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Effect of rock phosphate, PSB and FYM on P concentration and dry matter yield of soybean (*Glycine max*)

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Abstract
A pot experiment was conducted in order to study the influence of different combinations of rock phosphate (RP), FYM and phosphate solubilizing bacteria (PSB) on phosphorus concentration and dry matter yield of soybean variety MACS-1460 grown in an acid soil of Manipur. Result revealed that plant P concentration and dry matter yield of soybean were affected significantly by the application of SSP, rock phosphate, FYM and PSB either singly or in combination. Fertilization of rock phosphate in presence or absence of PSB and FYM significantly increased P concentration and dry matter yield of soybean over control at different stages of crop growth. Comparatively higher P concentration and dry matter yield of soybean was recorded in soil treated with T_{11} (100% RD of P_2O_5 from RP + PSB_2 + FYM at 5t ha^{-1}) which is at par with T_{10} (100% RD of P_2O_5 from RP + PSB_1 + FYM at 5t ha^{-1}) at the time of harvest. Agronomic efficiency of rock phosphate as P source for crop production is enhanced by the solubility effect of FYM and PSB application. Application of PSB and FYM in combination enhanced organic P mineralization thereby increasing soil P availability, plant P concentration, growth and dry matter yield of soybean.

Keywords: Rock phosphate, phosphate solubilizing bacteria (PSB), farm yard manure (FYM), P concentration, dry matter yield, soybean

1. Introduction
Soybean (*Glycine max* L. Merrill) is the world's most important seed legume, which contributes to 25% of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding. Soybean meal is valuable ingredient in formulated feeds for poultry and fish. It has a wide range of geographical adoption, unique chemical composition, good nutritional value, high yield potential, functional health benefits and variety of end users (food, feed and nonedible). Soybean has capacity to give return even under minimum agricultural inputs and management practices. It performs well under cropping systems and rotations and also included under inter and mixed-cropping systems. Area under soybean around the world is increasing day by day not only due to economic gains to farming community but also due to its harmony with environment by reducing the dependency on chemical sources of nutrients to increase the crop yield.
Moreover, as a legume, the crop improves soil fertility by fixing atmospheric nitrogen to the extent of 65-115 kg/ha (Alexander, 1977) [4] through phenomenon of symbiosis in root nodules depending upon agro climatic conditions, variety, strain, etc. Therefore soybean crop known as "Golden bean", "Miracle crop", "Wonder crop", and "gold of soil".
Phosphorus is known to play an important role in growth and development of the crop and have direct relation with root proliferation, straw strength, grain formation, crop maturation and crop quality. The requirement of P, which is essential for root growth and nodulation, has to be largely fulfilled through inorganic fertilizers. Rock phosphate (RP) is one of the cheap source of P but it cannot be used directly as a soil amendment due to its extreme poor solubility in water (0.1%). However, the availability of RP-P can be enhanced by applying it with compost and through the specific use of bio inoculants (Chutia *et al.*, 1988; Sundra *et al.*, 2002 and Egamberdiyeva *et al.*, 2004) [7, 25, 8]. Enhancing P availability to crop through phosphate-solubilizing bacteria (PSB) holds promise in the present scenario of escalating

prices of phosphatic fertilizers in the country and a general deficiency of P in Indian soils (Alagawadi and Gaur, 1988) [3]. Many micro-organisms have been identified as an agent for promoting better nutrient availability to plant and facilitating its uptake. Bio-fertilizers play an important role in increasing yield through the natural processes of nitrogen (N) fixation, phosphate solubilization and stimulating plant growth through the synthesis of growth promoting substances, improvement in soil structure and texture, soil pH and other properties of soil. Kaleem *et al.* (2010) [14] reported inoculation with Rhizobium facilitates effective growth, increase in the dry matter production, increased nodulation and improved yield of soybean. The most important P source in arable soils is chemical fertilizers, but 75 to 90% of the P combines with iron, calcium and aluminum in soil (Turan *et al*., 2006) [26]. Seed inoculation with PSB can solve this problem and convert it in available form, which can be easily taken up by the plant. To avoid the environmental hazards, declining human health and producing more crop yields to meet the increasing food demand of world's huge population, the integrated nutrient management comprising combination of chemical, organic and bio-fertilizers may be a useful way as mentioned by Ayoola and Makinde (2007) [5]. It was reported that PSM in combination with phosphorus fertilizer and organic manure significantly improved seed phosphorus content, tillers m^{-2}, grain and biological yield (Afzal *et al.*, 2005) [2]. Considering the above points a pot experiment was conducted to study the influence of various combinations of rock phosphate (RP), FYM and phosphate solubilizing bacteria (PSB) on phosphorus concentration and dry matter yield of soybean variety MACS-1460 grown in an acid soil.

