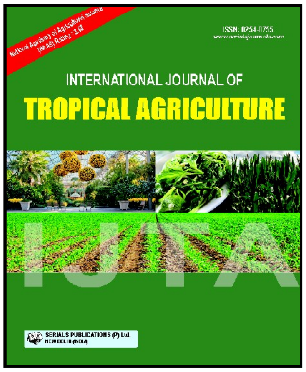

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Response of Soybean [*Glycine max* (L.) Merrill] to Lime and Integrated Nutrient Management on Growth, Yield and Soil Properties in Acidic Soils of Nagaland

Anniecia Lynrah, D Nongmaithem* and Lanunola Tzudir

**Department of Agronomy, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema -797 106, Nagaland, India*

Abstract: A field experiment was carried out at School of Agricultural Sciences and Rural Development (SASRD), Nagaland University during *kharif* season of 2015 to study the response of soybean (*Glycine max*. L. Merill.) to different levels of lime and integrated nutrient management in acidic soils of Nagaland. The results revealed that application of lime @ 1.5 t ha^{-1} recorded significantly highest soil pH after the harvest of the crop (5.01) and gave significantly highest growth and yield of soybean. Among the nutrient sources, application of 50% RDF+ Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed performed the best among the different nutrient sources and gave the highest yield of 2.14 t ha^{-1}.

Key words: Integrated nutrient management, lime, soybean, yield.

INTRODUCTION

Soybean (*Glycine max*.L.Merill) is an important pulse crop that is grown in diverse environments throughout the world. Being a leguminous crop, it helps to enrich the soil by fixing atmospheric nitrogen through root nodule. It is one of the most popular food items of the majority of the people of Nagaland and is utilized as a pulse crop and as a fermented product locally known 'Akhuni' or 'Axone'. Lime as an amendment for increasing nutrient availability in acid soils is considered to be the most important ameliorant for better growth, nodulation, and higher nitrogen fixation by legumes especially in north eastern states where most of the soil is acidic in nature. Soil acidity is known to induce nitrogen deficiency in legume if they depend solely on symbiotic nitrogen fixation. Aluminium and Manganese toxicity caused by soil acidity as well as calcium and phosphorus deficiency in acids soil inhibit *Rhizobium* growth and root infection resulting in symbiotic failure [1]. For meeting calcium demands and creating favourable soil conditions for better uptake of other essential nutrients, liming is an important management practice in acid soils. Liming helps in raising the base saturation of the soil and inactivating iron, aluminum, and manganese in the soil solution. Kamprat, [2] reported the need for raising soil pH beyond the point of neutralizing exchangeable aluminum, particularly for legumes.

Soybean being a high protein and energy crop and its productivity is often limited by the low availability of essential nutrients or imbalanced nutrition forming one of the important constraints to soybean productivity in India. Hence there is an urgent need of 'Integrated Nutrient Supply and Management' system for promoting efficient and balance use of plant nutrients where the emphasis should be given on increasing the proper and balance use of mineral fertilizers, organic manures, biofertilizers, green manuring etc. The conjunctive use of fertilizers, organics and biofertilizers and their practices improve soil structure, physical properties and especially the water holding capacity of soil which could be the great asset in increasing agriculture production. Keeping in view the deteriorating soil nature due to over use of synthetic chemicals along with the need to ameliorate acidic soil particularly in Nagaland condition as well as taking into consideration the importance of soybean in the economy of the state, a field experiment was conducted to study the response of soybean to lime and integrated nutrient management under acidic soils of Nagaland.

MATERIALS AND METHODS

A field experiment was carried out at School of Agricultural Sciences and Rural Development (SASRD), Nagaland University during the period of July to September 2015. The experimental site was located at an altitude of 25°45′43″ N latitude and 95°53′04″ E longitude at an elevation of 310 m above mean sea level. The climate of the experimental area is broadly classified as subtropical humid. The experimental design was split plot design (SPD) with three replications. The main plot treatments consists of four levels of lime: (L_1): 0 t ha^{-1}, (L_2): 0.5 t ha^{-1}, (L_3): 1.0 t ha^{-1} and (L_4): 1.5 t ha^{-1} while the sub-plot treatments consists of four sources of nutrients: (N_1): 100% RDF, (N_2): 50% RDF + FYM @ 5 t ha^{-1} + Vermicompost @ 2 t ha^{-1} , (N_3): 50% RDF + Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed and (N_4): FYM @ 5 t ha^{-1} + Vermicompost @ 2 t ha^{-1}+Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed. Soybean variety JS-9560 was sown at a spacing of 40 cm × 10 cm and the recommended package of practices were followed. The soil was sandy loam and acidic in reaction (pH 4.7). The soil contained 1.2% oxidizable organic carbon, 109 kg ha^{-1} mineralizable nitrogen, 200 kg ha^{-1} available potassium, and 7.84 kg ha^{-1} available phosphorus. Fertilizers were applied uniformly to all plots at recommended rates (20 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} in the form of urea, single super phosphate and muriate of potash, respectively. The data related to each character were analyzed statistically by applying the techniques of analysis of variance as described by Cochran and Cox [3] and the significant of different source of variations was tested using Fisher Schedecor 'F' test at 0.05 level of probability.

