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RESEARCH PAPER

Effect of different phosphorus sources and P solubilizers on growth, yield and yield attributes of soybean

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Abstract: A field experiment was carried out at Agricultural Research Station Farm, Bagalkot during *kharif* 2019. The experiment consisted of 12 treatments with different phosphorus sources and P solubilizers. The experiment was laid out in a randomized block design with three replications. The results indicated that soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* recorded significantly higher plant height (51.13 and 62.89 cm respectively at pod initiation stage and at harvest) and number of branches (5.2 and 6.2, respectively at pod initiation stage and at harvest) which was on par with soil application of 100 per cent RDP through DAP and seeds treated with talc powder based *Pseudomonas striata* (50.44 and 60.15 cm plant height, 5.0 and 6.1 number of branches at pod initiation stage and at harvest respectively). Similarly significantly higher number of pods plant^{-1} (62.77), pod weight plant^{-1} (25.71 g), seed weight plant^{-1} (16.80 g), seed yield (2385 kg ha^{-1}) and haulm yield (2615 kg ha^{-1}) were recorded in treatment with soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* and it was on par with soil application of 100 per cent RDP through SSP and seeds treated with liquid formulation of *Pseudomonas striata*. Significantly higher net return (₹ 58163 ha^{-1}) and BC ratio (2.35) were realised with the treatment soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata.*

Key words: Liquid formulation, Phosphorus, *Pseudomonas striata,* Soybean

Introduction

Soybean (*Glycine max* (L.) Merill) is generally recognized as golden or miracle crop owing to its high nutritive value besides its differential utility. The oil content ranges between 20-22 per cent while the protein content is 40-44 per cent. Soybean is one of the best and cheapest sources of vital quality protein, mineral calcium and vitamin 'A'. In India, the crop is being cultivated over an area of 11.32 million hectares with an annual production of 13.79 million tones and productivity is 1219 kg ha^{-1}. In Karnataka, the crop is cultivated over an area of 0.32 million hectares with an annual production of 0.24 million tones and with a productivity of 744 kg ha^{-1} (Anon., 2017).

The productivity of soybean is low due to inadequate / imbalanced application of nutrients that led to deficiency of major and minor nutrients. In soybean phosphorus has greater significance than other plant nutrients for higher yield. The yield and quality of soybean can be increased with adequate supply and availability of phosphorus. Phosphorus is an important plant nutrient involved in several energy transformation and biochemical reactions including biological nitrogen fixation. It is an essential structural component of nucleic acids (RNA and DNA) and plays a vital role in plant reproduction and seed formation. Phosphatic fertilizers are known to have low use efficiency due to chemical fixation in soil and poor solubility of native soil phosphorus. Although microbial interventions are in vogue for improving P solubilisation as well as mobilization all through the bygone century, but meagre work has been reported on phosphorus nutrition compared to nitrogen fixation. Phosphorus applied through chemical fertilizers enter into the immobile pools through precipitation reaction with highly reactive aluminium (Al^{3+}) and iron (Fe^{3+}) in acidic soil and calcium (Ca^{2+}) in calcareous or alkaline soils. The use efficiency of P fertilizer throughout the world is around 10-25 per cent and concentration of bioavailable P in soil is very low reaching the level of 1.0 mg kg^{-1} soil. At this juncture, the role of microorganisms in modulating soil P dynamics and augment availability of phosphate to plants (Devi *et al.,* 2012) is of pivotal importance. Release of phosphorus by PSB from insoluble and fixed/adsorbed forms is an important aspect regarding P availability in soils. Therefore, with this backdrop present investigation entitled "Effect of different phosphorus sources and P solubilizers on growth, yield and yield attributes of soybean" was planned and executed.

