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Performance of cluster bean (*Cyamopsis tetragonoloba*) as influenced by nitrogen and phosphorus fertilization and biofertilizers in Western Rajasthan

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ABSTRACT

A field experiment was conducted to assess the effect of *Rhizobium* and phosphorus solubilizing bacteria (PSB) alone and in combination with different recommended NP levels i.e. RDF (20-17.4 kg N-P/ha) on performance of rain fed cluster bean (*Cyamposis tetragonoloba* L. Taub.) at Bikaner. Increasing NP levels resulted in significant increase in growth, yield attributes, and yield. The increase in seed yield was significant up to 50% RDF in 2004 (1.01 t/ha) and up to 75% RDF in 2005 (1.15 t/ha). However biological yield (mean 4.66 t/ha) increased significantly upto 75% RDF during both the years. Unfertilized control recorded the least seed and biomass yields. However, P uptake increased significantly up to application of 100% RDF N, K uptake and B:C ratio increased only up to 75% RDF. The highest net returns (Rs 22,393 /ha) were recorded with 100% RDF. The growth, yield attributes, and yield increased significantly due to inoculation of cluster bean with biofertlizers. Combined inoculation of *Rhizobium* and PSB was more promising from productivity and profitability point of view as compared to their sole inoculation. Integrated use of 75% RDF with *Rhizobium* + PSB inoculation was the best for cluster bean.

Key words: Growth, Nutrient uptake, *Rhizobium*, Yield

Low amount of rainfall with very erratic distribution characterizes arid regions of Rajasthan. In Bikaner, rains are received during July to September from South-West monsoons with very high degree of variation in total number of rainy days and amount of rainfall. Further, high evaporative demand of the atmosphere coupled with high wind velocity result in elevated evapo-transpirational losses that severely restrict the length of growing season. As the soils of the region are coarse textured with very poor nutrient and water retention capacity imposes sever limitations on crop performance. Cluster bean (*Cyamopsis tetragonoloba* L. Taub) is an important crop of this region due to its drought resistance (Yadav, 1998). In recent years, demand of cluster bean in global market has increased tremendously due to gum extracted from its seeds that has a wide range of industrial uses. Under such agro-climatic and soil conditions, even a highly drought resistant crop like cluster bean becomes less efficient in transforming the available amount of moisture in to biomass optimally. Studies showed positive response of crops to improved soil fertility under arid and semi arid conditions and the yield can be substantially enhanced by supplying the nutrients under limited water conditions (Garg, 2003). Fertilizer application has always been a matter of dilemma under such conditions not only due to peculiar climatic and extremely poor supporting soil, but disadvantaged position of resource poor farmer of this area also seldom allows him to take such a risky and cost increasing decision. Such a complex agro-climatic and socio-economic conditions culminate in very poor crop yield. Thus, nutrient management and preferably integrated with reduced risk and cost that can improve the yield to some stable level assumes the greatest significance. With this background, the present investigation was done.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station, Bikaner, during the *kharif* seasons of 2004 and 2005. The soil was loamy sand having pH of 8.3 and organic carbon 0.17 % and available N, P and K of 105.6, 9.72 and 199.9 kg /ha, respectively. The field was prepared by employing one deep ploughing by disc plough followed by two cross harrowings and planking. The area is characterized as hyper arid having an average rainfall of

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257 mm. But during 2004 and 2005 a rainfall of 102.8 and 410.4 mm was received. The experiment was laid out in Factorial RBD with 3 replications. Four recommended dose of N and P fertilizers (RDF) i.e. 20-17.4 kg N-P/ha and 4 biofertilizer treatments (control, *Rhizobium*, phosphate solubilizing bacteria, PSB, *Rhizobium* + PSB) were taken as two factors. Cluster bean 'RGC-936' was sown in rows 30 cm apart. Plant to plant distance was maintained as 10 cm by thinning out extra plants at 15 DAS. The crop was sown on 2 August and 5 July and harvested on 13 November and 3 November in 2004 and 2005, respectively. Due to long dry spells during both the crop seasons, one life saving irrigation was given on 12 September, 2004 and on 28 August during 2005. The rainfall received during 2005 was more in quantum and comparatively well distributed, however, during both the years dry spells prevailed during 33 to 37 standard meteorological weeks. Seeds of cluster bean were treated with biofertilizers @ 5 g / kg just before the sowing. Other package of practices was followed as per the recommendations for the crop in the zone. Nutrient content in seed and straw of the crop were estimated by following the standard methods and these contents were multiplied by the corresponding seed and straw yield to obtain the nutrient uptake. The observations recorded were analyzed following standard statistical methods.

