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Full length Research paper

Evaluating Yield response of fababean (*Vicia faba* L.) through integrated use of Rhizobium strains and lime on acidic soils of Anded district North western

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Rhizobial strains have contributed to enhance N_2 fixation, soil fertility and yield of legume crops when they are sufficient quantity in the soil under favorable soil environment. A field experiment was implemented to evaluate yield response and economic profitability of faba bean through inoculation of strain together with lime. The experiment consists four types of strains [(BF-17, BF-04, BF-1018 and BF-1035), control, 21kgha^{-1} urea and 150kgha^{-1}ureaunder limed and unlimed condition). The treatments were arranged in split plot design where, strains were sub-plots and lime was the main plot with three replication. The collected data was analyzed using SAS using 9.3 software version. Based on the results obtained, number of podsplant^{-1},number of seeds pod^{-1}, seed yield and above ground biomass yield of faba bean was significantly (P<0.01) affected due to integrated use of inoculants with lime. The result revealed that inoculation of BF-04 strain together with lime produced the highest number of pods plant^{-1} (14.33), number of seeds pod^{-1} (2.44) and seed yield (3623.6kg ha^{-1}) where the seed yield obtained due inoculation of BF-17 strain with lime was statically comparable with application of BF-04 strain + lime (3612.5kg ha^{-1}). In case of biomass yield, similar to seed yield combined use strains with lime recorded the highest value but among each strain no significant variation was observed. This result clearly suggested that proper inoculation of effective strains along with lime improved soil fertility and faba bean yield. The highest net income was also obtained from plots treated with strain lime compared with other treatments. Reducing soil fertility constrains through the integrated use of strain and lime could be a possible option to increase yield. However, to draw a conclusive recommendation, the study has to be repeated over several seasons as lime and strains have long-term effects.

Key words: Economic analysis, strain, seed yield, soil acidity.

INTRODUCTION

Soil acidity is one of the most important constraints for faba bean production in Ethiopia highlands (Endal kachew, 2018). Different research findings revealed that acidic soil covers about 43% of the arable lands of which strong soil acidity covers 28.1% of the entire country (Tegbaru, 2015). To fulfill the increasing demand for food and raw materials, soil health and fertility has remained as the major factor to increase and sustain crop yields. This calls for proper use of knowledge of soil acidity and its amelioration to maximize agricultural productivity.

Faba bean is ranked first among cool season food legume crops 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 unavailable atmospheric N_2in a form available for plants (Beck *et al.,* 1991).Since legumes are more sensitive to soil acidity compared with cereals, fababean yield in the country showed a reduction in acidic soils due to low P availability and deficiency of major basic cations (Ca and Mg) or toxicity of Al, Fe, and Mn because the solubility and availability of important nutrients to plants is closely related to the pH of the soil (Norton and Tyndall, 2017).

Soil acidity and associated low nutrient availability also led to poor nodulation, stunted growth, and reduced biomass and grain yields in fababean (Hajkowicz and Young, 2005). Soil acidity with particularly at a pH lower than 5 also seriously affects the survival and multiplication of rhizobia (Kucuk and Kivanc, 2008). Therefore, rhizobia-faba bean symbiotic association is importantly hindered by soil acidity that leads to no or reduced nodulation, in turn to the absence of symbiotic N_2 fixation.

The most widely employed technology in acidic soil reclamation is application of lime in combined with acid-tolerant rhizobial strains for optimum benefit (Adane, 2014). Suchan integrated approach will be economically feasible, and environmentally sound (Abebe and Tolera, 2014). In north western part of the country in general, and Aneded district in particular, deficiency of microbial population and soil acidity is a well-known problem that limits crop productivity. As part of the solution to such a problem in soils, the combined application of lime and inoculation of resistant strains on fababean was not been investigated so far, in which fababean was one of the potential legume crops in the area.Thus, this study was conducted with the purpose to evaluate the yield response and economic importance of fababean through integrated use rhizobial strains with lime.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Debre Markose Agricultural Research Center Aneded district during main cropping season. The experimental site is geographically located at 07° 40′.157″ N latitude and 036°46′.999″ E longitude and an altitude of 1771m above sea level. The average annual maximum and minimum air temperature ranges from 11.8°C to 27.2°C and, the area receives adequate amount of rainfall, 1500mm per annum with monomodial pattern of rain fall distribution.

