



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(10): 346-350
Received: 19-08-2025
Accepted: 21-09-2025

Samir Khan
Master Scholar, Department of
Agronomy, School of Agricultural
Sciences, Jaipur National
University, Jaipur, Rajasthan,
India

Yasir Ajeej Tamboli
Assistant Professor, Department of
Agronomy, School of Agricultural
Sciences, Jaipur National
University, Jaipur, Rajasthan,
India

Ajeet Singh
Assistant Professor, Department of
Agronomy, School of Agricultural
Sciences, Jaipur National
University, Jaipur, Rajasthan,
India

Ashok Kumar Singh
Associate Professor, Department of
Agronomy, School of Agricultural
Sciences, Jaipur National
University, Jaipur, Rajasthan,
India

Rajendra Kumar Bansal
Director & Professor, Department
of Plant Pathology, School of
Agricultural Sciences, Jaipur
National University, Jaipur,
Rajasthan, India

Ganesh Ram Chaudhary
Professor, Department of
Agricultural Economics, School of
Agricultural Sciences, Jaipur
National University, Jaipur,
Rajasthan, India

Corresponding Author:

Samir Khan
Master Scholar, Department of
Agronomy, School of Agricultural
Sciences, Jaipur National
University, Jaipur, Rajasthan,
India

Influence of integrated nutrient management on growth dynamics and developmental stages of barley (*Hordeum vulgare* L.)

Samir Khan, Yasir Ajeej Tamboli, Ajeet Singh, Ashok Kumar Singh, Rajendra Kumar Bansal and Ganesh Ram Chaudhary

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i10e.3997>

Abstract

The present investigation was conducted during 2024-25 at the Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan, with the objective of evaluating Integrated Nutrient Management (INM) practices in barley (*Hordeum vulgare* L.). The experiment was laid out in Randomized Block Design with three replications. The experiment consists of nine treatments as follows, T₁: Control (no treatment applied); T₂: 100% RDF (60 N + 30 P₂O₅ kg/ha); T₃: Vermicompost @ 5 t/ha; T₄: Azotobacter (seed treatment) + Vermicompost @ 5 t/ha; T₅: 50% RDF + Vermicompost @ 2.5 t/ha; T₆: 75% RDF + Vermicompost @ 2.5 t/ha; T₇: 50% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha; T₈: 75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha; T₉: 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha. The present study revealed that significantly higher plant height, number of tillers per metre row length and dry matter accumulation (g/m²) with the soil application of 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₉) and it was at par with 75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₈) and 100% RDF-60 N + 30 P₂O₅ kg/ha (T₂) compared to rest of the treatment. Whereas, Integrated Nutrient Management practices did not exhibit a significant influence on plant stand, days required to 50% flowering and maturity.

Keywords: Growth, development, phenology, Integrated Nutrient Management (INM) and barley

Introduction

Barley (*Hordeum vulgare* L.) is the fourth most important cereal globally, after wheat, rice and maize and ranks second in acreage and production among *rabi* cereals in India, following wheat. Originating in Abyssinia and Southeast Asia, it is a hardy crop that thrives under drought, salinity and alkalinity, making it ideal for arid regions. Two-thirds of global barley production is used for animal feed, while the rest is for malting and limited human consumption. Barley is nutritionally rich in protein, fiber and essential minerals, and is used in various food products and Ayurvedic medicine. In India, barley is cultivated on 551 thousand hectares, producing 1699 thousand tonnes with an average productivity of 3080 kg/ha, largely concentrated in the northwestern region (Anonymous, 2024) ^[2], whereas in Rajasthan state, crop grown on 3.30 lakh hectares area and produce 11.25 lakh metric tonnes with average productivity of 3400 kg/ha (Anonymous, 2023) ^[1]. Rajasthan leads in production, followed by Uttar Pradesh and Madhya Pradesh, collectively contributing 83% of the national out-put. The highest average yield is observed in Punjab (3,840 kg/ha), followed by Haryana (3,570 kg/ha), Rajasthan (3,400 kg/ha) and Uttar Pradesh (3070 kg/ha) (Anonymous, 2023) ^[1].

