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Evaluation of Micro-Dosing Lime Application on Selected Soil Chemical Properties and Faba Bean Crop Performance in Acid Soil Prone Areas of Central Ethiopia

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Abstract

High cost of lime has precluded their use by smallholder farmers to reclaim soil acidity in Ethiopia particularly in the study area. To address the problem, we tested a precision technique referred to as micro-dosing, which involves application of small, affordable quantities of lime on an acid soil in Welmera and Jeldu districts, Ethiopia. Experimental treatments consisted of control (without amendment); 6.25 % of recommended lime; 12.5% of recommended lime; 25.0 % of recommended lime; 33.3 % recommended lime and Full recommended lime. Soil chemical parameters, faba bean seed yield and yield components were determined. Micro- dosing and full application of lime significantly affected the soil pH and Exchangeable acidity. Seed yield of faba bean were significantly increased from 47.6 % to 95.9 % over untreated plots due to liming. The highest net benefit and the MRR of 92423.7 birr ha-1 and 956.4% respectively were obtained from the micro dosing application of 25 % of recommended lime per hectare. Therefore, micro- dosing of 25% recommended lime application (determined through exchangeable acidity based lime requirement) during planting time appeared the most economically affordable treatment and that can increase faba bean production on acid soils of central highlands of Ethiopian.

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Keywords: Biomass yield; Exchangeable acidity; Lime; Seed yield; Soil pH

Introduction

Faba bean (*Vicia faba* L.) is an important highland pulse crop in Ethiopia, which covered 466,697 ha of the cultivated land with annual production of 1,006,752 tons and a productivity of 2157 kg ha^{-1}. The crop takes the largest share of the area under pulses production. It is a crop of manifold merits in the economy of the farming communities in the highlands of Ethiopia and serves as a source of food and feed [1]. It is one of the legumes being integrated into the smallholder farming systems to improve soil fertility through atmospheric nitrogen (N_2) fixation and serve as cheap source of protein. According to report of the productivity of faba bean in Ethiopia is quite low as compared to UK, which is about 3 t ha^{-1}. Several factors account for the low productivity of faba bean, of which soil acidity and fertility decline, frequent disease occurrence, parasitic weeds and lack of high yielding varieties could be mentioned as key factors [2].

Soil acidity is one of the main factors that limit and prevent profitable and sustained agricultural productivity in many parts of the world [3]. It is expanding both in scope and magnitude in Ethiopia, severely limiting crop production. The increasing trend of soil acidity and exchangeable Al^{3+} in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid forming inorganic fertilizers [4]. About 43% of the total arable land in Ethiopia is affected by soil acidity. Soil acidity limits or reduces crop production primarily by impairing root growth thereby reducing nutrient and water uptake. Acidic soils are also poor in basic cations such as Ca, Mg, K and some micronutrients which are essential to crop growth and development [5]. The soils of the study sites were characterized by extreme and very strong acidity, with very high exchangeable aluminum and very low available phosphorous content. In order to alleviate such types of problems, soil amendment techniques are crucial from these amendments liming is preferable technique.

Liming is an important practice to achieve optimum yields of all crops grown on acid soils. Application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop yields on acid soils. Adequate liming minimizes toxicity of Al and Mn to crop plants [2,6] and improves soil structure (aeration); Gere mew improves availabilities of Ca, P, Mo, and Mg, and N_2 fixation; and reduces the availabilities of Mn, Zn, Cu, and Fe and leaching loss of cations; resulting in increased available P, and P up take and use efficiency [6]. For several crops, liming results in some chemical changes in the soil such as, increase in pH and decrease in exchangeable acidity and Al content [6], increase in Cation Exchange Capacity (CEC), and exchangeable Ca, decrease in toxic elements, for example Al^{3+} and Mn^{2+} and changes in the proportion of basic cations in CEC sites [7,8]. Also reported that liming is the most widely used relatively long-term methods of soil acidity amelioration and its success is well documented. Limited knowledge on lime usage method application and its effectiveness, availability and high hauling costs of liming materials [9].

