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Effect of Nutrient Management on Growth and Yield of Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub)

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Abstract
Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub**)**) is a climate-resilient legume extensively cultivated in arid and semi-arid regions for its multipurpose value. A field experiment was conducted during the Kharif season of 2024 at Suresh Gyan Vihar University, Jaipur, to assess the effect of various nutrient management practices on the growth and yield of clusterbean. Ten treatments involving combinations of RDF (Recommended Dose of Fertilizers), Rhizobium, and phosphate-solubilizing bacteria (PSB) were evaluated in a randomized block design. Results revealed that 100% RDF (T_4) significantly enhanced plant height (81.19 cm), dry matter accumulation (72.00 g plant^{-1}), number of branches per plant (14.36), number of pods per plant (23.50), and number of seeds per pod (9.00). This treatment also recorded the highest seed yield (942 kg ha^{-1}) and straw yield (2548 kg ha^{-1}). Notably, the integrated treatment T_{10} (50% RDF + Rhizobium + PSB) performed comparably, confirming the potential of integrated nutrient management in improving clusterbean productivity sustainably under dryland conditions.

Keywords: Clusterbean, integrated nutrient management, growth, yield, biofertilizers

1. Introduction

Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub).), commonly known as guar, is a drought-hardy legume predominantly grown in arid and semi-arid regions due to its ability to withstand high temperatures, low rainfall, and poor soil fertility (Saha *et al*., 2018) [18]. Native to the Indian subcontinent, it is valued for its multipurpose use as food, fodder, green manure, and as a source of industrially significant guar gum. Its adaptability and agronomic resilience have made it an important crop, especially in rainfed agricultural systems (Dave *et al*., 2024) [5]. India is the leading producer, contributing about 80% of the global clusterbean production, with Rajasthan being the highest in both area and output (Anonymous, 2023) [3]. Despite its potential, productivity is often limited by suboptimal nutrient management and poor soil fertility in dryland regions. Although clusterbean can biologically fix atmospheric nitrogen through Rhizobium symbiosis (Saha *et al*., 2017) [19], it still requires external nitrogen during early growth stages. Overuse of nitrogen, however, can inhibit nodulation and reduce nitrogen fixation efficiency (Soumare *et al*., 2020) [23]. Phosphorus is another critical nutrient for legume growth, influencing root development and nodule function, but is often unavailable in arid soils due to fixation (Khare *et al*., 2025) [10].

Integrated nutrient management (INM), involving the use of organic, inorganic, and biological sources such as phosphorus-solubilizing microorganisms (PSMs) and arbuscular mycorrhizal fungi (AMF), has shown promise in improving nutrient availability, crop yield, and soil health (Choudhary *et al*., 2020) [4]. These biofertilizers enhance nutrient mobilization, phytohormone production, and soil microbial activity, contributing to sustainable crop production. Despite their benefits, adoption of biofertilizers is limited due to lack of awareness, poor product quality, and inadequate distribution systems (Masso *et al*., 2013) [13]. Therefore, systematic research on nutrient management strategies is essential to optimize productivity and economic viability in clusterbean-based cropping systems (Al-Suhaibani *et al*., 2020) [2]. Hence, the present study was undertaken with the following objectives to study the impact of nutrient management on growth, yield, and quality of clusterbean and to evaluate the effect of nutrient management on nutrient content and uptake in clusterbean.