Despite Rajasthan being a major barley producer, its productivity remains lower than the national average due to factors like varying soil fertility, limited irrigation and inconsistent crop management practices. Among these, nutrient management plays a crucial role in optimizing yields. While traditional reliance on chemical fertilizers, particularly nitrogenous and phosphatic, has boosted crop production, excessive and imbalanced use has led to several challenges. These include depletion of soil organic matter, reduced crop quality, salinity and sodicity issues, increased pest and disease pressures and buildup of residual pollutants.

Over time, this overdependence on chemical fertilizers can cause micronutrient deficiencies, nutrient imbalances, and long-term soil health degradation Malik (2017) ^[12] at Hisar reported that 100% RDF resulted in significantly taller plants, higher dry matter production, and greater leaf area index of barley compared to 50% and 75% RDF.

Organic amendments, such as vermicompost have become a key solution for improving soil health by enhancing its chemical, physical, and biological properties. They improve soil structure, increase water retention and promote microbial activity, leading to higher crop yields. Vermicompost, produced by earthworms, boosts soil aeration and nutrient availability, further supporting plant growth. Biofertilizers like *Rhizobium*, *Azotobacter* and *Azospirillum* play an equally important role by fixing nitrogen, solubilizing phosphorus and promoting plant growth. Together, organic amendments and biofertilizers restore natural nutrient cycles, reduce dependence on chemical fertilizers and improve soil structure and disease resistance. Farhan *et al.* (2022) ^[8] reported that integrating biofertilizers with chemical fertilizers reduced chemical fertilizer use by 25% while maintaining better growth and development in barley, indicating an eco-friendly nutrient management approach.

Integrated Nutrient Management (INM) is a comprehensive approach that combines inorganic fertilizers, organic amendments and biofertilizers to ensure a balanced nutrient supply throughout the crop growth cycle. Indiscriminate use of high-analysis chemical fertilizers causes soil degradation, poor crop quality, salinity, pests, and pollution (Chakarborti and Singh, 2004) ^[6]. In barley cultivation, INM enhances nutrient use efficiency, improves soil health, and boosts yields while maintaining environmental quality. Practices such as crop rotation and intercropping with legumes further support soil fertility and nutrient balance. Research has shown that INM leads to higher yields, improved soil health and economic benefits for farmers. Choudhary and Gautam (2006) ^[7] reported that the highest net return was achieved with 60 kg N ha⁻¹ + 40 kg P₂O₅ ha⁻¹ + 5 t FYM ha⁻¹ + biofertilizer, while Behera *et al.* (2007) ^[3] found that 100% NPK + poultry manure was the most profitable treatment, followed by 100% NPK + FYM. Especially in semi-arid regions like Rajasthan, where soil fertility management is critical, INM offers a sustainable and eco-friendly solution for long-term cereal production. In view of these considerations, the present study was undertaken to evaluate the effects of combined organic, inorganic and biofertilizer applications on barley growth, yield and soil fertility.

Materials and Methods

Experimental Site

The experiment was conducted at the Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan, situated at a latitude of 26°85' N and longitude of 75°87' E, with an elevation of 390 meters above sea level. The site is located in the NARP agro-climatic zone IIIa, the Semi-Arid Eastern Plain Zone, of Rajasthan.

Weather

The region experiences a hot semi-arid climate with extreme temperatures and low to moderate rainfall. Summer temperatures can soar up to 45 °C, while winter temperatures drop to around 5 °C. The monsoon season brings limited rainfall, averaging 527 mm annually, with humidity levels ranging from 20-30% in summer to 60-80% during the monsoon. Winds typically range from 5-15 km/h, with gusts

reaching up to 40 km/h during dust storms. The area enjoys 8-10 hours of sunshine in summer, 6-8 hours in winter, and 4-6 hours during the monsoon. During the 2024-25 rabi season, temperatures varied between 33.8 °C and 8.6 °C, with occasional rainfall.