RESULTS AND DISCUSSION

Effect of Lime

From the results of the study, it is revealed that application of lime at the levels of 0 t ha^{-1} to 1.5 t ha^{-1} produced higher growth traits. This result could be attributed to higher photosynthesis and better translocation to the fruiting sink due to liming. The increase in vegetative growth with liming may result from better availability of nutrients due to moderation of soil reaction as also opined by Andy and Abdullah, [4]. Application of lime @ 1.5 t ha^{-1} significantly increased plant height (47.07 cm), leaf area index (0.322) and number of root nodules plant^{-1} (70.68) (Table 1). It may also be due to increased biological N fixation. Workneh *etal.* [5] also reported that a sufficient Ca^{2+} supply in the soil has shown to mitigate N_2 fixation limitations of leguminous plant. This improvement might be due to the indirect effect of increasing the nitrogen availability to the plants through increased nitrification by moderating the pH

Table 1

Effect of lime and integrated nutrient management on plant height (cm), leaf area index and number of root nodule plant^{-1}

Treatments	*Plant height*	*Leaf area index*	*Number of root nodule plant^{-1}*
Lime application (t ha^{-1})			
L_1	39.39	0.202	46.93
L_2	41.57	0.229	49.54
L_3	45.65	0.316	56.71
L_4	47.07	0.322	70.68
S.Em±	0.77	0.013	2.368
CD (P = 0.05)	2.68	0.046	8.195
INM			
N_1	43.59	0.263	53.53
N_2	44.11	0.268	57.06
N_3	45.09	0.269	64.98
N_4	40.89	0.249	48.28
S.Em±	0.99	0.010	2.253
CD (P = 0.05)	2.89	NS	6.576

L_1= 0, L_2 = 0.5, L_3 = 1, L_4 = 1.5, N_1=100% RDF (20:80:60 NPK kg ha^{-1}), N_2= 50% RDF+ FYM @ 5 t ha^{-1} + Vermicompost @ 2 t ha^{-1}, N_3 = 50% RDF + Rhizobium @20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @20 g kg^{-1} seed, N_4 = FYM @ 5 t ha^{-1} + Vermicompost @ 2 t ha^{-1} + Rhizobium @20g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @20g kg^{-1} seed, NS = not significant, RDF= recommended dose of fertilisers.

in acid soil. This is in agreement with the work of Rajasree and Pillai, [6]. The lowest plant height in lime-untreated soil may be attributed to the toxic effect of soil acidity, which may lead to stunting of plants which was also reported by Oluwatoyinbo *et al.* [7]

Similarly yield attributes including number of pods plant^{-1}, seed yield and stover yield were recorded significantly with the application of 1.5 t ha^{-1} of lime. This may be due to the fact that liming improved soil pH which increases plant availability of soil nutrients. Highest seed yield (2.71 t ha^{-1}) and stover yield (2.97 t ha^{-1}) may be due to the fact that liming helps increased in vegetative growth which resulted in increased dry matter production, excellent seed filling and ultimately seed yield and stover yield of the crop (Table 2).This is in agreement with the work of Panwar *et al.* [8] and Mathew *et al.* [9]. Soybean grown on lime treated soil showed higher harvest index than soybean grown on un-limed soil, indicating that the treatments promoted better partitioning of food reserves to sinks via, effective photosynthetic activity performed by the sources (photosynthetic parts of plant).

The addition of lime increased soil pH, an effect that may have accelerated the process of mineralization of nitrogen leading to higher growth and yield attributes of soybean. Highest pH (5.07) was recorded with the application of 1.5 t ha^{-1} (Table 3). This might be due to a higher amount of exchangeable calcium concentration which replaced the exchangeable aluminium Al^{3+} with increasing lime levels. The result is in conformity with the findings of Verma and Singh, [10]. Similarly highest available nitrogen (243 kg ha^{-1}) in the soil following liming may have resulted from an increase in soil pH that accelerated the rate of decomposition and mineralization of organic matter (Table 3). Nitrogen fixation may also be increased by increasing microbial activity under a favorable soil environment. Highest available phosphorus (18.00 kg ha^{-1}) in the soil may be due to dissolution of complex Fe and Al

Table 2
Effect of lime and integrated nutrient management on number of pods plant^{-1}, number of seeds pod^{-1}, test weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}), and harvest index (%)

