



Effect of Weed Management and Nitrogen Levels on Weed Dynamics and Nutrient Depletion in Barley (*Hordeum vulgare* L.)

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ABSTRACT

Background: Barley (*Hordeum vulgare* L.) productivity is often constrained by weed infestation and improper nitrogen management. Weeds compete with crops for essential resources such as nutrients, moisture, light and space, thereby reducing growth and yield. Nitrogen fertilization enhances crop performance but also influences weed growth and nutrient dynamics, making integrated weed and nutrient management essential for sustainable production.

Methods: A field experiment was conducted during the *Rabi* season of 2021-22 at SGT University, Gurugram, Haryana, using a factorial randomized block design with three replications. The study comprised four weed management practices (W_1 : weedy check, W_2 : weed-free, W_3 : metsulfuron @ 4 g ha⁻¹ and W_4 : 2,4-D @ 0.5 kg ha⁻¹) and four nitrogen levels (N_0 , N_1 , N_2 and N_3). Observations on weed density, dry matter accumulation and nitrogen uptake by weeds were recorded and statistically analyzed using analysis of variance (ANOVA).

Result: Weed density and biomass were significantly influenced by weed management practices. Treatment W_1 recorded the highest weed growth, whereas W_2 maintained negligible weed presence throughout the crop growth period. Among herbicides, W_3 was more effective than W_4 in reducing weed density and biomass. Nitrogen levels significantly affected weed dry matter, with the lowest biomass observed under N_3 likely due to improved crop competitiveness. Nitrogen uptake by weeds was highest under W_1 and lowest under W_2 . A positive relationship between weed biomass and nitrogen uptake was observed, indicating that higher biomass leads to greater nutrient depletion.

Key words: Herbicide efficiency, Nitrogen fertilization, Nutrient uptake by weeds, Weed biomass accumulation, Weed management.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops worldwide, ranking fourth after wheat, rice and maize and plays a crucial role in food, feed and malting industries. Its adaptability to diverse agro-climatic conditions and relatively low input requirement makes it a preferred crop in semi-arid and temperate regions (Bogale *et al.*, 2024). In India, barley is gaining importance because it is suitable for resource-constrained environments and the growing demand in the food and beverage industries. The productivity of barley is considerably influenced by agronomic management practices and particularly nutrient management. Despite its wide adaptability, barley productivity is often constrained by several biotic factors, among which weed infestation is one of the most significant yield-limiting factors (Kaur *et al.*, 2025).

Weeds are one of the major biological constraints in the cultivation of barley, causing substantial reductions in productivity because weeds compete aggressively with crop plants for essential resources such as nutrients, moisture, light and space, particularly during the early growth stages of barley. This competition leads to considerable reductions in crop growth, yield and resource-use efficiency. Yield losses due to weed infestation in cereal crops vary depending on weed density, species composition and environmental conditions and can be substantial under

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unmanaged situations (Meena *et al.*, 2021; Chaudhary *et al.*, 2022). Effective weed management is therefore essential for achieving optimum crop performance. Uncontrolled weed growth not only suppresses crop growth but also causes considerable depletion of essential nutrients from the soil. Weeds remove significant quantities of nitrogen, phosphorus and potassium, thereby reducing nutrient availability for crop uptake and ultimately lowering grain yield and economic returns (Pisal *et al.*, 2013).

Chemical herbicides have traditionally been the most widely used method for weed control due to their rapid and effective action. However, their indiscriminate and repeated use has resulted in several concerns, including herbicide

resistance, environmental pollution and adverse effects on non-target organisms (Naeem *et al.*, 2022). Alongside weed management, nitrogen (N) fertilization is a key factor influencing barley productivity. Nitrogen is essential for vegetative growth, chlorophyll formation and overall crop development. However, nitrogen application also affects weed dynamics, as higher nitrogen levels may stimulate both crop and weed growth, thereby intensifying crop-weed competition (Cammarano *et al.*, 2024; Fazil *et al.*, 2022).

The interaction between weed management practices and nitrogen levels plays a critical role in determining weed density, biomass accumulation and nutrient removal by weeds. Effective weed control measures have been reported to reduce weed biomass and nutrient depletion, thereby improving crop nutrient uptake and yield (Das *et al.*, 2026; Kumari *et al.*, 2025). Both the crop and weed are impacted by nitrogen fertilizer, although nitrogen efficacy mostly dependent on weed control strategies work. When combined with efficient herbicidal or cultural weed management techniques, an adequate supply of nitrogen increases crop vigor and competitiveness, which can affect weed growth (Kumar *et al.*, 2015; Rani *et al.*, 2022).

