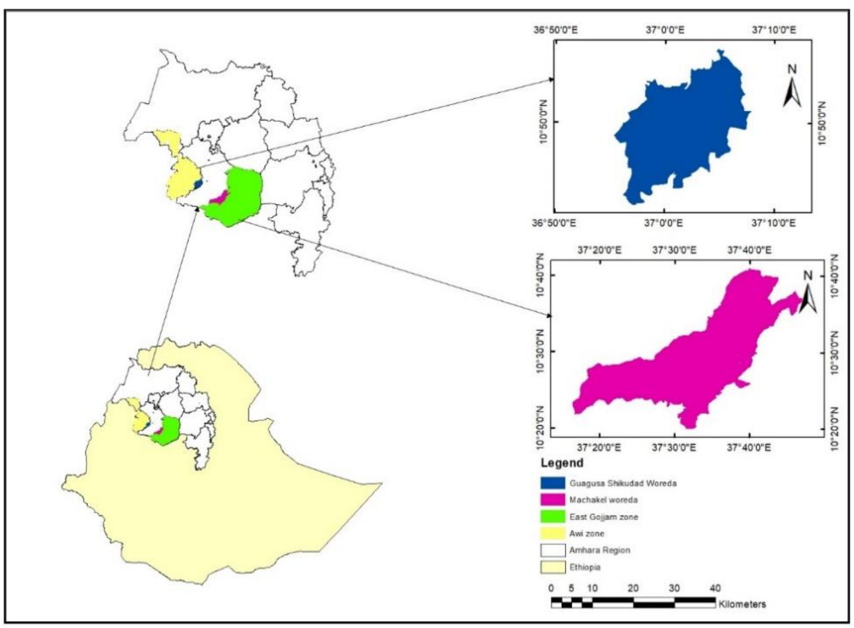

Figure1.The geographical location of the study Areas

Experimental Design and Experimentation: The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Which has thirteen treatments from this the twelve’s were obtained from the combination of three levels of farm yard manure (0,2 and 4 tha^{-1}) and four levels of lime (0,25,50,100 % tha^{-1}) in addition to one pilot treatment (92N,69P_2O_5). The experiment was carried out under rain-fed conditions and food barley variety HB-1307 was used as a test crop. The total area of each plot was 4m x 3 m (12 m^2) having 1m space between plots and blocks as well as 0.2m betweenrows . Recommended fertilizer was applied during the growing period in all plots except pilot plots. Soil samples were collected at depths of 0-20 cm beforehand planting. Simultaneously the core samples per each soil sample were collected for the determination of the bulk density which is important for the calculation of the amount of lime using the following formula.

$$\mathbf{Lime(CaCO3)kg^{-1}ha^{-1}} = \frac{\mathbf{Exacidity(cmolkg^{-1}ha^{-1}) * 0.2m * 10000m^2 * BD(Mgm^{-3}) * 1000}}{\mathbf{2000}} \mathbf{* 1.5}$$

The soil samples were air-dried, ground, and sieved based on the standard procedures. Analysis of soil chemical properties including exchangeable acidity was done in Adet Agricultural Research Center Soil Laboratory. Bulk density was determined by the core sampling method. Before and after sowing major chemical properties of soil such as exchangeable acidity, OC, pH, CEC, total N, and AvP (available P) were analyzed following the compiled laboratory manual of Sahlemedhin and Taye (2000).

Soil pH was measured in water at the ratio of 1:2.5 using a glass electrode pH meter. The soil OC content was determined following the wet digestion method as outlined by Walkley and Black which involves digestion of the OC in the soil samples with Potassium dichromate ($K_2Cr_2O_7$) in sulphuric acid solution. Available P was determined by Olsen extracting method (ref). Total N content in the soil sample was determined following the Kjeldahl method (ref). CEC was determined by extracting the soil samples with ammonium acetate (1N NH_4OAc) followed by repeated washing with ethanol (96%) to remove the excess ammonium ions in the soil solution. Percolating the NH_4^+saturated soil with sodium chloride would displace the ammonium ions adsorbed in the soil and the ammonium liberated from the distillation was titrated using 0.1N NaOH.

Agronomic Data Collection: Plant height and Spike length were measured at maturity from randomly selected five plants and averaged for a single reading. Similarly, Grain and Biomass yield was measured by balance from central rows by avoiding both the right and left two rows as borders for single reading

Statistical Analysis: All data were subjected to analysis of variance by using SAS software program version 9.4 (SAS Institute, 2002) proc glm model. A least significant test (LSD) at a 0.05 probability level was employed to separate treatment means where significant differences exist (Gomez and Gomez, 1984).

