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Impact of organic and inorganic weed management practices on the growth, yield and economics of wheat (*Triticum aestivum* L.)

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Abstract

A field experiment was conducted during the rabi season of 2024–25 at the Agricultural Farm, Maharishi University of Information Technology, Lucknow (U.P.), India, to assess the effectiveness of post-emergence application of fenoxaprop in combination with pre-emergence application of sulfosulfuron in wheat (*Triticum aestivum* L.). The treatments comprised weed-free (T_7) and unweeded control (T_8), fenoxaprop 10 WP @ 100 g a.i. ha^{-1} at 35 DAS (T_4), sulfosulfuron 75% WP @ 25 g a.i. ha^{-1} at 35 DAS (T_5), sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ 32 g a.i. ha^{-1} at 35 DAS (T_6), one hand weeding at 25 DAS (T_1), two hand weeding at 25 and 45 DAS (T_2), and application of paddy straw mulch between two rows of wheat @ 6.0 t ha^{-1} (T_3). The treatments were evaluated based on weed dynamics, crop growth, and yield performance. The results indicated that the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ 32 g a.i. ha^{-1} at 35 DAS (T_6) resulted in the lowest total weed dry weight, which was statistically at par with sulfosulfuron 75% WP @ 25 g a.i. ha^{-1} (T_5) and significantly superior to other treatments. Among all treatments, the highest grain yield (48.2 q ha^{-1}) was recorded under weed-free conditions (T_7), which was comparable to T_6 (45.3 q ha^{-1}). However, considering labour scarcity, the application of sulfosulfuron + metsulfuron methyl (T_6) proved to be the most economical, recording the highest net return (Rs.85,274 ha^{-1}) and benefit-cost ratio (2.15). This treatment was found comparable to sulfosulfuron alone (T_5) and fenoxaprop (T_4), owing to enhanced crop productivity and profitability.

Keywords: Wheat, herbicides, weed dynamics, productivity, profitability

Introduction

Wheat (*Triticum aestivum* L.) is one of the most significant cereal crops cultivated worldwide and plays a crucial role in global food security. It ranks first among cereal crops in terms of cultivated area and overall production. India is the second-largest producer of wheat globally, contributing approximately 13.5% to total world production (Choudhary *et al.*, 2021). Wheat serves as a staple food for nearly 4.5 billion people across 94 countries, supplying about 21% of total dietary calories and 20% of protein intake. In addition, wheat-based diets provide essential micronutrients necessary for proper growth and metabolic functions. In India, wheat is cultivated over an area of about 30.22 million hectares, with a production of 93.50 million tonnes (Singh *et al.*, 2019) ^[18]. Uttar Pradesh is a leading wheat-producing state, covering nearly 9.54 million hectares with an average productivity of 34.32 q ha^{-1} and a total production of 32.74 million tonnes (Sharma *et al.*, 2020). With the global population increasing rapidly, the demand for food is expected to rise by nearly 60% by 2050, with most of this demand to be met from existing agricultural land (Santini *et al.*, 2021) ^[17]. However, achieving higher productivity remains a major challenge due to constraints such as climate change, improper nutrient management, and severe weed infestation.

Weed management is a critical factor in enhancing wheat productivity, as weeds compete with crops for essential resources such as nutrients, water, light, and space, thereby significantly reducing yields. Despite being a major constraint, weed infestation is often underestimated compared to pests and diseases. The critical period of crop-weed competition in wheat occurs between 11 and 21 days after crop emergence (Kadam *et al.*, 2021) ^[7]. Studies have reported that mixed weed infestations can reduce grain yield by up to 34.3% in late-sown wheat (Meena *et al.*,

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2017) [13]. Traditionally, weeds were managed through cultural practices such as tillage, manual weeding, and crop rotation. However, with the advent of herbicides, chemical weed control has become the most widely adopted and efficient method in many countries, including India (Kairovin, 2023). Due to labour shortages, high wages, and the impracticality of manual or mechanical weeding on large farms, herbicides are increasingly preferred in wheat cultivation. Modern ready-mix herbicide combinations have proven effective in controlling a broad spectrum of weeds (Deshmukh *et al.*, 2020) [4].

Manual weeding, although effective, is labour-intensive, time-consuming, and suitable only for small-scale operations. Rising labour costs and scarcity have encouraged the adoption of herbicides either alone or in combination with cultural practices. In addition to chemical methods, mulching has emerged as an alternative weed management practice. Organic mulches, such as paddy straw, are biodegradable and improve soil fertility, whereas inorganic mulches, like plastic sheets, are durable but environmentally unsustainable.

