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Response of Faba Bean and Acid Soil Properties to Lime and P Fertilizer Application in Hagereselam District Sidama Ethiopia

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Abstract: In the Southern region acid soils, cover poor soil fertility and associated low soil pH adversely affect appreciable areas of arable land and reduce or cause total failure of some sensitive crop yields such as faba bean crops. Faba bean is the most sensitive crop to soil acidity. A field experiment was carried out for three cosuquative years (2014/15 – 2018/19), to identify the influence of lime and P fertilizer on the acid properties of soils under faba bean crop grown on Nitisol and acidic loam Haplic Alisols of Hankomolicha, Southern Region of Ethiopia. The treatments were Five levels of Lime (0, 58.5, 117, 175.5, and 234 kg/ha^{-1}) and four levels of phosphorous (0, 23, 46, and 69 kg/ha^{-1}). The experiment was Laid out in Randomized complete block design with three replications. Pooled mean analysis result showed that, above ground biomass and grain yield were significantly at ($p > 0.05$) influenced by the application of phosphorus fertilizer, lime and by their combined effect. The maximum above ground biomass 17.65 ton/ha and grain yield 6.6 ton/ha was obtained at 46 kg P ha^{-1}. Amongst the liming treatments, the highest above ground biomass and grain yield of faba bean was obtained at the rate of 117 kg/ha ($P < 0.05$). Although at these two levels separately thousand seed weight didn't show significant increase their interaction shows statistically significant effect. In this particular study, as the levels of P increases from 0 to 46 kg P ha^{-1} both above ground biomass and grain yield were increased. It was suggested that for sustainable and higher productivity of faba bean in Hagereselam in Southern Ethiopia, 117 kg ha^{-1} lime and 46 kg P ha^{-1} application is the best solution.

Keywords: Faba Bean, Phosphorus Rates, Available P, Soil Acidity, Basic Cations

1. Introduction

The most significant pulse crop in Ethiopia is the faba bean (*Vicia faba* L.), which takes up about 34% of the total area used for growing pulses [4]. It is a significant winter-sown legume crop grown throughout the world and is important as a cheap food full of proteins and carbohydrates [20]. Based on acreage, production, and foreign exchange earnings, it was the top-ranked cool season food legume [3]. The four primary roles of the faba bean in agroecosystems are to provide high-protein food and feed, boost soil fertility by supplying nitrogen to agroecology systems through symbiotic N_2 fixation with Rhizobium, diversify the crop system to ease pressure on growth and yield from other crops in the rotation, and use less fossil fuel for crop production [15]. Soil acidity and associated low nutrient availability is one of the major constraints to faba bean (*Vicia faba* L.) production on Ethiopian highlands. Under such acid soils, severe chemical imbalance caused by toxic levels of exchangeable aluminum (Al), manganese (Mn) and hydrogen (H) ions coupled with a parallel critical deficiency in available nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn) and molybdenum (Mo) limits the growth and production of legumes [6].

Soil acidity, either natural or developed by human activity, has serious negative effects on the sustainability of annual crop production in various parts of the world. Soil acidity management and crop productivity improvement are therefore important for enhancing food provision globally and regionally.

Several research reports indicated that soil acidity can be easily corrected by liming to increase crop yields of barley [10]; potato [8] bread wheat [14], soybean [5]. Lime ($CaCO_3$ or its equivalent) is widely known as the effective ameliorant for correcting soil acidity [1]. Although not permanent, the direct effect of lime lasts longer than any other amendment [7]), such as organic materials [16].

In the recent past there was a massive campaign to demonstrate the beneficial effect of liming in ameliorating soil acidity on several crops and locations on farmers' field and encouraging results were obtained. But its cost and availability are the main limitation for its wider use. Application of organic matter is another option to mitigate soil acidity. Soil organic matter sequesters Al^{3+} there by avoid its toxic effect on crops growing in acidic soil [17]. In the past few years, experiments were conducted by Wondogent agricultural research to find viable solution to soil acidity around Hagereselam of Southern region and encouraging results were obtained and are briefed in this paper.