Economic Analysis: The partial budget and marginal rate of return (MRR) were used for evaluating the change in farming methods that affect partially rather than the whole farm practice and also concerned with a planning tool to estimate the profit change within a farm (CIMMYT, 1988). This was computed by adjusting the yield downward by 10% and multiplying it by the local field price (23 ETBKg^{-1} of Barley). And the cost of farmyard manure and lime was 0.2 and 0.8 ETBKg^{-1} respectively. Net benefits were considered by current fertilizer (Farm yard manure) cost of 0.2 ETBKg^{-1}, cost of lime Kg^{-1} 0.8 ETB, field price of Barley was 20 ETB Kg^{-1}, and cost of labor per man day in the area was 70 ETB. Dominance analysis was done by listing treatments in increasing order of cost thathas net benefit less than or equal to treatments with lower costs that vary dominated (CIMMYT, 1988).

Result and Discussion

*Soil Chemical Properties before Planting and After Harvest***:** Laboratory results of the soil before planting and after harvesting across districts from each experimental site are described in Tables 1 and 2. The analysis result of soil samples before planting indicated that the sites were acidic with a high exchangeable acidity across each site, which is an unsuitable range of soil exchangeable acidity for barley production Tekalign (1991). Similarly the total N, available P, OC, and CEC of the soil in Guagusa shikudadd and Machakel 2020/21 as well as Machakel 2020/22 before planting were (0.188.0.115 & 0.131%), (14.403,5.776 & 4.560 ppm), (2.734,1.509 & 1.450%), (29.64,24.70 & 23.30 cmol (+) Kg^{-1}), respectively (Table1).The total N content of the soil was within the range of low up to medium according to Tekalign (1991) who classified the range of total N < 0.1, 0.1- 0.15, 0.15-0.25, and > 0.25% as very low, low, medium and high, respectively. Based on Olsen *et al*.,1954 classification, available P content ranged < 5 as very low, 5 -15 as low, 15 -25 as medium, and > 25 mgKg^{-1} as high. Hence the available P of the soil before planting across sites lies under very low to low ranges. Similarly, according to Landon (1991) the soil OC content of the study area before planting ranged 1.45-2.7 and rated as low tomedium On the other hand cation exchange capacity (CEC) ranged from 23-30 cmol(+)Kg^{-1} and are rated as medium and high in the study sites before planting. Generally, the nutrient contents of the study sites especially at Machakel are not good in terms of the availability of major plant nutrients besides Guagusa shikudad with nice CEC.

On the other hand, after harvest, all soil chemical properties changed from the initial soil samples (before planting) in values across experimental sites except inconsistency Guagusa shikudad due to the application of lime with farmyard manure as compared to control and pilot treatments (Table2). Numerically the higher value most of selected soil chemical properties displayed in table two was scored by the application of lime and farm yard manure across sites as compared to control. The increment of these

Table 1. Soil chemical properties before planting across experimental sites

Guagusa shikudad (2020/21)						
BD (gcm $^{-3}$)	TN%	OC%	CEC	AVP (ppm)	Ex. Acidity	LM per site
1.3	0.188	2.734	29.64	14.403	3.33	6.5
Machakel (2020/21)						
BD (gcm $^{-3}$)	TN%	OC%	CEC	AVP (ppm)	Ex. Acidity	LM per site
1.2	0.115	1.509	24.70	5.776	4.81	8.6
Machakel (2021/22)						
BD (gcm $^{-3}$)	TN%	OC%	CEC	AVP (ppm)	Ex. Acidity	LM per site
1.4	0.131	1.450	23.30	4.560	5.60	11.3

