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Integrated nutrient management in rainfed cluster bean (*Cyamopsis tetragonoloba*) in arid region of India

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Abstract

Results of field experiment, conducted to evaluate the effect of nutrient levels and biofertilizers on growth, yield and nutrient uptake and economics of rainfed cluster bean indicated that increasing levels of nutrients brought significant improvement in growth and yield and nutrient uptake of cluster bean. Seed yield increased significantly up to 75% of recommended level of N and P and it was 55 per cent higher than control. Total uptake of N and K, crude protein yield and B: C ratio also increased significantly up to application of 75% of recommended level of N and P, whereas straw yield, total P uptake and net returns increased up to 100% of recommended level of N and P. However, post harvest fertility status improved significantly only up to 50% of recommended level of N and P. Inoculation with Rhizobium and PSB, either as sole or in combination, also had positive impact on growth and yield parameters thus significantly higher seed and straw yields were obtained with the inoculation of Rhizobium and PSB. However, combined application of these two biofertilizers was significantly better over their sole inoculations in improving the growth and yield characters and yield of the cluster bean. The highest net returns and B: C ratio were also observed with the combined inoculation of Rhizobium and PSB and also improved the post harvest available N and P status of soil, respectively

Keywords: Cluster bean, PSB, rhizobium, nutrient uptake, yield parameters

Introduction

Arid regions of Rajasthan are highly unstable with viewpoint of crop production because of scanty rainfall with erratic distribution coupled with very poor supportive soils and high evaporative demand of atmosphere. At Bikaner, rains are received during July to September from Southwest monsoons of Indian subcontinent with very high degree of variation in total number of rainy days and amount of rainfall. As the soils of the region are coarse textured with very poor nutrient and water retention capacity, thus these very poor supporting soils worsen the crop growing situation by imposing severe limitations on crop choice under prevailing agro climatic conditions. Cluster bean (*Cyamopsis tetragonoloba* L. Taub) is an important crop of this region due to its drought resistance capacity (Yadav, 1998) [6] it has been proved to give reasonable production under diverse rainfall situations. In recent years, increasing demand of cluster bean in global market has resulted in better remuneration to the growers. Though this crop is highly adaptable to the agroclimatic and soil conditions of the region but capitalization of available moisture in to biomass production optimally is the real issue to be addressed. Decision pertaining to application of fertilizer nutrient has never been easy under these conditions because of uncertainty about available moisture and increase in cost. If sufficient moisture is not available fertilizer application may even have some negative effect on the performance of the crop. Further, the farmers of the region are resource poor and such a complex agroclimatic and socioeconomic conditions culminate in very poor crop yield in the region. Under the circumstances where application of fertilizer nutrient is not feasible every time due to complex moisture availability situations, crop nutrition to optimize available soil moisture in to reasonable production, from already nutrient deficient soils with very poor support system. The role of microbial inoculants namely rhizobia and phosphate solubilizing bacteria (PSB) gets elevated significance under such scarce situations.

The rhizobia inoculants can fix nitrogen symbiotically in association with legume crops particularly in the soils of experimental site of this study which are low in native nitrogen. Further, soil of this location was possessing medium level of phosphorus and inoculation with PSB has the potential to improve the nutrient supply by solubilizing native and applied fertilizer phosphorus. Both of these nutrients namely nitrogen and phosphorus are very crucial for stabilizing cluster bean production under very limited soil moisture and highly nutrient deficient soils and integrated nutrition of these two nutrients in this way is highly desirable and identification of suitable combination of fertilizer doses combined with the biofertilizers is of paramount importance in these hyper arid scanty rainfall regions supported with poor soils. Thus, nutrient management and preferably integrated nutrient management (INM) with reduced risk and cost that can improve the yield to some stable level assumes the greatest significance. Integration of fertilizer nutrient with biofertilizers will not only be cost effective but will also have some positive impact on the soil fertility. Use of biofertilizers will ensure the continuous supply of N and P through fixation and / or solubilization that will be highly beneficial whenever sufficient moisture is available during crop span. With such background, present investigation was planned and conducted for two years.