Soil Sampling and Physico-chemical analysis

Prior to conducting the experiment, representative soil sample was collected from experimental site at plow depth of 0-20cm and analyzed following standard laboratory procedures. The soil sample was air-dried and ground to pass through a 2mm sieve mesh. Soil pH was determined (1:2.5 soil to water ratio) using a glass electrode attached to a digital pH meter (Page, 1982), soil texture was determined by hydrometer method (Day, 1965). Methods as described by Walkley and Black for organic carbon, and wet oxidation Kjeldahl method was used to determine total N, as described by Jackson (1967). Exchangeable acidity was determined from a neutral 1 N KCl extracted solution through titration with a standard NaOH solution based on the procedure described by McLean (1965). Available P was determined using Olsen extraction method (Olsen and Dean, 1965). Cations exchange capacity (CEC) of the soil was determined following ammonium acetate extraction method.

Experimental design and procedure

The experimental treatment includes (Control, four types of strains [FB-17, FB-04, FB-1018, FB-1035], 21kgha^{-1}urea and 150kgha^{-1}urea under limed an unlimited soil condition). The treatments were arrangement in split plot design with three replications. The amount of lime applied was determined based on the exchangeable acidity, mass per 0.15m furrow slice and bulk density of the soil, considering the amount of lime needed to neutralize the acidity of the soil up to the permissible level for crop growth.

The total experimental area contains 42 treatments accommodating ten rows plot^{-1}and gross plot area was 3m*4m (12m^2). The experimental plots were kept with 0.1m and 0.4m spacing between plants and each row respectively. Treatments were assigned randomly to experimental plots within a block. Planting was done according to farmer's local planting calendar and the seeds per hill were put in a row and covered with thin soil on rows made. To ensure that all the applied inoculum stick to the seed, the required quantity of strain was suspended in sugar solution. The thick slurry of the inoculant was mixed gently with dry seed so that all the seeds received a thin coating of the inoculant. All inoculations were done just before sowing under shade to maintain viability of bacterial cells. The inoculated and un-inoculated seeds were then sown separately. Seeds were covered immediately with soil after sowing to avoid the death of bacterial cells due to direct sun light radiation. Triple super phosphate (46% P_2O_5) which was used as a source of phosphorus (P) was applied to all plots uniformly at sowing, while nitrogen (N) in the form of urea was applied in two splits to avoid losses by leaching i.e. half at sowing time and the remaining half was applied a month after planting.Harvesting was doneat physiological maturity by leaving the outer most rows on both sides of each plot to avoid border effects.

Data collection and analysis

Yield and yield related parameters

Representative plants were randomly selected from net plot to collect yield and yield attributes of faba bean during harvesting. The recorded parameters include number of pods plant^{-1}, number of seeds pod^{-1}, seed yield and above ground biomass yield. The number of pods plant^{-1}was counted from five randomly selected plants of the middle rows from each plot and their averages were recorded. To estimate the number of seeds pod^{-1}, the total number of seeds pod^{-1}was counted from five randomly selected representative plants and their averages were used. Seed yield of faba bean (kgha^{-1}) was measured from each net plot and converted into hectare base. Similar to seed yield, above ground biomass yield from the net plot area was harvested, after gained constant weight the dried above ground biomass was weighed and converted into hectare base.

Statistical analysis

The collected data was subjected to analysis of variance (ANOVA) as per the design used in the experiment using statistical analysis software version 9.3 (SAS, 2012), and interpretation were made following the procedure of (Gomez and Gomez, 1984). Mean separation was conducted using the least significant difference (LSD)at 5% probability level to assess differences among treatment means where significant differences were obtained by the analysis of variance.

Economic analysis

To determine the economic feasibility of the treatments, mainly the costs of inputs and the prices of outputs (yield) was used based on the procedure recommended by CIMMYT (1988) manual. It was analyzed separately by calculating gross benefit, total costs that vary and net benefit for each treatment. Economically optimum yield levels were identified using net benefits (additional income obtained). The field price of 1kg of faba bean that farmers receive from sale was taken as 110 birr. Costs of fertilizer and strains were40.00 birr kg^{-1} and 50.00 birr packet^{-1} respectively. Seed yield of faba bean was adjusted downwards by 10% to more closely approximate yields. The cost benefit analysis was calculated as follows: Cost of cultivation = the sum of cost input, adjusted seed yield = grain yield*10/100, gross benefit = adjusted grain yield*cost of cultivation (price of yield) and net benefit = gross benefit-total variable cost (cost of cultivation).

