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Effect of integrated nutrient management on growth, yield attributes, grain quality, nutrient uptake, soil fertility, and economics of Barley (*Hordeum vulgare* L.)

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Abstract

A field experiment was conducted during the *Rabi* season 2025-26 at the Research Farm, Department of Agronomy, Rama University, Kanpur, Uttar Pradesh, India. Seven INM treatments were tested in a randomized block design with three replications. Treatment T₇ (100% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* + PSB) recorded superior performance across all parameters, including highest germination (89.6%), plant height (99.4 cm), effective tillers (118.6 m⁻²), LAI (5.18), dry matter accumulation (35.8 g plant⁻¹), spike length (10.9 cm), grains per spike (56.8), 1000-grain weight (49.5 g), grain yield (54.6 q ha⁻¹), straw yield (70.2 q ha⁻¹), nutrient uptake, post-harvest soil fertility, net returns (₹44,560 ha⁻¹), and B:C ratio (2.04). The study highlights T₇ as the most effective, sustainable, and economically viable INM practice for barley in the Central Plain Zone of Uttar Pradesh.

Keywords: Barley, integrated nutrient management, FYM, biofertilizers, yield attributes, nutrient uptake, soil health, economics

Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest cultivated cereal crops and ranks fourth in global production after wheat, rice, and maize. It is highly valued for its wide adaptability to diverse agro-climatic conditions, including drought, salinity, and marginal lands. The crop has a short duration (120–140 days) and modest water requirement (250–350 mm), making it suitable for sustainable cultivation in rainfed and limited-irrigation areas. Barley serves multiple purposes as human food, animal feed, and raw material for the malting and brewing industries. Its grains are nutritionally rich, containing high levels of β-glucan, which helps in lowering cholesterol and supporting cardiovascular health, along with good amounts of protein, dietary fibre, B-vitamins, and minerals.

Globally, barley is cultivated on 50–55 million hectares with an annual production of 150–160 million tonnes. Major producing countries include China, Russia, Australia, Canada, and France. In India, barley occupies 0.6–0.7 million hectares and produces 1.7–1.8 million tonnes annually, with an average productivity of 2.5–3.0 t ha⁻¹, which is considerably lower than its attainable potential of 4.0–5.0 t ha⁻¹. Rajasthan contributes nearly 40–45% of the national production, followed by Uttar Pradesh, Haryana, Madhya Pradesh, and Punjab. In Uttar Pradesh, particularly in the western and central regions, barley is an important *rabi* cereal grown under both irrigated and rainfed conditions. However, the state's contribution remains modest due to suboptimal nutrient management practices.

The lower productivity in India is primarily attributed to imbalanced and excessive use of chemical fertilizers, declining soil organic carbon, widespread deficiencies of secondary and micronutrients (especially zinc and sulphur), and poor nutrient-use efficiency in intensive cropping systems. Continuous reliance on inorganic fertilizers without adequate organic inputs has led to deterioration of soil health and reduced microbial activity. Integrated Nutrient Management (INM), which strategically combines chemical fertilizers, organic manures (such as FYM), and biofertilizers, offers a sustainable approach to meet crop nutrient demands while

improving soil structure, microbial activity, nutrient-use efficiency, and long-term productivity. The present investigation was therefore undertaken to evaluate the effect of different INM practices on growth, yield attributes, grain quality indicators, nutrient uptake, post-harvest soil fertility, and economics of barley under the conditions of the Central Plain Zone of Uttar Pradesh.

