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Full Length Research Paper

Yield Response of Faba bean to Fertilizer Rate, Rhizobium Inoculation and Lime Rate at Gedo Highland, Western Ethiopia

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The experiment was conducted at Gedo highland with the objective of determining the effect of rhizobium inoculation, fertilizer and lime application rates on nodulation and yield of faba bean. Three factors, rhizobium inoculation (0 and 10 g/1 kg seed), fertilizer rates (75,100 and 125 kg ha-1 DAP) and lime rate (0, 2, 4 and 6 t ha^{-1}) were combined in 2x3x4 factorial arrangements of RCBD in three replications. There were significant differences on nodule number, nodule volume and nodule dry due to the effect of fertilizer and lime application rates, but not by rhizobium inoculation. Nodule number was decreased as the function of increasing rates of either fertilizer or lime application. The residual effect of the lime in the second year also significantly reduced nodule numbers as compared to the control. Grain yield of the crop was highly affected by both fertilizer and lime application but not by strains. The highest significant economic yield was obtained at 100 kg ha^{-1} as compared to other rates. Significantly higher grain yield in both years was also obtained when 4 t ha^{-1} of Lime was applied, indicating that the residual effect of lime improved the yield of the crop though no significant difference was obtained on nodules when compared with untreated plots. Generally, applications of either 100 kg ha^{-1} DAP or 4 t ha^{-1} lime is advised around Gedo highlands. However, introduction of new rhizobium strains to the area did not significantly increase both nodule number and grain yield.

Key words: Faba bean, inorganic fertilizer, lime, rhizobium inoculation

INTRODUCTION

Faba bean (Vicia fabae) is ranked first among cool season food legumes based on area of production and foreign exchange earnings (CSA, 2010). It has also a great contribution for sustainable soil fertility management due to its ability to fix atmospheric N_2 (Beck et al., 1991). Even though faba bean is the leading pulse crop in the country, the national yield has remained low. Several abiotic factors contributed to low productivity of which poor soil fertility, acidity of the soil in high rain fall areas and low existence of effective indigenous rhizoba population in the area (Carter et al., 1998).

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Soil acidity is one of a biotic factor that globally known to reduce nodulation and yield of faba bean. Since soils in highlands of western Ethiopia where faba bean produced is ranged from moderate to strongly acidic, it might significantly reduce the nodulation potential of the crop. Faba bean produce maximum dry weight between 7 and 8 soil pH (Jessop and Mahoney 1998). Research results from different countries indicted that the application of lime with chemical fertilizer improve the nodulation and yield of fababean since it produce high nodule number on neutral or slightly acidic soil.(Wood et al.,1984).

External seed inoculation of rhizobia is also one of another practices to increase the nitrogen fixation potential of the crops since there might be low population of effective indigenous rhizobia or due to higher competitions with non-effective ones (Tolera et al.,2009).

Figure 1: Lime application and its subsequent residual effects on nodule number per plant of faba bean at Gedo

