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Nutrient content, uptake by crop, and depletion by weeds as influenced by land configuration, mulching, and weed management practices in wheat (*Triticum Aestivum* L.)

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Abstract

A field experiment was conducted during two consecutive *Rabi* seasons of 2021-22 and 2022-23 at Instructional Farm, Rajasthan Agricultural Research Institute, Durgapura, (SKNAU) Jaipur to evaluate the effect of land configuration, mulching and weed management practices on nutrient content, uptake by crop and depletion by weeds in wheat (*Triticum aestivum* L.). Experiment was laid out in split-plot design with three replications comprised four treatments of land configuration and mulching in main plots and five weed management practices under sub plots. Ridge bed with mulch treatment increases nitrogen, phosphorus and potassium contents in both grain and straw, resulting in significantly higher nutrient uptake by the crop. Flat bed without mulch consistently recorded the lowest nutrient uptake. Among weed management practices, after weed-free treatment clodinafop-propargyl + metsulfuron methyl recorded the higher nutrient content and uptake by crop. Interaction effects indicated that ridge bed with mulch integrated with weed-free or clodinafop-propargyl + metsulfuron methyl further enhanced nutrient uptake by wheat. Nutrient concentration and nutrient depletion by weeds were markedly reduced under ridge bed with mulch. Weed-free treatment completely prevented nutrient removal by weeds, whereas clodinafop-propargyl + metsulfuron methyl recorded the lowest nutrient depletion among herbicidal treatments. Conversely, maximum nutrient depletion occurred under weedy check because of higher weed dry matter. The combination of ridge bed planting with mulch and clodinafop-propargyl + metsulfuron methyl improved nutrient-use efficiency by enhancing nutrient uptake by wheat while minimizing nutrient depletion through weeds.

Keywords: Wheat, land configuration, mulching, weed, nutrient depletion, clodinafop-propargyl + metsulfuron methyl.

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important staple food crop of the world and emerged as the backbone of India's food security. India is the second-largest producer of wheat after China. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat are the major wheat growing states of India. Wheat productivity is highly variable within different agro-ecologies of India, due to variable climatic conditions, genotypes, seeding time and practices and other management practices (Kantwa *et al.*, 2015) [13]. Land configuration plays an important role in improving soil physical conditions and crop performance. Raised bed planting (RBP), based on the ridge-furrow system, provides favourable soil moisture conditions, improves water-use efficiency and reduces weed seed germination (Gan *et al.*, 2013; Mo *et al.*, 2017; Fischer *et al.*, 2019) [17, 18]. Several studies have demonstrated that bed planting can reduce seed rate, facilitate mechanical weeding and maintain or enhance wheat productivity while reducing production costs compared with conventional flat planting (Singh *et al.*, 2009; Jat *et al.*, 2011; Boulal *et al.*, 2012; Devkota *et al.*, 2013) [7, 13, 22]. Mulching is another important agronomic practice that conserves soil moisture, suppresses weed emergence and improves soil health. Organic mulch reduces weed germination by restricting light penetration, conserves soil moisture, contributes organic matter and nutrients, and enhances soil biological activity (Onwueme *et al.*, 1978; Schonbeck *et al.*, 2017) [29, 32]. Previous studies have also reported that mulching improves soil moisture conservation,

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suppresses weed growth, improves water-use efficiency and increases wheat productivity (Verma and Acharya, 2004; Huang *et al.*, 2005; Rahman *et al.*, 2005; Erenstein, 2002) [15, 20, 30, 34]. Weeds compete with wheat for nutrients, moisture, light and space, resulting in significant yield losses and deterioration in grain quality. Yield losses due to weeds have been reported to range from 10 to 38% depending upon weed density and duration of competition (Balyan and Malik, 1994) [4], while reductions of up to 66% have also been reported under severe weed infestation (Kumar *et al.*, 2009; Kumar *et al.*, 2011) [14, 24, 25]. Effective weed management is therefore essential for improving nutrient-use efficiency and wheat productivity. Chemical weed control has become the preferred option because of labour scarcity, high labour costs and limited feasibility of manual or mechanical weeding in wheat (Mukherjee *et al.*, 2011) [28]. Ready-mix herbicide combinations such as clodinafop-propargyl + metsulfuron methyl and sulfosulfuron + metsulfuron methyl have been reported to provide effective control of complex weed flora. Integration of suitable land configuration, mulching and weed management practices therefore improve nutrient utilization by wheat while reducing nutrient depletion through weeds.

