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Influence of Weed and Nitrogen Management on Growth, Productivity and Economics of Barley (*Hordeum vulgare* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Background: Barley (*Hordeum vulgare* L.) productivity is often constrained by severe weed competition and improper nitrogen management, which adversely affect crop growth, yield, and nutrient use efficiency. Integrated weed and nitrogen management is therefore essential to enhance productivity and profitability under semi-arid conditions.

Methods: A field experiment was conducted during the *Rabi* season of 2021–22 at the Agronomy Research Farm, SGT University, Gurugram, Haryana. The experiment was laid out in a factorial randomized block design with three replications, comprising four weed management treatments (W_1: weedy check, W_2: weed-free, W_3: metsulfuron, W_4: 2,4-D) Observations on growth, yield attributes, yield, nitrogen uptake, and economics were recorded and analyzed statistically.

Results: Weed management and nitrogen levels significantly influenced growth, yield attributes, and productivity of barley. Treatment W_2 and W_3 improved plant growth, dry matter accumulation, and yield

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attributes over W_1. Among nitrogen levels, N_3 recorded superior performance, followed by N_2. Grain yield, biological yield, and nitrogen uptake increased with effective weed control and higher nitrogen levels. Among interaction W_2* N_2 showed maximum productivity and nutrient uptake.W_3 resulted in higher profitability, while N_3 recorded maximum returns, though N_2 was more cost-effective.

Keywords: Barley; weed management; nitrogen levels; yield; nutrient uptake.

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest and most important cereal crops cultivated worldwide, ranking fourth after wheat, rice, and maize. It serves as a major source of food, feed, and raw material for malting and brewing industries. Owing to its wide adaptability to diverse agro-climatic conditions, barley plays a crucial role in ensuring food security, particularly in semi-arid and temperate regions (Kaur *et al*., 2024; Cammarano *et al*., 2024).

Barley productivity is often constrained by weed infestation and improper nitrogen management. Weeds compete for nutrients, moisture, light, and space during early growth, reducing crop vigor and yield by 20–50% depending on conditions (Mendera *et al*., 2024; Dorado *et al*., 2025; Naeem *et al*., 2022; Safdar *et al*., 2022). Timely weed control is essential.

Effective weed management is essential for improving barley productivity. Herbicide application is widely adopted due to its efficiency and cost-effectiveness. Proper weed control enhances growth, yield attributes, and economic returns in barley cultivation Kumar & Jha, (2017).

Nitrogen is essential for plant growth, aiding chlorophyll formation, photosynthesis, and protein synthesis. Adequate supply enhances growth and yield, while inefficient management reduces efficiency and causes environmental issues, requiring optimization (Sisay *et al*., 2025; Scapino *et al*., 2025). Efficient nitrogen management not only increases crop yield but also improves economic returns and minimizes environmental risks by reducing input losses (Loukakis *et al*., 2025).

The interaction between weed management and nitrogen fertilization plays a crucial role in crop performance. While nitrogen enhances both crop and weed growth, effective weed control improves nutrient use efficiency. Thus, integrating suitable weed management with optimum nitrogen levels is essential for maximizing productivity and economic returns in barley cultivation. (Bogale *et al*., 2024; Al-Jayashi *et al*., 2024; Singh *et al*., 2025; Hirich *et al*., 2026; Shpanev and Smuk, 2025)..Therefore, the present study was undertaken to evaluate the influence of weed and nitrogen management on growth, productivity, nutrient uptake, and economics of barley

2. Materials and Methods

The present field investigation was conducted during the *Rabi* season of 2021–22 at the Agronomy Research Farm, Faculty of Agricultural Sciences, SGT University, Gurugram, (Haryana), India. The experimental site is situated in the semi-arid region of the north-western Indo-Gangetic plains, characterized by typical climatic conditions of the area.