Conversely, inadequate weed control combined with higher nitrogen application can enhance weed growth and nutrient depletion. Integrated approaches involving optimum nitrogen levels and efficient weed management are essential for sustainable barley production. Similar findings were reported by Al-Gburi *et al.* (2024); Al-Jayashi *et al.* (2024); Arshad *et al.*, (2025), emphasizing balanced agronomic practices.

Weed infestation and nitrogen nutrition are two major factors determining barley productivity under semi-arid conditions. While nitrogen fertilization enhances crop growth and yield, it may also stimulate weed proliferation and nutrient depletion when not integrated with effective weed management practices. Although several studies have independently evaluated weed control measures and nitrogen fertilization in barley, limited information is available on their interactive effects on weed dynamics and nutrient removal under semi-arid agroecosystems. Therefore, the present investigation was undertaken to evaluate the effect of different weed management practices and nitrogen levels on weed population, weed dry matter accumulation, nutrient depletion by weeds and overall weed dynamics in barley.

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 and is characterized by hot summers, cool winters and erratic rainfall distribution. Prior to sowing, composite soil samples were collected from the 0-15 cm soil depth and analyzed following standard analytical procedures.

The experimental soil was sandy loam in texture, low in available nitrogen, medium in available phosphorus and potassium and slightly alkaline in reaction. The initial soil characteristics were determined to provide a baseline for evaluating the effects of weed management practices and nitrogen levels on weed dynamics and nutrient depletion.

The crop was grown under semi-arid climatic conditions prevailing during the experimental season. Meteorological data pertaining to rainfall, temperature and relative humidity were obtained from the nearby agrometeorological observatory. Overall, the weather conditions remained conducive for normal growth and development of the barley crop throughout the season. The experimental field was naturally infested with a mixed population of grassy and broad-leaved weeds. The predominant grassy weeds were *Phalaris minor* Retz. and *Avena ludoviciana* Durieu, while the major broad-leaved weeds included *Chenopodium album* L., *Melilotus indica* (L.) All., *Anagallis arvensis* L. and *Rumex dentatus* L. The weed flora was uniformly distributed across the experimental area before the imposition of treatments.

The experiment was laid out in a factorial randomized block design (FRBD) with three replications. The treatment structure consisted of sixteen treatment combinations comprising four weed management practices and four nitrogen levels. The weed management treatments included W_1 : weedy check, W_2 : weed-free, W_3 : metsulfuron-methyl @ 4 g ha⁻¹ applied at 30 days after sowing (DAS) and W_4 : 2,4-D @ 0.5 kg ha⁻¹ applied at 30 DAS. Nitrogen was applied at four levels, viz., N_0 (0 kg N ha⁻¹), N_1 (30 kg N ha⁻¹), N_2 (60 kg N ha⁻¹) and N_3 (90 kg N ha⁻¹). Nitrogen was supplied through urea according to treatment specifications, with half of the required dose applied as a basal application at sowing and the remaining half top-dressed at the active tillering stage. In total, forty-eight plots were maintained, each measuring 3.0 m × 2.7 m.

Barley variety BH 393 was sown on 22 November 2021 using a seed rate of 100 kg ha⁻¹ with a row spacing of 22.5 cm. Recommended agronomic practices were followed uniformly in all plots throughout the crop growth period. A basal dose of phosphorus at 40 kg P₂O₅ ha⁻¹ was applied uniformly to all treatments, while nitrogen was applied according to the designated treatment levels. Other crop management practices were carried out as per the regional recommendations for barley cultivation.

Observations on weed density and weed dry matter accumulation were recorded at appropriate crop growth stages using the quadrat sampling method. Weed samples collected from the sampling area were first sun-dried and subsequently oven-dried at a constant temperature until a constant weight was achieved for determination of dry matter accumulation. Nutrient depletion by weeds and nutrient uptake by the crop were estimated through standard analytical procedures. Nitrogen content in plant samples was determined following the methods described by Jackson (1973) and nutrient uptake was

computed by multiplying nutrient concentration with corresponding dry matter yield.