Mulching suppresses weed growth by restricting light penetration, conserves soil moisture, stabilizes soil temperature, and reduces soil erosion. Paddy straw mulch, commonly available after rice harvest, is particularly useful in wheat fields as it helps control weeds and enhances soil moisture retention. Studies indicate that mulching can increase yield as well as water use efficiency (WUE) and nutrient use efficiency (NUE) in crops like wheat and maize. However, its adoption is limited by the availability of straw, its competing uses (e.g., livestock feed), and the cost associated with plastic mulches.

Weed infestation can cause yield losses ranging from 15% to 40% or even higher, along with deterioration in produce quality. Among various biotic stresses, weeds contribute the highest yield losses (33%), followed by diseases, insects, storage pests, rodents, and other factors. In wheat, yield losses due to weeds may range from 37.0% to 57.1% depending on the severity of infestation (Deshmukh *et al.*, 2020) [4]. Factors such as weed emergence time, competition intensity, weed species, crop density, and environmental conditions significantly influence yield reduction. Weeds possess aggressive growth characteristics, including rapid growth rate, greater height, extensive root systems, and dense canopy formation, enabling them to outcompete crop plants for resources. As a result, wheat is highly susceptible to weed competition, leading to substantial yield reductions (Verma *et al.*, 2021) [21].

Herbicides, which are chemicals designed to control unwanted plant growth, have become the primary tool for weed management. They are easy to apply, cost-effective, and particularly suitable for large-scale farming (Powles and Shaner, 2001) [14]. However, continuous use of herbicides with the same mode of action has led to the development of herbicide resistance, particularly in *Phalaris minor* in north-western India. To overcome resistance issues, researchers are exploring alternative herbicides and combinations. Herbicide mixtures, whether pre-mixed or tank-mixed, offer broader weed control, reduce individual herbicide doses, and minimize the risk of resistance development. These combinations often exhibit synergistic effects, improving weed suppression and enhancing crop yield. Studies have demonstrated that herbicide mixtures are more effective than single herbicides in controlling both grassy and broadleaf weeds (Singh *et al.*, 2015; Khan *et al.*, 2021) [18, 1]. Recent advancements have introduced several effective ready-mix herbicide combinations that provide efficient control of diverse weed flora in wheat fields. These combinations not only improve weed management but also

contribute to higher productivity and sustainability in wheat cultivation (Deshmukh *et al.*, 2020) [4].

Materials and Methods

The field experiment was conducted at the Agricultural Farm, Maharishi University of Information Technology, Lucknow (U.P.), situated in the North-Western Plains Zone of wheat cultivation. During the crop growth period, the weekly mean maximum temperature ranged from 19.1°C to 36.7°C, while the minimum temperature varied between 3.0°C and 3.6°C. The region receives an average annual rainfall of about 862 mm, with more than 80% occurring during the south-west monsoon period (July to September). The relative humidity during the crop season ranged from 36.6% to 96.6%. Prior to sowing, soil samples were collected randomly from ten locations at a depth of 0–15 cm. These samples were thoroughly mixed to form a composite sample, which was air-dried, ground, and passed through a 2 mm sieve for analysis of physical and chemical properties. The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 7.4), with a bulk density of 1.49 g cm⁻³. It was low in available nitrogen and organic carbon (0.43%), and medium in available phosphorus and potassium. The experiment was laid out in a randomized block design (RBD) with three replications to evaluate different weed management practices in wheat. The gross and net plot sizes were 5.0 × 4.0 m² and 4.0 × 3.2 m², respectively. A total of eight treatments were included: one hand weeding at 25 days after sowing (DAS), two hand weedings at 25 and 45 DAS, application of paddy straw mulch between rows at 6.0 t ha⁻¹, fenoxaprop 10 WP @ 100 g a.i. ha⁻¹ at 35 DAS, sulfosulfuron 75% WP @ 25 g a.i. ha⁻¹ at 35 DAS, sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ 32 g a.i. ha⁻¹ at 35 DAS, weed-free treatment, and unweeded control.