Sampling and analyses

The soil in the experimental area is sandy loam of Gangetic alluvial origin, with 67.54% sand, 22.92% silt, and 9.54% clay. It has an alkaline pH of 7.84, low organic carbon (0.42%), and moderate levels of nitrogen (143.20 kg/ha), phosphorus (19.75 kg/ha), and high potassium (235.19 kg/ha). Physical analysis showed a bulk density of 1.56 Mg/m³, particle density of 2.49 Mg/m³, and porosity of 38.90%. The soil was analyzed using methods like the International Pipette Method and techniques for pH, conductivity, and nutrient analysis, as per established research standards. The procedures used were based on Piper (1950) ^[15] and Black (1950) ^[5], Olsen *et al.* (1954) ^[14], Richards (1954) ^[19], Subbaiah and Asija (1956) ^[22] and Jackson (1973) ^[10].

Experimental setup

The experiment was laid out in Randomized Block Design with three replications. The experiment consists of nine treatments as follows, T₁: Control (no treatment applied); T₂: 100% RDF (60 N + 30 P₂O₅ kg/ha); T₃: Vermicompost at 5 t/ha; T₄: Azotobacter (seed treatment) + Vermicompost @ 5 t/ha; T₅: 50% RDF + Vermicompost @ 2.5 t/ha; T₆: 75% RDF + Vermicompost @ 2.5 t/ha; T₇: 50% RDF + Azotobacter (Seed treatment) + Vermicompost at 2.5 t/ha; T₈: 75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha; T₉: 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha. All necessary agronomic practices were followed to ensure optimal crop growth and development. Observations were made from five randomly selected plants in each plot to assess various growth attributes and dry matter from the gross plot. Additionally, the number of days from sowing to 50% flowering and physiological maturity was recorded. Statistical analysis was conducted for each character based on the experimental design, and the simple correlation coefficient ('r') for each character was calculated as per Gomez and Gomez (1984) ^[9].

Results and Discussion

The influence integrated nutrient management practices on growth parameters, including plant population, plant height, number of tillers and dry matter accumulation. Data presented in Table 1 and 2 indicate the integrated nutrient management practices significantly enhanced the growth parameters viz. plant height (cm), number of tillers plant per meter row length and dry matter accumulation (g/m²) at 30, 60, 90 DAS and at harvest, respectively.

Effect INM practices

Plant Population

Plant population is a critical indicator of crop establishment and survival under different nutrient management practices. However, the influence of integrated nutrient management practices did not show a significant effect on plant stand. Although plant population at 20 DAS and at maturity was statistically unaffected, slight numerical improvements under soil application of 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha as well as 75% RDF (T₉) + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₈) and 100% RDF- 60 N + 30 P₂O₅ kg/ha (T₂) compared to control.

Plant height (cm)

Plant height, a key parameter reflecting vegetative growth, exhibited significant improvement with the application of integrated nutrient management practices at all stages of growth. The presented in Table 1 showed that significantly tallest plants of 28.55 cm, 69.57 cm, 91.72 and 96.31 cm at 30, 60, 90 DAS and at harvest, respectively were observed in soil application of 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₉) and it was at par with 75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₈) and 100% RDF-60 N + 30 P₂O₅ kg/ha (T₂) compared to control. These observations suggest that 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₉), enhanced vegetative growth throughout the crop cycle, likely due to improved nutrient uptake and utilization. The photosynthetic activity thereby rapid cell division and cell elongation and consequently better growth of plant. Improved growth and yield attributes increased with increased dose of N, may be due to fact that N being an important constituent of nucleotides, proteins, chlorophyll and enzymes involves in various metabolic process which has a direct impact on vegetative and reproductive phase of plants. Similar results also observed by Rathore *et al.* (2003) [17], Rathore and Gautam (2003) [16], Kumar (2005) [5], Choudhary and Gautam (2006) [7], Malik (2017) [12], Shirinzadeh *et al.* (2013) [20], Bhawana *et al.* (2018) [4] and Farhan *et al.* (2022) [8].