Materials and Methods

The experiment was conducted at Agricultural Research Station, Rajasthan Agricultural University, Bikaner, India, during the *kharif* (July to September) seasons of 2004 and 2005. The soil was loamy sand having pH of 8.3 and OC 0.17% and available N, P and K were 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 harrowing and planking. The area was characterized as hyper arid with average rainfall of 257 mm and during both the years the rainfall received was below the normal. The experiment was laid out in Factorial RBD with three replications. Four nutrient levels (control, 50%, 75% and 100% of recommended N and P) and four treatments of biofertilizers (Control, Rhizobium, Phospho Solubilising Bacteria and Combined inoculation of Rhizobium and Phospho Solubilising Bacteria) were taken as two factors. Cluster bean Variety 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 August 2 and July 5 and harvested on November 13 and 3 during 2004 and 2005, respectively. Due to long dry spells during both the crop seasons, one life saving irrigation was given during every year of experiment. The gross and net plot areas were 3.0 x 4.0 m and 1.8 x 3.0 m, respectively. The recommended dose of fertilizer was 20 kg N and 40 kg P₂O₅ / ha. Seeds of cluster bean were inoculated 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. For recording growth and yield attributes five plants were selected randomly from sampling rows of each plot and average values were used for this purpose. 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 uptake of a nutrient by seed and straw. Total of uptake by seed and straw was recorded as total uptake of the particular nutrient. Economics of treatments was worked out on the basis of prevailing market prices of inputs and produce. The observations recorded were analysed statistically following standard statistical method.

Results and Discussion

Growth parameters

Nutrient levels

Growth parameters namely plant height, plant dry matter and branches / plant recorded at harvest increased significantly with the increasing levels of nutrient. Plant height increased significantly up to application of 100% and plant dry matter and branches / plant increased significantly only up to 75% of recommended N and P (Table 1). External application of N and P probably enabled the increased availability of these nutrients which influenced the growth of plant to a great extent and significant improvements in the growth parameters were observed. Singh and Singh (1989) ^[5] have also reported response of cluster bean with the application of these nutrients. However, prevailing moisture stress during crop season probably inhibited the response of nutrients only up to 75% RDF.

Biofertilizers

The highest plant height, plant dry matter and branches / plant were recorded with the combined inoculation of the biofertilizers followed by sole inoculation with Rhizobium and PSB, respectively (Table 1). The soil of experimental site was low in available N and inoculation with Rhizobium might have increased the amount of symbiotically fixed N that had led to the significant improvement in growth parameters. However, combined inoculation with Rhizobium and PSB showed complimentary, resulting in significantly better performance over their sole inoculations. Rathore *et al.* (2007) ^[3] also noticed the positive impact on growth of cluster bean when applied with Rhizobium and PSB.

Yield contributing parameters

Nutrient levels

Significant increase in number of pods / plant, seeds / pod and pod length was obtained with the increasing levels of nutrient and the highest values of these yield contributing parameters were recorded with the application of 100% recommended level of N and P (Table 1). However, no significant increase in test weight was recorded with the application of any nutrient level. Significant improvement in dry matter accumulation also led to its proportionately increased flow towards sink and increase in branches / plant enabled more bearing area resulting in more number of pods / plant. Improved availability of N and P also had significant effect on pod length and number of seeds / pod.

Biofertilizers

Seed inoculation with biofertilizers whether separately or in combination significantly improved the yield contributing parameters namely number of pods / plant, seeds / pod and pod length, however, combined inoculation of these biofertilizers was observed as the most effective in this regard than the individual effects (Table 1). Test weight was not affected by any biofertilizer treatment. Increased availability of N and P by way of symbiotic fixation of N or increased solubility of P on account of inoculation with Rhizobium and PSB, respectively resulted in significant improvements in yield contributing attributes. These results are in close agreement of those reported by Rathore *et al.* (2007) ^[3].

Yields and Quality

Nutrient levels

Significant increase in seed and straw yields was recorded with the increasing levels of nutrients, however, seed yield increased significantly only up to 50% and straw yield up to 100% level of

recommended N and P and the magnitude of increase in comparison to control was 55 and 60 per cent, respectively (Table 1). Quality of cluster bean also improved and significantly higher amount of total crude protein yield was obtained up to application of 50% level of recommended N and P and the extent of increase was 65 per cent with this level of nutrients in comparison to control. Significant increase in seed and straw yield is obvious outcome of significantly improved performance of growth and yield parameters due to improved availability of N and P. Increase in productivity of cluster bean with the application of N and P has also been reported by Palsania *et al.* (2002) ^[1].

