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Nutrient uptake and phosphorus use efficiency of cowpea as influenced by genotypes, phosphorus levels and liquid based PSB

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Abstract
A study was conducted to evaluate the response of cowpea genotypes (DC-15, GC-3 and KBC-9) to phosphorus levels (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) and liquid based PSB with respect to nutrient uptake and phosphorus use efficiency at MARS, University of Agricultural Sciences, Dharwad during *kharif* 2019 under rainfed condition. The results indicated that among the genotypes, the genotype DC-15 recorded significantly higher nitrogen (74.35 kg ha^{-1}), phosphorus (11.00 kg ha^{-1}), potassium uptake (48.57 kg ha^{-1}) and recovery efficiency (0.040 kg kg^{-1}) over other genotypes. Among the phosphorus levels, application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} recorded significantly higher nitrogen (71.55 kg ha^{-1}), phosphorus (11.32 kg ha^{-1}) and potassium (46.33 kg ha^{-1}) uptake over other levels. Whereas, application of 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher recovery efficiency (0.041 kg kg^{-1}) over other levels. Among the interactions, the genotype DC-15 with the application of 75 kg P_2O_5 ha^{-1}+ liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher nitrogen (83.60 kg ha^{-1}), phosphorus (12.02 kg ha^{-1}) and potassium (49.66 kg ha^{-1}) uptake over the control and other treatments. Further, genotype DC-15 with the application of 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher recovery efficiency (0.057 kg kg^{-1}) over the control and other treatments.

Keywords: Cowpea genotypes, phosphorus levels, liquid based PSB, phosphorus use efficiency

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is an important protein rich legume in the semi tropics which occupy the unique position in agriculture by virtue of their high protein content, inherent capability to fix atmospheric nitrogen in root nodules. Among the edaphic factors (soil physiochemical characteristics), phosphorus deficiency is the most limiting soil fertility factor for cowpea production. This occurs as a result of either inherent low levels of P in the soils or depletion of the nutrient through cultivation.

Phosphorus is among the most needed elements for crop production in most tropical soils, which tend to be phosphorus deficient. Phosphorus, although not required in large quantities, is critical to cowpea yield because of its multiple effects on plant nutrition. It plays a key role in many plant processes such as energy metabolism, nitrogen fixation, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation. It is critical to cowpea yield because it is reported to stimulate growth, initiate nodule formation as well as influence the efficiency of the *Rhizobium*-legume symbiosis (Nkaa *et al.*, 2014). Phosphorus application influences the contents of other nutrients in cowpea leaves and seed.

Compared to other major nutrients, phosphorus is the least mobile and available to plants, because a major portion of phosphorus in the form of soluble inorganic phosphate gets rapidly immobilized and thereby, it is unavailable, when applied as chemical fertilizers. Hence, the use of phosphorus solubilizing bacteria either in the form of carrier based or liquid based, can save the crop requirement of phosphatic fertilizer. Because, the quality standards of liquid based biofertilizers are good and stable for six months, they were considered as the best substitute for regaining soil health, enhancing crop yields and sustainable food production in the modern agriculture.

Cowpea being a leguminous crop responds more to phosphorus than nitrogen and potassium. This fact necessitates determining the adequate supply of phosphorus to cowpea based on field experimentation for realising the genetic yield potential of newly evolved varieties. Therefore, this study is intended to govern the response of cowpea genotypes to differential P and PSB applications so as to determine suitable recommendations.

Materials and Methods

The experiment was conducted during *kharif* 2019 under AICRP, MULLARP at MARS, Dharwad which comes under Northern Transition Zone (Zone 8) of Karnataka. The texture of the experimental soil was clay loam having pH of 7.85 and electrical conductivity of 0.32 dS m^{-1}. The soil was low in available nitrogen (232.5 kg ha^{-1}), medium in available phosphorus (22.6 kg ha^{-1}) and high in available potassium (381.9 kg ha^{-1}), respectively.

The experiment was laid out in two factorial RBD with single control design with twelve treatment combinations and replicated thrice. The first factor consists of three genotypes (DC-15, GC-3 and KBC-9) and second factor consists of four phosphorus levels (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) along with liquid based PSB @ 4ml kg^{-1} seeds and control (DCS-47-1+ RDF (25:50:25) N: P_2O_5: K_2O kg ha^{-1} + carrier based PSB @ 500g ha^{-1}). The spacing adopted was 45 cm × 10 cm. Phosphorus was applied through Single Super Phosphate (SSP) @ (0, 25, 50, 75 kg ha^{-1}) as per the treatment requirements at the time of sowing and other agronomic management practices were followed as per standard recommendation.

Phosphorus was determined by Olsen's method and potassium by extracting with neutral normal ammonium acetate solution by using flame photometer Jackson (1973) [4]. Nitrogen in plants was determined by micro Kjeldahl method Jackson (1973) [4]. Phosphorus use efficiency is worked out in terms of recovery efficiency using the formula of Fageria *et al*. (2011) [2] and expressed in kg kg^{-1}. The data recorded was analysed statistically following the procedure described by Gomez and Gomez (1984) [3]. The level of significance used in 'F' test was P=0.05 and critical difference values were calculated where the 'F' test was found significant.

Results and Discussion

Nutrient uptake

Nutrient uptake was found significant between the genotypes (Table 1). The genotype DC-15 recorded significantly higher nitrogen (74.35 kg ha^{-1}), phosphorus (11.00 kg ha^{-1}) and potassium uptake (48.57 kg ha^{-1}) over other genotypes and it was on par with the genotype KBC-9 (71.64 kg ha^{-1}) with respect to nitrogen uptake. Further, lower nitrogen (49.14 kg ha^{-1}), phosphorus (9.82 kg ha^{-1}) and potassium uptake (37.33 kg ha^{-1}) was recorded by the genotype GC-3. This might be due to their varietal differences in nutrient uptake. These results are in line with findings of Pradeepa (2014) [6] and Shilpa (2015) [7].

