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Integrated Effects of Nitrogen Fertilization, Cutting Management and Plant Growth Regulators on Nutrient Uptake and Quality of Barley (*Hordeum vulgare* L.)

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ABSTRACT

Background: Dual-purpose barley (*Hordeum vulgare* L.) plays a vital role in arid and semi-arid agro-ecosystems by providing both forage and grain. However, improper cutting schedules, sub-optimal nitrogen fertilization and inefficient use of plant growth regulators (PGRs) often limit nutrient uptake, grain quality and seed viability.

Methods: A field experiment was conducted during the *rabi* seasons of 2023-24 and 2024-25 at Mandawa, Rajasthan, using dual-purpose barley variety RD 2715. The study involved 18 treatment combinations comprising three cutting schedules (40, 50 and 60 DAS), three nitrogen levels (100, 125 and 150% RDN) and two plant growth regulators (chlormequat chloride and ethephon), laid out in a factorial randomized block design with three replications.

Result: Cutting at 40 DAS recorded significantly higher uptake of N, P and K in both grain and straw compared to later cuttings. Application of 125% and 150% RDN significantly enhanced nutrient content, nutrient uptake, seed viability and crude protein content over 100% RDN, with both higher levels remaining statistically at par. Among PGRs, chlormequat chloride consistently resulted in higher nutrient uptake and protein content compared to ethephon, although differences in protein content were statistically non-significant. Seed viability and protein content showed a positive response to increased nitrogen levels, while cutting schedules had a non-significant effect on seed viability.

Key words: Cutting schedules, Dual-purpose barley, Nitrogen management, Nutrient uptake, Plant growth regulators.

INTRODUCTION

Barley (*Hordeum vulgare* L.) has traditionally been cultivated as an important cereal crop for human consumption, livestock feed and malting purposes in India (Kaur *et al*., 2024). Globally, it ranks as the fourth most important cereal crop after wheat, maize and rice, contributing nearly 7% to total global cereal production (Arebu, 2022). Taxonomically, barley belongs to the family Poaceae and genus *Hordeum*, possessing a diploid chromosome number of 2n = 14. In India, more than 75% of the total barley production is utilized for cattle and poultry feed, followed by its use in malting and beverage industries (20%), while only about 5% is consumed directly as human food (Takarli *et al*., 2025). With increasing health awareness and the recognition of barley as a rich source of β-glucan, the crop has gained renewed interest as a functional food ingredient either in direct form or blended with other cereals such as wheat (Kumbhar *et al*., 2025).

Barley is an important *rabi* cereal crop in Rajasthan, occupying approximately 2.74 lakh hectares, accounting for 8.23% of the total rabi cereal area and contributing 7.46% to total *rabi* cereal production in the state (Singh and Kumar, 2023). Nutritionally, barley grains contain about 10.6 g protein, 2.1 g fat, 64.0 g carbohydrates, 50.0 mg calcium, 6.0 mg iron, 31.0 mg vitamin B1, 0.1 mg vitamin B2 and 50.0 µg folate per 100 g of grain (Maheshwari *et al*., 2025). The crop is cultivated widely across the world and in India, it is primarily grown in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, West Bengal and Bihar. Nationally, barley covers 0.62 million hectares with a production of 1.91 million tonnes and an average

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productivity of 3030 kg ha^{-1} (Anonymous, 2019). In Rajasthan alone, barley is grown over 0.27 million hectares with a productivity of 3324 kg ha^{-1} (Anonymous, 2019).

Nitrogen is the most limiting nutrient in Indian soils, particularly in the loamy sand soils of Rajasthan. Among essential nutrients, nitrogen plays a pivotal role in determining yield potential in cereal crops and its deficiency severely restricts plant growth and development (Choudhary *et al.,* 2023). Nitrogen is a fundamental constituent of proteins, chlorophyll, phospholipids, nucleotides, amino acids, enzymes and photosynthetic pigments (Bocso and Butnariu, 2022). Nitrogen uptake and partitioning in plants are largely governed by crop demand and nutrient supply during various growth stages. High nitrogen requirement is observed during tillering, booting, stem elongation, heading and grain filling stages to support reproductive development and protein accumulation in grains (Leghari *et al*., 2016). Application of the entire nitrogen dose at sowing may not adequately meet crop demand throughout the growth cycle, potentially reducing seed yield and nitrogen concentration in grain and straw.

