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Growth and yield response of cowpea genotypes to phosphorus levels and liquid-based phosphate-solubilizing bacteria

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Abstract

A field experiment was conducted conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2019 under rainfed condition. It comprised of 12 treatment combinations with three genotypes (DC-15, GC-3 and KBC-9) and 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}). Treatments were replicated thrice and laid out in two factorial RBD with single control design. Among the genotypes, the genotype DC-15 recorded significantly higher seed yield (1232 kg ha^{-1}) and growth parameters followed by the genotype KBC-9. The genotype GC-3 recorded lower seed yield. Whereas, the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher seed yield (1341 kg ha^{-1}) and growth parameters over other phosphorus levels. Among the treatment combinations, significantly higher growth parameters such as number of branches per plant (17.63), leaf area index (1.87) and dry matter production (44.11 g $plant^{-1}$) were recorded by the genotype DC-15 with the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds over the control and other treatments at harvest. Similar treatment recorded significantly higher yield related parameters such as number of pods per plant (15.47), seed weight per plant (21.54 g $plant^{-1}$) and seed yield (1464 kg ha^{-1}) over the control and other treatments.

Keywords: Cowpea genotypes, phosphorus levels, liquid based PSB, seed yield

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is grown extensively in semi-arid and arid tropics as a multipurpose grain legume during *kharif*, late *kharif* and summer. It has been originated from Central Africa and mainly cultivated in Asia, Africa, Central and South America. The area under cowpea is estimated to be over 14.5 million hectares world-wide, with 7.4 million tonnes of production. In India, it is cultivated in 5.3 million hectares area with 3.03 million tonnes production with the national productivity of 527 kg ha^{-1}. In Karnataka, cowpea is cultivated in area of 3.14 lakh hectare with a production of 1.42 lakh tonnes and productivity of 487 kg ha^{-1} (Anon, 2018). It is either used as grain, green pods as vegetables or fodder or green manuring. It is also grown as inter crop, catch crop, mixed crop and mulch crop.

Cowpea is called ''Vegetable meat'' due to its high protein content with better biological value, bears green tender pods containing protein (4.3 g), carbohydrate (8.0 g), fats (0.6 g) and fiber (2 g) per 100g of edible portion. Amino acids particularly leucine, lysine and phenylalanine contents are comparatively high in cowpea. Tender fruits contain calcium (80 mg), phosphorus (74 mg) and iron (2.5 mg) per 100 g fresh weight (Gopalakrishnan, 2007) [5].

Phosphorus is an essential element for pulse production, as it promotes root formation due to increased cell division, nodule count and in turn the crop yield. It plays a vital role in oxidation-reduction, cellular energy transfer reactions, photosynthesis, respiration and influences the efficiency of the *Rhizobium*-legume symbiosis. Phosphorus is also required in large quantities in young cells such as shoot and root tips where metabolism is high and cell division is rapid and aids in flower initiation, seed and fruit development.

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, there is a necessity to minimize phosphorus loss from the soil for better crop production. Microbial enzymatic activity is essential for the mineralization of left-over organic phosphorus in the soil. When phosphorus solubilizing bacteria is used either in the form of carrier based or liquid based, it can save the crop requirement of phosphatic fertilizer.

Liquid biofertilizer formulation is the most promising and updated technology of conventional carrier-based production technology encourages early root development, rapid cell development, produce organic acids like malic, succinic, fumaric, citric, tartaric and alpha keto glutaric acid which increases phosphorus uptake, availability of other micro nutrients as well as total yield.

Genotypic differences by which they exhibit differential ability to grow at low or high phosphorus conditions and different forms of PSB may help in increasing fertilizer use efficiency. Therefore, this study is intended to govern the response of cowpea genotypes to differential phosphorus and PSB applications.

Materials and Methods

The experiment was conducted during *kharif* 2019 under AICRP, MULLARP at MARS, Dharwad which is situated at 15°26' N latitude and 75°01' E longitude at an altitude of 678 m above mean sea level, comes under Northern Transition Zone (Zone 8) of Karnataka which lies between the Western Hilly Zone (Zone 9) and Northern Dry Zone (Zone 3). The experimental site was located in plot no. 148 of 'F' block, MARS, Dharwad.