The uptake of nutrients by cowpea crop increased significantly with increase in the levels of phosphorus (Table 1). The application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} recorded significantly higher nitrogen (71.55 kg ha^{-1}), phosphorus (11.32 kg ha^{-1}) and potassium uptake (46.33 kg ha^{-1}) over other phosphorus levels. Whereas, lower nitrogen (59.09 kg ha^{-1}), phosphorus (9.46 kg ha^{-1}) and potassium uptake (41.81 kg ha^{-1}) was recorded with the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds. This might be due to better root growth which might have helped in more nutrient absorption and sufficient nutrient supply. Such higher values of nutrient uptake with increasing levels of phosphorus were reported by Singh and Singh (2017) [8]. Also, the application of phosphorus accelerates the uptake of nutrients (N, P and K) significantly and higher values were ascribed to vigorous root growth and higher dry matter production in green gram (Singh *et al*., 2018) [9].

Interactions were found significant in the nutrient uptake (Table 1). The genotype DC-15 with the application of 75 kg P_2O_5 ha^{-1}+ liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher nitrogen (83.60 kg ha^{-1}), phosphorus (12.02 kg ha^{-1}) and potassium uptake (49.66 kg ha^{-1}) over the control and other treatments. The percent increase of nitrogen, phosphorus and potassium uptake was 12.19%, 19.48% and 8.68%, respectively over the control. Further, lower nitrogen (47.18 kg ha^{-1}), phosphorus (9.20 kg ha^{-1}) and potassium uptake (32.78 kg ha^{-1}) was recorded by the genotype GC-3 with the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds. Better root growth with increased nutrient contents in the root zone attributed by *Rhizobium* and liquid based PSB might be the reason for extraction of available plant nutrients from soil depth and ultimately which improved the nutrient content in plant parts over carrier based PSB. Enhanced potassium uptake was due to the synergistic effect between nitrogen and phosphorus. Such positive effect of inoculation on nitrogen and phosphorus uptake by legume was reported by Kant *et al.* (2016) [5] in black gram and Singh *et al.* (2018) [9] in green gram.

Phosphorus use efficiency (Recovery efficiency)

Significant difference was noticed among the genotypes with respect to recovery efficiency (Table 1). The genotype DC-15 recorded significantly higher recovery efficiency (0.040 kg kg^{-1}) than the genotype GC-3 (0.016 kg kg^{-1}) and it was on par with the genotype KBC-9 (0.035 kg kg^{-1}).

Phosphorus levels showed significant variation with respect to recovery efficiency (Table 1). The application of 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher recovery efficiency (0.041 kg kg^{-1}) over the application of 50 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds (0.025 kg kg^{-1}) and 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds (0.025 kg kg^{-1}). Such significant values of higher recovery efficiency with the lower level of phosphorus was reported by Ahirwar *et al.* (2016) [1] in pigeonpea.

Recovery efficiency differed significantly among the interactions between the genotypes and phosphorus levels (Table 1). The genotype DC-15 with the application of 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher recovery efficiency (0.057 kg kg^{-1}) over the control and other treatments. It was on par with the genotype KBC-9 with the application of 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds (0.052 kg kg^{-1}). Further, lower recovery efficiency (0.014 kg kg^{-1}) was recorded by the GC-3 genotype with the application of 25 and 50 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds.

Table 1: Major nutrients uptake (kg ha^{-1}) and recovery efficiency of cowpea as influenced by genotypes, phosphorus levels and liquid based PSB

	Nitrogen uptake (kg ha^{-1})					Phosphorus uptake (kg ha^{-1})					Potassium uptake (kg ha^{-1})					Recovery efficiency (kg kg^{-1})			
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean	P_2	P_3	P_4	Mean
G_1	67.97	71.47	74.35	83.60	74.35	9.64	11.05	11.29	12.02	11.00	46.89	48.51	49.21	49.66	48.57	0.057	0.033	0.032	0.040
G_2	47.18	48.73	49.79	50.86	49.14	9.20	9.55	9.89	10.64	9.82	32.78	37.91	38.77	39.87	37.33	0.014	0.014	0.019	0.016
G_3	62.11	70.36	73.90	80.17	71.64	9.53	10.82	10.98	11.28	10.66	45.75	47.73	48.89	49.46	47.96	0.052	0.029	0.023	0.035
Mean	59.09	63.52	66.01	71.55		9.46	10.48	10.72	11.32		41.81	44.72	45.63	46.33		0.041	0.025	0.025	
Control	74.51					10.06					45.69								
	G	P	G×P	Control Vs Others		G	P	G×P	Control Vs Others		G	P	G × P	Control Vs Others		G	P		G × P
S.Em±	1.06	1.23	2.13	1.6		0.08	0.09	0.15	0.1		0.12	0.14	0.24	0.2		0.003	0.003		0.005
Cd (5%)	3.1	3.6	6.2	4.6		0.2	0.3	0.4	0.3		0.4	0.4	0.7	0.5		0.009	0.009		0.016

Factor 1: Genotypes (G)	Factor 2: Phosphorus levels (P)
G_1: DC-15	P_1: 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds
G_2: GC-3	P_2: 25 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds
G_3: KBC-9	P_3: 50 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds
	P_4: 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds

Control: DCS-47-1+ RDF (25:50:25 N: P_2O_5: K_2O kg ha^{-1}) + with carrier based PSB @ 500 g ha^{-1}

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