In intensive cereal production systems, plant growth regulators (PGRs) are increasingly used to reduce lodging and improve crop standability. These compounds are applied to shorten straw length and enhance lodging resistance by modifying plant architecture. PGRs act at the cellular level, influencing plant physiology by reducing stem elongation and shortening upper internodes and peduncles (Sabagh *et al*., 2021). Some studies also report alterations in stem thickness and assimilate partitioning. Although PGR applications are generally timed according to the main stem growth stage, their effects may extend to tillers even without direct exposure. Integration of nitrogen management with growth regulator application may therefore influence nutrient uptake dynamics, biomass partitioning and grain quality in dual-purpose barley systems (Sonia *et al.,* 2025).

Considering the agronomic importance of barley in Rajasthan and the need to optimize nitrogen fertilization, plant growth regulator use and cutting schedules under semi-arid irrigated conditions, the present investigation was undertaken to evaluate the integrated effects of cutting management, nitrogen levels and plant growth regulators on nutrient content, nutrient uptake, seed viability and protein content of dual-purpose barley.

MATERIALS AND METHODS

Experimental site and climate

The field experiment was conducted during the *rabi* seasons of 2023-24 and 2024-25 at the Research Farm, Mandawa, Jhunjhunu district, Rajasthan, India. The site falls under agro-climatic zone II A (Transitional Plains of Inland Drainage Zone) of Rajasthan and is characterized by arid climatic conditions. During the cropping seasons, maximum and minimum temperatures ranged between 17.9°C to 40.5°C and 6.0°C to 23.1°C, respectively. Total rainfall received during the crop period was 40.4 mm. Relative humidity varied from 18.5% to 85.0% and average sunshine hours ranged from 2.0 to 10.4 hours per day.

Soil characteristics

Before layout of the experiment, soil samples were collected from 0-30 cm depth at five random locations and combined into a composite sample for analysis. The soil was loamy sand in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen and medium to high in available phosphorus and potassium.

Experimental design and crop management

The experiment consisted of 18 treatment combinations arranged in a factorial randomized block design (FRBD) with three replications, totaling 54 plots. Dual-purpose barley variety RD 2715 was sown at 22.5 cm row spacing using a seed rate of 100 kg ha^{-1}. Gross and net plot sizes were 18.0 m^2 and 7.2 m^2, respectively.

Fertilizer, irrigation and PGR application

The recommended fertilizer dose comprised 60 kg N, 20 kg P_2O_5 and 40 kg K_2O ha^{-1}. Nitrogen was applied in two splits: 50% basal and 50% at first irrigation. Additional nitrogen (125% and 150% RDN) was applied after green fodder cutting. Phosphorus and potassium were applied as basal. Irrigation was provided at critical growth stages (CRI, tillering, jointing, booting and grain filling). Chlormequat chloride (1.25 litre ha^{-1} at GS30-31) and ethephon (0.5 litre ha^{-1} at GS39-40) were applied using a knapsack sprayer with a spray volume of 500 litre ha^{-1}. The treatments along with their symbols and details are given in Table 1.

Characteristics of cultivars

RD 2715 is a six-row barley variety developed by SKNAU, Durgapura, Jaipur (Rajasthan) for dual purpose utilization. It possesses high degree of resistance against yellow and brown rust. It starts heading in about 80-85 days and matures in about 120-125 days with average plant height of 70.0 cm and has 1000 grain weight of about 43.0 g identified as dual-purpose barley variety for timely sown irrigated condition of central zone.

Observations recorded

Chemical analysis

N content in grain and straw

N content in grain and straw was determined by micro-Kjeldahl method as per procedure suggested by (AOAC, 1995).

$$\text{N uptake in grain (kg ha}^{-1}\text{)} = \frac{\text{N content in grain (\%)} \times \text{Grain yield (kg/ha)}}{100}$$

$$\text{N uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{N content in straw (\%)} \times \text{Straw yield (kg/ha)}}{100}$$

P content in grain and straw

P content in grain and straw was determined by Wet digestion (Diacid) Vanadomolybdo phosphoric acid yellow colour method as per procedure outlined by Jackson (1973).