The experimental data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for a factorial randomized block design as described by Gomez and Gomez (1984). The significance of treatment effects was tested at the 5% probability level and treatment means were compared using the critical difference (CD) test wherever the F-test was found significant. Similar statistical approaches have been widely adopted in studies pertaining to weed management and nutrient optimization in barley and other cereal crops.

RESULTS AND DISCUSSION

Results and discussion present and interpret experimental findings, explaining the effects of different treatments on weed density, biomass accumulation and nutrient uptake. The relationships among variables are analyzed systematically and treatment comparisons are discussed based on observed trends. The findings are interpreted using established scientific principles and supported by relevant literature to ensure clarity, consistency and validity of the conclusions.

Weed population dynamics

Weed density was significantly influenced by different weed management practices (Table 1), indicating the strong role of chemical and cultural control methods in regulating weed flora in barley (Chaudhary, 2019; Kumar *et al.*, 2020). Among the treatments, W_1 recorded the highest weed density, whereas W_2 effectively eliminated weed population throughout the crop growth period, highlighting the importance of timely weed control.

Among herbicidal treatments, W_3 and W_4 significantly reduced weed density at harvest, with W_3 proving more effective. Nitrogen levels showed a non-significant effect at early stages but significantly influenced weed density at later stages. The lowest weed density was observed under N_3 , possibly due to enhanced crop competitiveness (Kumar *et al.*, 2020). Similar results were reported by Choudhary *et al.* (2016), who observed significantly lower weed density under clodinafop + metsulfuron-methyl and sulfosulfuron treatments compared with weedy check conditions.

The interaction effect (Table 2) revealed that the combination of W_3 with N_3 resulted in minimum weed density, indicating the synergistic effect of effective herbicide application and adequate nitrogen supply (Chaudhary, 2019; Singh *et al.*, 2018).

Accumulation of weed biomass

Weed dry matter accumulation followed a trend similar to weed density (Table 3), confirming that effective weed management practices play a crucial role in reducing weed biomass and minimizing crop-weed competition. Among the treatments, W_1 recorded the highest weed biomass due to the absence of any control measures, which allowed unrestricted weed growth and efficient utilization of available

Table 1: Weed population as influenced by weed management and nitrogen levels in barley.

Treatment	Weed density (no. m ⁻²)				
	Chenopodium album		Rumex dentatus		Total
	30 DAS	At harvest	30 DAS	At harvest	30 DAS
Weed management					
W_1 : Weedy check (no weed control)	3.71*(14.26)	3.27(11.19)	4.08(17.15)	3.68(14.04)	7.03(49.92)
W_2 : Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
W_3 : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	3.58(13.32)	1.46(2.63)	3.97(16.26)	1.58(3.00)	7.05(50.20)
W_4 : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	3.66(13.90)	1.65(3.22)	4.03(16.74)	1.76(3.60)	6.41(41.59)
SEm±	0.08	0.06	0.19	0.11	0.20
CD (P = 5%)	0.22	0.17	0.54	0.31	0.59
Nitrogen management					
N_0 : Control (0 kg N ha ⁻¹)	2.82(8.45)	2.05(4.70)	3.14(10.36)	2.02(4.58)	5.44(30.09)
N_1 : 30 kg N ha ⁻¹	2.93(9.08)	1.87(4.00)	3.37(11.86)	1.91(4.15)	5.66(32.54)
N_2 : 60 kg N ha ⁻¹	3.05(9.80)	1.70(3.39)	3.16(10.49)	2.05(4.70)	4.86(24.12)
N_3 : 90 kg N ha ⁻¹	2.85(8.62)	1.46(2.63)	3.11(10.17)	1.75(3.56)	5.23(27.85)
SEm±	0.08	0.06	0.19	0.11	0.20
CD (P = 5%)	NS	0.17	NS	NS	0.86
					NS

*Weeds count transformed to $\sqrt{n + 0.5}$. Actual values were given in parenthesis.