The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, and had low to medium fertility status based on initial soil analysis. Soil samples were collected from 0-15 cm depth before sowing and analyzed using standard procedures, including alkaline $KMnO_4$ method for nitrogen (Subbaiah and Asija, 1956), Olsen's method for phosphorus (Olsen *et al*., 1954), and flame photometric method for potassium determination (Jackson, 1973).

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications. The treatments consisted of two factors: weed management and nitrogen levels. Weed management included four treatments, *viz*., weedy check (W_1), weed-free (W_2), metsulfuron at 4 g ha^{-1} applied at 30 DAS, (W_3), and 2,4-D at 0.5 kg ha^{-1} applied at 30 DAS (W_4). Nitrogen was applied at four levels: 0 kg ha^{-1} (N_0), 30 kg ha^{-1} (N_1), 60 kg ha^{-1} (N_2), and 90 kg ha^{-1} (N_3). Thus, a total of 16 treatment combinations were evaluated.

Each plot measured 3.0 m × 2.7 m, and the total number of experimental plots was 48. Barley variety BH 393 was sown on 22 November 2021-22 using a seed rate of 100 kg ha^{-1}, maintaining a row spacing of 22.5 cm. The field was prepared by ploughing followed by harrowing and planking to obtain a fine tilth. A pre-sowing irrigation was applied to ensure uniform germination.

Fertilizers were applied as per treatments and phosphorus at 40 kg ha^{-1} as basal. Irrigation was given at CRI and subsequent stages. Herbicides were applied at 30 DAS as per treatment in the treated plots, while weed-free plots were manually throughout the crop season.Growth parameters such as plant height and dry matter accumulation at different growth stages were observed. Yield attributes including effective tillers, spike length, grains per spike, and test weight were also recorded. Yield parameters such as grain yield, straw yield, biological yield, and harvest index (Grain yield/Biological yield *100) were computed following standard agronomic procedures. In addition, nitrogen content and uptake in grain and straw, as well as economic parameters including cost of cultivation, gross return, net return, and benefit–cost ratio, were calculated using established methods (Jackson, 1973).

The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for Factorial Randomized Block Design, and treatment means were compared at the 5% level of significance using the critical difference (CD) test, as described by (Gomez and Gomez, 1984).

3. Results and Discussion

The present investigation clearly demonstrated that both weed management practices and nitrogen levels significantly influenced growth, yield attributes, productivity, nutrient uptake, and economic returns of barley.

3.1 Crop Establishment and Plant Growth

The initial plant population was not significantly influenced by weed management or nitrogen levels (Table 1), indicating uniform crop establishment across treatments. Plant height increased progressively with crop growth (Table 2). Among weed management treatments, W_2 recorded the highest plant height at harvest, followed by W_3, which remained statistically at par, while W_1 showed comparatively lower growth." This improvement may be attributed to reduced competition for light, nutrients, and moisture, as also reported by (Al-Gburi *et al*., 2024; Kumar & Singh 2018; Naeem *et al*., 2022; Cammarano *et al*., 2024; Sisay *et al*., 2025).

Nitrogen levels significantly influenced plant height, with N_3 producing the tallest plants, followed by N_2, N_1, and N_0 (Table 2). Dry matter accumulation followed a similar pattern (Table 3), with maximum biomass under W_2 and N_3. Interaction effects (Tables 4 and 5) further confirmed enhanced growth under combined treatments.

3.2 Yield Attributes

Yield attributes were significantly influenced by both weed and nitrogen management practices (Table 6). Among weed treatments, W_2 recorded superior performance in terms of yield attributes, which was statistically at par with W_3, while W_1 showed comparatively lower values. This indicates that effective chemical weed control can serve as a viable alternative to manual weeding.

Among nitrogen levels, N_3 recorded the highest values of yield attributes, followed by N_2, N_1, and N_0 (Table 6). This improvement may be attributed to enhanced nutrient availability and increased photosynthetic efficiency (Loukakis *et al*., 2025; Saikia *et al*., 2018; Scapino *et al*., 2025).

