

Liming Effects on Yield and Yield Attributes of Nitrogen Fertilized and Bradyrhizobia Inoculated Soybean (*Glycine max* L.) Grown in Acidic Soil at Jimma, South Western Ethiopia

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Abstract
Soil acidity is one of the major soil chemical constraints which limit agricultural productivity in the mid and highlands of Ethiopia. The study was conducted to evaluate the influence of lime, bradyrhizobia and nitrogen fertilizer on yield and yield attributes of soybean in acid soil at melko south western Ethiopia during June to October of 2012. The crop was evaluated in terms of pod number, seed per pod, seed yield, hundred seed weight, straw yield and harvest index. The result revealed that pod number per plant, seed yield, seeds per pod and hundred seed weight were significantly ($P < 0.05$) increased when lime and bradyrhizobia were simultaneously used. However, straw yield and harvest index were not significantly ($P \geq 0.05$) improved by lime and bradyrhizobia. Except seeds number per pod and seed yield, the effect of nitrogen on yield attributes was not observed. It had neither interaction with lime and bradyrhizobia nor its effect on yield attribute was significant. Saving currency invested to buy chemical nitrogen fertilizer and maintaining soil healthy, simultaneous use of lime and bradyrhizobia give similar seed yield with the one recorded when nitrogen fertilizer is applied.
Keywords: Soil acidity**,** Bradyrhizobia, Lime, Nitrogen fertilizer, Soybean, Yield, Yield attributes

1. Introduction

Food insecurity and diseases caused by malnutrition are permanent challenges of humankind since the down of history. Soil acidity is a major constraint to food crop production mainly in highly weathered soils of tropical and subtropical regions. Currently, about 41% of potential arable land of Ethiopia is acidic among which south Western part of the country is highly affected (Abebe, 2007). Acidic soils cause poor plant growth resulting from aluminum (Al^{+3}) and manganese toxicity (Mn^{+2}) or deficiency of essential nutrients like phosphorus, calcium and magnesium. Restoring, maintaining and improving fertility of this soil is major priorities as a demand of food and raw materials are increasing rapidly.

Suitability of soils as a medium for crop growth and development considerably depend on its reaction. Liming acid soil make the soil environment better for leguminous plants and associated microorganisms as well as increase concentration of essential nutrients by raising its pH and precipitating exchangeable aluminum (Kisinyo *et al*., 2005; Negi *et al*., 2006; Guo *et al*., 2009; Kisinyo *et al*., 2012). Availability of essential nutrients and biological activity in soils are generally greatest at intermediate pH at which organic matter beak down and release of essential nutrients like N, P and S is enhanced. Improving soil fertility on the other hand, is basic to achieve long term food security and improve farmers' standard of living, while mitigating environmental degradation (IFPRI, 2010; Jensen *et al.*, 2012).

Ethiopia imports about 65% of soybean, sunflower and palm edible oil for human consumption (Wijnands *et al. 2011*). Increasing soybean production can save foreign currency paid for this import if productivity of the crop is improved through lime and bio fertilizer application indeed. It is also true that soybean is an important source of protein for small scale farmers who rarely obtain foods of animal products. It is a multipurpose crop and can be used for animal feed and raw materials for industry as well as incorporates plant usable nitrogen in to soil through fixation.

Nitrogen is an essence to life both for plants and animals. In spite of its abundance in the atmosphere, nitrogen (N_2) is inert and cannot chemically be combined with other elements into usable forms by plants. On the other hand, because of environmental concerns and economic constraints, nitrogen requirement of crops cannot often be met solely through mineral fertilization. For the same reason, the use of leguminous crops for this inert nitrogen fixation and incorporation into agricultural soil is getting prime importance in Ethiopian context (W-meskel, 2007; Bekere and Hailemariam, 2012; Bekere *et al*., 2013). The study was therefore, conducted to investigate the impact of lime, bradyrhizobia and nitrogen fertilizer on yield and yield attributes of soybean grown in acidic soil at Melko, Jimma.

2. Materials and Methods

Field experiment was conducted at Jimma Agricultural Research Center, Melko, during June to October in 2012. Jimma Agricultural Research Center is found in South Western Ethiopia; in Oromiya National Regional State. It is located at 7°40'47"N latitude and 36°49'47"E longitude. The mean maximum and minimum temperature of the Center are 26.2 and 11.3°C respectively. The elevation of the Center is 1,753 m above sea level and it receives 1,529.5 mm average annual rainfall.

A field of unknown history of soybean cultivation and bradyrhizobia inoculation was selected and an area of 546 m^2 was prepared. The field was then divided into three replications and each replication was divided into eight experimental units making a total of twenty four plots with an area of 16 m^2. Before planting, a composite soil sample was taken from the upper 0-0.15 m of the experimental field and analyzed for selected physical and chemical properties (Bray and Kurtz, 1945; Wakley and Black, 1934) In this line, exchangeable acidity which is sum total of exchangeable aluminum and hydrogen ion in the soil solution, pH, organic carbon, available phosphorus and nitrogen content of the experimental soil were 2.31 cmol kg^{-1}, 4.43, 1.87%, 3.85 mg kg^{-1} and 0.17%, respectively.