Table 2: Interaction effect of weed management and nitrogen levels on weed density of *Chenopodium album* 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)	3.62(13.60)	3.53(12.96)	3.29(11.32)	2.61(7.31)	3.27(11.19)
W ₂ : Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
W ₃ : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	1.76(3.60)	1.68(3.32)	1.34(2.30)	1.05(1.60)	1.46(2.63)
W ₄ : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	2.11(4.95)	1.56(2.93)	1.46(2.63)	1.46(2.63)	1.65(3.22)
Mean	2.05(4.70)	1.87(4.00)	1.70(3.39)	1.46(2.63)	
SEm±	0.11				
CD (P = 5%)	0.330				

Table 3: Weed dry matter as influenced by weed management and nitrogen levels in barley.

Treatment	Weed dry weight (g m ⁻²)					
	Chenopodium album		Rumex dentatus		Total weeds	
	30 DAS	At harvest	30 DAS	At harvest	30 DAS	At harvest
Weed management						
W ₁ : Weedy check (no weed control)	1.21*(1.96)	12.12(147.39)	1.19(1.92)	11.77(139.03)	3.95(16.10)	20.92(438.15)
W ₂ : Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
W ₃ : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	1.07(1.64)	8.15(66.92)	1.28(2.14)	7.70(59.79)	2.89(8.85)	12.59(159.01)
W ₄ : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	1.05(1.60)	8.43(71.56)	1.22(1.99)	8.59(74.29)	2.40(6.25)	13.20(174.74)
SEm±	0.05	0.30	0.05	0.26	0.33	0.50
CD (P = 5%)	0.13	0.86	0.13	0.76	0.95	1.45
Nitrogen management						
N ₀ : Control (0 kg N ha ⁻¹)	0.98(1.46)	7.93(63.38)	1.08(1.67)	7.73(60.25)	2.03(4.62)	12.45(155.50)
N ₁ : 30 kg N ha ⁻¹	1.06(1.62)	7.73(60.25)	1.11(1.73)	7.52(57.05)	2.87(8.74)	12.13(147.64)
N ₂ : 60 kg N ha ⁻¹	1.03(1.56)	7.21(52.48)	1.12(1.75)	7.08(50.63)	2.87(8.74)	11.06(122.82)
N ₃ : 90 kg N ha ⁻¹	0.97(1.44)	6.54(43.27)	1.08(1.67)	6.44(41.97)	2.27(5.65)	11.78(139.27)
SEm±	0.05	0.30	0.05	0.26	0.33	0.50
CD (P = 5%)	NS	0.86	NS	0.76	NS	NS

*Weeds dry weight transformed to $\sqrt{n + 0.5}$. Actual values were given in parenthesis.

resources. In contrast, W_2 maintained negligible weed growth throughout the crop period owing to continuous manual removal, thereby preventing competition for nutrients, moisture, light and space (Puniya *et al.*, 2016; Yadav *et al.*, 2018).

Among the herbicidal treatments, W_3 recorded the lowest weed biomass, followed by W_4 , indicating the higher efficacy of metsulfuron in controlling broadleaf weeds. The superior performance of metsulfuron may be attributed to its systemic mode of action and its effectiveness during the critical period of crop-weed competition (Chhokar *et al.*, 2012). This suggests that chemical weed control can be an efficient alternative to manual weeding under practical field conditions.

Nitrogen levels significantly influenced weed biomass accumulation. The lowest biomass was observed under N_3 , which may be attributed to enhanced crop vigor and canopy development under higher nitrogen supply, leading to improved competitiveness of the crop over weeds (Kumar *et al.*, 2017). Increased nitrogen availability likely favoured crop growth more than weed growth, thereby suppressing weed biomass at later stages (Jack *et al.*, 2021).

The interaction effects (Table 4 and 5) further revealed that the combination of $W_3 \times N_3$ resulted in minimum weed biomass, indicating a synergistic effect of effective herbicide application and optimum nitrogen levels. Conversely, W_1 combined with higher nitrogen levels resulted in maximum weed growth, as increased nutrient availability promoted weed proliferation in the absence of control measures (Yadav *et al.*, 2018).

Nutrient uptake by weeds

Nitrogen uptake by weeds was significantly influenced by weed management practices (Table 6), indicating a strong relationship between weed biomass and nutrient removal. Among the treatments, W_1 recorded the highest nitrogen depletion due to greater weed density and biomass accumulation, which enhanced nutrient extraction from the soil. In contrast, W_2 exhibited negligible nitrogen removal owing to the absence of weed growth, thereby minimizing nutrient losses.