Phenological parameters

The data presented in Table 1 revealed that integrated nutrient management practices had a measurable impact on the time required to attain 50% flowering and days required to maturity in barley. Although the differences among treatments were statistically non-significant, integrated nutrient management plots consistently reached 50% flowering and maturity earlier than the control (T₁) and Vermicompost @ 5 t/ha (T₃). No fertilizer application in treatment T₁ had induced early flowering and early maturity as compared to higher fertility treatments (T₉, T₈ and T₂) which on the other hand has prolonged the growth, flowering and maturity duration. Corroborative findings have also been reported by Rehman *et al.* (2010) [18], Neelam and Nanwal (2013) [13] and Malik (2017) [12].

Number of tillers per metre row length

The number of tillers per metre row length, an important determinant of yield potential, was positively influenced by integrated nutrient management practices (Table 2 & Fig. 1). Perusals of data indicate that irrespective of the treatments,

number of tillers in barley increased slightly up to 90 DAS and thereafter marginally decreased at maturity. Among various combinations of nitrogen fertilizer, the maximum tillering of 67.15, 116.10, 137.50 and 118.80 per metre row length at 30, 60, 90 DAS and at maturity, respectively was observed in 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₉) and it was at par with 75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha (T₈) and 100% RDF-60 N + 30 P₂O₅ kg/ha (T₂) compared to control. In contrast, under control, the lowest number of tillers of 51.36, 93.17, 109.03 and 96.83 at 30, 60, 90 DAS and at harvest, respectively. Whereas, T₇ to T₃ treatments recorded intermediate values. These results demonstrate that, increase in tillers of barley in INM might be due adequate quantity and balanced proportion of plant nutrient supplied to the crop as per need during the growing period resulting in favorable environment for crop growth. Corroborative findings have also been reported by Rathore *et al.* (2003) [17], Rathore and Gautam (2003) [16], Suthar (2006) [23], Singh and Prasad (2011) [21], Upadhyay and Vishwakarma (2014) [24] and Malik (2017) [12].

Dry Matter Accumulation (g/m²)

