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Short communications

# Growth and yield response of different cowpea (*Vigna unguiculata* (L.) Walp.) varieties under varying phosphorus management

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**Abstract**

A field experiment was conducted at the Integrated Farming System Research Station (IFSRS) under Kerala Agricultural University (KAU), located at Karamana in Thiruvananthapuram, Kerala, during summer 2021 for studying the performance of grain cowpea varieties in summer rice fallows and to assess the influence of beneficial phosphorus inoculants in enhancing phosphorus availability for the crop. The treatments included three varieties of grain cowpea and five different strategies for phosphorus nutrition. The test crop varieties were Kanakamony, PGCP-6 and DC-15. Phosphorus levels comprised the KAU recommended dose of P(RDP) i.e. @30 kg $P_2O_5$ $ha^{-1}$and lower doses of RDP (75 and 50 %) along with either AMF, PSB or both. Factorial RBD was the experimental design followed, with the treatment combinations laid out in three replications. Growth parameters of the crop including count of branches per plant, root mass and root volume; parameters contributing to yield including pod count per plant and average weight of pods were significantly higher for the variety PGCP-6 which also recorded higher grain yield and nutrient uptake. Application of AMF and PSB, along with 75 per cent of RDP and with 50 per cent of RDP recorded higher and comparable growth attributes (plant height, count of branches, effective nodulation, AMF root colonization, root mass and volume), yield and yield contributing attributes (harvest index, number of pods and grain yield per plant) and uptake of major plant nutrients.

**Keywords**: AMF, Grain cowpea, P management, PSB, Summer rice fallows,Varieties.

Cowpea [*Vigna unguiculata* (L.) Walp] is an important pulse crop of Kerala, suitable for summer rice fallows mostly because of its short duration and soil fertility restorative nature. The crop is nutritionally important as a rich source of protein, dietary fibre, vitamins and minerals.As grain cowpea is of short duration and moderately drought tolerant, it can thrive in summer. As a summer season crop in rice-based cropping systems,grain cowpea could be beneficial in terms of economics and improvement in soil fertility. According to Pillai et al. (2007), cowpea as a summer crop in rice fallows enhanced the soil organic carbon and the yield of succeeding rice crop and resulted in positive soil nitrogen balance.Many promising varieties of grain cowpea from other states are performing well in Kerala in terms of growth and yield. Considering the drastic climatic changes, new and improved varieties of grain cowpea be popularised for cultivation in summer rice fallows. The present study evaluated three promising grain cowpea varieties in summer rice fallows of Kerala.

Fertility evaluation studies conducted across the state revealed that more than 64 per cent of the soils are high in available phosphorus (KSPB, 2013). Considerable build-up of the nutrient is a consequence of continuous overdose of fertilizers.

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As higher P levels in soils affect the cycling and availability of other nutrients, it is essential to address the issue by reducing P fertilizers. Microbial inoculants like Arbuscular Mycorrhizal Fungi (AMF) and Phosphorus Solubilising Bacteria (PSB) play a great role in mobilizing or solubilizing phosphorus, thereby enhancing P availability to crop plants.The synergistic interactions resulting from the combined application of AMF and PSB occurring in crop root zone contributes to increased uptake of crop nutrients. As a result, improved crop growth occurs in comparison with individual applications (Minaxi et al., 2013; Zhang et al., 2016).The inclusion of these P inoculants in phosphorus nutrition schedule can therefore reduce the dose of phosphorus fertilizers. The effect of these two microbial inoculants alone and in combination in enhancing P availability was studied under reduced rates of phosphorus fertilizers. Based on the above, this study was planned to evaluate the crop performance of different grain cowpea varieties under different P management techniques,which integrated phosphorus inoculants with reduced rates of P fertilizers.

