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Effect of Tillage and Weed Management Practices on Growth, Yield Attributes, and Economics of Wheat

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted during *Rabi*2023-24 at the research farm, Bihar Agricultural University, Sabour, Bhagalpur, Bihar. The experiment consisted of three tillage operations in main plots and six weed management practices in sub plots laid out in split plot design with three replications. Results revealed that zero tillage with paddy residue led to higher plant height (102.97 cm), leaf area index (2.56), biomass accumulation (570.90 g m^{-2}), no. of spikes m^{-2}(256.45), no. of grains $spike^{-1}$(49.08), grainyield (3640.86 kg ha^{-l}), net returns (65638 ₹ ha^{-1}) and benefit cost ratio

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(1.69) which was statistically at par with zero tillage without residue among weed management practices, hand weeding treatment was found significantly superior in all crop traits but it was not economical for farmers due to higher cost of cultivation. However different herbicidal treatments, sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} were found significantly superior, higher plant height (102.62 cm), leaf area index (2.42), biomass accumulation (580.48 g m^{-2}),no. of spikes m^{-2}(270.36), no. of grains $spike^{-1}$(49.59), grainyield (3895.68 kg ha^{-l}), net returns(70756 ₹ha^{-1}) and B:C ratio (1.81) which was statistically at par with mesosulfuron methyl + iodosulfuron methyl sodium (12+2.4) g a.i. ha^{-1}.

Keywords: Mesosulfuron methyl; iodosulfuron; sulfosulfuron; metsulfuron methyl; weed management; economics.

1. INTRODUCTION

Wheat (*Triticum aestivum*) is one of the most important staple foods of India. It comprises approximately 12% protein, 2% total fat, and 55% carbohydrates (Kumar et al., 2011). In India terms of wheat production with about 107.86 MT share in global wheat production ranks second after China (MoA & FW, 2023). In terms of wheat production In India, Bihar ranks 6th rank with 6.22 MT in national share. As food demand is projected to rise from 236.2 million tonnes in 2010 to 303-318 million tonnes by 2030, improving wheat production and productivity becomes imperative (DACFW, 2017). However, wheat productivity in India is facing challenges due to stagnating or declining yields, driven by factors such as improper tillage practices, imbalanced fertilizer use, water shortages, and severe weed infestations (Kantwa et al., 2015). Traditional tillage methods often lead to increased weed populations by improving germination conditions. In contrast, zero-till systems, which minimize soil disturbance, can enhance yields and conserve resources, including water (Shekhar et al., 2014). The rice-wheat cropping system prevalent in northern India typically requires multiple tillage operations for seedbed preparation, significantly increasing costs. Zero tillage, which retains crop residues and eliminates extensive field preparation, offers a sustainable alternative that improves soil quality and resource use efficiency (Das et al.,2018). Weed management is critical, as weeds can cause yield reductions of 15% to over 50% (Singh et al., 2016). The herbicide market in India is growing rapidly as farmers increasingly depend on chemical weed control due to migration of workers and rising labour cost, making it more challenging for farmers to manage weeds manually. However, heavy reliance on herbicides has caused issues such as a shift from broad-leaved to grassy weeds, the emergence of herbicide-resistant species, and environmental residue concerns. Isoproturon, once effective against for controlling *Phalaris minor* and some broadleaf weeds, has led to resistance, prompting the recommendation of sulfosulfuron for post-emergence treatment (Walia et al., 2005). New herbicides like clodinafop, metribuzin, and metsulfuron methyl have been introduced (Tiwari and Vaishya,2004) with clodinafop primarily targeting grasses, while sulfosulfuron controls both grasses and some broad-leaved weeds (Chhokar and Malik, 2002, Chhokar et al.,2006). In areas where graminicides like clodinafop are used, there has been a significant increase in broad-leaved weeds, necessitating broad-spectrum weed control through combinations of herbicides. Tank-mixes or pre-mixes are more efficient and cost-effective than single applications. Ready-mix formulations, such as sulfosulfuron+ metsulfuron methyl, clodinafop+ metsulfuron methyl, and mesosulfuron+ iodosulfuron offer high potency at lower doses,effectively control both grassy and broad-leaved weeds while being environmentally safer (Bharat amd Karchroo, 2002). Foliar (post-emergence) applications are preferred over soil applications, as they minimize soil residue impacts and may enhance soil health. Identifying suitable tillage practices and herbicides is crucial for effective weed management in wheat cultivation. Effective control often necessitates the use of combinations of herbicides for broad-spectrum management. This investigation aims to assess the effects of various tillage and post-emergence herbicide practices on growth, yield attributes, soil chemical properties and economics of wheat. The study seeks to contribute valuable insights into improving wheat productivity and ensuring food security in India.