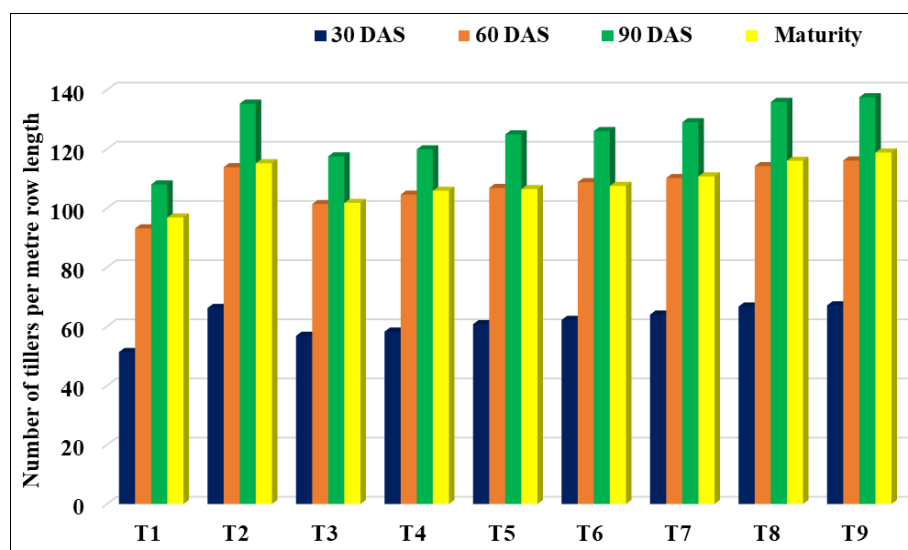
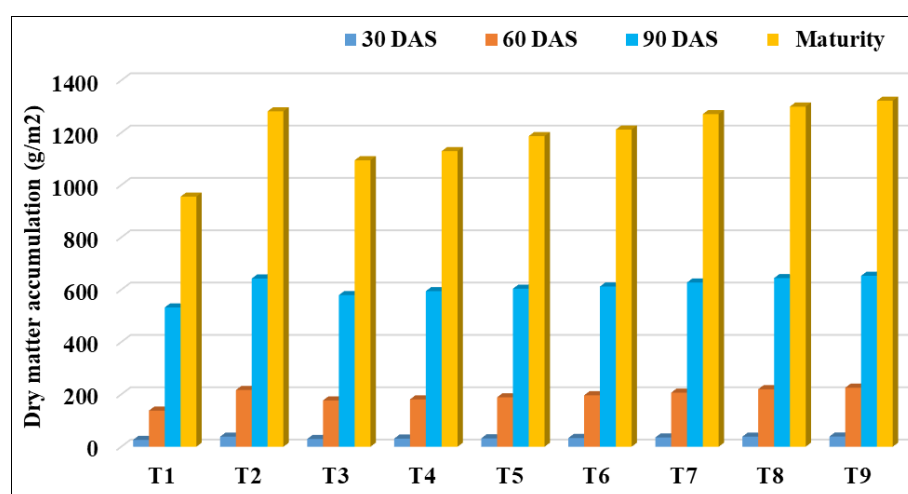
Dry matter accumulation, an indicator of overall biomass production and crop vigor, exhibited significant differences among treatments at all stages of growth (Table 2 & Fig. 2). At 30 DAS, T₉ recorded the highest accumulation of 39.13 g/m², followed by T₈ (38.70 g/m²) and T₂ (38.47 g/m²), while the control showed the lowest accumulation (26.20 g/m²). This trend continued at 60 DAS, with maximum biomass recorded in T₉ (225.67 g/m²), followed by T₈ (219.80 g/m²), and the at control 138.00 g/m². At 90 DAS, T₉ (653.23 g/m²) followed by T₈ (644.40 g/m²) and T₂ (642.87 g/m²) again demonstrated superior biomass accumulation, whereas the control remained the lowest (532.33 g/m²). At maturity, the highest dry matter was observed in T₉ (1322.33 g/m²), followed by T₈ (1299.93 g/m²) and T₂ (1281.90 g/m²), while the control treatment accumulated the least (955.67 g/m²). The enhanced dry matter accumulation under soil-applied 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha, indicates improved photosynthetic efficiency and nutrient assimilation, resulting in higher biomass production throughout the growth period. The crop cycle, reflecting improved photosynthesis, enzyme activity and nutrient assimilation. Similar results also observed by Rathore *et al.* (2003) [17], Rathore and Gautam (2003) [16], Suthar (2006) [23], Singh and Prasad (2011) [21], Upadhyay and Vishwakarma (2014) [24] and Malik (2017) [12].

Table 1: Plant population per meter row length and Plant height (cm) of barley as influenced by integrated nutrient management practices

Treatments		Plant Population (m ⁻¹ row length)		Plant height (cm)				Phenological parameters	
		20 DAS	At Maturity	30 DAS	60 DAS	90 DAS	At Maturity	Days to 50% flowering	Days to Maturity
T ₁	Control	33.63	29.85	21.17	53.20	71.48	76.42	64.74	126.81
T ₂	100% RDF (60 N + 30 P ₂ O ₅ kg/ha)	36.22	34.89	28.52	69.45	90.82	96.23	74.09	137.37
T ₃	Vermicompost @ 5 t/ha	35.03	33.40	26.16	61.88	80.96	85.76	70.82	133.97
T ₄	Azotobacter (Seed treatment) + Vermicompost @ 5 t/ha	34.50	33.50	26.36	63.28	82.58	87.51	70.32	134.80
T ₅	50% RDF + Vermicompost @ 2.5 t/ha	34.60	33.93	26.86	65.42	84.02	88.12	70.62	135.07
T ₆	75% RDF + Vermicompost @ 2.5 t/ha	35.00	34.33	27.04	67.22	86.74	91.90	71.25	136.01
T ₇	50% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	35.89	34.55	27.17	68.35	87.55	92.08	72.59	136.87
T ₈	75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	36.00	34.67	28.55	69.57	91.72	96.31	72.41	137.10
T ₉	100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	37.33	35.33	29.42	70.72	92.35	97.98	75.64	138.02
S.E.m±		1.89	1.57	0.79	1.31	1.23	1.75	1.99	3.15
CD (p=0.05)		NS	NS	2.37	3.93	3.69	5.24	NS	NS

