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# Effect of nutrient management on growth, productivity and nutrient uptake of rainfed clusterbean (*Cyamopsis tetragonoloba*) in arid region

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2004 and 2005 to study the effect of chemical and biofertilizer on growth, yield and nutrient uptake of rainfed clusterbean (*Cyamopsis tetragonoloba* (L.) Taub). Significant improvement in growth, yield and nutrient uptake was recorded with sole and integrated application of nutrients through chemical fertilizers and bio fertilizers. Application of chemical fertilizers registered significant improvement in seed yield over control and magnitude of increase with application of 50, 75 and 100 % of recommended dose of fertilizer (20 kg N, 40 kg $P_2O_5$ /ha) was 21.1, 45.6 and 50.9 % over the control respectively. Association between *Rhizobium* and phosphate solublising bacteria was synergistic and inoculation of both fertilizers significantly improved the seed yield. Inoculation of *Rhizobium*, phosphate solublising bacteria and *Rhizobium* + phosphate solublising bacteria recorded 21.0, 14.0 and 24.6 % higher seed yield than the control respectively. Integration of biofertilizer with chemical fertilizer @ 50 % recommended dose of fertilizer brought significant improvement in yield and nutrient uptake over the respective sole application of chemical and biofertilizer and was comparable with application of 100 % recommended dose of fertilizer.

**Key words:** Chemical fertilizer, *Rhizobium*, Phosphate solublising bacteria, Productivity, Nutrient uptake, Clusterbean, Arid region

In arid region of Rajasthan, low annual rainfall (150–450 mm) and high potential evapotranspiration demand (1 250–2 000 mm) limits the length of crop growing period up to 10–14 weeks. Rainfall pattern in most of the years supports short duration crops like legumes and they achieve higher grain yield than the long duration crops (Rao and Singh 2004). Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub) is an important legume crop grown traditionally for feed and fodder. It has acquired a status of industrial crop due to its gum content and potentially suitable for diversified industrial use. Though the area under cluster bean is maximum in Rajasthan yet its average productivity is very low (0.25 tonne/ha) as compared to Gujarat (0.37 tonne/ha), Haryana (0.70 tonne/ha) and Punjab (1.20 tonnes/ha) (Henry 2003). Limited moisture and improper nutrient management are considered as major limiting factors for achieving higher productivity of clusterbean in arid region. The nutrient management thus assumes importance to sustain its productivity. Given the poor socio-economic conditions of farmers coupled with low and erratic rainfall distribution, the intensive use of chemical fertilizers is a risky preposition in these regions. So low-cost nutrient supplementation through biofertilizers as integrated nutrient supply system may be a better option to fulfill nutrient requirement of the crops. Hence a study was undertaken to asses the effect of chemical and biofertilizers on growth, productivity and nutrient uptake of clusterbean in arid region of western Rajasthan.

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## MATERIALS AND METHODS

The field experiment was conducted at Regional Research Station, Bikaner during rainy season of 2004 and 2005.The soil was sandy , alkaline in reaction with pH 8.2, bulk density 1.48 g/cm$^3$ in upper 15 cm soil depth, organic carbon 1.0 g/kg , available N 89.7 kg/ha, available P 8.0 kg/ha and available K 234.1 kg/ha .The climate represent hyper arid with annual rainfall of 247 mm and most (70–80%) of which occurs during July–September. The experiment was laid out in randomized block design with 3 replications and 10 nutrient management treatments, viz $T_1$, control; $T_2$, 50% of recommended dose of fertilizer; $T_3$, 75 % of recommended dose of fertilizer; $T_4$, 100 % of recommended dose of fertilizer; $T_5$, *Rhizobium*; $T_6$, phosphate solublising bacteria; $T_7$, *Rhizobium* + phosphate solublising bacteria; $T_8$, 50 % of recommended dose of fertilizer + *Rhizobium*; $T_9$, 50 % of recommended dose of fertilizer + phosphate solublising bacteria and $T_{10}$, 50 % of recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria. 'RGC 936' clusterbean was sown with hand plough at 40 cm row-to-row

