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SD Pawar
College of Agriculture, Latur, Vasantrao Naik Krishi Vidyapeeth, Parbhani Maharashtra, India

PN Karanjikar
College of Agriculture, Latur, Vasantrao Naik Krishi Vidyapeeth, Parbhani Maharashtra, India

VG Takankhar
College of Agriculture, Latur, Vasantrao Naik Krishi Vidyapeeth, Parbhani, Maharashtra, India

Correspondence
SD Pawar
College of Agriculture, Latur, Vasantrao Naik Krishi Vidyapeeth, Parbhani Maharashtra, India

Effect of phosphorus and biofertilizers on growth and yield of soybean (*Glycine max* (L.) Merill) under rainfed condition

SD Pawar, PN Karanjikar and VG Takankhar

Abstract
The experiment entitled "Effect of phosphorus and *biofertilizers* on growth and yield of Soybean (*Glycine max* (L.) Merill) under rainfed condition" was conducted on research farm of College of Agriculture Latur (M.S.) during kharif season of 2015. The experimental field was leveled and well drained. The soil was clayey loam in texture, low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), high in potassium (385.89 kg ha^{-1}) and slightly alkaline (pH 8.5) in reaction. The experiment was laid out in randomized block design. There were ten treatments which were replicated thrice. The treatments mainly comprised of T_1- No phosphorous application, T_2- 45 kg P_2O_5/ha through SSP, T_3- 60 kg P_2O_5/ha through SSP, T_4- 45 kg P_2O_5/ha through SSP + PSB, T_5- 45kg P_2O_5/ha through SSP + *Rhizobium* (R.I.), T_6- 45 kg P_2O_5/ha through SSP+ VAM, T_7- 45 kg P_2O_5/ha through SSP+PSB+R.I., T_8- 45 kg P_2O_5/ha through SSP+PSB +VAM, T_9- 45 kg P_2O_5/ha through SSP+R.I.+VAM, T_{10}-45kg P_2O_5/ha through SSP+PSB+R.I.+ VAM. Rainfed soybean responded positively to different phosphorus application treatments. Application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM (T_{10}) performed the best amongst the various phosphorus treatments evaluated with regards to growth, yield attributing characters and yield of soybean. Maximum seed yield, straw yield and biological yield was produced by application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM (T_{10}) which was followed application of 45 kg P_2O_5/ha through SSP+R.I.+VAM (T_9) and 45 kg P_2O_5/ha through SSP+PSB+R.I. (T_7) and was found significantly superior over rest of the treatments

Keywords: Soybean, phosphorus, biofertilizer, rainfed, growth, yield

Introduction
Soybean (*Glycine max* (L.) Merill) is a leguminous crop and belongs to family Fabaceae with sub family Faboideae. Soybean is a important crop in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world. It is an excellent health food and contains about 40 per cent quality protein, 23 per cent carbohydrates and 20 per cent cholesterol free oil. Soybean protein is rich in valuable amino acid, lysine (5%) which is deficient in most of the cereals. It also contain 60 per cent polyunsaturated fatty acids (52.8% linolenic acid + 7.2 % linoleic acid). It has high caloric value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereals of same quantity. Soybean is the cheapest source of proteins and it is called "Poor man's meat". In India area sown under soybean was 108.34 lakh ha, productivity 959 kg/ha and production was 104.36 lakh MT. In Maharashtra area was 38 lakh ha, productivity 808 kg/ha and production was 30.72 lakh MT. In Marathwada region area was 12.36 lakh ha, productivity 826 kg/ha and production was 10.21 lakh MT (Anonymous, 2013). [1] Now a days, there is vast scope for soybean production due to high nutritional quality, more production and short duration (90-110 days), tolerate long dry spell and being leguminous crop helps in improving the fertility and productivity of soil. But prices of fertilizers are increasing day by day and therefore, it is necessary to reduce the cost of fertilizers by using *Rhizobium*, PSB and VAM inoculation to increase yield of legume crops. Biofertilizers cannot replace chemical fertilizers, but certainly are capable of reducing their input. Seed inoculation with effective *Rhizobium* inoculants is recommended to ensure adequate nodulation and N_2 fixation for maximum growth and yield of pulse crop. Farmers are facing severe problem on availability of chemical fertilizers for soybean production. Growers generally use chemical fertilizers to increase soybean production. However, it gives hazardous effect as soil and water pollution. Use of biofertilizer (*Rhizobium*, PSB & VAM) compared with chemical fertilizers are an attractive and environmental safety method of soybean production. Biofertilizers helps to minimize the use of chemical fertilizer and proved environmental safe and eco-friendly. Phosphorus is an essential major nutrient for the development of plants as it stimulates early

development and promotes healthy growth of seedlings. It also enhances the formation of nodules and nitrogen fixation in legumes. Many scientists used various selected strains of phosphate solubilizers which increase the dry matter, grain yield and 'P' uptake (Bothe *et al.*, 2000) [2]. Seed treatment with biofertilizers had their significant effect on microbial population in conjunction with P application in soybean field. Hence an attempt was made to study the effect of phosphorus and biofertilizers on growth and yield of Soybean (*Glycine max* (L.) Merill) under rainfed condition.