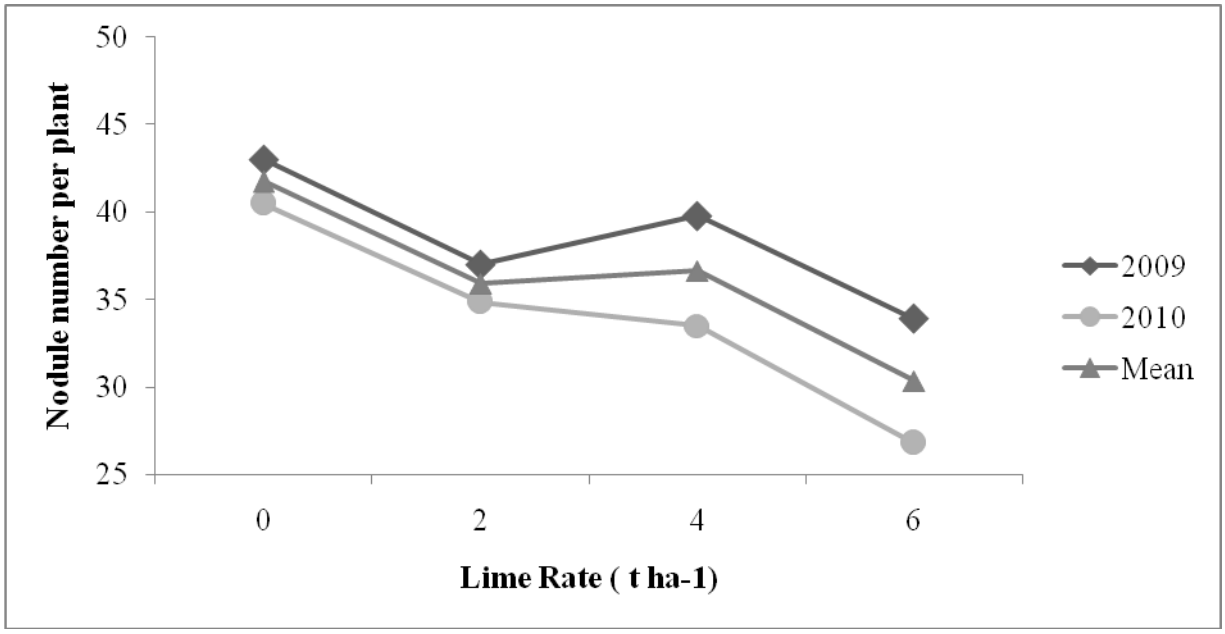

Table 1: Interaction effect of lime and fertilizer application on nodule volume and nodule dry weight of faba bean at Gedo

Variables	NV (ml)	NDW (g)	NV (ml)	NDW (g)	NV (ml)	NDW (g)	NV (ml)	NDW (g)
DAP (kg ha^{-1})	Lime rate (t ha^{-1})							
	0		2		4		6	
75	1.04	0.22	0.88	0.18	0.68	0.13	0.78	0.20
100	0.94	0.26	0.81	0.18	0.76	0.19	0.81	0.19
125	1.0	0.21	0.65	0.17	0.76	0.18	0.55	0.17
LSD (P<0.05)	NV	0.15						
	NDW	0.07						

NV= Nodule Volume; NDW= Nodule Dry weight; LSD= least Significant value; ml= mil liter; g=gram; DAP=Diammonium Phosphate

Applications of strains improved early nodulation and increased grain yield (Carter et al., 1998). Besides to strain inoculation, application of chemical fertilizer, particularly nitrogen and phosphorus, are needed to improve the production of the crop (Otieno et al., 2009). The same author indicated that nitrogen is required as starter fertilizer at the early growth stage since there is no nodule formation where atmospheric nitrogen is fixed. Phosphorus deficiency is also another significant factor that reduces the nodulation since both effective rhzobium bacteria and the crop require in larger quantity (Getachew and Rezene, 2006). The objective of this study was, therefore, to determine the effect of chemical fertilizer rates, rhizobium strain and lime rate and their interaction on nodulation and grain yield of faba bean in the area.

MATERIAL AND METHODS

Site Description

The experiment was conducted at Gedo highland in 2009 and 2010 consecutive years. The site is laid at 9.01314^{o} latitude and 37.4495^{o} longitude and its altitude is 2450 m.a.s.l. The area receive monomodial pattern of rain fall

Table 2: Main effects of chemical fertilizer rate, rhizobium inoculation and lime rates on Nodule number, nodule volume, nodule dry weight and plant height of faba bean at Gedo