RESULTS AND DISCUSSION

Soil Properties before Sowing

Before implementing the experiment, the soil result was clay in textural class:sand (38%), silt (16%) and clay (46%). The pH value was 4.90which fall under strongly acidic in reaction according to the rating done by Tekalign (1991). Total N and cation exchange capacity (CEC) of the soil, were found 0.19% and 17.8cmol (+)/kg, respectively. The total N CEC of soil was rated as medium, according to Tekalign (1991) and Hazelton and Murphy (2007) respectively. The organic carbon content of the soil was 2.14 rated as medium according to Tekalign (1991). The value of available P and carbon to nitrogen ratio (C:N) were found 7.33ppm and 11.26%, respectively. Available P in soil was low, according to the rating of Jones and Benton (2003). The lower nutrient level and other chemical properties indicated that the experimental soil had some limitations with regard to its use for crop production.

Effects of Strains and Lime on yield and yield attributes of fababean

Number of pods per plant

Analysis of variance showed there was a highly significant interaction effect ($p<0.01$) due to inoculation of different rhizobium strains with lime on number of pods plant^{-1}. Accordingly, the highest number of pods plant^{-1} (14.33) was recorded from plots treated with inoculation of FB-04 strain under limed condition which produced 35.19 more number of pods plant^{-1}compared within oculated seeds with FB-04 strain alone. However, the lowest number of pods plant^{-1} (0.01) was recorded from the control plots' indicating almost no fababean yield is expected without inoculating the seeds with strains and lime application in highly acidic soils. The highest value recorded indicates that there was a synergistic effect between the two factors (strains and lime) which in turn favored height increments through biological N_2 fixation and by minimizing the effect of soil acidity due to liming. Inoculation of sufficient strains on fababean seeds plays an important role in physiological and developmental processes in plant life and the favorable effect of these strains might accelerate the growth processes, which ultimately resulted in increased yield and quality. The current result was in agreement with (Farfour,2013) who reported that inoculating mung bean and soybean with Brady rhizobium significantly increased pod number and pod weight.

In general, when the number of viable rhizobia inoculated per seed increases, the number of pods plant^{-1} formed is influenced by the treatment given by Brady rhizobium strain thereby nodulation and yield are improved whenever the soil is neutral in reaction.

Number of seeds per pod

Analysis of variance showed that inoculation of seeds with strain along with lime significantly affects number of seeds pod^{-1}. The maximum number of seeds pod^{-1} (2.40) was obtained from inoculation of seeds with FB-04 strains under limed condition which produced 12.68% seed advantages over inoculating seeds with FB-04 strains alone. The possible reason for an increase in the

Table1. Physico- chemical properties of the soil of experimental site before sowing

Soil depth (cm)	Physical properties					Chemical properties					
	Clay (%)	Silt (%)	Sand (%)	Textural class	BD (gcm^{-3})	pH (H_2O)	TN (%)	Av.P (ppm)	CEC cmol(+)/kg	OC (%)	Ex.acidity (meq/100g)
0-20	46	16	38	Clay	1.25	4.90	0.19	7.33	17.8	2.14	0.98

BD= Bulk Density, CEC = Cation exchange capacity, OC = Organic carbon, TN = Total nitrogen, Av.P = Available phosphorus.

Table 2.Effects of rhizobium inoculation and lime on number of pods plant^{-1} and number of seeds pod^{-1}

Rhizobium inoculants	**Limed**	**Unlimed**	**Limed**	**Unlimed**
	NPP	NPP	NSPP	NSPP
FB-17	13.47abc	9.73de	2.40a	2.13abc
FB-04	14.33a	10.60cd	2.33ab	2.13abc
FB-1018	13.67ab	9.60de	2.27abc	2.00c
FB-1035	10.80bcd	10.33d	2.07bc	2.17abc
Control	8.20de	0.01g	2.13abc	0.01d
21 kgha^{-1} urea	7.87de	4.60f	2.00c	2.00c
150 kgha^{-1} urea	10.73bcd	7.13ef	2.20abc	2.00c
Mean	11.30	7.43	2.20	1.78
LSD (5%)	2.94		0.30	
CV (%)	18.80		8.95	