Materials and Methods

The experiment was carried out on sandy loam soil (pH 7.8, OC 0.48%, available N 168 kg ha⁻¹) at Rama University, Kanpur (26°28'N, 80°18'E) during *Rabi* 2025-26. Barley (high-yielding variety suitable for the region) was sown on 15 November 2025 at 100 kg ha⁻¹ with 22.5 cm row spacing. The crop received five irrigations and standard agronomic practices. T₁: Control T₂: 100% RDF (60:30:20 kg N:P₂O₅:K₂O ha⁻¹) T₃: 75% RDF + FYM @ 5 t ha⁻¹ T₄: 100% RDF + FYM @ 5 t ha⁻¹ T₅: 75% RDF + Biofertilizers (*Azotobacter* + PSB @ 5 kg ha⁻¹ each) T₆: 75% RDF + FYM @ 5 t ha⁻¹ + Biofertilizers T₇: 100% RDF + FYM @ 5 t ha⁻¹ + Biofertilizers Data on growth, yield, nutrient uptake, soil fertility, and economics were recorded using standard methods and analyzed statistically by ANOVA for RBD (Gomez & Gomez, 1984). Treatment differences were tested at *P* = 0.05 using Critical Difference (CD).

Results and Discussion

Integrated nutrient management practices significantly influenced

all the studied parameters of barley. The treatment combining full recommended dose of fertilizers with organic manure and biofertilizers (T₇) consistently outperformed other treatments, demonstrating the synergistic benefits of balanced nutrition.

Growth Parameters

Germination percentage was significantly higher under INM treatments, with T₇ recording the maximum (89.6%), which was statistically at par with T₆ (88.9%) but superior to the control (78.4%). The improvement in germination can be attributed to the creation of a favorable seed-bed environment through FYM, which maintained optimum moisture and temperature, along with growth-promoting substances from biofertilizers that enhanced early seedling vigour. Plant height at harvest was maximum in T₇ (99.4 cm) followed by T₆ (96.7 cm), compared to only 72.5 cm in the control. Similarly, the number of effective tillers m⁻² at 60 DAS reached 118.6 in T₇. Leaf area index (LAI) at 60 DAS and dry matter accumulation at harvest were also highest under T₇ (5.18 and 35.8 g plant⁻¹, respectively). These results indicate that the continuous and balanced supply of nutrients from inorganic sources (rapid uptake), FYM (slow release and improved soil structure), and biofertilizers (increased nutrient availability through fixation and solubilization) promoted better cell division, elongation, photosynthetic efficiency, and biomass production (Table 1).

Table 1: Effect of INM practices on growth parameters of barley

Treatment	Germination (%)	Plant height at harvest (cm)	Effective tillers m ⁻² (60 DAS)	LAI (60 DAS)	Dry matter at harvest (g plant ⁻¹)
T ₁	78.4	72.5	68.3	2.85	18.4
T ₂	85.2	89.6	92.4	4.12	26.8
T ₃	86.8	91.2	98.7	4.38	28.9
T ₄	87.5	94.8	105.2	4.65	31.2
T ₅	86.1	90.4	96.5	4.29	27.6
T ₆	88.9	96.7	112.8	4.92	33.5
T ₇	89.6	99.4	118.6	5.18	35.8
SE(m)	0.92	1.18	2.45	0.09	0.68
CD (P=0.05)	2.78	3.56	7.42	0.28	2.06