distance. The crop was sown on 2 August and 30 June in 2004 and 2005 respectively. The net plot size was 5.0 m × 3.2 m. The recommended dose of fertilizer was 20 kg of N + 40 kg of $P_2O_5$ /ha was applied as basal dose through urea and single superphosphate as per treatments. Biofertilizers were applied as seed treatment @ 5 g/kg of seed just before sowing. Other cultural practices were applied uniformly as per recommendation for the crop in the area. One life saving irrigation of 5 cm applied during long dry spells in both the years. Five random plants were selected from each plot excluding the border row for taking observation on growth and yield attributes. The representative dry sample of shoots and seeds were analyzed for ascertaining nutrient (N, P, K) content. The N, P and K content were analyzed by micro-kjeldahl, vanadomolybdophosphoric yellow colour and flame-photometery methods respectively (Jackson 1973). Data was statistically analysed by the procedure described by Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

*Growth character*

Nutrient management had significant influence on growth characters of clusterbean, viz plant height, drymatter accumulation and leaf area (Table 1). Significant variation in plant height due to nutrient management was recorded at 60 days after sowing and harvesting stages. Maximum plant height at these stages was registered with application of 100% recommended dose of fertilizer ($T_4$) which was significantly superior to all other nutrient management treatments except application of 75 % recommended dose of fertilizer and inoculation of both biofertilizers integrated with 50% recommended dose of fertilizer ($T_{10}$). Nutrient management had significant influence on drymatter accumulation at all the stages. Progressive improvement in drymatter accumulation was recorded with application of successive level of chemical fertilizers and difference in dry matter accumulation between 75 and 50 % of recommended dose of fertilizer ($T_3$, $T_2$) and 100 and 75 % of recommended dose of fertilizer ($T_4$, $T_3$) was significant at harvesting stage only. Inoculation of biofertilizers alone failed to cause significant improvement in drymatter accumulation over control. At harvesting highest drymatter accumulation was observed with application of 100% recommended dose of fertilizer ($T_4$) which being at par with integrated application of chemical fertilizer @ 50 % recommended dose of fertilizer with inoculation of both biofertilizers ($T_{10}$). Significant variations in number of branches/plant were recorded under different nutrient management treatments. Maximum number of branches was recorded under $T_{10}$ followed by $T_4$, $T_3$ and $T_8$. Application of chemical and biofertilizers brought significant improvement in leaf area over control. Application of chemical fertilizer @ 75 and 100% of recommended dose of fertilizer ($T_3$ and $T_4$) registered significantly higher leaf area over control at both stages, ie 30 and 60 days after sowing. At 60 days after sowing highest leaf area index (2.3) was recorded with application of 50 % recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria ($T_{10}$) which was at par with application of chemical fertilizer @ 50 and 75 % of recommended dose of fertilizer ($T_3$, $T_4$) and integration of 50 % recommended dose of fertilizer with single inoculation of *Rhizobium* ($T_8$) and phosphate solublising bacteria ($T_9$). The increased availability of nutrients with application of chemical fertilizers and biological nitrogen fixation by *Rhizobium* increased solublization of native and applied phosphorus by phosphate

Table1 Growth and yield characters of clusterbean as influenced by nutrient management (pooled data of 2 years)