2. Materials and Methods

A pot experiment was conducted during the *kharif* season of 2019 in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal, Manipur. It comes under the Eastern Himalayan Region (II) and subtropical zone (NEH -4) of Manipur. The climatic condition of Imphal valley is subtropical. The rainy season usually begins by May and extends up to September. The average annual rainfall of Imphal valley is 1212 mm and the winter normally begins from mid November and extends up to the end of February.

An acidic soil from the surface soil layer (0-20 cm depth) was collected from the research farm of the College of Agriculture, Central Agricultural University, Iroisemba, Imphal following the methods as outlined by Jackson (1973) [13]. The general characteristics of the soil are presented in Table 1. Five kg of air dried soil was filled in each of a series of pots. Recommended dose of 20 kg N ha^{-1} in the form of urea and 40 kg K_2O ha^{-1} in the form of muriate of potash were applied in each experimental pots and mixed properly with the soil. According to different sets of treatment rock phosphate and SSP was applied to each pot as phosphorus sources based on the recommended dose (60 kg P_2O_5 ha^{-1}) for the test crop soybean (variety MACS-1460). FYM was mixed thoroughly with the soil at the rate of 5 t ha^{-1} as per treatments. Soybean seeds were treated with two PSBs. PSBs used were *Bacillus megatherium* and another PSB bought from the market. The inoculated seeds were dried under shade and sown immediately after drying. Five seeds of soybean were sown to each pot. After germination, one seedling was maintained throughout the experiment. The soils of each treatment were moistened to 60% of water holding capacity throughout the experiment.

The experiment was laid out in a Randomized Block Design with eleven treatments replicated thrice. The treatments were T_1 -control,T_2-100% recommended dose (RD) of P_2O_5 from SSP,T_3-100% RD of P_2O_5 from RP,T_4-75% RD of P_2O_5 from SSP + 25% RD of P_2O_5 from RP,T_5-50% RD of P_2O_5 from SSP + 50% RD of P_2O_5 from RP, T_6-25% RD of P_2O_5 from SSP + 75% RD of P_2O_5 from RP, T_7- 100% RD of P_2O_5 from RP + PSB_1,T_8-100% RD of P_2O_5 from RP + PSB_2,T_9-100% RD of P_2O_5 from RP + FYM at 5t ha^{-1},T_{10}- 100% RD of P_2O_5 from RP + PSB_1 + FYM at 5t ha^{-1} and T_{11}- 100% RD of P_2O_5 from RP + PSB_2 + FYM at 5t ha^{-1}. The whole plants were collected on 30^{th}, 60^{th}, 90^{th} days after sowing seeds and at harvest by destructive sampling. The collected plant samples were washed properly with tap water and finally rinsed with deionized water. The plant material was then dried at 60˚C for 48 hours in a hot air oven and dry matter yield was recorded. Ground plant samples were used for the determination of phosphorus concentration. Di-acid (HNO_3: $HClO_4$) extracts of plant samples were subjected to analysis of P using the vanadomolybdate phosphoric acid yellow colour (ammonium molybdate + ammonium metavanadate) method (Jackson, 1973) [13]. Soil texture, pH, EC, organic carbon, CEC, available N, P and K were determined following the standard procdures as described by Jackson (1973) [13].

Data obtained were statistically analysed by the method of analysis of variance to test the significance of the treatment effects as well as result interpretation as given by Gomez and Gomez (1984) [11]. F-test at 5% level of probability was used to test the significance of treatment effect and wherever the "F" test was significant critical difference (CD) values were given at 5% level of significance.

