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Sonal Kumari
Department of Soil Science and Agricultural Chemistry, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

DK Shahi
Department of Soil Science and Agricultural Chemistry, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

P Mahapatra
Department of Soil Science and Agricultural Chemistry, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

AK Singh
Department of Agronomy, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Satish Kumar Pandey
Department of Agronomy, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Correspondence
Sonal Kumari
Department of Soil Science and Agricultural Chemistry, Ranchi Agriculture College, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

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Response of added P, S and microbial inoculant on biological nitrogen fixation and yield of soybean

Sonal Kumari, DK Shahi, P Mahapatra, AK Singh and Satish Kumar Pandey

Abstract
A field experiment was conducted at experimental farm of Birsa Agricultural University during the *kharif* season, 2016 to study the response of added P, S and microbial inoculant on biological nitrogen fixation and yield of soybean with 18 treatment combinations having two levels of inoculation (I_0 and I_1), three levels of phosphorus (P_{40}, P_{60} and P_{80} kg ha^{-1}) and three levels of sulphur (S_0, S_{15} and S_{30} kg ha^{-1}) in a split-split plot design replicated thrice. The soil of the experimental site was sandy clay loam in texture having good drainage and fairly moisture retention capacity with acidic pH (5.2), EC (0.08dS m^{-1}), low in organic carbon (2.6 g kg^{-1}),CEC (8.5 cmol (p^{+}) kg^{-1}), total nitrogen (0.157%) and available nitrogen (181.5 kg ha^{-1}), medium in available phosphorus (23.9 kg ha^{-1}) and available sulphur (17.0 ppm) was above the critical range. Microbial population in initial soil was 29.33×10^4 Propagules g^{-1}, 22×10^6 CFU g^{-1}, 8.9×10^6 CFU g^{-1} for fungi, bacteria and actinomycetes, respectively. The results revealed that different levels of phosphorus and sulphur along with microbial inoculation significantly influenced the nodulation parameters and yield such as number of nodules (33.0plant^{-1}), fresh weight of nodule (0.69 gplant^{-1}) and dry weight of nodule (0.31 gplant^{-1}) were recorded maximum with application of phosphorus @ 80 kg P_2O_5 ha^{-1}while having statistical equivalence with 60 kg P_2O_5 ha^{-1} for number of nodules per plant. BNF and yield of soybean remarkably increased with increasing doses of phosphorus and recorded maximum of 84.0 kg ha^{-1}, 24.0 q and 27.1 q ha^{-1} BNF, grain and straw yield, respectively with 80 kg P_2O_5 ha^{-1}. Application of 30 kg S ha^{-1} was found equally effective with application of 15 kg S ha^{-1} in respect to number of nodules, fresh weight, dry weight of nodule and grain yield and recorded maximum value of 31.4plant^{-1}, 0.67 gplant^{-1} and 0.30 gplant^{-1}, and 23.6 q ha^{-1}, respectively with application of 30 kg S ha^{-1}.BNF increased with increasing doses of sulphur and recorded maximum of 77.0 kg ha^{-1} with 30 kg S ha^{-1}. Microbial inoculation significantly increased the number of nodules (34.0plant^{-1}), fresh weight (0.69 gplant^{-1}), dry weight of nodule (0.30 gplant^{-1}), BNF (83.4 kg N ha^{-1}), grain yield (23.4 q ha^{-1}) and straw yield (26.4 q ha^{-1}).

Keywords: Biological nitrogen fixation and yield of Soybean, P, S and microbial inoculant

Introduction

Soybean (*Glycine max* (L.) Merill) is a leguminous oil seed crop, occupying 2nd rank for oil seed production (8569.80 MT, 2015-16, MOA, GOI) in India. It is an important high-quality protein source for human and animal nutrition. In terms of food components, soybean contains 35 - 40% protein, 19- 22% oil, 35% carbohydrate (17% of which is a dietary fibre), 5% minerals and several other components including vitamins (Liu, 1997). Soybean with the soil bacteria *Bradyrhizobiumjaponicum* symbiotically colonizing the plant's roots and are able to fix atmospheric nitrogen (N_2).Soybean can biologically fix nitrogen in the range of 85 - 154 kg N ha^{-1} (Giller, 2001) [5]. Phosphorus (P) and sulphur (S) are major nutrient elements for grain legumes. Phosphorus has very positive effects on nodule formation and nitrogen fixation in legume crops (Sepetolu, 2002) [14]. Phosphorus in the soil has developmental activity in the plant's root growth.