| Treatment | Plant height (cm) | | | Dry matter accumulation (g /plant) | | | Branch/ plant | | Leaf area index/plant) | | Pods/ plant | Pod length (cm) | Seeds /pod | 1000-seeds weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS* | 60 DAS | Harvest | 30 DAS* | 60 DAS | Harvest | 30 DAS | 60 DAS | 30 DAS | 60 DAS | | | | |
| $T_1$ | 15.6 | 50.0 | 78.3 | 1.3 | 4.7 | 6.4 | 4.2 | 9.4 | 0.8 | 1.4 | 25.7 | 4.5 | 4.4 | 26.8 |
| $T_2$ | 16.2 | 66.5 | 88.7 | 1.4 | 6.0 | 7.9 | 4.3 | 11.4 | 1.0 | 1.9 | 28.3 | 5.7 | 5.5 | 27.8 |
| $T_3$ | 15.9 | 72.9 | 94.7 | 1.6 | 6.5 | 9.9 | 4.4 | 12.8 | 1.1 | 2.1 | 30.9 | 6.5 | 6.2 | 28.1 |
| $T_4$ | 16.3 | 76.3 | 103.3 | 1.7 | 7.2 | 12.7 | 4.4 | 13.5 | 1.2 | 2.2 | 32.5 | 6.8 | 6.4 | 29.4 |
| $T_5$ | 15.6 | 60.2 | 89.5 | 1.4 | 5.7 | 7.2 | 4.6 | 10.9 | 0.7 | 1.6 | 27.1 | 5.8 | 5.3 | 27.6 |
| $T_6$ | 15.3 | 57.4 | 58.0 | 1.3 | 5.6 | 7.1 | 4.0 | 10.6 | 0.7 | 1.7 | 27.5 | 5.8 | 5.2 | 27.6 |
| $T_7$ | 15.8 | 63.6 | 92.3 | 1.4 | 6.0 | 7.7 | 4.1 | 11.2 | 0.8 | 1.7 | 28.3 | 6.4 | 5.5 | 27.9 |
| $T_8$ | 16.5 | 67.9 | 95.0 | 1.6 | 6.5 | 9.1 | 4.4 | 12.6 | 1.1 | 2.1 | 29.9 | 6.4 | 5.9 | 28.2 |
| $T_9$ | 16.0 | 63.9 | 92.7 | 1.6 | 6.3 | 8.2 | 4.0 | 12.4 | 1.1 | 2.2 | 29.3 | 6.5 | 6.0 | 28.2 |
| $T_{10}$ | 17.5 | 72.8 | 99.7 | 1.7 | 7.1 | 11.3 | 4.4 | 13.9 | 1.1 | 2.3 | 32.3 | 7.2 | 6.5 | 29.8 |
| CD (*P*=0.05) | NS | 8.5 | 7.9 | 0.2 | 0.8 | 1.4 | NS | 1.8 | 0.2 | 0.3 | 2.7 | 0.9 | 0.8 | NS |

*DAS,Days after of sowing

$T_1$, Control; $T_2$, 50 % of recommended dose of fertilizer; $T_3$, 75 % of recommended dose of fertilizer; $T_4$, 100 % of recommended dose of fertilizer; $T_5$, *Rhizobium*; $T_6$, phosphate solublising bacteria; $T_7$ , *Rhizobium* + phosphate solublising bacteria; $T_8$, 50 % of recommended dose of fertilizer + *Rhizobium*; $T_9$ , 50 % of recommended dose of fertilizer + phosphate solublising bacteria ; $T_{10}$, 50 % of recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria

solublising bacteria. This might have favored the plant growth characters under aforesaid treatments. Singh and Singh (1989) also reported improvement in growth attributes of clusterbean with application of nutrients.