3. Results and Discussion

3.1. Total phosphorus in plant

Data on changes in P concentration in soybean grown in rock phosphate fertilized soil in presence or absence of PSB and FYM are presented in Table 2. Results show that irrespective of different treatments P content in soybean declined up to 90^{th} days after sowing and increased there after up to harvest. However, untreated control represents a different pattern of decrease up to 60^{th} day followed by an increase till harvest. Presentation of P decline with crop age was also stated earlier by Setia and Sharma (2007) [22].

The data signifies that total P concentration was significantly more in soybean grown soil treated with rock phosphate in presence or absence of FYM and PSB over control at different growth stages of the plant. This is at par with the findings of Egamberdiyeva *et al*. (2004) [8]; Sarkar *et al.* (2018b) [21] and Bhutia *et al.* (2019) [6]. Further study revealed that comparatively higher P concentration was observed in T_{11} showing parity with T_{10} and T_9 on 30^{th} days after sowing and at harvest. On 60^{th} and 90^{th} days after sowing T_{11} accumulates significantly higher P concentration followed by T_{10} which was at par with T_9. This may be because of increased soil available P due to the application of PSB and FYM (Chutia *et al.*, 1988; Sundra *et al*., 2002; Egamberdiyeva *et al*., 2004) [7, 25]. Molla *et al*. (1984) [16]; Gaur (1990) [10] and Adhikari *et al.* (2014) [1] found that the introduction of P solubilizing microorganisms in the rhizosphere of crop and soil increase the availability of P from insoluble sources of phosphate, desorption of fixed phosphates and also increases the efficiency of phosphatic fertilizers. Application of FYM made native and applied P available to crops either due to chelation of calcium or by the formation of soluble organic metallic complexes (Chutia *et al.*, 1988; Reddy *et al*., 2006) [7, 18]

3.2. Dry matter yield

Data on Dry matter yield of soybean grown in rock phosphate fertilized soil in presence or absence of PSB and FYM are presented in Table 3. Irrespective of different treatments dry matter yield of soybean increased progressively up to 90 DAS followed by a slight decrease at harvest. The dry matter yield of the plant is greatly influenced by the different treatments. All the treatments involving P addition showed statistically better results of dry matter when compared to the control. This is at par with the findings of Shahzad *et al.* (2008)[23] and Sarkar *et al.* (2018a) [20]. Higher agronomic effectiveness of rock phosphate was revealed in increased dry matter yield of crop (IKerra *et al*., 1994) [12]. Among the different treatments soil applied with both PSB and FYM in combination significantly enhanced more dry matter yield than others (Shanmugam, 2008; Mashori *et al*., 2013) [24, 15]. Critical study of the result revealed significantly higher yield in T_{11} followed by T_{10}, T_9 and T_8 on 30 and 90 DAT. However, on 60 DAT and at harvest there is no significant difference between T_{11} and T_{10} but statistically higher than T_9. The increase in yield under PSB and FYM could be due to continued availability of P that helped in proliferation of root development and hence, better nutrient acquirement and biomass accumulation (Egamberdiyeva *et al*., 2004; Parassana *et al*., 2011; Saleem *et al*., 2013; Yu *et al*., 2014) [8, 17, 19, 27].

Table 1: General characteristics of the soil

Soil Characteristics	Results
Textural class:	Textural class
Sand (%):	16.8
Silt (%):	25.7
Clay (%)	57.5
Soil Texture	Clay
pH (1:2.5 soil: water ratio)	5.2
EC (1:2.5 soil: water ratio, dSm^{-1})	0.28
CEC [$cmol(p+)kg^{-1}$]	15.2
Organic carbon (%)	1.22
Available nitrogen (Kg ha^{-1})	296.50
Available phosphorus (Kg ha^{-1})	38.50
Available potassium (Kg ha^{-1})	210.28

Table 2: Changes in total-P concentration (mg kg^{-1}) in soybean grown in rock phosphate fertilized soil applied with phosphorus solubilizing bacteria and farm yard manure