2. MATERIALS AND METHODS

The experiment was conducted at experimental farm of Bihar Agricultural University, Sabour, Bhagalpur, India, during the *rabi* season of 2023-2024 to assess the effect of tillage and weed management practices on weed dynamics, productivity and profitabilityof wheat. The experiment was conducted in middle gangetic plains region of agro-climatic zone III A, The soil of the experimental plot was silty clay loam in texture, low in fertility status of organic carbon (0.47%) and nitrogen (191.86 kg available N ha^{-1}), medium range of phosphorous (27.26 kg available P_2O_5 ha^{-1}) and potassium (143.21 kg available K_2O ha^{-1}) and neutral to slightly alkaline condition in nature (pH = 7.89).The experiment consisted of three tillage operations in main plots i.e., T_1 (Conventional tillage) ,T_2 (zero tillage without residue) and T_3 (zero tillage with paddy residue) and six weed management practices in sub plots i.e., W_1: clodinafop propargyl + metsulfuron methyl (60+4) g a.i. ha^{-1} at 30 DAS as PoE (Post-Emergence) ,W_2: sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} at 30 DAS as PoE, W_3: mesosulfuron methyl + iodosulfuronmethyl sodium (12+2.4) g a.i. ha^{-1} at 30 DAS as PoE, W_4: clodinafop propargyl + metribuzin (54+120) g a.i. ha^{-1} at 30 DAS as PoE, W_5: Hand weeding at 20-25 and 40-45 DAS, W_6: Weedy check laid out in split plot design with three replicationswith subplot size was 3.0m × 4.0m (12.0m^2).The wheat variety 'HD-2967' was shown on 06th December 2023 at a seed rate of 125 kg per hectare in rows spaced 20 cm apart and harvesting was done on 13th April 2024. No farm operation or residue was left in zero tillage without residue while, 30% of paddy residue was left in the field in case of zero tillage with paddy residue. A uniform recommended dose of 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied for wheat crop through urea, diammonium phosphate (DAP) and murate of potash (MOP), respectively. Half dose of nitrogen along with the full dose of phosphorus and potash was applied as basal at the time of sowing, rest half dose of N was top dressed in two equal splits, with one part added at the tillering stage and the other at the spike initiation stage of wheat. Weedy plots, however, continued to be infested with native weeds throughout the growing season. All herbicides were applied post-emergence at 30 DAS directly to the weed foliage using a knapsack sprayer with a flat fan nozzle. The experimental data were analyzed using analysis of variance (ANOVA) to evaluate various parameters. Treatment effects were assessed with the 'F' test (variance ratio), and critical differences (C.D.) at the 5% significance level were calculated to compare treatment means.

3. RESULTS AND DISCUSSION

3.1 Dominant weed Flora

The prominent weeds noted in the wheat fields were grassy weeds (*Phalaris minor, Polypogonmonspeliensis*and*Cynodondactylon,*),sedges (*Cyperusrotundus)* and broad leaf weeds (*Rumexdentatus, Anagallisarvesnsis*, *Medicagodenticulata, Solanum nigrum*, *Melilotus indica, Chenopodium album, Physalis minima, Vicia sativa, Fumaria parviflora,* and *Polygonumplebeium*).