Depending on phosphorus applications, the contact area of the root expands with the growth of root which in turn, gives rise to a flourishing in productivity, also making it easier for the plant to benefit from the other nutritional elements in higher proportions (Marschner, 1995) [11]. Sulphur plays a vital role in plant metabolism. It constitutes the main element of amino acids such as cysteine and methionine, which are of essential nutrient value. In addition to these functions, ferro-sulphur proteins play an important role in nitrogen fixation and electron movement in photosynthesis (Kadıolu, 2004) [8]. Sulphur has positive effects on root growth in plants in general. This element positively affects nodulation in legume crops (Kacar, 1984) [7].

Materials and methods

The experiment was conducted under field condition at experimental farm of Soil Science and Agricultural Chemistry, B.A.U, Ranchi. The soil of the experimental site was sandy clay loam in texture having good drainage and fairly moisture retention capacity with acidic pH (5.2), EC (0.08dS m-1), low in organic carbon (2.6 g kg-1),CEC (8.5 cmol (p+) kg-1), total nitrogen (0.157%) and available nitrogen (181.5 kg ha-1), medium in available phosphorus (23.9 kg ha-1) and available sulphur (17.0 ppm) was above the critical range. Soybean (var. JS-335) was taken as a test crop during the Kharif season, 2016 with 18 treatment combinations comprising two levels of inoculation (I_0 and I_1), three levels of phosphorus (40, 60 and 80 kg ha-1) and three levels of sulphur (0, 15 and 30 kg ha-1) in split-split plot design with three replications. The data on nodulation and yield parameters were recorded by following standard methods. Assessment of nodulation by five randomly selected whole plants from each treatment and replications were uprooted at 50% flowering stage. The roots were washed carefully to remove soil particles and the nodules were separated from the roots and counted, fresh weight of nodules were taken and then root nodules were oven dried at 70^0Cfor 72 hours and their dry weight was measured. Total nitrogen content in nodule was determined by Kjeldhl's method (Jackson, 1973) [6]. BNF (kg N ha^{-1}) potential was calculated based on number of nodules per plant, dry weight of nodules (g), N content in nodules (%) and plant population (350,000 ha^{-1}). Grain and straw yield were recorded at harvest and expressed in q ha^{-1}. The harvest index is a ratio of economic yield to the biological yield per hectare and expressed in percentage.

Results and Discussion

Nodulation parameters

Data as indicated in the table 1 shows that number of nodules per plant, fresh weight and dry weight of nodules and biological nitrogen fixation were significantly affected by the different level of phosphorus. Among the levels of phosphorus, application of 80 kg P_20_5 ha^{-1} produced the highest number of nodules (33.0 $plant^{-1}$) and was found to be significantly superior over 40 kg P_2O_5 ha^{-1} that produced minimum number of nodules (26.4$plant^{-1}$). However, it was remained at par with 60 kg P_20_5 ha^{-1} (30.3$plant^{-1}$) while in case of fresh weight and dry weight of nodules per plant, application of 80 kg P_20_5 ha^{-1} was found to be significant over 60 kg P_20_5 ha^{-1} and 40 kg P_20_5 ha^{-1} and recorded maximum fresh weight and dry weight of nodules (0.69g and 0.31g $plant^{-1}$, respectively) followed by 60 kg P_20_5 ha^{-1} (0.66g and 0.29g $plant^{-1}$, respectively) whereas, the lowest fresh weight and dry weight of nodules (0.61g and 0.26g $plant^{-1}$, respectively) were registered with 40 kg P_20_5 ha^{-1}. Application of phosphorus had significant effect on biological nitrogen fixation and followed the sequence of P_{80} (84.0 kg N ha^{-1}) > P_{60} (73.0kg N ha^{-1}) > P_{40}(55.5kg N ha^{-1}). During nodulation, phosphorus is an essential ingredient for *Rhizobium* bacteria to convert atmospheric nitrogen into an ammonium (NH_4^+) form usable by plants. Adequate supply of phosphorus seems to have promoted root growth, resulting in higher production and development of root nodules. The increase in number of nodules may also resulted in increase in fresh and dry weight of nodules. (Tahir *et al.*, 2009; Abbasi *et al.*, 2012) [15, 1]. BNF varied from 55.5 to 84.0kg N ha^{-1} in acid soils under sub-humid condition however, several authors reported for BNF variation starting from 80 to 154 kg ha^{-1} (Giller, 2001) [5]. It is apparent from data that the number of nodules per plant was significantly affected by different level of sulphur application (Table 1). Application of 30 kg S ha^{-1}gave the highest number of nodules (31.4$plant^{-1}$) and found significantly superior over 0 kg S ha^{-1} (28.5$plant^{-1}$) which was at par with 15 kg S ha^{-1} (30.0$plant^{-1}$). Fresh weight and dry weight of nodules per plant were observed significantly high under the treatment receiving 30 kg S ha^{-1} (0. 67g and 0.30g $plant^{-1}$, respectively) over 0 kg S ha^{-1} (0.63g and 0.28g $plant^{-1}$, respectively) which was however, at par with 15 kg S ha^{-1} (0.66g and 0.29g $plant^{-1}$, respectively) while in case of BNF, doses of sulphur followed the significant sequence of S_{30}(77.0kg N ha^{-1}) > S_{15} (70.5kg N ha^{-1}) > S_0 (65.0kg N ha^{-1}).The increase in number of nodules and weight of nodule might be due to vital role of sulphur in formation of ferrodoxin iron containing plant protein that act as electron carrier in photosynthesis and involved in N-fixation by nodule bacteria. (Dhage *et al.*, 2014; Long Kumar *et al.*, 2017) [4, 10]. The data pertaining to number of nodules, fresh weight, dry weight of nodulesper plant and BNF as influenced by the levels of microbial inoculation is presented in table 1. Inoculated plot produces significantly more number of nodules (34.0 $plant^{-1}$), fresh weight (0.69g $plant^{-1}$) and dry weight (0.30 g$plant^{-1}$) and BNF (83.3 kg N ha^{-1}) than uninoculated (26.0 $plant^{-1}$, 0.62g $plant^{-1}$, 0.28g $plant^{-1}$ and 58.2 kg N ha^{-1}, respectively). It may be because *Rhizobium* involves in BNF and provide the better root growth which facilitated more area for nodule formation. (Zerpa *et al.*, 2013; Aminu *et al.*, 2015) [17, 3].