This experiment was carried out in the summer of 2021 (March to June, 2021) at IFSRS, Karamana, Thiruvananthapuram, Kerala, KAU, located at 8°28'28"North latitude and 76°57'47"East longitude, at an altitude of 5 m above mean sea level. The experimental site experienced a humid tropical climate; the mean maximum and minimum temperatures were in the range of 30-34°C and 23-29°C respectively during the crop phase.The soil had a sandy loam texture, pH moderately acidic (5.52), medium in organic carbon (1.34 %), low in available N (213.25 kg $ha^{-1}$), high in P (41.12 kg $ha^{-1}$) and low in K (68.59 $kgha^{-1}$). Plots of 4.5 m x 3 m size were prepared and the crop was planted at a spacing of 30 cm x 15 cm. The design of the experiment was Randomized Block (Factorial). There were three replications. The two factors studied were grain cowpea varieties (v) and phosphorus management (p). Grain cowpea varieties tested were Kanakamony ($v_1$), PGCP-6 ($v_2$) and DC-15($v_3$). P management comprised of five levels viz., $p_1$- Recommended dose of phosphorus (RDP) as per the KAU POP (30 kg $P_2O_5$ $ha^{-1}$), $p_2$- 75% RDP + AMF, $p_3$- 75% RDP + PSB, $p_4$- 75% RDP + AMF + PSB and $p_5$- 50% RDP + AMF + PSB. In all the treatments, FYM @ 20$tha^{-1}$, lime @ 250 kg $ha^{-1}$, N @ 20 kg $ha^{-1}$and $K_2O$ @ 10 kg $ha^{-1}$ were applied as recommended by the package of practices of KAU (KAU, 2016). Half the dose of N along with full dose of P and K fertilizers were applied 7 days after crop sowing (DAS) and the rest of nitrogen at 30 DAS. Urea, rajphos and muriate of potash were the chemical fertilizers used to supply the nutrients. Biofertilizer rhizobium was applied @ 100 g per kg seed as seed treatment, common for all treatments. At sowing, AMF @ 5 g per pit and PSB - FYM mixture@ 10 g per pit (20 g PSB per kg of FYM) were applied to the treatment plots.

Observations on growth attributes viz., height of plant, number of branches per plant, root mass and root volume were recorded at 30, 45 and 60 DAS. Root mass of three randomly selected plants were separated, washed with clean water and dried to a constant weight (at 65°C for ten hours in a hot air oven). The mean value was calculated and expressed as root mass in g per plant. Root volume was measured by the water displacement method (Mishra and Ahmed, 1990). The number of effective nodules at 30 and 45 DAS and AMF root colonization per cent at 45 and 60 DAS were also recorded.AMF root colonization per cent was estimated as per the procedure suggested by Philips and Hayman (1970).Cowpea yield and yield contributing attributes were recorded at harvest and the grain yield expressed as kg $ha^{-1}$. Crop nutrient uptake (at harvest) was worked out as the product of nutrient content (%) and dry matter production (kg $ha^{-1}$) and expressed as kg $ha^{-1}$. The standard analytical procedures given by Jackson, (1973) was adopted for analysing nutrient content (%).Micro kjeldahl distillation after digestion using $H_2SO_4$was used for estimating N content. Vanado-molybdo phosphoric yellow colour method using

Table 1. Effect of varieties and phosphorus management on nutrient uptake by cowpea

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|
| | N | P | K |
| Varieties (v) | | | |
| $v_1$: Kanakamony | 81.39 | 12.29 | 52.96 |
| $v_2$: PGCP-6 | 99.17 | 13.69 | 60.30 |
| $v_3$: DC-15 | 97.22 | 13.64 | 61.46 |
| SEm (±) | 2.70 | 0.35 | 2.03 |
| CD (0.05) | 7.814 | 0.999 | 5.881 |
| Phosphorus management (p) | | | |
| $p_1$: KAU POP | 87.46 | 12.01 | 55.06 |
| $p_2$: 75% P + AMF | 91.54 | 13.15 | 56.53 |
| $p_3$: 75% P + PSB | 85.70 | 11.35 | 53.92 |
| $p_4$: 75% P + AMF + PSB | 98.10 | 14.90 | 62.02 |
| $p_5$: 50% P + AMF + PSB | 100.16 | 14.63 | 63.67 |
| SEm (±) | 3.48 | 0.45 | 2.62 |
| CD (0.05) | 10.088 | 1.29 | 7.592 |

spectrophotometer after digestion using nitric-perchloric acid (9:4) was used for estimating P content. Flame photometry method after digestion using nitric-perchloric acid (9:4) was used for estimating K content.The data were statistically analysed and critical difference (at 5 per cent probability level) between treatment means were compared as recommended by Panse and Sukhatme (1985).