3.2 Effect on Growth Parameters of Wheat

The results revealed that different tillage operations and weed management practices significantly affected plant height at all the progressive growth stages.In main plot statistically highest plant height (102.97cm) (Table 1), biomass accumulation (570.90 g m^{-2})and leaf area index (2.56)were observed under zero tillage with paddy residue at 90 DAS over the other treatments i.e. conventions tillage (CT) and zero tillage (ZT). Similar results were also obtained by Kumar et al.,2016 Shukla et al.,2018. This could be due to the residual effects of the previous crop enhancing the soil's physical, chemical, and biological conditions. It helps reduce soil moisture and nutrient losses and regulates soil temperature in zero tillage with paddy residue. These improvements support plant growth, leading to greater plant height, higher biomass accumulation, increased and leaf area index of wheat. The benefits arise from nitrogen mineralization, better moisture availability, reduced crop-weed competition, and higher photosynthetic rates.

However in sub plot treatments like different weed management practices, hand weeding treatment exhibited the statisticallyhighest plant height (105.29 cm), above ground biomass accumulation(601.47 g m^{-2})and leaf area index (2.58) since the crop was not adversely affected by intense competition with weeds. These findings were also in agreement with those of Meena et al.,2017 and Singh et al., 2021 among differentherbicidal treatmentssignificantly higher plant height (102.62 cm), above ground biomass accumulation(580.48 g m^{-2})and leaf area index (2.42)found in sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} followed by mesosulfuron methyl + iodosulfuron methyl sodium (12+2.4) g a.i. ha^{-1} was also getting significantly highest plant height, above ground biomass accumulationand leaf area index of wheat. Similar result was also reported by Meena et al.,2017, Kumar et al.,2014, Kanaujiya et al.,2021 and Shukla et al.,2023 In weedy plots, natural resources such as water, nutrients, space, sunlight, and carbon dioxide were often exhausted by the invading weeds. As a result, under these stressed conditions, crop plants struggled to grow and developed to their full potential, leading to reduced wheat production.

3.3 Effect on Yield Attributes Yield and Economics of Wheat

On the basis of data analysis yield attributes yield and economics were significantly influenced by different tillage operations and weed management practices except test weight (g), however, tillage methods did not significantly affect the harvest index of wheat. statistically maximum number of spikes m^{-2} (256.45 m^{-2}), number of grains $spike^{-1}$ (49.08), grain yield (3640.86 kg ha^{-l}) and straw yield (5334.84 kg ha^{-l}), were recorded under zero tillage with paddy residue which was at par with zero tillage without residue have been presented in (Table 2) and graphically depicted in (Figs. 1& 2). Among in sub plot treatments, hand weeding treatment exhibited statistically maximum number of spikes m^{-2} (280.31 m^{-2}), number of grains $spike^{-1}$ (50.79), grain yield (4045.17 kg ha^{-l}), straw yield (5549.71 kg ha^{-l}) and harvest index (42.13) and statistically minimumthese yield attributes, yield and economicsfound in weedy check plots. This improvement in yield attributes,yield and economics were found due to effective weed control and enhanced growth and development of wheat under hand weeding conditions. The reduced competition between crops and weeds with hand weeding likely contributed to better yield components and, consequently, higher yields. These findings were also in agreement with those of Sharma and Singh, 2023, Meena et al.,2017 and Duary et al.,2021. Among different herbicidal treatments in sub plots the sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} recorded statistically maximum number of spikes m^{-2} (270.36 m^{-2}), number of grains $spike^{-1}$ (49.59), grain yield (3895.68 kg ha^{-l}), straw yield (5408.76 kg ha^{-l}) and harvest index (41.88) followed by mesosulfuron methyl + iodosulfuron methyl sodium (12+2.4) g a.i. ha^{-1}. All the herbicidal treatments recorded significantly higher grain and straw yield of wheat as compared to weedy, graphically depicted in (Fig. 2). As a result of efficient weed control during the early stages led to significantly higher yields, likely due to enhanced water and nutrient uptake and increased photosynthesis. The rise in both grain and straw yields was primarily due to a higher number of spikes per square meter, more grains per spike, increased test weight, and a better harvest index. Conversely, the weedy plot had the lowest grain yield due to substantial nutrient and moisture depletion by weeds and