P uptake in grain (kg ha^{-1}) =

$$\frac{\text{P content in grain (\%)} \times \text{Grain yield (kg/ha)}}{100}$$

P uptake in straw (kg ha^{-1}) =

$$\frac{\text{P content in straw (\%)} \times \text{Straw yield (kg/ha)}}{100}$$

K content in grain and straw

K content in grain and straw was determined by flame photometry method as per the procedure outlined by Jackson (1973).

K uptake in grain (kg ha^{-1}) =

$$\frac{\text{P content in grain (\%)} \times \text{Grain yield (kg/ha)}}{100}$$

K uptake in straw (kg ha^{-1}) =

$$\frac{\text{P content in straw (\%)} \times \text{Straw yield (kg/ha)}}{100}$$

Grain quality

Viability

Viability was checked by tetrazolium test.

Crude protein conten

Protein analysis of grain was calculated by multiplying N content (%) by 6.25 (based on assumption that N content 16 % of protein) (AOAC, 1995).

$$\text{Protein content (\%)} = \text{N content in \%} \times 6.25$$

Statistical analysis

To determine the significance of the various variables or the effects of the different treatments used in the experiment, the data were analyzed using the Microsoft Excel and OPSTAT software at a 95% level of significance (LSD (0.05).

RESULTS AND DISCUSSION

Nutrient content in crop

Nitrogen content

Cutting management

Data presented in Table 2 indicate that nitrogen concentration in grain and straw was significantly influenced by cutting schedules during both years. Cutting at 40 DAS recorded significantly higher nitrogen concentration compared to 60 DAS, while remaining at par with 50 DAS in most cases.

Nitrogen levels

Nitrogen concentration in grain and straw increased progressively with increasing nitrogen levels. The highest values were recorded under 150% RDN, followed by 125% RDN. However, 150% RDN remained statistically at par with 125% RDN and both were significantly superior to 100% RDN.

PGRs

Chlormequat chloride (CCC) recorded numerically higher nitrogen concentration in grain and straw compared to ethephon during both years; however, the differences were statistically non-significant.

Phosphorus content

Cutting management

Phosphorus concentration in grain and straw was significantly higher under 40 DAS compared to 60 DAS, while remaining at par with 50 DAS in most instances.

Nitrogen levels

Phosphorus concentration increased with increasing nitrogen levels up to 150% RDN. The highest phosphorus

Table 1: Treatment with their symbols and details.

Treatments		
	Cutting schedules	
T_1	40 DAS	Cutting at 40 days after sowing
T_2	50 DAS	Cutting at 50 days after sowing
T_3	60 DAS	Cutting at 60 days after sowing
	Nitrogen levels (N)	
T_4	100% RDN	RDF (60 kg N+20 kg P_2O_5/ha)
T_5	125% RDN	RDF+25 per cent extra N
T_6	150% RDN	RDF +50 per cent extra N
	Plant growth regulator (PGR)	
T_7	CCC (Chlormequat chloride)	CCC @ 1.25 liters /ha at (Growth stage) GS30 31; ethephon (cerone) @ 0.5 litre/ha at GS39-40
T_8	Ethephon (Cerone)	CCC @ 1.25 litre/ha at GS30-31 + ethephon @ 0.5 litre/ha at GS39-40

Table 2: Effect of cutting schedules, nitrogen level, PGR's on NPK content (%) of dual purpose barley.