RESULTS AND DISCUSSION

Growth parameters

Nutrient levels: Plant height, branches/plant and leaf area index (LAI) of cluster bean increased significantly with increasing RDF up to 75%. However, plant height during 2004 and LAI in 2005 increased significantly upto 100% RDF (Table 1). Increased availability of N and P through fertilizers might have influenced the growth of the crop. Singh and Singh (1989) have also reported positive response of cluster bean to the application of these nutrients.

Biofertilizers: The highest number of branches / plant and LAI (during both the years) and plant height (2005) was recorded with the combined inoculation of the biofertilizers over *Rhizobium* or PSB alone and no biofertilizers. However, during 2004, *Rhizobium* inoculation recorded at par plant height as that of combined inoculation and PSB was further at par to control. Probable increase in N availability in soil due to symbiotic N fixation in the soil having low available N might have augmented the growth of the crop, whereas effect of PSB was not as pronounced possibly due to medium level of P in the experimental soil. However, their combined application exhibited complimentary effect resulting in significantly better over their sole inoculations. It was further evident that the effect of biofertilizers was more revealing in the 2005 during which rainfall was more favourable than 2004. Rathore *et al.* (2007) also noticed the positive impact on growth of cluster bean when *Rhizobium* and PSB are applied together.

Yield attributes and yield

Nutrient levels: Progressive and significant increase in number of pods/plant, seeds/pod, seed and biological yields of cluster bean were obtained with the increasing levels of fertility over control during both the years (Table 1). Application of 50 and 75% RDF being at par recorded significantly lower pods/plant and seeds/pods than 100% RDF in 2004. However, during 2005, pods/plant produced with 75% and 100% RDF being at par were significantly higher than that produced with 50% RDF. Further, the increase in seeds/pod over 50% RDF was significant with 100% RDF only. No significant increase in test weight was recorded, during any year (hence data not given). Better growth performance of test crop perhaps resulted in greater accumulation of biomass and thus its increased flow towards sink also led to positive improvements in the yield contributing characters.

During 2004, increase in seed yield over control was significant only up to 50% RDF while during 2005 the response was obtained up to 75% RDF. Application of 50% RDF increased seed yield over control by 48 and 35.6% in 2004 and 2005 respectively. The increase in seed yield with 75% RDF over 50% RDF in 2005 was to the tune of 17.1%. Biological yield increased significantly up to 75% RDF only during both the years. Significant improvements in yield contributing characters with the application of fertilizers resulted in significant increase in seed yield. During 2005, better moisture availability during early growth phase of the crop insured better growth as dry matter, however, stress observed during later phase of crop reduced the translocation of dry matter towards sink (Earl and Davis, 2003).However, during 2004, reverse was true. Increase in productivity of cluster bean with the application of N ad P has also been reported by Palsania *et al.* (2002).

Biofertilizers: Seed inoculation of biofertilizers significantly improved the yield contributing parameters and yield of cluster bean (Table 1). The highest number of pod / plant, seeds/pod and pod length was recorded with the combined inoculation of *Rhizobium* and PSB during both the years. *Rhizobium* and PSB alone treatments also proved significantly better over control in improving the above parameters. PSB treatment with the exception for pods/plant and pod length in 2004, was found at par with control. Low soil moisture during poor rainfall year might have reduced the efficiency of PSB. Biofertilizers have no

Table 1. Growth, yield attributes and yield of cluster bean as influenced by nutrient levels and biofertilizers

