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Phosphorus, Sulfur and Cobalt Fertilization Effect on Yield and Quality of Soybean (*Glycine max* L. Merrill) in Acidic Soil of Northeast India

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ABSTRACT

Soybean production on acidic soils of northeast India is often constrained by inadequate availability of phosphorus (P), sulfur (S) and cobalt (Co). To ascertain their individual and synergistic effects on growth, yield and quality of soybean, we conducted a field experiment on an acid alfisol (pH 4.5), with 12 treatments consisting of three levels of P (30, 60 and 90 kg P_2O_5 ha^{-1}), two levels of S (15 and 30 kg S ha^{-1}) and two levels of Co (1 and 2 kg Co ha^{-1}) application in factorial combination. In general, growth and yield parameters of soybean responded positively to higher doses of P, S and Co applications, with the response to P fertilization being the best. Higher doses of P also improved seed protein content of soybean. Based on the results of this study, we conclude that 60 kg P_2O_5 ha^{-1} along with 15 kg S and 1 kg Co is advisable for optimum growth, yield and quality of soybean on acid alfisols of northeast India.

Keywords: Micronutrient deficiency, nutritional quality, pulse production, soil acidity

INTRODUCTION

Soybean (*Glycine max* L. Merrill), one of the premier crops, contains 18–20% oil and 40 – 42% protein. It is a good source of isoflavones which helps preventing heart diseases, cancer and HIV. In India, the average productivity of soybean is quite low as compared to other developed or developing countries. The northeastern regions of India is one of the promising soybean growing belts, where crop is grown on slopes, *jhum* lands, terraces and plains. Cultivation of soybean on marginal land combined with sub-optimal nutrient supply is the major hurdle in realizing potential productivity of 2.5–3.0 t ha^{-1}. Sub-optimum phosphorus (P) supply in soil is reported to commonly affect the growth, nodulation and yield of soybean on acid soils (Laltlanmawia et al. 2004; Sentimenla et al. 2012). Sulfur (S) is an important secondary nutrient which helps in synthesis of important amino acids (methionine, cysteine and cystine), chlorophyll and vitamins (biotin and thiamine). It also helps in nitrate reduction and assimilation of nitrogen (N) by root nodule bacteria. Cobalt (Co) is a constituent of cobalamine enzyme and is responsible for formation of leghemoglobin required for N fixation; it also governs the number and size of the root nodules (Yadav and Khanna 1988). It is essential for microorganisms fixing atmospheric N and also helps in formation of vitamins B_{12} in symbiotic microorganisms (Singh et al. 2012). Hence, these three essential nutrients (P, S and Co) are crucial for satisfactory field performance of soybean. Since information on the response of soybean to application of these nutrients in acidic soils of north east India is scarce, the present study was conducted to determine the effect of different levels of P, S and Co application on growth, yield and quality of soybean on an acidic soil of this region.

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MATERIALS AND METHODS

A field experiment was conducted at the Experimental Research Farm (20° 4' 45'' N latitude; 93° 53' 04'' E longitude) of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema. The soil of the experimental farm was sandy loam in texture and acidic in reaction (pH 4.5), with 13.8 g kg^{-1} organic carbon, 250.8 kg ha^{-1}available N, 17.9 kg ha^{-1} available P_2O_5 and 165.3 kg ha^{-1} available K_2O. The treatments comprised of three levels of P (30, 60 and 90 kg P_2O_5 ha^{-1}, henceforth referred to as P_{30}, P_{60} and P_{90}), two levels of S [15 and 30 kg S ha^{-1} (S_{15} and S_{30})] and two levels of Co [1 and 2 kg Co ha^{-1} (Co_1 and Co_2)] in factorial combination in a randomized complete block design with three replications. *Rhizobium*, N, K and Mo were added uniformly in each plot. FYM was applied @ 2 tons ha^{-1} two weeks before sowing. Different levels of P, S and Co were applied at the time of sowing through single super phosphate (SSP), elemental S and cobalt chloride, respectively. The seed of soybean crop (variety JS 335) was sown with a distance of 45 cm row-to-row and 10 cm plant-to-plant. All standard agronomic practices were followed during crop growth period.

The observations including plant height, number of leaves per plant, nodules per plant, fresh weight of nodules, pods and filled pods were recorded. Plants were harvested at maturity, and sun-dried. After threshing, seeds and stover were separated, air-dried and finally oven-dried at a temperature of 65°C + 3°C to attain a constant weight. Dried seeds and stover samples were grinded in a Willey mill, and analysed for N by steam distillation procedure as described by Jackson (1973). Protein content of soybean seeds was worked out by multiplying the percentage value of seed N content with a conversion factor 6.25. Experimental data were analyzed using standard statistical procedure (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Application of P, S and Co did result in improved growth and yield parameters of soybean, although the degree of response was different for the three nutrients. Higher doses of P application (P_{60} and P_{90}) invariably improved all the growth and yield attributes of soybean (plant height, number of leaves, number of nodules per plant, weight of fresh nodules, number of total pods and filled pods per plant and stover yield) relative to its lowest dose (P_{30}) (Table 1). This resulted in significantly improved seed yield at higher doses of P fertilization (28.2 and 30.2 q ha^{-1} yield at P_{60} and P_{90} respectively, compared to 23.5 q ha^{-1} at P_{30}). In contrast, higher doses of S and Co (relative to their lower doses) improved only few growth parameters, and could not increase the seed yield of soybean (Table 1). In case of seed protein content also, higher doses of P application (P_{60} and P_{90}) were found effective, while S_{30} and Co_2 could not result in any significant increase in protein percentage. Interaction effect of these three nutrients on plant growth, yield and quality was not found significant, as the beneficial

Table 1: Effect of P, S and Co fertilization on growth, yield and quality of soybean

