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Effect of Phosphorus Levels with and without Phosphate solubilizing bacteria on growth, yield and quality of Cowpea (Vigna unguiculata L.

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1. ABSTRACT

A field experiment entitled "Effect of phosphorus levels with and without phosphate solubilizing bacteria on growth, yield and quality of cowpea (*Vigna unguiculata* L. Walp) in semi-arid region of South-Eestern Rajasthan was conducted during *Kharif* season of 2021 at the Experimental Farm of Agronomy, Mewar University, Gangrar, Chittorgarh (Rajasthan). The experiment consists of eight treatments, levels of phosphorus with and without PSB *viz.*, 0, 20, 40 and 60 kg P_2O_5 ha^{-1}, PSB, 20 kg P_2O_5 ha^{-1}+PSB, 40 kg P_2O_5 ha^{-1} +PSB and 60 kg P_2O_5 ha^{-1} +PSB replicated four times laid down in RBD. Cowpea variety Pratap RC-19 was used with seed rate 15 kg ha^{-1}.

Growth attributes *viz.*, plant height at 60 DAS and at harvest responded with 40 kg P_2O_5 ha^{-1} except 30 DAS where it responded with 60 kg P_2O_5 ha^{-1} over control. Primary and secondary branches per plant, number of trifoliate leaf of cowpea statistically significantly responded up to 40 kg P_2O_5. ha^{-1} at harvest. Similarly, root nodule number at 45 DAS responded up to 40 kg P_2O_5. ha^{-1} whereas nodule dry weight was responded up to 60 kg P_2O_5. ha^{-1} at 45 DAS over 40 kg, 20 kg P_2O_5 ha^{-1} and control. Yield attributing characters namely number of pods per plant and pod length were perceptibly increase, ed by application of 40 kg P_2O_5. ha^{-1} over 20 kg P_2O_5 ha^{-1} and control. Further, application of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing yield attributes. 1000-grain weight, seeds per pod and harvest index was significantly higher up to 20 kg P_2O_5 ha^{-1} and control. Grain, straw and

biological yields of cowpea perceptibly increased with the application of 40 kg and 60 kg P_2O_5. ha^{-1} but the higher dose of 60 kg P_2O_5 ha^{-1} remained statistically at par with 40 kg P_2O_5 ha^{-1}. Improvement in N content both in grain and straw, P content in straw and K content both in grain and straw, protein content in grain and grain protein yield was significantly improved up to 40 kg P_2O_5. ha^{-1}. P content in grain was responded with 60 kg P_2O_5 ha^{-1}. Similarly, NPK uptake by both grain and straw and total uptake of nutrients (NPK)Nwas increased significantly under 40 kg P_2O_5. ha^{-1} over 20 kg P_2O_5 ha^{-1} and control. The dose of 60 kg P_2O_5 ha^{-1} remained statistically at par with 40 kg P_2O_5. ha^{-1} in enhancing gross and net returns and B:C over 20 kg P_2O_5 ha^{-1} and control.

2. INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp)is the most important grain legume in the third world, particularly Africa. It is commonly known as black-eyed pea, China pea and marble pea. It is an important source of dietary protein in developing countries of Asia and Africa. It is used as fodder, vegetable, pulse and green manure crop. The economic importance of cowpea is difficult to ascertain, since production statistics no longer kept separate from those of other pulses. It is now cultivated throughout sub-saharian Africa, south east Asia, Latin America, Australia and USA. The highest cowpea producing nations are Nigeria, India and Brazil. It is grown all over India, more particularly in the central and Peninsular regions. Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh and Rajasthan are the principle states of cowpea cultivation. In Rajasthan, cowpea grown in 52903 ha. Land with production of 34435 matric tones

3. MATERIALS AND METHODS

A field experiment entitled "Effect of phosphorus levels with and without phosphate solubilizing bacteria on growth, yield and quality of cowpea (*Vigna unguiculata* L. Walp) was conducted at Agriculture farm, Department of Agriculture, Mewar University, Gangrar during *kharif*–2021. The details of the experimental techniques, materials and methods, techniques adopted for the evaluation of the treatments during the course of study are described in this chapter.