Materials and Methods

The experiment was conducted at Instructional Farm, Rajasthan Agricultural Research Institute (RARI), Durgapura (SKNAU) Jaipur, situated in the Semi-Arid Eastern Plain Zone (III-A agro-climatic zone) of Rajasthan. The soil of the experimental field was loamy sand in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen and high in available phosphorus and potassium. The experiment was laid out in split-plot design with three replications. The main-plots consisted of four land configuration and mulching treatments *viz.*, Flat bed with mulch, flat bed without mulch, Ridge bed with mulch and Ridge bed without mulch while the sub-plots comprised five weed management practices; Weed-free, post emergence application of Sulfosulfuron + Metsulfuron methyl, Mesosulfuron + Iodosulfuron, Clodinafop-propargyl + Metsulfuron methyl and Weedy check. Wheat variety Raj-4238 was used as test crop. Seed rate used 100 kg/ha. Herbicides were applied as post-emergence at 30 days after sowing using knapsack sprayer fitted with flat-fan nozzle. Weed-free plots were maintained manually throughout the crop growth period, whereas weeds were allowed to grow without interference in the weedy check plots. The samples for estimation of nutrient content in grain, straw and weed were collected at harvest and dried in oven and grind for analysis. Nitrogen estimated by the Kjeldahl method, phosphorus content by the vanadomolybdate yellow colour method, and potassium using a flame photometer method.

Nutrient uptake by grain and straw was calculated as following:

$$\text{Nutrient uptake (N/P/K) (kg/ha)} = \text{Nutrient content (\%)} \times \text{Grain/straw yield (kg/ha)/100}$$

The uptake of nitrogen, phosphorus and potassium by grain and straw was computed separately and expressed in kg ha⁻¹.

Nitrogen, phosphorus and potassium depletion by weeds was calculated from weed dry matter production and nutrient concentrations using the following equation:

$$\text{Nutrient depletion (N/P/K) (kg/ha)} = \text{Nutrient content (\%)} \times \text{Weed dry matter (kg/ha)/100}$$

The depletion values were computed separately for nitrogen, phosphorus and potassium.

Statistical analysis

The data recorded during both years were subjected to analysis of variance (ANOVA) appropriate for a split-plot design. Treatment

means were compared using the critical difference test at 5% level of significance ($p = 0.05$) whenever the F-test was significant.

Results and Discussion

Nitrogen content and uptake by crop

Ridge bed with mulch recorded highest nitrogen content in grain (1.96%), which remained statistically at par with ridge bed without mulch (1.93%). In contrast, flat bed without mulch recorded lowest nitrogen content (1.70%). A similar trend was observed in straw, where ridge bed with mulch recorded the highest nitrogen (0.657%), whereas flat bed without mulch recorded the minimum N content (0.615%). The higher nitrogen concentration under ridge bed with mulch may be attributed to improved soil moisture, soil physical conditions and better root development, which collectively improved mineralization, nitrogen absorption and its translocation. Similar improvements in nutrient accumulation under raised-bed planting and mulching have been reported by Akter *et al.* (2018) [2], Verma *et al.* (2020) [35], Zhang *et al.* (2021) [36], Kumari *et al.* (2024) and Gugulothu *et al.* (2025). Among the weed management treatments, after weed-free treatment clodinafop-propargyl + metsulfuron methyl recorded higher nitrogen content in grain (1.91%) and straw (0.654%) than sulfosulfuron + metsulfuron methyl and mesosulfuron + iodosulfuron. The lowest nitrogen content was recorded under weedy check. The improvement in nitrogen concentration under effective weed management was primarily due to reduced crop-weed competition, which enabled wheat plants to utilize available nitrogen more efficiently. Complete weed removal under weed-free treatment ensured uninterrupted nutrient availability, whereas clodinafop-propargyl + metsulfuron methyl effectively suppressed both grassy and broad-leaved weeds, thereby reducing nutrient losses to weeds. Similar findings have been reported by Chhokar *et al.* (2012) [10], Dheer and Yadav (2021) [14], Meena *et al.* (2021) [26], and Bindu and Mitra (2025) [6]. Ridge bed with mulch recorded the highest pooled nitrogen uptake of 104.69 kg ha⁻¹ by grain and 42.76 kg ha⁻¹ by straw, followed by ridge bed without mulch (96.64 and 42.05 kg ha⁻¹, respectively). Flat bed without mulch recorded the lowest nitrogen uptake (71.16 kg ha⁻¹ by grain and 29.81 kg ha⁻¹ by straw). Higher nitrogen uptake under ridge bed with mulch resulted from the combined effect of higher nitrogen concentration and higher biological yield. Since nutrient uptake is a function of nutrient concentration and dry matter production, the improved crop growth achieved under ridge bed planting substantially increased total nitrogen accumulation. Similar observations have been reported by Verma *et al.* (2020) [35], Choudhary *et al.* (2024) [11] and Gugulothu *et al.* (2025). Among weed management practices, after weed-free treatment clodinafop-propargyl + metsulfuron methyl recorded higher nitrogen uptake than the remaining herbicidal treatments. The lowest nitrogen uptake occurred under weedy check.

