Indian Journal of Hill Farming 27(1):37-41 Available online at www.kiran.nic.in

Nutrient Management for Improving Mungbean [*Vigna radiata* (L.) Wilczek] Productivity in Acidic Soil of Northeast India

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Received 18.3.2014, Revised 18.4.2014, Accepted 18.4.2014

ABSTRACT

A field experiment was carried out to study the effect of sulphur (S) and cobalt (Co) fertilization in combinations with *Rhizobium* inoculant (RI) and recommended NPK fertilization (RDF) on growth, yield and nutrient uptake of mungbean in an acidic soil of northeast India. Application of RI alone or in combination with S or Co (without NPK) could not significantly increase the grain yield, but combined application of RI+S+Co did increase it up to 450 kg ha^{-1} from 240 kg ha^{-1} at control. Noticeably, application of recommended NPK (without any other inorganic or organic inputs) led to a better grain yield (530 kg ha^{-1}), which was more than twice the yield at control. And further addition of RI+ S+ Co along with NPK (RDF) nearly tripled the yield (730 kg ha^{-1}) compared to that of control. Effect of RI, S and Co application on crop yield was mediated mostly through increased nodulation and nutrient uptake, which were correlated well with seed yield.

Keywords: Cobalt, Pulse production, Root nodulation, *Rhizobium* inoculation, Sulphur

INTRODUCTION

Mungbean, a high protein (23-24 percent) legume, occupies 14 percent of total pulses' area and 7 percent of total pulse production in India, with an average national productivity of 363 kg ha^{-1}. In northeastern region of India, mungbean is grown on hill slopes, *Jhum* lands, terraces and plains, where there lies a vast scope of enhancing its productivity through judicious nutrient management. Cultivation on marginal to sub-marginal lands, with minimal supply of nutrients, is thought to be a major cause for low productivity of mungbean in Northeast India. A balanced dose of major nutrients (NPK), sulphur (S) and cobalt (Co) are crucial for productive performance of mungbean. Mungbean, being a rich source of protein, needs to be judiciously fertilized with S, as this element plays a key role in protein synthesis. Sulphur is a constituent of essential amino acids – methionine, cysteine and cystine– the building blocks of protein. Sulphur fertilization is considered critical for seed yield and protein synthesis and for improvement in quality of produce in legumes through their enzymatic and metabolic effects (Bhattacharjee et al. 2013). Cobalt, being a constituent of cobalamine enzyme, plays a key role in governing the number and size of the nodules. Moreover, Co application also increases formation of leghemoglobin required for nitrogen fixation, thereby improves the nodules activity (Awomi et al. 2012). Although plenty of research has been conducted on balanced fertilization of legumes, there is little information available on yield and nutrient uptake of mungbean in response to application of S and Co in combination with different nutrient sources including biofertilizer and mineral fertilizers in acid soils of northeast India. The present study was, therefore, undertaken to quantify the extent of benefits that can be derived from application of S and Co in different combinations with varying nutrient sources in terms

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of yield and nutrient uptake of mungbean in study area.

MATERIALS AND METHODS

Experimental site and treatment description

A field experiment was conducted for consecutive two years in the University farm of SASRD, Medziphema (Nagaland) with 10 treatments comprising of *Rhizobium* inoculant (RI), recommended dose of NPK fertilizers (RDF), S and Co applied alone or in combinations. Some relevant physico-chemical properties of the experimental soil are shown in Table 1.

Table 1: General physico-chemical properties of the experimental soil

Soil properties	Values/description
Soil type	Typic Hapludalf
pH (1:2 soil/water)	4.8
EC (ds/m)	0.32
Organic carbon (%)	1.13
Textural class	Sandy loam
Available N (kg ha^{-1})	231.2
Available P (kg ha^{-1})	6.3
Available K (kg ha^{-1})	160.3
Available S (kg ha^{-1})	21.5
Available Zn (mg kg^{-1})	0.82
Available Mn (mg kg^{-1})	7.71
Available Cu (mg kg^{-1})	0.98
Available Fe (mg kg^{-1})	40.3
Available Co (mg kg^{-1})	0.08