3.1. EXPERIMENTAL SITE AND LOCATION

The experiment was conducted at Agriculture farm, Department of Agronomy, Mewar University,Gangrar during *kharif*–2021. It is 25 km away from district headquater of Chhitorgarh at 25º0344" N latitude and 74º6361" E latitude at the altitude of 395 metres above mean seas level. Bhilwara is the nearest district whch is 35 km from Mewar University.

The region experiences hot and wet summers and dry winters. The annual precipitation is 500-1000 mm. According to "Agro-ecological map" brought by the National Bureau of Soil Survey and Land Use Planing (NBSS & LUP), Chhitorgarh falls under Agro-ecological Region No. 5 namely Hot Semi-Arid Eco-region with Medium and Deep Black Soils receiving 500-1000mm rainfall. Gentle to very gently sloping deep, loamy to clayey soil and nearly level to very gently sloping deep black soils are the dominant types, Clayey, slightly alkaline, calcareous soils with swell-shrink properties typify the . Dry deciduous forest makes up the natural vegetation Hot Semi-Arid Eco-region with Medium and Deep Black soils. AS per NARP Chhitorgarh fallls under Agroclimatic zone IVa known as Semi-arid souther plans zone.

3.2. CLIMATE AND WEATHER CONDITIONS

The climate of Chittorgarh is quite dry and parched. The summer season extends from April to June an is quite hot. The average temperature in summers falls between 43.8°C to 23.8° C. The winter season lasts from October to February. Chittorgarh weather in the winters is pretty cool. The temperature

averages around 28.37° C to 11.6°C. The monsoon season falls during the months of June to August. As far as climatic conditions of Chittorgarh, Rajasthan in monsoon are concerned, there is rainfall that averages around 60 cm to 80 cm.

3.3. SOIL OF HTE EXPERIMENTAL FIELD

In order to know the physical and chemical properties of the soil, samples were taken randomly from 15 cm soil depth from different spots of the experimental field and a reprensentative composite sample was prepared by mixing all these samples together. This composite sample was analysed to determine the mechanical composition, physico-chemical properties, organic carbon, availabel N, P and K in the soil.

3.4. EXPERMENTAL DETAILS

3.4.1. Treatments

The 8 treatments combinations of the experiment comprised four replications having treatments of phosphorus, PSB and phosphorus with PSB. The phosphorus was applied through DAP. Three packets of PSB each of 250 g was used for the treatment of one hectare area seed of cowpea. The details of the treatments are given in Table 3.2.

Table 3.2. Details of the treatments with their symbols

Treatments	:	Treatment symbols
Control	:	T_0
20 kg P_2O_5 ha^{-1}		T_1
40 kg P_2O_5 ha^{-1}	:	T_2
60 kg P_2O_5 ha^{-1}	:	T_3
PSB	:	T_4
20 kg P_2O_5+PSB	:	T_5
40 kg P_2O_5+PSB	:	T_6
60 kg P_2O_5+PSB		T_7

3.4.2. Experimental design and layout

The experiment was laid out in the RBD with four replications. The application of phosphorus levels and in conjugation of PSB with phosphorus was applied before sowing having randomization of Fisher, Table, 1950. The plan of the lay out is given in Fig. 3.1. The gross and net plot size 4.0 x 3.6 m and 4.0 x 3.0m, respectively.

3.5. Salient Features Of The Crop Variety

RC-19 variety of cowpea was released from SKN, University of Jobner, Jaipur Rajasthan from its centre Rajasthan Agriculture Research Institute, Durgapura, Jaipur. College of Agriculture, SKN, University,Jobner during 2013. RC-19 variety of cowpea is high yielding and early maturing has been

developed with fawn coloured grain (RC 19) developed for grain purpose. It has the yield potential of 12-14 q ha^{-1}.