Materials and Methods

The experiment was conducted during *kharif* season of 2015 on the Farm of College of Agriculture, Latur (M.S.). The topography of experimental field was uniform and leveled. the soil of experimental plots was clayey in texture. The chemical composition of experimental plots indicated that the soil was low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), very high in available potassium (385.89 kg ha^{-1}) content and alkaline in reaction having pH 8.5. The experiment was laid out by using randomized block design with three replications. The treatments were consisting of *Rhizobium*, PSB and VAM viz [10-12].

T_1- No phosphorous application,
T_2- 45 kg P_2O_5/ha through SSP
T_3- 60 kg P_2O_5/ha through SSP
T_4- 45 kg P_2O_5/ha through SSP + PSB
T_5- 45kg P_2O_5/ha through SSP + *Rhizobium* (R.I.)
T_6- 45 kg P_2O_5/ha through SSP+ VAM
T_7- 45 kg P_2O_5/ha through SSP+PSB+R.I.
T_8- 45 kg P_2O_5/ha through SSP+PSB +VAM
T_9- 45 kg P_2O_5/ha through SSP+R.I.+VAM
T_{10}- 45kg P_2O_5/ha through SSP+PSB+R.I.+ VAM

The gross and net plot size of each experimental unit was 5.4 m x 4.8 m and 4.5 m x 4.2 m, respectively.

Results and Discussion

Effect on growth characters

The effect of different treatments on plant height was found to be significant and the higher plant height was recorded by the application of 45k g P_2O_5/ha through SSP+PSB+R.I.+VAM (T_{10}) (19.37 cm) as compared to other treatments. But it was found to be at par with application of 45 kg P_2O_5/ha through SSP+R.I. +VAM (T_9) and 45 kg P_2O_5/ha through SSP+PSB+R.I. (T_7). The application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+VAM (T_{10}) recorded higher mean number of functional leaves (8.42) and it was significantly superior over rest of the treatments. Similarly 45 kg P_2O_5/ha through SSP+PSB+R.I. +VAM (T_{10}) also recorded higher number of branches as compared to other treatments. Total dry matter accumulation $plant^{-1}$ was found to be increased continuously with advancement in age of the crop till at harvest. The application of 45 kg P_2O_5/ha through SSP+PSB+R.I. + VAM (T_{10}) recorded the higher dry matter accumulation at harvest (7.82 g). Least dry matter $plant^{-1}$ was recorded by (T_1) i.e. un-inoculated and without phosphorus applied (4.38 g). Similar trend was observed in case of root nodules. The increase in growth attributes may be due to better uptake and translocation of plant nutrients to growing plants. Similar kinds of observations were recorded by Kalhapure and Memane, (2002) [5], Nagaraju and Mohankumar, (2010) [7] and Gupta and Seema Sahu, (2012) [3]

Table 1: Height $plant^{-1}$, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, total dry matter $plant^{-1}$ and number of nodules $plant^{-1}$ of soybean as influenced by various treatments at harvest.

Treatments	Height $plnat^{-1}$	No. of leaves $plnat^{-1}$	No. of branches $plnat^{-1}$	Total dry matter $plnat^{-1}$	No. of nodules $plnat^{-1}$
T_1- No phosphorous application	12.89	7.13	8.30	6.43	22.00
T_2- 45 kg P_2O_5/ha through SSP	13.59	7.23	8.30	7.21	24.00
T_3- 60 kg P_2O_5/ha through SSP	14.65	7.33	8.87	6.47	25.00
T_4- 45 kg P_2O_5/ha through SSP + PSB	15.02	7.43	8.77	6.10	23.33
T_5- 45kg P_2O_5/ha through SSP + *Rhizobium* (R.I.)	17.83	8.83	9.03	6.44	27.00
T_6- 45 kg P_2O_5/ha through SSP+ VAM	16.09	7.83	9.37	6.49	25.33
T_7- 45 kg P_2O_5/ha through SSP+PSB+R.I.	18.86	9.28	10.53	6.43	27.00
T_8- 45 kg P_2O_5/ha through SSP+PSB +VAM	17.62	8.40	9.37	5.91	25.33
T_9- 45 kg P_2O_5/ha through SSP+R.I.+VAM	21.20	9.70	9.93	6.55	27.33
T_{10}- 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM	19.50	10.90	10.53	7.82	28.33
SE ±	0.77	0.47	0.32	0.25	1.17
C.D. at 5%	2.29	1.40	0.97	0.73	3.49
General Mean	27.15	8.40	9.20	6.58	25.47