Numerous physiological and biochemical processes in plants, including photosynthesis, the conversion of sugar to starch, and the transport of genetic traits all involve phosphorus [21]. It has favorable effects on nodule formation and nitrogen fixation in legume crops and is crucial for the nucleus and cell membrane's structural integrity [20], [18]. Despite the significant addition of phosphorus to soil, the amount of phosphorus that is typically available to plants is low because different chemical reactions, especially in areas with high rainfall, limit the amount of phosphorus that is available to plants. One of the most crucial elements that profoundly influences plant growth and metabolism is phosphorus. Due to P's role in the energy transfer rate that needs to occur in the nodule, legumes require high amounts of phosphorous, making it a major yield-limiting nutrient in many parts of the world [12]. [19] drew attention to the fact that as the solubility of the phosphorous in soil solution increases, plants take up more iron, which increases nitrogen fixation by legumes, which increases protein content and seed quality. Phosphorous stimulates nodule growth and development by contributing to nodule metabolism [13]; [11]. One of the most pervasive soil constraints in highland soils is phosphorus deficiency. Furthermore, [9] said that the acidity of the soil could make faba beans more susceptible to chocolate spot infection, lowering yield. Since phosphorus is the least mobile of the major plant nutrients, it can easily be made unavailable to plant roots.

Due to gradual drops in average yield, faba bean production in Ethiopia is constrained and unable to keep up with the rising local seed demand [2]. It is a crucial crop in the hankomolicha because it helps to break up the monoculture food barley farming system, which is constantly attacked by new rust races and suffers from significant yield reductions. Unquestionably, subsistence cropping systems in Ethiopia are characterized by low crop yields that are mostly nutrient-related soil constraints to crop production. There is very little research on the use of P and how it affects legume growth, nodulation, N_2 fixation, grain yield, and yield components in Ethiopia. Furthermore, it is crucial in the highlands like the study area to plant this crop in the crop rotation system with the application of the best phosphorus fertilizer, which is a limiting factor for the production of faba beans. Indeed, it is crucial to test alternative technologies on different varieties in order to determine their survivability and determine how well-suited they are to the local production environment. The goals of the current study are to ascertain how different faba bean varieties respond to phosphorus fertilizer rates with regard to nodulation and yield components of faba beans as well as to determine how different faba bean varieties interact with phosphorus application rates with regard to yield and yield components of faba beans.

Specific Objectives:

1) To determine optimum lime and P fertilizer application for faba bean in acid soil.
2) To determine the effects of liming and Phosphate fertilizer application on yield and yield components of faba bean grown around in Hagereselam.

2. Material and Methods

2.1. Description of Experimental Area

This study was carried out at Hankomolicha in Sidama zone, which is found in the Southern Nations Nationalities and Peoples Regional State. It is located 356 km south of Addis Ababa. The study area is located on latitude of at 6°-9, N and 35°3'E. With an elevation of 3050m.a.s.l.

2.2. Experimental Layout and Treatment Application

This activity was apartment based on barley cereal and faba bean legume crops rotation system in two sets. In each season, the selected barley and faba bean were sow at a time in different sets in the same block. The experiment was laid out in randomised complete block design (RCBD) arranged factorially with five levels of lime (0.0x, 0.5x, 1.0x, 1.5x and 2.0x, exchangeable Al^{3+} and H^{1+}) content of the soils, and four levels of P (0, 23, 46 and 69 kg/ha). Twenty treatments in three replications used in the experiment. A high yielding faba bean (Dosha) variety was use as a test crop at a seed rate of 125 kg ha^{-1}. The plot size used was 4.5×5.1 meters (22.95 m^2). All plots were hand weeded at 30 and 60 days after sowing. Barley was the preceding crop for faba bean (*Vaciafaba L.*).

The mass of soil per 15 cm hectare-furrow-slice, the density of the soil sample, and the exchangeable Al^{3+} and H^{1+} of each site were used to calculate the amount of lime that was applied at each level according to Eq. (1). assuming that an equivalent mole of $CaCO_3$ would neutralize one mole of exchangeable acidity. In the first year, the entire dosage of lime was applied all at once. All treatments were being applied at the suggested rate of N. At least a month before planting, lime was spread evenly by hand and worked into the soil. The sources of N and P, respectively, were used to be urea and triple super phosphate. Urea was applied in two separate applications, whereas the entire rate of phosphorus was applied at sowing in a band. For the duration of the experiments, the plots were maintained permanently so that the effects of the lime would be visible.

$$LR, CaCO_3\ (kg/ha) = \frac{cmolEA/kg\ of\ soil * 0.15\ m * 10^4\ m^2 * B.D.(Mg/m^3) * 1000}{2000} \tag{1}$$

Growth, yield and yield components of data were collected. At crop maturity, the whole plot area (22.95 m^2) was hand harvested at ground level from each plot for determination of grain yield and biomass yield. Soil samples were randomly collected prior to experimentation and after harvesting for analysis of soil pH and exchangeable acidity. Soil pH was determined by using a pH meter in a 1:2.5 soil/water suspension using pH meter, and exchangeable acidity was extract by 1M KCl [22]. The collected data were statistically analyzed using SAS computer software version 9.0 English (SAS, 2000). For those parameters in which their ANOVA results found to be significant, further means separations were perform using least significant difference (LSD) at 5% probability level.