Material and methods

A field experiment was carried out at the Agriculture Research Station, Bagalakot, (Karnataka) during *Kharif* 2019. The soil of the experimental site is deep black, texturally clay, alkaline in reaction (pH 8.42), with low salinity (0.41 dSm^{-1}), low in available Nitrogen (240.9 kg N ha^{-1}), available Phosphorus (25.48 kg P_2O_5 ha^{-1}) and high in available Potassium (355.4 kg K_2O ha^{-1}). Soybean variety JS 335 was sown at a spacing of 30 x 10 cm with a seed rate of 75 kg ha^{-1}. Seeds treated with *Pseudomonas striata* (liquid formulation and Talc powder) as per treatment. A uniform fertilizer dose of 40 kg N, 25 kg K_2O and 12 kg Zn ha^{-1} in the form of Urea, MOP and $ZnSO_4$ respectively were applied at the time of sowing and DAP, SSP and Sulphur bentonite were applied as per treatments. The plot was kept weed free by taking two times cycle weeder and hand weeding at 30 and 45 days after sowing.

The experiment comprised of twelve treatment combinations involving different P sources, P dosage and P solubilizers *viz*., T_1-75 per cent recommended dose of phosphorus through DAP + *Pseudomonas striata* (liquid formulation), T_2-100 per cent recommended dose of phosphorus (80kg P-$_2O_5$ ha^{-1}) through DAP + *Pseudomonas striata* (liquid formulation), T_3-75 per cent recommended dose of phosphorus through DAP + *Pseudomonas striata* (Talc powder), T_4-100 per cent recommended dose of phosphorus through DAP + *Pseudomonas striata* (Talc powder), T_5-75 per cent recommended dose of phosphorus through DAP, T_6-100 per cent recommended dose of phosphorus through DAP, T_7-75 per cent recommended dose of phosphorus through SSP + *Pseudomonas striata* (liquid formulation), T_8-100 per cent recommended dose of phosphorus through SSP + *Pseudomonas striata* (liquid formulation), T_9-75 per cent recommended dose of phosphorus through SSP+ *Pseudomonas striata* (Talc powder), T_{10}-100 per cent recommended dose of phosphorus through SSP + *Pseudomonas striata* (Talc powder), T_{11}-75 per cent recommended dose of phosphorus through SSP and T_{12}-100 per cent recommended dose of phosphorus through SSP.

The observations on plant height, number of branches per plant, number of pods per plant, number of seeds per pod, pod weight per plant, seed weight per plant, seed yield, haulm yield and harvest index were recorded by adopting standard procedure. The data collected from the experiment at different growth stages and from laboratory analysis was subjected to statistical analysis as described by Gomez and Gomez (1984).

Results and discussion

Effect of different phosphorus sources and P solubilizers on growth attributes of soybean

The plant height was significantly influenced by different treatments. The treatment soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* (T_2) recorded significantly higher plant height of 35.29, 51.13 and 62.89 cm, respectively at flower initiation, pod initiation stage and at harvest similarly significantly higher number of branches with values of 3.4, 5.2 and 6.2, respectively were recorded at flower initiation, pod initiation stage and at harvest. Hence, T_2 was found most effective in enhancing growth parameters of soybean at all phenological stages and was on par with treatment receiving soil application of 100 per cent RDP through SSP and seeds treated with liquid formulation of *Pseudomonas striata* (T_8) (Table 1).

The increase in phenological parameters and distribution of dry matter in different plant parts might be due to beneficial effect of microorganisms that led to phosphate solubilization and increasing the availability of soluble phosphate and enhancing the plant growth by improving biological nitrogen fixation. These findings are supported from the results obtained by Shahid *et al.,* 2009 they found significantly higher plant height, number of branches with treatments receiving 75 and 100 kg P_2O_5 ha^{-1} and seeds inoculated with *Rhizobium.* Further, Sharma *et al.* (2002), revealed that positive improvement in growth parameters under increased phosphorus application might be due to increased metabolic process in plants resulting into greater meristematic activities and apical growth there by improving plant height, branches per plant and ultimately resulted in improved dry matter accumulation.