Treatments	Plant height (cm)	No. of leaves	No. of nodule $plant^{-1}$	Weight of fresh nodule $plant^{-1}$ (g)	No. of pods $plant^{-1}$	No. of filled pods $plant^{-1}$	Stover yield (q ha^{-1})	Seed yield (q ha^{-1})	Protein (%)
Phosphorus									
P_{30}	61.0	187.7	73.7	8.01	156.6	127.8	34.4	23.5	36.15
P_{60}	68.4	234.1	116.2	8.85	199.5	193.3	37.9	28.2	38.76
P_{90}	75.3	274.0	200.4	10.11	200.1	204.0	41.4	30.2	40.03
CD at 5%	2.1	11.9	5.0	0.48	12.5	5.1	2.0	2.61	1.56
Sulfur									
S_{15}	66.1	227.9	124.0	8.69	181.6	170.7	36.0	26.9	38.24
S_{30}	70.3	235.9	136.2	9.29	201.1	179.4	39.8	27.6	38.39
CD at 5%	1.7	NS	4.1	0.39	10.2	4.2	1.6	NS	NS
Cobalt									
Co_1	67.3	230.7	128.7	8.86	186.5	172.7	37.1	27.3	38.36
Co_2	69.1	233.2	131.5	9.29	196.2	177.4	38.7	27.4	38.27
CD at 5%	NS	NS	NS	0.39	NS	4.2	1.6	NS	NS

effect of P application was not modified in presence of other two nutrients (Figure 1). Thus, the highest seed yield and protein content was recorded at P_{90} (though statistically, they were on par with the yield and protein content obtained at P_{60}), irrespective of the levels of S and Co application.

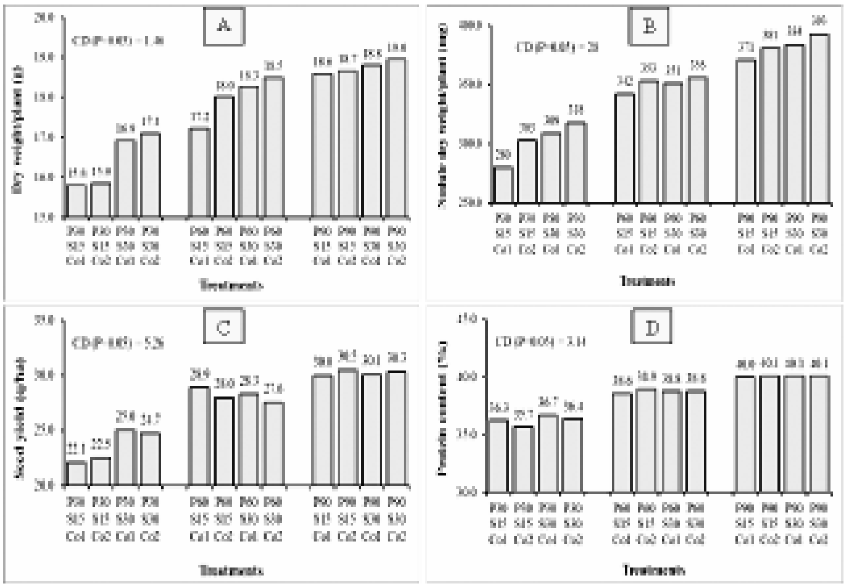

Fig. 1: Interaction effect of P, S and Co fertilization on some selected growth, yield and quality attributes of soybean

The most beneficial effect of P application on plant growth, yield and quality can be understood given the fact that the experimental soil was severely deficient in P availability, which is considered a major limiting factor for crop production on acidic soils of northeast India (Kumar 2011; Kumar et al. 2012; Singh et al. 2014). Such positive response of pulses to P application in acidic soils has also been reported by Vara et al. 1994; Raychaudhury et al. 1997; Laltlanmawia et al. 2004, 2005 and most recently by Awomi et al. 2012. This could be ascribed to the better root growth and more efficient uptake and utilization of other nutrients and water by plant subsequent to adequate P application. Although, S application (S_{30}) caused improvement in some growth attributes, as also reported by Gupta and Sharma (2003) and Sentimenla et al. (2012), it failed to cause significant improvement in seed yield of soybean over that produced at S_{15}. May be the S requirement of crop on the experimental soil was satisfied at S_{15} and therefore further addition of S (S_{30}) was not effective in improving seed yield. Similar results were found in case of Co application also, which caused improvement in some of the growth parameters, as also reported by More and Jadhav (1998), Mohanti et al. (2004) and Awomi et al. (2012), but failed to increase the final seed yield of soybean. We again envisage that Co requirement of the crop might have been fulfilled at Co_1 and thus no improvement in seed yield was observed with its further addition (Co_2). Increase in seed protein content caused by P application can be attributed to improved nitrogen (N) nutrition of crop. Laltlanmawia et al. (2004) and Sentimenla et al. (2012) also observed significant increase in protein content of soybean by application of P in acidic soils of Nagaland. In contrast to the earlier report by More and Jadhav (1998), who observed the best growth and yield of soybean at $P_{90}S_{30}Co_2$, relatively lower doses of P, S and Co fertilization (P_{60} S_{15} Co_1) resulted in statistically similar yield as that found with P_{90} S_{30} Co_2 in the present investigation.

Some of the contradictory results on the optimum doses of P, S and Co fertilization, as reported in foregoing discussion, indicates the differential nutritional requirement of soybean for different soils of the region. Thus nutritional requirement of the crop must be assessed on site-specific basis for recommendation of optimum fertilizer doses for soybean. However, in light of the results reported here, we conclude that the concomitant application of P, S and Co ($P_{60}S_{15}Co_1$) is advisable for the best growth, yield and quality of soybean on acid alfisols of the study area.

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