The interaction effect on spike length (Table 7) further revealed that combinations of effective weed management (W_2 and W_3) with higher nitrogen levels (N_2 and N_3) resulted in improved spike development, emphasizing the importance of integrated weed and nutrient management practices.

3.3 Yield Performance

Grain yield, straw yield, and biological yield were significantly influenced by weed and nitrogen management practices (Table 8). Among weed treatments, W_2 recorded the highest grain yield, which was statistically at par with W_3, while W_1 resulted in the lowest yield due to severe weed competition. This clearly indicates the detrimental effect of uncontrolled weeds on crop productivity.

Nitrogen application significantly enhanced yield, with N_3 producing the highest yield, followed by N_2, N_1, and N_0 (Table 8). However, the response beyond N_2 was comparatively less pronounced, suggesting diminishing returns at higher nitrogen levels. Similar trends have been reported by (Sisay *et al*., 2025; Pooniya *et al*., 2021; Kumar *et al*., 2022; Kantwa *et al*., 2025; Bogale *et al*., 2024).

Interaction effects (Tables 9 and 10) revealed that combinations of effective weed management (W_2 and W_3) with higher nitrogen levels (N_2 and N_3) significantly improved straw and biological yield, indicating better utilization of available resources.

3.4 Harvest Index

Harvest index was significantly influenced by weed and nitrogen management practices (Table 8). Among weed control treatments, W_2 recorded the highest harvest index, followed by W_3 and W_4, while W_1 showed lower values, indicating better assimilate partitioning under effective weed control. Similar findings were reported by (Arshad *et al*., 2025; Puniya *et al*., 2023). Interaction effects (Table 11) showed that W_2 combined with higher nitrogen levels (N_2 and N_3) improved harvest index. This may be due to synergistic effects of nitrogen and weed control on photosynthesis and dry matter distribution, as also reported by (Dolijanović *et al*., 2025; Shekhawat *et al*., 2021).

3.5 Nitrogen Content and Uptake

Nitrogen content and uptake were significantly influenced by weed and nitrogen management practices (Table 12). Among weed treatments, W_2 recorded higher nitrogen uptake, followed by W_3, while W_1 showed lower uptake due to nutrient competition. This may be attributed to reduced crop–weed competition and improved nutrient availability, as reported by (Kumar *et al*., 2022; Naeem *et al*., 2022).

Among nitrogen levels, N_3 recorded the highest uptake, followed by N_2, N_1, and N_0, indicating better nutrient utilization under higher nitrogen application. Similar trends were observed by (Loukakis *et al*., 2025; Kantwa *et al*., 2025; Scapino *et al*., 2025; Saikia *et al*., 2018).

3.6 Economic Analysis

Economic analysis (Table 13) revealed that among weed management treatments, W_3 recorded the highest net return and benefit–cost ratio, outperforming W_2, W_4, and W_1, mainly due to reduced cost of weed control and efficient resource utilization.

Among nitrogen levels, N_3 recorded the highest net return and B:C ratio, followed by N_2, N_1, and N_0. However, considering input costs and marginal returns, N_2 may be a more economically viable option under limited resource conditions.

These findings are in agreement with (Singh *et al*., 2025; Sunil *et al*., 2025; Bogale *et al*., 2024), who also reported higher profitability under integrated weed and nutrient management practices.

