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Influence of Nano-Nitrogen Application on Growth and Yield Performance of Barley under Semi-Arid Conditions

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Abstract

A field experiment was conducted during the Rabi season of 2025–26 at the Agricultural Research Farm of Vivekananda Global University, Jaipur. The experiment consisted of nine treatments arranged in a Randomized Block Design (RBD) with three replications. The treatments included a control (P + K only) along with various combinations of 50% or 100% RDN integrated with single or double foliar sprays of nano-nitrogen at rates of 400 ml ha^{-1} or 800 ml ha^{-1} applied at CRI and/or tillering stages. The results indicated that nano-nitrogen application significantly improved growth and yield parameters of barley. Among the treatments, T8 (100% RDN + 800 ml NN ha^{-1} at CRI + 800 ml NN ha^{-1} at tillering) produced the highest tiller density (74.20 tillers m^{-1}), plant height (95.72 cm), and dry matter accumulation (131.18 g plant^{-1}). The superior growth performance under T8 translated into improved yield attributes and yield levels. This treatment recorded the highest grain yield (5,509 kg ha^{-1}), biological yield (13,139 kg ha^{-1}), straw yield (7,630 kg ha^{-1}), and harvest index (41.93%). Economic evaluation also demonstrated the advantage of this treatment, with the highest gross return (Rs. 149,056 ha^{-1}), net return (Rs. 97,400 ha^{-1}), and benefit–cost ratio (1.89), despite a slightly higher cost of cultivation. Based on the findings, it can be concluded that foliar application of nano-nitrogen at 800 ml ha^{-1} at both CRI and tillering stages along with 100% RDN is the most effective approach for enhancing barley productivity and profitability under the semi-arid agro-climatic conditions of Jaipur.

Keywords: Barley, Nano-Nitrogen Fertilizer, Recommended Dose of Nitrogen (RDN), Foliar Nutrient Application, Yield and Economics

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Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest cultivated cereal crops and ranks fourth among cereals globally after wheat, rice, and maize. It is widely grown in temperate and semi-arid regions due to its adaptability to diverse agro-climatic conditions. In India, barley is an important rabi crop, contributing significantly to food security, livestock feed, and malting industries.

Despite its importance, barley productivity is often constrained by suboptimal agronomic practices, nutrient imbalances, and environmental stress conditions. Improving growth and yield through appropriate management practices is therefore essential. Growth parameters such as tiller number, plant height, and dry matter accumulation are critical determinants of yield in barley, as they directly influence the plant's capacity for photosynthesis and biomass production.

Yield attributes such as spike length, number of spikelets, grains per spike, and grain weight play a crucial role in determining final grain yield. These attributes are influenced by both genetic potential and environmental conditions, including nutrient availability and management practices. Recent advances in crop management emphasize the importance of integrated approaches to enhance productivity. Improved treatments involving nutrient management, growth regulators, and other agronomic inputs have shown promising results in increasing crop yield and quality (Singh *et al*., 2018).

Economic analysis is also a key component in evaluating the feasibility of agricultural practices. Farmers are increasingly adopting technologies that not only improve yield but also maximize profitability. Therefore, understanding the economic implications of different treatments is essential for recommending sustainable practices. Several studies have demonstrated that improved agronomic practices can significantly enhance barley yield and quality

(Kumar *et al*., 2019; Sharma *et al*., 2021). However, comparative evaluation of multiple treatments under field conditions is necessary to identify the most effective combinations.

The present study was undertaken to evaluate the effect of different treatments on growth parameters, yield attributes, yield, and economics of barley.

Materials and Methods

Experimental Site and Design

A field experiment was conducted during the rabi season under suitable agro-climatic conditions. The soil of the experimental field was fertile and suitable for barley cultivation.

The soil of the experimental field was loamy sand in texture with 24.6% coarse sand, 54.0% fine sand, 9.3% silt, and 5.7% clay. The soil was alkaline in reaction with pH 8.1 and EC 1.11 dS m^{-1}. It was low in organic carbon (0.17%) and available nitrogen (128.2 kg ha^{-1}), low in available phosphorus (15.8 kg ha^{-1}), and medium in available potassium (152.1 kg ha^{-1}). The barley variety used in the experiment was RD 2715. Experimental details including gross plot size (5 m × 4 m), net plot size (4 m × 3.55 m), and row spacing (22.5 cm) have also been clearly described.