2. Materials and Methods

A field experiment entitled "Effect of Nutrient Management on Growth and Yield of Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub)" was carried out during the Kharif season of 2024 at the Agronomy Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan. The experimental site is situated on the southeastern periphery of Jaipur city and lies at 26°49' North latitude and 75°51' East longitude, with an average altitude of 390 meters above mean sea level. The region falls under Agro-climatic Zone IIIa, known as the Semi-Arid Eastern Plain Zone of Rajasthan, characterized by low and erratic rainfall, high evapotranspiration, and sandy loam soils with low fertility. The experiment was conducted using ten different nutrient management treatments, laid out in a Randomized Block Design (RBD) with three replications to minimize experimental error (Panse and Sukhatme, 1985) [16]. The total number of plots was thirty (10 treatments × 3 replications). Each plot had a gross size of 4.0 m × 3.0 m (12.0 m²) and a net plot area of 3.0 m × 1.8 m (5.4 m²) was used for data collection. The clusterbean variety used for the study was 'Karan Guar 1', sown at a spacing of 30 cm × 10 cm using a seed rate of 20 kg ha⁻¹. The experimental layout followed the random allocation of treatments as per the method of Fisher and Yates (1963) [8]. The ten treatments included: T_0 - Control, T_1 - 50% Recommended Dose of Fertilizers (RDF), T_2 - 75% RDF, T_3 - 100% RDF, T_4 - Rhizobium (liquid formulation), T_5 - Phosphate Solubilizing Bacteria (PSB, liquid), T_6 - Rhizobium + PSB, T_7 - 50% RDF + Rhizobium, T_8 - 50% RDF + PSB, and T_9 - 50% RDF + Rhizobium + PSB. RDF was applied as per the general fertilizer recommendation for clusterbean cultivation in the region. The crop was harvested on 7th November 2024. Biological yield, grain yield, and straw yield were recorded from the net plot area. Post-harvest, the plant samples were bundled, labeled, and sun-dried before threshing. Threshing was performed manually by beating with wooden sticks, followed by winnowing using traditional methods. Grain and straw yields were weighed using a physical balance and expressed in kg per plot, which were later converted to kg ha⁻¹.

Biometric observations were recorded from five randomly selected and permanently tagged plants in each plot. Growth parameters such as plant stand per metre row length were assessed at 20 days after sowing (DAS) and at harvest. Plant height (cm) and dry matter accumulation (g plant⁻¹) were recorded at 30 DAS, 60 DAS, and harvest. Dry matter was measured by oven-drying samples at 70°C until constant weight. Whereas, the number of branches per plant was observed at 60 DAS and at harvest stage. Yield attributes included, number of pods per plant, and number of seeds per pod, which were counted from the tagged plants at harvest. For yield estimation, seed yield was recorded from the net plot and converted to kg ha⁻¹. Straw yield was calculated by subtracting the seed yield from the biological yield. All collected data were subjected to appropriate statistical analysis to interpret treatment effects.

3. Results and Discussion

3.1 Growth attributes

The data on plant stand (plants m⁻¹ row length) at 20 days after sowing (DAS) and at harvest showed no statistically significant differences among the nutrient management treatments (Table 1), despite slight numerical variations ranging from 9.71 to 10.00 plants m⁻¹ at 20 DAS. This indicates that nutrient application had no marked influence on plant population. The uniformity in plant stand suggests that early establishment in clusterbean is mainly affected by factors such as seed viability, soil moisture, and field conditions, rather than nutrient availability. Similar observations were reported by Pandey *et al*. (2019) [15] and Gamit *et al*. (2022) [9], who emphasized that in legumes, plant population is more dependent on sowing quality and environmental factors than on early-stage nutrient inputs.

The effect of nutrient management treatments on plant height of clusterbean at 30 DAS, 60 DAS, and harvest (Table 1) and Significant variation was observed across all growth stages. At 30 DAS, the tallest plants (21.63 cm) were recorded under 100% RDF (T_4), followed by 75% RDF-T_3 (19.26 cm) and 50% RDF + Rhizobium + PSB -T_{10} (18.39 cm), while the shortest plants were found in the control (T_1) at 12.39 cm. This trend continued at 60 DAS, where T_4 again showed the highest plant height (64.20 cm), followed by T_3 (62.90 cm) and T_{10} (60.04 cm). The control remained significantly lower (40.44 cm). At harvest, T_4 maintained its superiority (81.19 cm), with T_3 (77.68 cm) and T_{10} (74.15 cm) also performing well, whereas T_1 showed the lowest height (49.94 cm). These results confirm that plant height in clusterbean responds significantly to nutrient application, especially macro-nutrients like nitrogen and phosphorus, which are essential for chlorophyll formation, cell elongation, and energy transfer (Fathi, 2022) [7]. The comparable performance of T_{10} to higher RDF levels indicates the synergistic effect of integrated nutrient management, where Rhizobium enhances nitrogen fixation and PSB improves phosphorus solubilization, thus promoting vegetative growth. Similar outcomes were reported by Sharma *et al*. (2019) [20] and Gamit *et al*. (2022) [9], highlighting the advantage of combining chemical and biofertilizers in legume cultivation under semi-arid conditions.