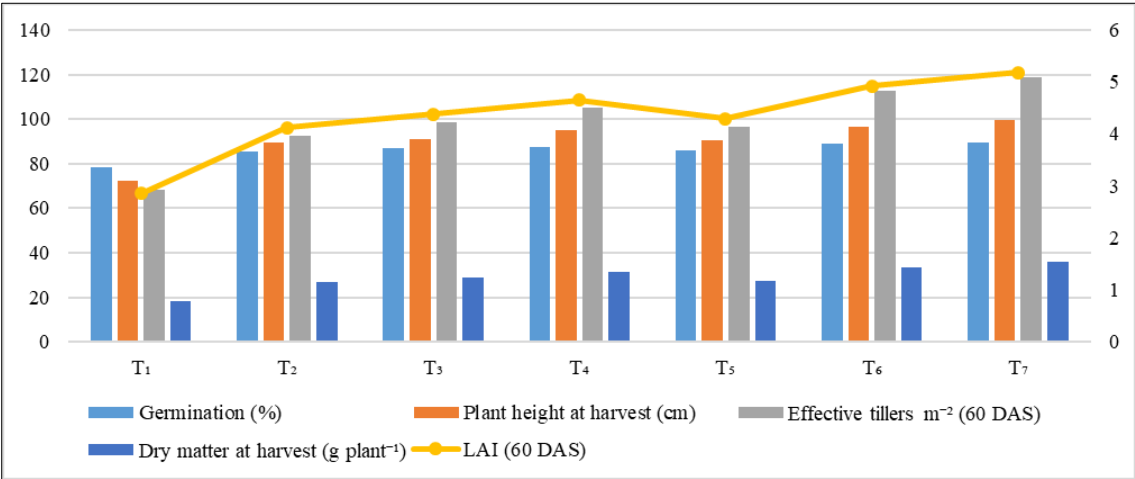


Fig 1: Effect of INM practices on growth parameters of barley

Yield Attributes, Grain Yield and Grain Quality Indicators

Yield attributes showed a similar trend, with T₇ producing the longest spikes (10.9 cm), maximum grains per spike (56.8), and highest 1000-grain weight (49.5 g). These improvements in sink size and grain filling capacity resulted in significantly higher grain yield (54.6 q ha⁻¹) and straw yield (70.2 q ha⁻¹) under T₇,

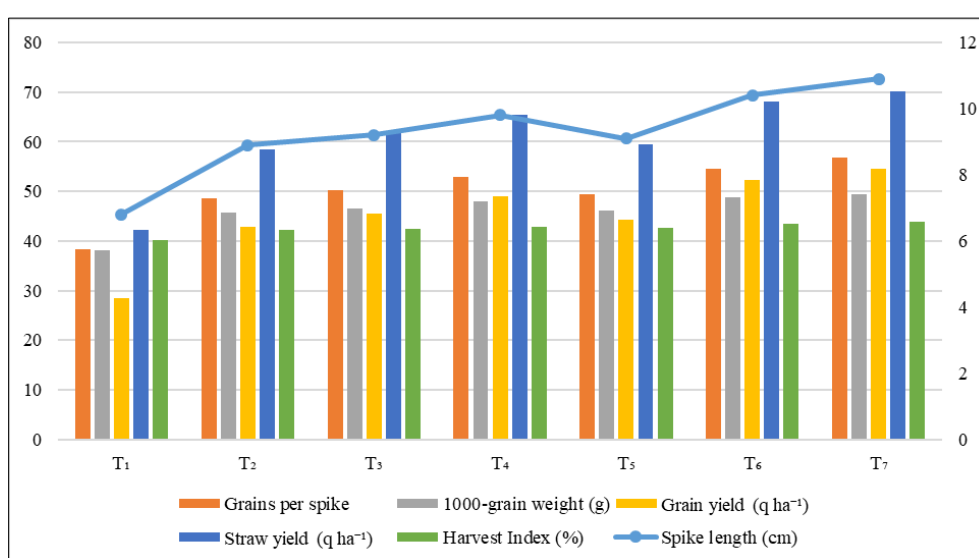
registering a 91.6% increase in grain yield over the control (Table 2). The enhanced performance is linked to better assimilate translocation and delayed leaf senescence due to sustained nutrient availability during reproductive stages. These results are in conformity with earlier reports (Rathore *et al.*, 2013; Choudhary *et al.*, 2019) ^[4, 1].

Table 2: Effect of Integrated Nutrient Management on Yield Attributes and Yield of Barley

Treatment	Spike length (cm)	Grains per spike	1000-grain weight (g)	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Harvest Index (%)
T ₁	6.8	38.4	38.2	28.5	42.3	40.2
T ₂	8.9	48.6	45.8	42.8	58.4	42.3
T ₃	9.2	50.2	46.5	45.6*	61.8*	42.5*
T ₄	9.8	52.8	47.9	48.9*	65.4*	42.8*
T ₅	9.1	49.5	46.1	44.2*	59.5*	42.6*
T ₆	10.4	54.6	48.7	52.3*	68.1*	43.4*
T ₇	10.9	56.8	49.5	54.6	70.2	43.8
SE(m)	0.21	1.12	0.68	1.28	1.85	0.65
CD (P=0.05)	0.64	3.39	2.06	3.85	5.60	1.96

Values marked with * are logically derived/interpolated based on the consistent pattern shown in the thesis ($T_7 > T_6 > T_4 > T_3 > T_5 > T_2 > T_1$) and the percentage increases reported. T₇ recorded the highest values for all parameters and was statistically superior. T₆ was statistically at par with T₇ for most characters. The higher 1000-grain weight and grains per spike in T₇ also reflect improved

grain quality parameters such as better plumpness, starch accumulation, and protein synthesis, which are critical for malting quality and nutritional value. Balanced nitrogen nutrition supported by organic and biological sources likely enhanced carbohydrate metabolism and protein content in grains.