Wheat was sown with a row spacing of 20 cm and plant-to-plant spacing of approximately 10 cm. Pre-sowing irrigation was applied to ensure proper field preparation and germination, followed by subsequent irrigations as required. Fenoxaprop was applied as a post-emergence herbicide at 35 DAS, while metsulfuron methyl was used as a pre-emergence application within 24 hours of sowing. All other agronomic practices were followed as per regional recommendations.

Weed observations were recorded using a 0.25 m² quadrat (0.5 m × 0.5 m), placed randomly in each plot at 25 (before herbicide application), 30, 60, and 90 DAS. Weed population was counted species-wise, and weeds were harvested from the sampled area. The collected weeds were first sun-dried and then oven-dried at 70°C for 72 hours to determine dry weight.

Economic analysis of the treatments was carried out based on prevailing market prices of inputs and outputs. The total cost of cultivation included expenses incurred on seeds, fertilizers, herbicides, and labour involved in various field operations. Statistical analysis of the data was performed using the analysis of variance (ANOVA) technique in SPSS software. Treatment means were compared using the critical difference (CD) at 5% level of significance ($P < 0.05$).

Results and Discussion

Effect of Weedicides on Weed Dynamics

Different weed management practices significantly influenced total weed density at various crop growth stages. The data shows on table No. 1 and 2. The unweeded control recorded the highest weed density (11.56, 11.58, and 11.21 m⁻²) at 30, 60, and 90 DAS, respectively.

Among the treatments (excluding the weed-free condition), the

lowest weed density (9.84 m^{-2}) was observed with the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ $32 \text{ g a.i. ha}^{-1}$ at 35 DAS. This treatment also resulted in the minimum weed density at later stages, recording 5.44 and 4.86 m^{-2} at 60 and 90 DAS, respectively. These values were

statistically at par with sulfosulfuron 75% WP @ $25 \text{ g a.i. ha}^{-1}$ (5.59 and 4.98 m^{-2}) and fenoxaprop 10 WP @ $100 \text{ g a.i. ha}^{-1}$ (6.04 and 5.23 m^{-2}) at the respective stages. The data were transformed using the square root transformation ($\sqrt{x + 1}$), with original values presented in parentheses.

Table 1: Shows the total weed density (number per m^2) as impacted by various weed control strategies.

Treatment		Density of total weeds (number per m^2)		
		30 DAS	60 DAS	90 DAS
T ₁	One hand weeding at 25 DAS	10.51(109.5)	6.46(40.7)	5.56(29.9)
T ₂	Two Hand weeding (25 DAS and 45 DAS)	9.46(88.4)	4.87(22.7)	4.31(17.6)
T ₃	Use paddy straw within two rows of wheat @ 6.0 t/ha	10.69(113.2)	6.62(42.8)	5.88(33.6)
T ₄	Fenoxaprop 10wp @ $100 \text{ g a.i. ha}^{-1}$ at 35 DAS	10.41(107.4)	6.04(35.5)	5.23(26.4)
T ₅	Sulfosulfuron 75%wp @ $25 \text{ g a.i. ha}^{-1}$ at 35 DAS	10.29(104.8)	5.59(30.2)	4.98(23.8)
T ₆	Sulfosulfuron 75wp + Metsulfuron Methyl 5wp @ $32 \text{ g a.i. ha}^{-1}$ at 35 DAS	9.84(95.8)	5.44(28.6)	4.86(22.6)
T ₇	Weed free	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₈	Unweeded Control	11.56(132.6)	11.58(133.2)	11.21(124.6)
SEm($\pm$)		0.35	0.24	0.22
C.D. (P=0.05)		1.01	0.69	0.64

Weed management practices also had a significant impact on total weed dry matter accumulation. The unweeded control exhibited the highest weed dry weight (6.40 , 9.36 , and 13.23 g m^{-2}) at 30, 60, and 90 DAS, respectively. The increase in dry weight at earlier stages followed by a decline at later stages may be attributed to leaf senescence and reduced biomass accumulation. Similar trends were reported by Kaur *et al.* (2019)^[9] and Ahmed *et al.* (2020)^[1].

Among herbicidal treatments, the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ $32 \text{ g a.i. ha}^{-1}$ at 35 DAS

resulted in the lowest weed dry weight (5.41 g m^{-2} at 30 DAS). At 60 DAS, this treatment recorded significantly lower dry weight (3.92 g m^{-2}), which was statistically comparable to sulfosulfuron 75% WP @ $25 \text{ g a.i. ha}^{-1}$ (4.04 – 4.66 g m^{-2}) and significantly superior to the remaining treatments. These findings are in agreement with the results reported by Hussein *et al.* (2022) and Soni *et al.* (2023)^[19]. The data were transformed using the square root method ($\sqrt{x + 1}$), with original values given in parentheses.