Table 1. Effect of different treatments on initial population of barley

Treatments	Initial population (no. m^{-1}) at 30 DAS
Weed management	
W_1: Weedy check (no weed control)	40.16
W_2: Weed-free	45.83
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	41.67
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	40.00
SE(m) ±	2.46
C.D. at 5 %	NS

Treatments	Initial population (no. m^{-1}) at 30 DAS
Nitrogen management	
N_0: Control (0 kg N ha^{-1})	39.83
N_1: 30 kg N ha^{-1}	41.25
N_2: 60 kg N ha^{-1}	42.00
N_3: 90 kg N ha^{-1}	44.58
SEm±	2.46
CD (P = 5%)	NS

Table 2. Effect of different treatments on plant height of barley at different growth stages

Treatment	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Weed management				
W_1: Weedy check (no weed control)	5.87	45.90	64.99	69.26
W_2: Weed-free	8.33	51.68	69.10	73.57
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	7.20	50.35	68.57	72.77
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	6.83	47.97	66.81	72.31
SE(m)±	0.80	2.12	1.00	1.07
C.D. at 5 %	NS	NS	2.91	3.11
Nitrogen management				
N_0: Control (0 kg N ha^{-1})	6.95	40.75	58.01	62.31
N_1: 30 kg N ha^{-1}	6.79	46.26	65.80	69.11
N_2: 60 kg N ha^{-1}	7.04	51.99	72.46	78.63
N_3: 90 kg N ha^{-1}	7.45	56.90	73.20	77.87
SEm±	0.80	2.12	1.00	1.07
CD (P = 5%)	NS	6.16	2.91	3.11

Table 3. Effect of weed and nitrogen management on plant dry weight of barley at different growth stages

Treatment	Plant dry weight (g $plant^{-1}$)			
	30 DAS	60 DAS	90 DAS	At Harvest
Weed management				
W_1: Weedy check (no weed control)	5.87	36.35	120.98	165.56
W_2: Weed-free	8.33	42.68	151.76	209.68
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	7.20	38.79	136.12	193.68
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	6.83	38.55	131.55	179.20
SE(m)±	0.80	3.72	2.40	2.69
C.D. at 5 %	NS	NS	6.95	7.81
Nitrogen management				
N_0: Control (0 kg N ha^{-1})	6.79	33.12	113.79	144.64
N_1: 30 kg N ha^{-1}	6.95	36.81	122.30	174.07
N_2: 60 kg N ha^{-1}	7.04	38.73	139.13	204.28
N_3: 90 kg N ha^{-1}	7.45	47.70	165.19	225.14
SEm±	0.80	3.72	2.40	2.69
CD (P = 5%)	NS	NS	6.95	7.81

Table 4. Interaction of weed and nitrogen on dry weight of barley at 90 DAS

Treatment	N_0: Control (0 kg N ha^{-1})	N_1: 30 kg N ha^{-1}	N_2: 60 kg N ha^{-1}	N_3: 90 kg N ha^{-1}	Mean
W_1: Weedy check (no weed control)	116.8	118.7	122.0	126.4	121.0
W_2: Weed-free	124.1	127.4	161.4	194.1	151.8
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	100.5	115.5	141.7	186.9	136.1
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	113.7	127.6	131.4	153.5	131.6
Mean	113.8	122.3	139.1	165.2	
SEm±	4.79				
CD (P = 5%)	13.9				

Table 5. Interaction of weed and nitrogen on dry weight of barley at harvest

Treatment	N_0: Control (0 kg N ha^{-1})	N_1: 30 kg N ha^{-1}	N_2: 60 kg N ha^{-1}	N_3: 90 kg N ha^{-1}	Mean
W_1: Weedy check (no weed control)	130.0	163.4	176.8	192.0	165.6
W_2: Weed-free	161.3	179.6	230.8	267.1	209.7
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	164.6	180.3	208.8	221.1	193.7
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	122.7	173.0	200.7	220.4	179.2
Mean	144.6	174.1	204.3	225.1	
SEm±	5.38				
CD (P = 5%)	15.6				