Where, NPP= Number of pod per plant, NSPP= Number of seed per pod.

number of seeds pod^{-1} might be availability of P via liming fornodule formation, protein synthesis, fruiting, and seed formation, and strain can bemade to the availability of growth-limiting primary nutrients such as N in sufficient amount in the soils, which in turnp romotes vegetative growth. Inoculation of efficient N_2-fixing symbioses most directly related to effective nodule formation for enhanced plant growth. However, the population density, effectiveness in forming nodules, competitive ability, concentration of available soil N and acidic level of the soil are the major factors that determine the degree of inoculation response. Thus, advantages of inoculation of legume crops can be an important practice if the farmer's field is low in N availability or if the faba bean cultivar has large N demand (Kubota *et al*., 2008).

Seed yield

Analysis of variance showed that there was significant effect observed on seed yield of fababean due to combined use of inoculation with lime. The maximum seed yield (3623.6kgha^{-1}) was obtained from plots treated by FB-04 strain under limed condition which was stastically at par with FB-17 strain under limed condition, whereas the minimum seed yield (175.00kgha^{-1}) was recorded from the control plots. Integrated use of inoculants along with lime produced 1781.83-1970.63% too much yield advantages compared with control plots. In comparing only inoculants, all strains produced stastically similar yield indicating farmers can use either of the stains in soils which are not acidic in reaction. The current results demonstrated that soil N is a limiting factor and the existing rhizobium bacteria may not be able to supply the required amount of N through biological fixation unless the soil ameliorated by liming. Thus, the seed yield could be strongly improved by means of inoculation seeds by resistant strain coupled with lime. The result is in agreement with the finding of (Carter *et al.,*1998) who reported that forming effective N_2 fixing symbioses between legumes and their N_2 fixing bacteria is developed whenever there is low nutrient availability (N and P) which can affect the development of the plant. Unless this condition is avail, the most effective rhizobium strains cannot form effective association in nodulation and N fixation with the host plant.

In general, separate application of strains and lime individually was not adequate to increase the seed yield of fababean significantly when compared with integration of lime and strains in the study area. This indicates that the synergistic effect of applied lime along with strains was significant in ameliorating soil acidity and increasing the overall economy of the crop.

Biomass yield

The highest aboveground biomass yield (8261.9kgha^{-1}) was obtained from plots treated with FB-1018 strain coupled with lime which was stastically at par with plots treated by FB-17,FB-04 and FB-1035 strains under limed condition whereas the lowest value (811.9kgha^{-1}) was

Table 3. Effects of rhizobium inoculation and lime on seed yield, biomass yield and HI of fababean

Rhizobium inoculants	Seed yield (kgha^{-1})		Biomass yield(kgha^{-1})		Harvest Index (%)	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
FB-17	3612.50a	2516.2c	8038.70a	6214.30b	45.38ab	40.81a-d
FB-04	3623.60a	2551.9c	7997.00a	5842.30b	46.11a	44.31ab
FB-1018	3550.3ab	2533.3c	8261.90a	5701.20b	43.16abc	45.29ab
FB-1035	3293.20b	2416.5c	8114.60a	5583.30b	40.60a-d	44.79ab
Control	920.40f	175.00g	2529.8de	811.90f	35.64a-e	22.16e
21 kgha^{-1} urea	1241.50e	314.50g	3946.4cd	1283.90ef	32.23b-e	28.05de
150 kgha^{-1} urea	1791.40d	634.90f	4916.7bc	2306.50e	37.87a-d	30.25cde
Mean	2576.13	1591.76	6257.87	3963.34	40.14	36.52
LSD (5%)	309.68		1445.00		13.66	
CV (%)	8.89		16.91		21.30	

