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INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON NUTRIENT CONTENT, GROWTH AND QUALITY OF CLUSTER BEAN AND BARLEY IN A CLUSTER BEAN-BARLEY CROPPING SYSTEM

Pravin N. Gajbhiye*, Manoj Pandey and Raj Bahadur Singh

Department of Agricultural Chemistry and Soil Science, Raja Balwant Singh College, Bichpuri Agra (U.P.) 283 105, India.
*Corresponding author Email: npraving@gmail.com

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ABSTRACT

Integrated Nutrient Management enhances soil fertility and crop productivity in legume-cereal systems by integrating organic, inorganic, and biological nutrients, improving nitrogen fixation, soil health, and nutrient efficiency while reducing chemical fertilizer dependence. The present investigation was initiated was laid out in randomized block design comprising of ten treatments with three replications. The treatments consisted T_1: control, T_2: 100% recommended dose of fertilizer (RDF), T_3: 75 % RDF, T_4: 50% RDF, T_5: 50% RDF+$ZnSO_4$ @ 20 kg ha^{-1}, T_6: 50% RDF+FYM @ 5 t ha^{-1}, T_7: 50% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1}, T_8: 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1}, T_9: 75% RDF+FYM @ 5 t ha^{-1}, T_{10}: 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1}. The findings revealed that the application of 75% RDF combined with $ZnSO_4$ @ 20 kg ha^{-1} and FYM @ 5 t ha^{-1} resulted in the highest and statistically significant improvement in growth parameters of *kharif* cluster bean and the subsequent *rabi* barley crop. However, most growth attributes remained statistically comparable to the treatment receiving 100% RDF for the respective crops, indicating the efficacy of integrated nutrient management in sustaining crop performance with reduced chemical fertilizer input. The application of 75% RDF + $ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} resulted in the highest total N, P, and K concentrations in both cluster bean seed and stover, with statistically significant differences compared to other treatments. However, these values were statistically comparable to all treatments except those receiving 75% RDF and 50% RDF without FYM. This treatment also recorded the highest total Zn content in cluster bean, demonstrating significant superiority over all other treatments. In barley, total N, P, and K content in both grain and straw did not exhibit significant variation across treatments. However, the highest total Zn content in barley grain (22.15 mg kg^{-1}) was observed in the 75% RDF + $ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} treatment, which was significantly superior to all other treatments.

The application of 75% RDF + $ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} significantly enhanced gum content in cluster bean, whereas protein content remained statistically unaffected across treatments. In barley, although starch and protein content exhibited a numerical increase under integrated nutrient management, the differences were not statistically significant among treatments. Overall, the integrated application of organic and inorganic nutrient sources improved growth parameters and crop quality, underscoring its role in promoting sustainable crop production in the nutrient-deficient soils of Agra.