Table 6. Effect of different treatments on yield attributes of barley

Treatment	Effective tillers (no. m^{-1})	Spike length (cm)	Grains spike^{-1}	Test weight (g)
Weed management				
W_1: Weedy check (no weed control)	75.08	5.52	39.90	36.50
W_2: Weed-free	88.50	5.98	44.45	37.16
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	85.25	5.88	43.15	36.87
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	84.08	5.80	41.69	36.62
SE(m)±	2.54	0.08	1.34	0.54
C.D. at 5%	7.38	0.25	NS	NS
Nitrogen management				
N_0: Control (0 kg N ha^{-1})	71.33	5.02	35.83	35.87
N_1: 30 kg N ha^{-1}	80.50	5.87	42.77	36.45
N_2: 60 kg N ha^{-1}	84.58	5.99	45.30	37.08
N_3: 90 kg N ha^{-1}	96.50	6.30	45.30	37.75
SEm±	2.54	0.08	1.34	0.54
CD (P = 5%)	7.38	0.25	3.90	NS

Table 7. Interaction of weed and nitrogen on spike length of barley

Treatment	N_0: Control (0 kg N ha⁻¹)	N_1: 30 kg N ha⁻¹	N_2: 60 kg N ha⁻¹	N_3: 90 kg N ha⁻¹	Mean
W_1: Weedy check (no weed control)	4.27	5.83	6.00	5.99	5.52
W_2: Weed-free	5.33	5.83	5.88	6.89	5.98
W_3: Application of Metsulfuron-methyl at 4 g ha⁻¹ at 30 DAS	5.11	6.38	5.78	6.27	5.89
W_4: Application of 2,4-D at 0.5 kg ha⁻¹ at 30 DAS	5.38	5.44	6.33	6.05	5.80
Mean	5.02	5.87	6.00	6.30	
SEm±	0.17				
CD (P = 5%)	0.50				

Table 8. Effect of different treatments on yield and harvest index of barley

Treatment	Grain yield (kg ha⁻¹)	Straw yield (kg ha⁻¹)	Biological yield (kg ha⁻¹)	Harvest index (%)
Weed management				
W_1: Weedy check (no weed control)	1984	2574	4,972	36.09
W_2: Weed-free	2538	3,261	5,530	47.43
W_3: Application of Metsulfuron-methyl at 4 g ha⁻¹ at 30 DAS	2494	3,019	5,468	44.77
W_4: Application of 2,4-D at 0.5 kg ha⁻¹ at 30 DAS	2261	3,004	5,369	44.91
SE(m)±	38	52	82	0.97
C.D. at 5 %	111	151	238	2.81
Nitrogen management				
N_0: Control (0 kg N ha⁻¹)	1294	1,751	3,145	41.06
N_1: 30 kg N ha⁻¹	2068	2,752	4,850	43.12
N_2: 60 kg N ha⁻¹	2817	3,510	6,510	43.61
N_3: 90 kg N ha⁻¹	3098	3,846	6,834	45.40`
SEm±	38	52	82	0.97
CD (P = 5%)	111	151	238	2.81

Table 9. Interaction of weed and nitrogen on straw yield of barley

Treatment	N_0: Control (0 kg N ha⁻¹)	N_1: 30 kg N ha⁻¹	N_2: 60 kg N ha⁻¹	N_3: 90 kg N ha⁻¹	Mean
W_1: Weedy check (no weed control)	1,353	2,696	2,830	3,418	2,574
W_2: Weed-free	1,852	3,002	3,634	4,558	3,261
W_3: Application of Metsulfuron-methyl at 4 g ha⁻¹ at 30 DAS	1,925	2,727	3,747	3,678	3,019
W_4: Application of 2,4-D at 0.5 kg ha⁻¹ at 30 DAS	1,874	2,583	3,828	3,731	3,004
Mean	1,751	2,752	3,510	3,846	
SEm±	104				
CD (P = 5%)	301				