Factors	NN (plant^{-1})	NV(ml plant^{-1})	NDW(g plant^{-1})	PH (cm)
DAP (kg ha^{-1})				
75	38	0.85	0.18	125
100	35	0.83	0.21	126
125	33	0.74	0.19	130
LSD (P<0.05)	3	0.08	0.02	2.9
Strain(g kg^{-1} seed)				
0	37	0.77	0.19	126
10	35	0.84	0.19	128
LSD (P<0.05)	NS	NS	NS	NS
Lime (ton ha^{-1})				
0	41	0.99	0.23	123
2	35	0.78	0.17	128
4	37	0.73	0.17	127
6	30	0.71	0.18	129
LSD (P<0.05)	3.5	0.09	0.03	3.3
CV (%)	**21**	**23**	**27**	**6**
F-probability level				
Year	**	**	**	**
Fertilizer (F)	*	NS	NS	**
Strain(S)	NS	NS	NS	NS
Lime (L)	**	**	**	**
FxS	NS	*	NS	NS
FxL	NS	*	*	NS
SxL	NS	NS	NS	NS
FxSxL	NS	NS	NS	NS

*, **= significant at P=0.05 and 0.01, respectively; NS= not significant; LSD= least significant level; CV=coefficient of variation

distribution that receive from June to September cropping season, which is the main rain season.The soil of the area is reddish, which is slightly acidic. Wheat, Barley, Faba bean, Field bean, Linseed and Noug are the major crops that are commonly grown in the area.

Experimental Design and Procedures

The experiment consisted of three factors, namely inorganic fertilizer rates (75, 100 and 125 kg DAP ha^{-1}), rhizobuim inoculation (0 and 10g EAL-110 kg^{-1} seed) and lime rates (0, 2, 4 and 6 ton ha^{-1}). The experiment was arranged as 3x2x4 treatment combination in RCBD with three replications.

The experimental site was plowed three times and prepared very well before time of planting. The area of each plot was 2m x2m. In first year (2009), lime was applied to each plot as per treatment allocation just one month before time of planting. Similarly, rhizobium strain was inoculated to the seed at the start of the year. In second year (2010), however, both lime and rhizobium strains were not applied. Each plot was stayed permanently for the next cropping season.

Table 3: Main effects of chemical fertilizer rate, rhizobium inoculation and lime rates on yield and yield traits of faba bean at Gedo

Factors	Pods plant^{-1}	Seeds pod^{-1}	GY (kg ha^{-1})	SW(g)
DAP (kg ha^{-1})				
75	13	2	4007	569
100	12	3	4479	563
125	13	2	4157	575
LSD (P<0.05)	NS	NS	339	NS
Strain(g kg^{-1} seed)				
0	12	2	4202	567
10	13	2	4226	570
LSD (P<0.05)	NS	NS	NS	NS
Lime (ton ha^{-1})				
0	12	2	3729	573
2	12	2	4157	575
4	12	2	4379	563
6	13	2	4591	565
LSD (P<0.05)	NS	NS	392	NS
CV (%)	19	16	20	4.4
F-probability level				
Year	NS	NS	**	NS
Fertilizer (F)	NS	NS	*	NS
Strain(S)	NS	NS	NS	NS
Lime (L)	NS	NS	**	NS
FxS	NS	NS	*	NS
FxL	NS	NS	NS	NS
SxL	NS	NS	NS	NS
FxSxL	NS	NS	NS	NS

***, **= significant at P=0.05 and 0.01, respectively; NS= not significant; LSD= least significant level; CV=coefficient of variation**

Table 4: Analysis of correlation matrix for nodule number, nodule volume, nodule dry weight and grain yield across lime application rates

	Lime	NN	NV	NDW	Yield
Lime	1				
NN	-0.88*	1			
NV	-0.93*	0.82	1		
NDW	-0.67*	0.65	0.93*	1	
Yield	0.98**	-0.88*	-0.96**	-0.80*	1

NN=Nodule Number; NV=Nodule Volume; NDW=Nodule Dry Weight

Improved variety of faba bean (Dagaga) was used as test crop. Five rows in 40 cm spacing in each plot were prepared. Diammoium phosphate (DAP) was applied in the rows as per treatment and mixed with soil just at the time of planting. Rhzobium strain (EAL-110) was mixed by sugar with addition of some water in order to facilitate for the adhesion of the strain on the seed. The seed was dressed with mixed strains and planted immediately. All

other management practices were also applied uniformly as per site recommendation.