Effect on yield characters and yield

Data revealed that the number of pods per plant were observed more with the application of 45kg P_2O_5/ha through SSP+PSB+R.I. + VAM (T_{10}) which was significantly superior overall other treatments and at par with the treatment 45 kg P_2O_5/ha through SSP+R.I. +VAM (T_9) and 45 kg P_2O_5/ha through SSP+PSB+R.I. (T_7). The application of 45kg P_2O_5/ha through SSP+PSB+R.I. + VAM (T_{10}) recorded significantly higher pod weight $plant^{-1}$ (5.09 g). Statistically similar results were recorded for application of 45 kg P_2O_5/ha through SSP+R.I. +VAM (T_9) (4.81 g). Similarly application of 45 kg P_2O_5/ha through SSP+PSB+R.I. + VAM (T_{10}) also recorded significantly higher number of seeds $plant^{-1}$ and seed yield $plant^{-1}$. More number of seeds $plant^{-1}$ was due to better growth of plant and pod bearing capacity which was enhanced due to different treatment as reported by Oad *et al*., (2002) [8]. The application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM (T_{10}) recorded higher mean seed yield (1108 kg ha^{-1}) and it was followed by application 45 kg P_2O_5/ha through SSP+R.I.+VAM (T_9) (1014 kg ha^{-1}) and 45 kg P_2O_5/ha through SSP+PSB+R.I. (T_7) (979 kg ha^{-1}). In case of straw yield also the application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM (T_{10}) recorded significantly higher mean straw yield (1495 kg ha^{-1}) followed by the application of 45 kg P_2O_5/ha through SSP+R.I.+VAM (T_9) (1355 kg ha^{-1}). This might because of the cumulative effect in increasing growth contributing characters which have been clearly exhibited on the final produce i.e. seed and straw yield ha^{-1}. Similar kind of results was reported by Ingle *et al.*, (2001). [4]

Table 2: Number of pods plant^{-1}weight of pods plant^{-1}, seed yield plant^{-1}, number of seeds plant^{-1} and seed yield kg ha^{-1} and straw yield kg ha^{-1}of soybean as influenced by various treatments

Treatments	No. of pods plant^{-1}	Weight of pods (g)	No. of seeds plant^{-1}	Seed yield plant^{-1}	Seed yield kg ha^{-1}	Straw yield Kg ha^{-1}
T_1- No phosphorous application	12.46	3.03	25.67	2.23	808	954
T_2- 45 kg P_2O_5/ha through SSP	14.02	3.08	26.47	2.47	884	1084
T_3- 60 kg P_2O_5/ha through SSP	14.25	3.37	27.67	2.50	917	1108
T_4- 45 kg P_2O_5/ha through SSP + PSB	14.75	3.65	28.33	2.62	920	1144
T_5- 45kg P_2O_5/ha through SSP + *Rhizobium* (R.I.)	17.29	4.20	29.00	3.00	959	1189
T_6- 45 kg P_2O_5/ha through SSP+ VAM	15.35	3.85	28.67	2.73	929	1168
T_7- 45 kg P_2O_5/ha through SSP+PSB+R.I.	18.11	4.30	31.83	3.20	979	1284
T_8- 45 kg P_2O_5/ha through SSP+PSB +VAM	16.38	3.90	28.67	2.78	939	1196
T_9- 45 kg P_2O_5/ha through SSP+R.I.+VAM	20.18	4.81	32.33	3.33	1014	1355
T_{10}- 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM	21.55	5.09	34.67	3.57	1104	1495
SE $\pm$	0.74	0.25	1.31	0.14	46	80
C.D. at 5%	2.21	0.74	3.88	0.42	136	239
General Mean	16.43	3.93	29.33	2.84	945	1198

Conclusions

On the basis of present investigation following broad conclusions can be drawn.

1. Rainfed soybean responded positively to different phosphorus application treatments. Application of 45 kg P_2O_5/ha through SSP+PSB+R.I.+ VAM (T_{10}) performed the best amongst the various phosphorus treatments evaluated with regards to growth, yield attributing characters and yield of soybean.
2. Application of 45 kg P_2O_5/ha through SSP+R.I.+VAM (T_9) was the second best treatment in improving growth, yield attributing characters and yield of soybean.

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