Treatments	(N) N content (%)				(P) Phosphorus content (%)				(K) Potassium content (%)			
	Grain		Straw		Grain		Straw		Grain		Straw	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Cutting schedules												
40 DAS	2.669	2.679	1.499	1.512	1.396	1.402	1.130	1.136	1.372	1.376	2.256	2.259
50 DAS	2.662	2.669	1.496	1.502	1.390	1.398	1.128	1.133	1.368	1.373	2.240	2.242
60 DAS	2.658	2.666	1.492	1.498	1.385	1.396	1.125	1.131	1.366	1.369	2.228	2.233
S.Em. ±	0.0032	0.0039	0.0020	0.0042	0.0032	0.0018	0.0015	0.0015	0.0018	0.0020	0.0081	0.0076
C.V. (%)	0.21	0.25	0.23	0.48	0.23	0.13	0.23	0.23	0.19	0.21	0.62	0.58
C.D. (P= 0.05)	0.0077	0.0094	0.0048	0.0101	0.0077	0.0043	0.0036	0.0036	0.0043	0.0048	0.0195	0.0183
Nitrogen levels (N)												
100% RDN	2.643	2.649	1.492	1.502	1.385	1.391	1.122	1.127	1.362	1.364	1.226	1.228
125% RDN	2.682	2.691	1.504	1.512	1.397	1.405	1.134	1.140	1.377	1.379	1.260	1.262
150% RDN	2.705	2.714	1.512	1.513	1.399	1.410	1.137	1.143	1.380	1.388	1.276	1.280
S.Em. ±	0.018	0.019	0.006	0.004	0.004	0.006	0.005	0.005	0.005	0.007	0.015	0.015
C.V. (%)	1.16	1.20	0.69	0.48	0.53	0.69	0.77	0.76	0.67	0.88	2.07	2.06
C.D. (P= 0.05)	0.043	0.046	0.014	0.010	0.010	0.014	0.012	0.012	0.012	0.017	0.036	0.036
Plant growth regulator (PGR)												
CCC (Chlormequat chloride)	2.687	2.694	1.504	1.510	1.395	1.403	1.132	1.138	1.374	1.378	1.258	1.261
Ethephon (Cerone)	2.667	2.676	1.502	1.508	1.393	1.401	1.130	1.136	1.372	1.376	1.250	1.252
S.Em. ±	0.010	0.009	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.005
C.V. (%)	0.61	0.48	0.12	0.09	0.10	0.07	0.13	0.12	0.10	0.10	0.55	0.71
C.D. (P= 0.05)	0.061	0.055	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.024	0.030

content was recorded under 150% RDN, which remained statistically at par with 125% RDN but was significantly superior to 100% RDN.

PGRs

CCC recorded marginally higher phosphorus concentration in grain and straw compared to ethephon, but the differences were statistically non-significant.

Potassium content

Cutting management

Potassium concentration in grain and straw was significantly higher under cutting at 40 DAS compared to 60 DAS, while remaining statistically at par with 50 DAS.

Nitrogen levels

Application of 125% and 150% RDN significantly improved potassium concentration compared to 100% RDN. However, 150% RDN remained statistically at par with 125% RDN.

PGRs

Potassium concentration was slightly higher under CCC compared to ethephon, though the differences were statistically non-significant.

Nutrient uptake by crop

Nitrogen uptake

Cutting management

Nitrogen uptake in both grain and straw was significantly influenced by cutting schedules (Table 3). Cutting at 40 DAS recorded significantly higher nitrogen uptake compared to 50 and 60 DAS during both years. Nitrogen uptake decreased progressively with delay in cutting.

Nitrogen levels

Application of 125% and 150% RDN significantly increased nitrogen uptake in grain and straw compared to 100% RDN. However, 150% RDN remained statistically at par with 125% RDN.

PGRs

CCC recorded numerically higher nitrogen uptake in grain and straw compared to ethephon; however, the differences were statistically non-significant.

Potassium uptake

Cutting management

Potassium uptake was significantly affected by cutting schedules. Cutting at 40 DAS recorded the highest potassium uptake in grain and straw, followed by 50 DAS, while the lowest uptake was observed at 60 DAS.

Nitrogen levels

Potassium uptake increased significantly with increasing nitrogen levels. Both 125% and 150% RDN recorded significantly higher uptake compared to 100% RDN, while 150% RDN remained at par with 125% RDN.

PGRs

CCC resulted in numerically higher potassium uptake in grain and straw compared to ethephon, but the differences were statistically non-significant.

Phosphorus uptake

Cutting management

Phosphorus uptake in grain and straw was significantly influenced by cutting schedules. The highest uptake was recorded under 40 DAS, followed by 50 DAS, while 60 DAS recorded the lowest values.

Nitrogen levels

Phosphorus uptake increased significantly with increasing nitrogen levels. Both 125% and 150% RDN recorded significantly higher uptake compared to 100% RDN, with 150% RDN remaining statistically at par with 125% RDN.