Varieties and P management exhibited a significant influence on the crop uptake of N, P, K by cowpea as detailed in Table 1. Among varieties, $v_2$ (PGCP-6) recorded higher N and P uptake and was comparable with variety $v_3$ (DC-15). Higher K uptake was recorded with $v_3$ (DC-15) comparable to $v_2$ (PGCP-6). This can be substantiated on the basis of improved growth and higher yield potential exhibited by the varieties. Similar findings for nutrient uptake were made earlier by Magani and Kuchinda (2009) and Bhagat et al. (2018) in cowpea.

Higher N and K uptake were recorded with treatment $p_5$ (50% RDP + AMF + PSB) and was comparable with $p_4$ (75% RDP + AMF + PSB) and $p_2$ (75% RDP + AMF). The treatment $p_4$recorded higher P uptake of 14.90 kg ha$^{-1}$and was comparable with $p_5$ (14.63 kg ha$^{-1}$). The treatments with AMF and PSB recorded higher nutrient uptake (Table 1) and it could be attributed to the mutually beneficial and synergetic action of AMF and PSB. Pramanik and Bera (2012) reported such mutually beneficial synergistic effect.

The root area is extended by the growth of mycorrhizal hyphae thereby enhancing crop absorption of plant nutrients. Organic phosphate compounds are mineralised and insoluble inorganic P compounds in the rhizosphere are solubilised by PSB (using organic acids they produce). These could make available more P to plants (Etesami, 2020). Fixation of phosphate ions added throughP fertilizers was also prevented by the action of PSB.

Table 2. Effect of varieties and phosphorus management on plant height and number of branches per plant of cowpea

| Treatments | Plant height (cm) | | | Number of branches per plant | | |
|---|---|---|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| Varieties (v) | | | | | | |
| $v_1$: Kanakamony | 36.76 | 65.92 | 84.00 | 3.56 | 4.60 | 5.40 |
| $v_2$: PGCP-6 | 42.30 | 73.29 | 89.57 | 4.42 | 5.94 | 7.44 |
| $v_3$: DC-15 | 40.01 | 68.72 | 87.27 | 3.66 | 5.03 | 6.31 |
| SEm (±) | 1.64 | 1.87 | 1.30 | 0.17 | 0.03 | 0.21 |
| CD (0.05) | NS | 5.403 | 3.758 | 0.496 | 0.098 | 0.619 |
| Phosphorus management (p) | | | | | | |
| $p_1$: KAU POP | 39.48 | 65.60 | 84.66 | 3.91 | 5.03 | 5.82 |
| $p_2$: 75% P + AMF | 41.04 | 70.08 | 87.68 | 3.78 | 5.18 | 6.48 |
| $p_3$: 75% P + PSB | 37.71 | 64.53 | 82.79 | 3.89 | 5.02 | 5.74 |
| $p_4$: 75% P + AMF + PSB | 41.68 | 74.28 | 90.56 | 4.02 | 5.39 | 7.19 |
| $p_5$: 50% P + AMF + PSB | 38.53 | 72.07 | 89.03 | 3.80 | 5.33 | 6.68 |
| SEm (±) | 2.11 | 2.41 | 1.68 | .22 | 0.04 | 0.28 |
| CD (0.05) | NS | 6.975 | 4.852 | NS | 0.127 | 0.799 |

Table 3. Interaction effect of varieties and phosphorus management on plant height and number of branches per plant of cowpea