3.6.1. Field preparation

After the harvest of the rabi crop, the experimental field was prepared by ploughing with tractor drawn harrow, planked and beds of 4.0 x 3.6 m size were prepared according to the plan of layout. A uniform dose of 20 kg N ha^{-1} was applied as basal dose through DAP and urea adjusting the dose of phosphorus treatments at the time of sowing.

3.7.2. Treatment application

3.7.2.1 Phosphorus- Phosphorus was applied through DAP as per treatment. The whole quantity was drilled in furrows 30 cm apart at depth of 10 cm.

3.7.2.2 PSB- Phosphate solubilizing bacteria (PSB) was applied as seed treatment before sowing of crop. 250 ml water was taken, gently warmed and .250g jaggary was added in water and stirred. The jaggary solution kept for cooling followed by mixing of seed and seed was treated and sown in the next day morning.

3.7.3 Seed and sowing

Before sowing, seed was treated with Carbendazim @2.0 g seed kg^{-1} as prophylactic measure against seed borne diseases. Sowing was done on 02.07.2021 using seed rate of 15 kg ha^{-1}.

3.7.4. Thinning

In order to maintain a uniform plant, stand through 30 x 10cm spacing, the extra plants were thinned out at 20 DAS.

3.7.5. Weeding and hoeing

In order to keep experimental field plots free from weed competition, hoeing and weeding at 30 DAS and 50 DAS was done twice during the crop growing period.

3.7.6. Plant protection

The crop was sprayed at the pod initiation with quinalphos @ 2 ml per litre water for protect sucking and flower biting insects/ flies etc.

3.7.7. Harvesting

The crop was harvested from the net area of the individual plot to obtain yield data when grain was fully matured and colour of the crop changed to brownish. The harvesting was completed on 24 October, 2021. The produce from each plot was tied in bundles and left in the field for sun drying to facilitate the threshing operation.

3.7.8. Threshing and winnowing

After through drying, the produce of each plot was weighed with the help of a electronic balance to record biological yield per plot. Threshing was done manually by beating with wooden sticks and winnowed traditionally. The produce obtained from each plot was weighed on electronic balance and the weight recorded as seed yield per plot (kg) and converted as q ha^{-1}.

3.8. Treatment evaluation

To evaluate the effect of phosphorus levels, with and without PSB and PSB alone on cowpea , observation on plant growth parameters, yield attributing characters, yield, nutrient content and their uptake was recorded. The economics of the treatment was also calculated.

3.8.1 Growth parameters

3.8.1.1. Plant stand

The number of plants per metre row length randomly selected at four locations in each plot were counted after thinning at 20 DAS of the crop. The mean plant stand per metre row length was worked out and recorded as plants per metre row length.

3.8.1.2. Plant height

Plant height was recorded at 30 DAS, 60 DAS and at harvest by selecting 10 plants randomly from each plot. The height of these plants from each plot was recorded from base of the plants to the tip of the main shoot and mean was recorded as plant height (cm).

3.8.1.3. Dry matter per plant

Ten plants from each plot were selected randomly at harvest and then material was air dried and placed in hot oven at 70^{o}C for about 72 hours still constant weight was attained. The average dry matter was worked out and recorded as dry matter per plant (g).

3.8.1.4. Number of root nodules

The number of root nodules from 5 randomly selected plants were recorded at 40 DAS. For recording number of root nodules, five plants were removed carefully along with the soil taking out of the root portion from easily removable depth (30cm). The roots were washed with a fine jet of water and finally dipped in water so that adhered soil was removed. The number of root nodules were counted and removed from drying to get dry weight of root nodules. The mean number of root nodules per plant was recorded.

3.8.1.5. Wight of dry roots per plant

The weight of dry root per plant of randomly selected five plants from sampling rows were recorded at 45 DAS. For recording weight of roots, the roots up rooted and dried were weighted by drying the roots in a hot air oven at 70^{o}C for about 72 hours till weight is attained constant. The average root dry weight per plant was worked out and mean weight was recorded in g.

