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Influence of Biofertilizer and Phosphorus on Cowpea (*Vigna unguiculata* (L.) Walp.) Yield and Economics in the Eastern Uttar Pradesh Region

***Jayshree*[1*] *and Umesha C.*[2]**
[1]*M.Sc. Scholar, Department of Agronomy,*
NAI, SHUATS, Prayagraj (Uttar Pradesh), India.
[2]*Assistant Professor, Department of Agronomy,*
NAI, SHUATS, Prayagraj (Uttar Pradesh), India.

(Corresponding author: Jayshree)*
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ABSTRACT: The field experiment was carried out on sandy loam soil at Crop Research Farm, Naini Agricultural Institute, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) in the Kharif season of 2020. Randomized Blocks Design was used to set up the experiment and consisting of ten treatment combinations which were replicated thrice. There have been significant and ongoing efforts to boost pulse production by combining chemical fertilizers with biofertilizers. Despite the fact that India began commercially producing biofertilizers in the late 1970s, continued efforts are still required to create consistent yield responses in the efficient biofertilizer technology. The experiment's findings showed that with dual inoculation of PSB and VAM and 55 kg of phosphorus per hectare, plant height (81.09 cm), yield attributing parameters such as pods per plant (14.73), seeds per pod (8.85), test weight (80.19 g), seed yield (2.62 t/ha), stover yield (6.45 t/ha). The experiment's economics, or the highest gross return of INR 88390.42 per hectare and the highest net return of INR 59808.94 per hectare, were likewise achieved with the dual inoculation of PSB and VAM coupled with 55 kg of phosphate per hectare, whereas maximum benefit cost ratio (2.14) was recorded in co-inoculation of PSB and VAM with 45 kg P/ha.

Keywords: Biofertilizers, Cowpea, Economics, Phosphorus, PSB, VAM, Yield.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) usually referred to as lobia, black-eyed pea, crowder pea and southern pea is an important legume crop with variety of uses including vegetables, pulses, green manuring and cattle feed and believed to be originated in Central Africa. Cowpea is well adapted to several humid tropics and subtropical climates in India, with a drought tolerant character, however it is intolerant to frost and water logging. (Sharma and Jat 2003). This crop is known for its drought resistance due to its shadowing effect. Its wide and droopy leaves help to retain soil moisture, and the crop grows so densely and completely that it essentially covers the ground, preventing soil erosion and allowing for the use of green manure later on. Cowpea is becoming more economically important across the country because of its high protein content, drought resistance, adaptation to various soil types, and ability to boost soil fertility. Uttar Pradesh, Punjab, Haryana, Rajasthan, and Madhya Pradesh are among the northern Indian states where it is cultivated. In Uttar Pradesh, there are 23.61 lakh hectares of cowpea planted in total during 2017–2018, with a production of about 22.34 lakh tonnes (Anonymous, 2018).

Phosphorus application to pulse crops has been proven to be particularly effective because it promotes the rhizobium bacterial growth for biological nitrogen fixing, improving the efficacy of pulses as soil restorers and serving a dual purpose by increasing current and future crop yields. In legumes, a sufficient phosphorus supply has been associated with enhanced growth and output, enhanced quality, and huge nodule development. (Sammuria *et al*., 2009). With regard to accessible phosphorus, Indian soils are in low to medium condition. Plants only take up around 25% of phosphate that is soluble in water during the application season, with the rest being transformed to insoluble forms (Yadav *et al.,* 2017). Biofertilizers are environmentally safe, cost-effective, and renewable sources of plant nutrients that can be used to supplement fertilizer for sustainable agriculture growth. As a result, biofertilizers have become an important aspect of plant nutrient management for increasing crop yields (Shroti *et al.,* 2018). The secret to healthy soil and plants is the coordinated use of inorganic and organic fertilizers, which refers to the use of both types of fertilizers for the plant to benefit to the fullest. As a result, inoculating biofertilizers with inorganic fertilizer promotes crop growth (Singh *et al.,* 2021). By secreting acidic chemicals, the introduction of phosphorus-solubilizing bacteria to crops and soils improves the availability of phosphorus from insoluble sources, the desorption of fixed phosphate, and the effectiveness of phosphatic fertilizers. (Gaur, 1988). Phosphorus cycle and plant phosphorus uptake are both significantly influenced by Vesicular Arbuscular Mycorrhiza (VAM) (Biswas and Patra 2007). VAM aids phosphorus feeding by improving the availability of phosphorus as well as its mobility and absorption capability. PSB produces acidic chemicals that aid in the solubilization of inaccessible soil phosphorus, plant phosphorus uptake, and crop growth and yield. Rather than PSB an obligate symbiont of VAM help in stimulating absorption of phosphorus in plants by spreading hyphal growth in the root zone near to nutrient area. Therefore, in the current context, with advances in knowledge, technology, and care for the ecosystem, alternate sources of nutrients are being prioritized over fertilizers alone to ensure environmental sustainability.