Treatment	Plant height (cm) at harvest		Branches/ plant at harvest		Leaf area Index (60 DAS)		Pods/ plant		Seeds/ pod		Pod length (cm)		Seed yield (kg/ha)		Biological yield (kg/ha)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Nutrient levels (% RDF)																
0	53.0	53.3	8.9	9.6	2.67	2.65	24.2	24.8	5.0	5.0	4.90	4.95	684	725	2,913	3,197
50	70.8	73.5	9.6	12.6	3.09	3.15	32.9	34.2	6.3	6.7	6.58	6.83	1,013	983	4,040	4,429
75	71.2	81.3	10.1	13.7	3.19	3.26	33.1	37.7	6.4	7.1	6.62	7.55	1,030	1,151	4,464	4,849
100	80.8	85.2	10.3	14.1	3.24	3.32	37.6	39.6	6.8	7.2	7.51	7.91	1,088	1,159	4,678	5,099
SEm±	2.2	2.0	0.2	0.3	0.03	0.02	1.0	0.9	0.1	0.2	0.20	0.18	30	32	110	120
CD (P=0.05)	6.3	5.7	0.5	0.9	0.08	0.06	2.8	2.7	0.4	0.5	0.58	0.53	87	93	317	347
Biofertilizers																
No biofertilizers	63.8	64.0	9.1	11.0	2.85	2.86	29.2	29.8	5.6	5.8	5.90	5.95	807	842	3,505	3,820
Rhizobium	70.1	76.6	9.7	12.7	3.17	3.22	32.6	35.6	6.2	6.7	6.51	7.11	1,011	1,053	4,206	4,609
PSB	67.7	70.3	9.9	12.7	2.96	3.03	31.5	32.6	6.2	6.4	6.29	6.53	908	975	3,860	4,191
Rhizobium + PSB	74.3	82.4	10.3	13.7	3.22	3.28	34.5	38.3	6.5	7.2	6.90	7.65	1,090	1,147	4,526	4,954
SEm±	2.2	2.0	0.2	0.3	0.03	0.02	1.0	0.9	0.1	0.2	0.20	0.18	30	32	110	120
CD (P=0.05)	6.3	5.7	0.5	0.9	0.08	0.06	2.8	2.7	0.4	0.5	0.58	0.53	87	93	317	347

RDF: 20-17.4 kg N-P/ha

influence on test weight. Increased activity of biofertilizers was reflected in the significant improvements in growth parameters and this better growth possibly paved the way for significant improvements in yield contributing characters. Rathore *et al.* (2007) have also reported similar results with biofertilizers.

Combined inoculation of *Rhizobium* and PSB resulted in the significantly higher seed yield than other biofertilizers treatments during 2005 but during 2004 it was found as at par to *Rhizobium* inoculation alone. The increase in seed yield over control owing to combined inoculation of biofertilizers was 35 and 36% during 2004 and 2005, respectively. Inoculation with *Rhizobium* resulted in significantly higher seed yield over control and PSB during 2004 but during 2005 it was at par with that of PSB. Magnitude of increase in seed yield due to inoculation of *Rhizobium* was 25% during both the years and corresponding enhancement in seed yield with PSB inoculation was 13 and 16%, during 2004 and 2005 respectively. Biological yield recorded with combined inoculation was found significantly higher over alone applications of *Rhizobium* and PSB. Similarly, biological yield obtained with *Rhizobium* was also significantly higher when compared with inoculation of PSB alone. Improvement in crop productivity due to biofertilizers application could be obtained on account of significant improvement in growth and yield contributing characters of the crop. Variations in response of PSB during poor and relatively good rainfall year seem to be suggestive of its more sensitivity towards low available soil moisture than *Rhizobium*. During good rainfall year its effect on growth and yield parameters is more positive than poor rainfall year. Though harvest index was not affected by any of the biofertilizer treatments, however, environmental effect was observed as it was more favourable during 2004 than 2005. The better availability of moisture during 2005 improved the biomass accumulation significantly, however, this accumulated biomass could not be converted in to economic yield optimally due to stress during later period. Thus lower values for harvest index were observed during 2005 than 2004. Water stress at pre-anthesis reduces the time to anthesis while stress at post-anthesis shorten the grain filling period thus later is more detrimental for grain yield regardless of the stress severity (Samrah, 2003) as happened in the present investigation.

Nutrient uptake and economics

Nutrient levels: Nutrient (NPK) uptake of seed and straw increased significantly with each successive increase of fertilizers upto 75 and 100% RDF respectively. The mean total uptake (seed + straw) of N-P-K was highest i.e. 82.3-10.16-52.17 with 100% RDF and was the

least with control (47.9-8.56-32.84 kg N-P-K/ha). Nutrient uptake is the manifestation of the nutrient content and seed and straw yield, hence N and P uptake increased due to both of these factors while K uptake increased solely due to increase in dry matter production. The highest net returns (Rs. 22,393/ha) were obtained with the 100% RDF whereas, the highest B:C ratio (3.83) was recorded with the 75% RDF.