3.8.1.6. Number of trifoliate leaves

The randomly selected five plants from sampling rows were recorded at harvest. For recording number of trifoliate leaves, the average leaves per plant was worked out and mean was recorded.

3.8.1.7. Branches per plant

The randomly selected five plants from sampling rows were recorded at harvest. For recording number of branches per plant, the average number of branches per plant was worked out and mean was recorded.

3.8.2. Yield attributes

3.8.2.1. Number of pods per plant

The pods of randomly selected five plants were counted and mean was recorded as number of pods per plant.

3.8.2.2 Number of seeds per pod

The seeds of randomly selected five plants were counted and mean was recorded as number of seeds per pod.

3.8.2.3. Pod length

The length of 10 selected pods of randomly selected five plants were counted and mean was recorded as pod length in cm.

3.8.2.4. 1000- seed weight

1000-seeds were counted from the produce of each plot and weighed on electric balance. The weight was recorded as test weight (g).

3.8.3. Yield and Harvest Index

3.8.3.1. Seed yield

After threshing and winnowing, the mean seeds obtained from each plot were weighed and weight recorded as seed yield (kg $^{-1}$ plot) and converted in terms of q ha^{-1}.

3.8.3.2. Straw yield

The straw yield (kg plot^{-1}) was obtained by subtracting the seed yield from biological yield per plot recorded earlier and converted as straw (kg $^{-1}$ plot) and converted in terms of q ha^{-1}.

3.8.3.3 Biologicals yield

The harvested material from net plot of each ploy was thoroughly sun dried. After, drying, the produce of the individual net plot was weighed with the help of electronic balance and weigh recorded in kg as biological yield per plot and then converted in to q ha^{-1}.

3.8.3.4. Harvest index

The ratio of economic yield (seed yield) to the biological yield was worked out to estimate harvest index and expressed as percentage (Singh and Stoskopf, 1971).

3.9. Plant analysis

3.9.1. Plant analysis

The plant samples as harvest both in terms of seed and straw from each plot were completely dried and ground to a fine powder for estimating nutrient content. The nutrient contents in the seed and straw were estimated by using standard analytical methods as given below:

(a) Nitrogen

Nitrogen was estimated by digesting plant samples with sulphuric acid and hydrogen peroxide, estimation of nitrogen was done by colorimetric method using Spectrophotometer after development of colour with Nesser's reagent (Snell and Snell, 1939). Nitrogen was calculated and expressed in percentage.

(b) Phosphorus

Phosphorus was estimated by digesting plant samples with di-acid mixture of HNO_3 and $HCLO_4$ and was estimated by Vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and was calculated and expressed in percentage.

(C) Potassium

Flame photometric method (Metson,1956) was used for the estimation of potassium.

3.9.1.2. Protein content

The per cent protein in grain was computed by multiplying the nitrogen content in seed with constant factor 6.25 (A.O.A.C, 1966).

3.9.1.4. Soil analysis

The soil samples collected from each plot before of the crop were subjected to chemical analysis to determine the contents as listed in Table 3.1.

3.10.1. Analysis of variance and Test of Significance

In order to test the significant of variation in the experimental data obtained for various treatments effects, data were statistically analysed as per procedure described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment mean wherever the 'F' test was significance at 5 % and 1 % level of significance. The analysis of variance for all the data discussed have been given in appendices in the end.

3.10.2. Economics of the treatments

In order to evaluate the economic feasibility of the treatments, the net returns (Rs. ha^{-1}), B:C ratio and suitable level of phosphorus with and without PSB was worked out on the basis of yield, treatment cost and market prevailing price of produce and treatment costs. The estimated cost was analysis as per the procedure described by Panse and Sukhatme (1985).