Table 1. Effect of tillage and weed management practices on plant height(cm), above ground biomass accumulation (g m^{-2}), leaf area index (LAI)at 90 DAS of wheat

Treatment Details	Plant height (cm)	Biomass accumulation (g m^{-2})	Leaf Area Index (LAI)
Main plots: tillage operations			
Conventional tillage(CT)	97.93	523.46	2.12
Zero tillage (ZT) without rice residue	99.84	549.50	2.30
Zero tillagewithout rice residue (ZT+R)	102.97	570.90	2.56
SEm (±)	**0.95**	**8.79**	**0.06**
C.D.*(P=0.05)*	**3.75**	**34.51**	**0.23**
Sub plots: weed management practices			
Clodinafop propargyl + metsulfuron methyl (60+4) g	100.37	548.47	2.29
sulfosulfuron + metsulfuron methyl (30+2) g	102.62	580.48	2.42
mesosulfuron methyl + iodosulfuron methyl sodium (12+2.4) g	101.12	568.35	2.34
Clodinafop propargyl + metribuzin (54+120) g	97.59	541.93	2.22
hand weeding at 20-25 and 40-45 DAS	105.29	601.47	2.58
weedy check	94.48	447.02	2.09
SEm (±)	**2.20**	**13.05**	**0.06**
C.D.*(P=0.05)*	**6.36**	**37.70**	**0.19**

severe crop-weed competition, which resulted in poor development of source and sink, suboptimal yield components, and a higher weed index.Similar result was also reported by Kumar et al.,2016 and Kumar et al., 2016, Different tillage operations and weed management practices had a significant impact on the net returns and B:C ratio in wheat. Among all weed management practices, Singh et al.,2021, Duary et al.,2021 and Shukla et al.,2023.