2.1. Treatments and their application

Calcium carbonate ($CaCO_3$), Legumefix and urea were used as a source of lime, bradyrhizobia and nitrogen in the investigation, respectively. The experiment consisted of two levels of bradyrhizobia, with and without inoculation; two levels of lime; with and without lime; two levels of nitrogen fertilizer; with and without nitrogen fertilizer. Treatments were control (without lime + without bradyrhizobia + without nitrogen fertilizer), lime only, bradyrhizobia only, nitrogen fertilizer only, bradyrhizobia + lime, bradyrhizobia + nitrogen fertilizer, lime + nitrogen fertilizer and bradyrhizobia + lime + nitrogen fertilizer. Clark 63K, a well performing soybean variety in the area was used as a test crop. The experiment was conducted in factorial RCB design with three replications. The amount of lime applied was determined based on exchangeable acidity, mass per 0.15m furrow slice and bulk density of the soil (Shoemaker *et al*., 1961; Tran and van Lierop, 1982; Van Lierop, 1983). Accordingly, 2.6 ton ha^{-1} of lime in the form of $CaCO_3$ was uniformly applied and incorporated into the soil a month before sowing. Splitting into two, recommended rate of nitrogen fertilizer (46 Kg N ha^{-1}) was applied for nitrogen treatment.

Soybean seeds were washed with distilled water and surface sterilized with 70% ethanol. Seeds were then rinsed 3 to 4 times with tap water; moistened with a 0.2 M dilute sucrose solution and inoculated by covering them with paste of inoculum which was made from a rate of 10 g of peat-based powder inocula per 100 g (Somasegaran and Hoben, 1985; Deaker et al., 2004) of seed just before planting. The seeds were then sown on 10th June. Agronomic practices were uniformly applied for all treatments throughout the experimental period.

2.2. Data Collection and Analysis

Yield and yield attribute parameters such as pod number per plant, seed per pod, seed yield, hundred seed weight, straw yield and harvest index were recorded at harvesting and after threshing. The data were subjected to analysis of variance using SAS packages and treatment means were separated by Least Significant Difference ($LSD_{0.05}$) method (Gomez and Gomez, 1984).

3. Result and Discussion

3.1. Effect of Lime, Bradyrhizobia and Nitrogen Fertilizer on Yield and Yield Attributes of Soybean

3.1.1. Pod number per plant

Interaction effect of lime and bradyrhizobia was significant whereas nitrogen fertilizer neither had interaction with lime and bradyrhizobia nor significantly ($P < 0.05$) affected pod number of the soybean (Table 1; Table 3). Highest number of pods per plant (39.40) was produced when the crop was grown in both limed soil and bradyrhizobia inoculation.

Table 1. Interaction effect of lime and bradyrhizobia on pod per plant and hundred seed weight of soybean at Melko, Jimma.

Parameter	Lime (ton ha^{-1})	Bradyrhizobia without inoculation	Bradyrhizobia Inoculation
Pod per plant	0	27.61c	33.53b
	2.6	35. 46b	39.43a
		LSD $_{0.05}$= 3.9	
Hundred seed weight (g)	0	16.0b	18.6a
	2.6	16.3b	20.5a
		LSD $_{0.05}$= 2.2	

Values followed with the same letter/s for a parameter are not significantly different at $P < 0.05$.

Pod number recorded from lime treated alone and bradyrhizobia alone was not significantly different. This may be because lime created better soil environment for naturally existing soybean nodulating bacteria in uninoculated treatment (Bekere and Hailemariam, 2012; Bekere et al., 2013). This finding is also in line with reports of Malik et al.(2006) and Bhuiyan et al. (2008) who indicated more pod number per plant of soybean and mung bean with rhizobia inoculation than uninoculated treatment.

3.1.2. Seed number per pod

The interaction effect of lime, bradyrhizobia and nitrogen fertilizer was significantly ($P < 0.05$) in case of seed number per pod of the soybean (Table 2). Regardless of nitrogen fertilization, lime and bradyrhizobia inoculation gave significantly higher seeds per pod. Nitrogen fertilized soybeans produced significantly ($P < 0.05$) more seed number than unfertilized ones under bradyrhizobia inoculation whereas nitrogen fertilizer had no effect when the crop was grown without inoculation (Table 2). This is in agreement with reports of Cassman et al.(1980) and Seneviratne et al. (2000) on nodulation parameters of soybean. Significantly lower number of seeds was recorded from soybeans grown without lime, bradyrhizobia and nitrogen fertilizer. Number of seeds recorded from bradyrhizobia inoculated and uninoculated soybeans were not significantly ($P \geq 0.05$) different when the crop was grown under nitrogen fertilization but without lime (Table 2). Bradyrhizobia and nitrogen fertilizer had no significant effect on seed yield of soybean under lime application.