Micro-dosing technology was developed and promoted by ICRISAT and partner institutions a decade ago to promote the use of fertilizers in the semi-arid tropics [10,11]. The technology was developed for providing sufficient nutrients, especially on poor soils or degraded lands in amounts that are not too costly and are not damaging to the environment [11]. Even though it's indicated advantages its limitations are frequent application and it applied during the planting time. Nevertheless, some studies have shown that micro dosing is affordable to farmers as it feches higher returns to farmers from the fertilizer quantities that they forced to purchase [10,12].

Amendment of acidic soil with application of lime has been widely practiced and recommended by several researchers to reduce the negative effects of soil acidity on nutrient availability and crop productivity [2,6,13,14]. As a result, many researches have been conducted in different parts of Ethiopia with large amounts of lime [15,16] who reported that large amounts of lime had tremendous role in the change of soil chemical properties of acidic soils [17]. Reported that, without a significant yield loss and harming soil health, splitting lime into one third and half and applying in three and two consecutive years, give similar yield with the full rate of lime applied once in the first year. However, there is no much scientific research conducted on the application of lime in small amount (micro dosing) in Ethiopia. Therefore, there is need to test this technology in highly acid prone areas that limit crop production that has threatened the livelihood of small holder farmers in the area. Thus, this study was aimed to investigate the short term effects of micro-dosing of lime on improving yield and yield components of faba bean and selected soil chemical properties in acidic soil of central highlands of Ethiopia.

Materials and Methods

The study was conducted for two consecutive seasons (2019 and 2020) at Welmera and Jeldu districts. Welmera and Jeldu districts are located at a distance of 30 and 73 kilometers in the Northwest direction from Addis Ababa, respectively to the direction of Ambo town. The site at Welmera located at latitude of 09° 03.302' North and longitude of 038° 05.623 East, with an altitude of 2390 meter above sea level (masl); and the site at Jeldu located at 09°16.094' North and longitude of 038°30.362' East, with an altitude of 2582 masl. The mean annual rainfall of the districts is 1300-1428 mm. The annual mean temperature also varies from 12°C to 25°C with mean value of 18.5°C. The districts are classified into one agro- climatic zone, which is highland with wet and cool weather condition (Holetta meteorology station).

Experimental treatments design and procedure

The amount of lime applied was calculated based on exchangeable acidity, bulk density, 0.15 m plough depth as follows

$$LR\,(CaCO_3\;kg/ha) = \frac{EA\,(cmol/kg\;of\;soil) * 0.15\,m * 10^4\;m^2 * BD\,(Mg/m^3) * 1000}{2000} * 2.0$$

Where LR=Lime requirement of the soil based on exchangeable acidity and EA=Exchangeable acidity.

The exchangeable acidity of Welmera and Jeldu sites were 1.32 meq/100g soil and 3.42 meq/100g soil respectively.

Based on the above equation, full dose of lime applied was 2640 and 6840 kg ha^{-1} $CaCO_3$ for Wlemera and Jeldu, respectively. Accordingly, the treatments consisted of control (without amendment), 6.25 % of recommended lime, 12.5% of recommended lime, 25 % of recommended lime, 33.3 % recommended lime and Full recommended lime, using randomized complete block design with three replications.. The control refers to farmers' practice where no lime was applied. All the treatments received full recommended site specific fertilizer uniformly at planting. Lime and fertilizer were applied using band application method at planting and mixed with the soil manually. Faba bean variety Moti was used as a test crop. The plot size was 4mx 3m. Spacing between plots and replications was 1 m and 1.5 m, respectively. Five central rows were considered as net harvestable plot. All other cultural practices were applied uniformly to all the experimental units as per the requirement of the crop.