The experiment consisted of nine treatments (T_1 to T_9) laid out in a randomized block design with appropriate replications. Standard agronomic practices were followed uniformly for all treatments.

S. No.	Treatments	Treatments details
1	T_1	Control
2	T_2	Control + NN_{800} at tillering + NN_{800} at tillering
3	T_3	25% RDN + NN_{400} at CRI + NN_{400} at tillering
4	T_4	25 % RDN + NN_{800} at CRI + NN_{800} at tillering
5	T_5	50 % RDN + NN_{400} at CRI + NN_{400} at tillering
6	T_6	50 % RDN + NN_{800} at CRI + NN_{800} at tillering
7	T_7	100 % RDN + NN_{400} at CRI + NN_{400} at tillering
8	T_8	100% RDN + NN_{800} at CRI + NN_{800} at tillering
9	T_9	Recommended dose of fertilizer

The nano-nitrogen fertilizer used in the experiment was a liquid nano-nitrogen formulation (IFFCO Nano Urea Liquid) containing 4.0% total nitrogen in nano form. The product was procured from IFFCO and applied as foliar spray at doses of 400 ml ha^{-1} and 800 ml ha^{-1} at CRI and tillering stages as per treatment specifications. Treatments involving 25%, 50%, and 100% Recommended Dose of Nitrogen (RDN) integrated with foliar nano-nitrogen sprays were designed to evaluate the possibility of reducing conventional nitrogen application through nano-nitrogen supplementation.

Crop Management

Barley was sown at recommended spacing and seed rate. Proper land preparation, irrigation, weed management, and plant protection measures were adopted to ensure optimal crop growth.

Observations Recorded

Growth parameters:

- Germination count (15, 30, 60, 90 DAS, and harvest)
- Number of tillers per metre row length
- Plant height (cm)
- Dry matter accumulation (g)

Yield attributes:

- Stand count (m^{-2})
- Ear heads (m^{-2})
- Spike length (cm)
- Number of spikelets per spike
- Number of grains per spike
- Grain weight per spike
- 1000-grain weight (g)

Yield and economics:

- Grain yield (kg ha^{-1})
- Straw yield (kg ha^{-1})
- Biological yield (kg ha^{-1})
- Harvest index (%)
- Cost of cultivation
- Gross returns
- Net returns
- Benefit-cost ratio

Statistical Analysis

The experimental data were analyzed using analysis of variance (ANOVA) appropriate for Randomized Block Design (RBD) following the procedure described by Fisher and Yates (1957). Statistical analysis was performed using OPSTAT statistical software. Prior to analysis, assumptions of ANOVA including normality and homogeneity of variance were verified. Treatment means were compared using Critical Difference (CD) at 5% probability level, and standard error of mean (SEm ±) values were calculated for all parameters.

Results and Discussion

Growth Parameters

The data presented in **Table 1** indicate that growth parameters were significantly influenced by different treatments. Germination count increased progressively with improved treatments. The highest germination count was recorded under T_8 (54.73 at 15 DAS and 74.20 at harvest), while the lowest was observed under T_1. Improved germination may be attributed to better seed-soil interaction and favorable conditions created by treatments. Number of tillers is a critical parameter affecting yield. T_8 recorded the highest number of tillers (95.72 at harvest), followed by T_7 and T_6. Increased tillering may be due to improved nutrient availability and better growth conditions. Plant height showed significant variation among treatments. T_8 recorded maximum plant height (90.53 cm at 60 DAS and 92.53 cm at 90 DAS). Increased plant height is often associated with enhanced vegetative growth and nutrient uptake. Dry matter accumulation increased significantly with treatments. The highest dry matter (131.18 g at harvest) was recorded under T_8. Increased dry matter indicates higher photosynthetic efficiency and biomass production.

These findings are in agreement with Sharma *et al*. (2021), who reported improved growth parameters under optimized management practices.