The treatments were T_1: absolute control; T_2: *Rhizobium* inoculant (RI); T_3: RI + S; T_4: RI + Co; T_5: RI + S + Co; T_6: RDF (20: 17.47: 16.67kg N: P: K ha^{-1}); T_7: RDF + RI; T_8: RDF + RI + S; T_9: RDF + RI + Co; T_{10}: RDF + RI + S + Co. The experiment was laid out in a randomized complete block design with three replications. The RDF was applied by broadcasting through urea, SSP and MOP. Sulphur was applied @ 20 kg ha^{-1} through ammonium sulphate. *Rhizobium* inoculant (RI) was applied through seed treatment. Cobalt was applied @ 10mg kg^{-1} through seed treatment with cobalt sulphate. The full dose of P, K and half of N was applied as basal dose. The remaining N was applied 30 days after sowing. Mungbean cultivar 'K- 851' was sown during 1st week of June in both the years and harvested at physiological maturity.

Sample collection and analysis

Soil samples were collected before start of the experiment and after harvest of the crop. Three sub-samples (0-15 cm depth) were collected randomly from each plot, air dried and ground to pass through a 2-mm sieve. The sub-samples were mixed to form composite samples for each plot. Three representative plant samples were also collected from each plot, separated into grain and stover, washed, oven dried and ground in a Willey mill. Root nodules were counted in three representative samples from each plot in a 30 days-old crop. The plant height and yield data were recorded at physiological maturity stage and after harvest of the crop, respectively. The processed soil and plant samples were subjected to required analyses. The soil pH was determined by a standard pH meter in a 1:2 soil/water suspension. Soil organic carbon (SOC) content was determined by modified Walkley–Black method (Nelson and Sommers 1982). Available N was determined following alkaline $KMnO_4$ distillation procedure (Subbiah and Asija 1956). Available P and K were determined following standard procedures as outlined by Jackson (1973). Available S was determined turbidimetrically following standard procedure (Baruah and Borthakur 1997). Micronutrient contents were determined as DTPA-extractable Zn, Mn, Cu, Fe (Lindsay and Norvell 1978) and Co using Atomic Absorption Spectrophotometer (GBC, Avanta Grade, Version 932 plus). S and Co content in plant samples (after digestion with di-acid mixture at 250°C) was analyzed using turbidimetric method and Atomic Absorption Spectrophotometer (AAS), respectively.

Experimental data were analyzed using standard statistical procedure of Gomez and Gomez (1984). Data pertaining to all the parameters are presented on two years' pooled mean basis. Significance of treatments' effect was tested at 5% level of probability. Pearson's correlation coefficients were used to determine the relationships among different growth, yield and nutrient uptake parameters.

RESULTS AND DISCUSSION

Plant growth and nodule development

The growth and yield parameters of the crop are presented in Fig 1. Sole application of RI led to a plant height of 43.3 cm, which was significantly higher than control (34.7cm). Sole application of RDF increased plant height (53cm) significantly over sole RI. A gradual increase in plant height was recorded with combination of RDF+ RI along with S and Co separately and concurrently. The plant height (66 cm) recorded with conjoint application of RDF, RI, S and Co was the maximum amongst all the treatments. Significant increase in nodule count over control was recorded due to application of RI along with S and Co separately or in combination. The positive effect of RI on plant growth and nodulation in mungbean was reported by Chovatia et al. (1993). Pattanayak et al. (2000) also reported improved nodulation in mungbean in response to seed treatment with Co in combination with RI. As anticipated, sole application of RI was superior to sole RDF application in terms of nodule count. Combined application of RDF and RI, however, brought about a noticeable increase in nodule count in comparison to their sole applications. The maximum number of nodules (46.3) was recorded under combined application of RDF+ RI with S and Co, which was at par with that recorded under combined application of RI, S and Co (45.67). Application of Co has been shown to significantly enhance nodulation in faba bean (Kandil 2007) and mungbean (Awomi et al. 2012). The observed increase in growth and nodulation response of mungbean to RI, S and Co application reinforces the importance of these inputs to legume crops.