*Yield attributes*

Different nutrient supply strategies exhibited a variable response in influencing the yield attributes (Table 1). Application of chemical fertilizers @ 75 and 100 % of recommended dose of fertilizer ($T_3$, $T_4$), and integration of biofertilizer with 50 % recommended dose of fertilizer ($T_8$, $T_9$, $T_{10}$) resulted in significantly higher number of pods/plant than the control. Highest number of pods/plant were recorded with application of 100% recommended dose of fertilizer ($T_4$) which was at par with 75 % recommended dose of fertilizer ($T_3$) and integrated use of 50 % recommended dose of fertilizer with *Rhizobium* ($T_8$) and *Rhizobium* + phosphate solublising bacteria ($T_{10}$). Integrated use of inoculation of both biofertilizers with 50 % of recommended dose of fertilizer ($T_{10}$) recorded longest pod followed by 100 % recommended dose of fertilizer ($T_4$). Except single inoculation of phosphate solublising bacteria ($T_6$) all other nutrient management treatments brought significant improvement in number of seeds/pod over the control. Highest number of seeds/pod were registered with application of 50 % recommended dose of fertilizer with inoculation of *Rhizobium* and phosphate solublising bacteria ($T_{10}$) which was at par with 100 % recommended dose of fertilizer ($T_4$), 75% recommended dose of fertilizer ($T_3$), 50 % recommended dose of fertilizer + phosphate solublising bacteria ($T_9$) and 50 % recommended dose of fertilizer + *Rhizobium* ($T_8$). The variation in 1000-seed weight under various treatments was non-significant. Better growth associated with increased availability of plant nutrients might have resulted in better development of yield attributes under aforesaid treatments.

*Productivity*

Nutrient management had significant influence on seed, stover, and biomass productivity (Table 2). Application of chemical fertilizer registered significant improvement in seed yield and magnitude of increase with application of recommended dose of fertilizer by 50 % ($T_2$), 75 % ($T_3$) and 100 % ($T_4$) was 21.1, 45.6, and 50.9 % over the control, respectively. The difference in seed yield realized with $T_3$ and $T_4$ was non-significant. Inoculation of *Rhizobium* ($T_5$), phosphate solublising bacteria ($T_6$) and *Rhizobium* + phosphate solublising bacteria ($T_7$) recorded 21.1, 14.0 and 24.6 % higher seed yield than the control respectively. Significant response to inoculation of biofertilizer was reported by Meena *et al.* (2002). Further integration of biofertilizer with 50 % recommended dose of fertilizer brought significant improvement in seed yield over respective dose of chemical fertilizer and sole inoculation of biofertilizer. Highest seed yield was registered with application of 100 % recommended dose of fertilizer ($T_4$) followed by 75% recommended dose of fertilizer ($T_3$), 50 % recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria ($T_{10}$), and 50 % recommended dose of fertilizer + *Rhizobium* ($T_8$). The increased growth coupled with better expression of yield attributes might have attributed for enhancing the seed yield under aforesaid treatments. Application of chemical fertilizer at the rate of 50, 75 and 100% of recommended dose of fertilizer ($T_2$, $T_3$, $T_4$) resulted in 25.9, 38.9 and 45.1 % higher stover yield than the control respectively. Sole inoculation of biofertilizer have positive effect on stover yield and magnitude of improvement was highest with combined inoculation of *Rhizobium*+ phosphate solublising bacteria ($T_7$) followed by single inoculation of *Rhizobium* ($T_5$) and phosphate solublising bacteria ($T_6$). Integration of biofertilizer with 50% recommended dose of fertilizer ($T_8$, $T_9$, $T_{10}$) resulted in further improvement in stover yield as

Table 2 Effect of nutrient management on productivity, quality and economics of clusterbean (pooled data of 2 years)