EXPERIMENTAL RESULTS

4.1.2 Plant height 30 cm

Table 4.1 and revealed the plant height of cowpea at 30 DAS was increased up to 60 kg P2O5 ha-1 over control and dose of 20 kg P2O5 ha-1 and 40 kg P2O5 ha-1 and 60 kg P2O5 ha-1 found mutually at par each other. Further, treatment of PSB alone was also significant over control in enhancing plant height. The doses of phosphorus with PSB found mutually ap par each other but significant over PSB alone as well over control (Appendix-I, Fig. 4.1).

4.1.3 Plant height 60 DAS

Table 4.1 and revealed the plant height of cowpea responded up to 40 kg P_2O_5. ha^{-1} at 60 DAS. The dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing plant height over 40 kg P_2O_5. ha^{-1}. Per cent increase of 45.22 and 30.57 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}, respectively over control. Seed treatment of PSB alone also recorded 8.92 per cent increase in plant height over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and control. 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB registered an increase to the tune of 47.37 and 34.50, per cent, respectively over control (Appendix-I, Fig. 4.1).

4.1.4 Plant height at harvest

Plant height of cowpea responded up to 40 kg P_2O_5. ha^{-1} at harvest and further dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing plant height over 40 kg P_2O_5. ha^{-1}. Per cent increase of 41.99 and 28.38 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}, respectively, over control. Seed

treatment of PSB alone also recorded 6.49 per cent increase in plant height over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and control. Application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB registered per cent increase to the tune of 46.78 and 34.75, respectively over control (Table 4.1, Appendix-I, Fig. 4.1).

4.1.5 Primary branches/plant

Primary branches per plant of cowpea statistically significantly responded up to 40 kg P_2O_5. ha^{-1} at harvest and further dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing primary branches over 40 kg P_2O_5. ha^{-1}. Per cent increase of 44.92 and 28.94 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}, respectively over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and registered per cent increase of 47.77 and 36.23, respectively over control. Seed treatment of PSB alone also recorded 6.70 per cent increase in primary branches per plant over control. (Table 4.2, Appendix-II, Fig. 4.2).

4.1.6 Secondary branches per plant

Table 4.2 and revealed the secondary branches per plant of cowpea responded up to 40 kg P_2O_5. ha^{-1}. The dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing secondary branches per plant over 40 kg P_2O_5. ha^{-1}. Per cent increase of 48.80 and 33.64 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}, respectively over control. Seed treatment of PSB alone also recorded 11.70 per cent increase in secondary branches per plant over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and control. Respective treatments of phosphorus and PSB noted an increase to the tune of 49.35 and 61.92, per cent, respectively over control (Appendix-II, Fig. 4.2).

4.1.8. Dry weight per plant

An examination of data (Table 3) showed that dry matter per plant of cowpea perceptibly enhanced by 40 kg P_2O_5. ha^{-1} at harvest and further dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing dry matter per plant over 40 kg P_2O_5. ha^{-1}. Application of 40 kg P_2O_5. ha^{-1} registered an increase of 48.80 and 36.04 per cent recorded over 20 kg P_2O_5 ha^{-1} and control, respectively. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB and control and registered per cent increase of 61.86 and 49.29, respectively over control. Seed treatment of PSB alone also recorded 11.58 per cent increase in dry matter per plant over control. (Appendix-III).

4.1.9. Number of root nodules per plant

Number of root nodules per plant of cowpea statistically significantly responded up to 40 kg P_2O_5. ha^{-1} at 45 DAS and further dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in root nodules over 40 kg P_2O_5. ha^{-1}. Per cent increase of 48.73 and 35.95 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}over control, respectively. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone as well over control and registered per cent increase of 61.82 and 50.81, respectively over control. Seed treatment of PSB recorded 9.31 per cent increase in nodulation of cowpea over control.