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 in two factorial RBD with single control design with twelve treatment combinations. Wherein, 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}). Treatments were replicated thrice.

The seeds were treated with *Rhizobium* @ 200 g ha^{-1} (carrier based) and liquid PSB @ 4ml kg^{-1} seed. In control, seeds were treated with carrier based PSB @ 500 g ha^{-1} and *Rhizobium* @ 200 g ha^{-1}. The spacing adopted was 45 cm × 10 cm. Nitrogen was applied through urea @ 25 kg ha^{-1} along with potassium as Murate of Potash (MOP) @ 25 kg ha^{-1} uniformly to all the treatments. 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. Five plants were randomly selected in net plot area to take growth and yield observations such as the total number of branches per plant, leaf area index, dry matter, number of pods per plant, seed weight per plant and seed yield at harvest. The data recorded from the experiment was analyzed statistically following the procedure described by Gomez and Gomez (1984). 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

Growth and yield of cowpea as influenced by genotypes

The DC-15 genotype recorded significantly higher number of branches per plant, leaf area index and dry matter production per plant (15.04, 1.72 and 41.35 g $plant^{-1}$, respectively) than the genotype GC-3 (12.05, 1.54 and 36.64 g $plant^{-1}$, respectively). Further, it was on par with the genotype KBC-9 with respect to number of branches per plant (14.58) and dry matter production per plant (17.88 g $plant^{-1}$) at harvest (Table 1). The plants of various varieties respond differently to environmental factors based on their genetic makeup and their adaption capability. These findings were in agreement with Agbogidi and Egho (2012) [1].

The differences in dry matter production and its accumulation in different plant parts was mainly because of various physiological factors during crop growth and the photosynthetic ability of plant depends upon leaf area and leaf area index. At harvest, the genotype DC-15 recorded significantly higher leaf area index over other genotypes owing to higher dry matter production due to higher photosynthesis area. This indicates that the genotype DC-15 produced more dry matter weight as compared to others. The results were in conformity with earlier findings of Malagi (2005) [11], Prabhamani (2014) [15] and Shilpa (2015) [17].

Genotypes play a significant role in crop production and the probable yield of a genotype is determined by its genetic makeup and prevailing environmental conditions. The genotype DC-15 recorded significantly higher seed yield (1232 kg ha^{-1}) than the genotype GC-3 (1004 kg ha^{-1}) and it was on par with the genotype KBC-9 (1187 kg ha^{-1}). The percent increase in seed yield was 22.71% over GC-3 (Table 2). Such significant differences in genotypes with respect to seed yield have been reported by Malagi (2005) [11], Kumar *et al.* (2013) [9], Prabhamani (2014) [15] and Pradeepa (2014) [16].

Seed yield is governed by number of factors which have direct or indirect impacts. The factors directly responsible for high seed yield are the number of pods per plant, number of seeds per pod, test weight, seed weight per plant and harvest index. (Jakusko *et al.*, 2013) [7]. Higher seed yield of the DC-15 genotype was due to higher yield components *viz.*, number of pods per plant and seed weight per plant (13.18 and 19.20 g $plant^{-1}$, respectively) over other genotypes KBC-9 (12.83 and 18.67 g $plant^{-1}$, respectively) and GC-3 (8.34 and 15.37 g $plant^{-1}$, respectively). This improvement was mainly due to significantly higher photosynthetic efficiency, which might have led to formation of higher number of pods per plant and number of seeds per pod. Thus, due to integration of major favourable yield components, the genotype DC-15 produced higher seed yield compared to other genotypes. Similar results were also reported by Prabhamani (2014) [15] and Shilpa and Wali (2018) [18].

Growth and yield of cowpea as influenced by phosphorus levels

Phosphorus aids in rapid and healthy root development in the leguminous crops. It increases the rate of nodulation, pod development and hastens the maturity. Phosphorus helps in storage and transfer of energy necessary for metabolic processes thereby enhancing plant growth and biological yield (Singh *et al.*, 2014) [20]. The response of cowpea to applied phosphorus varies considerably depending upon the phosphorus status of soil and their genetic mechanisms.