MATERIALS AND METHODS

A field experiment was conducted at the Department of Agronomy's Crop Research Farm, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.) during *Kharif* season of year 2020. At 25° 24' 42" N latitude, 81° 50' 56" E longitude, and 98 m above MSL, the experimental site is situated. The soil in the experimental field had a sandy loam texture with a soil reaction of 7.4, was low in available nitrogen (190.8 kg/ha), low in available phosphorus (18.25 kg/ha), and medium in available potassium (236.20 kg/ha).Randomized block design was used to set up the experiment. with three replications and comprised of ten treatment combinations *viz.,* the farmer practice RDF plot is T_1. T_2, T_3, and T_4 involve seeding PSB with 35, 45, and 55 kg of phosphorus per hectare, respectively. T_5, T_6, and T_7 involve seed inoculation with VAM and 35, 45, and 55 kg of phosphorus per hectare, respectively. The treatments T_8, T_9, and T_{10} involve seed inoculation with PSB and VAM combined with 35, 45, and 55 kg of phosphorus per hectare, respectively. The cowpea variety Pusa dofasli was sown on 24 June, 2020 using seed rate @ 25 kg/ha with a 30 cm row spacing. At sowing, urea and MOP were used to apply a uniform dose of Nitrogen at 25kg/ha and Potassium at 20kg/ha and required quantity of Phosphorus as per the treatments through Single Super Phosphate. Farmer's practice for cowpea is 25:50:20 NPK kg per hectare. To inoculate the seed, 10 ml/kg of PSB culture and 10 g/kg of seed with VAM culture were utilised as per the treatment and shade dried before sowing. The standard recommendations for other agronomic management methods were followed. Five plants were chosen at random to record plant height, characteristics that indicate the yield, such as test weight, seed yield, number of pods per plant, number of seeds per pod, stover yield (t/ha) and harvest index. At harvest, yield and yield attributes had been noted. The recorded data were put through statistical analysis using the ANOVA standard technique (Gomez and Gomez 1984) at 5 percent level of significance. Fixed and variable cost data were evaluated to determine the cost of cultivation, gross return, net return, and benefit cost ratio.

RESULTS AND DISCUSSIONS

The observation recorded on plant height, test weight, seed yield, stover yield, and other yield-attributing characters including the number of pods per plant, the number of seeds per pod and harvest index are depicted in Table 1. At harvest, in comparison to other treatments, a significant and better plant height (81.09 cm) was seen with the two-fold inoculation of PSB and VAM combined with 55 kg of phosphate per hectare. Plant height increased as the crop stage progressed, regardless of treatment, and peaked at harvest. The production of aliphatic, aromatic acids, and phosphatic lipases by VAM and PSB are responsible for the increase in plant height, as well as the solubilization and mineralization of organic phosphorus-containing compounds (Yadav *et al*., 2017). Comparable results were also found reported by Sammauria *et al*. (2009); Pramanik and Bera (2012); Mir *et al.* (2013); Biswas *et al*. (2015); Nadeem *et al.* (2017); Sudharni *et al.* (2018). Dual inoculation of PSB and VAM with 55 kg of phosphate per hectare was shown to significantly differ between the treatments and the highest number of pods per plant (14.73), whereas plants produced pods when 45 kg of phosphate was co-injected into phosphorus-solubilizing bacteria (PSB) and vesicular arbuscular mycorrhiza (VAM) per hectare was found statistically on par with highest treatment. A sufficient supply of nutrients may have aided vegetative growth, resulting in a higher quantity of pods per plant (Yadav *et al.,* 2017). Singh and Pareek (2003); Sudharni *et al.* (2018) also lend support to these results. A notably greater amount of seeds each pod (8.85) was recorded with 55 kg of phosphorus per hectare were added to the simultaneous inoculation of PSB and VAM. However, seeds per pod in PSB + VAM along with 45 kg P/ha, PSB along with 45 kg P/ha and PSB along with 55 kg P/ha were found statistically on par with highest treatment. Due to a synergistic interaction between PSB and AM, the dual inoculation produced greater yield qualities (Pramanik and Singh 2003). The application of phosphorus and seed treatment with both microbes may have facilitated improved carbohydrate accumulation and remobilization to the plant's reproductive organs, which are the nearest sink, resulting in increased blooming, fruiting, and seed formation (Kumawat, 2006). Singh and Pareek (2003); Khan *et al.* (2017) reported a comparable finding. Test weight of cowpea was found to be significant and maximum test weight (80.19 g) was documented with combined inoculation of Vesicular Arbuscular Mycorrhiza (VAM) and Phosphate Solubilizing Bacteria (PSB) with 55 kg of phosphate per hectare whereas test weight in PSB + VAM along with 45 kg P/ha was shown to be statistically at par to PSB + VAM along with 55 kg P/ha. Zafar *et al.* (2020) also stated that increase in test weight attributed to more nutrient accumulation in seed, more photosynthates accumulation due to better photosynthesis under better nutrient availability with the use of biofertilizers. Similar findings were also reported by Selvakumar *et al*. (2012), Jaga and Sharma (2015); Singh *et al*. (2018).