PGRs

CCC recorded numerically higher phosphorus uptake in grain and straw compared to ethephon; however, the differences were statistically non-significant.

Quality of seed

Seed viability

Cutting management

Cutting schedules did not significantly influence seed viability during either year (Table 4).

Nitrogen levels

Seed viability showed a numerical increase with increasing nitrogen levels; however, the differences among nitrogen treatments were statistically non-significant.

PGRs

Plant growth regulators did not significantly affect seed viability.

Protein content in crop

Cutting management

Crude protein content in grain and straw was not significantly influenced by cutting schedules. However, numerically higher values were observed under 40 DAS.

Nitrogen levels

Crude protein content showed a positive numerical trend with increasing nitrogen levels. Although 150% RDN recorded the highest protein content, differences among nitrogen levels were statistically non-significant.

PGRs

The effect of plant growth regulators on crude protein content was statistically non-significant. However, CCC

Table 3: Effect of cutting schedules, nitrogen level, PGR's on NPK uptake of dual purpose barley.

Treatments	(N) Nitrogen uptake (kg/ha)				(P) Phosphorus uptake (kg/ha)				(K) Potassium uptake (kg/ha)			
	Grain		Straw		Grain		Straw		Grain		Straw	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Cutting schedules												
40 DAS	58.68	61.12	29.40	34.06	14.66	15.39	7.33	7.75	13.85	14.43	62.15	63.40
50 DAS	53.68	55.42	27.52	31.50	13.34	13.95	6.75	7.15	12.66	13.14	56.71	58.38
60 DAS	33.91	36.33	17.93	21.91	8.63	9.38	4.71	5.21	8.27	8.81	37.46	40.52
S.Em. ±	7.68	7.55	3.63	3.65	1.82	1.82	0.79	0.74	1.71	1.63	7.41	6.87
C.V. (%)	22.42	20.97	19.47	17.68	18.01	17.01	18.37	16.77	19.75	18.51	21.14	19.47
C.D. (P= 0.05)	18.46	18.15	8.72	8.77	4.37	4.37	1.90	1.77	4.12	3.92	17.81	16.50
Nitrogen levels (N)												
100% RDN	50.29	53.83	24.53	28.43	12.55	13.51	5.99	6.33	11.86	12.67	51.10	52.63
125% RDN	57.87	61.76	30.08	34.08	14.43	15.54	7.50	7.94	13.75	14.63	62.06	63.56
150% RDN	61.05	64.65	31.74	35.18	15.09	16.21	7.94	8.26	14.38	15.42	65.57	65.99
S.Em. ±	3.19	3.16	2.16	2.00	0.73	0.80	0.57	0.56	0.74	0.80	4.26	4.03
C.V. (%)	8.43	7.82	8.17	7.30	5.07	4.84	7.96	7.16	5.14	5.05	8.00	7.49
C.D. (P= 0.05)	7.67	7.60	5.19	4.80	1.75	1.93	1.37	1.35	1.78	1.93	10.24	9.69
Plant growth regulator (PGR)												
CCC (Chlormequat chloride)	59.59	63.12	31.11	34.91	14.75	15.79	7.64	8.00	14.01	14.88	64.11	65.11
Ethephon (Cerone)	53.21	57.04	26.45	30.22	13.30	14.39	6.64	7.00	12.64	13.60	55.04	56.35
S.Em. ±	3.19	3.04	2.33	2.35	0.73	0.70	0.50	0.50	0.69	0.64	4.54	4.38
C.V. (%)	7.99	6.95	8.11	7.64	5.09	4.62	5.00	4.67	5.19	4.70	8.04	7.78
C.D. (P= 0.05)	19.42	18.50	14.17	14.29	4.43	4.25	3.03	3.03	4.20	3.89	27.60	26.63

recorded numerically higher protein content compared to ethephon.

Cutting management

Nutrient content, uptake and quality

Cutting at 40 days after sowing (DAS) resulted in significantly higher nutrient uptake of nitrogen, phosphorus and potassium compared with delayed cutting at 60 DAS, while 50 DAS remained intermediate. The superior uptake under early cutting may be attributed to enhanced regrowth potential and improved assimilate redistribution during the reproductive phase. Early cutting likely maintained a favorable source-sink balance and allowed sufficient recovery time prior to grain filling (Bendada *et al*., 2022), thereby improving overall nutrient absorption and partitioning efficiency.