Table 1: Plant stand and height of clusterbean as influenced by nutrient management practices

Treatments	Plant stand (m⁻¹ row length)		Plant height (cm)		
	20 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: Control	9.71	9.49	12.39	40.44	49.94
T_2: 50% RDF	9.81	9.60	17.81	58.14	71.81
T_3: 75% RDF	9.92	9.71	19.26	62.90	77.68
T_4: 100% RDF	10.00	9.79	21.63	64.20	81.19
T_5: Rhizobium liquid	9.77	9.56	14.26	46.56	57.50
T_6: PSB liquid	9.72	9.51	14.18	46.29	57.17
T_7: Rhizobium + PSB	9.78	9.56	14.79	48.28	59.62
T_8: 50% RDF + Rhizobium	9.86	9.64	18.12	59.15	73.05
T_9: 50% RDF + PSB	9.85	9.64	17.99	58.73	72.54
T_{10}: 50% RDF + Rhizobium + PSB	9.89	9.68	18.39	60.04	74.15
S.Em±	0.29	0.29	0.50	1.63	2.01
LSD (p=0.05)	NS	NS	1.48	4.83	5.97

Dry matter accumulation in clusterbean was significantly influenced by nutrient management at all growth stages (Table 2). At 30 DAS, the highest accumulation was observed under 100% RDF -T_4) (10.92 g plant^{-1}), followed by 75% RDF-T_3 (9.73 g) and 50% RDF + Rhizobium + PSB-T_{10} (9.29 g), while the control (T_1) recorded the lowest (6.26 g). Similar trends continued at 60 DAS and harvest, with T_4 consistently showing the highest biomass (53.00 g and 72.00 g), statistically at par with T_3 and T_{10}. The control treatment remained significantly lower at all stages. The results highlight the positive impact of balanced and integrated nutrient supply on biomass production by enhancing nutrient uptake, root growth, and photosynthetic efficiency. Biofertilizer use (T_{10}) proved nearly as effective as higher chemical inputs, indicating a synergistic effect. These findings are in agreement with Pandey *et al*. (2019) [15] and Gamit *et al*. (2022) [9].

Table 2: Number of branches and dry matter accumulation of clusterbean as influenced by nutrient management

Treatments	Number of branches plant^{-1}		Dry matter accumulation (g plant^{-1})		
	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: Control	6.50	7.84	6.26	32.47	44.54
T_2: 50% RDF	9.34	11.28	8.99	46.69	64.03
T_3: 75% RDF	10.11	12.20	9.73	50.50	69.27
T_4: 100% RDF	11.00	14.36	10.92	53.00	72.00
T_5: Rhizobium liquid	7.48	9.03	7.20	37.38	51.27
T_6: PSB liquid	7.44	8.98	7.16	37.17	50.98
T_7: Rhizobium + PSB	7.76	9.36	7.47	38.76	53.17
T_8: 50% RDF + Rhizobium	9.50	11.47	9.15	47.49	65.14
T_9: 50% RDF + PSB	9.44	11.39	9.09	47.16	64.68
T_{10}: 50% RDF + Rhizobium + PSB	9.65	11.64	9.29	48.21	66.12
S.Em±	0.26	0.32	0.25	1.31	1.79
LSD (p=0.05)	0.78	0.94	0.75	3.88	5.32

The number of branches per plant in clusterbean was significantly affected by nutrient management at 60 DAS and harvest (Table 2). At 60 DAS, the highest number of branches (11.00) was recorded under 100% RDF (T_4), followed by 75% RDF-T_3 (10.11) and 50% RDF + Rhizobium + PSB -T_{10} (9.65). The control (T_1) recorded the lowest value (6.50). Treatments with integrated nutrient use (T_8, T_9, T_{10}) performed better than sole biofertilizer applications. At harvest, T_4 again recorded the maximum number of branches (14.36), followed by T_3 (12.20) and T_{10} (11.64), while the control remained lowest (7.84). The enhanced branching in T4 and integrated treatments indicates improved axillary bud growth, driven by better nutrient availability, particularly nitrogen and phosphorus. Nutrient-induced cytokinin activity, linked to nitrate availability, plays a key role in promoting branching (Ahmad *et al*., 2023) [1]. The strong performance of T_{10} also supports the role of biofertilizers in nutrient substitution and improved nutrient use efficiency, as noted by Nikam *et al*. (2018) [14].