Table 2: Number of tillers per metre row length at maturity, Dry matter accumulation (g/m²) and Phenological parameters of barley as influenced by integrated nutrient management practices

Treatments		Number of tillers per metre row length				Dry matter accumulation (g/m ²)			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At Maturity
T ₁	Control	51.36	93.17	108.03	96.83	26.20	138.00	532.33	955.67
T ₂	100% RDF (60 N + 30 P ₂ O ₅ kg/ha)	66.25	113.83	135.33	115.17	38.47	216.83	642.87	1281.90
T ₃	Vermicompost @ 5 t/ha	56.85	101.37	117.50	101.77	29.53	177.00	579.37	1094.80
T ₄	Azotobacter (Seed treatment) + Vermicompost @ 5 t/ha	58.28	104.57	119.87	105.87	31.17	181.00	594.67	1129.73
T ₅	50% RDF + Vermicompost @ 2.5 t/ha	60.77	106.83	124.93	106.43	32.17	188.90	604.10	1187.07
T ₆	75% RDF + Vermicompost @ 2.5 t/ha	62.23	108.77	126.03	107.50	33.40	196.70	612.37	1212.10
T ₇	50% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	64.03	110.17	129.03	110.73	35.53	206.80	627.67	1271.33
T ₈	75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	66.76	114.20	135.90	116.00	38.70	219.80	644.40	1299.93
T ₉	100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha	67.15	116.10	137.50	118.80	39.13	225.67	653.23	1322.33
S.Em±		1.12	2.32	4.16	2.39	1.12	2.32	4.16	13.50
CD (p=0.05)		3.35	6.95	12.46	7.17	3.35	6.95	12.46	40.47

**Fig 1:** Number of tillers per metre row length at maturity of barley as influenced by integrated nutrient management practices**Fig 2:** Dry matter accumulation (g/m²) of barley as influenced by integrated nutrient management practices.

Conclusion

Based on one year study, it can be concluded that performance in terms of growth of barley in treatment T₉ (100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha) was at par with treatment T₈ (75% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha and T₂ (100% RDF-60 N + 30 P₂O₅ kg/ha). Integrating integrated nutrient management

practices in barley cultivation optimizes nutrient use efficiency and boosts productivity, particularly in semi-arid regions. The application of 100% RDF + Azotobacter (Seed treatment) + Vermicompost @ 2.5 t/ha resulted in superior dry matter accumulation and biomass production across all growth stages. This emphasizes its critical role in enhancing photosynthesis, nutrient assimilation, and overall crop vigor.

Future Prospects

The results of this study highlight the critical role of integrated nutrient management (INM) practices in enhancing barley growth and biomass production. Future research could focus on optimizing INM strategies by combining organic and inorganic fertilizers to maximize nutrient use efficiency. Additionally, investigating the interactions between organic and inorganic fertilizers and their combined impact on growth will contribute to the development of sustainable and high-yielding barley production systems.

Acknowledgement

I express my sincere gratitude to the School of Agricultural Sciences, Jaipur National University, Jaipur, for providing the necessary facilities and guidance to carry out this research. I am deeply thankful to my supervisor for their invaluable advice, constant encouragement and expert guidance throughout the study. I also acknowledge the support of the staff and colleagues who assisted in fieldwork, data collection and analysis. Their contributions have been instrumental in the successful completion of this research.

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