***Key words*:** Barley, Cluster bean, growth, nutrient content, quality .

Introduction

Cluster bean (*Cyamopsis tetragonoloba* L. Taub), commonly known as "Guar," is a leguminous vegetable crop native to India and belongs to the family Leguminosae (Hymowitz and Upadhya 1963). It is a significant legume cultivated in both irrigated and rainfed conditions, particularly during the summer and monsoon seasons. Guar is highly resilient to drought and thrives in arid regions, making it well-suited to the climatic and soil conditions of Agra. The young green pods of guar are consumed as a vegetable, while the entire plant serves as fodder for livestock. Additionally, guar seed endosperm contains 19-43% galactomannan gum, which forms a viscous gel in cold water (Chavan *et al*., 2015). It is widely used as a thickening and stabilizing agent in various sectors, including food processing, pharmaceuticals, textiles, and cosmetics (Baviskar *et al*., 2010). Whereas, barley (*Hordeum vulgare* Linn.) is among the earliest cultivated cereal grains and has played a crucial role in human sustenance since ancient times (Baik, 2016). This hardy cereal can be grown in different landscapes, including plains and hills, and is suited for both rainfed and irrigated conditions (Singh *et al*., 2016). While barley was historically consumed as a staple food, the availability of other widely preferred cereals like wheat and rice led to its primary use in livestock feed, brewing, and malting industries (Baik *et al*., 2008). Currently, barley serves various purposes based on regional demands. In developed nations, it is mainly used as animal fodder, whereas in developing countries, it remains a key dietary component. Economically, its most significant applications are in malt and beer production. Global statistics indicate that around 70% of barley is utilized as animal feed, 21% for brewing and distillation, and approximately 6% for direct human consumption (Tricase *et al*., 2018). With increasing consumer awareness regarding health benefits and natural foods, barley is now gaining recognition as a functional food. Advancements in research have highlighted its nutritional properties and potential health benefits, leading to a renewed interest in its consumption worldwide. Incorporating legumes into cropping systems increases overall productivity and yield stability. A legume-based cropping system is a sustainable agricultural practice that integrates legumes into crop rotations or intercropping arrangements to enhance soil fertility, improve crop productivity, and promote environmental sustainability. Legumes form symbiotic associations with nitrogen-fixing bacteria (*Rhizobium* spp.), which convert atmospheric nitrogen into a plant-available form, reducing the dependence on synthetic fertilizers (Peoples *et al*., 2009). Studies have shown that crop rotations involving legumes result in higher yields of subsequent cereal crops due to improved soil nutrient availability and organic matter content (Franke *et al*., 2018). Additionally, legumes contribute to soil microbial diversity, further enhancing nutrient cycling (Vanlauwe *et al*., 2019). Legume-based cropping systems enhance soil health by increasing organic matter, improving soil aggregation, and reducing compaction (Lal, 2015). The deep root systems of certain legumes help break hardpans, promoting better water infiltration and aeration (Doran and Zeiss, 2000).

Integrated Nutrient Management (INM) is a sustainable approach that optimizes soil fertility and crop productivity by combining organic, inorganic, and biological nutrient sources. In legume-cereal based cropping systems, INM enhances nitrogen fixation, improves soil health, and increases nutrient use efficiency while reducing reliance on chemical fertilizers (Dwivedi *et al*., 2016; Jat *et al*., 2020). Legumes contribute to biological nitrogen fixation, benefiting subsequent cereal crops, while INM practices further enhance nutrient recycling, organic matter buildup, and microbial activity (Ladha *et al*., 2016; Reddy *et al*., 2019). This approach ensures long-term agricultural sustainability by improving yield stability, reducing environmental impacts, and enhancing soil resilience to degradation (Choudhary *et al*., 2021; Sapkota *et al*., 2019). It optimizes biomass accumulation, increases essential nutrient uptake, and enhances fodder and grain quality, contributing to better crop productivity and sustainability (Dwivedi *et al*., 2016; Choudhary *et al*., 2021). Given the advantages of integrated nutrient management and the legume-cereal cropping sequence, this study was undertaken to assess the impact of combined organic and inorganic nutrient sources on the growth parameters and quality of cluster bean and barley in a sequential cropping system.

Materials and methods

The experiment was carried out at Department of Agricultural Chemistry and Soil Science, R.B.S. College Research farm Bichpuri, Agra (U.P.) for two consecutive years with cluster bean as *kharif* crop followed by barley during *Rabi* season. Geographically the Agra district is located on South-East of Delhi representing the semi-arid region of South- Western Uttar Pradesh. The experimental site intersects at 27.20 N latitude and 77.90E longitude about 21 km away in the south of Agra city. The experimental soil was sandy loam in texture, alkaline in soil reaction with pH 8.0, EC 0.30 dSm^{-1}, low in organic carbon 3.3 g kg^{-1}, available nitrogen 152 kg ha^{-1}, phosphorus 7.3 kg ha^{-1}, potassium 147 kg ha^{-1} and marginally deficient available zinc content of 0.47 mg kg^{-1}. The experiment was laid out in Randomised block design comprising 10 treatments and replicated thrice. The treatments consisted T_1: control, T_2: 100% recommended dose of fertilizer (RDF), T_3: 75 % RDF, T_4: 50% RDF, T_5: 50% RDF+$ZnSO_4$ @ 20 kg ha^{-1}, T_6: 50% RDF+FYM @ 5 t ha^{-1}, T_7: 50% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1}, T_8: 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1}, T_9: 75% RDF+FYM @ 5 t ha^{-1}, T_{10}: 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} for both the crops. The recommended fertilizer dose was 20:60:40 kg N: P_2O_5: K_2O per hectare for cluster bean and 80:40:40 kg N: P_2O_2: K_2O per hectare for barley crop. Urea, single super phosphate, and muriate of potash were used as nutrient

Table 1: Effect of INM treatments on growth attributes of cluster bean (Pooled mean).