3.2 Yield attributes and yield

Nutrient management practices significantly influenced both the number of pods per plant and seeds per pod in clusterbean (Table 3). The highest number of pods (23.50) was recorded under 100% RDF (T_4), statistically at par with 75% RDF-T_3 (22.27) and 50% RDF + Rhizobium + PSB-T_{10} (21.26). Treatments such as T_8 (20.94) and T_9 (20.80) also produced significantly more pods than the control -T_1 (14.32). Similarly, seeds per pod were highest in T_4 (9.00), followed by T_3 (8.20) and T_{10} (7.83), all significantly outperforming the control (5.27) and sole biofertilizer treatments. This indicates that nutrient availability—particularly in integrated treatments—enhanced pod setting and seed development. The improved pod and seed numbers are attributed to better vegetative growth, assimilate supply, and hormonal balance under nutrient-rich conditions, which stimulate floral initiation and reproductive efficiency (Singh *et al*., 2023) [22]. Higher nutrient uptake, especially of nitrogen and phosphorus, likely supported enhanced pollen viability, embryo development, and seed filling (Kumar *et al*., 2018) [11]. These results align with findings by Prajapati *et al*. (2020) [17], and Sharma *et al*. (2019) [20], affirming the effectiveness of integrated nutrient management in improving yield attributes in legumes.

Table 3: Yield attributes and yield of clusterbean as influenced by nutrient management practices

Treatments	Number of pods/ plant	Number of Seed/ pod	Seed yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})
T_1: Control	14.32	5.27	539	1895
T_2: 50% RDF	20.59	7.58	775	2346
T_3: 75% RDF	22.27	8.20	839	2344
T_4: 100% RDF	23.50	9.00	942	2548
T_5: Rhizobium liquid	16.48	6.07	621	1990
T_6: PSB liquid	16.39	6.03	617	2066
T_7: Rhizobium + PSB	17.09	6.29	644	2014
T_8: 50% RDF + Rhizobium	20.94	7.71	789	2326
T_9: 50% RDF + PSB	20.80	7.66	783	2330
T_{10}: 50% RDF + Rhizobium + PSB	21.26	7.83	801	2334
S.Em±	0.58	0.21	22	64
LSD (p=0.05)	1.71	0.63	64	191

Nutrient management practices significantly influenced seed and straw yield in clusterbean (Table 3). The highest yield (942 kg ha⁻¹) was recorded under 100% RDF (T_4), which was statistically at par with 75% RDF-T_3 (839 kg ha^{-1}) and 50% RDF + Rhizobium + PSB-T_{10} (801 kg ha^{-1}). The lowest yield was observed in the control-T_1 (539 kg ha^{-1}). These results reflect the positive impact of nutrient availability on yield attributes such as pod and seed formation, driven by improved photosynthesis and assimilate partitioning (Fang *et al*., 2019) [6]. Straw yield followed a similar trend, with T_4 (2548 kg ha^{-1}) producing the highest biomass, statistically at par with T_3 (2344 kg ha^{-1}) and T_{10} (2334 kg ha^{-1}). The control treatment recorded the lowest straw yield (1895 kg ha^{-1}). Integrated treatments involving 50% RDF with biofertilizers (T_8-T_{10}) also outperformed sole inoculant applications, indicating synergistic effects on vegetative growth and delayed senescence (Wen *et al*., 2024) [24]. Overall, treatments that enhanced both seed and straw yield also maximized biological yield, confirming the role of balanced and integrated nutrient supply in optimizing crop productivity. These findings are in line with earlier studies by Kumawat *et al*. (2017) [12], Singh *et al*. (2018) [21], Sharma *et al*. (2019) [20] and Gamit *et al*. (2022) [9], which emphasize the effectiveness of integrated nutrient management in improving yield outcomes in legumes.

4. Conclusion

The study clearly demonstrated that nutrient management significantly influenced the growth, yield attributes, and productivity of clusterbean. While plant stand remained unaffected, parameters such as plant height, dry matter accumulation, and number of branches showed marked improvement under 100% RDF, followed closely by 75% RDF and 50% RDF + Rhizobium + PSB. Yield attributes like pods per plant and seeds per pod, as well as seed and straw yields, were also significantly enhanced under these treatments. Notably, the integrated approach (50% RDF + biofertilizers) performed comparably to higher fertilizer doses, indicating its potential to reduce chemical inputs while maintaining productivity. These findings highlight the effectiveness of integrated nutrient management as a sustainable strategy for improving clusterbean performance in semi-arid regions.

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