Treatments	Days After Sowing			
	30	60	90	Harvest
T1 (Control)	5652.36	4669.33	4915.74	5482.28
T2 (100% RD of P_2O_5 from SSP)	6633.71	6093.58	5711.96	6725.88
T3 (100% RD of P_2O_5 from RP)	6799.80	6226.70	5889.84	6919.29
T4 (75% RD of P_2O_5 from SSP + 25% RD of P_2O_5 from RP)	6643.11	5583.03	5479.85	6776.24
T5 (50% RD of P_2O_5 from SSP + 50% RD of P_2O_5 from RP)	6676.06	5788.69	5363.58	6825.20
T6 (25% RD of P_2O_5 from SSP + 75% RD of P_2O_5 from RP)	6876.75	5912.15	5469.48	6788.08
T7 (100% RD of P_2O_5 from RP + PSB_1)	6941.62	6165.81	5868.84	6457.67
T8 (100% RD of P_2O_5 from RP + PSB_2)	7094.56	6159.99	5951.06	6717.38
T9 (100% RD of P_2O_5 from RP + FYM at 5t ha^{-1})	7180.91	6312.56	6140.96	6789.74
T10 (100% RD of P_2O_5 from RP + PSB_1 + FYM at 5t ha^{-1})	7305.45	6391.74	6188.98	6932.21
T11 (100% RD of P_2O_5 from RP + PSB_2 + FYM at 5t ha^{-1})	7391.38	6555.79	6296.48	7045.21
S.E.d(±)	54.08	35.97	33.30	66.50
$CD_{0.05}$	159.54	106.10	98.24	196.17

Table 3: Dry matter yield (g $plant^{-1}$) of soybean grown in rock phosphate fertilized soil applied with phosphorus solubilizing bacteria and farm yard manure

Treatments	Days After Sowing			
	30	60	90	Harvest
T1 (Control)	2.36	4.51	4.66	4.30
T2 (100% RD of P_2O_5 from SSP)	2.73	5.17	5.45	5.20
T3 (100% RD of P_2O_5 from RP)	3.06	5.22	5.53	5.08
T4 (75% RD of P_2O_5 from SSP + 25% RD of P_2O_5 from RP)	2.63	4.52	4.92	4.38
T5 (50% RD of P_2O_5 from SSP + 50% RD of P_2O_5 from RP)	2.60	4.88	5.27	4.63
T6 (25% RD of P_2O_5 from SSP + 75% RD of P_2O_5 from RP)	2.50	4.68	5.06	4.51
T7 (100% RD of P_2O_5 from RP + PSB_1)	3.18	5.19	5.48	5.25
T8 (100% RD of P_2O_5 from RP + PSB_2)	3.26	5.35	5.71	5.28
T9 (100% RD of P_2O_5 from RP + FYM (5t ha^{-1})	3.59	5.41	5.78	5.48
T10 (100% RD of P_2O_5 from RP + PSB_1 + FYM (5t ha^{-1})	3.73	5.57	5.90	5.70
T11 (100% RD of P_2O_5 from RP + PSB_2 + FYM (5t $ha^{-1)}$	3.92	5.57	5.98	5.77
S.E.d(±)	0.02	0.02	0.01	0.02
$CD_{0.05}$	0.07	0.07	0.04	0.07

4. Conclusion

It can be concluded that there is significant increase in P concentration and dry matter yield of soybean in rock phosphate fertilized soil in presence or absence of PSB and FYM over the control. Among the different treatments, significantly higher P concentration and dry matter yield of soybean was observed in soil treated with T_{11} (100% RD of P_2O_5 from RP + PSB_2 + FYM at 5t ha^{-1}) which is at par with T_{10} (100% RD of P_2O_5 from RP + PSB_1 + FYM at 5t ha^{-1}) at the time of harvest. Efficiency of rock phosphate as a P source for crop production is enhanced by the solubility effect of FYM and PSB application. Combined application of PSB and FYM enhanced organic P mineralization thereby increasing soil P availability, plant P concentration, growth and dry matter yield of soybean.

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