Soil sampling and analysis

A composite soil samples were collected from the experimental plots in a diagonal pattern from the depth of 0-20 cm before planting and after harvesting. Uniform slices and volumes of soil were obtained in each sub-sample by the vertical insertion of an auger after which the sub-samples were made into a composite soil sample. Then, soil samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2mm sieve and analyzed for the selected soil physico-chemical properties mainly total nitrogen, soil pH, exchangeable acidity, available phosphorus, available potassium, cation exchange capacity and exchangeable bases using standard laboratory procedures. Soil texture was determined using Bouyoucos hydrometer method. The pH of the soil was determined according to FAO (2008) using 1:2.5 (weight/volume) soil sample to water solution ratio using a glass electrode attached to digital pH meter. Total nitrogen was analyzed by Micro-Kjeldhal digestion method using sulphuric acid. The Cation Exchange Capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc. Available phosphorus was determined by the Bray II method. Exchangeable acidity was extracted using unbuffered 1M KCl, The basic cations (Ca, Mg, Na and K) were extracted using ammonium acetate at soil pH 7 and determined using atomic absorption spectrophotometry.

Data Collection

At harvest, five plants were taken at random from the center to estimate: plant height (cm), number of pods per plant, number of seeds per pod and thousand seeds weight (g). Total aboveground biomass yield was determined by weighing after complete sun-drying at harvest from the net plot of 7.2 m^2 and converted into kilogram per hectare. Grain yield was measured by threshing the dried plants from the net plot area.

Statistical Analysis

All the agronomic and soil data were subjected to analysis of variance (ANOVA) using SAS computer software version 9.3 (SAS, 2002) and the least significant difference between means (LSD) used to separate the treatment means at statistical significance level of $P \leq 0.05$. Partial budget analysis was carried out following CIMMYT (1988) procedure based on local market price.

Results and Discussion

The Analysis of variance showed that there was a significant micro-dosing effect of lime application ($P \leq 0.01$) on selected soil chemical properties (soil pH, exchangeable acidity), growth (plant height) and yield and yield components (number of pods per plant, biomass yield and thousand seed weight of faba bean) (Table 1).

Source of variations	Soil pH	Exch. Acidity	Plant height	No. pods plant-1	Grain yield	Biomass yield	Thousand seed weight
Treatment	*	**	**	*	**	**	**

Table 1: Level of significance for soil chemical properties, growth and yield parameters of wheat for treatment.

Where; ns, * and ** = non-significant, significantly different at 5%, and 1%, respectively.

Soil physico-chemical properties of the experimental site

The soils textural class was clay (Table 2). The soil was very strongly acid in reaction. The exchangeable soil acidity was 2.248 cmol $_{(+)}$ kg^{-1} soil. Under such soil acidity environment, crop growth is adversely affected due to the toxicity of Al affecting plant roots development, reduced availability P and microbial activity such as atmospheric N_2 fixation and OM decomposition. The available P falls within the low range and therefore indicates the need for applying supplemental P in these soils. Exchangeable Ca^{2+} and Mg^{2+} were in the range of medium, while exchangeable K^+ was in the very high range. The soils had medium total N. The result of LR determination indicates that the amount of lime required to raise the pH of the soils was 3.01 t $CaCO_3$ ha^{-1}. Since the soil has high clay content and CEC and thus high buffering capacity, high amount of lime was required to alleviate acidity and increase the productivity of acid sensitive crops.

Parameters	Jeldu	Welmera	Rating	References
Clay [%]	44	61	----	----
Silt [%]	41	26	----	----
Sand [%]	15	12	----	----
Textural Class	Clay	Clay	----	----
pH [1:2.5]	4.42	4.6	very strongly acidic	Tekalign (1991)
Exchangeable acidity [cmol(+) kg-1 soil]	3.42	1.32	----	----
P [mg kg-1])	10.9	16.64	Medium	Landon (1991)
N (%)	0.244	0.14	Moderate	Tekalign (1991)
CEC [cmol(+) kg-1 soil]	18.18	19.14	Moderate	Hazelton and Murphy (2007)
K [cmol(+) kg-1 soil]	1.225	1.19	Very high	FAO (2006)
Ca [cmol(+)kg-1 soil]	8.37	7.01	Medium	FAO (2006)
Mg [cmol(+)kg-1 soil]	1.09	1.41	Medium	FAO (2006)

Table 2: Status of selected soil physical and chemical properties of the experimental sites before sowing of faba bean.