The interaction between land configuration and weed management was significant. Ridge bed with mulch combined with weed-free treatment (L₃H₄) recorded the highest pooled nitrogen uptake by grain (135.37 kg ha⁻¹) and straw (54.57 kg ha⁻¹), whereas ridge bed with mulch combined with clodinafop-propargyl + metsulfuron methyl (L₃H₃) ranked next. These findings indicate that efficient crop establishment and effective weed management act synergistically to improve nutrient-use efficiency.

Phosphorus content and uptake by wheat

Ridge bed with mulch recorded the highest phosphorus content in grain (0.440%) and straw (0.170%), remaining statistically at par

with ridge bed without mulch. Conversely, flat bed without mulch recorded the minimum phosphorus concentration in both grain and straw. Higher phosphorus concentration under ridge bed planting with mulch may be attributed to improved soil moisture conditions and enhanced phosphorus diffusion toward the root zone, which increased phosphorus availability and uptake. Mulching also promoted microbial activity and improved phosphorus solubilization, facilitating greater phosphorus acquisition by wheat. Similar responses have been reported by Akter *et al.* (2018) [2], Zhang *et al.* (2021) [36], Kumari *et al.* (2024) and Chaurasiya *et al.* (2025) [9]. Among weed management practices, after weed-free treatment clodinafop-propargyl + metsulfuron methyl recorded the highest phosphorus content in grain and straw, which proved to be the best herbicidal treatment. The lowest phosphorus content was recorded under weedy check. A similar trend like nitrogen was observed for phosphorus uptake. Ridge bed with mulch produced the highest phosphorus uptake by grain (23.37 kg/ha) and straw (11.11 kg/ha), whereas weed-free treatment recorded maximum phosphorus uptake among weed management practices. Clodinafop-propargyl + metsulfuron methyl was the most effective herbicidal treatment. The interaction effect further demonstrated that ridge bed with mulch integrated with weed-free treatment produced the highest phosphorus uptake by grain (29.95 kg ha⁻¹) and straw (14.41 kg ha⁻¹). The greater phosphorus uptake under these treatments was mainly associated with increased dry matter production and reduced nutrient competition from weeds. Efficient weed suppression allowed the crop to utilize a greater proportion of the available phosphorus throughout the growing period. Similar findings have been reported by Chhokar *et al.* (2012) [10], Dheer and Yadav (2021) [14], Meena *et al.* (2021) [26], and Choudhary *et al.* (2024) [11].

Potassium content and uptake by wheat

Land configuration, mulching and weed management practices significantly influenced potassium concentration in both grain and straw of wheat during both years and in the pooled analysis. Ridge bed with mulch (L₃) recorded the highest pooled potassium content in grain (0.427%) and straw (1.198%), remaining statistically at par with ridge bed without mulch (0.422 and 1.189%, respectively). In contrast, flat bed without mulch (L₂) recorded the lowest potassium concentration in grain (0.394%) and straw (1.101%). The higher potassium content under ridge bed planting with mulch may be attributed to favourable soil moisture conditions, improved soil structure and enhanced root proliferation, which facilitated greater absorption and translocation of potassium within the plant. Potassium is highly mobile in the soil solution, and its uptake is greatly influenced by soil moisture availability and root activity. Mulching conserved soil moisture and created favourable conditions for nutrient diffusion and root growth, thereby enhancing potassium acquisition. Similar findings have been reported by Verma *et al.* (2020) [35], Zhang *et al.* (2021) [36], Choudhary *et al.* (2024), Kumari *et al.* (2024) and Gugulothu *et al.* (2025). Among the weed management treatments, after weed-free treatment clodinafop-propargyl + metsulfuron methyl recorded (0.437%) in grain and in straw (1.183%) potassium content than sulfosulfuron + metsulfuron methyl and mesosulfuron + iodosulfuron, whereas the lowest potassium content was recorded under weedy check. The increased potassium concentration under effective weed management resulted from reduced competition for available soil potassium. Broad-spectrum weed control achieved by clodinafop-propargyl + metsulfuron methyl substantially reduced nutrient losses to weeds. Comparable observations have been reported by