| Interaction | Plant height (cm) | | | Number of branches per plant | | |
|---|---|---|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| $v_1p_1$ | 36.67 | 62.27 | 82.29 | 3.53 | 4.49 | 5.07 |
| $v_1p_2$ | 38.27 | 67.50 | 83.93 | 3.13 | 4.68 | 5.59 |
| $v_1p_3$ | 32.91 | 58.03 | 78.54 | 3.87 | 4.50 | 4.75 |
| $v_1p_4$ | 40.37 | 72.03 | 89.03 | 3.73 | 4.80 | 5.67 |
| $v_1p_5$ | 35.59 | 69.77 | 86.22 | 3.53 | 4.53 | 5.93 |
| $v_2p_1$ | 41.58 | 69.71 | 87.39 | 4.20 | 5.80 | 6.60 |
| $v_2p_2$ | 44.35 | 73.93 | 91.83 | 4.73 | 5.78 | 7.40 |
| $v_2p_3$ | 39.39 | 70.42 | 84.71 | 4.50 | 5.75 | 6.97 |
| $v_2p_4$ | 44.92 | 76.48 | 91.47 | 4.60 | 6.21 | 8.53 |
| $v_2p_5$ | 41.25 | 75.93 | 92.42 | 4.07 | 6.17 | 7.68 |
| $v_3p_1$ | 40.19 | 64.81 | 84.30 | 4.00 | 4.80 | 5.78 |
| $v_3p_2$ | 40.50 | 68.81 | 87.29 | 3.47 | 5.10 | 6.47 |
| $v_3p_3$ | 40.84 | 65.14 | 85.11 | 3.30 | 4.80 | 5.51 |
| $v_3p_4$ | 39.76 | 74.33 | 91.18 | 3.73 | 5.16 | 7.37 |
| $v_3p_5$ | 38.75 | 70.51 | 88.46 | 3.80 | 5.29 | 6.43 |
| SEm (±) | 3.66 | 4.17 | 2.90 | 0.38 | 0.08 | 0.48 |
| CD (0.05) | NS | NS | NS | NS | 0.22 | NS |

Table 4. Effect of varieties and phosphorus management on number of effective nodules per plant and AMF root colonization per cent of cowpea

| Treatments | Number of effective nodules | | AMF root colonization percent | |
|---|---|---|---|---|
| | 30 DAS | 45 DAS | 45 DAS | 60 DAS |
| Varieties (v) | | | | |
| $v_1$: Kanakamony | 12.89 | 21.07 | 57.78 | 48.89 |
| $v_2$: PGCP-6 | 15.29 | 29.59 | 57.56 | 51.33 |
| $v_3$: DC-15 | 14.49 | 28.50 | 57.78 | 51.78 |
| SEm (±) | 0.64 | 0.99 | 1.27 | 1.03 |
| CD (0.05) | 1.845 | 2.866 | NS | NS |
| Phosphorus management (p) | | | | |
| $p_1$: KAU POP | 10.22 | 21.49 | 17.04 | 8.89 |
| $p_2$: 75% P + AMF | 14.80 | 26.22 | 76.67 | 73.33 |
| $p_3$: 75% P + PSB | 12.58 | 25.35 | 19.63 | 10.74 |
| $p_4$: 75% P + AMF + PSB | 17.11 | 29.55 | 86.67 | 78.52 |
| $p_5$: 50% P + AMF + PSB | 16.41 | 29.32 | 88.52 | 81.85 |
| SEm (±) | 0.82 | 1.28 | 1.64 | 1.33 |
| CD (0.05) | 2.382 | 3.7 | 4.742 | 3.86 |

The combined application of AMFand PSB, enhances the acquisition of P by the host plant through their mutually beneficial interactions (Sharma et al., 2013). AMF hyphal growth is got promoted by PSB by providing inorganic P through mineralization and stimulating root colonization. Carbon released by AMF is used by PSB for its growth and uses the extensive hyphal network of the AMF to explore more soil root zone volume containing insoluble P (Wang et al., 2016). These synergistic interactions between AMF and PSB increase the populations of both and also crop growth and nutrient uptake compared with their sole inoculation.

Higher N uptake can be explained with better root development (Table 5) and increased N fixation brought about through better nodulation (Table 4). The increase in K uptake can be attributed to increased soil volume explored by AMF for better absorption of K. These findings are well matched with the results of Ramana (2007) in French bean, Rathore et al. (2010) in black gram and Kalyani et al. (2020) in cowpea.