4.1.10. Nodule dry weight (g)

Data (Table 4.3, Appendix-III) indicated that nodule dry weight per plant of cowpea statistically significantly responded up to 60 kg P_2O_5. ha^{-1} at 45 DAS over 40 kg, 20 kg P_2O_5 ha^{-1} and control. A registered per cent increase of 73.67, 59.92 and 43.81 was recorded under 60 kg, 40 kg and 20 kg P_2O_5 ha^{-1} and over control, respectively. Further, application of 60 kg P_2O_5+PSB responded significantly in dry weight of nodules of cowpea over and 40 kg P_2O_5+PSB, and 20 kg P_2O_5+PSB and over PSB alone and registered per cent increase of 83.89, 71.3 and 54.03, respectively over control. Seed treatment of PSB recorded 11.59 per cent increase in dry weight of root nodule weight.

4.2 Yield Attributes

4.2.1. Number of pods per plant

Table 4.4 and Appendix-IV revealed the number of pods per plant of cowpea perceptibly increased by application of 40 kg P_2O_5. ha^{-1} and further application of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing number of pods per plant over 40 kg P_2O_5. ha^{-1}. Per cent increase of 53.23 and 33.50 was recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1} over control, respectively. Seed treatment of PSB alone also recorded 12.53 per cent increase in number of pods per plant over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB and control and registered an increase to the tune of 66.25 and 40.82, per cent, respectively over control (Fig. 4.4).

4.2.2. Seeds per pod

Table 4.4 and showed that seeds per pod cowpea responded up to 40 kg P_2O_5. ha^{-1} over 20 kg P_2O_5 ha^{-1} and control. Application of 40 kg P_2O_5. ha^{-1} noted an increase of 51.09 and 29.83 per cent over 20 kg P_2O_5 ha^{-1} and control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and control and registered an increase to the tune of 65.17 and 42.13, per cent, respectively over control. Seed treatment of PSB alone also recorded 11.01 per cent increase in secondary branches per plant over control. (Appendix-IV, Fig. 4.4).

4.3 Yield

4.3.1. Grain yield

Grain yield data presented in Table 4.5 indicated that grain yield of cowpea perceptibly increased with the application of 40 kg and 60 kg P_2O_5. ha^{-1} but the higher dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing grain yield perceptibly over 40 kg P_2O_5. ha^{-1}. Fertilization of 40 kg P_2O_5 ha^{-1} brought noticeable increase to the extent of 58.52 and 38.12 over 20 kg P_2O_5 $ha^{-1}$and control, respectively. Seed treatment of PSB brought significant increase in grain yield of cowpea and recorded 19.00 per cent increase over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly over PSB alone and control and registered an increase to the tune of 73.93 and 45.69 per cent, respectively over control (Appendix-V). Further, data analysis showed that all treatments of phosphorus and PSB alone as well in phosphorus combination were statistically higher in grain yield improvement over control. Application of phosphorus *viz.*, 60 kg, 40 kg and 20 kg P_2O_5. ha^{-1}, PSB alone

and phosphorus in conjugation with PSB *viz.*, 60 kg P_2O_5+PSB, 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB were responded significantly over control and respective treatments registered an increase of 84.45, 73.93, 45.69, 19.00, 64.56, 58.52 and 38.12 respectively over control (Appendix-V, Fig. 4.5).

4.3.4. Harvest index

Harvest index data (Table 4.5 and Appendix-V) significantly responded up to 20 kg P_2O_5. ha^{-1}. The higher doses of phosphorus *viz*., 40 kg and 60 kg P_2O_5 ha^{-1} remained statistically at par in enhancing harvest index of cowpea. 20 kg P_2O_5. ha^{-1} recorded 11.26 per cent increase in harvest index over control. Seed treatment of PSB was non-significant for increasing harvest index over control. Application of 20 kg P_2O_5+PSB responded significantly over control having 9.07 per cent increase over control in HI. The dose of 40 kg P_2O_5+PSB and 60 kg P_2O_5+PSB doses were mutually non-significant in respect of increase in harvest index of cowpea.