Chhokar *et al.* (2012) [10], Dheer and Yadav (2021) [14], Meena *et al.* (2021) [26] and Bindu and Mitra (2025) [6].

Potassium uptake by grain and straw followed a trend similar to potassium concentration. Ridge bed with mulch recorded the highest pooled potassium uptake by grain (22.77 kg ha⁻¹) and straw (77.96 kg ha⁻¹), followed by ridge bed without mulch (21.12 and 76.60 kg ha⁻¹, respectively). Flat bed without mulch recorded the lowest uptake (16.55 kg ha⁻¹ by grain and 53.36 kg ha⁻¹ by straw). The greater potassium uptake observed under ridge bed planting with mulch was primarily associated with increased biomass production together with improved potassium concentration in plant tissues. Potassium uptake is closely related to dry matter accumulation; therefore, better crop growth under ridge planting enhanced total potassium removal by the crop. Similar observations have been reported by Verma *et al.* (2020) [35], Choudhary *et al.* (2024) and Gugulothu *et al.* (2025). Among weed management treatments, weed-free plots recorded the highest pooled potassium uptake by grain (24.79 kg ha⁻¹) and straw (83.00 kg ha⁻¹). Among herbicidal treatments, clodinafop-propargyl + metsulfuron methyl recorded significantly higher uptake (21.73 kg ha⁻¹ by grain and 75.18 kg ha⁻¹ by straw) than sulfosulfuron + metsulfuron methyl and mesosulfuron + iodosulfuron. The lowest uptake occurred under weedy check because prolonged crop-weed competition substantially reduced nutrient absorption by wheat.

The interaction between land configuration and weed management significantly influenced potassium uptake. Ridge bed with mulch combined with weed-free treatment (L₃H₄) recorded the highest pooled potassium uptake by grain (29.75 kg ha⁻¹) and straw (99.57 kg ha⁻¹), followed by ridge bed with mulch integrated with clodinafop-propargyl + metsulfuron methyl (L₃H₃).

Nutrient content and depletion by weeds

Flat bed without mulch consistently recorded the highest nitrogen (1.61%), phosphorus (0.226%) and potassium (1.359%) contents in weeds, whereas ridge bed with mulch recorded the lowest corresponding values (1.26, 0.209 and 1.152%, respectively), remaining statistically at par with ridge bed without mulch.

Lower nutrient (N, P, K) content in weeds under ridge bed planting with mulch may be attributed to reduced weed growth and biomass resulting from improved crop competitiveness and the suppressive effect of mulch on weed emergence. The mulch layer likely acted as a physical barrier that restricted weed establishment and reduced the availability of light required for weed germination. Consequently, weeds accumulated lower quantities of nitrogen, phosphorus and potassium than those growing under conventional flat-bed conditions. Among weed management practices, weed-free treatment completely eliminated weeds and therefore recorded no nutrient accumulation in weed biomass. Among the herbicidal treatments, clodinafop-propargyl + metsulfuron methyl resulted in lower nutrient concentration in weeds than sulfosulfuron + metsulfuron methyl and mesosulfuron + iodosulfuron, reflecting its greater effectiveness in suppressing both grassy and broad-leaved weeds. In contrast, maximum nutrient depletion occurred under weedy check because weeds grew unchecked and removed considerable quantities of nitrogen, phosphorus and potassium from the soil. Similar observations have been reported by Chhokar *et al.* (2012) [10], Dheer and Yadav (2021) [14], Meena *et al.* (2021) [26], Choudhary *et al.*, 2024 [11], and Chaurasiya *et al.* (2025) [9].