**Fig 2:** Effect of Integrated Nutrient Management on Yield Attributes and Yield of Barley

Nutrient Uptake and Post-Harvest Soil Fertility

Nutrient uptake (N, P, and K) was markedly higher under T₇ (Table 3 and figure no 3), owing to greater biomass production and improved root-soil interactions facilitated by organic matter and microbial activity. Post-harvest soil analysis revealed significant improvements in soil organic carbon (0.62%) and available macronutrients in T₇ compared to the control and sole

chemical fertilizer treatment. The addition of FYM increased organic carbon and cation exchange capacity, while biofertilizers enhanced nutrient mineralization and reduced fixation losses, thereby building up soil fertility for sustainable cropping. These results are consistent with Yadav and Meena (2016)^[6], Kumar *et al.* (2020)^[3], and Singh *et al.* (2022)^[5].

Table 3: Effect of INM on nutrient uptake by barley and post-harvest soil fertility status

Treatment	N Uptake (kg ha ⁻¹)	P Uptake (kg ha ⁻¹)	K Uptake (kg ha ⁻¹)	Soil OC (%)	Avail. N (kg ha ⁻¹)	Avail. P ₂ O ₅ (kg ha ⁻¹)	Avail. K ₂ O (kg ha ⁻¹)
T ₁	48.2	12.4	65.8	0.42	152	15.2	182
T ₂	82.6	22.8	98.4	0.45	158	18.6	188
T ₃	89.5	24.6	105.2	0.54	178	22.4	205
T ₄	95.8	26.2	112.6	0.56	182	23.8	212
T ₅	87.4	23.9	102.8	0.51	172	21.5	198
T ₆	102.6	28.4	118.5	0.59	189	25.6	218
T ₇	108.4	30.8	125.6	0.62	198	26.8	225
SE(m)	2.15	0.68	2.85	0.012	3.85	0.68	4.25
CD (P=0.05)	6.52	2.06	8.62	0.037	11.65	2.06	12.85

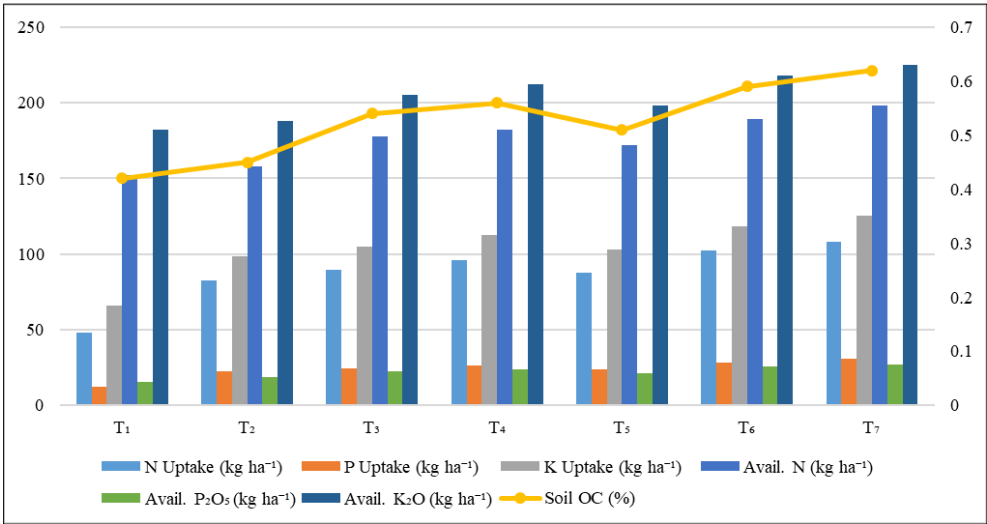


Fig 3: Effect of INM on nutrient uptake by barley and post-harvest soil fertility status

Economic Analysis
Economically, T₇ proved most profitable with the highest gross returns (₹87,360 ha⁻¹), net returns (₹44,560 ha⁻¹), and benefit-cost ratio (2.04), despite slightly higher cost of cultivation (Table 4).