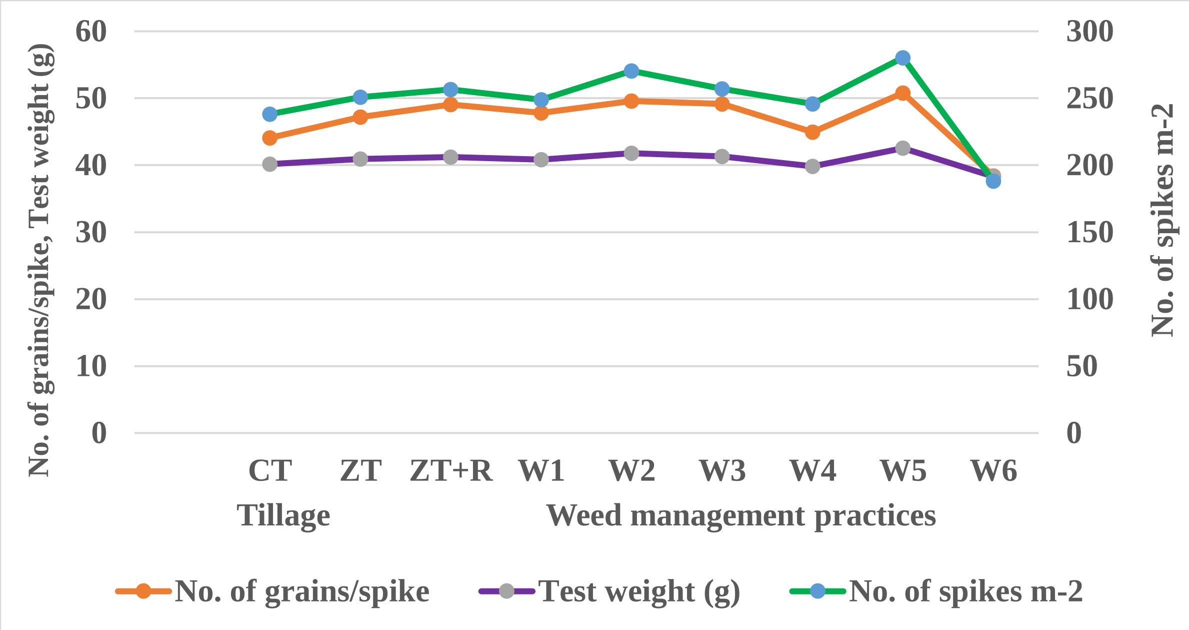

Fig. 1. Effect of tillage and weed management practices on yield attributing characters of wheat crop

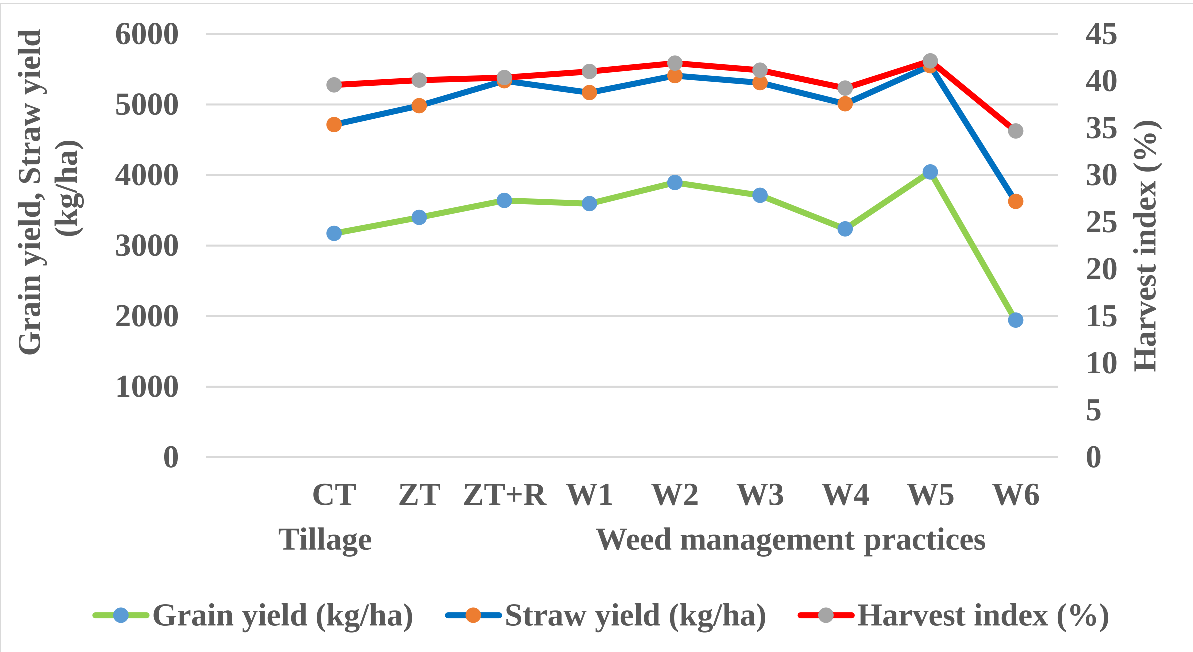

Fig. 2. Effect of tillage and weed management practices on yield parameters characters of wheat crop

Table 2. Effect of tillage and weed management practices on yield attributingcharacters, yield and economics of wheat crop