The application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher number of branches per plant, leaf area index and total dry matter production (15.98, 1.85 and 42.52 g $plant^{-1}$, respectively) over other phosphorus levels (Table 1). Whereas, the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded lower number of branches per plant, leaf area index and total dry matter production (12.01, 1.40 and 35.39 g $plant^{-1}$, respectively) at harvest.

Increase in dry matter accumulation might be attributed to significant increase in growth parameters *viz.*, leaf area index and number of branches with increase in phosphorus levels. This might be due to phosphorus role in cell division and enlargement (Kumar *et al.*, 2016) [10] and further, at higher phosphorus level the plant fixed more atmospheric nitrogen and supplied to the crop, there by enhanced the growth. Pandey *et al.* (2016) [14] in lentil reported the similar findings.

Phosphorus aids in transferring photosynthates from the stalks, leaves and other growing parts to the economically important organs like seeds. The application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher number of pods per plant, seed weight per plant and seed yield (13.39, 20.24 g $plant^{-1}$ and 1341 kg ha^{-1}) over other phosphorus levels (Table 2). Whereas, the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded lower number of pods per plant, seed weight per plant and seed yield (8.52, 14.19 g $plant^{-1}$ and 913 kg ha^{-1}).

Such similar trend of increasing yield with increasing phosphorus levels was reported by Maqsood *et al.* (2000) in lentil. The percent increase in yield was 46.87% over 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4 ml kg^{-1} seeds. This may be attributed to the increased rate of photosynthesis leading to better translocation of nutrients to sink. These findings were in conformity with Singh and Singh (2017) [21], Sudharani *et al.* (2018) [26] and Singh *et al.* (2018) [22, 24] in Rajmash.

The increase in yield attributes due to phosphorus application might be attributed to the utilization of large quantities of nutrients through well-developed root system, nodulation and its role in seed formation and grain filling (Nkaa *et al.*, 2014) which might have resulted in better plant development and ultimately higher yield in cowpea. Similar results of increase in yield contributing characters with increasing levels of phosphorus were reported by Medhi *et al.* (2014) [12] in greengram, Singh and Singh (2017) [21] and Singh *et al.* (2018) [22, 24] in chickpea.

Growth and yield of cowpea as influenced by interactions of genotypes, phosphorus levels and liquid based PSB

Increase in growth parameters attributed higher dry matter production which were significantly influenced by the cowpea genotypes to various phosphorus levels with liquid based PSB. The genotype DC-15 with the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher number of branches per plant, leaf area index and total dry matter production (17.63, 1.87 and 44.11 g $plant^{-1}$ respectively) over the control and other treatments (Table 1). Whereas, the genotype GC-3 with the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded lower number of branches per plant, leaf area index and total dry matter production (11.00, 1.20 and 35.39 g $plant^{-1}$ respectively).

Increase in various growth parameters of cowpea genotypes to applied phosphorus levels with liquid based PSB inoculation might be due to the phosphorus which regulates cell multiplication and elongation. Whereas, PSB plays an important role in production of growth-promoting hormones, improved solubilization of phosphorus there by nutrient availability to plant for various metabolic process and photosynthetic rates leading to better growth. These results were in similar line with Kant *et al.* (2016) [8] in blackgram, Sodge *et al.* (2016) [25], Heisnam *et al.* (2017) [6] and Singh *et al.* (2018) [22, 24] in green gram.

Phosphatic fertilizer levels along with the seed inoculation of *Rhizobium* and liquid based PSB exerted significant effect on yield and yield attributing parameters of cowpea genotypes. The genotype DC-15 with the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher number of pods per plant, seed weight per plant and seed yield (15.47, 21.54 g $plant^{-1}$ and 1464 kg ha^{-1}, respectively) over the control and other treatments (Table 2). It was on par with the genotype KBC-9 with the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds (15.15, 21.33 g $plant^{-1}$ and 1399 kg ha^{-1}, respectively). Further, lower number of pods per plant, seed weight per plant and seed yield (6.16, 12.81 g $plant^{-}1$ and 893 kg ha^{-1}, respectively) were recorded by the genotype GC-3 with the application of 0 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds. The percent increase of grain yield was 19.02% over the control. The grain and haulm yield of the crop increased significantly, when inoculation was supplemented with phosphorus due to the synergistic effect of *Rhizobium* and PSB inoculation. Results were in similar line with Sodge *et al.* (2016) [25], Kant *et al.* (2016) [8] in blackgram, Singh *et al.* (2018) [22, 24] in green gram.