Biofertilizers: Nutrient uptake by seed and straw increased significantly due to inoculations with biofertilizers as compared to the control. *Rhizobium* was significantly better than PSB in this respect but combined application of these was significantly superior to their sole inoculations. Total uptake of N increased by 28 and 41% over control with the inoculation of *Rhizobium* and combined inoculation of both the biofertilizers, respectively. PSB inoculation and its combined use with *Rhizobium* improved the total uptake of P by 16 and 38% respectively, over control. Significant increase in N content due to *Rhizobium* inoculation was probably the result of increased and regular supply of N due to symbiotic relationship as in dry area pulses symbiotic N-fixation contributes more than mineral N in improving the N content of plant (Malhotra *et al.*, 2004). Increased solubility of native P due to inoculation with PSB might have some augmenting effect on the native population of *Rhizobium* strain present in the soil with probable increase in symbiotic N-fixation by that native population of the *Rhizobium.* As N-fixing legume plants usually require more P than plants dependant on mineral N fertilizer, because P plays very vital role in the nodule development and their activity (Serraj *et al.,* 2004). Inoculation with PSB perhaps increased the solubility of native as well as applied P with net increase in availability thus uptake of this nutrient enriching its content in plant. The increase in N and P content in plant due to combined inoculation was obvious as their sole applications were effective in improving the contents. Increased uptake of N and P may be explained as increase in content of these nutrients in plant and increase in plant dry matter due to their effect, however, increased dry matter is the sole reason of significant improvement in the K uptake by seed and straw. Rathore *et al.* (2007) observed the highest total

Table 2. Nutrient uptake (kg/ha) and economics (Rs/ha) of cluster bean as influenced by nutrient levels and biofertilizers (pooled data of 2 years)

Treatment	N		P		K		Economics		
	Seed	Straw	Seed	Straw	Seed	Straw	Total cost	Net returns	Net B:C ratio
Nutrient levels (% of RDF)									
0	23.6	24.3	2.48	3.40	5.16	27.68	4,973	12,729	2.56
50	35.4	35.5	3.68	4.90	7.38	38.43	5,418	19,463	3.59
75	39.3	39.8	4.11	5.54	7.95	41.79	5,641	21,613	3.83
100	40.4	41.9	4.27	5.89	8.17	44.00	5,864	22,393	3.82
SEm±	0.7	0.7	0.08	0.11	0.16	0.71			
CD (P=0.05)	2.1	1.9	0.23	0.30	0.44	2.00			
Biofertilizers									
No Biofertilizers	28.0	29.9	2.98	4.22	5.97	33.00	5,454	15,434	2.80
Rhizobium	36.8	37.2	3.73	5.02	7.57	39.77	5,474	20,314	3.68
PSB	33.1	33.6	3.56	4.80	6.90	36.31	5,474	18,065	3.27
Rhizobium + PSB	40.8	40.9	4.26	5.68	8.23	42.83	5,494	22,385	4.05
SEm±	0.7	0.7	0.08	0.11	0.16	0.71			
CD (P=0.05)	2.1	1.9	0.23	0.30	0.44	2.00			

Table 3. Interaction effect of nutrient levels and biofertilizers on seed yield and N uptake of cluster bean (2005)

Biofertilizers	% RDF							
	0	50	75	100	0	50	75	100
	Seed yield (kg / ha)				Total N uptake (kg/ha)			
Control	649	801	806	1,113	38.74	56.42	59.01	81.19
Rhizobium	767	1,003	1,264	1,179	52.66	77.34	87.91	82.93
PSB	682	940	1,159	1,120	46.22	64.87	79.96	81.09
Rhizobium + PSB	802	1,187	1,376	1,223	58.05	86.26	98.05	90.33
SEm±		65				3.75		
CD (P=0.05)		186				10.84		

uptake of N, P and K with the integrated application of 50 % level of RDF and *Rhizobium* and PSB under Bikaner conditions. Combined inoculation of both the biofertilizers resulted in the highest net return (Rs 22,385) and B:C ratio (4.05) validating the opinion that these two are complimentary in improving the yield of legumes.

Interaction of Fertilizers x Biofertilizers

Significant interaction effect between nutrient levels and biofertilizers was found for seed yield and total uptake of N during 2005 (Table 3). Combined inoculation of *Rhizobium* and PSB + 75% RDF gave the highest seed yield that was significantly higher than 100% RDF. Combined inoculation of biofertilizers was found significantly better over rest of the biofertilizers treatments up to 75% RDF. However, at 100% RDF, inoculation with biofertilizers could not increase the seed yield. Because the higher availability of fertilizer nutrients have the adverse effect on the microbial activity of the biofertilizers. At lower levels some complimentary effect was observed because availability of fertilizer nutrients at lower levels provided starter dose for rhizobial activity and build up of plant for microbial association. PSB also found effective in solubilising the applied and native soil P. Same trend was observed for total N uptake.

It may be concluded that application of 20-17.4 kg N-P/ha (RDF) has positive effect on yield of cluster bean, under normal rainfall, but under low rainfall situation, chemical fertilizers may be reduced to less than that of recommended level. Combined inoculation of *Rhizobium* and PSB, was found promising to their sole application.

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