Biofertilizers

Different biofertilizer treatments also led to significant increase in the seed, straw and crude protein yield over control (Table 1). The highest seed yield was recorded with combined inoculation of Rhizobium and PSB that was significantly higher in comparison to control and rest of biofertilizers treatments. The increase in seed yield with combined inoculation of biofertilizers was 36, 8 and 19 per cent higher than control, Rhizobium and PSB, respectively. Straw and crude protein yields were also recorded as significantly higher than rest of the biofertilizer treatments. Inoculation with Rhizobium and PSB alone also resulted in significantly higher seed, straw and crude protein yield over control. Magnitude of increase in seed yield due to inoculation of Rhizobium and PSB was 25 and 14 per cent, respectively. Significant improvement in growth and yield contributing characters due to inoculation with biofertilizers led to Improvement in crop productivity of the test crop.

Integrated Effect

Significant effect on N and P content in seed was noticed under integrated application of nutrient levels and biofertilizer inoculations (fig. 1). N content in seed increased significantly due to microbial inoculations in comparison to control; however, all inoculation treatments were at par to each other in this respect. With the application of fertilizer nutrients the significance of microbial inoculations over control became non significant suggesting that symbiotic N fixation was not in tune to the increasing seed yield thus diluting effect was visible. The highest content was noticed with the combined application of 75% level of recommended N and P and combined inoculation with biofertilizers. Increased P availability under this treatment improved the symbiotic N fixation efficiency because under sole inoculation decrease in N content was observed beyond application of 50% recommended level of N and P.

Inoculation with PSB either as sole or in combination with Rhizobium in integration with 75% level of recommended N and P improved the P content of seed up to the level observed with 100% level of recommended N and P indicating 25 per cent saving of fertilizer nutrient in this respect. Combined microbial inoculation with no fertilizer nutrients resulted in the significantly higher P content than sole inoculations because increased rhizobial activity, improved root growth due to increased availability of N and increased root volume in turn increased the extracting capacity resulted in higher content.

Total Nutrient uptake

Nutrient levels

Total uptake of nutrients increased significantly with the increasing levels of nutrients and total uptake of N increased significantly up to 75% and that of P and K up to 100% level of recommended N and P (Table 2). The quantum of increase of

total uptake of N, P and K with respective levels of nutrients was 65, 73 and 31 per cent, respectively as compared to the control. 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 because of increased availability of these nutrients in soil while K uptake increased solely due to increase in dry matter production.

Biofertilizers

The highest uptake of nutrients by crop may be explained by two reasons firstly, increased availability of N and P due to symbiotic N fixation and increased solubility of P enabled the test crop for higher uptake of these nutrients. Secondly, better availability of these nutrients also enhanced the biomass accumulation significantly contributing in greater uptake of nutrients from soil. Total uptake of N increased by 28 and 41 per cent over control with the inoculation of Rhizobium and combined inoculation of both the biofertilizers, respectively (Table 2). Alone inoculation of PSB and combined inoculation of Rhizobium and PSB improved the total uptake of P by 16 and 38 per cent respectively, over control. Significant increase in N content due to Rhizobium inoculation probably was the result of increased and regular supply of N due to symbiotic relationship as in dry area legumes, symbiotic N fixation contributes more than mineral N in improving the N content of plant (Malhotra *et al.* 2004) ^[1]. 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 fixation of N by that native population of the Rhizobium because 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) ^[4]. Inoculation with PSB perhaps increased the solubility of native as well as applied P with net increase in availability thus increased uptake of this nutrient enriched its content in plant. The increase in N and P content in plant, due to combined inoculation, was obvious as their sole applications were also effective in improving the respective nutrient contents.

Post harvest fertility status

Nutrient levels

Improvement in below ground growth of cluster bean also took place because of viewing improvement in above ground growth of the test crop (Table 2). Such accumulation of biomass in soil and its stratified decomposition led to significant increase in the experimental soil after the end of the experiment, however, the significant response could be obtained only up to 50% of recommended level of N and P. The environmental factors accelerating the burning of organic intermediates possibly limit the increase in organic carbon content of the soil. Status of available N and P also increased significantly up to application of 50% of recommended level of N and P. The retention capacity of soil was very poor due to coarse texture and poor organic carbon content, therefore, released N from fertilizer is subjected to three probable fates namely possible uptake by crop, volatilization and leaching. The soil pH was alkaline and soil was calcareous and these reduce the solubility and thus availability of the applied fertilizer P. K status of the soil was not affected by any level of nutrients.