Nutrient concentration in grain and straw was also significantly higher under 40 DAS compared to 60 DAS, although differences between 40 and 50 DAS were mostly at par. The decline in nutrient concentration and uptake under delayed cutting (60 DAS) may be associated with reduced regrowth vigor, diminished photosynthetic capacity and shortened effective grain filling duration. These findings support earlier reports by Yadav and Kumar (2003), who emphasized the importance of appropriate cutting timing for optimizing biomass accumulation and nutrient utilization. Similarly, Dhillon *et al*. (2020) highlighted that cutting management plays a crucial role in regulating nutrient uptake and dry matter production in dual-purpose barley systems.

Protein content and seed viability were not significantly influenced by cutting schedules. However, numerically higher protein content under 40 DAS may be related to relatively better nitrogen assimilation. Since nitrogen is a key structural component of amino acids and enzymes, improved nitrogen uptake under optimal cutting timing can indirectly contribute to enhanced grain quality (Leghari *et al*., 2016).

Effect of nitrogen

Nutrient concentration, uptake and quality

Application of higher nitrogen levels (125% and 150% RDN) significantly enhanced nutrient concentration and uptake of nitrogen, phosphorus and potassium in both grain and straw compared with 100% RDN. Although 150% RDN recorded the highest values, it remained statistically at par with 125% RDN, indicating diminishing marginal returns beyond 125% RDN. Similar responses have been reported in barley and other cereals, where increased nitrogen availability promotes greater nutrient assimilation and uptake due to improved biomass production and root proliferation (Habiyaremye *et al*., 2021). Enhanced nitrogen supply stimulates metabolic activity and root growth, thereby improving the absorption and translocation of P and K along with N (Sunkad *et al*., 2025).

Despite improved nutrient uptake under higher nitrogen levels, crude protein content and seed viability exhibited only numerical increases and remained statistically non-significant among nitrogen treatments. Although 150% RDN recorded the highest protein content

Table 4: Effect of nitrogen, PGRs and cutting schedules on seed viability (%) and crude protein content of dual-purpose barley.

Treatment	Seed viability (%)		Crude protein content (Grain)		Crude protein content (Straw)	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Cutting schedules						
40 DAS	84.38	86.18	11.427	11.489	4.119	4.196
50 DAS	83.16	84.36	11.383	11.427	4.101	4.134
60 DAS	82.49	83.71	11.358	11.408	4.070	4.109
S.Em. ±	0.55	0.71	0.020	0.024	0.014	0.025
C.V. (%)	1.14	1.45	0.31	0.36	0.59	1.04
C.D. (P= 0.05)	2.16	2.78	0.078	0.094	0.055	0.098
Nitrogen levels (N)						
100% RDN	81.15	82.59	11.264	11.307	4.070	4.132
125% RDN	84.66	85.96	11.507	11.564	4.145	4.195
150% RDN	85.67	87.66	11.651	11.707	4.195	4.201
S.Em. ±	1.38	1.50	0.112	0.118	0.038	0.021
C.V. (%)	2.86	3.04	1.69	1.77	1.59	0.88
C.D. (P= 0.05)	5.42	5.88	0.44	0.46	0.15	0.08
PGRs						
CCC (Chlormequat chloride)	84.39	86.05	11.536	11.585	4.143	4.185
Ethephon (Cerone)	83.27	84.75	11.412	11.467	4.130	4.167
S.Em. ±	0.56	0.65	0.062	0.059	0.007	0.009
C.V. (%)	0.94	1.07	0.76	0.72	0.23	0.31
C.D. at 5%	3.41	3.96	0.38	0.36	0.04	0.06

and seed viability, the differences were not large enough to exceed the critical difference. Nitrogen is a fundamental constituent of amino acids, enzymes and chlorophyll and its availability directly governs protein synthesis; however, under the present conditions, the incremental increase beyond 125% RDN did not translate into statistically distinct improvements in quality parameters. Similar trends of diminishing response at higher nitrogen levels have been documented in cereal systems (Ishfaq *et al*., 2023).