Micro-dosing application effect of lime on selected soil chemical properties after harvesting

The results of micro dosing application effect of lime on selected soil chemical properties after a harvesting were presented in Table 3. Post-harvest soil analysis result indicated that micro dosing effects of lime application had significant effect on Soil pH and Exchangeable acidity. The responses of Soil pH and Exchangeable acidity to soil amendment using agricultural lime ($CaCO_3$) varied significantly among study sites. The analysis of variance showed Soil pH and Exchangeable acidity were significantly affected by the location. The highest Soil pH (5.79) and the lowest exchangeable acidity (0.20) were attained from Welmera location (Table 3). While the lowest soil pH and the highest exchangeable acidity was obtained from Jeldu site. The variation in soil pH and exchangeable acidity between districts could be due to the difference in climatic factors, agronomic practices and soil fertility status especially the magnitude of variation in soil acidity of the study site.

Factors	Soil pH [1:2.5]	Exchangeable Acidity [cmol(+)kg-1]
Locations		
Welmera	5.79a	0.20b
Jeldu	5.13b	2.08a
LSD(0.05)	0.13	0.08
Treatments		
Control	5.29c	1.62a
6.25% of recommended lime	5.4abc	1.53ab
12.5% of recommended lime	5.36bc	1.46b
25.0% of recommended lime	5.55ab	0.98c
33.3% of recommended lime	5.62a	0.66d
Full recommended lime	5.53ab	0.57d
Mean	5.46	1.14
LSD(0.05)	0.23	0.14
CV (%)	3.46	0.09

Table 3: Micro dosing application effect of lime on soil pH and Exchangeable acidity.

CV- coefficient of variation, LSD- least significant difference

Soil pH

The analysis of variance (ANOVA) showed that soil pH of all limed plots had a significant difference (P<0.01) as compared to the control plot. The highest soil pH was registered (5.62) for the treatment in which 33.3% of recommended lime (1.01 t ha^{-1}) of lime was applied but this was at par with soil pH obtained with the application of 25 % of recommended lime and full dose. The lowest soil pH (5.29) was registered for the control plot which improved soil pH to 5.62 (Table 3). The increase in soil pH with increased lime application rate was associated with the presence of basic cations particularly Ca^{2+} and replaced H^+ on exchangeable site resulting to the rise of pH. Application of high quantities of lime increases the pH of bulk soil. However, micro doses application of lime increases pH more efficiently on the application than applying to the bulk soil [11] stated that micro dosing provides sufficient nutrients, especially on poor soils or degraded lands reducing application cost and maintaining favorable environment. Thus, small scale farmers could afford micro dosing application of lime with limited expenditure by increasing its pH significantly than unlimed plot. These findings are in agreement with the findings of [18] who reported increase in soil pH with the increased in lime addition.

Exchangeable acidity

As revealed by the analysis of variance (ANOVA), there was a highly significant (P<0.01) variation in exchangeable acidity among treatments. The highest exchangeable acidity (1.62 $cmol_{(+)}kg^{-1}$) value was measured from the control plot while the lowest (0.57 $cmol_{(+)}kg^{-1}$) from a plot that received 33.3 % of recommended lime application i.e. 3.01 t ha^{-1} lime but at par with exchangeable acidity obtained at 25 and full recommended lime (Table 3). Hence, increasing lime rate from the lower to higher rates resulted in consistent reduction of exchangeable acidity. The reduction of exchangeable acidity of the soil might be due to the increased replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al as $Al(OH)_3$, furthermore the increase in soil pH due to lime application contributed for decreasing the exchangeable acidity [6]. In their study on the effect of lime and P on acidic Nitosls of Welmera district on average indicated that applied lime neutralized the acidity and increased pH from 4.75 to 5.34, lowered the exchangeable acidity from 2.32 to 0.43 $cmol_{(+)}kg^{-1}$. Similarly, reported that application of 2 t ha^{-1} lime reduce exchangeable acidity from 0.6 to 0.44 $cmol_{(+)}kg^{-1}$. Likewise, also stated that, addition of 11.2 and 9.2 t ha^{-1} of lime reduced the exchangeable acidity of a very strong acid soil from the original value of 2.31 to 0.23 and 0.14 $cmol_{(+)}kg^{-1}$, respectively. Lowering of exchangeable acidity and rising of pH can provide a wide range of benefits in terms of soil quality, notably by chemically improving the availability of plant nutrients, and in some cases by reducing the availability of detrimental elements such as Al [14]. Similarly, an application of the highest rate of lime appreciably reduced soil exchangeable acidity from 2.44 to 0.42 $cmol_{(+)} Kg^{-1}$ after harvest. Many authors [18] also reported improvement of exchangeable acidity due to application of lime on acidic soil.