Biofertilizers

Increased microbial activity in the rhizosphere not only led to above ground growth but it also contributed in the production of more biomass in its close vicinity and this led to significant

improvements in post harvest fertility status of the experimental site (Table 2). Significant increase in organic carbon content of soil was observed with the inoculation of Rhizobium and PSB, respectively. The combined inoculation of these biofertilizers was found as at par to the sole inoculation of individual biofertilizer in case of both N and P. Post harvest status of soil K remained as not affected.

Economics

Nutrient Levels

Successive increase in nutrient levels improved the monetary returns and the highest gross and net returns were obtained with the application of recommended level of nutrients (Table 2). However, marginal returns obtained with this treatment were observed in decreasing trend thus the highest B: C ratio was recorded with the 75% recommended level of the N and P.

Biofertilizers

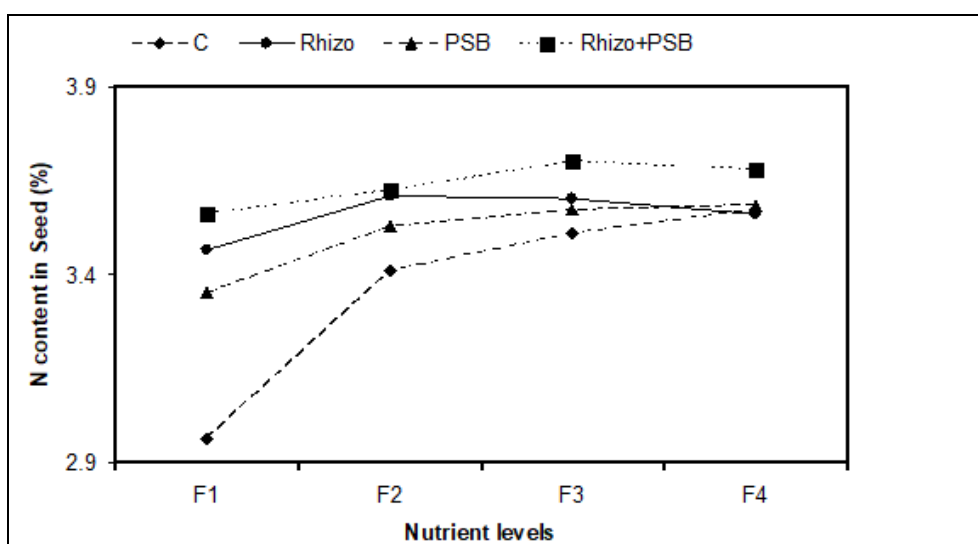
Combined inoculation with both Rhizobium and PSB was the most effective treatment with regards to gross and net returns and B: C ration that was followed by sole inoculations with Rhizobium and PSB (Table 2).

Estimation of biofertilizers efficiency

In order to get an estimation of efficiency of biofertilizers in terms of additional amount of nutrient obtained, on account of treatment, need to be worked out. The contribution of any biofertilizer may be understood by two figures (Fig 2 & 3). Firstly, the additional amount of uptake of a particular nutrient due to biofertilizer and secondly increase in the soil status of this nutrient. Addition of both these will give the estimated benefit of the treatment. In present investigation, it was observed that inoculation with Rhizobium alone is capable of fixing about 20 kg N of atmospheric N in symbiosis with the cluster bean. However, its efficiency increase in combination with PSB and such treatment fixed about 30 kg N. Inoculation with PSB increased the solubility of native P and extent of such solubility was not much increased when its inoculation was combined with Rhizobium. It was also clear that use of these biofertilizers not only fix or solubilize the N and P but these also improved the mining of the native K from soil, as evident from the mobilization of the K. This may be ascribed to the better growth of absorbing part of the plant namely roots and secondly increased uptake of N and P had some synergistic effect on the uptake of K.

