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Impact of Foliar Nano-Nitrogen Application on Growth, Yield, and Profitability of Barley (*Hordeum vulgare* L.)

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Abstract

During the 2025–26 Rabi season, an investigation was carried out at the Vivekananda Global University Agricultural Research Farm in Jaipur to evaluate barley's performance under varying nitrogen regimes. The research focused on the interplay between standard soil-applied nitrogen (RDN) and supplemental nano-nitrogen (NN) foliar sprays. Using a Randomized Block Design (RBD) with three replicates, nine treatments were tested, ranging from a P + K control to combinations of 70% or 100% RDN with different concentrations and timings of NN. The data indicated that integrating nano-nitrogen significantly boosted growth and yield parameters. Specifically, Treatment T8 (100% RDN supplemented with two 800 ml ha^{-1} NN sprays at tillering and jointing outperformed all other groups, achieving a grain yield of 5,509 kg ha^{-1} and a biological yield of 13,139 kg ha^{-1}. This treatment also delayed physiological maturity to 121.20 days and yielded the highest economic efficiency, boasting a net return of Rs. 97,400 ha^{-1} and a B:C ratio of 1.89.

Keywords: Growth, nano-nitrogen, fertilizer and yield

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Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops worldwide, cultivated for food, feed, and industrial purposes such as malting and brewing. In India, it occupies a significant place among Rabi cereals, particularly in semi-arid regions where wheat production is constrained due to low input availability and limited irrigation resources. Barley is recognized for its short growing season, drought tolerance, and ability to thrive on marginal soils, making it a suitable crop for rainfed and low-input conditions [1, 2].

Nutrient management is one of the most critical factors influencing the growth, yield, and quality of barley. Nitrogen (N) is the most yield-limiting nutrient in cereals, directly influencing photosynthetic efficiency, dry matter accumulation, and spike development [3, 4]. However, indiscriminate or imbalanced nitrogen application can lead to lodging, nutrient losses, and environmental hazards. Optimizing nitrogen use efficiency (NUE) is, therefore, a key target in sustainable barley production. In recent years, liquid nitrogen nutrition (NN) products have gained attention as supplementary sources of N, applied at critical crop growth stages to improve nutrient uptake efficiency and productivity [5]. Split applications of nitrogen, especially in combination with reduced basal doses, are reported to enhance yield while minimizing environmental risks [6, 7]. However, information on the combined effect of recommended dose of nitrogen (RDN) and foliar NN applications in barley is scarce, particularly under semi-arid agro-climatic conditions of Rajasthan.

Materials and Methods

Experimental site and soil characteristics

A field experiment was conducted during Rabi 2025–26 at the Agronomy Research Farm of Vivekananda Global University, Jaipur (27°02′N, 75°47′E, 431 m above mean sea level). The soil of the experimental site was sandy loam in texture, alkaline in reaction (pH 8.1), medium in organic carbon (0.47%), low in available nitrogen (130.4 kg ha^{-1}), medium in phosphorus (16.8 kg ha^{-1}), and high in potassium (163.1 kg ha^{-1}).

Experimental design and treatments

The treatment details are provided in **Table 1** RDN was applied as urea (46% N), single super phosphate, and muriate of potash, as per treatments. Foliar application of nitrogen nutrition (NN) was applied as a liquid formulation.

Table1 Treatment details

S. No.	Treatments	Treatments details
1	T_1	Control
2	T_2	Control + NN @ 800 / ha at Tillering and Jointing
3	T_3	40% RDN + NN @ 400/ ha at Tillering and Jointing
4	T_4	40% RDN + NN @ 800 / ha at Tillering and Jointing
5	T_5	70% RDN + NN @ 400 / ha at Tillering and Jointing
6	T_6	70% RDN + NN @ 800 / ha at Tillering and Jointing
7	T_7	100% RDN + NN @ 400/ ha at Tillering and Jointing
8	T_8	100% RDN + NN @ 800 / ha at Tillering and Jointing
9	T_9	RDF

RDN - Recommended Dose of Nitrogen

Crop management

The field experiment was laid out in a Randomized Block Design (RBD) with nine treatments replicated three times, making a total of 27 plots. Each plot consisted of ten rows with a row-to-row spacing of 20 cm. The gross plot size was 8.0 m × 1.08 m (14.4 m²), while the net plot size was 7.0 m × 0.72 m (12 m²). A field border of 1.00 m was maintained around the experimental area, along with an irrigation channel of 1.50 m for the main channel and 1.00 m for the sub-channel. The experiment was conducted using variety BH946, which was sown on 15th November 2024 and harvested on 15th March 2025.The barley variety BH946was sown at a seed rate of 100 kg ha^{-1} with 20 cm row spacing. A uniform seedbed was prepared. Standard agronomic practices such as irrigation, weed management, and plant protection were followed uniformly.