Micro dosing application effect of lime on growth parameters, yield and yield components of wheat

The micro dosing application effects of lime and locations on growth parameters, grain yield and yield components of faba bean are presented in tables 4 and 5.

Location	Plant height(cm)	Number of pods per plant	Number of seeds per pods
Jeldu	93.1b	10.3	23.9b
Welmera	140.3a	10.9	28.9a
LSD (5%)	7.3	NS	4.0
Treatments			
Control	91.4c	6.3c	20.4b
6.25% of recommended lime	111.9b	10.5b	26.5ab
12.5% of recommended lime	121.9ab	11.0ab	27.1ab
25.0% of recommended lime	126.4a	11.9ab	30.8a
33.3% of recommended lime	130.1a	12.8a	30.7a
Full recommended lime	118.6ab	11.1ab	22.9b
Mean	116.7	10.6	26.4
CV (%)	8.99	16.15	21.9
LSD (5%)	12.6	2.1	6.9

Table 4: Micro dosing effect of lime application on plant height, number of pods per plant and number of seed per pods from 2019/20 to 2020/21.

CV- coefficient of variation, LSD- least significant difference

Location	Seed yield (kg ha-1)	Biomass Yield (kg ha-1)	Thousand seed weight (g)
Jeldu	2455.6b	6985b	737.7
Welmera	2795.0a	10980a	738.6
LSD (1%)	292.6	532.7	NS
Treatments			
Control	1640.5c	5949c	688.0c
6.25% of recommended lime	2500.6b	8455b	746.3abc
12.5% of recommended lime	2422.0b	8930b	724.7bc
25.0% of recommended lime	3215.3a	10112a	790.1a
33.3% of recommended lime	3148.2a	10541a	747.4ab
Full recommended lime	2825.1ab	9909a	733.4abc
Mean	2625.3	8982.5	738.3
CV (%)	16.12	8.58	6.68
LSD (1%)	506.8	922.7	59.0

Table 5: Effect of micro dosing lime application on seed yield, biomass yield and thousand seed weight from 2019/20 to 2020/21.

CV- coefficient of variation, LSD- least significant difference

Effects of location

The responses of faba bean to soil amendment using agricultural lime ($CaCO_3$) varied significantly among study sites. The analysis of variance showed all grain yield and yield components of faba bean except number of pods per plant and thousand seed weight were significantly affected by the location. The highest plant height (140.3 cm), numbers of seeds per pods (28.9), seed yield (2795 kg ha^{-1}) and biomass (10980 kg ha^{-1}) yields of faba bean were attained from Welmera location (Tables 4 and 5). While the lowest was obtained from Jeldu site. The variation in yield and yield attributes of faba bean crop between districts could be due to the difference in climatic factors, agronomic practices and soil fertility status especially the magnitude of variation in soil acidity of the study site.

Plant height

Analysis of variance indicated that plant height was significantly affected by the micro-dosing lime application and location (Table 4). Plant height increased with of the increase in micro dosing lime rates from the control to the highest rate. The significantly tallest plant (126.4 and 130.1cm) was recorded at 25 and 33% of recommended lime; respectively. In contrast, the control plots exhibited significantly lower plant height (91.4 cm) compared to all other treatments. The synergy between lime application and nutrient availability and consequent uptake by plant was very conspicuous in terms of response observed as increased plant height. The increase in plant height with increasing lime rates on acidic soils is highly likely related to the increase in nutrient availability and reduced toxicity of some nutrients such as Al and Mn [6,19-21] reported that liming reduced the detrimental effect of soil acidity on plant growth. Similar results were reported by [22] indicated that plant height was significantly increased with increasing lime rates. With the neutralization of part of the soil acidity by lime application, which create favourable negative charges

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of the soil exchange complex to adsorb the basic cations [23]. This improves soil fertility and gives favourable condition for agricultural production such as; increased plant height observed in this study.