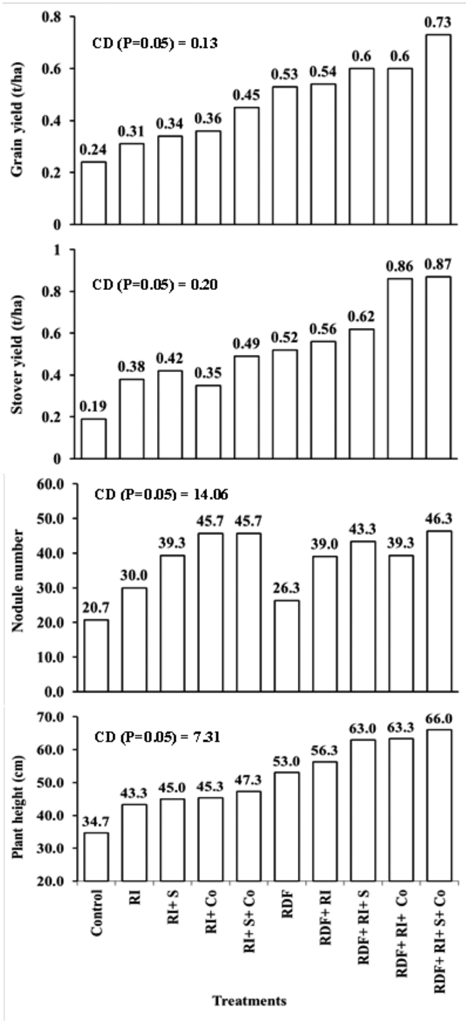

Fig. 1: Growth and yield of mungbean as influenced by *Rhizobium* (RI) inoculation, NPK (RDF), sulphur (S) and cobalt (Co) application

Grain and stover yield

The variable plant growth and nodulation under different treatment combinations led to differences in grain and stover yields as well (Fig. 1). Application of RI alone or in combination with S or Co (without NPK application) could not significantly increase the grain yield, but combined application of RI+S+Co did increase it up to 450 kg ha^{-1} from 240 kg ha^{-1} at control. Interestingly, sole application of recommended NPK (without any other inorganic or organic inputs) led to a better grain yield (530 kg ha^{-1}), which was more than twice the yield at control. And further addition of RI+ S+ Co along with recommended NPK (RDF) nearly tripled the yield (730 kg ha^{-1}). There was almost two-fold difference between the average yields of the treatments' group with and without RDF (*i.e.* 600 and 340 kg ha^{-1}, respectively), which shows the mungbean yield can be doubled in study area by application of recommended dose of NPK fertilizers. Inclusion of biofertilizer (*Rhizobium*), Co and S along with RDF can further raise the yield to be tripled over that obtained with no use of organic and inorganic fertilizations (control). Significant improvement in seed and biomass yield of mungbean owing to seed treatment with Co and Mo along with application of RI was also reported by Pattanayak et al. (2000). Increased seed yield (31%) of mungbean due to Co application (1 kg ha^{-1}) has also been reported by Awomi et al. (2012). A 20 percent increase in mungbean yield over control owing to S application was reported by Aulakh (2003). Similar effect of S application on soybean seed yield was reported by Mishra and Agarwal (1994). Stover yield followed nearly the same trend as grain yield in response to different treatment combinations (Fig.1). Considering all the growth and yield attributes, it can be asserted that S and Co when combined with RDF+ RI played a key role in enhancing grain yield and dry matter production of mungbean. Similar effects of S application on mungbean yield were reported by Ravichandran et al. (1997). Application of S has been reported to enhance N uptake, stimulate photosynthetic activity and synthesis of chloroplast protein resulting in higher dry matter production in soybean (Reddy and Reddy 2001b). The present results are also in agreement with the findings of Ibrahim et al. (1989), where the better growth and yield of another legume (Faba bean) owing to Co application was attributed to promotion of many developmental processes such as stem and coleoptile elongation, opening of hypostyle hooks, leaf disc expansion and bud development *etc*. The findings of Jana et al. (1994) depicted the benefits of Co application in improving nodulation and maintaining a high population of *rhizobia* in the rhizosphere.