S. No.	Treatments	Plant height(cm)	No. of Pod plant^{-1}	No. of Seed Pod^{-1}	1000 seed Wt.(g)
T_1	Control	105.5	33.6	4.3	28.4
T_2	100% RDF	126.2	41.8	6.5	30.2
T_3	75% RDF	115.9	37.2	6.0	29.2
T_4	50% RDF	107.6	34.6	5.4	28.6
T_5	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	111.0	35.6	5.5	28.8
T_6	50%RDF+FYM @ 5 t ha^{-1}	113.6	36.4	5.8	29.2
T_7	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	121.3	39.0	6.3	29.8
T_8	75%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	119.0	38.5	6.1	29.3
T_9	75%RDF+FYM @ 5 t ha^{-1}	123.3	40.0	6.4	29.8
T_{10}	75%RDF+$ZnSO_4$@ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	128.7	42.6	6.6	30.5
SEm$\pm$		0.37	0.21	0.09	0.17
CD@0.05		0.99	0.60	0.24	0.47

sources for nitrogen, phosphorus, and potassium, respectively. While, zinc sulphate was used to supply Zn in both the crops. Well decomposed FYM @ 5 t ha^{-1} was applied before sowing of *kharif* and *Rabi* crop and seed treatment with *Rhizobium* and *Azobacter* was common to all treatments except control. All. the other recommended agronomic management practices were followed during the growth period of the crops. The treatment wise observation of growth attributes was recorded by randomly selecting five plants from every replicated plot and average values were reported accordingly. Gum content in cluster bean was estimated by adopting the methodology suggested by Association of Official Analytical Chemists (Anonymous 2005). The starch content in barley was estimated by Anthone method as suggested by David (1990). Total nitrogen content was determined using the Micro-Kjeldahl method as outlined by Bremner and Malvaney (1982). Total phosphorus was analyzed using the Vanadomolybdate Yellow Color method in a nitric acid system, following Jackson (1973). Total potassium was measured with a Flame Photometer, as described by Chapman and Pratt (1961). Zinc content in plant samples was estimated using the method proposed by Zoroski and Bureau (1977). Protein content was calculated by multiplying the total nitrogen content by a factor of 6.25. The observed and laboratory data was analysed statistically, following the methodology recommended by Panse and Sukhatme (1985).

Results and Discussion

Growth attributes of Cluster bean

The pooled data in Table 1 showed that growth parameters of cluster bean, including plant height, number of pods per plant, seeds per pod, and 1000-seed weight, were significantly affected by different treatments. The application of 75% RDF + $ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} resulted in the highest plant height (128.7 cm), seeds per pod (6.6), number of pods per plant (42.6), and 1000-seed weight (30.5 g), surpassing all other treatments. However, the number of seeds per pod was statistically similar to T_2 (100% RDF, 6.5) and T_9 (75% RDF + FYM @ 5 t ha{ ¹, 6.4), while the 1000-seed weight was comparable to 100% RDF (30.2 g).

The improved performance of cluster bean with the application of FYM and zinc sulphate can be attributed to enhanced soil fertility, better nutrient availability, and improved microbial activity. FYM enriches the soil with organic matter, enhances nutrient retention, and improves soil structure, which facilitates better root growth and nutrient uptake (Mandal *et al.*, 2020; Choudhary *et al.*, 2021). Zinc is an essential micronutrient involved in enzymatic activities, protein synthesis, and photosynthesis, contributing to better plant growth, pod formation, and seed development (Alloway, 2008; Hafeez *et al.*, 2013). Studies have shown that the combined application of FYM and $ZnSO_4$ improves nitrogen use efficiency, enhances soil microbial biomass, and increases seed yield and quality (Singh and Prasad, 2017; Dwivedi *et al.*, 2016). These findings are in accordance with that of Singh *et al.*, (2016), Sharma *et al.*, (2019) and Lal *et al.*, (2023). Ajam *et al.*, (2024) reported increase growth performance of cluster bean due to combine application of NPK and Zn fertilizer.