Number of pods per plant and seeds per pod

Results of pooled analysis over two years revealed that number of seeds per pod and number of pods per plant were significantly affected by the micro dosing lime application (Table 4). Significantly higher number of pods per plant and number of seeds per pod were recorded for the plants that received 25 and 33% of recommended lime plots as compared to the lowest was recorded for the control. Liming showed the maximum increase in pod length and pod number per plant of pea in acid soil over the control [24]. Liming also had a significant influence on pod yield of groundnut [25].

Seed yield

Significant variation in seed yield was observed due to the micro-dosing application effect of lime (Table 5). Micro dosing application at 25% recommended lime gave the highest economic yield, but at par with yield obtained at 33.3% of recommended lime (3148.2 kg ha^{-1}). However; a considerable (96%) decrease in yield was recorded when lime was not applied as compared to 25% of recommended lime application. The result also indicated that there was a linear increase in grain yield of faba bean with increasing lime application rates. In other words, lime application strongly affected yield of the crop through positive correlation observed on biomass yield, pods per plant and seeds per plant which directly affected yield of the crop (Table 5). An increase of seed yield from 47.6% to 95.9% was obtained over untreated plots. However, the highest yield was obtained when 25% of recommended lime (3215.3 kg ha^{-1}) followed by 33.3% of recommended lime (3148.2 kg ha^{-1}) and full recommended lime were applied even though both means were at par The result reveals that applying calcium containing lime materials might improve nutrient availability, particularly phosphorus, through reduction of phosphorus fixation [18,26]. Reported that application of lime influenced the availability of soil nutrients, resulting in increased yield and yield components of crops. The above result showed that the increase in lime application rate had direct relation to grain yield of faba bean production since yield was proportionally increased with increasing lime rate. These indicated that lime might enhance the nutrient availability of the soil by increased soil pH and available phosphorous [27]; released nitrogen [28] and also reduced aluminum toxicity [14,17]. Also reported that, without a significant yield loss and harming soil health, splitting lime into one third and half and applying in three and two consecutive years, give similar yield with the full rate of lime applied once in the first year. This confirms that micro dose applications of lime are more effective than single heavy applications of lime.

Biomass yield

Biomass yield of the crop was highly significantly ($P \leq 0.01$) affected by micro dosing application of lime. The highest biomass yield was obtained in plots that receiving 25% and 33% micro dosing application of recommended lime while the lowest biomass yield obtained from Control (Table 5). The result had direct relation with the seed yield increments with increased application of lime (Table 6). The highest biomass yield obtained in plots treated with limed, was probably due to the positive effects of liming on soil properties. Liming improved overall soil properties; soil pH and available P, contrary to this, exchangeable acidity reduced from 2.44 to 0.42 cmol $_{(+)}$ kg^{-1}. This implies that, the overall soil chemical properties become good for crop production. [14,27] indicated that lime might enhance the availability of soil nutrients such as phosphorous through increasing soil pH and reduce aluminum and manganese toxicity. Similarly, the significant increase in faba bean biomass yield due to liming was attributed by increased availability of essential macronutrients such as calcium, magnesium, phosphorus sulphur and decreased the availability of possibly toxic nutrients such as iron, aluminum and manganese in soil [7].

	Biomass Yield	Pant height	Pods per plant	Seeds per Pod
Plant height	-0.377*			
Pods per plant	0.432**	0.475**		
Seeds per Pod	0.625**	-0.021**	0.517**	
Seed yields	0.725**	0.192ns	0.677**	0.648**

Table 6: Correlation among growth parameters, yield and yield components of faba bean at Welmera and Jeldu districts.