| Treatment | Seed yield (tonnes/ ha) | Stover yield (tonnes/ha) | Total biomass yield (tonnes/ ha) | Harvest index (%) | Protein content (%) | Protein yield (kg /ha) | Total cost (Rs/ha) | Gross return (Rs/ ha) | Net return (Rs/ ha) | Benefit: cost ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 0.57 | 1.93 | 2.51 | 23.2 | 20.4 | 117.5 | 4 940.8 | 9 340.0 | 4 399.3 | 0.9 |
| $T_2$ | 0.69 | 2.43 | 3.12 | 22.1 | 24.0 | 167.3 | 5 384.8 | 11 400.0 | 6 015.3 | 1.1 |
| $T_3$ | 0.83 | 2.68 | 3.51 | 23.6 | 26.6 | 220.3 | 5 606.8 | 13 470.0 | 7 863.3 | 1.4 |
| $T_4$ | 0.86 | 2.80 | 3.66 | 23.6 | 27.0 | 233.0 | 5 828.8 | 13 980.0 | 8 151.3 | 1.4 |
| $T_5$ | 0.69 | 2.28 | 2.97 | 23.1 | 24.4 | 168.6 | 4 950.8 | 11 250.0 | 6 299.3 | 1.3 |
| $T_6$ | 0.65 | 2.23 | 2.88 | 22.6 | 24.1 | 157.3 | 4 955.8 | 10 680.0 | 5 724.3 | 1.2 |
| $T_7$ | 0.71 | 2.44 | 3.15 | 22.5 | 24.4 | 173.4 | 4 965.8 | 11 670.0 | 6 704.3 | 1.4 |
| $T_8$ | 0.81 | 2.52 | 3.33 | 24.2 | 25.7 | 207.5 | 5 281.2 | 13 050.0 | 7 768.8 | 1.5 |
| $T_9$ | 0.76 | 2.46 | 3.22 | 23.5 | 24.4 | 183.9 | 5 286.8 | 12 340.0 | 7 053.8 | 1.3 |
| $T_{10}$ | 0.82 | 2.85 | 3.67 | 22.3 | 27.2 | 223.5 | 5 296.8 | 13 510.0 | 8 213.8 | 1.6 |
| CD ($P$=0.05) | 0.11 | 0.29 | 0.34 | NS | 2.6 | 32.8 | | | | |

$T_1$, Control; $T_2$, 50 % of recommended dose of fertilizer; $T_3$, 75 % of recommended dose of fertilizer; $T_4$, 100 % of recommended dose of fertilizer; $T_5$, *Rhizobium*; $T_6$, phosphate solublising bacteria; $T_7$, *Rhizobium* + phosphate solublising bacteria; $T_8$, 50 % of recommended dose of fertilizer + *Rhizobium*; $T_9$, 50 % of recommended dose of fertilizer + phosphate solublising bacteria ; $T_{10}$, 50 % of recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria

compared to sole inoculation of biofertilizer ($T_5$,$T_6$, $T_7$). Highest stover yield was realized with inoculation of both biofertilizers with 50% recommended dose of fertilizer ($T_{10}$), which remained at par with 75% and 100% recommended dose of fertilizer ($T_3$, $T_4$). Application of chemical fertilizers brought significant improvement in biomass yield. Application of fertilizers @ 50, 75 and 100 % of recommended dose of fertilizer resulted in 24.3, 39.4 and 45.8 % higher biomass yield, respectively than control. Singh (2002) and Saxena *et al.* (2003) reported that application of 20 kg N + 40 kg $P_2O_5$ /ha recorded 36.0 and 41.8 % higher seed yield of clusterbean over the control respectively. Palsania *et al.* (2002) also reported significant improvement in productivity of clusterbean with application of 30 kg N + 60 kg $P_2O_5$ /ha.

*Nitrogen uptake*

Distinct variation in nutrient uptake was noticed under different nutrient management treatments (Table 3). Nutrient management had significant influence on nitrogen uptake by clusterbean. Application of chemical fertilizer @ 50, 75 and 100 % of recommended dose of fertilizer ($T_2$, $T_3$, $T_4$) resulted in 42.7, 76.8 and 84.6 % higher N uptake over the control respectively. Integrated use of chemical fertilizer @ 50 % of recommended dose of fertilizer with *Rhizobium* ($T_8$), phosphate solublising bacteria ($T_9$) and *Rhizobium* + phosphate solublising bacteria ($T_{10}$) recorded higher total nitrogen uptake over respective sole application of chemical fertilizer and biofertilizers.