Effect of plant growth regulators

Nutrient concentration, uptake and quality

Application of chlormequat chloride (CCC @ 1.25 L ha^{-1}) resulted in comparatively higher nutrient concentration and uptake of nitrogen, phosphorus and potassium than ethephon; however, the differences were statistically non-significant. The numerical superiority of CCC may be associated with its influence on plant architecture and assimilate partitioning.

CCC is known to inhibit gibberellin biosynthesis, resulting in reduced internodal elongation and improved canopy structure. Such physiological adjustments can enhance source-sink balance and potentially improve nutrient use efficiency (Dastan *et al*., 2011; Liang *et al*., 2023). Improved structural stability may also favor sustained photosynthetic activity and biomass accumulation, thereby supporting nutrient uptake. Sabagh *et al*. (2021) reported that CCC can enhance physiological efficiency and root activity, which may contribute to improved nutrient acquisition.

Since nutrient uptake is a function of both nutrient concentration and total biomass, the numerically higher uptake observed under CCC could be associated with improved dry matter accumulation and nutrient utilization efficiency. However, under the present experimental conditions, these differences did not attain statistical significance.

CONCLUSION

Early cutting at 40 DAS resulted in significantly higher nitrogen, phosphorus and potassium uptake compared to delayed cuttings, indicating better nutrient utilization efficiency under timely cutting management. However, nutrient concentration and crude protein content were not significantly influenced by cutting schedules. Application of 125% and 150% recommended nitrogen dose significantly improved nutrient concentration, nutrient uptake, crude protein content and seed viability compared to 100% RDN, with 150% RDN remaining statistically at par with 125% RDN. These findings confirm nitrogen as a major determinant of productivity and grain quality in dual-purpose barley. Among plant growth regulators, chlormequat chloride significantly enhanced nutrient uptake compared to ethephon, although differences in nutrient concentration and crude protein content were statistically non-significant. From a practical perspective, early cutting combined with 125% RDN and chlormequat chloride application may be considered an effective agronomic strategy for improving nutrient uptake and maintaining grain quality in dual-purpose barley under irrigated semi-arid conditions. Future research should evaluate long-term soil fertility dynamics, nitrogen use efficiency, economic feasibility and the integration of optimized cutting and nutrient management strategies with improved barley genotypes to enhance sustainability and resource-use efficiency.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions.

Conflict of interest

No conflicts of interest regarding the publication of this article.

REFERENCES

Anonymous. (2019). Progress Report of All India Coordinated Wheat and Barley Improvement Project 2015-16. ICAR-Indian Institute of Wheat and Barley Research, Karnal, India.

AOAC. (1995). Official Methods of Analysis. 16th edition. Association of Official Analytical Chemist, Washington, DC.

Arebu, H.Y. (2022). Influence of organic fertilizers on productivity of barley: A review. *Agricultural Science Digest.* **42(2):** 121-127. doi: 10.18805/ag.DF-374.

Bendada, H., Guendouz, A., Benniou, R. and Louahdi, N. (2022). The effect of spike row type on the grain yield and grain filling parameters in barley (*Hordeum vulgare* L.) genotypes under semi-arid conditions. *Agricultural Science Digest.* **42(1):** 72-75. doi: 10.18805/ag.D-311.

Bocso, N.S. and Butnariu, M. (2022). The biological role of primary and secondary plants metabolites. *Journal of Nutrition and Food Processing*. **5(3):** 1-7.

Choudhary, R., Singh, B.K., Choudhary, A., Choudhary, J.S., Jat, S.K. and Kumar, R. (2023). Influence of plant growth regulators on growth, yield and yield components in garden pea. *Legume Research.* **46(10):** 1366-1369. doi: 10.18805/LR-4880.

Dastan, S., Mobasser, H.R., Ghanbari-Malidarreh, A., Arab, R., Ghorbannia, E. and Rahimi, R. (2011). Effects of sowing dates and CCC application on morphological traits, agronomical indices and grain yield in barley cultivars. *World Applied Sciences Journal*. **14(11):** 1717-1723.

