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Research Paper

Effect of basal and foliar application of diammonium phosphate in cognizance with phosphate-solubilizing bacteria on growth, yield and quality of rainfed chickpea (*Cicer arietinum*)

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ABSTRACT

A rainfed experiment was conducted during the winter (*rabi*) seasons of 2011–12 and 2012–13 at Kumarganj, Faizabad, Uttar Pradesh to study the effect of diammonium phosphate (DAP) applied through soil and foliage in conjunction with phosphate-solubilizing bacteria (PSB) on growth characters, yield attributes and yield, seed protein content, nutrient uptake and phosphorus-use efficiency (PUE) of chickpea (*Cicer arietinum* L.). The application of 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits 45 and 60 days after sowing + PSB significantly increased the growth attributes (plant height, primary branches/plant, leaf area/plant, number and dry weight of nodules/plant, root and shoot dry weight/plant, root: shoot ratio), yield attributes and yield (pods/plant, 1,000-seed weight, seed yield, biological yield), seed protein content, N and P uptake and PUE of chickpea. However, seeds/pod and harvest index were not affected significantly due to the application of DAP in cognizance with PSB. Thus, split application of 100 kg DAP/ha (½ through soil + ½ through foliage in 2 splits at 45 and 60 DAS) in conjunction with PSB proved effective in enhancing growth, yield (1,486 kg/ha; 102% increase over the control) and quality of chickpea grown under rainfed conditions.

Key words **:** Basal, Chickpea, DAP, Foliar, PSB, Quality, Yield

Chickpea is the world's third most important food legume with 96% cultivation in the developing countries. It is one of the most important winter (*rabi*) pulses of India, grown on 8.3 million ha area, with a production of 7.7 million tonnes registering the productivity of 928 kg/ha (CACP, 2012). Phosphorus fertilization to legumes is more important than that of nitrogen. The cultivation of pulses without phosphatic fertilizer is one of the important factors responsible for their low productivity. Phosphorus nutrition in legumes simulates a greater attention in increasing the productivity , as it encourages healthy root growth and promotes rhizobial activity resulting in increased nodulation that exemplify nitrogen fixation (Gaur, 1990). Phosphorus is an essential nutrient for grain legumes, as it helps in improving nodulation (Abidi *et al.*, 2001), seed yield (Varughese and Pathak, 1987) and seed protein content (Guhey *et al.*, 2000) of chickpea. In most of the areas, basal application of 15–20 kg N/ha as starter dose and 20–40 kg P_2O_5/ha was most economical in chickpea, and foliar nutrition has also proved effective in rainfed areas (Ali *et al.*, 2012). The nitrogen to phosphate ratio in diammonium phosphate (DAP) makes it an excellent product, for direct basal application and DAP is typically 90% water-soluble which also makes it suitable for foliar application. Efficiency of soil-applied phosphatic fertilizers throughout the world is around 10–25%, as these are converted readily to less available forms by the process of phosphorus fixation. Phosphate-solubilizing bacteria (PSB) play an important role in enhancing phosphorus availability to plants by lowering soil pH and by microbial production of organic acids and mineralization of organic phosphorus by acid phosphatises, which infers that PSB inoculants hold great prospects for sustaining crop production with optimized phosphorus fertilization. Thus, adopting proper nutrient-management practices in conjunction with PSB will help improve the yield and quality of chickpea besides maintaining the soil fertility. Since data are lacking regarding combined effect of DAP application (basal + foliar) and PSB inoculation on chickpea, a field experiment was conducted to study the effect of DAP applied through soil and foliage in cogni-

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zance with PSB on growth, yield and quality of chickpea under rainfed conditions.