Table 1 Growth parameters of barley at successive stages of crop growth as influenced by various treatments

Treatment	Germination count	Number of tillers $metre^{-1}$ row length				Plant height (cm)				Dry matter accumulation in plants (g)			
	15 DAS	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest
T_1	48.36	37.53	67.36	53.53	53.03	9.41	37.24	67.57	72.17	4.33	32.7	58.47	103.02
T_2	49.03	38.36	69.86	64.53	62.03	11.08	37.84	73.47	78.28	4.56	36.87	60.11	106.24
T_3	49.53	39.2	70.86	68.2	63.2	11.9	41.07	78.64	83.68	4.68	39.18	63.6	108
T_4	50.53	40.86	72.53	73.53	66.53	12.11	43.57	79.47	85.51	5.03	40.52	68.95	109.98
T_5	51.03	43.2	73.36	76.53	69.03	12.51	44.3	82.32	88.2	5.35	41.63	70.95	111.8
T_6	52.2	48.2	77.86	85.86	70.53	12.94	45.64	84.55	90.76	5.74	43.11	90.08	120.22
T_7	53.53	52.7	87.86	86.2	72.36	13.08	46.84	89.24	94.08	5.76	44.7	91.2	127.55
T_8	54.73	54.7	90.53	92.53	74.2	13.11	52.07	90.57	95.72	5.78	46.45	93.08	131.18
T_9	51.86	45.53	74.53	78.2	69.86	12.56	44.5	83.74	88.82	5.66	42.11	78.52	116.04
SEm ±	1.25	1.04	1.65	1.19	0.63	0.26	2.43	2.48	1.09	0.42	1.16	1.17	0.94
CD (p=0.05)	NS	2.90	4.76	3.38	1.66	0.56	7.11	7.26	3.06	9.34	3.27	3.30	2.60

Yield Attributes

Yield attributes were significantly influenced by treatments (**Table 2**). Stand count and ear heads per square meter increased significantly with treatments. T_8 recorded the highest stand count (343.70 m^{-2}) and ear heads (321.48 m^{-2}). Spike length, number of spikelets, and grains per spike also increased significantly. T_8 recorded the highest spike length (8.65 cm), grains per spike (43.04), and grain weight per spike (1.88 g). The increase in yield attributes may be due to better nutrient uptake and improved physiological processes, leading to enhanced reproductive development. 1000-grain weight was highest under T_8 (41.04 g), indicating better grain filling. Higher grain weight is associated with improved assimilate translocation during grain development

Yield Performance

Grain yield and biological yield were significantly influenced by treatments (**Table 3**). T_8 recorded the highest grain yield (5509.10 kg ha^{-1}), followed by T_7 (5225.43 kg ha^{-1}). The lowest yield was observed under T_1 (2977.76 kg ha^{-1}). Biological yield followed a similar trend, with maximum under T_8 (13138.86 kg ha^{-1}). Straw yield also increased significantly with treatments. Harvest index ranged from 40.35% to 41.93%, with the highest under T_8, indicating efficient partitioning of assimilates. The increase in yield may be attributed to improved growth parameters and yield attributes, leading to higher productivity.

Table 2 Yield attributes of barley at successive stages of crop growth 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	271.48	250.80	6.71	36.30	36.30	2.32	35.96	1.41	32.55
T_2	287.83	263.45	6.93	36.94	37.25	2.06	36.96	1.55	33.85
T_3	292.78	277.96	7.20	37.86	38.41	1.87	38.08	1.60	35.16
T_4	307.90	288.76	7.55	38.87	39.66	1.70	39.39	1.67	35.49
T_5	319.94	300.19	7.69	39.96	41.20	1.31	40.73	1.73	36.47
T_6	327.04	308.82	8.06	40.25	41.60	1.22	41.25	1.80	38.75
T_7	335.98	315.61	8.54	41.09	42.55	1.16	42.14	1.84	39.41
T_8	343.70	321.48	8.65	41.77	43.39	1.03	43.04	1.88	41.04
T_9	323.33	305.43	7.93	39.97	41.28	1.24	40.88	1.77	38.58
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 3 Yield and economics of barley at successive stages of crop growth 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

Economic Analysis

Economic analysis revealed significant differences among treatments. T_8 recorded the highest gross returns (Rs. 149,056.10 ha^{-1}), net returns (Rs. 97,400.48 ha^{-1}), and B:C ratio (1.89). This indicates that T_8 is the most profitable treatment. Higher economic returns under T_8 may be due to higher yield and efficient resource utilization.

Overall Interpretation

The results clearly indicate that improved treatments significantly enhanced growth, yield attributes, and yield of barley. The superiority of T_8 can be attributed to its ability to improve plant growth, increase tillering, enhance spike characteristics, and improve grain filling.

Conclusion

The present study demonstrates that different treatments significantly influence growth, yield attributes, yield, and economics of barley. Among all treatments, T_8 proved to be the most effective, recording the highest growth parameters, yield attributes, grain yield, and economic returns. Therefore, T_8 can be recommended for enhancing barley productivity and profitability under similar agro-climatic conditions.

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