** and * indicate significant at P<0.01 and P<0.05 level, respectively.

Thousand seed weight

The analysis of variance showed that the micro dose application rates had significant (p<0.01) effect on thousand seed weight (Table 5). The highest thousand seed weights of 790.1 and 747.4 g were recorded from micro dose application of 25 and 33.3% of recommended lime, respectively whereas 688 g was recorded from the control plot (Table 5). Statistically, the two micro dose lime rates were comparable and significantly superior to all other treatments. Maximum grain weight obtained from the micro dose application rate of lime might be attributed to neutralizing effect of lime. These findings agree with the reports of [18] that also showed that all the lime treatments had higher mean value of thousand seed weights relative to the control, where no lime was applied.

Relationship between seed yield and yield components of faba bean

All the independent variables showed a significant positive and linear relationship with seed yield (Table 6). The correlation analyses revealed that, there was a significant (P<0.01) positive correlation between seed yield and yield related agronomic parameters of faba bean. Seed yield was significantly and positively correlated with biomass yield (r=0.725**), Pods per plant (r=0.677**) and Seeds per Pod (r=0.648**). Biomass yield was positively correlated with almost all agronomic parameters of faba bean crop except plant height. This indicates that increasing yield components of faba bean could result in increased seed yield of faba bean and vice versa.

Economic Analysis

As shown in table 7, total variable costs, which are responsible for yield increase in each treatment, were listed. The economic analysis revealed that application of 6.25 and 25% of recommended lime gave marginal rate return values above 100% which is acceptable. The treatments were dominated by application of 12.5 and 33.3% of micro-dose lime application and full application of recommended lime. The net benefit and the MRR were 92423.7 birr ha^{-1} and 956.4%, respectively from the application of 25% of recommended lime application per hectare. The lowest net benefit was 48722.9 birr ha^{-1}, recorded from the control plot (Table 7). Therefore, micro dose application is the most economically affordable treatments after all treatments. The result is in agreement with [11,28] who reported that micro dosing is one technology that can be affordable to farmers and ensures that poor farmers get the highest returns from this method as they cannot able to purchase highest dose of lime to reclaim the bulk of soil [29-31]. The return of most treatments increased as crop yield raised due to minimum increment in cost of production when compared with the obtained net returns with an acceptable MRR an increase in output will always raise profit as long as the marginal rate of return is higher than the minimum rate of return 100% (CIMMYT, 1988).

Treatments	TY	ADY	GB	TVC	NB	MRR %
Control	1640.5	1624.1	48722.9	0.0	48722.9	
6.25% of recommended lime	2500.6	2475.6	74267.8	767.7	73500.1	3227.5
12.5% of recommended lime	2422.0	2397.8	71933.4	1535.4	70398.0D	-
25.0% of recommended lime	3215.3	3183.1	95494.4	3070.8	92423.7	956.4
33.3% of recommended lime	3148.2	3116.7	93501.5	4061.0	89440.5D	-
Full recommended lime	2825.1	2796.8	83905.5	12183.0	71722.5D	-

Table 7: Dominance and marginal analysis of faba bean yield.

TY=Total yield, ADY=Adjustable yield@10%, GB=Gross Benefit, TVC=-Total Variable Cost, NB=Net Benefit, MRR=Marginal Rate of Return (1 kg of lime with transport costs=3 birr and 1 kg of faba bean costs=30 Birr)

Conclusion

It is indicated that lime increased soil pH and reduced exchangeable acidity. Application of small amounts of lime; for producers that can't afforded to purchase high dose of lime to reclaim their acidic soil, significantly increased faba bean yield suggesting that micro-dosing has the potential to increase faba bean production on study area in P deficient acid soils. The results consistently demonstrate that 25 % of recommended lime as micro-dose resulted in better faba bean growth and yield. However; both growth and grain yields were similar with the other treatments. The results suggest that there is a potential to reduce application rates and increase yield of faba bean through micro-dosing of agricultural lime and provide a solid basis for wider evaluation of the concepts for subsequent rolling out to farmers. Profitability was clearly related to yield and the associated costs of production. Therefore, micro dose application of 25% recommended lime based on exchangeable acidity at planting time is the most economically affordable to increase faba bean production and improve the pH and availability of P on acid soils of central highlands of Ethiopian.

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