Treatment	No. of spikes m^{-2}	No. of grains spike^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Net returns (₹ha^{-1})	Benefit-Cost ratio
Main plots: tillage operations								
Conventional tillage(CT)	238.05	44.07	40.18	3170.50	4716.08	39.60	46708	1.05
Zero tillage (ZT) without rice residue	250.76	47.20	40.95	3400.94	4984.30	40.08	58778	1.52
Zero tillage without rice residue (ZT+R)	256.45	49.08	41.20	3640.86	5334.84	40.35	65638	1.69
Sem (±)	**3.55**	**0.84**	**0.58**	**65.05**	**114.22**	**0.32**	**1892**	**0.04**
C.D.*(P=0.05)*	**13.95**	**3.29**	**NS**	**255.41**	**448.48**	**NS**	**7431**	**0.17**
Sub plots: weed management practices								
Clodinafop propargyl + metsulfuron methyl (60+4) g	249.01	47.80	40.84	3593.09	5170.27	41.01	62392	1.58
sulfosulfuron + metsulfuron methyl (30+2) g	270.36	49.59	41.81	3895.68	5408.76	41.88	70756	1.81
mesosulfuron methyl + iodosulfuron methyl sodium (12+2.4) g	256.98	49.16	41.32	3713.00	5307.75	41.14	65844	1.67
Clodinafop propargyl + metribuzin (54+120) g	245.79	44.96	39.83	3236.94	5010.19	39.22	53269	1.33
hand weeding at 20-25 and 40-45 DAS	280.31	50.79	42.54	4045.17	5549.71	42.13	68834	1.53
weedy check	188.08	38.40	38.31	1940.73	3623.77	34.68	21154	0.59
Sem (±)	**6.63**	**1.92**	**0.96**	**57.72**	**97.89**	**0.90**	**1270**	**0.03**
C.D.*(P=0.05)*	**19.15**	**5.55**	**NS**	**166.71**	**282.73**	**2.60**	**3667**	**0.09**

3.4 Effect on Economics of Wheat

Effect of tillage and weed management practices on economics of wheat crop has been presented in (Table 2). In comparison to conventional tillage and zero tillage without residue, zero tillage with paddy residue incurred the statistically highest net returns (₹ 65638 ha^{-1}) with maximum benefit-cost ratio (1.69). This was due to due to more number of tillage operations carried out under conventional tillage. Zero tillage (ZT) primarily offers positive environmental benefits, such as conserving fossil fuels, reducing greenhouse gas emissions, and saving water. The appeal of ZT technology lies in its resource efficiency, its capacity to boost crop production, and its improved soil physical properties. Similar results were also found by Kumar et al.,2016 and Kumar et al.,2018. Different tillage operations and weed management practices had a significant impact on the net returns and benefit-cost ratio in wheat. Among all weed management practices in sub plots, hand weeding treatment incurred the significantly highest net return (₹ 68834 ha^{-1}) and benefit-cost ratio (1.53). Among the different herbicidal treatments, sulfosulfuron+ metsulfuronmethyl (30+2) g a.i. ha^{-1} registered the statistically maximum net return (₹ 70756 ha^{-1}) highest benefit-cost ratio (1.81) which was followed by W_3 (Mesosulfuron methyl + Iodosulfuron methyl sodium (12+2.4) g a.i. ha^{-1}) and W_1clodinafoppropargyl + metsulfuronmethyl (60+4) ga.i. ha^{-1}. Singh et al., 2021 and Duary et al.,2021 also reported similar results.

4. CONCLUSION

The study demonstrated that the zero tillage with paddy residue along with sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} is recommended for maximizing the plant height, leaf area index, biomass accumulation, no. of spikes m^{-2}, no. of grains $spike^{-1}$, grain yield, net returns and benefit cost ratio. Therefore, zero tillage with paddy residue with sulfosulfuron+ metsulfuron methyl (30+2) g a.i. ha^{-1} presents a viable option for enhancing wheat productivity and contributing to more efficient and sustainable agricultural practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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