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Research Farm of the Narendra Deva University of Agriculture and Technology, Faizabad (26.32°N and 82.12°E) during the winter (*rabi*) seasons of 2011–12 and 2012–13. The soil was silt loam and alkaline (pH 8.7). It was low in organic carbon (0.36%) and available nitrogen (172.9 kg/ha) and medium in available phosphorus (13.5 kg/ha) and potassium (261.0 kg/ha). Twelve treatments (T_1, control; T_2, 100 kg DAP/ha as basal; T_3, 100 kg DAP/ha as basal + PSB; T_4, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 days after sowing (DAS); T_5, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS + PSB; T_6, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS; T_7, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS + PSB; T_8, 25 kg DAP/ha as basal + 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS; T_9, 25 kg DAP/ha as foliar at 45 DAS; T_{10}, 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS; T_{11}, 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS; T_{12}, 100 kg DAP/ha as foliar in 4 splits at 45, 60, 75 and 90 DAS) were replicated thrice in randomized block design with plot size of 4.5 × 5.0 m.

Chickpea cultivar 'Pusa 362' (*desi*) was sown in rows, 45 cm apart, with seed rate of 100 kg/ha on residual soil moisture of the rainy (*kharif*) season on 10 October 2011 and 1 October 2012. The crop was fertilized as per treatments where basal dose of DAP was drilled in the furrows 5 cm below the seed and foliar dose of DAP was sprayed @ 2.5% (25 kg DAP dissolved in 1,000 litres water) and PSB (containing 1×10^8 CFU/ml of PSB) was inoculated with seed @ 1.25 l/ha one hour prior to sowing and then dried in shade. The crop was grown under rainfed conditions and harvested on 15 March 2012 and 18 March 2013. The rainfall received during growing period (October–March) of crop was 86 mm (2 years mean) [32 mm in January; 52 mm in February; 2 mm in March). The number of primary branches/plant, leaf area/plant and number and dry weight of nodules/plant were recorded at 90 days after sowing (DAS). At maturity, data on plant height, root and shoot dry weight/plant, pods/plant, seeds/pod, 1,000-seed weight, seed yield and biological yield were recorded, and plant samples collected at harvesting time were analysed for N and P content in seed and straw. The data collected on growth, yield and quality parameters of chickpea were statistically analysed as per analysis of variance procedure outlined for randomized block design (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth attributes

Growth-contributing characters, viz. plant height, primary branches/plant and leaf area/plant, were maximum with the split application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) in conjunction with PSB (Table 1). The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB, being at par with 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, 100 kg DAP/ha (¼ as basal + ¾ as foliar in 3 splits at 45, 60 and 75 DAS), 100 kg DAP/ha as foliar in 4 splits at 45, 60, 75 and 90 DAS, 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS), resulted in significantly superior plant height to rest of the treatments. The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB being at par with 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB also recorded significantly more number of primary branches/plant and higher leaf area/plant than the remaining treatments. The increase in plant height and leaf area of chickpea may be owing to the improvement in vigour of the plants possibly by balanced supply and higher uptake of N and P. The foliar-fed nutrients are possibly efficiently absorbed by the plant leading to the differentiation into more number of branches/plant. Dwivedi and Tiwari (1991) also reported improvement in plant growth with the application of 100 kg DAP/ha as basal and 2% spray of triple superphosphate in chickpea. The application of 100 kg DAP/ha (½ through soil + ½ through foliage in 2 splits at 45 and 60 DAS) + PSB, being at par with 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, 100 kg DAP/ha as basal + PSB, 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS), significantly improved the number and dry weight of nodules/plant over rest of the treatments. With regard to root and shoot dry weight/plant, 100 kg DAP/ha (½ through soil + ½ through foliage in 2 splits at 45 and 60 DAS) + PSB was significantly superior to rest of the treatments. However, 100 kg DAP/ha (½ through soil + ½ through foliage in 2 splits at 45 and 60 DAS) + PSB, being at par with 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), significantly reduced the root: shoot ratio as compared to remaining treatments. Abidi *et al.* (2001) also reported that phosphorus is an essential nutrient for grain legumes, as it helps in improving nodulation and N-fixation (Gaur, 1990) as well as enhancing nodule dry biomass (Singh *et al.*, 2010). Growth promotional activities of PSB through production of growth-promoting substances and proliferation of beneficial organisms in the rhizosphere might have also improved the dry weight of nodules (Gupta, 2006). Pathak *et al.* (1985) also reported increased plant dry weight with the application of 100 kg DAP/ha (½ soil + ½ foliar) over 100 kg DAP/ha as basal in chickpea.