Anon significant deviation in N content of nodule was observed due to application of phosphorus, sulphur and microbial inoculation. (Table 1).

Table 1: Effect of P, S and microbial inoculation on number, fresh weight, dry weight, N content of nodules and BNF of soybean

Treatment	No. of nodules per plant	Fresh weight of nodules per plant (g)	Dry weight of nodules per plant (g)	N content in nodule (%)	BNF (kg N ha^{-1})
Phosphorus level (kg ha^{-1})					
P_1	26.4	0.61	0.26	2.22	55.5
P_2	30.3	0.66	0.29	2.25	73.0
P_3	33.0	0.69	0.31	2.26	84.0
S.Em (±)	1.36	0.01	0.005	0.02	3.79
CD (P=0.05)	4.43	0.04	0.015	NS	12.37

Sulphur level (kg ha^{-1})					
S_1	28.5	0.63	0.28	2.24	65.0
S_2	30.0	0.66	0.29	2.25	70.5
S_3	31.4	0.67	0.30	2.25	77.0
S.Em (±)	0.71	0.01	0.004	0.01	1.95
CD (P=0.05)	2.07	0.03	0.012	NS	5.68
Inoculation level					
I_0	26.0	0.62	0.28	2.24	58.2
I_1	34.0	0.69	0.30	2.26	83.4
S.Em (±)	1.26	0.01	0.003	0.01	3.48
CD (P=0.05)	7.67	0.06	0.01	NS	21.20
C.V. (%)	10.1	6.01	5.77	2.54	11.7

Yield

Critical examination of data given in table 2 reveals that phosphorus levels significantly influenced the grain and straw yield. The application of 80 kg P_20_5 ha^{-1} produced significantly higher grain yield (24.0 q ha^{-1}) and straw yield (27.1 q ha^{-1}) over 40 kg P_20_5 ha^{-1} (21.0 q 23.6 q ha^{-1} for grain and straw yield, respectively). It was also evident that application of 60 kg and 40 kg P_20_5 ha^{-1} differed significantly with each other. The increase in grain and straw yield of soybean over lower dose of phosphorus might be due to increase translocation of photosynthates towards the sink development have occurred (Wu *et al.*, 2012; Dhage *et al.*, 2014) [16, 4]. The perusal of data presented in table 2 shows that the different doses of sulphur influenced significantly the grain yield of soybean. Significantly higher grain yield (23.6 q ha^{-1}) was recorded with the application of 30 kg S ha^{-1} as compared to 0 kg S ha^{-1} (21.5 q ha^{-1}) which was at par with 15 kg S ha^{-1} (22.3 q ha^{-1}). The increase in grain yield of soybean by sulphur application might be due to the effect of sulphur in utilizing large quantities of nutrients through their well developed root system, which resulted in better utilization of plant nutrients from soil (Parakhia *et al.*, 2016 and Longkumer *et al.*, 2017) [13, 10]. The results further revealed in table 2 that apparently the straw yield of soybean was found non significant with different doses of sulphur application. Inoculation had pronounced and significantly affected the grain and straw yield of soybean. The inoculation produced significantly higher grain and straw yield 23.4 q and 26.4 q ha^{-1}, respectively as compared to uninoculated plot (21.6 q and 24.5 q ha^{-1} of grain and straw yield, respectively). This might be due proper establishment and greater infection of N-fixers and use of specific rhizobial strain homologous for the test plant may have influenced to develop healthy and efficient nodules supplemented with P and S in adequate number on root biomass, resulting in efficient dinitrogen reduction and its assimilation leading to increase in yield (Morad *et al.*, 2013 and Adeyeye *et al.*, 2017) [12, 2]. Harvest index was observed to be around 47% and there was non significant difference among the treatments.