4.4.4. Protein content

Data presented (Table 4.7 and Appendix-VII) revealed that protein content in grain of cowpea responded significantly up to 40 kg P_2O_5. ha^{-1}. The dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in protein content in grain over 40 kg P_2O_5. ha^{-1}. K content in straw increased to the tune of 16.48 and 10.99 per cent recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1} over control, respectively. Protein content in grain was appreciably improved by seed treatment of PSB alone over control and recorded 8.14 per cent increase in protein content in grain over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly protein content in grain over PSB alone and control. 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB and PSB perpetually registered an increase in protein content in grain to the tune of 19.08, 15.25 and 8.14, per cent, respectively over control (Appendix-VI, Fig. 4.6).

4.4.5. Protein yield of grain

Protein yield of grain of cowpea responded significantly up to 40 kg P_2O_5. ha^{-1}. The dose of 60 kg P_2O_5 ha^{-1} remained statistically at par in grain protein yield over 40 kg P_2O_5. ha^{-1}. Grain protein yield increased to the tune of 84.60 and 53.38 per cent recorded under 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1} over control, respectively. Grain protein yield was appreciably improved by seed treatment of PSB alone over control and recorded 28.73 per cent increase in grain protein yield over control. Further, application of 40 kg P_2O_5+PSB and 20 kg P_2O_5+PSB responded significantly grain protein yield over PSB alone and control. 40 kg P_2O_5+PSB increased protein grain yield 20 kg P_2O_5+PSB and PSB perpetually registered an increase in grain protein yield to the tune of 107.13 and 67.99, per cent, respectively over control (Table 4.7 and Appendix-VII, Fig. 4.6).

Table 4.1 Effect of phosphorus levels and PSB on plant stand and plant height at various periodical growth stages of cowpea

Treatments	Plant stand per metre row length	Plant height (cm)		
		30 DAS	60 DAS	At harvest
Control	10.16	25.97	39.25	56.20
20 kg P_2O_5 ha^{-1}	10.47	33.03	51.25	72.15
40 kg P_2O_5 ha^{-1}	10.03	35.50	57.00	79.80
60 kg P_2O_5 ha^{-1}	10.00	37.08	58.75	81.25
PSB	10.99	30.57	42.75	59.85
20 kg P_2O_5+PSB	10.05	37.83	57.50	80.65
40 kg P_2O_5+PSB	9.76	38.83	63.00	87.85
60 kg P_2O_5+PSB	9.92	39.00	63.75	88.85
SEm±	0.47	0.96	1.70	2.34
CD (P=0.05)	1.39	2.81	5.00	6.89
CV %	9.31	5.50	6.28	6.18

Table 4.2 Effect of phosphorus levels and PSB on branches and number of trifoliate leaves of cowpea

Treatments	Primary branches/plant	Secondary branches per plant	Number of trifoliate leaves per plant
Control	4.63	5.41	15.84
20 kg P_2O_5 ha^{-1}	5.97	7.23	20.90
40 kg P_2O_5 ha^{-1}	6.71	8.05	23.10
60 kg P_2O_5 ha^{-1}	6.75	8.15	23.26
PSB	4.94	6.04	17.10
20 kg P_2O_5+PSB	6.73	8.08	23.03
40 kg P_2O_5+PSB	7.30	8.76	25.20
60 kg P_2O_5+PSB	7.36	8.90	25.39
SEm±	0.17	0.22	0.71
CD (P=0.05)	0.50	0.65	2.09
CV %	5.44	5.81	6.56

Table 4.3 Effect of phosphorus levels and PSB on dry weight of plant, dry weight of root and number of root nodules of cowpea

Treatments	Dry weight of plant (g)	No. of root nodules/plant	Nodules dry root weight (g)
Control	16.23	12.99	0.509
20 kg P_2O_5 ha^{-1}	22.08	17.66	0.732
40 kg P_2O_5 ha^{-1}	24.15	19.32	0.814
60 kg P_2O_5 ha^{-1}	24.91	20.03	0.884
PSB	18.11	14.20	0.568
20 kg P_2O_5+PSB	24.23	19.59	0.784
40 kg P_2O_5+PSB	26.27	21.02	0.872
60 kg P_2O_5+PSB	28.11	21.36	0.935
SEm±	0.95	0.42	0.013
CD (P=0.05)	2.80	1.24	0.040
CV %	8.27	4.62	3.52