Effect of different phosphorus sources and P solubilizers on yield and yield attributes of soybean

Different phosphorus treatments had significant influence on yield attributes and yield. Significantly higher number of pods per plant (62.77), pod weight per plant (25.71 g) and seed weight per plant (16.80 g) were recorded in treatment receiving soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* (T_2) which is significantly superior over rest of the treatments (Table 1). The increase in yield parameters in T_2 might be due to increase in the nutrient's availability for host plants when P solubilizers are treated to seeds by colonizing the rhizosphere of the plant. It also improves the activity of *Rhizobium* and formation of root nodules and helps in N fixation besides providing tolerance against soil-borne diseases. The increase in phosphorus availability stimulates early root growth and development further helps in early establishment of seedlings. The positive effect of phosphorus resulted in increased nutrient uptake by the crop, led to improved translocation of photosynthates to sink which improves the growth parameters like plant height, number of branches, leaf area, total dry matter production and distribution in different plant parts that resulted in the improvement in yield parameters per plant which are the evidences for higher seed yield. These results are supported with the finding obtained by Jalalzai *et al.* 2018, they found that application of recommended NPK + FYM + PSB and *Rhizobium* recorded significantly higher number of pods per plant and seed weight per plant.

The significantly higher seed yield of 2385 kg ha^{-1} and haulm yield of 2615 kg ha^{-1} was recorded with the treatment which received soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* (T_2) and was on par with treatment soil application of 100 per cent RDP through SSP and seeds treated with liquid formulation of *Pseudomonas striata* (T_8) with seed yield of 2278 kg ha^{-1} and haulm yield of 2554 kg ha^{-1} but significantly superior over rest of the treatments (Table 2).

The increased seed and haulm yield of soybean in T_2 might be due to utilization of optimum quantity of nutrients through well developed root system and nodules and also the beneficial effect of phosphorus observed on growth and yield parameters .These findings are supported from the results obtained by Tomar *et al.,* 2010, they found that application of phosphorus @ 80 kg P_2O_5 ha^{-1} increased seed yield and straw yield. These findings are supported from the results obtained by Geeta 2014, she found that the application of phosphorus @ 80 kg P_2O_5 ha^{-1} cured with FYM + PSB + VAM recorded higher yield and yield attributes.

Economics of different phosphorus sources and P solubilizers

The gross and net returns were significantly influenced by different phosphorus sources and P solubilizers. The

Table 1. Growth parameters and yield attributes of soybean as influenced by different phosphorus sources and P solubilizers

Treatments	Plant height (cm)			Number of branches $plant^{-1}$			Yield attributes			
	Flower initiation	Pod initiation	At harvest	Flower initiation	Pod initiation	At harvest $plant^{-1}$	No. of pods $plant^{-1}$ (g)	Pod weight $plant^{-1}$ (g)	Seed weight pod^{-1}	No of seeds
T_1: 75% recommended dose of phosphorus through DAP + *P striata* (liquid formulation)	28.07	44.07	51.27	2.3	4.3	4.9	49.47	19.71	14.0	2.4
T_2: 100 % recommended dose of phosphorus through DAP + *P striata* (liquid formulation)	35.29	51.13	62.89	3.4	5.2	6.2	62.77	25.71	16.8	2.6
T_3: 75% recommended dose of phosphorus through DAP + *P striata* (Talc powder)	32.55	43.79	51.49	2.7	4.4	5.0	49.00	20.49	13.5	2.5
T_4: 100 % recommended dose of phosphorus through DAP + *P striata* (Talc powder)	34.95	50.44	60.15	3.0	5.0	6.1	60.73	24.71	16.4	2.4
T_5: 75% recommended dose of phosphorus through DAP	30.90	40.53	51.14	2.5	3.7	4.3	42.53	17.92	11.7	2.5
T_6: 100 % recommended dose of phosphorus through DAP	34.05	45.93	54.99	2.6	4.2	4.7	50.13	19.06	13.0	2.5
T_7: 75% recommended dose of phosphorus through SSP + *P striata* (liquid formulation)	30.70	44.21	52.48	3.3	4.3	4.9	49.67	21.02	13.9	2.4
T_8: 100 % recommended dose of phosphorus through SSP + *P striata* (liquid formulation)	33.04	48.91	59.76	3.3	5.1	6.0	61.27	25.08	16.3	2.6
T_9: 75% recommended dose of phosphorus through SSP+ *P striata* (Talc powder)	32.40	45.63	53.47	3.1	4.1	5.0	49.30	20.53	13.8	2.3
T_{10}: 100 % recommended dose of phosphorus through SSP + *P striata* (Talc powder)	30.70	48.98	58.65	2.7	5.0	6.0	60.73	24.60	15.7	2.5
T_{11}: 75% recommended dose of phosphorus through SSP	32.22	40.63	52.31	3.0	3.7	4.4	43.20	17.16	11.3	2.4
T_{12}: 100 % recommended dose of phosphorus through SSP	31.52	44.84	54.97	2.9	4.1	4.8	49.87	19.78	13.2	2.5
S.Em.±	1.34	1.71	2.39	0.26	0.27	0.35	4.09	0.80	0.47	0.1
LSD (p=0.05)	NS	5.02	7.01	NS	0.80	1.03	12.00	2.37	1.38	NS