Yield attributes and yield

The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB, being at par with 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, recorded significantly more pods/plant and higher 1,000-seed weight over rest of the treatments (Table 2). However, seeds/pod were not affected significantly by the application of DAP in cognizance with PSB. Pathak *et al.* (1985) also reported more pods/plant with DAP at 100 kg/ha (½ soil + ½ foliar) than DAP at 100 kg/ha as basal in chickpea. The chickpea gave significantly higher seed and biological yield with the application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB over rest of the treatments. The effect of DAP application in cognizance with PSB on harvest index was found non-significant. The increase in seed yield can be attributed to the effective metabolic activities coupled with increased rate of photosynthesis, leading to better translocation of nutrients and expression of developmental characters. Due to the split application of DAP (½ through soil + ½ through foliage in 2 splits) in conjunction with PSB, the plant could have accumulated the needed quantity of N and P and thus might have influenced positively on performance of the crop. The foliar application of DAP twice met out N and P requirement at the critical stages of the crop due to ensured and prompt delivery of mineral nutrients to the site of photosynthesis. Further, nutrients applied through foliage would be easily available and translocated in the plants without any loss (Srinivasan and Ramaswamy, 1992). Varughese and Pathak (1987) also found higher productivity of chickpea when DAP was applied ½ as basal and ½ as foliar both. The PSB might have also played an important role in enhancement of crop yields by providing more phosphorous to plants, which is otherwise unavailable to plants (Gyaneshwar *et al.*, 2002). Velayutham *et al.* (2003) also reported increased

Table 1. Plant height (cm), primary branches/plant, leaf area/plant (cm^2), nodules/plant, nodule dry weight/plant (mg), root dry weight/plant (g), shoot dry weight/plant (g) and root: shoot ratio of chickpea as affected by basal and foliar application of diammonium phosphate (DAP) in conjunction with phosphate solubilising bacteria (PSB) (pooled data of 2 seasons)

Treatment	Plant height	Primary branches/ plant	Leaf area/ plant	Nodules/ plant	Nodule dry weight/ plant	Root dry weight/ plant	Shoot dry weight/ plant	Root: shoot ratio
T_1, Control	43.7	3.9	494.0	14.2	151	0.91	12.98	0.071
T_2, 100 kg DAP/ha as basal	48.5	4.3	552.6	19.0	207	0.95	16.85	0.057
T_3, 100 kg DAP/ha as basal + PSB	49.7	4.4	583.5	20.1	224	0.97	18.50	0.053
T_4, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS	50.4	4.5	586.5	19.3	210	0.97	18.76	0.053
T_5, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS + PSB	51.3	4.7	617.5	20.3	226	0.99	20.47	0.049
T_6, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS	51.9	4.9	615.2	19.6	214	0.99	20.48	0.049
T_7, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS + PSB	53.0	5.0	644.1	20.7	230	1.02	22.32	0.047
T_8, 25 kg DAP/ha as basal + 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS	51.3	4.5	585.9	18.8	203	0.96	18.45	0.053
T_9, 25 kg DAP/ha as foliar at 45 DAS	45.7	4.0	524.2	15.7	166	0.93	15.08	0.063
T_{10}, 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS	47.6	4.3	549.7	17.0	181	0.94	16.54	0.058
T_{11}, 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS	49.6	4.5	572.4	18.3	194	0.95	17.94	0.054
T_{12}, 100 kg DAP/ha as foliar in 4 splits at 45, 60, 75 and 90 DAS	51.2	4.5	573.8	18.4	194	0.96	18.87	0.052
SEm±	1.0	0.1	11.8	0.5	7	0.01	0.51	0.002
CD (P=0.05)	3.0	0.4	34.7	1.5	21	0.03	1.51	0.006

