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Nutrient status and yield of clusterbean [*Cyamopsis tetragonoloba* (L.)Taub] as influenced by fertility levels and liquid biofertilizers

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Abstract
A field experiment was conducted under loamy sand soil during kharif, 2016 at S.K.N. College of Agriculture, Jobner, Rajasthan study to the effect of fertility levels and organic manures on growth, yield and quality of clusterbean. The treatments consisted of four fertility levels i.e. F_0 (Control), F_1 (50% RDF), F_2 (75% RDF) and F_3 (100% RDF and four liquid biofertilizers i.e. B_0 (Control), B_1 (N-fixer), B_2 (P-fixer) and B_3 (N+P fixer) were replicated three times in randomized block design. The results showed that the seed, straw, biological yields, N, P and K content and uptake in seed and straw and protein content of clusterbean increased significantly with the increase in each level of applied fertilizer up to 75% RDF. However, there was no significant difference between 75% and 100% RDF. Results further indicated that seed inoculation with N+P fixer showed significantly highest seed, straw and biological yields K content in seed and straw, total uptake of N, P, K and protein content over all the treatments, while both P-fixer and N-fixer remained at par with each other but proved significantly superior over control. Based on the results of one years investigation, it can be concluded that Combined application of 75% RDF and N+P-fixer recorded significantly higher seed yield (1745 kg/ha) and proved equally effective as 100% RDF when combined with N+P-fixer.

Keywords: RDF, clusterbean, growth, liquid biofertilizers and yield

Introduction
Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] popularly known by its vernacular name "*Guar*" is an important legume crop mainly grown under rainfed conditions of arid and semi-arid regions of tropical India during *kharif* season. Clusterbean is grown for different purposes *viz*. vegetable, green fodder, green manuring, production of seed and for endospermic gum. Besides all these, it provides concentrate and fodder for cattle and adds to the fertility of soil by fixing considerable amount of atmospheric nitrogen. Seeds of clusterbean contain 28-33% gum. Clusterbean being a legume has the capacity to fix atmospheric nitrogen by its effective root nodules, the major requirement of nitrogen is met through *Rhizobium* present in the root nodules. Application of higher dose of nitrogen may reduce nodule number and nodule growth and thus adversely affects the nitrogen fixing capacity (Singh and Nair, 1995) [12]. In terms of significance, phosphorus is the most indispensable mineral nutrient for legume crops as it helps in better root growth and development and thereby making them more efficient in biological nitrogen fixation (BNF). Phosphorus is an essential constituent of nucleic acid (RNA and DNA), ADP and ATP, nucleoproteins and several co-enzymes.

Liquid biofertilizers are liquid formulations containing the dormant form of desired microorganisms and their nutrients along with the substances that encourage formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions. The dormant form on reaching the soil, germinate to produce fresh batch of active cells. These cells grow and multiply by utilizing the carbon source in the soil or from root exudates. The advantages of liquid biofertilizers over conventional carrier based biofertilizers are: longer shelf life (12-24 months), no effect of high temperature and no contamination, no loss of properties due to storage at high temperature up to 45 ^{0}C, high populations can be maintained i.e. more than 10^9 cells/ ml up to 12 to 24 months, easy to use by the farmers, high export potential, dosages are 10 times less than carrier-based inoculants, quality control protocols are easy and quick.

Several strains of phosphate solubilizing bacteria and fungi are isolated. The mechanism action of these microorganisms involve secretion of organic acids which lower the pH and increase the availability of sparingly soluble phosphorus sources. Phosphate solubilizing bacteria change the unavailable phosphorus of soil in available form for crop. Inoculation of seeds with phosphate solubilizing bacteria increases nodulation, crop growth, nutrient uptake and crop yield (Shubhangi *et al*, 2008) [10]. A combination of chemical and biological sources of nitrogen and phosphorus seems to be a cheap and effective way of increasing production under limited resources.