Growth attributes of barley

The pooled analysis of growth parameters for rabi barley indicated that treatment T_{10} (75% RDF + $ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1}) resulted in the highest plant height (94.7 cm), tillers per plant (5.6), spikes per plant (6.4), spikelets per spike (23.5), grains per spike (68.1), and 1000-seed weight (42.8 g) However, these values were statistically comparable to T_2 (100% RDF),

Table 2: Effect of INM treatments on growth attributes of barley (Pooled mean).

S. No.	Treatments	Plant height (cm)	No. of Tillers plant^{-1}	No. of Spike Pod^{-1}	No. of Spikelets Spike^{-1}	No. of Grains Spike^{-1}	1000 seed Wt.(g)
T_1	Control	85.5	2.8	3.5	16.6	50.5	40.1
T_2	100% RDF	94.5	5.6	6.3	23.3	66.8	42.5
T_3	75% RDF	89.8	4.9	4.8	20.1	58.3	41.1
T_4	50% RDF	86.2	4.2	3.9	17.8	52.7	40.4
T_5	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	87.7	4.4	4.2	18.5	54.6	40.6
T_6	50%RDF+FYM @ 5 t ha^{-1}	88.3	4.6	4.5	19.4	56.5	40.9
T_7	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	90.8	5.0	5.2	21.3	61.2	41.4
T_8	75%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	91.1	5.2	5.3	21.5	60.7	41.6
T_9	75%RDF+FYM @ 5 t ha^{-1}	92.2	5.3	5.7	22.2	64.1	42.0
T_{10}	75%RDF+$ZnSO_4$@ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	94.7	5.6	6.4	23.5	68.1	42.8
SEm±		0.41	0.08	0.10	0.29	0.51	0.51
CD@0.05		1.17	0.24	0.28	0.84	1.44	1.45

which recorded plant height (94.5 cm), tillers per plant (5.6), spikes per plant (6.3), spikelets per spike (23.3), grains per spike (66.8), and 1000-seed weight (42.5 g).

The application of FYM resulted in better barley growth compared to treatments without it. Additionally, the combined use of FYM and $ZnSO_4$ outperformed treatments where only FYM or $ZnSO_4$ was applied individually. Studies have shown that the combined application of FYM and $ZnSO_4$ significantly improves barley growth parameters such as plant height, tiller production, spike density, and grain weight compared to individual applications of either FYM or Zn. This is because FYM enhances Zn bioavailability by reducing its fixation in the soil, ensuring better uptake by plants. Similar results are also observed by Kumar *et al*., (2021), Jat *et al*., (2020) and Rehman *et al*., (2018). The results are also in agreement with that of Kumar and Jat, (2021) who reported higher growth performance of barley crop in barley based cropping system under integrated nutrient management consisting 75% RDF along with FYM and microbial consortia. Liza Kumari *et al*., (2022) reported higher growth and yield attributes due to application of INM in barley.

Nutrient Content in Cluster bean

The pooled data presented in Table 3 exhibited that the total N, P, K and Zn content in seed and stover of cluster bean was significantly highest in treatment consisting application of 75%RDF + $ZnSO_4$ @ 20 kg ha^{-1} +FYM @ 5 t ha^{-1}. This treatment recorded the total N, P and K content in cluster bean seed to the tune of 2.59, 0.35 and 0.22% while, in stover it ranged from 0.79, 0.22, 0.86 % respectively these values are significantly highest over all the treatments. Nonetheless it was at par with all the other treatment, except control and treatment receiving 75% RDF (T_3) and 50% RDF (T_4) without FYM. Similarly, the total Zn content was highest in treatment 75%RDF + $ZnSO_4$ @ 20 kg ha^{-1} +FYM @ 5 t

Table 3: Nutrient content in cluster bean as influenced by INM treatments (Pooled mean).