Collected Parameters

Effective Nodules per plant was collected at 50% flowering. Five sample plants were randomly selected from each plot. Undisturbed soil core containing entire rooting system of each sampled plants were safely wrapped in plastic and the soil clods were carefully removed leaving the nodule on the root. The remaining soil on the root was washed using pure water on sieve. Volume of nodules was measured using a graduated measuring cylinder. Finally, the nodules were dried at 70 ^{0}C for 24 hours in an oven to a constant weight. The average of five plants was taken as nodule dry weight per plant.

Yield and yield traits: Plant height, Grain yield and thousand seed weight were also collected and subjected to analysis of variances.

Statistical analysis: Genstat discovery version three was used for analysis of variance and mean separation was done by least significant differences (LSD) at 0.05 probability level.

RESULT AND DISCUSSION

Nodule number

Pooled analysis of two years data revealed that nodules number per plant of faba bean were significantly affected by fertilizer and lime applications (Table-2). However, all treatment interactions, except strain by lime, did not considerably vary number of nodules. Inoculation of rhizobium strain (EAL-110) did not significantly increase nodules per plant in contrast with uninoculated seeds. This might be higher competitions with effective indigenous bacteria or probably poor adaptability of the inoculated strains to the soil environment (Thies et. al., 1991; Tolera et al., 2009)

Higher number of nodules was obtained at lower fertilizer rate (Table-2). However, the lowest nodules number were recorded when 125 kg DAP ha^{-1} was dry weight, but not by rhizobium inoculation. Interaction of lime by fertilizer and rhizobium by fertilizer considerably ($P<0.05$) affected nodule dry weight. The highest dry weight (0.22 g plant^{-1}) was obtained at 100 kg DAP ha^{-1}(Table-1 and 2) without lime application. This result with other findings might indicate that higher rates of phosphorus in DAP might enhance nitrogen fixing capacity in the nodule (Getachew and Rezene, 2006). Lime application significantly reduced fertilizer response as it may increase soil pH in which phosphorus fixation might be enhanced and enhance reduce nutrient availability.

Plant height (cm)

Plant height was significantly influenced only by fertilizer and lime applications. Highly significant variation was also observed between cropping season. Increasing fertilizer rates increased plant height (Table-2). This result indicates that applying by increasing doses of chemical fertilizer, particularly nitrogen, might increase vegetative growth of the crop resulting in higher plant height that might lead to lodging (Adem, 2006; Muoneke et al., 2009).

Considerable increase in plant height was attained with an increase in lime application rates. The lowest significant plant height was recorded from untreated lime when compared with treated plots. This result and other report showed that applying lime might improve or avail nutrient, particularly nitrogen availability (Mesfin, 1997).

Pods plant^{-1},seeds pod^{-1} and thousand seed weight

Results of pooled analysis over two years revealed that number of pods per plant, number of seeds per pod and applied. This result may indicate that higher doses of chemical fertilizer, particularly nitrogen, might suppress the nodulation potential of the crops (Fujita et al., 1992; Laws and Graves, 2005).

The highest rate of lime application significantly reduced nodules number when compared with untreated plot, which gave the highest number of nodules (Table-2). This might indicate that application of lime may considerably increase pH of the soil in which the beneficial rhizobium bacteria might not fix atmospheric nitrogen (Mesfin, 1997). Moreover, the residual effect of applied lime in the next season (2010) was significantly decreased number of nodules than in the beginning year (2009) although linear decrease in number was observed as the function of increasing lime rates in each cropping season (Fig-1). This result indicates that high dissolution of calcium carbonate might result in higher pH rises that might directly affect the optimum pH ranges for effective bacterial activities (Adams and Pearson, 1967).