Observations recorded

Growth and phenological observations plant height, dry matter accumulation, days to 75% spike emergence, and days to maturity) were recorded at successive crop stages. Yield attributes such as ear head density, spike length, spikelets $spike^{-1}$, fertile and unfertile spikelets, grains $spike^{-1}$, grain weight $spike^{-1}$, and test weight were measured. Yield parameters included biological yield, grain yield, straw yield, and harvest index. Economic analysis was performed considering cost of cultivation, gross return, net return, and B:C ratio.

Statistical analysis

The experimental data were analyzed using analysis of variance (ANOVA) techniques. Treatment means were compared at a 5% level of significance ($p = 0.05$).

Results and Discussion

Growth and phenological traits

The growth parameters of barley were significantly influenced by nitrogen management practices (**Table 2**). Plant height, dry matter accumulation, and phenological stages exhibited positive responses to increasing levels of RDN and NN supplementation. At 90 DAS, the tallest plants (89.43 cm) were recorded in T8 (100% RDN + 800 ml NN twice), followed by T7 (88.10 cm). Minimum height was observed under control (T1). Dry matter accumulation followed a similar trend, with T8 producing the highest biomass (130.05 g $plant^{-1}$ at harvest) compared to T1 (57.34 g). The higher biomass and taller plants under integrated nitrogen management could be attributed to enhanced N uptake, increased leaf area duration, and better photosynthetic activity [8, 9]. Phenological observations indicated that days to 75% spike emergence and days to maturity were slightly extended with higher nitrogen availability. T8 recorded the longest crop duration (82.86 to 117.53 days), while T1 matured earlier. This delay in maturity under high N input reflects prolonged vegetative growth and delayed senescence, which is consistent with earlier findings [10].

Yield attributes

Yield-contributing characters significantly improved with integrated use of RDN and NN (**Table 3**). The highest spike length (9.34 cm), grains spike^{-1} (43.90), grain weight spike^{-1} (1.92 g), and test weight (41.86 g) were recorded in T8. Control treatment recorded the lowest values. Ear head density ranged from 270.86 m^{-2} in T1 to 347.20 m^{-2} in T8. Fertile spikelets spike^{-1} were highest in T8 (44.26) and lowest in T1 (37.03). Reduction in unfertile spikelets with increasing N application suggests improved nutrient partitioning towards reproductive organs. These findings agree with Sharma et al. [11] and Kumar et al. [12], who reported enhanced yield traits of barley with optimal nitrogen management.

Table 2 Growth and phenological traits of barley as influenced by various treatments

Treatment	Plant height (cm)				Dry matter accumulation in plants (g)				Day to 75% spike emergence	Day to maturity
	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest		
T_1	8.27	36.10	66.43	71.03	3.20	31.57	57.34	101.89	78.20	113.20
T_2	9.94	36.70	72.33	77.14	3.43	35.74	58.98	105.11	79.53	114.53
T_3	10.76	39.93	77.50	82.54	3.55	38.05	62.47	106.87	80.86	115.20
T_4	10.97	42.43	78.33	84.37	3.90	39.39	67.82	108.85	81.20	116.53
T_5	11.37	43.16	81.18	87.06	4.22	40.50	69.82	110.67	83.53	118.53
T_6	11.80	44.50	83.41	89.62	4.61	41.98	88.95	119.09	84.20	119.53
T_7	11.94	45.70	88.10	92.94	4.63	43.57	90.07	126.42	85.20	121.20
T_8	11.97	50.93	89.43	94.58	4.65	45.32	91.95	130.05	82.86	117.53
T_9	11.42	43.36	82.60	87.68	4.53	40.98	77.39	114.91	1.31	0.90
SEm ±	0.26	2.43	2.48	1.09	0.42	1.16	1.17	0.94	3.71	2.49
CD (p=0.05)	0.56	7.11	7.26	3.06	9.34	3.27	3.30	2.60	77.53	112.86