3. Result and Discussion.

Table 1. *Effects of Phosphorus and Lime affected by PH, EA, Avail P and All O^3 as in 2015/16 to 2017/2018 year at hagereselam woreda cropping season.*

TRT	PH	EA	Av. P	Al_3
1	4.72^{abc}	0.97ab	5.74b	0.52bac
2	5.03^{a}	0.33b	4.59b	0.093c
3	4.73^{abc}	1.57^{a}	5.44^{b}	0.97^{a}
4	4.53^{c}	1.02^{ba}	4.59^{b}	0.57^{bac}
5	4.70^{abc}	1.28^{ba}	4.71^{b}	0.89^{ba}
6	4.81^{abc}	0.98^{ba}	11.86^{a}	0.64^{bac}
7	4.74^{abc}	1.16^{ba}	5.26^{b}	0.71^{bac}
8	4.97^{ab}	0.20^{b}	3.72^{b}	0.036^{c}
9	4.73^{abc}	1.18^{ba}	6.19^{b}	0.70^{bac}
10	4.97^{ab}	0.30^{b}	5.49^{b}	0.22^{bac}
11	4.74^{abc}	0.61^{ba}	7.57^{b}	0.29^{bac}
12	4.85^{abc}	0.95^{ba}	4.97^{b}	0.47^{bac}
13	4.84^{abc}	0.48^{ba}	4.08^{b}	0.15^{bc}
14	4.90^{ab}	0.49^{ba}	4.47^{b}	0.27^{bac}
15	4.82^{abc}	0.68^{ba}	4.71^{b}	0.33^{bac}
16	4.64^{bc}	1.08^{ba}	5.43^{b}	0.72^{bac}
17	4.88^{ab}	1.00^{ba}	5.16^{b}	0.49^{bac}
18	4.98^{a}	0.25^{b}	4.69^{b}	0.04^{c}
19	4.99^{a}	0.34^{b}	4.06^{b}	0.11^{bc}
20	4.92^{ab}	$0.73b^{a}$	5.14^{b}	0.34^{bac}
LSD@0.05	0.33	1.11	4.1	0.78
CV	4.20	86.7	46.53	109.65

Significantly different $p<0.05$.

3.1. Plant Height and Number of Pods

Analysis of variance revealed that, application of different level of P showed negative relation and inconsistence result with respect to plant height and number of pods. The highest mean plant height was obtained at 0 kg P ha^{-1} and 69 kg P ha^{-1} t (Table 1). However, plant height positively and significantly influenced by application of lime; the highest pooled mean plant height was obtained at 117 kg lime ha^{-1}, while the lowest was that of the control. Similarly, number of pods per plant was significantly influenced by both application of phosphorus, lime and their interaction. However; it was the application of lime at the rate of 117kg/ha that gave the highest number of pods per plant. Maximum and minimum mean number of pods per plant Moreover, there was an interaction effect between phosphorus and lime on number of pods per plant.

Table 2. *Means for plant height and number of pods of faba bean as affected by phosphorus fertilizer, lime and their interaction at Hankomolicha during 2014/2015 to 2017/2018 cropping season.*

TRT	PH				NP			
	2015	2016	2017	Pooled mean	2015	2016	2017	Pooled mean
P. LEVEL KG/ha^{-1}								
control	110.13b	97.24	117.5a	113.84a	15.4	9.49	10.78a	11.89a
23	98b	94.57	106.38ab	100.54bc	15.53	9.24	9.20ab	11.32ab
46	96.8b	94.97	100.02b	97.2c	14.86	8.1	8.28b	10.41b
69	101.53a	102.29	112.16ab	105.32b	16.4	8.53	10.09ab	11.69a
LSD@0.05	8.02	ns	13.49	5.8	ns	ns	1.98	1.01

TRT	PH				NP			
	2015	2016	2017	Pooled mean	2015	2016	2017	Pooled mean
LIME Level kg/ha^{-1}								
control	101.33	98.30b	105.51	101.7b	14.6	8	8.63b	10.43c
58.5	102.83	100.26b	111.95	105.01ab	16.7	8.38	9.80ab	11.64ab
117	105	110.65a	113.1	109.58a	16.4	9.28	10.99a	12.23a
175.5	100.5	104.80a	109.25	104.85ab	15.5	8.91	9.32ab	11.48abc
234	98.4	96.50b	105.28	100.06b	14.5	8.9	9.18ab	10.86bc
LSD@0.05	ns	9.64	ns	6.54	ns	ns	2.21	1.17
P*L Interaction	ns	**	ns	***	NS	**	ns	***
CV	10.69	11.44	16.77	13.44	18.13	22.62	27.99	22.3

TRT Treatment, pH, plant height NP no of pod Significantly different $p<0.05$.