Seed yield (t/ha). Significant increase in seed yield (2.62 t/ha) was documented in dual inoculation PSB and VAM + 55 kg phosphorus per hectare might be as under this treatment, a simultaneous rise in the number of pods per plant, the number of seeds per pod, and the test weight resulted in a higher seed production. Increased grain yield could be attributable to increased availability of photosynthates to the reproductive portion during the pod filling stage when varied Phosphorus levels and bio-fertilizers were used (Kachave *et al.,* 2018). Similar findings were also reported by Bhat *et al.* (2005); Beg and Singh (2009); Bhat *et al*. (2013); Prajapati *et al.* (2017); Venkatarao *et al.* (2017); Yadav *et al.* (2017); Zafar *et al*. (2020).

Stover yield (t/ha). The maximum and significant stover yield (6.45 t/ha) was observed in treatment with the applications of 55 kg of phosphorus per hectare is added to the inoculation of both Vesicular Arbuscular Mycorrhiza and Phosphate Solubilizing Bacteria. Increased stover yield could be attributed to biofertilizer inoculation, which increased phosphorus availability and favored greater nitrogen fixation, dry matter buildup, quick development, higher absorption and utilization of P and other plant nutrients, and eventually a positive impact on growth and yield qualities, leading in an increase in stover production. These finding are in line with the result observed by Gupta and Sharma (2006); Bhat *et al.* (2013); Patel *et al.* (2013); Verma *et al.* (2017); Yadav *et al.* (2017); Parmar *et al.* (2020).

Harvest Index (%). Two fold inoculation of PSB and VAM along with 55 kg phosphorus per hectare significantly increased harvest index (29.11 %) over all the treatments. It could be because of the interrelationship between seed yield and numerous growth and yield attributing features, which confirmed agricultural productivity's substantial dependency on vegetative and reproductive growth (Verma *et al.*, 2017). Additionally, these results were confirmed by Pramanik and Bera (2012); Patel *et al.* (2013); Ram *et al*. (2018).

Economics. The total cost of cultivation varies between INR 26511.48 to INR 28581.48 per hectare are depicted in Table 2. Maximum Gross return (INR 88390.42/ha), Net return (INR 59808.94/ha) were obtained with co-inoculation of PSB and VAM plus 55 kg phosphorus per hectare whereas, combined inoculation of PSB and VAM together with 45 kg phosphorus per hectare fetched the highest benefit cost ratio (2.14). Due to the fact that net return is determined by multiplying grain and stover yields by market selling prices and subtracting cultivation costs, which includes treatment costs, it appears to be directly tied to much greater yields (grain and stover) attained under the treatments. The highest B: C was observed with simultaneous PSB and VAM inoculation along with 45 kg P/ha might be due to on par seed yield and stover yield with PSB + VAM + 55 kg P/ha and also low cost of cultivation as compare to PSB + VAM plus 55 kg P/ha as well as larger difference in net return than 55 kg P/ha and rest of the treatments. Hence T_9 is also economically viable and can be used as an alternate source to T_{10} so that farmers can save on inorganic phosphorus.

Table 1: Influence of Biofertilizer and Phosphorus levels on plant height and yield attributes of Cowpea (At Harvest).

Treatments	Plant height (cm)	Pods per plant (No.)	Seeds per pod (No.)	Test weight (g)
Control (Farmer's practice)	68.01	11.00	7.71	78.04
PSB + 35 kg P/ha	65.79	10.73	6.35	77.91
PSB + 45 kg P/ha	75.93	13.20	8.26	78.88
PSB + 55 kg P/ha	74.20	12.67	8.05	78.63
VAM + 35 kg P/ha	61.84	10.27	6.29	77.68
VAM + 45 kg P/ha	70.57	11.80	7.84	78.14
VAM+ 55 kg P/ha	71.06	12.33	7.92	78.61
PSB + VAM + 35 kg P/ha	69.58	11.33	7.90	78.11
PSB + VAM + 45 kg P/ha	77.55	13.87	8.78	79.44
PSB + VAM + 55 kg P/ha	81.09	14.73	8.85	80.19
SE(m)±	2.40	0.44	0.27	0.38
CD (P=0.05)	7.15	1.34	0.81	1.16

Table 2: Influence of Biofertilizer and Phosphorus levels on Yield of Cowpea.