The height and number of branches of observational plants were recorded at 30, 45 and 60 DAS and are abridged in Tables 2 and 3. Among varieties, taller plants were recorded in PGCP-6 comparable to DC-15 at crop stages 45 and 60 DAS.Significantly highest number of branches per plant was observed in PGCP-6 at all crop growth stages. Kanakamony recorded shorter plants and the least number of branches per plant.Such differences in growth parameters viz., plant height and number of branches observed among varieties areattributed to

Table 5. Effect of varieties and phosphorus management on root mass and root volume per plant of cowpea

| Treatments | Root mass (g) | | | Root volume ($cm^3$) | | |
|---|---|---|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| Varieties (v) | | | | | | |
| $v_1$: Kanakamony | 3.94 | 5.01 | 6.56 | 13.24 | 20.01 | 23.77 |
| $v_2$: PGCP-6 | 4.12 | 6.02 | 7.88 | 14.34 | 23.32 | 25.47 |
| $v_3$: DC-15 | 3.73 | 5.47 | 7.43 | 12.77 | 21.35 | 25.67 |
| SEm (±) | 0.06 | 0.14 | 0.34 | 0.27 | 0.44 | 0.56 |
| CD (0.05) | 0.173 | 0.414 | 0.986 | 0.775 | 1.262 | 1.613 |
| Phosphorus management (p) | | | | | | |
| $p_1$: KAU POP | 3.78 | 5.01 | 6.18 | 13.51 | 19.79 | 22.52 |
| $p_2$: 75% P + AMF | 3.91 | 5.48 | 7.50 | 13.27 | 21.62 | 25.53 |
| $p_3$: 75% P + PSB | 4.01 | 5.27 | 6.40 | 13.15 | 21.00 | 22.73 |
| $p_4$: 75% P + AMF + PSB | 4.02 | 5.91 | 8.19 | 13.73 | 23.21 | 27.55 |
| $p_5$: 50% P + AMF + PSB | 3.92 | 5.83 | 8.18 | 13.58 | 22.17 | 26.50 |
| SEm (±) | 0.08 | 0.19 | 0.44 | 0.35 | 0.56 | 0.72 |
| CD (0.05) | NS | 0.535 | 1.273 | NS | 1.629 | 2.083 |

varietal character as reported by Karikari et al. (2015).

Several research reports provide data on the superiority of DC - 15 cowpea variety over Kanakamony with regard to better growth performance. Mathew (2003) reported that Kanakamony grown with KAU POP recommendation of nutrients produced an average plant height of 79.33 cm and 5.67 branches per plant at harvest.Pradeepa and Ganajaximath (2017) reported that DC-15 supplied with the recommended dose of fertilizers produced a higher plant height of 84.67 cm at harvest and 10.69 branches per plant at 60 DAS, in a study at UAS, Dharwad.

Among different levels of P management, the application of $p_4$ (75% RDP + AMF + PSB) recorded taller plants and higher number of branches per plant at 45 and 60 DAS and was comparable to $p_5$ (50% RDP + AMF + PSB) and $p_2$ (75% RDP + AMF). Shorter plants and leastcount of branches were recorded in $p_3$ (75% RDP + PSB). Increased crop height and more number of branches with the combined application of AMF and PSB obtained in $p_4$ and $p_5$ could be attributed to the improved root system in these treatments (Table 5), which in turn helped better nutrient assimilation for enhanced crop growth. According to Bouhraoua et al. (2015) and Bona et al. (2017), the synergistic effect of PSB and AMF resulted in increase in plant growth compared to separate inoculation of PSB and AMF.

Higher number of effective nodules were recorded with PGCP-6 and was comparable with DC-15 at 30 and 45 DAS (Table 4). This difference observed among the varieties could be attributed to the genetic difference in the varieties interacting with rhizobia in forming effective nodules. Binjola et al. (2014) observed higher number of nodules (14.41) per plant for variety PGCP-6 in a study conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Soumya (2014) reported that DC-15 managed with the recommended dose of fertilizers produced more nodules (13.03) per plant. Ayodele and Oso (2014), Karikari et al. (2015) and Augustine and Godfre (2019) reported varietal differences in nodules per plant in cowpea.

Among P management,higher number of effective nodules was recorded with $p_4$, comparable with $p_5$ and $p_2$ at 30 and 45 DAS (Table 4). Better nodulation could be attributed to favourable effects of combined application fertilizer P, AMF and PSB on root proliferation (Table 5) hence providing more root surface for rhizobial infection (Nadeem et al., 2017).