Further, the combined inoculation of seeds (PSB and *Rhizobium*) along with the phosphatic fertilizer treatment increased supply of nutrients to crop, where *Rhizobium* fix the atmospheric nitrogen and PSB solubilize the phosphorus providing favourable balanced nutrition leading to increase in yield attributing characters. These results were in conformity with Sodge *et al.* (2016) [25] and Heisnam *et al.* (2017) [6].

Among the carrier based and liquid based PSB, seed inoculation with liquid based PSB reported significant increase of plant growth and yield parameters. This might be due to more efficiency of liquid biofertilizer and better uptake and translocation of nutrients to plant growing parts. Similar results were reported by Shravani (2018) [19] in greengram.

Table 1: Number of branches per plant, leaf area index and dry matter production (g plant^{-1}) of cowpea at harvest as influenced by genotypes, phosphorus levels and liquid based PSB

	Number of branches per plant					leaf area index					Total dry matter production				
	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**
G_1	12.93	14.00	15.60	17.63	15.04	1.53	1.68	1.80	1.87	1.72	37.71	40.39	43.18	44.11	41.35
G_2	11.00	11.53	12.47	13.20	12.05	1.20	1.38	1.74	1.83	1.54	32.05	35.65	38.83	40.03	36.64
G_3	12.10	13.73	15.40	17.10	14.58	1.48	1.50	1.56	1.84	1.60	36.39	37.60	39.21	43.43	39.16
MEAN	12.01	13.09	14.49	15.98		1.40	1.52	1.70	1.85		35.39	37.88	40.41	42.52	
Control	12.53					1.63					42.92				
	G	P	G × P	Control Vs Others		G	P	G × P	Control Vs Others		G	P	G × P	Control Vs Others	
S.Em ±	0.16	0.18	0.31	0.2		0.004	0.005	0.008	0.006		0.30	0.34	0.60	0.44	
CD (5%)	0.5	0.5	0.9	0.7		0.012	0.014	0.024	0.018		0.9	1.0	1.7	1.3	

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}	

Table 2: Number of pods plant^{-1}, Seed weight plant^{-1} (g plant^{-1}) and seed yield (kg ha^{-1}) in cowpea as influenced by genotypes, phosphorus levels and liquid based PSB

	Number of pods plant^{-1}					Seed weight plant^{-1} (g plant^{-1})					Seed yield (kg ha^{-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**
G_1	10.11	13.09	14.04	15.47	13.18	15.30	19.70	20.27	21.54	19.20	936	1208	1319	1464	1232
G_2	6.16	8.28	9.39	9.54	8.34	12.81	14.39	16.41	17.84	15.37	893	976	1007	1161	1004
G_3	9.30	12.92	13.94	15.15	12.83	14.47	18.98	19.87	21.33	18.67	909	1139	1302	1399	1187
MEAN	8.52	11.43	12.46	13.39		14.19	17.69	18.85	20.24		913	1108	1209	1341	
Control	13.24					17.77					1230				
	G	P	G × P	Control Vs Others		G	P	G × P	Control Vs Others		G	P	G × P	Control Vs Others	
S.Em ±	0.12	0.14	0.24	0.2		0.22	0.25	0.43	0.32		20	23	41	30	
CD (5%)	0.3	0.4	0.7	0.5		0.6	0.7	1.26	0.9		59	69	119	87	

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}	

Conclusion

Among the three genotypes, the genotype DC-15 can be recommended over other tested genotypes for its cultivation in Northern Transitional Zone (Zone-8) of Karnataka during *kharif* season due to its determinate growth habit along with high seed yielding ability (1232 kg ha^{-1}). Whereas, among the phosphorous levels, the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds recorded significantly higher yield (1341 kg ha^{-1}) and better growth parameters over other phosphorus levels. Therefore, the application of 75 kg P_2O_5 ha^{-1} + liquid PSB @ 4ml kg^{-1} seeds to the genotype DC-15 is optimum to get higher yield (1464 kg ha^{-1}) and better growth parameters.

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