Nutrient uptake and correlation study

Application of S alone or with Co along with different nutrient sources brought about a significant improvement in S uptake (Fig.2). Combining RI with S and S+ Co enhanced S uptake

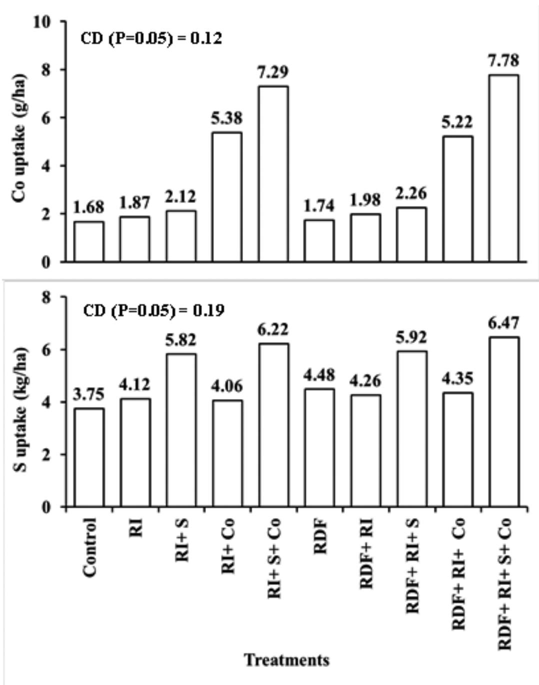

Fig. 2: Sulphur and cobalt uptake by mungbean as influenced by *Rhizobium* inoculation (RI), NPK (RDF), sulphur (S) and cobalt (Co) application

by 41.3 and 51 %, respectively over sole RI application. Similarly, combining RDF+ RI with S and S+ Co improved S uptake by 39 and 51.9 %, respectively over sole application of RDF+ RI. Such improvement in S uptake in response to S application in soybean was reported by Reddy and Reddy (2001a). The minimum crop uptake of Co (1.68 g ha^{-1}) was recorded in control. Application of RI caused significant enhancement in Co uptake over control. Fortifying RI with S and/ or Co further improved Co uptake. The combination of RDF+ RI when applied along with S and/ or Co resulted in even better Co uptake. Co application alone or together with S caused a significant improvement in Co uptake. Conjoint application of RDF+ RI with S and Co led to maximum uptake of Co (7.78 g ha^{-1}). Increased crop uptake of Co subsequent to Co application may have resulted due to its deficiency in soil and high requirement by the crop, and that caused by S and RDF may be due to their positive effect on plant growth and synergism with Co nutrition in legumes (Bhattacharjee et al. 2013).

The correlations of S and Co uptake with grain yield and nodulation of the crop is presented in Table 2. Significant positive correlations of grain yield was observed with nodule count (r = 0.516; p = 0.05) and S uptake (r = 0.507; p = 0.05), while Co uptake showed comparatively weaker correlation (r = 0.448; p > 0.05). This shows the importance of proper nodulation for better productive performance of mungbean, and highlights the benefits of S application on the crop (Reddy and Reddy 2001a&b). Nodule count was highly correlated with S uptake. Even stronger correlation of nodule count was observed with Co uptake (r = 0.702; p = 0.01), which underlines the beneficial effect of Co application to legumes (Pattanayak et al. 2000; Kandil 2007).

Table 2: Correlations (r) of sulphur and cobalt uptake with yield and nodulation in mungbean

	Grain yield	Nodule count	Sulphur uptake	Cobalt uptake
Grain yield	1	0.516*	0.507*	0.448
Nodule count	-	1	0.642*	0.702**
Sulphur uptake	-	-	1	0.514*
Cobalt uptake	-	-	-	1

*significant at 5%; **significant at 1%

CONCLUSION

Application of recommended dose of mineral fertilizers (NPK) can potentially double the productivity of mungbean, and addition of biofertilizer (*Rhizobium*), Co and S along with recommended NPK can further raise the yield three-fold over that obtained with no organic and inorganic fertilizations (control). Thus, S and Co application along with NPK and biofertilizer is a recommendable option to boost the productivity of mungbean in acidic soils of northeast India.

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