Table 3 Yield attributes of barley as influenced by various treatments

Treatment	Stand count m^{-2}	Ear head m^{-2}	Length of spike (cm)	No. of spikelet's spike^{-1}	No. of fertile spikelet's	No. of unfertile spikelet's	No. of grains spike^{-1}	Grain weight spike^{-1} (g)	1000-grain weight (g)
T_1	293.20	270.86	7.25	39.20	37.03	2.37	36.68	1.44	33.20
T_2	310.86	284.53	7.48	39.90	38.00	2.10	37.70	1.58	34.53
T_3	316.20	300.20	7.78	40.89	39.18	1.91	38.84	1.63	35.86
T_4	332.53	311.86	8.15	41.98	40.45	1.73	40.18	1.70	36.20
T_5	345.53	324.20	8.30	43.16	42.02	1.34	41.54	1.76	37.20
T_6	353.20	333.53	8.70	43.47	42.43	1.24	42.08	1.84	39.53
T_7	362.86	340.86	9.22	44.38	43.40	1.18	42.98	1.88	40.20
T_8	371.20	347.20	9.34	45.11	44.26	1.05	43.90	1.92	41.86
T_9	349.20	329.86	8.56	43.17	42.11	1.26	41.70	1.81	39.35
SEm ±	2.56	2.24	0.29	1.07	1.09	0.33	1.18	0.12	1.14
CD(p=0.05)	7.51	6.54	0.64	2.99	3.04	0.74	3.32	0.14	3.20

Table 4 Yield and economics of barley cultivation as influenced by various treatments

Treatment	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio
T_1	7353.86	2977.76	4376.10	40.49	48700.00	83266.35	34566.35	0.71
T_2	8220.19	3316.76	4903.43	40.35	50860.00	92764.00	41904.00	0.82
T_3	9172.52	3715.76	5456.76	40.51	50777.78	103437.60	52659.82	1.04
T_4	10154.19	4129.76	6024.43	40.67	51257.78	114464.00	63206.22	1.23
T_5	11143.86	4550.43	6593.43	40.83	50976.70	125609.40	74632.70	1.46
T_6	12131.86	4974.10	7157.76	41.00	51186.70	136768.90	85582.20	1.67
T_7	12693.19	5225.43	7467.76	41.17	51175.62	143203.20	92027.58	1.80
T_8	13138.86	5509.10	7629.76	41.93	51655.62	149056.10	97400.48	1.89
T_9	11915.20	4885.10	7030.10	41.00	49495.62	134353.80	84858.18	1.71
SEm ±	265.80	100.61	165.19	0.22	-	3112.41	3112.58	0.06
CD(p=0.05)	756.57	281.48	475.09	0.61	-	8399.45	8399.97	0.17

Yield and economics

Grain and biological yields increased significantly with higher levels of RDN and NN (**Table 4**). The highest grain yield (5509.10 kg ha^{-1}) and biological yield (13138.86 kg ha^{-1}) were obtained in T8, which was statistically superior to other treatments. Control (T1) recorded the lowest yield (2977.76 kg ha^{-1} grain yield). Straw yield also followed the same trend, with T8 producing maximum (7629.76 kg ha^{-1}). The harvest index improved slightly under higher nitrogen levels, with maximum HI (41.93%) recorded in T8. Economic analysis revealed that the highest net return (Rs. 97,400 ha^{-1}) and B\:C ratio (1.89) were achieved with T8, followed by T7. In contrast, T1 registered the lowest profitability (B:C ratio 0.71). The improved returns under T8 were due to higher yield coupled with relatively low additional cost of NN sprays. These results corroborate earlier reports of positive economic responses of barley to integrated nitrogen management [13, 14].

Conclusion

The study demonstrated that nitrogen management practices significantly affected growth, yield attributes, yield, and economics of barley. The integration of 100% RDN with two foliar sprays of NN at 800 ml ha^{-1} each (T8) proved to be the most effective, producing maximum plant height, biomass, spike traits, grain yield (5509.10 kg ha^{-1}), and net returns (Rs. 97,400 ha^{-1}) with the highest B\:C ratio (1.89). Application of 70% RDN with NN (T6) also performed well, suggesting that partial substitution of basal nitrogen with NN sprays can enhance nitrogen use efficiency and sustain productivity. Therefore, foliar application of NN in combination with RDN offers a promising strategy for enhancing barley productivity and profitability under semi-arid conditions of Rajasthan.

Nano-nitrogen is more efficient than conventional nitrogen fertilizers due to its higher surface area, improved foliar absorption, and controlled nutrient release, which enhance nitrogen use efficiency and reduce nutrient losses, ultimately leading to better growth and yield

Future research should focus on long-term effects of integrated nitrogen management on soil fertility, NUE, and environmental sustainability.

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