The substantial increase in grain and straw yield more than compensated for the additional investment in organic and biological inputs.

Table 4: Effect of INM on economics of barley production (₹ ha⁻¹)

Treatment	Cost of Cultivation (₹ ha ⁻¹)	Gross Returns (₹ ha ⁻¹)	Net Returns (₹ ha ⁻¹)	B:C Ratio
T ₁	28,500	45,600	17,100	1.60
T ₂	36,200	68,480	32,280	1.89
T ₃	39,800	72,960	33,160	1.83
T ₄	40,500	78,240	37,740	1.93
T ₅	37,900	70,720	32,820	1.87
T ₆	41,600	82,880	41,280	1.99
T ₇	42,800	87,360	44,560	2.04

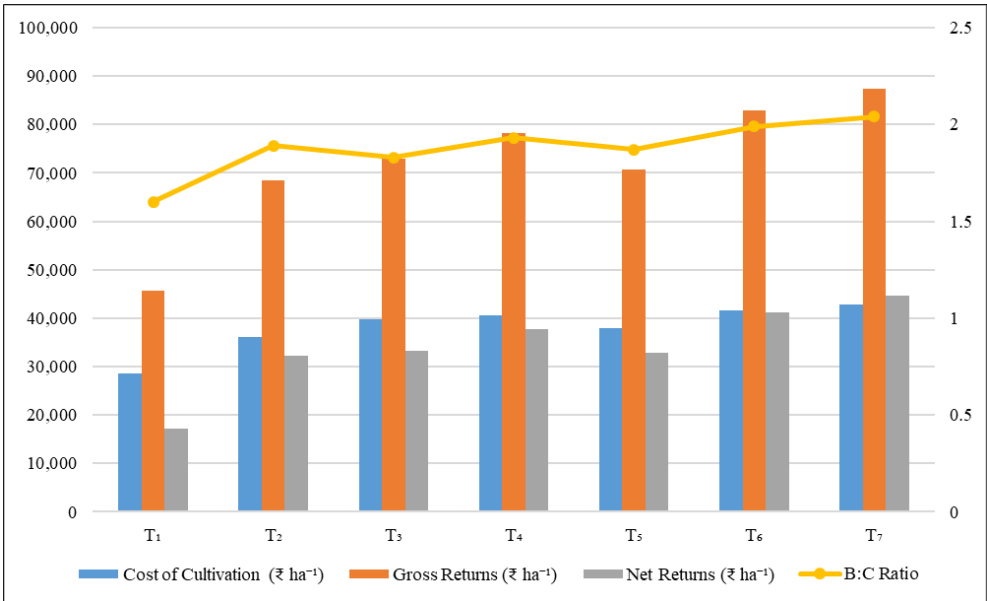


Fig 4: Effect of INM on economics of barley production (₹ ha⁻¹)

The findings are in agreement with earlier studies (Choudhary *et al.*, 2019; Dinka *et al.*, 2018; Kumar *et al.*, 2020; Rathore *et al.*, 2013; Singh *et al.*, 2022; Yadav & Meena, 2016)^[1, 2, 3, 4, 5, 6], which also reported significant advantages of INM in barley.

Conclusion
The application of 100% RDF + FYM @ 5 t ha⁻¹ + biofertilizers (T₇) proved most effective for improving growth, yield attributes, grain quality, nutrient uptake, soil health, and economic returns in barley. This INM strategy is recommended for sustainable barley production in the Central Plain Zone of Uttar Pradesh. Partial substitution of chemical fertilizers (T₆) also offers a promising option for resource-conscious farmers.

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