Table 2. Soil chemical properties after planting across experimental sites

Treatments	Guagusa shikudad (2020/21)					Machakel (2020/21)					Machakel (2021/22)				
	pH	TN %	OC %	CEC (cmol Kg^{-1})	AVP (ppm)	pH	TN %	OC %	CEC (cmol Kg^{-1})	AVP (ppm)	pH	TN %	OC %	CEC	AVP (ppm)
0,0 (FY*, LM)	5.25	0.07	3.13	31.9	16.01	5.19	0.22	2.52	23.18	9.231	5.04	0.18	1.65	26.94	11.76
0,25% (FY, LM)	5.32	0.11	3.1	34.46	18.14	5.4	0.21	2.17	24.48	12.17	5.33	0.19	1.33	25	11.32
0,50% (FY, LM)	5.45	0.2	3.02	33.18	13.89	5.71	0.19	1.98	30.16	17.94	4.96	0.17	1.31	25.26	12.01
0,100%(FY, LM)	5.48	0.16	2.75	34.5	15.33	6.34	0.22	2.26	29.24	16.32	5.52	0.17	1.36	28.32	10.19
2,0 (FY, LM)	5.2	0.13	3.37	34.96	17.58	5 .18	0.17	2.37	27.66	8.27	5.12	0.18	1.36	25.5	11.26
2,25% (FY, LM)	5.27	0.14	3.06	37.04	19.27	5.22	0.22	1.92	29.28	12.11	5.18	0.19	1.39	30.42	11.76
2,50%(FY, LM)	5.38	0.16	3.19	34.02	16.89	5.43	0.22	2.39	31.64	11.21	5.32	0.18	1.67	30.52	8.88
2,100%(FY, LM)	5.76	0.13	2.94	35.14	17.7	5.48	0.22	2.22	25.94	9.652	5.56	0.18	1.41	29.82	10.63
4,0 (FY, LM)	5.24	0.17	3.44	34.66	19.33	5.07	0.18	2.35	25.32	11.87	4.9	0.13	1.42	20.66	10.51
4,25% (FY, LM)	5.31	0.16	3.21	34.54	17.7	5.18	0.23	1.92	27.5	7.55	4.98	0.14	1.58	28.4	8.755
4,50% (FY, LM)	5.2	0.2	3.19	31.36	19.96	5.73	0.24	2.13	32.16	14.52	5.03	0.18	1.3	29.34	10.13
4,100%(FY, LM)	5.54	0.13	3.08	33.92	16.83	6.14	0.21	2.44	28.6	10.25	5.78	0.16	2.12	31.28	10.82
Pilot	5.08	0.13	3.1	38.4	17.64	5.15	0.22	2.28	28.36	10.91	5.15	0.19	1.07	26.36	9.881

**NB: FY =farmyard manure levels (0, 2, 4 tha^{-1}), LM=lime levels (0, 25, 50,100%) of Lime requirements in each sites, pilot = (92 N, 69 $P2O_5$), pH=concentration of hydrogen, TN=total Nitrogen, OC=organic carbon, CEC=cation exchange capacity, AVP=available Phosphorus*

Plant Height and Spike Length: The combined application of farm yard manure and lime was not significantly ($P < 0.05$) affected plant height (PH) and spike length (SL) across the year and sites (Table 3). Besides the application of farmyard manure (FYM), significantly affected plant height as compared to the control traetment. However, different lime application rates did not show statistical difference with the control treatment in pant hieght. This might be dueto amelroation propertes of lime rather to serves a plant nutrent.. The highest value of plant height (72.9cm) was achieved with the addition of 4 tha^{-1} farmyard manure as compared to both control and pilot treatments that scored (63.1 and 64.8cm) respectively (Table 3). The increase plant height in response to the application of farmyard manure may be due to the improvement of soil properties that enhance good water absorption and nutrient utilization to the plant root system or rhizosphere. Moreover, application of farmyard manure (FYM) may deliver balanced micro and macronutrients as well as enhanced availability of plant nutrients, which would help to boost the metabolic activity of microorganisms and improvement of plant growth. The result is in agreement with the findings of Tolera *et al.,* (2018) who observed that the highest plant height of food barley was obtained by application of 50% vermicompost with 50% conventional compost next to 50:50% conventional with NP. Similarly, the study conducted by Molla *et al*., (2018) indicated that an application of 4 tha^{-1} vermicompost significantly increased food barley height by a value of 6.39 cm as compared to the control.