Among herbicidal treatments, W_3 resulted in the lowest nitrogen uptake by weeds, followed by W_4 , indicating the higher efficiency of metsulfuron in suppressing weed growth and limiting biomass production. Reduced weed biomass directly contributed to lower nutrient depletion under these treatments.

Nitrogen levels did not exert a significant effect on nitrogen uptake by weeds; however, a slight increasing trend was observed with higher nitrogen application, with maximum uptake under N_3 . This may be attributed to increased weed growth under higher nutrient availability, although the differences remained statistically non-significant.

Overall, nitrogen uptake by weeds was primarily governed by weed biomass rather than nitrogen levels. A positive relationship between weed dry matter and

Table 4: Interaction effect of weed management and nitrogen levels on dry matter of *Rumex dentatus* 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)	11.48(132.29)	11.71(137.62)	11.87(141.40)	12.02(144.98)	11.77(139.03)
W_2 : Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
W_3 : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	8.88(79.35)	8.48(72.41)	7.47(56.30)	5.99(36.38)	7.70(59.79)
W_4 : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	9.84(97.33)	9.19(84.96)	8.27(68.89)	7.03(49.92)	8.59(74.29)
Mean	7.73(60.25)	7.52(57.05)	7.08(50.63)	6.44(41.97)	
SEm±	0.52				
CD (P = 5%)	1.52				

Table 5: Interaction effect of weed management and nitrogen levels on total weed dry matter 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)	20.56(423.21)	21.18(449.09)	21.36(456.75)	20.57(423.62)	20.92(438.15)
W_2 : Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
W_3 : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	12.80(164.34)	13.10(172.11)	9.44(89.61)	15.01(225.80)	12.59(159.01)
W_4 : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	15.72(247.62)	13.52(183.29)	12.73(162.55)	10.83(117.79)	13.20(174.74)
Mean	12.45(155.50)	12.13(147.64)	11.06(122.82)	11.78(139.27)	
SEm±	1.00				
CD (P = 5%)	2.90				

Table 6: Nitrogen uptake by weeds as influenced by weed management and nitrogen levels in barley.

Treatment	N uptake weeds (kg ha ⁻¹)
Weed management	
W ₁ : Weedy check (no weed control)	37.25
W ₂ : Weed free	0.00
W ₃ : Application of Metsulfuron-methyl at 4 g ha ⁻¹ at 30 DAS	23.25
W ₄ : Application of 2,4-D at 0.5 kg ha ⁻¹ at 30 DAS	27.57
SEm±	2.51
CD (P = 5%)	7.28
Nitrogen management	
N ₀ : Control (0 kg N ha ⁻¹)	21.26
N ₁ : 30 kg N ha ⁻¹	21.29
N ₂ : 60 kg N ha ⁻¹	21.59
N ₃ : 90 kg N ha ⁻¹	23.94
SEm±	2.51
CD (P = 5%)	NS

nitrogen uptake was observed, confirming that greater biomass results in higher nutrient removal. Similar findings were reported by Patel *et al.* (2012); Kumar *et al.* (2022); Meena *et al.* (2021).

CONCLUSION

The study clearly demonstrated that weed management practices and nitrogen levels significantly influenced weed dynamics, biomass accumulation and nutrient uptake in barley. Effective weed control treatments, particularly W₂ and W₃, substantially reduced weed density and biomass, thereby minimizing competition for essential resources. Among herbicides, W₃ proved more efficient than W₄ in suppressing broadleaf weeds and limiting nutrient depletion.

Nitrogen application influenced weed growth indirectly by enhancing crop competitiveness. Although nitrogen levels did not significantly affect nitrogen uptake by weeds, higher levels, especially N₃, reduced weed biomass due to improved crop vigor. The interaction between weed management and nitrogen levels revealed that combining effective herbicide application with higher nitrogen levels resulted in better weed suppression and reduced nutrient losses. Overall, integrated weed and nitrogen management is essential for minimizing weed competition, improving resource use efficiency and enhancing sustainable barley production under semi-arid conditions.

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Disclaimer

The interpretations and conclusions presented in this study are solely those of the authors and do not necessarily reflect the views of the affiliated institution. The authors are not responsible for any consequences arising from the use of this information.

Informed consent

The study adhered to institutional ethical standards and did not involve human or animal subjects.

Conflict of interest

The authors declare that there are no financial or personal conflicts of interest related to this study.

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