S. No.	Treatments	N		P		K		Zn	
		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
		-----------------------------%-----------------------------						---(mg kg^{-1})---	
T_1	Control	2.46	0.67	0.30	0.18	0.60	0.77	19.44	14.39
T_2	100% RDF	2.56	0.79	0.34	0.20	0.71	0.85	20.91	16.18
T_3	75% RDF	2.48	0.71	0.32	0.19	0.66	0.82	20.88	16.04
T_4	50% RDF	2.48	0.65	0.31	0.18	0.64	0.83	19.75	15.10
T_5	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	2.49	0.68	0.30	0.18	0.68	0.81	20.40	16.35
T_6	50%RDF+FYM @ 5 t ha^{-1}	2.49	0.70	0.30	0.18	0.64	0.83	20.40	15.69
T_7	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	2.51	0.73	0.32	0.19	0.68	0.82	21.45	16.53
T_8	75%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	2.51	0.74	0.32	0.19	0.68	0.84	21.44	16.76
T_9	75%RDF+FYM @ 5 t ha^{-1}	2.53	0.75	0.33	0.21	0.69	0.85	20.73	16.25
T_{10}	75%RDF+$ZnSO_4$@ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	2.59	0.79	0.35	0.22	0.71	0.86	22.27	17.12
SEm±		0.04	0.03	0.01	0.01	0.03	0.029	0.24	0.27
CD@0.05		0.10	0.09	0.03	0.03	0.10	0.082	0.68	0.76

Table 4: Nutrient content in barley as influenced by INM treatments (Pooled mean).

S. No.	Treatments	N		P		K		Zn	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
		---%						---(mg kg^{-1})---	
T_1	Control	1.84	0.31	0.30	0.125	0.72	1.33	14.70	11.51
T_2	100% RDF	1.91	0.34	0.33	0.129	0.74	1.34	20.26	16.62
T_3	75% RDF	1.88	0.34	0.31	0.129	0.73	1.34	20.24	16.31
T_4	50% RDF	1.87	0.35	0.29	0.127	0.72	1.29	19.69	13.14
T_5	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	1.88	0.34	0.29	0.127	0.72	1.32	20.80	17.01
T_6	50%RDF+FYM @ 5 t ha^{-1}	1.88	0.34	0.29	0.126	0.72	1.33	19.97	14.16
T_7	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	1.91	0.33	0.30	0.128	0.72	1.32	20.65	16.93
T_8	75%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	1.91	0.34	0.31	0.128	0.73	1.32	22.06	17.45
T_9	75%RDF+FYM @ 5 t ha^{-1}	1.92	0.33	0.32	0.129	0.72	1.33	20.40	16.21
T_{10}	75%RDF+$ZnSO_4$@ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	1.93	0.35	0.34	0.130	0.73	1.33	22.15	19.15
SEm±		0.033	0.035	0.011	0.002	0.013	0.015	0.62	0.38
CD@0.05		NS	NS	0.031	NS	NS	NS	1.76	1.08

ha^{-1} to the tune of 22.27 mg kg^{-1} in seed and 17.12 mg kg^{-1} in stover of cluster bean which significantly superior over all the treatments.

The variability in nutrient content of cluster bean due to combine application 75% recommended dose of fertilizer along with FYM and $ZnSO_4$ could be due to increase availability of nutrient through FYM moreover, the application of Zn has been associated with enhanced root growth, which facilitates more efficient absorption of water and nutrients. Hence, the combined use of FYM and Zn creates a synergistic effect, further boosting the nutrient content in cluster bean plant. The results are in accordance with Ram *et al*., (2013) who reported increase nutrient concentration in rice due to combine application of FYM and Zn. Sharma *et al*., (2019) reported increase in nutrient content of cluster bean due to integrated nutrient management practice.

Nutrient content in barley

The total N, P and K content in barley grain and straw did not differ within the treatments, however significantly highest total Zn content in barley grain (22.15 mg kg^{-1}) was recorded in treatment receiving 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} over all the other treatments while, statistically at par with treatment consisting 50% RDF+$ZnSO_4$ @ 20 kg ha^{-1} (20.80 mg kg^{-1}), 50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1} (20.65 mg kg^{-1}), 75%RDF+$ZnSO_4$ @ 20 kg ha^{-1} (22.06 mg kg^{-1}) and 75% RDF + FYM @ 5 t ha^{-1} (20.40 mg kg^{-1}). However, the straw Zn content was highest in treatment of 75%RDF + $ZnSO_4$ @ 20 kg ha^{-1} +FYM @ 5 t ha^{-1} (19.15 mg kg^{-1}) which was significantly superior over all the treatments (Table 4).