Nodule volume (ml plant^{-1})

There was a significant variation between cropping season, which might be seasonal variation that influences the microbial activities (Table-2). Similar to nodule number, fertilizer and lime application considerably varied nodule volume (Table-1). It was concluded that the response of increasing fertilizer rates under an increase rate of lime uses was significantly declined (Table-1). Moreover, increasing fertilizer application from 75 kg ha^{-1} to 125 kg ha^{-1} of DAP markedly decrease nodule volume (Table-2). The lowest nodule volume was recorded with the highest rate of chemical fertilizer and lime application rate (Table-1 and 2). This result might indicate that re-multiplication of rhizobia might considerably be suppressed due to higher doses of nitrogen (Thies et al., 1991; Otieno et al., 2009) or due to the effect of lime that might increase soil pH range in which microbial activities may be hampered (Tolera et al., 2009). Rhizobial inoculation, however, did not significantly increase nodule volume when compared with uninoculated plot.

Nodule dry weight (g plant^{-1})

Pooled analysis of variance revealed that both fertilizer and lime application significantly ($P<0.01$) varied nodule

thousand seed weight were not significantly affected by main and interaction effects of treatment combinations (Table-3).

Grain yield (kg ha^{-1})

Significant variations in grain yield were observed due to main effect of fertilizer and lime application whereas rhizobium inoculation did not considerably increase when compared with uninoculated plot. Application of 100 kg DAP ha^{-1} gave the highest economic yield, averaged over rhizobium strains and lime rates, but at par with yield obtained at 125 kg DAP ha^{-1}(4157 kg ha^{-1}). However, a considerable 12% decrease in yield was recorded when 75 kg DAP ha^{-1} was used as compared to 100 kg DAP ha^{-1}. This result may indicate that applying chemical fertilizer constituting phosphorus and small amount of nitrogen significantly increase economic yield of the crop (Getachew and Rezene, 2006).

The result also indicated that there was a linear increase in grain yield of faba bean as the function of increasing lime application rates. In other words, lime application was strongly effected on yield of the crop though negative correlation was observed on nodule parameters, which indirectly affected on yield of the crop (Table-3 and 4). In other words, there is strong correlation (p=0.98) of lime with yield of the crop. Significant increases from 11% to 23% of grain yield were obtained over untreated plots. However, the highest yield was obtained when 6 ton ha^{-1}(4591 kg ha^{-1}) followed by 4 t ha^{-1}(4379 kg ha^{-1}) of lime were applied even though both means were at parity. Either uses of 2 ton ha^{-1} or 4 ton ha^{-1} did not significantly vary yield of the test crop. The result reveals that applying calcium containing lime materials might improve nutrient availability, particularly phosphorus, through reduction of phosphorus fixation (Mesfin, 1998).

CONCLUSIONS

Introducing of new strains did not significantly increases nodules and even grain yield and other parameters, indicating that the indigenous micro-organism compete with the introduced one or there may be some non effective microbes that may hinder. Increasing the rates of inorganic fertilizer also significantly reduce the nodules of the crop. This might be the availability of nitrogen that may hamper the fixation potential of the microbes. Application of lime and its residual effects did not also increase the nodulation as compared with the unlimed plot.

Both pods per plant and thousand seed weight were not affected by any factor. But, grain yield was significantly affected both by fertilizer and lime application rates. Application of 100 kg ha^{-1} gave the optimum grain yield per ha as compared with other fertilizer rates. Although number of nodules did not significantly increased by lime application over the control, significant increase in yield was obtained when compared with untreated plot. The result indicate that applying lime to the soil might considerably improve the nutrient availability, particularly phosphorus, since it improve soil pH under which maximum availability of the nutrient may be obtained. Application of 4 ton ha^{-1} gave the optimum grain yield. Therefore, uses of 100 kg ha^{-1} and 4 ton ha^{-1} generally recommended getting optimum grain yield over the control. However, introducing new strains to the area is not generally advised since no variation was obtained either under inoculated or uninoculated treatment.

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