Materials and Methods

A field experiment was carried out during the kharif season, 2016 at S.K.N. College of Agriculture, Jobner (26^0 05' North, longitude of 75^0 28' East and at an altitude of 427 metres above mean sea level), Rajasthan. The soil was sandy loam having bulk density 1.52 Mg/m^3, pH 8.03. The soil was poor organic carbon (0.21%), low available nitrogen (126.3 kg/ha) and phosphorus (19.2 kg/ha) and medium in potassium (150.3 kg/ha). The experiment was laid out in randomized block design with three replications. The treatments comprising four fertility levels i.e. F_0 (Control), F_1 (50% RDF), F_2 (75% RDF) and F_3 (100% RDF and four liquid biofertilizers i.e. B_0 (Control), B_1 (N-fixer), B_2 (P-fixer) and B_3 (N+P fixer). Clusterbean variety "RGC-1038" was sown on 14th July, 2016 and on harvested at 22th October, 2016. Seed @ 20 kg/ha was taken with 30 cm row spacing. Crop was raised with recommended package of practices of weed management 30 days after sowing was used. Three irrigations were applied during growing season. A recommended dose of fertilizer was 20:40:0 kg N, P_2O_5 and K_2O/ha as per treatments. Half dose of nitrogen and full dose of phosphorus was applied as basal dose through urea and DAP, remaining dose of nitrogen was top dressed at the time of first and second irrigation. The biofertilizer applied as per treatments. Harvesting of clusterbean was done from each net plot when ears were dry. The harvested material of each plot was tied up in bundles separately, tagged and kept on the threshing floor for sun drying. The threshing was done manually by beating the dried bundles of each plot separately with wooden sticks followed by winnowing. Grain yield recorded in kg/plot was converted to kg/ha.

Results and Discussion

Yield

Effect of fertility levels

It is evident from data (Table 1) that seed, straw and biological yields were significantly influenced due to increasing levels of fertilizer up to 75% RDF whereas, it was at par with 100% RDF in respect of the above parameter. The overall improvement in vigour and crop growth as explained in preceding paragraphs due to adequate supply of nitrogen early in the life of a plant is considered important in promoting rapid vegetative growth and biomass. At later stage in reproductive phase when the current photosynthesis is not able to furnish the increased assimilate demand of the plant sinks, the storage compounds probably remobilize and move to active sinks (pods and seeds) which ultimately increased number of pods and seeds per pod. During leaf senescence also, carbohydrates, nitrogenous compounds, phosphorus and other mobile nutrients are remobilized and translocated to current plant sinks i.e. seeds which are very close to the source resulting into higher test weight due to bold seed formation. the increased supply of N, P and K and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and resulted in increased seed and straw yields. The biological yield is a function of seed and straw yields. Thus, significant increase in biological yield with the application of N and P could be ascribed due to increased seed and straw yield. The results of present investigation are in line with those of Reddy *et al.* (2011) [8] and Singh and Kumar (2016) [11] who obtained increased yield attributes, seed yield per plant, seed, straw and biological yields with the combined application of fertilizers (N and P) up to optimum level.

Effect of liquid biofertilizers

It is further evident from data (Table 1) that combined application of N+P-fixer proved significantly superior as compared to all the other treatments. Application of N-fixer and P-fixer individually remained at par with each other but both significantly increased the seed, straw and biological yields over control.

Inoculation of seed with N-fixer might have increased the concentration of an efficient and healthy strain of *Rhizobium* in rhizosphere, which in turn resulted in greater fixation of atmospheric nitrogen in soil for use by the plants and consequently resulting into higher plant growth, which in turn resulted in higher production of assimilates and their partitioning to different reproductive structures such as yield attributes and ultimately the seed yield increased over no inoculation. The increase in straw yield was the result of increased plant growth in terms of dry matter production and number of branches due to overall better nutritional environment in the rhizosphere (Kumawat and Khangarot, 2002) [5]. Greater root extension under higher availability of phosphorus might have helped in greater uptake of other nutrients especially micronutrient and secondary nutrients, enhanced photosynthates and their partitioning between vegetative and reproductive structure might have helped in improving the yield attributes (number of pods per plant, number of seeds per pod, test weight and seed yield per plant) and finally the seed yield over no inoculation (Singh *et al.*, 2012). These findings corroborate the results of Chattopadhyay and Dutt (2003) [2] and Khan *et al.* (2012) [4].

Quality parameters

Effect of fertility levels

Results indicated that N, P and K content in seed and straw as well as total uptake and protein content increased significantly with the increase in each level of applied fertilizer up to 75% RDF. However, there was no significant difference between 75% and 100% RDF (Table 2). Another reason for higher nitrogen content might be due to increased activity of nitrate reductase enzyme. Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. The influence of applied nitrogen and phosphorus and higher N_2 fixation by root nodules, the availability of these nutrients in soil increased and consequently resulted to higher uptake by plants. These results are in close conformity with the findings of Reddy *et al.* (2011) [8] and Singh and Kumar *et al.* (2016) [11].