3.2. Effects of Phosphorus and Lime on Above Ground Biomass, Grain Yield and 1000 Seed Weight

The pooled mean analysis result showed that, above ground biomass and grain yield were significantly ($p>0.05$) influenced by application of phosphorus fertilizer, lime and by their combined effect. The maximum above ground biomass 17.65 ton/ha and grain yield 6.6 ton/ha was obtained at 46 kg P ha^{-1}. Amongst the liming treatments, the highest above ground biomass and grain yield of faba bean was obtained at the rate of 117kg/ha ($P < 0.05$). Although at these two levels separately, thouthend seed weight didn't show significant increase their interaction shows statistically significant effect. In this particular study it was found that as the levels of P increases from 0 to 46 kg P ha^{-1} both above ground biomass and grain yield were increased.

Table 3. *Means for above ground biomass, grain yield and 1000 seed weight of faba bean as affected by phosphorus fertilizer, lime and their interaction at Hankomolicha during 2014/2015 to 2017/2018 cropping season.*

TRT	AGB (t/ha^{-1})				GY (t/ha^{-1})				TSW (cm)			
P. LEVEL KG/ha	Year 1	Year 2	Year 3	Pooled mean (t/ha^{-1})	Year 1	Year 2	Year 3	Pooled mean (t/ha^{-1})	Year 1	Year 2	Year 3	Pooled mean
Control	24.4	6.25	22.31	14.41b	9.46a	2.14	8.32	5.4b	84.54ab	126.24a	74.46	85.5b
23	20.06	5.5	17.68	14.65b	7.59b	2.08	6.89	5.5b	82.33b	107.28b	70.62	86.7b
46	20.66	5.18	18.1	17.65a	7.59b	1.93	6.87	6.6a	80.35b	102.28b	73.94	95.4a
69	24.13	5.71	19.23	16.36ab	8.75ab	2.23	7.22	6ab	89.95a	121.21a	74.15	95.12a
LSD@0.05	ns	ns	ns	2.47	1.55	ns	Ns	0.8	6.21	12.06	ns	4.9
LIME Level kg/ha												
Control	2.08	5.15	17.14b	14.45b	7.3b	1.80b	6.42b	5.18b	84.42	103.84c	75.51ab	87.9b
58.5	22.5	5.52	20.75ab	16.25ab	9.14a	1.90ab	7.67ab	6.24a	82.14	113.15abc	70.56ab	88.6b
117	23.66	6.23	24.54a	18.16a	8.71ab	2.38a	9.72a	6.94a	86.28	125.34a	76.73a	96.1a
175.5	23.83	5.83	17.72b	15.79ab	9.13a	2.31a	6.56b	6ab	84.1	119.83ab	68.92c	90.95ab
234	20.5	5.53	16.50b	14.17b	7.44ab	2.07ab	6.25b	5.26b	82.14	109.10bc	76.ab	89.89b
LSD@0.05	0.55	1.19	6.21	2.76	1.73	0.48	2.28	0.94	6.9	13.49	7.54	5.53
P*L	ns	**	ns	**	**	***	*	***		***	ns	***
CV	30.51	25.6	38.98	37.5	25.2	27.7	37.7	34.3	9.9	14.31	12.43	13.07

AGB above ground biomass, GY Grain yield TSW, 1000 seed weight Significantly different $p<0.05$.

4. Conclusions

This finding has shown that, Overall, the result revealed that liming and the application of phosphorus fertilizer produced significant changes in aboveground biomass and grain yield. The application of 117kg ha^{-1} lime has drastically increased faba bean grain yield. 117kg ha^{-1} lime and 46 kg P ha-1 application is thus the optimum solution for sustainable and improved productivity of faba bean in Hankomolicha in Southern Ethiopia. If other factors keep constant, grain yield increases as the lime rate increases. Additionally, liming improves faba bean productivity in the study area Hankomolicha. According to this experiment, the optimum lime requirements were 117kg/ha and TSP/ha, respectively, to solve the problems of fababean in the study area and to improve its productivity.

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