Dhillon, B.S., Uppal, R.S. and Goyal, M. (2020). Forage quality and productivity of barley (*Hordeum vulgare* L.) as influenced by cutting management under staggered sowing in North-West India. *Archives of Agronomy and Soil Science*. **66(9):** 1244-1258.

Habiyaremye, C., Schroeder, K.L., Reganold, J.P., White, D., Packer, D. and Murphy, K.M. (2021). Effect of nitrogen and seeding rate on β-glucan, protein and grain yield of naked food barley in no-till cropping systems in the palouse region of the pacific Northwest. *Frontiers in Sustainable Food Systems*. **5:** 663445.

Ishfaq, M., Wang, Y., Xu, J., Hassan, M.U., Yuan, H., Liu, L. and Li, X. (2023). Improvement of nutritional quality of food crops with fertilizer: A global meta-analysis. *Agronomy for Sustainable Development*. **43:** 74.

Jackson, M.L. (1973). Soil Chemical Analysis, Pentice Hall of India Pvt. Ltd., New Delhi, India. **498:** 151-154.

Kaur, A., Purewal, S.S., Phimolsiripol, Y. and Bangar, S.P. (2024). Unraveling the hidden potential of Barley (*Hordeum vulgare*): An important review. *Plants*. **13(17):** 2421.

Kumbhar, R.A., Yang, K., Mari, B.S.N., Memon, S., Liu, Y., Zhao, H. and Feng, Z. (2025). Exploring the significance of β-glucan in grains of hulless barley. *Plant Molecular Biology Reporter*. pp 1-13.

Leghari, S.J., Wahocho, N.A., Laghari, G.M., Laghari, A.H., Bhabhan, G.M., Talpur, K.H. and Lashari, A.A. (2016). Role of nitrogen for plant growth and development: A review. *Advances in Environmental Biology*. **10(9):** 209-219.

Liang, X.G., Gao, Z., Fu, X.X., Chen, X.M., Shen, S. and Zhou, S.L. (2023). Coordination of carbon assimilation, allocation and utilization for systemic improvement of cereal yield. *Frontiers in Plant Science*. **14:** 1206829.

Maheshwari, D.K., Chauhan, R.S., Ranjan, H., Sharma, V., Maheshwari, H., Kumar, A. and Singh, P. (2025). Effect of nitrogen, organic manures and zinc foliar spray on different growth parameters of two-row barley (*Hordeum distichon* L.). *International Journal of Plant and Soil Science*. **37(10):** 91-100.

Sabagh, A.E., Mbarki, S., Hossain, A., Iqbal, M.A., Islam, M.S., Raza, A. and Farooq, M. (2021). Potential role of plant growth regulators in administering crucial processes against abiotic stresses. *Frontiers in Agronomy*. **3:** 648694.

Singh, S.K. and Kumar, S. (2023). Advances in Wheat and Barley Production Technologies. In Advances in Crop Production and Climate Change. CRC Press. (pp. 27-59).

Sonia, B., Bokado, K. and Devi, H.S. (2025). Effect of varying lopping schedules and stump heights on growth, fodder yield and quality of dual-purpose barley (*Hordeum distichon* L.). *Indian Journal of Agricultural Research.* ***59*****(10):** 1570-1576. doi: 10.18805/IJARe.A-6397.

Sunkad, G., Patil, M.S., Yenjeerappa, S.T., Kulkarni, S.A., Rao, S. and Naik, N.M. (2025). Metabolic profiling of plant growth promoting microorganisms (PGPMs) from chickpea rhizosphere and their antagonistic activity against dry root rot pathogen *Rhizoctonia bataticola. Legume Research.* **48(6):** 959-965. doi: 10.18805/LR-4976.

Takarli, H., Bekada, D.E., Benakriche, B.M. and Medjahed, M. (2025). From barley (*Hordeum vulgare* L.) to superfood: Fermentation's impact on nutritional profile and food safety. *Asian Journal of Dairy and Food Research.* **44(3):** 448-456. doi: 10.18805/ajdfr.DRF-436.

Yadav, R.K. and Kumar, A. (2003). Effect of cutting management and nitrogen levels on biomass and proximate quality of barley (*Hordeum vulgare*) in saline soil. *Indian Journal of Agronomy*. **48(3).** doi: https://doi.org/10.59797/ija.v48i3.3077.