Table 2: Effect of P, S and microbial inoculation on yield of soybean

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Phosphorus level (kg ha^{-1})			
P_1	21.0	23.7	47.0
P_2	22.6	25.6	46.8
P_3	24.0	27.1	46.8
S.Em (±)	0.39	0.43	0.14
CD (P=0.05)	1.30	1.42	NS
Sulphur level (kg ha^{-1})			
S_1	21.5	24.5	46.7
S_2	22.3	25.4	46.7
S_3	23.6	26.7	47.1
S.Em (±)	0.53	0.61	0.14
CD (P=0.05)	1.55	NS	NS
Inoculation level			
I_0	21.6	24.5	46.8
I_1	23.4	26.4	47.0
S.Em (±)	0.16	0.10	0.11
CD (P=0.05)	0.99	0.61	NS
CV (%)	10.0	10.3	1.28

References

1. Abbasi MK, Tahir MM, Azam W, Abbas Z, Rahim N. Soybean yield and chemical composition in response to phosphorus – potassium nutrition in Kashmir. American Society of Agronomy. 2012; 104(5):1476-1484.
2. Adeyeye AS, Togun AO, Olaniyan AB, Akanbi WB. Effect of fertilizer and *Rhizobium* inoculation on growth and yield of soybean variety. Advances in Crop Science and Technology. 2017; 5:255.
3. Aminu SM, Shamsuddeen U, Dianda M. Effects of inoculation on the growth of soybean planted in soils from different geographical location in Northwestern Nigeria. International Conference, 2015, 978-993.
4. Dhage SJ, Patil VD, Dhamak AL. Influence of phosphorus and sulphur levels on nodulation, growth parameters and yield of soybean (*Glycine max* L.) grown on Vertisol. An Asian Journal of Soil Science. 2014; 9(2):244-249.
5. Giller KE. Nitrogen fixation in tropical cropping systems. CABI International, Wallingford, UK, 2001.
6. Jackson ML. *Soil chemical analysis*. Prentice-Hall of India (Pvt.) Ltd., New Delhi, 1973.

7. Kacar B. Plant nutrition. Ankara Univ. Agricultural Fac. Pub.: 899 Practice Guide, 1984, 250.
8. Kadıolu A. Plant Physiology, Practice Guide. Trabzon, Turkey, 2004.
9. Liu KS. Chemistry and nutrition value of soybean components. In: Soybean chemistry, Technology and Utilization. Chapman and Hall. New York, USA, 1997.
10. Longkumer LT, Singh AK, Jamir Z, Kumar M. Effect of sulphur and boron nutrition on yield and quality of soybean (*Glycine max* L.) grown in an acid soil. Communication in Soil Science and Plant Analysis. 2017; 48(4):405-411.
11. Marschner H. Mineral nutrition of higher plants. 2nd edition. Academic Press, Inc. London, G.B., 1995, 446.
12. Morad M, Sara S, Alireza E, Reza CM, Mohammad D. Effects of seed inoculation by *Rhizobium* strains on yield and yield components in common bean cultivers (*Phaseolus Vulgaris* L.). International Journal of Bioscience. 2013; 3(3):134-141.
13. Parakhia DV, Parmar KB, Vekaria LC, Bunsa PB, Donga SJ. Effect of various sulphur levels on drymatter, yield attributes of soybean (*Glycin max* L.) varieties. The Ecoscan. 2016; 10(1&2):51-54.
14. Sepetolu H. Grain legumes. Departmant of Field Crops, Faculty of Agriculture, University of Ege Publication: 24/4, zmir, Turkey, 2002.
15. Tahir MM, Abbasi MK, Rahim N, Khaliq A, Kazmi MH. Effect of *Rhizobium* inoculation and nitrogen, phosphorus fertilization on growth, yield and nodulation of soybean (*Glycine max* L.) in the sub-humid hilly region of Jammu and Kashmir, Pakistan. African Journal of Biotechnology. 2009; 8(22):6191-6200.
16. Wu DT, Xiao-Xue Z, Zhen-Ping G, Chun-Mei MA, Lei Z. Effect of phosphorus nutrition on phosphorus absorption and yields of soybean. Acta Metallurgica Sinica. 2012; 18(3):670-677.
17. Zerpa M, Maryz J, Mendez J. Effect of *Bradyrhizobiumjaponicum* inoculants on soybean growth and nodulation. Annals of Biological Research. 2013; 4(7):193-199.