Treatments	Seed Yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
Control(Farmer's practice)	1.34	5.05	19.41
PSB + 35 kg P/ha	1.10	4.53	18.98
PSB + 45 kg P/ha	2.06	5.77	26.48
PSB + 55 kg P/ha	1.84	5.67	24.76
VAM + 35 kg P/ha	1.03	4.29	19.19
VAM + 45 kg P/ha	1.61	5.37	22.90
VAM+ 55 kg P/ha	1.76	5.53	23.99
PSB + VAM + 35 kg P/ha	1.63	5.46	23.61
PSB + VAM + 45 kg P/ha	2.57	6.32	28.68
PSB + VAM + 55 kg P/ha	2.62	6.45	29.11
SE(m)±	0.11	0.31	1.50
CD (P=0.05)	0.34	0.95	4.48

Table 3: Economics of different treatments in Cowpea.

Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C
Control (Farmer's practice)	26951.48	47647.65	20696.17	0.77
PSB + 35 kg P/ha	26511.48	39690.72	13179.24	0.50
PSB + 45 kg P/ha	27511.48	70401.11	42889.63	1.56
PSB + 55 kg P/ha	28511.48	63846.61	35335.13	1.24
VAM + 35 kg P/ha	26521.48	37415.76	10894.28	0.41
VAM + 45 kg P/ha	27521.48	56210.51	28689.03	1.04
VAM+ 55 kg P/ha	28521.48	61157.53	32636.05	1.14
PSB + VAM + 35 kg P/ha	26581.48	57111.31	30529.83	1.15
PSB + VAM + 45 kg P/ha	27581.48	86473.78	58892.30	2.14
PSB + VAM + 55 kg P/ha	28581.48	88390.42	59808.94	2.09

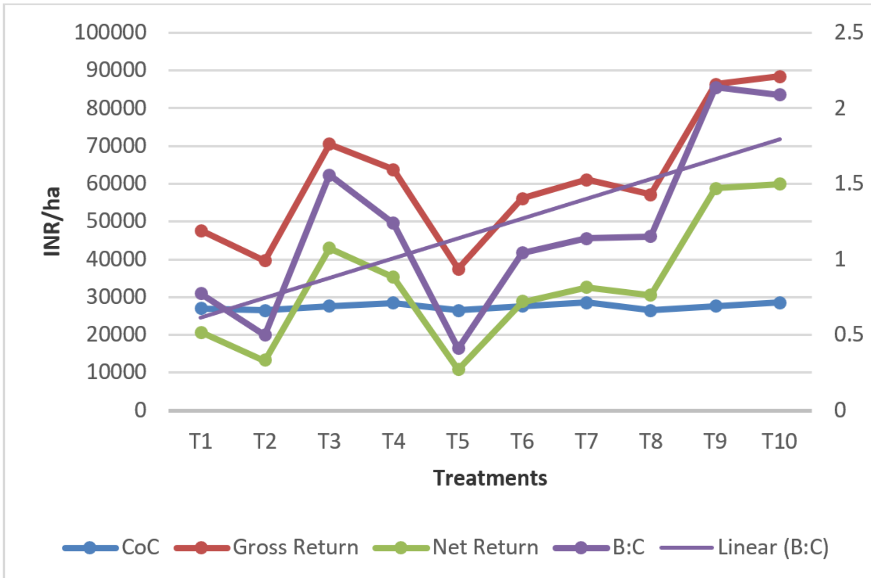

Fig. 1. Economics of different treatments in Cowpea.

Fig. 2. Experimental Plot of cowpea.

CONCLUSIONS

Based on the results of one-year experimentation, it may be concluded that when comparing the various treatments, it was observed that the combined inoculation of PSB and VAM with 55 kg of phosphorus per hectare produced the highest yield attributes, harvest index, seed yield, and stover output. Maximum gross return and net return ratio was also recorded with the same, while thorough going benefit cost ratio was observed in combined inoculation of PSB and VAM with 45 kg P/ha. Acceptance of any agricultural recommendation will mainly depend on its benefit cost ratio, therefore among the two treatments *i.e.,* PSB + VAM + 55 kg P/ha and PSB + VAM + 45 kg P/ha latter treatment was found to be more economically feasible for farmer's practice.

FUTURE SCOPE

Because biofertilizers are eco-friendly, simple to use, non-toxic, and affordable, they have become a highly effective companion for chemical fertilizers for reducing the excessive use or pollution Additionally, they enable plants to use nutrients that are naturally rich in soil or the environment and serve as a complement to agrochemicals. As a result, utilizing both inorganic P and biofertilizer (Phosphobacteria and Arbuscular Mycorrhiza) resources is preferable for optimal phosphorus consumption for good pod development and production in a sustainable manner.

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Conflict of Interest. None.

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