*Phosphorus uptake*

Application of chemical and biofertilizers registered significantly higher total phosphorus uptake over control. Highest total phosphorus uptake was recorded with application of chemical fertilizer @ 100 % of recommended dose of fertilizer ($T_4$) which was significantly higher over all other treatments except integrated use of chemical fertilizer @ 50 % of recommended dose of fertilizer with *Rhizobium* + phosphate solublising bacteria ($T_9$). Application of chemical fertilizer @ 50, 75 and 100 % of recommended dose of fertilizer ($T_2$, $T_3$, $T_4$) resulted in 24.0, 42.0 and 62.0 % higher total phosphorus uptake over the control respectively. Inoculation of phosphate solublising bacteria ($T_6$) and integrated use of phosphate solublising bacteria with chemical fertilizer @ 50% of recommended dose of fertilizer ($T_9$) recorded 16.0 and 38.0 % higher total phosphorus uptake over control, respectively.

*Potassium uptake*

Distinct variation in potassium uptake was noticed under different nutrient management treatments. Application of chemical fertilizers @ 50, 75 and 100% of recommended dose of fertilizer ($T_2$, $T_3$, $T_4$) recorded 27.3, 46.5 and 51.7 % higher total potassium uptake over the control respectively. Highest uptake of potassium was recorded with application of chemical fertilizer @ 50 % of recommended dose of fertilizer with *Rhizobium* + phosphate solublising bacteria ($T_{10}$) which was at par with application of chemical fertilizer @ 75 and 100 % of recommended dose of fertilizer ($T_3$, $T_4$). The steady supply of nutrients with the use of chemical fertilizers and biofertilizers might have attributed to higher nutrient uptake under aforesaid treatments. The results corroborate the findings of Singh and Singh (1990).

*Protein content and yield*

Significant increase in protein content of seed of clusterbean was recorded up to application of 75 % of recommended dose of fertilizer ($T_3$)(Table 2). Inoculation of biofertilizer brought significant increase in protein content over control only. Highest protein content (27.2%) in seed was recorded with application of 50% recommended dose of

Table 3 Content and uptake of nutrients by clusterbean as influenced by nutrient management (pooled data of 2 years)

| Treatment | N content (%) | | P content (%) | | K content (%) | | N uptake (kg /ha) | | | P uptake (kg /ha) | | | K uptake (kg /ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed | Stover | Seed | Stover | Seed | Stover | Seed | Stover | Total | Seed | Stover | Total | Seed | Stover | Total |
| $T_1$ | 3.3 | 0.9 | 0.31 | 0.17 | 0.78 | 1.25 | 18.8 | 17.0 | 35.8 | 1.8 | 3.2 | 5.0 | 4.5 | 24.1 | 28.6 |
| $T_2$ | 3.8 | 1.0 | 0.32 | 0.16 | 0.76 | 1.28 | 26.8 | 24.3 | 51.1 | 2.2 | 4.0 | 6.2 | 5.3 | 31.1 | 36.4 |
| $T_3$ | 4.3 | 1.0 | 0.33 | 0.16 | 0.75 | 1.33 | 35.2 | 28.1 | 63.3 | 2.7 | 4.4 | 7.1 | 6.2 | 35.7 | 41.9 |
| $T_4$ | 4.3 | 1.0 | 0.33 | 0.19 | 0.89 | 1.28 | 37.3 | 28.8 | 66.1 | 2.9 | 5.3 | 8.1 | 7.7 | 35.7 | 43.4 |
| $T_5$ | 3.9 | 0.8 | 0.32 | 0.16 | 0.79 | 1.31 | 27.0 | 19.3 | 46.3 | 2.2 | 3.7 | 6.0 | 5.4 | 29.9 | 35.3 |
| $T_6$ | 3.9 | 0.9 | 0.32 | 0.17 | 0.83 | 1.30 | 25.2 | 19.7 | 44.9 | 2.1 | 3.7 | 5.8 | 5.4 | 28.7 | 34.1 |
| $T_7$ | 3.9 | 0.9 | 0.32 | 0.17 | 0.72 | 1.27 | 27.7 | 22.9 | 50.7 | 2.2 | 4.1 | 6.3 | 5.1 | 31.1 | 36.2 |
| $T_8$ | 4.1 | 1.0 | 0.33 | 0.18 | 0.77 | 1.31 | 33.2 | 25.1 | 58.3 | 2.7 | 4.5 | 7.2 | 6.2 | 33.1 | 39.3 |
| $T_9$ | 3.9 | 1.0 | 0.33 | 0.18 | 0.86 | 1.33 | 29.4 | 24.5 | 54.0 | 2.5 | 4.5 | 6.9 | 6.5 | 32.7 | 39.2 |
| $T_{10}$ | 4.4 | 1.0 | 0.33 | 0.17 | 0.86 | 1.36 | 35.8 | 27.3 | 63.0 | 2.7 | 4.9 | 7.6 | 7.1 | 38.7 | 45.8 |
| CD ($P$=0.05) | NS | NS | NS | NS | 0.08 | NS | 5.2 | 5.4 | 8.4 | 0.3 | 0.5 | 0.7 | 1.2 | 4.9 | 5.3 |