* *Pseudomonas striata* is seed inoculated NS - Non significant

Table 2. Yield and economics of soybean as influenced by different phosphorus sources and P solubilizers

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest Index (%)	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
T_1 : 75% recommended dose of phosphorus through DAP + *P straita* (liquid formulation)	2024	2250	47.3	42236	86021	43785	2.04
T_2 : 100 % recommended dose of phosphorus through DAP + *P straita* (liquid formulation)	2385	2615	47.7	43205	101368	58163	2.35
T_3 : 75% recommended dose of phosphorus through DAP + *P straita* (Talc powder)	2008	2214	47.3	42071	85357	43286	2.03
T_4 : 100 % recommended dose of phosphorus through DAP + *P straita* (Talc powder)	2270	2547	47.1	43040	96483	53443	2.24
T_5 : 75% recommended dose of phosphorus through DAP	1972	2210	46.9	42011	83805	41794	1.99
T_6 : 100 % recommended dose of phosphorus through DAP	2119	2398	46.8	42980	90061	47081	2.10
T_7 : 75% recommended dose of phosphorus through SSP + *P straita* (liquid formulation)	2013	2221	47.4	40859	85558	44699	2.09
T_8 : 100 % recommended dose of phosphorus through SSP + *P straita* (liquid formulation)	2278	2554	47.0	41128	96806	55678	2.35
T_9 : 75% recommended dose of phosphorus through SSP+ *P straita* (Talc powder)	2001	2285	46.7	40694	85035	44341	2.09
T_{10} : 100 % recommended dose of phosphorus through SSP + *P straita* (Talc powder)	2261	2509	47.4	40963	96085	55122	2.35
T_{11} : 75% recommended dose of phosphorus through SSP	1965	2176	47.2	40634	83526	42892	2.06
T_{12} : 100 % recommended dose of phosphorus through SSP	2114	2353	47.3	40903	89844	48941	2.20
S.Em.±	87.4	72.9	1.24	-	3716	3716	0.09
LSD (p=0.05)	256.4	213.8	NS	-	10899	10899	0.26

* *Pseudomonas striata* is seed inoculated   NS - Non significant

treatment soil application of 100 per cent RDP through DAP and seeds treated with liquid formulation of *Pseudomonas striata* (T_2) recorded significantly higher gross return of ₹ 101368 ha^{-1} and net return of ₹ 58163 ha^{-1} and was on par with treatment soil application of 100 per cent RDP through SSP and seeds treated with liquid formulation of *Pseudomonas striata* (T_8) with a gross return of ₹ 96806 ha^{-1} and net return of ₹ 55678 ha^{-1} this was mainly due to the higher economic yield realised in above said treatment. Soil application of 100 per cent RDP (80kg $P\text{-}_2O_5$ ha^{-1}) through DAP and seeds treated with liquid formulation of *Pseudomonas striata* registered the highest benefit cost ratio of 2.35 (Table 2). Similar results were reported by Mahanta and Rai (2008), who reported the highest BC ratio with the treatment which received 50 % rock phosphate + PSB + VAM.

Conclusion

In case of crop like soybean which demands higher phosphorus for realizing optimum economic yield the present study indicated that the soil application of 100 per cent RDP (80 kg P_2O_5 ha^{-1}) through DAP and seed treatment with liquid formulation of *Pseudomonas striata*) was found to be effective for realising higher soybean yield, higher gross and net return with better BC ratio.

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