Table 1: Growth and yield characters and yields of cluster bean as influenced by nutrient levels and biofertilizers (pooled data of two years)

Treatment	Growth characters (at harvest)			Yield characters				Yields (kg / ha)		
	Plant height (cm)	Plant Dry matter (g)	Branches / plant	Pods / plant	Seeds / pod	Pod length (cm)	Test weight (g)	Seed yield	Straw yield	Crude protein yield
Nutrient levels										
No fertilizer	53.1	9.3	9.3	24.5	5.03	4.9	26.0	705	2350	300
50% RD	72.2	12.9	11.1	33.5	6.51	6.7	26.5	998	3237	443
75% RD	76.2	14.2	11.9	35.4	6.74	7.1	26.9	1091	3566	494
100% RD	83.0	14.9	12.2	38.6	7.03	7.7	27.3	1123	3765	514
S.Em+	1.5	0.2	0.2	0.7	0.11	0.1	0.4	22	64	8
CD (0.05)	4.2	0.7	0.5	1.9	0.30	0.4	NS	63	180	23
Biofertilizers										
No Biofertilizers	63.9	11.2	10.0	29.5	5.67	5.9	25.8	824	2838	362
Rhizobium	73.3	13.4	11.2	34.1	6.44	6.8	26.8	1032	3375	462
PSB	69.0	12.3	11.3	32.1	6.32	6.4	27.0	942	3084	417
Rhizobium + PSB	78.3	14.5	12.0	36.4	6.87	7.3	27.2	1118	3621	510
S.Em+	1.5	0.2	0.2	0.7	0.11	0.1	0.4	22	64	8
CD (0.05)	4.2	0.7	0.5	1.9	0.30	0.4	NS	63	180	23



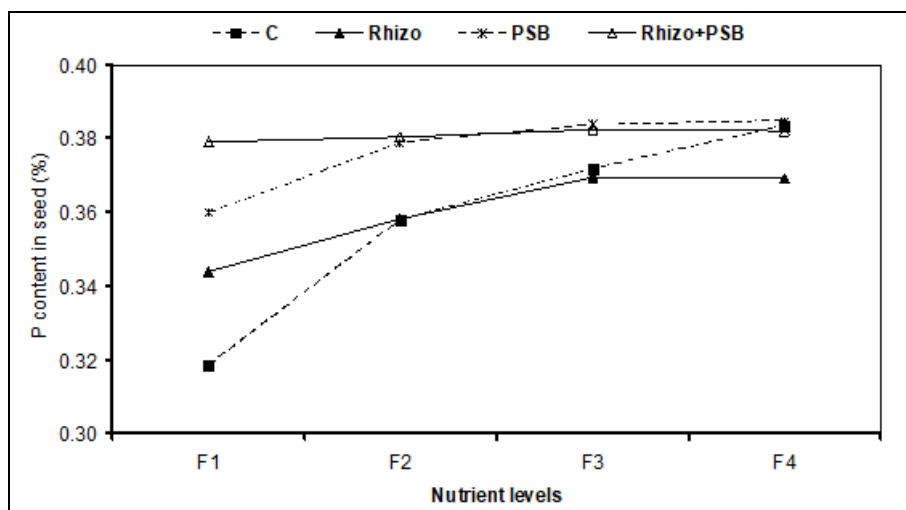


Fig 1: Integrated effect of nutrient levels and biofertilizers on N and P content of cluster bean seed (pooled data of 2 years)

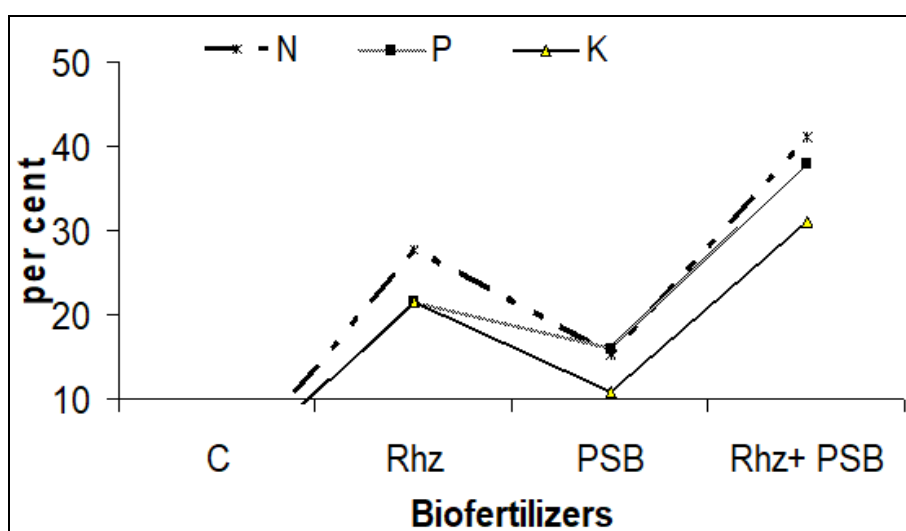


Fig 2: Per cent increase in total nutrient uptake of cluster bean due to biofertilizers (pooled data of 2 years)