Table 2: Total weed dry matter accumulation (g m^{-2}) as affected by various weed control strategies.

Treatment		Dry weight of total weeds (g m^{-2})		
		30 DAS	60 DAS	90 DAS
T ₁	One hand weeding at 25 DAS	5.98(34.8)	5.12(25.2)	5.64(30.8)
T ₂	Two Hand weeding (25 DAS and 45 DAS)	5.09(24.9)	3.79(13.4)	4.01(15.1)
T ₃	Use paddy straw within two rows of wheat @ 6.0 t/ha	6.28(38.4)	5.65(30.9)	6.08(36.0)
T ₄	Fenoxaprop 10wp @ $100 \text{ g a.i. ha}^{-1}$ at 35 DAS	5.95(34.4)	4.82(22.2)	5.14(25.4)
T ₅	Sulfosulfuron 75%wp @ $25 \text{ g a.i. ha}^{-1}$ at 35 DAS	5.71(31.6)	4.04(15.3)	4.66(20.7)
T ₆	Sulfosulfuron 75wp + Metsulfuron Methyl 5wp @ $32 \text{ g a.i. ha}^{-1}$ at 35 DAS	5.41(28.3)	3.92(14.4)	4.30(17.5)
T ₇	Weed free	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₈	Unweeded Control	6.40(39.9)	9.36(86.7)	13.23(174.0)
SEm($\pm$)		0.20	0.19	0.24
C.D. (P=0.05)		0.57	0.54	0.68

Effect of Weed Management Practices on Yield Attributes of Wheat

Weed management practices significantly influenced various yield attributes of wheat. The data shows on table No.3. The number of effective tillers was markedly affected by different treatments. The unweeded control recorded the lowest number of effective tillers (40.1), which was significantly lower than all other treatments. In contrast, the weed-free treatment produced the highest number of effective tillers (84.5).

Among the herbicidal treatments, the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ $32 \text{ g a.i. ha}^{-1}$ at 35 DAS resulted in the maximum number of effective tillers (78.8), which was statistically at par with sulfosulfuron 75% WP @ $25 \text{ g a.i. ha}^{-1}$ (74.7) and fenoxaprop 10 WP @ $100 \text{ g a.i. ha}^{-1}$ (72.4). This treatment produced 96.5% more effective tillers compared to the unweeded control.

Spike length was also significantly influenced by weed control measures. The shortest spike length (7.3 cm) was recorded under unweeded control, while the longest spike length (11.7 cm) was

observed under weed-free conditions. Among herbicidal treatments, sulfosulfuron + metsulfuron methyl recorded the highest spike length (10.6 cm), which was statistically comparable with sulfosulfuron alone (10.5 cm) and fenoxaprop (9.8 cm). This treatment resulted in a 45.2% increase in spike length over the unweeded control.

The number of spikelets per spike was significantly affected by different treatments. The unweeded control recorded the minimum number of spikelets (8.0 per spike), whereas the weed-free treatment produced the maximum (18.2 per spike). Among herbicides, sulfosulfuron + metsulfuron methyl recorded the highest number of spikelets (17.2 per spike), which was at par with sulfosulfuron alone, showing a 115% increase over the unweeded control.

Similarly, the number of grains per spike was significantly influenced by weed management practices. The lowest number of grains per spike (30.8) was observed under unweeded control, while the highest (45.7) was recorded under weed-free conditions. Among herbicide treatments, sulfosulfuron +

metsulfuron methyl resulted in the highest number of grains per spike (42.2), which was statistically comparable with sulfosulfuron alone and showed a 37.0% increase over the unweeded control.

Test weight was not significantly affected by different weed management practices. However, the lowest test weight (33.2 g) was recorded under unweeded control, while the highest (40.0 g) was observed under weed-free conditions. Among herbicidal

treatments, sulfosulfuron + metsulfuron methyl recorded the highest test weight (38.6 g). Similar findings were reported by Dev *et al.* (2013) [5] and Bhutto *et al.* (2016) [3]. Previous studies (Sudha *et al.*, 2016; Kaur *et al.*, 2017) [20, 10] have also indicated that integrated weed management practices, including both herbicides and manual weeding, are more effective than the use of herbicides alone.