Table3. The main effect of lime and farmyard manure on plant height and spike length of food barley at Machakel and Guagusa shikudad

Treatment	Guagusa Shikudad 2020/21		Machakel 2020/21		Machakel 2020/22		Combined over years	
	PH (cm)	SL (cm)	PH (cm)	SL (cm)	PH (cm)	SL (cm)	PH (cm)	SL (cm)
0 tha^{-1}FY*	70.7^{b}	6.4	58.8^{b}	6.1	63.4^{b}	5.8	63.1 ± 1.3^{b}	6.1
2 tha^{-1}FY	79.9^{a}	6.6	60.0^{b}	5.9	67.1^{ab}	5.9	69.0 ± 1.6^{a}	6.1
4 tha^{-1}FY	83.0^{a}	6.8	63.5^{a}	6.0	72.1a	6.0	72.9 ± 1.5^{a}	6.2
LSD	**5.0**	**NS**	**3.1**	**NS**	**5.0**	**NS**	**4.5**	**NS**
FY	*****	**-**	*****	**-**	*****	**-**	*****	**-**

N0 1 450.122 W5.984 re 06 00.38 0.72 090.122 W5.984 re 04f 1 0 0 1 450.122 W5.984 re 06 0 11.04

The study is in lined with the finding of Getachew *et al*., (2005) who found that the application of 4 and 8 tha^{-1} FYM with 26 $Kgha^{-1}$ P on acid Nitisols of Holetta, Ethiopia, increased faba bean seed yield by 97 and 104%, respectively, compared to the control treatments. In the same way, the study conducted by Mitku and Tamado, (2016) implied that an application of 5 tha^{-1} farmyard manure gives figuratively the highest (2581 $Kgha^{-1}$) grain yield of food barley as compared to control or untreated treatment. In addition, Molla *et al.*, (2017) indicated that the sole application of vermicompost with a rate of 2, 4 & 6 tha^{-1} can increase grain yield and above-ground biomass by 11, 17 & 26% as compared to control or unfertilized treatment.

Similarly, the sole application of lime beyond its combination with farmyard manure significantly affected both grain yield and above-ground biomass of food barley at ($p<0.05$) in table 4. The highest value of both gain yield (1.6 tha^{-1}) and above ground biomass (3.1tha^{-1}) was observed at 100% lime (8.8 tha^{-1}) application as compared to control and the pilot treatment. However, there was no statistical yield difference between different lime rates (Table 4). Similarly, except 25% of the full dose of lime, there no biomass yield difference among lime rates. This might be related to the amelioration of soil acidity as the pH increased thathave reduced the active forms of Al and Fe besides the enhancement of the availability of P, Ca, and Mg and improvement in the physical environment of soil in the plant root system. The study agreed with the findings of Rajneesh (2018) who revealed that the supplying of lime for four decades in wheat-maize cropping system increased grain yield of wheat continuously as compared to control and N alone treatments. Similarly, the result coincides with Asmamaw *et al*., (2020) who observed that an application of 25% lime gives a 90.23% yield advantage over previously wheat production years in highly acidic areas of the northwestern Amhara region.

Table4. Main effect of lime and farmyard manure on grain yield and above-ground biomass of Barley at Machakel and Guagusa shikudad.

Treatment	Guagusa 2020/21		Machakel 2020/21		Machakel 2020/22		Combined over years	
	GYtha^{-1}	BY tha^{-1}	GY tha^{-1}	BY tha^{-1}	GYtha-1	BYtha-1	GYtha^{-1}	BYtha^{-1}
0tha^{-1} FYM*	1.1^{b}	2.3^{c}	0.87^{b}	1.9^{b}	1.1^{b}	2.0^{b}	1.1±0.48^{c}	2.1±0.12^{c}
2tha^{-1} FYM	1.8^{a}	3.4^{b}	1.2^{a}	2.8^{a}	1.1^{b}	2.2^{b}	1.4±0.08^{b}	2.8±0.87^{b}
4tha^{-1} FYM	2.1^{a}	4.0^{a}	1.3^{a}	3.1^{a}	1.7^{a}	3.4^{a}	1.7±0.07^{a}	3.5±0.65^{a}
LSD								
FY								
0%Lime (0 tha^{-1})	1.5	3.0	0.82^{b}	1.8^{c}	1.1	2.2^{b}	1.2±0.09^{b}	2.3±0.18^{c}
25%Lime (2.2 tha^{-1})	1.6	3.0	1.1^{a}	2.5^{b}	1.3	2.6^{ab}	1.4±0.09^{a}	2.7±0.18^{b}
50%Lime (4.4 tha^{-1})	1.8	3.3	1.2^{a}	2.9^{b}	1.2	2.6^{ab}	1.4±0.08^{a}	2.9±0.15^{ab}
100%Lime (8.8 tha^{-1})	1.8	3.6	1.3^{a}	3.1^{a}	1.5	2.9^{a}	1.6±0.09^{a}	3.1±0.18^{a}
LSD	NS	NS	0.24	0.5	NS	0.46	0.20	0.40
Lime*FY	NS	NS	NS	NS	NS	NS	NS	NS
CV%	19.5	21.4	22.1	20.1	22.6	18.8	26.2	23.6
Lime	-	-	*	**	-	*	**	**
Pilot (92N,69P_2O_5)	1.1	2.2	0.67	1.5	1.1	2.2	1.0	2.1