Table 2: Nutrient uptake of cluster bean, post harvest fertility status and economics as influenced by nutrient levels and biofertilizers (pooled data of 2 years)

Treatment	Nutrient uptake (kg / ha)			Post harvest fertility status of soil (after 2 years)*				Economics			B:C ratio
	N	P	K	OC (%)	(Kg / ha)			Rs / ha			
					N	P	K	Gross returns	Total cost	Net returns	
Nutrient levels											
No fertilizer	47.95	5.87	32.85	0.1883	104.82	9.65	190.23	17702	4973	12729	3.56
50% RD	70.87	8.58	45.81	0.1982	107.74	10.10	197.13	24882	5418	19463	4.59
75% RD	79.11	9.65	49.74	0.2002	110.93	10.10	199.30	27254	5641	21613	4.83
100% RD	82.30	10.15	52.18	0.2004	110.65	10.13	200.52	28256	5864	22393	4.82
SEm+	1.32	0.18	0.83	0.0033	1.69	0.14	2.74				
CD (0.05)	3.74	0.50	2.34	0.0096	4.88	0.41	NS				
Biofertilizers											
No Biofertilizers	57.90	7.21	38.97	0.1901	105.97	9.64	191.32	20888	5454	15434	3.80
Rhizobium	73.95	8.75	47.34	0.1985	111.34	9.49	197.14	25788	5474	20314	4.68
PSB	66.73	8.36	43.20	0.1944	104.95	10.36	196.60	23539	5474	18065	4.27
Rhizobium + PSB	81.65	9.94	51.06	0.2041	111.88	10.50	202.13	27879	5494	22385	5.05
SEm+	1.32	0.18	0.83	0.0033	1.69	0.14	2.74				
CD (0.05)	3.74	0.50	2.34	0.0096	4.88	0.41	NS				

*Initial fertility status of experimental site: OC (%) = 0.1764, N = 105.6 (kg / ha), P = 9.72 (kg / ha), K = 199.9 (kg / ha)

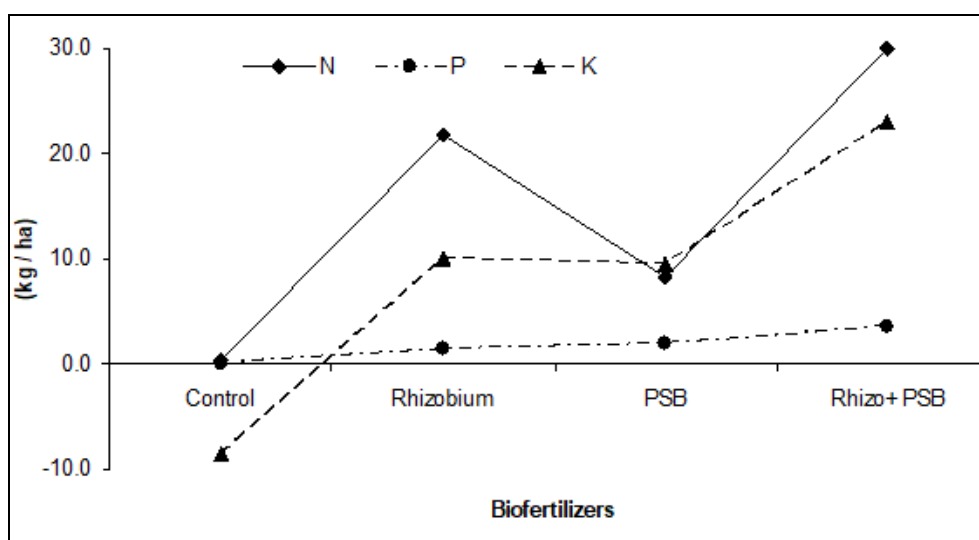


Fig 3: Effect of biofertilizers on extent of symbiotic fixation and / or mobilization of nutrients (After 2 years)

Conclusion

Application of fertilizer nutrients had positive effect on growth and yield of cluster bean, but under lower rainfall significant response was obtained at lower levels than that of recommended. Inoculations with biofertilizers also improved the growth and yield, however, combined inoculation of Rhizobium and PSB was better than their sole applications. Nutrient uptake increased significantly up to 75% of recommended level of the N and P and with combined inoculation with Rhizobium and PSB.

Conflict of Interest

The authors do not have any conflict of interest.

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