Table 3: Shows the impact of weed control strategies on Yield attributes

Treatments		Yield attributes				
		Effective tillers (per meter row length)	Spike length (cm)	Number of spikelets/spike	Number of grains/spike	Test weight (g)
T ₁	One hand weeding at 25 DAS	73.5	9.5	15.1	35.3	37.9
T ₂	Two Hand weeding (25 DAS and 45 DAS)	80.2	11.1	17.6	43.1	39.0
T ₃	Use paddy straw within two rows of wheat @ 6.0 t/ha	70.9	8.9	14.3	36.1	37.2
T ₄	Fenoxaprop 10wp @100g a.i. ha ⁻¹ at 35 DAS	72.4	9.8	14.8	37.2	37.6
T ₅	Sulfosulfuron 75%wp @ 25g a.i. ha ⁻¹ at 35 DAS	74.7	10.5	15.8	39.4	38.1
T ₆	Sulfosulfuron 75wp + Metsulfuron Methyl 5wp @ 32g a.i. ha ⁻¹ at 35 DAS	78.8	10.6	17.2	42.2	38.6
T ₇	Weed free	84.5	11.7	18.2	45.7	40.0
T ₈	Unweeded Control	40.1	7.3	8.0	30.8	33.2
SEm±		2.5	0.3	0.6	1.4	1.3
CD (p = 0.05)		7.2	0.9	1.7	3.9	NS

Crop Productivity

Weed management practices had a significant effect on grain yield of wheat. The data shows on table No.4. The lowest grain yield (28.8 q ha⁻¹) was recorded under the unweeded control, whereas the weed-free treatment produced the highest grain yield (48.2 q ha⁻¹).

Among the herbicidal treatments, the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ 32 g a.i. ha⁻¹ at 35 DAS resulted in the highest grain yield (45.3 q ha⁻¹). This was statistically at par with sulfosulfuron 75% WP @ 25 g a.i. ha⁻¹ (43.8 q ha⁻¹) and fenoxaprop 10 WP @ 100 g a.i. ha⁻¹ (42.9 q ha⁻¹). The combined application of sulfosulfuron and metsulfuron methyl increased grain yield by 57.2% over the unweeded control.

Biological yield was also significantly influenced by different weed control treatments. The unweeded control recorded the lowest biological yield (75.0 q ha⁻¹), while the highest biological yield (113.0 q ha⁻¹) was observed under weed-free conditions, which is in agreement with the findings of Singh *et al.* (2017) [18].

Among herbicidal treatments, the maximum biological yield (108.0 q ha⁻¹) was obtained with the application of sulfosulfuron + metsulfuron methyl @ 32 g a.i. ha⁻¹ at 35 DAS. This treatment was statistically comparable to sulfosulfuron alone (104.4 q ha⁻¹) and fenoxaprop (104.1 q ha⁻¹). The combined herbicide treatment resulted in a 44.0% increase in biological yield over the unweeded control.

Table 4: Shows the impact of weed control strategies on grain, straw, and biological yield (q ha⁻¹) and harvest index (%).

Treatments		Yield (q ha ⁻¹)			Harvest index (%)
		Grain	Straw	Biological	
T ₁	One hand weeding at 25 DAS	40.4	58.2	98.6	41.0
T ₂	Two Hand weeding (25 DAS and 45 DAS)	46.4	64.1	110.5	42.0
T ₃	Use paddy straw within two rows of wheat @ 6.0 t/ha	36.8	55.7	92.5	39.8
T ₄	Fenoxaprop 10wp @100g a.i. ha ⁻¹ at 35 DAS	42.9	60.3	104.1	41.2
T ₅	Sulfosulfuron 75%wp @ 25g a.i. ha ⁻¹ at 35 DAS	43.8	61.5	104.4	41.9
T ₆	Sulfosulfuron 75wp + Metsulfuron Methyl 5wp @ 32g a.i. ha ⁻¹ at 35 DAS	45.3	62.7	108.0	42.0
T ₇	Weed free	48.2	64.8	113.0	42.7
T ₈	Unweeded Control	28.8	46.2	75.0	38.4
SEm±		1.1	1.8	3.6	1.5
CD (p = 0.05)		3.2	5.5	10.4	NS