DAS, Days after sowing

Table 2. Effect of soil and foliar application of diammonium phosphate (DAP) in cognizance with phosphate solubilising bacteria (PSB) on pods/plant, seeds/pod, test weight (g), seed yield (kg/ha), biological yield (kg/ha), harvest index (%), protein content in seed (%), N uptake (kg/ha), P uptake (kg/ha) and phosphorus use efficiency (%) of chickpea (pooled data of 2 seasons)

Treatment	Pods/ plant	Seeds/ pod	Test weight	Seed yield	Biological yield	Harvest index	Protein content in seed	Nitrogen uptake			Phosphorus uptake			PUE
								Seed	Straw	Total	Seed	Straw	Total	
T_1, Control	29.7	1.2	159.2	734	2004	36.5	20.0	23.5	12.9	36.4	1.7	2.5	4.2	00.0
T_2, 100 kg DAP/ha as basal	32.9	1.3	168.7	1003	2718	36.8	21.2	34.2	18.8	53.0	2.5	3.7	6.2	10.0
T_3, 100 kg DAP/ha as basal + PSB	34.6	1.3	173.6	1155	3064	37.6	21.6	40.0	21.2	61.2	3.0	4.2	7.2	14.9
T_4, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS	34.7	1.3	173.8	1161	3101	37.3	21.6	40.3	21.5	61.8	3.0	4.4	7.4	15.9
T_5, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS + PSB	36.1	1.4	179.3	1318	3461	38.0	22.1	46.7	24.2	70.9	3.5	5.1	8.6	21.9
T_6, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS	36.2	1.4	179.4	1319	3448	38.1	22.1	46.7	24.2	70.9	3.5	5.1	8.6	21.9
T_7, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS + PSB	37.9	1.4	183.1	1486	3800	39.0	22.5	53.7	26.8	80.5	4.3	5.6	9.9	28.4
T_8, 25 kg DAP/ha as basal + 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS	34.9	1.3	174.1	1178	3083	38.1	21.8	41.3	20.9	62.2	3.1	4.3	7.4	15.9
T_9, 25 kg DAP/ha as foliar at 45 DAS	31.5	1.2	165.1	881	2371	37.1	20.2	28.6	15.5	44.1	2.1	3.1	5.2	20.0
T_{10}, 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS	33.0	1.3	168.7	999	2639	37.8	20.6	33.1	17.4	50.5	2.5	3.5	6.0	18.0
T_{11}, 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS	34.1	1.3	171.8	1107	2939	37.6	21.1	37.5	19.8	57.3	2.9	4.0	6.9	17.9
T_{12}, 100 kg DAP/ha as foliar in 4 splits at 45, 60, 75 and 90 DAS	34.8	1.3	173.7	1167	3122	37.3	21.7	40.6	21.8	62.4	3.1	4.4	7.5	16.4
SEm ±	0.7	0.1	1.6	38	93	1.2	0.2	1.4	0.9	1.7	0.1	0.2	0.2	2.2
CD (P=0.05)	2.1	NS	4.8	111	275	NS	0.5	4.0	2.8	5.1	0.3	0.6	0.7	6.3

PUE, Phosphorus-use efficiency

seed yield owing to the application of 20 kg P_2O_5/ha through DAP with PSB in chickpea.

Protein content, nutrient uptake and P-use efficiency

The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB, being at par with 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS), 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, was found to synthesise significantly more protein content in seed over rest of the treatments (Table 2). The protein content increased with the foliar spray of DAP led to the conclusion that increased availability of nitrogen and phosphorus increased the nitrogen accumulation and ultimately reflected on the development of protein. Phosphorus is an essential nutrient for grain legumes, as it helps in improving protein content (Guhey *et al.*, 2000). Jutur and Reddy (2007) also reported a positive correlation between PSB inoculation and protein content. The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB recorded significantly highest N and P uptake by seed over rest of the treatments, while it was at par with 100 kg DAP/ha (¾ as basal + ¼ as foliar at 45 DAS) + PSB, 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) with regard to N and P uptake by straw of chickpea. Total N and P uptake and phosphorus-use efficiency of chickpea were also recorded the highest with 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB, which was significantly superior to rest of the treatments. The higher N and P accumulation was associated with more biomass yield and N and P content of the plant. Phosphate-solubilizing bacteria are also known to increase N (Kharche *et al.*, 2006) and P (Rudresh *et al.*, 2005) uptake and its use by chickpea.