$T_1$, Control; $T_2$, 50 % of recommended dose of fertilizer; $T_3$, 75 % of recommended dose of fertilizer; $T_4$, 100 % of recommended dose of fertilizer; $T_5$, *Rhizobium*; $T_6$, Phosphate solublising bacteria; $T_7$, *Rhizobium* + phosphate solublising bacteria; $T_8$, 50 % of recommended dose of fertilizer + *Rhizobium*; $T_9$, 50 % of recommended dose of fertilizer + phosphate solublising bacteria ; $T_{10}$, 50 % of recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria

fertilizer with inoculation of both biofertilizers ($T_{10}$) followed by application of 100 % and 75 % of recommended dose of fertilizer ($T_3$, $T_4$). Among biofertilizers treatments, single inoculation of *Rhizobium* ($T_5$) and inoculation of *Rhizobium* + phosphate solublising bacteria ($T_7$) recorded 43.5 and 47.6 % higher protein yield over the control respectively. Further integration of 50 % recommended dose of fertilizer with *Rhizobium* ($T_8$), phosphate solublising bacteria ($T_9$) and *Rhizobium* + phosphate solublising bacteria ($T_{10}$) resulted in 23.1, 16.9 and 28.9 % higher protein yield over the respective sole biofertilizer treatments ($T_5$, $T_6$, $T_7$), respectively. Maximum protein yield was noticed with application of 100 % recommended dose of fertilizer ($T_4$) followed by 50 % recommended dose of fertilizer + *Rhizobium* + phosphate solublising bacteria ($T_{10}$), and 75 % of recommended dose of fertilizer ($T_3$). The increased protein yield might be attributed to higher content of protein and seed yield under aforesaid treatments.

*Economics*

Total cost of cultivation was highest under 100% recommended dose of fertilizer ($T_4$). However highest gross return (Rs 13 980/ ha) was recorded with application of 100 % recommended dose of fertilizer ($T_4$) followed by $T_{10}$ and $T_3$ (Table 2). The maximum net return was realized with integrated use of 50% recommended dose of fertilizer with inoculation of both biofertilizers ($T_{10}$). Integration of biofertilizer with chemical fertilizer ($T_8$, $T_{10}$) was more remunerative with higher benefit: cost ratio (1.5 and 1.6) than the sole application of chemical (1.1 to 1.4) and biofertilizers (1.3 to 1.4).

It can be concluded that nutrient management had favourable influence on growth, yield and nutrient uptake of clusterbean. Integrated use of chemical fertilizer @ 50 % of recommended dose of fertilizer with *Rhizobium* + phosphate solublising bacteria in clusterbean fetched maximum benefit : cost ratio and yield comparable to application of 100% recommended dose of fertilizer under arid rainfed condition.

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