Economics

Crop productivity is significantly influenced by different weed management practices. The data shows on table No.5. Among the treatments, the weedy check recorded the lowest grain yield (28.8 q ha⁻¹), whereas weed-free conditions produced the highest yield (48.2 q ha⁻¹). Application of Sulfosulfuron 75 WP + Metsulfuron Methyl 5 WP at 32 g a.i. ha⁻¹ at 35 DAS resulted in the highest grain yield (45.3 q ha⁻¹), which was statistically similar to Sulfosulfuron 75 WP at 25 g a.i. ha⁻¹ (43.8 q ha⁻¹) and Fenoxaprop 10 WP at 100 g a.i. ha⁻¹ (42.9 q ha⁻¹), all applied at

35 DAS. This combined herbicide treatment increased grain yield by 57.2% over the weedy check.

Weed control methods also had a marked effect on biological yield. The lowest biological yield was observed under weedy check conditions (75.0 q ha⁻¹), while weed-free plots recorded the highest (113.0 q ha⁻¹). Similar results were reported by Singh *et al.* (2017) [18]. The application of Sulfosulfuron + Metsulfuron Methyl at 32 g a.i. ha⁻¹ at 35 DAS produced the highest biological yield (108.0 q ha⁻¹), which was statistically at par with Sulfosulfuron alone (104.4 q ha⁻¹) and Fenoxaprop (104.1 q

ha⁻¹). This treatment improved biological yield by 44.0% compared to the weedy check.

Economic returns, expressed as the benefit-cost (B:C) ratio, were also significantly affected by weed management practices. The lowest B:C ratio (1.34) was recorded under weedy check

conditions. The highest B:C ratio was obtained with Sulfosulfuron + Metsulfuron Methyl at 32 g a.i. ha⁻¹ (2.15), followed closely by Fenoxaprop at 100 g a.i. ha⁻¹ (2.12). These findings are consistent with those reported by Singh *et al.* (2022) [18].

Table 5: Shows the effect of weed control strategies on wheat profitability.

	Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B: C ratio
T ₁	One hand weeding at 25 DAS	37139	112280	75141	2.02
T ₂	Two Hand weeding (25 DAS and 45 DAS)	41129	127995	86866	2.11
T ₃	Use paddy straw within two rows of wheat @ 6.0 t/ha	36769	103215	66446	1.81
T ₄	Fenoxaprop 10wp @100g a.i. ha ⁻¹ at 35 DAS	38129	119123	80994	2.12
T ₅	Sulfosulfuron 75%wp @ 25g a.i. ha ⁻¹ at 35 DAS	39509	120750	81241	2.06
T ₆	Sulfosulfuron 75wp + Metsulfuron Methyl 5wp @ 32g a.i. ha ⁻¹ at 35 DAS	39729	125003	85274	2.15
T ₇	Weed free	46359	132335	85976	1.85
T ₈	Unweeded Control	34909	81690	46781	1.34
	SEm±	-	3987	2698	0.11
	CD (p = 0.05)	-	11449	8091	0.31

Conclusion

Based on the results of the present study, it can be concluded that all weed management practices effectively reduced weed infestation and significantly improved wheat yield compared to the unweeded control. Among the treatments, maintaining weed-free conditions through manual weeding proved to be the most effective method for controlling grassy, broadleaf, and sedge weeds, resulting in the highest weed control efficiency. The weed-free treatment also recorded superior growth parameters, yield attributes, grain yield, and nutrient uptake. However, its performance was statistically comparable to the application of sulfosulfuron 75 WP + metsulfuron methyl 5 WP @ 32 g a.i. ha⁻¹ at 35 DAS and sulfosulfuron 75% WP @ 25 g a.i. ha⁻¹ at 35 DAS. Among the herbicidal treatments, the combined application of sulfosulfuron + metsulfuron methyl @ 32 g a.i. ha⁻¹ at 35 DAS proved more effective than sulfosulfuron alone in terms of weed control, crop productivity, and economic returns, including higher gross return, net return, and benefit-cost ratio. Although the weed-free treatment yielded the highest net returns, its practical application is limited due to labour scarcity and higher costs. Therefore, chemical weed management, particularly the use of herbicide combinations, offers a more feasible and economical alternative for farmers. Hence, the application of sulfosulfuron + metsulfuron methyl @ 32 g a.i. ha⁻¹ at 35 DAS can be recommended for effective weed control, enhanced productivity, and improved profitability of wheat. However, further validation through multi-season trials is suggested for more reliable conclusions.

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