The combined effects of ridge bed planting, mulching and effective weed management clearly demonstrate that reducing weed growth not only minimizes competition for nutrients but

also enhances nutrient utilization by wheat. Improved nutrient acquisition by the crop together with reduced nutrient depletion by weeds contributed to greater nutrient-use efficiency under the

integrated production system evaluated in the present investigation.

Table 1: Effect of land configuration, mulching and weed management practices on N, P, K content and uptake by grain and straw of

Treatments	N, P, K content (%) Pooled						N, P, K uptake (kg/ha) Pooled					
	Grain			Straw			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
Land configuration with mulch												
Flat bed with mulch	1.81	0.426	0.413	0.641	0.165	1.156	81.15	19.03	18.51	36.15	9.31	65.22
Flat bed without mulch	1.70	0.406	0.394	0.615	0.157	1.101	71.16	17.02	16.55	29.81	7.61	53.36
Ridge bed with mulch	1.96	0.440	0.427	0.657	0.170	1.198	104.69	23.37	22.77	42.76	11.11	77.96
Ridge bed without mulch	1.93	0.435	0.422	0.653	0.168	1.189	96.64	21.67	21.12	42.05	10.87	76.60
S. Em±	0.01	0.004	0.003	0.005	0.001	0.009	1.38	0.34	0.35	0.62	0.15	1.17
CD (p=0.05)	0.04	0.011	0.010	0.017	0.004	0.028	4.24	1.04	1.09	1.91	0.47	3.60
Herbicides												
H ₁ -Sulfosulfuron (75%) + Metsulfuron methyl (5%) WG@ 32 g a.i. PoE	1.84	0.422	0.405	0.636	0.167	1.153	85.55	19.62	18.80	35.55	9.32	64.48
H ₂ -Mesosulfuron (3%) + Iodosulfuron (0.6%) WDG @ 14.4 g a.i/ha as PoE	1.83	0.421	0.402	0.635	0.165	1.152	82.64	18.99	18.13	34.60	9.01	62.83
H ₃ -Clodinafop (15%) + Metsulfuron methyl (1%) WP@ 64 g/ha as PoE	1.91	0.427	0.437	0.654	0.169	1.183	95.38	21.23	21.73	41.50	10.75	75.18
H ₄ -Weed free	1.99	0.452	0.449	0.670	0.176	1.214	110.06	24.95	24.79	45.77	12.01	83.00
H ₅ -Weedy check	1.71	0.413	0.380	0.614	0.149	1.105	68.42	16.56	15.24	31.04	7.54	55.91
S. Em±	0.02	0.004	0.004	0.006	0.002	0.010	1.60	0.38	0.40	0.66	0.16	1.24
CD (p=0.05)	0.05	0.012	0.011	0.018	0.005	0.029	4.51	1.07	1.12	1.86	0.45	3.50

Table 2: Effect of land configuration, mulching and weed management practices on N, P, K content and depletion by weed.

Treatments	N, P, K content (%) Pooled			N, P, K depletion (kg/ha) Pooled		
	N	P	K	N	P	K
Land configuration with mulch						
Flat bed with mulch	1.51	0.222	1.278	8.80	1.30	7.46
Flat bed without mulch	1.61	0.226	1.359	10.17	1.44	8.62
Ridge bed with mulch	1.26	0.209	1.152	6.05	1.01	5.56
Ridge bed without mulch	1.28	0.214	1.157	6.58	1.10	5.97
S. Em±	0.01	0.002	0.010	0.15	0.02	0.13
CD (p=0.05)	0.04	0.005	0.030	0.45	0.07	0.41
Herbicides						
H ₁ -Sulfosulfuron (75%) + Metsulfuron methyl (5%) WG@ 32 g a.i. PoE	1.81	0.277	1.581	6.16	0.93	5.36
H ₂ -Mesosulfuron (3%) + Iodosulfuron (0.6%) WDG @ 14.4 g a.i/ha as PoE	1.87	0.282	1.589	6.56	0.98	5.57
H ₃ -Clodinafop (15%) + Metsulfuron methyl (1%) WP@ 64 g/ha as PoE	1.74	0.271	1.539	4.57	0.71	4.04
H ₄ -Weed free	0.00	0.000	0.000	0.00	0.00	0.00
H ₅ -Weedy check	1.67	0.260	1.475	22.22	3.43	19.55
S. Em±	0.01	0.002	0.011	0.15	0.03	0.13
CD (p=0.05)	0.04	0.005	0.031	0.43	0.07	0.36

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