Production economics

The application of 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB resulted in the highest gross returns (₹45,845/ha) as well as net returns (₹25,825/ha) and benefit : cost ratio (1.29) (Fig. 1). The plots receiving 100 kg DAP/ha (½ as basal + ½ as foliar in 2 splits at 45 and 60 DAS) + PSB significantly increased the productivity of chickpea to rest of the treatments which in turn recorded highest net return and benefit: cost ratio. Velayutham *et al.* (2003) found that application of either 20 kg P_2O_5/ha through DAP with PSB or application of PSB alone in chickpea recorded highest benefit: cost ratio.

On the basis of pooled analysis results of this two years study, it can be concluded that split application of 100 kg DAP/ha (½ as basal + ½ as foliar in two splits at 45 and 60 days after sowing) in conjunction with PSB would result in improved seed yield and quality with higher remuneration in chickpea under rainfed conditions.

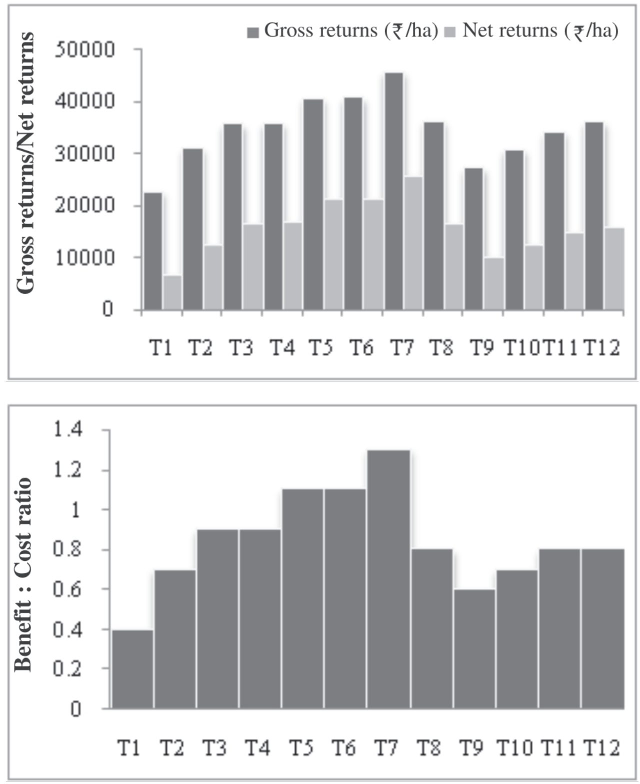

Fig. 1. Gross return, net return and benefit: cost ratio of chickpea as influenced by basal and foliar application of diammonium phosphate (DAP) in cognizance with phosphorus-solubilizing bacteria (PSB)

T_1, Control; T_2, 100 kg DAP/ha as basal; T_3, 100 kg DAP/ha as basal + PSB; T_4, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS; T_5, 75 kg DAP/ha as basal + 25 kg DAP/ha as foliar at 45 DAS + PSB; T_6, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS; T_7, 50 kg DAP/ha as basal + 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS + PSB; T_8, 25 kg DAP/ha as basal + 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS; T_9, 25 kg DAP/ha as foliar at 45 DAS; T_{10}, 50 kg DAP/ha as foliar in 2 splits at 45 and 60 DAS; T_{11}, 75 kg DAP/ha as foliar in 3 splits at 45, 60 and 75 DAS; T_{12}, 100 kg DAP/ha as foliar in 4 splits at 45, 60, 75 and 90 DAS

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