Varieties did not influence the percentage of AMF root colonization. Higher AMF root colonization per cent was observed in treatments $p_4$ and $p_5$ where in

Table 6. Effect of varieties and phosphorus management on yield and yield attributes of cowpea

| Treatments | No. of pods per plant | Average pod weight (g) | Grain yield per plant (g) | Grain yield (kg ha$^{-1}$) | Harvest index |
|---|---|---|---|---|---|
| Varieties (v) | | | | | |
| $v_1$: Kanakamony | 12.40 | 1.94 | 11.98 | 915 | 0.244 |
| $v_2$: PGCP-6 | 16.29 | 2.43 | 13.65 | 1111 | 0.269 |
| $v_3$: DC-15 | 13.63 | 2.15 | 13.43 | 1097 | 0.264 |
| SEm (±) | 0.44 | 0.08 | 0.09 | 5.6 | 0.002 |
| CD (0.05) | 1.275 | 0.241 | 0.261 | 16.279 | 0.006 |
| Phosphorus management (p) | | | | | |
| $p_1$: KAU POP | 12.83 | 1.94 | 12.49 | 896 | 0.230 |
| $p_2$: 75% P + AMF | 14.32 | 2.36 | 12.86 | 1079 | 0.266 |
| $p_3$: 75% P + PSB | 12.61 | 1.92 | 12.65 | 891 | 0.237 |
| $p_4$: 75% P + AMF + PSB | 15.72 | 2.61 | 13.71 | 1174 | 0.277 |
| $p_5$: 50% P + AMF + PSB | 15.06 | 2.05 | 13.39 | 1164 | 0.285 |
| SEm (±) | 0.57 | 0.11 | 0.12 | 7.2 | 0.003 |
| CD (0.05) | 1.646 | 0.311 | 0.337 | 21.016 | 0.008 |

combined application of P fertilizers and bioinoculants (AMF and PSB) was followed (Table 4). Stimulation of hyphal growth and root colonization of AMF can be done by PSB (Richardson et al., 2009). This synergistic action might have led to increased AMF root colonization in the treatments where combined application of AMF and PSB was followed instead of the application of AMF alone.

Significantly higher root mass and root volume were observed in PGCP-6 at 30 and 45 DAS. At 60 DAS, root mass was higher for PGCP-6 comparable to DC-15. Maximum root volume was recorded with DC-15 and was comparable with PGCP-6 at 60 DAS. Lowest root mass and root volume were recorded in Kanakamony (Table 5). The significant difference in the root parameters of cowpea varieties can be attributed to the genotypical difference among the varieties.

Root mass and root volume were higher for the treatment $p_4$ and were comparable with $p_5$ and $p_2$ at 45 and 60 DAS. Phosphorus management had no significant influence on root mass and volume at 30 DAS (Table 5). Gamalero et al. (2004) reported that co-inoculation of AMF and PSB exhibited a synergistic effect on root fresh weight.The symbiotic

Table 7. Interaction effect of varieties and phosphorus management on yield of cowpea

| Interaction | No. of pods per plant | Average pod weight (g) | Grain yield per plant (g) | Grain yield(kg ha$^{-1}$) | Harvest index |
|---|---|---|---|---|---|
| $v_1p_1$ | 11.72 | 1.72 | 11.61 | 778 | 0.212 |
| $v_1p_2$ | 12.48 | 2.05 | 11.85 | 971 | 0.256 |
| $v_1p_3$ | 11.41 | 1.63 | 12.25 | 777 | 0.221 |
| $v_1p_4$ | 13.76 | 2.27 | 12.67 | 1047 | 0.263 |
| $v_1p_5$ | 12.62 | 2.03 | 11.53 | 1000 | 0.268 |
| $v_2p_1$ | 14.17 | 2.37 | 13.19 | 969 | 0.242 |
| $v_2p_2$ | 16.90 | 2.48 | 13.23 | 1125 | 0.270 |
| $v_2p_3$ | 14.37 | 2.13 | 12.94 | 957 | 0.247 |
| $v_2p_4$ | 17.79 | 3.05 | 14.50 | 1254 | 0.288 |
| $v_2p_5$ | 18.21 | 2.13 | 14.36 | 1249 | 0.297 |
| $v_3p_1$ | 12.59 | 1.71 | 12.66 | 941 | 0.236 |
| $v_3p_2$ | 13.58 | 2.56 | 13.49 | 1142 | 0.272 |
| $v_3p_3$ | 12.05 | 1.99 | 12.75 | 940 | 0.243 |
| $v_3p_4$ | 15.61 | 2.52 | 13.95 | 1220 | 0.280 |
| $v_3p_5$ | 14.34 | 1.98 | 14.27 | 1243 | 0.291 |
| SEm (±) | 0.98 | 0.19 | 0.20 | 12.5 | 0.005 |
| CD (0.05) | NS | NS | 0.584 | 36.400 | NS |