**NB: FY=farmyard manure, GY=grain yield, BY= above-ground biomass*

Partial Budget Analysis: The marginal rate of returns of 100% was used to determine the acceptability of treatments. This economic analysis indicated that all most all the farmyard treatments give the highest net benefit than control (Table 5). Addition of both 2 and 4 tha^{-1} FY (farmyard manure) scored (24,170 ETB) and (28,540 ETB) net benefit with marginal rate of return of 424.3% respectively. This indicate that for every 1ETB invested for 2 and 4tha^{-1} FY in farm land can enables farmers obtain an additional 4.24ETB (CIMMYT, 1988). Similarly, economical analysis of lime also indicated that addition of 25%lime (2.2 tha^{-1}) numerically gives the highest (21600) net benefit with marginal rate of returns of 55.2% as compared to control and other dominated treatments. This also implies that for every 1ETB invested for 2.2 tha^{-1} (25% lime) in farm land can enables farmers obtain an additional 0.552ETB (CIMMYT, 1988). All Un-dominated treatment for farmyard manure and lime sole application could be acceptable for barley producers in the study area except the dominated one's. So that by considering the residual importance of farmyard manure for soil and crop production application 4 tha^{-1} FY with 25%lime (2.2 tha^{-1}) should be recommended in these acid hot spot areas for barley production.

Table 5. Partial budget and marginal analysis of barley as affected by the main effect of farmyard manure and lime application in acid hot spot areas of northwestern Amhara Region.

Farmyard manure	Actual Grain Yield tha^{-1}	10% Adjusted Grain Yield t ha^{-1}	Total variable Cost ETB ha^{-1}	Net Benefits ETB ha^{-1}	MRR%
$0tha^{-1}$FY	1.1	0.11	0	19800	0
$2tha^{-1}$FY	1.4	0.14	1030	24170	424.3
$4tha^{-1}$FY	1.7	0.17	2060	28540	424.3

Lime

Lime	Actual Grain Yield tha^{-1}	10% Adjusted Grain Yield t ha^{-1}	Total variable Cost ETB ha^{-1}	Net Benefits ETB ha^{-1}	MRR%
0%Lime(0tha^{-1})	1.2	0.12	0	21600	0
25%Lime(2.2tha^{-1})	1.4	0.14	2320	22880	55.2
50%Lime (4.4tha^{-1})	1.4	0.14	4640	20560	D
100%Lime (8.8tha^{-1})	1.6	0.16	9280	19520	D

Conclusion and Recommendation

Yield and yield components of barley were significantly affected by the effect of farmyard manure and lime as individual application rather than their combination. Barley that was grown on by sole application of farmyard manure and lime was improved in yield and yield components as compared to control and pilot treatment. The addition of farmyard manure as organic nutrient fertilizer had a positive impact on plant height, grain yield, and above ground-biomass. Application of farmyard manure gives a higher net benefit when compared to control. Treatments with the application of 2- and 4 tha^{-1} of FYM for this experiment give a better net benefit response with over 100% marginal rate of return than the control. Similarly, individual application of lime significantly affected both grain yield and above-ground biomass as compared to control and pilot treatment. Additionally, it also gives a higher net benefit with acceptable marginal returns as compared to control. The study identified that the highest net benefit could be obtained from the individual application of farmyard manure and lime. Related to this application 4tha^{-1}FY and 25% lime (2.2tha^{-1}) gives a higher net benefit with 424.3% and 55.2% marginal returns respectively. Therefore, resource-poor small-scale farmers can be benefited, if they apply these soil improvement rates depending on their convenience. As we see barley yield is low as compared to its biological yield potential and yield of wheat that we have achieved in the lime trial in this area is about 3-4 tha^{-1}. This may be related to its sensitivity to acidity than wheat. So to make barley an alternative crop in the farming system in this non-responsive acid hot spot area soils like Debrekelemo and Guagusa shikudad; It needs high investment to enhance soil organic matter through application such as compost, farmyard manure , vermicompost, and by practicing of agroforestry, soil and water conservation measures.

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