The variation in nutrient content of barley could be due to the contribution from legume crop in enhancing the soil nutrient status by virtue of biological N fixation and residue accumulation as a preceding crop. Moreover, the application of Zn during the two consecutive years of experimentation in a Zn deficient soil might have enhance

Table 5: Quality attributes in cluster bean and barley as influenced by INM treatment (Pooled mean).

S. No.	Treatments	Cluster bean		Barley	
		Gum (%)	Protein (%)	Gum (%)	Protein (%)
T_1	Control	22.22	15.4	52.0	11.5
T_2	100% RDF	26.62	16.0	52.7	11.9
T_3	75% RDF	25.69	15.5	52.3	11.8
T_4	50% RDF	25.36	15.5	51.8	11.7
T_5	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	25.56	15.5	52.4	11.8
T_6	50%RDF+FYM @ 5 t ha^{-1}	25.53	15.5	52.8	11.8
T_7	50%RDF+$ZnSO_4$ @ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	26.11	15.7	52.5	12.0
T_8	75%RDF+$ZnSO_4$ @ 20 kg ha^{-1}	25.88	15.7	52.7	11.9
T_9	75%RDF+FYM @ 5 t ha^{-1}	26.01	15.8	52.5	12.0
T_{10}	75%RDF+$ZnSO_4$@ 20 kg ha^{-1}+FYM @ 5 t ha^{-1}	26.65	16.2	52.8	12.0
SEm±		0.13	0.24	0.30	0.21
CD@0.05		0.37	0.73	NS	NS

the Zn availability in corresponding treatments which might have increased the uptake of Zn by the succeeding barley crop. Mali *et al*., (2017) reported similar results suggesting increase in nutrient content of barley due to precise nutrient management practice. The findings are in line with that of Ram *et al* (2013) who found enhanced Zn content in rice crop due to combine application of FYM and Zn.

Quality Parameters

From Table 5 it is indicative that the quality attributes of cluster bean and barley crop were substantially influenced due to implementation of nutrient management treatment. The pooled data revealed that the gum content in cluster bean crop was significantly highest (26.65%) in treatment of 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} over all the other treatment whereas, it was at par with T_2 *i.e* 100 % RDF (26.62%). The protein content in cluster bean crop did not differ statistically within the treatment however, highest protein content to the tune of 16.2% was recorded with 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1} which was significantly superior over control. The quality attributes of barley *viz.* starch content and protein content did not vary among the treatment. Nevertheless, numerically higher value of starch content (52.8%) and protein content (12.0%) was found in treatment receiving 75% RDF+$ZnSO_4$ @ 20 kg ha^{-1} + FYM @ 5 t ha^{-1}.

The substantial increase in gum content of cluster bean could be due to positive impact of combining organic amendment (FYM) along inorganic fertilizers on gum content and overall performance of cluster bean crop. The results are in close agreement with that of Rawat *et al*., (2017) who demonstrated that the application of 75% of the recommended dose of fertilizers (RDF) combined with 5 tonnes per hectare of vermicompost resulted in significantly higher gum content compared to other nutrient management treatments. Similar results are also reported by Sharma *et al*., (2019) who found that integrating 75% RDF with pressmud and Rhizobium inoculation led to the highest gum content in cluster bean. The findings suggested that the nutrient management treatment may not always lead to significant increases in starch and protein content in barley crops. The results are in corroboration with that of Randhawa *et al*., (2020) who found that integrated nutrient management could increase the yield component of malt barley but did not significantly influence the protein content. Similar results are also reported by Kumar *et al*., (2024) that nutrient management methods improved growth parameters and yield of barley, however, the protein content in grains did not differ significantly across various nutrient management strategies.

Conclusion

The study demonstrates that the integrated application of organic and inorganic fertilizers significantly enhances the growth performance of both cluster bean and barley. The increased nutrient concentration observed in both crops highlight the importance of organic manures and zinc supplementation, particularly in nutrient-deficient soils. The improved nutrient availability contributed to higher gum and protein content in cluster bean, reinforcing the beneficial role of integrated nutrient management. However, the impact of nutrient management on barley quality parameters was variable, as it did not always lead to a significant improvement in starch and protein content. These findings emphasize the need for crop-specific nutrient management strategies to optimize both productivity and quality.

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