action of AMF and PSB leads to enhancement in growth hormone production viz., auxins, cytokinins and gibberellins which caused proliferation of roots (Ramana, 2007).

No significant interaction effects of varieties and phosphorus management were recorded on growth parameters of the crop except for number of branches of cowpea plant observed at 45 DAS. The treatment $v_2p_4$ (6.21) recorded higher number of branches per plant and was comparable to $v_2p_5$ (6.17).

Yield attributes viz., number of pods per cowpea plant, average pod weight, grain yield per plant and harvest index and yield of cowpea revealed significant variation in response to varieties and P management as presented in Tables 6 and 7. Per plant pod count (16.29) and average pod weight (2.43) were significantly higher for PGCP-6. Higher grain yield per cowpea plant, total grain yield and harvest index were also recorded with PGCP-6 (13.65 g, 1111 kg $ha^{-1}$ and 0.269 respectively) however comparable to DC-15 (13.43 g, 1097 kg $ha^{-1}$ and 0.264 respectively). The variation in yield noticed among different varieties of cowpea could be well relatedwith the genotypic differences on efficient use of nutrients which could naturally result in yield differences. Augustine and Godfre (2019) also reported significant differences in yield and yield attributes among varieties. Lamani (2013) observed higher numbers of pods per plant (11.33) and grain yield (1100 kg $ha^{-1}$) for grain cowpea variety DC-15 grown with the recommended dose of fertilizers. Adarsh and John (2022) reported more cowpea pods per plant (22.8) and grain yield (1268.31 kg $ha^{-1}$) for variety PGCP-6 grown under KAU recommendation of nutrient management for grain cowpea.

Higher grain yield exhibited by variety PGCP-6 could be well related to higher plant height, branch count, root parameters etc as detailed in Tables 2, 3, 4 and 5 and the uptake of major plant nutrients (Table 1). The cumulative effect of improved yield attributes (Table 6) viz., pod count per plant, average weight of pods and the per plantgrain yield contributed to improved grain yield. Generally, the potential grain yield is considered as a varietal character.

Phosphorus management significantly impacted the yield and yield related parameters of cowpea. Treatment $p_4$ recorded higher pod count per cowpea plant (15.72), average weight of cowpea pod (2.61 g), per plant grain yield (13.71 g) and grain yield per ha (1174 kg $ha^{-1}$), comparable with $p_5$. Treatment $p_5$ recorded higher harvest index (0.285) comparable to $p_4$. Combined application of AMF and PSB could increase the yield parameters thereby increasing the yield of grain cowpea in the study. Improved root parameters (Table 5) along with effective nodulation (Table 4) helped in better nutrient uptake (Table 1) resulting in improved yield attributes and ultimately crop yield. These results are well supported by the research results documented by Ramana (2007) and Singh et al. (2015).

Significant interaction between varieties and phosphorus management was also observed with regard to cowpea yield. Higher grain yield ie., 14.50 g (per plant) and 1254 kg (per ha) were recorded in treatment combination $v_2p_4$ and this was comparable to $v_2p_5$, $v_3p_4$ and $v_3p_5$.

The experimental data suggest that variety PGCP-6 performed better in terms of growth. Application of AMF and PSB along withreduced doses of P i.e. 75 and 50 per cent of RDP, resulted in higher and comparable growth. Anyhow,the latter had an advantage of reduction of P fertilizer up to the tune of 50 per cent. Grain cowpea variety PGCP-6 managed with the application of 50 per cent RDP supplied with AMF@ 5 g per plantand PSB- FYM mixture @ 10 g per plant (20 g of PSB mixed with 1 kg of FYM) had the most favourable effects on growth and yield in the present study.

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