Table 10. Interaction of weed and nitrogen on biological yield of barley

Treatment	N_0: Control (0 kg N ha^{-1})	N_1: 30 kg N ha^{-1}	N_2: 60 kg N ha^{-1}	N_3: 90 kg N ha^{-1}	Mean
W_1: Weedy check (no weed control)	2,866	4,570	5,692	6,762	4,972
W_2: Weed-free	3,290	5,207	6,688	6,934	5,530
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	3,097	5,186	6,770	6,820	5,468
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	3,328	4,438	6,890	6,820	5,369
Mean	3,145	4,850	6,510	6,834	
SEm±	164				
CD (P = 5%)	476				

Table 11. Interaction of weed and nitrogen on barley harvest index

Treatment	N_0: Control (0 kg N ha^{-1})	N_1: 30 kg N ha^{-1}	N_2: 60 kg N ha^{-1}	N_3: 90 kg N ha^{-1}	Mean
W_1: Weedy check (no weed control)	35.67	33.50	34.91	40.27	36.09
W_2: Weed-free	43.68	53.26	44.62	48.14	47.43
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	43.71	42.35	45.67	47.33	44.77
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	41.16	43.37	49.23	45.86	44.91
Mean	41.06	43.12	43.61	45.40	
SEm±	1.94				
CD (P = 5%)	5.62				

Table 12. Effect of different treatments on nitrogen content (%) and uptake (kg ha^{-1}) in grain and straw of barley

Treatment	N content in grain (%)	N uptake by grain (kg ha^{-1})	N content in straw (%)	N uptake by straw (kg ha^{-1})	Total N uptake (kg ha^{-1})
Weed management					
W_1: Weedy check (no weed control)	1.48	29.45	0.43	11.02	40.47
W_2: Weed-free	1.48	37.45	0.45	14.83	52.28
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	1.48	36.77	0.44	13.58	50.35
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	1.50	33.91	0.43	13.15	47.06
SE(m)±	0.03	0.92	0.02	0.74	1.10
C.D. at 5%	NS	2.66	NS	2.15	3.21
Nitrogen management					
N_0: Control (0 kg N ha^{-1})	1.52	19.64	0.43	7.53	27.17
N_1: 30 kg N ha^{-1}	1.43	29.50	0.42	11.73	41.02
N_2: 60 kg N ha^{-1}	1.50	42.18	0.46	16.12	58.31
N_3: 90 kg N ha^{-1}	1.49	46.29	0.45	17.40	63.66
SEm±	0.03	0.92	0.02	0.74	1.10
CD (P = 5%)	NS	2.66	NS	2.15	3.21

Table 13. Economics of barley as influenced by weed and nitrogen management

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Weed management				
W_1: Weedy check (no weed control)	31351	76447	45096	2.42
W_2: Weed-free	43351	97524	54173	2.24
W_3: Application of Metsulfuron-methyl at 4 g ha^{-1} at 30 DAS	32526	94241	61715	2.88
W_4: Application of 2,4-D at 0.5 kg ha^{-1} at 30 DAS	32531	87713	55182	2.68
SEm±	-	-	-	-
CD (P = 5%)	-	-	-	-
Nitrogen management				
N_0: Control (0 kg N ha^{-1})	33709	50476	16767	1.51
N_1: 30 kg N ha^{-1}	34830	80261	45431	2.32
N_2: 60 kg N ha^{-1}	35351	107308	71958	3.07
N_3: 90 kg N ha^{-1}	35871	117881	82010	3.32
SEm±	-	-	-	-
CD (P = 5%)	-	-	-	-

4. Conclusion

The study demonstrated that weed management and nitrogen levels significantly influenced growth, yield, nutrient uptake, and economic returns of barley. Effective weed control treatments, particularly W_2 and W_3, improved crop performance by minimizing competition and enhancing resource use efficiency. Nitrogen application showed a positive response, with N_3 and N_2 enhancing productivity and nutrient uptake. The interaction of weed management and nitrogen levels indicated that combined application of effective weed control with optimum nitrogen is essential. Economically, W_3 and N_2 proved to be more viable, suggesting an efficient and sustainable approach for barley cultivation under semi-arid conditions. (recommendations).

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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