Effect of liquid biofertilizers

The results further indicated that the seed inoculation with N+P fixer showed significantly highest K content in seed and straw, total, N, P and K uptake and protein content over all the treatments, while both P-fixer and N-fixer remained at par with each other but proved significantly superior over control (Table 2). Application of N+P fixer proved significantly higher as compared to all the treatments except N-fixer. Inoculation of seed with P-fixer also increased the phosphorus concentration in seed and straw over control and N-fixer. The increase in these values due to inoculation of seed with N-fixer was probably due to more fixation of nitrogen resulting in to better utilization of nutrients by plants, which led to more chlorophyll formation and ultimately nitrogen concentration in seed and straw and protein content in seed. P-fixer enhanced the availability of phosphorus to plants, which might have utilized by the crop in greater root development and nodulation that in turn resulted in higher nitrogen fixation in the soil by nodules (Nagar and Meena, 2004) [7].

Inoculation of N-fixer and P-fixer was more beneficial in enhancing all the above parameters due to increased solublization and mineralization of organic phosphorus and availability of nitrogen and phosphorus. These results corroborate the findings of Bahadur *et al*. (2006) and Vanitha *et al*. (2014) [13].

Based on the results of one years investigation, it can be concluded that Combined application of 75% RDF and N+P-fixer recorded significantly higher seed yield (1745 kg/ha) and quality of clusterbean proved equally effective as 100% RDF when combined with N+P-fixer.

Table 1: Effect of fertility levels and liquid biofertilizers on yield attributes and yield of clusterbean

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
Fertility Levels				
F_0: Control	954	2385	3339	28.8
F_1: 50% RDF	1264	3186	4450	28.5
F_2: 75% RDF	1432	3632	5064	28.3
F_3: 100% RDF	1488	3725	5213	28.0
SEm$\pm$	37	93	130	0.7
CD (P=0.05)	106	269	376	NS
Liquid Biofertilizers				
B_0: Control	1014	2597	3610	28.8
B_1: N-fixer	1274	3206	4480	28.5
B_2: P-fixer	1349	3370	4719	28.2
B_3: N+ P fixer	1502	3755	5257	28.1
SEm$\pm$	37	93	130	0.7
CD (P=0.05)	106	269	376	NS

Table 2: Effect of fertility levels and liquid biofertilizers on nutrient content and uptake by clusterbean

Treatments	Nitrogen content (%)		Total N uptake (kg/ha)	Protein Content (%)	Phosphorus content (%)		Total P uptake (kg/ha)	Potassium Content (%)		Total K uptake (kg/ha)
	Seed	Straw			Seed	Straw		Seed	Straw	
Fertility Levels										
F_0: Control	2.901	0.821	47.4	19.7	0.253	0.142	5.8	0.370	0.894	24.9
F_1: 50% RDF	3.586	1.003	77.6	22.9	0.318	0.170	9.5	0.458	1.118	41.6
F_2: 75% RDF	3.763	1.045	92.6	25.1	0.334	0.182	11.5	0.496	1.173	50.1
F_3: 100% RDF	3.821	1.063	97.2	25.6	0.338	0.186	12.0	0.504	1.189	52.2
SEm$\pm$	0.056	0.010	2.3	0.6	0.005	0.002	0.3	0.007	0.007	1.3
CD (P=0.05)	0.163	0.028	6.7	1.9	0.015	0.007	0.8	0.021	0.022	3.6
Liquid Biofertilizers										
B_0: Control	3.256	0.929	57.6	20.4	0.293	0.157	7.1	0.423	1.039	31.5
B_1: N-fixer	3.616	1.010	79.8	24.6	0.301	0.165	9.3	0.445	1.068	40.7
B_2: P-fixer	3.420	0.958	79.7	22.3	0.317	0.175	10.4	0.467	1.091	43.8
B_3: N+ P fixer	3.778	1.035	97.7	26.1	0.331	0.181	12.0	0.494	1.176	52.7
SEm$\pm$	0.056	0.010	2.3	0.6	0.005	0.002	0.3	0.007	0.007	1.3
CD (P=0.05)	0.163	0.028	6.7	1.9	0.015	0.007	0.8	0.021	0.022	3.6

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