Table 4.4 Effect of phosphorus levels and PSB on yield attributing characters of cowpea

Treatments	No. of pods/ plant	Seeds/pod	Pod length (cm)	1000-grain weight (g)
Control	8.06	7.81	11.98	127.50
20 kg P_2O_5 ha^{-1}	10.76	10.14	15.64	153.71
40 kg P_2O_5 ha^{-1}	12.35	11.80	18.53	166.25
60 kg P_2O_5 ha^{-1}	12.72	12.20	19.23	171.29
PSB	9.07	8.67	15.48	132.44
20 kg P_2O_5+PSB	11.35	11.10	17.03	159.29
40 kg P_2O_5+PSB	13.40	12.90	19.70	176.14
60 kg P_2O_5+PSB	14.25	13.62	20.25	178.50
SEm±	0.45	0.32	0.51	4.49
CD (P=0.05)	1.34	0.94	1.51	13.20
CV %	7.92	5.79	5.98	5.68

Table 4.5 Effect of phosphorus levels and PSB on yield and harvest index of cowpea

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index
Control	779.06	1,499.68	2,278.74	34.19
20 kg P_2O_5 ha^{-1}	1,076.00	1,751.76	2,827.76	38.04
40 kg P_2O_5 ha^{-1}	1,235.00	1,967.45	3,202.45	38.61
60 kg P_2O_5 ha^{-1}	1,282.00	2,018.58	3,300.58	38.81
PSB	927.10	1,743.15	2,670.25	34.84
20 kg P_2O_5+PSB	1,135.00	1,909.40	3,044.40	37.29
40 kg P_2O_5+PSB	1,355.00	2,156.22	3,511.22	38.55
60 kg P_2O_5+PSB	1,437.00	2,202.35	3,654.25	39.37
SEm±	43.22	81.18	105.65	0.94
CD (P=0.05)	127.11	238.74	310.72	2.76
CV %	7.50	8.52	6.90	5.01

Table 11. Effect of phosphorus levels and PSB on economics of cowpea

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
Control	48,009	27,009	1.29
20 kg P_2O_5 ha^{-1}	64,711	42,918	1.97
40 kg P_2O_5 ha^{-1}	74,057	51,721	2.32
60 kg P_2O_5 ha^{-1}	76,757	53,878	2.35
PSB	56,925	35,625	1.67
20 kg P_2O_5+PSB	68,567	46,474	2.10
40 kg P_2O_5+PSB	81,241	58,605	2.59
60 kg P_2O_5+PSB	85,736	62,557	2.70
SEm±	2,451.80	2,451.80	0.12
CD (P=0.05)	7,210.78	7,210.78	0.32
CV %	8.23	9.31	9.06

CONCLUSION

The under mentioned conclusions are hereby drawn from the present study.

1. Application of 40 kg P_2O_5 ha^{-1} along with phosphate solubilizing bacteria (PSB) significantly increased growth and yield attributes and yield of cowpea.
2. The use of 40 kg P_2O_5 ha^{-1} in conjugation with phosphate solubilizing bacteria (PSB) significantly enhanced nutrient uptake (NPK) by cowpea.
3. Gross and net returns and B:C ratio significantly increased up to 40 kg P_2O_5 ha^{-1} with phosphate solubilizing bacteria (PSB).

Based on the results of the one-year experimentation, it can be suggested that application of 40 kg P_2O_5 ha^{-1} in conjugation with phosphate solubilizing bacteria (PSB) along with 20 kg N as basal dose for raising a good crop of cowpea is suggested under condition of Chittorgarh district (Rajasthan).

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