Treatments	*No. of pods plant^{-1}*	*No of seeds pod^{-1}*	*Test weight (g)*	*Seed yield (t ha^{-1})*	*Stover yield (t ha^{-1})*	*Harvest index (%)*
Lime application (t ha^{-1})						
L_1	18.40	3.08	140.44	1.52	1.87	44.86
L_2	21.37	3.12	143.03	1.81	2.14	45.84
L_3	27.04	3.24	144.67	2.21	2.57	46.16
L_4	30.26	3.28	144.87	2.71	2.97	47.67
S.Em±	0.78	0.09	1.21	0.03	0.07	0.88
CD (P = 0.05)	2.71	NS	NS	0.10	0.23	NS
INM						
N_1	23.02	3.16	142.84	2.05	2.36	46.02
N_2	25.25	3.24	143.62	2.07	2.43	45.79
N_3	26.35	3.33	143.91	2.14	2.46	45.80
N_4	22.48	2.98	142.64	2.00	2.29	46.91
S.Em±	0.93	0.10	1.35	0.02	0.04	0.53
CD (P = 0.05)	2.69	NS	NS	0.05	0.12	NS

phosphates, making phosphate available in the form of monocalcium phosphate as also reported by Singh *et al.* [11]; Dixit and Sharma, [12] (Table 3). Highest available soil potassium (275 kg ha^{-1}) may be due to the fact that liming increases potassium availability, owing to the displacement of exchangeable K by Ca (Table 3). Similar findings were reported by Haynes and Naidu, [13].

Effect of Integrated Nutrient Management

Growth parameters *i.e.*, plant height plant^{-1} and number of root nodules plant^{-1} were influenced significantly due to the different sources of nutrients where highest value of plant height (45.09 cm) and highest number of root nodule plant^{-1} (64.98) was recorded with treatment 50% RDF + Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20g kg^{-1} seed (Table 1). Increased in plant height might be due to increased biological nitrogen fixation and solubilisation of more amount of P by phosphate solubilising bacteria. This result is in conformity with the findings of Prajapat *et al.* [14]. Highest highest number of root nodule plant^{-1} might be due to higher number of bacteria available under *Rhizobium* inoculation and PSB which increased the symbiotic N fixation and increased the nodulation. This result is in conformity with the findings of Lanje *et al.* [15].

Similarly yield attributes including number of pods plant^{-1}, seed yield and stover yield were recorded significantly with the application of 50% RDF + Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed. Increased activity of microorganisms in root zone due to bio-inoculation was reflected in the significant improvements in growth parameters and this better growth might have possibly paved the way for significant improvements in yield contributing characters. The result is in conformity with the findings of Bodkhe and Syed, [16]. Highest seed yield (2.14 t ha^{-1}) and stover yield (2.46 t ha^{-1}) might be

Table 3
Effect of lime and integrated nutrient management on soil pH, Organic carbon and available soil nitrogen, available soil phosphorus and available soil potassium.

Treatments	*Soil pH*	*Organic carbon (%)*	*Available N (kg ha^{-1})*	*Available P_2O_5 (kg ha^{-1})*	*Available K_2O (kg ha^{-1})*
Lime application (t ha^{-1})					
L_1	4.70	1.22	231	15.24	219
L_2	4.71	1.26	233	16.11	259
L_3	4.74	1.29	234	16.19	270
L_4	5.01	1.32	243	18.00	275
S.Em±	0.03	0.07	1.63	0.09	1.12
CD (P=0.05)	0.08	NS	5.66	0.32	3.88
INM					
N_1	4.77	1.35	235	16.20	249
N_2	4.78	1.31	237	16.53	263
N_3	4.79	1.27	238	16.77	264
N_4	4.80	1.21	231	16.04	245
S.Em±	0.02	0.06	1.87	0.12	1.29
CD (P=0.05)	NS	NS	5.46	0.35	3.77

due to increased biological nitrogen fixation and solubilisation of more amount of P by phosphate solubilising bacteria and improve soil condition favourable for availability of nutrients to crop throughout the growth period (Table 2).

The data on soil available nitrogen, phosphorus and potassium after harvest of soybean showed increased fertility due to the different sources of nutrients over their initial levels. Soybean supplied with 50% RDF + Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed recorded maximum soil available nitrogen (238 kg ha^{-1}), phosphorus (16.77 kg ha^{-1}) and potassium (264 kg ha^{-1}) (Table 3). This increase might be due to the addition of these nutrients through inorganic fertilizers and improvement in nitrogen and phosphorus due to rhizobium and phosphorus solubilising bacteria respectively. The similar results were reported by Kaswala and Raman, [17].

From the results of the study, it is revealed that application of lime @ 1.5 tha^{-1} in acidic soils of Nagaland can increase the yield of soybean in the region. Minimizing the use of inorganic fertilizers *i.e.*, using 50% RDF along with the integration of biofertilizers Rhizobium @ 20 g kg^{-1} seed + Phosphate solubilising bacteria (PSB) @ 20 g kg^{-1} seed in soybean with can boost up the nutrient status of the soil and enhance the yield of soybean.

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