Table 4: Economics of inoculation and lime application on fababean production

Treatments	SY (kgha^{-1})	Adj.SY (kgha^{-1})	Economics			B:C (ETB ha^{-1})
			Cost of Cultivation (ETB ha^{-1})	Gross income (ETB ha^{-1})	Net income (ETB ha^{-1})	
BF_1L_1= BF-17+lime	3612.5	3251.25	8870.00	250346.25	241476.25	28.22
BF_2L_1= BF-04+lime	3623.6	3261.24	8870.00	251115.48	242245.48	28.31
BF_3L_1= BF-1018+lime	3550.3	3195.27	8870.00	246035.79	237165.79	27.74
BF_4L_1= BF-1035+lime	3293.2	2963.88	8870.00	228218.76	219348.76	25.73
F_0L_1= lime alone	920.4	828.36	8470.00	63783.72	55313.72	7.53
F_1L_1= 21kgha^{-1} urea +lime	1241.5	1117.35	9310.00	86035.95	76725.95	9.24
F_2L_1= 150kgha^{-1} urea +lime	1791.4	1612.26	14470.00	124144.02	109674.02	8.58
F_0L_0=Control (no strain & lime)	175.0	157.50	0.00	12127.50	12127.50	-
BF_1L_0= BF-17 strain alone	2516.2	2264.58	400.00	174372.66	173972.66	435.93
BF_2L_0= BF-04 strain alone	2551.9	2296.71	400.00	176846.67	176446.67	442.12
BF_3L_0 = BF-1018 strain only	2533.3	2279.97	400.00	175557.69	175157.69	438.89
BF_4L_0 = BF-1035 strain only	2416.5	2174.85	400.00	167463.45	67063.45	418.66
F_1L_0 = 21kgha^{-1} urea alone	314.5	283.05	840.00	21794.85	20954.85	25.95
F_2L_0 =150kgha^{-1} urea alone	634.9	571.41	6000.00	43998.57	37998.57	7.33

Adj.SY = Adjusted Seed Yield down to 10%, SY = Seed Yield, ETB = Ethiopian Birr, B:C benefit cost ratio

obtained from control plots (uninoculated and unlimed plots). Inoculation of fababean seeds with effective strains in conjunction with lime produced 884.97 to 917.60% biomass yield advantages over the control (Table 3.). The increase in aboveground biomass yield due to the application of lime integrated with strain to the soil probably creates more favorable physicochemical conditions in the soil, such as reduced Al^{3+}toxicity and increased nutrients availability. At the end this condition ultimately enhances growth, provide growth-regulating substances and improves the physicochemical and microbial properties of soils. Furthermore, there is reduction of Al^{3+} toxicity, which restricts roots growth and creates difficulty in accessing nutrients and water from a longer distance in the soil. Finally, application of lime along with inoculants could improve root nutrient uptake of the plant through promoting its growth. The current result is in line with the finding of (Beck and Duc, 1991) who reported that inoculation of faba bean was significant for total biological yield, seed yield and total N in the soil.

Harvest Index

The highest harvest index (46.11%) was recorded for yields obtained from plots treated with FB-04 strain with lime, whereas the lowest value (22.16%) was for yields obtained from control plot. The possible reason could be that combined application of lime and strain efficiency of fababean to partition the dry matter into the reproductive seed sinks. Integrated use of lime with effective strains significantly affected yield and yield components of fababean.

Economic analysis

The integrated use inoculants with lime recorded the highest seed yield and additional income compared with control. The highest net income was obtained from plots treated with inoculation of strains under limed condition (Table4.). It was conclusively proved that integrated use of strains and lime is highly remunerative in the study area. Similarly the highest B:C ratio (28.31) was recorded from plots treated with dual application of strains with lime, though this treatment has highest benefit over control. In case of only bio-fertilized plots, FB-04 strain showed highest benefit cost ratio of (442.12). From the outcome of the current study it can be concluded that combined use of rhizobium strains along with lime increases yield and produced the highest economic return.

CONCLUSION

Based on the results, we conclude that, integrated application of appropriate strain with lime improved yield and yield components of fababean following improvement of soil properties. The highest seed yield (3623.6kgha^{-1}) was obtained from the combined application of strain with lime. On the other hand the lowest seed yield (175kgha^{-1}) was recorded from control plots that showed a huge yield difference of about 3448.6kgha^{-1} compared to the highest seed yield.

Moreover, combined application of strain with recommended lime based on exchangeable acidity produced the highest net benefit of 242245.48 ETBha^{-1}compared to other treatments. The results of this study clearly indicate that the combined application of strains with lime ameliorate the adverse effects of soil acidity thereby the overall economy of the crop. Therefore, application of lime with effective strain could be suitable combinations not only yield but also from an economic benefit, to ameliorate soil acidity and improve soil fertility for sustainable fababean production.

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