3.1.3. Seed yield

Seed yield of the crop was significantly affected by the interaction effect of lime, nitrogen and bradyrhizobia inoculation (Table 2). When the crop was grown with lime, nitrogen fertilizer had no significant effect whereas the effect of the fertilizer was significant when the soybean was grown without lime (Table 2). Under both lime and without lime conditions, the effect of nitrogen fertilizer had no significant effect on seed yield of the crop.

Table 2. Effect of lime, bradrhizobia and nitrogen fertilizer on seed yield and seed per pod of Clark 63k Soybean at Melko, Jimma

Parameter	Lime (ton ha^{-1})	N (kg ha^{-1})	Bradyrhizobia	
			No inoculation	Inoculation
	0	0	1645.8c	1583.3c
Seed yield (kg ha^{-1})		46	1920.0b	2041.6b
	2.6	0	1979.2b	2060.2b
		46	2079.2b	2310.6a
			LSD $_{0.05}$= 146	
	0	0	1.58d	1.40f
Seed pod^{-1}		46	1.60bcd	1.70b
	2.6	0	1.99a	1.97a
		46	1.90a	1.95a
			LSD $_{0.05}$ = 0.11	

Values followed with the same letter/s for a parameter are not significantly different at $P < 0.05$.

However, lime with and without nitrogen fertilizer gave significantly more seed yield than with and without nitrogen fertilizer of non limed soil under the use of bradyrhizobia (Table 2). This result is supported by Munns et al. (1981), Guo et al. (2009), Chalk et al. (2010) and Bekere et al. (2013) who reported beneficial effect of lime for legumes grown in acidic soil. Inoculation had no significant ($P \geq 0.05$) effect when the crop was grown without lime regardless of nitrogen fertilizer. However, when lime was applied, inoculation with bradyrhizobia significantly increased seed yield of the soybean regardless of nitrogen fertilizer. This may be because of the fact that acidic soil environment was neutralized by the applied lime. Earlier findings also showed that rhizobium and nitrogen fertilizer give almost similar weight in legumes like soybean, haricot bean and mung bean (; Munns *et al.*, 1980; Cassman *et al.*, 1981). This indicates that bio fertilizer inoculants have a potential to substitute chemical fertilizer N for legumes.

3.1.4. Hundred seed weight

Hundred seed weight of the soybean was significantly ($P < 0.05$) influenced by an interaction effect of lime and bradyrhizobia inoculation. However, the effect of nitrogen fertilizer and its interaction with lime and bradyrhizobia was not significant (Table 1; Table 3). Lime did not significantly affect hundred seed weight when the crop was grown both by bradyrhizobia inoculation and without inoculation (Table 1).

Table 3. The effect of nitrogen fertilizer on number of pod, hundred seed weight, straw yield and harvest index of Clark 63K soybean at Melko, Jimma

N (kg ha^{-1})	number of pod $plant^{-1}$	HSW(g)	Straw yield (t ha^{-1})	Harvest Index
0	33	18.0	3.9	0.34
46	35	19.7	4.2	0.38
LSD $_{0.05}$	ns	ns	ns	ns
CV (%)	13.26	12.6	14.8	31.96

ns= not significantly different at $P < 0.05$; HSW= hundred seed weight

Nevertheless, bradyrhizobia inoculation produced significantly higher hundred seed weight than its uninoculated control under limed and unlimed conditions. The use of lime and *Bradyrhizobium japonicum* gave the highest

(20.5 g) hundred seed weight. Beneficial role of lime and bradyrhizobia is also reported in the earlier investigations (Chalk *et al*., 2010; Bekere *et al*., 2013)

3.1.5. Straw yield

The interaction effect of lime, nitrogen fertilizer and bradyrhizobia was not significantly ($P \geq 0.05$) as far as straw yield is concerned. It was also observed that nitrogen fertilizer and bradyrhizobia did not significantly influence straw yield of the crop (Table 3; Table 4). However, lime significantly increased straw yield over the soil which received no lime (Table 4).

Table 4. The effect of liming and bradyrhizobia inoculation on straw yield and harvest index of Clark 63K soybean at Melko, Jimma

Lime (ton ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
0	3.72b	0.38a
2.6	4.33a	0.32b
LSD 0.05	0.52	0.05
Bradyrhizobia		
Without inoculation	3.99	0.36
Inoculation	4.06	0.34
LSD 0.05	ns	ns
CV (%)	14.8	31.96

Values within a column followed with the same letter/s are not significantly different at $P < 0.05$.

3.1.6. Harvest index (HI)

The result revealed that there was no interaction effect of lime, bradyrhizobia and nitrogen fertilizer. It was also observed that unlike lime, nitrogen fertilizer and bradyrhizobia did not significantly ($P < 0.05$) affect harvest index of the crop (Table 3; Table 4). Munns et al.(1981) also reported similar results on haricot bean.

4. Conclusion

The use of lime and bradyrhizobia at the same time improves yield and its attributes than using the later alone in acidic soil. Saving currency invested to buy chemical nitrogen fertilizer and maintaining soil healthy, simultaneous use of lime and bradyrhizobia give similar seed yield with the one recorded when nitrogen fertilizer is applied.

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