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Effect of tillage and weed management on wheat yield and economics in an aerobic rice-wheat cropping system

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Abstract

A field experiment was conducted at Palampur during *rabi* 2022-23 in wheat under aerobic rice-wheat cropping system following strip plot design with fifteen treatments i.e. five tillage in main plots and three weed management in sub-plots. Amongst tillage treatments, significantly higher wheat grain equivalent yield and other attributes were recorded with zero tillage with residues of preceding aerobic rice under ZT+R-ZT+R than conventional tillage (CT-CT). Crop profitability with higher gross return of ¹ 132575 ha^{-1} and benefit cost ratio of 1.89 was noted with ZT-ZT+R outperforming CT-CT. Among different weed management practices, post emergence application of clodinafop 60 g ha^{-1} along with metsulfuron-methyl 4 g ha^{-1} recorded higher plant height, yield attributes, wheat grain equivalent yield, gross and net returns over integrated weed management practices. ZTR+H-ZTR+H (Conservation tillage combined with herbicide application) was found to be comparatively better than others for yield attributes and monetary gains in rice-wheat cropping system.

Keywords: Conventional tillage, zero tillage, residues, weeds, plant height, yield and economics

Rice–wheat cropping sequence (RWCS) is the world's largest agricultural production system, covers approximately 12.3 million hectares in India, 0.5 million hectares in Nepal, 2.2 million hectares in Pakistan, and 0.8 million hectares in Bangladesh. Approximately 85% of this area is located in the Indo-Gangetic plains (IGP) (Ladha *et al*. 2003). Traditionally, agricultural techniques have been relied heavily on tillage which involves modification of soil to promote crop growth, eradicate weeds, and regulates the flow of air and water through the soil. However, continuous use of intensive tillage (conventional tillage) has many negative consequences including breakdown of aggregates, soil erosion, soil carbon loss, and increased production costs and environmental pollution due to burning of crop residues (Singh *et al*. 2024). As a result, several countries are shifting towards conservation agriculture, which emphasize the minimum soil disturbance and surface retention of residues, to address the limitation of conventional agriculture (Hobbs 2001). Zero tillage, a key component of this approach, has been shown to mitigate production costs and other land preparation constraints but requires consistent implementation and adequate residue cover to be effective (Sindhu *et al*. 2007). Despite its lower energy requirements, zero tillage still requires adequate inputs particularly fertilizers and weed control measure to support the growth of healthy crops.

In conventional-tilled farming of wheat in rice-wheat cropping system, weeds are effectively controlled through mechanical uprooting and deep burial by tillage operations. However, reduction in tillage intensity and frequency generally increases weed infestation. In addition, presence of crop residues over the soil surface may intercept and bind the herbicides before reaching the soil surface. Weeds pose a major threat to crop productivity, accounting up to 37 per cent losses in agricultural output (Ghosh *et al*. 2021) and approximately 40 per cent reduction in wheat grain yield (Suresha *et al*. 2015). Given the significant losses brought on by weeds, it is imperative that they be managed as effectively by all possible means for enhancing crop yield (Rana *et al*. 2004 a and b). Therefore, the present investigation was conducted

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with an objective of increasing wheat crop yield and net returns in rice-wheat cropping system through the adoption of conservational agriculture practices.

Materials and Methods

The present study was carried out at the Experimental Farm of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *rabi* 2022-23 in a long-term experiment started since 2013 with an objective to study the impact of different tillage and weed management practices on yield and economics of wheat (*Triticum aestivum* L.). The experimental site was at 32 06' N latitude, 76° 542 E longitude and at an altitude of 1290 m above mean sea level. The research site falls under the mid-hills subhumid agro-climatic zone and its climate is characterized as wet temperate. The soil of the research site belongs to the order *Alfisol* and has been classified as Typic Hapludalf with silty loam texture. During the experimental period in *rabi* 2022-23 the mean weekly maximum and minimum temperature ranged between 14.2 to 29.3°C and 4.9 to 18.3°C, respectively. Furthermore, the crop received a total rainfall of 483.1mm during the entire growth season. At the initiation of experiment (2013), the soil samples were found to be acidic with pH value of 5.6, medium in organic carbon (8.4 g kg^{-1}), available N (233 kg ha^{-1}), available P (17.5 kg ha^{-1}) and available K (193.2 kg ha^{-1}).

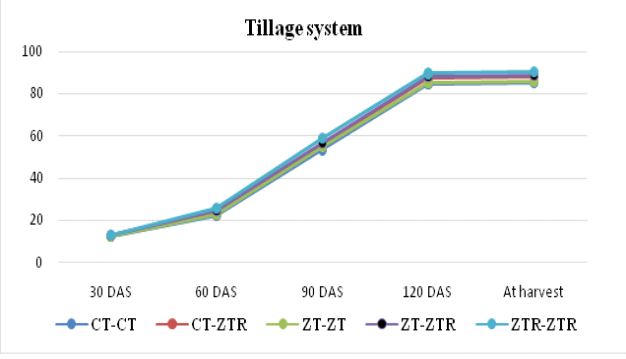
The experiment was laid out in a strip plot design with three replications. There were total of fifteen treatment combinations with five tillage treatments in the main plots *viz.* i) conventional tillage in both aerobic rice and wheat (CT-CT tillage system), ii) conventional tillage in aerobic rice followed by zero tillage with preceding crop residues in wheat (CT-ZT+R tillage system), iii) zero tillage in both aerobic rice and wheat (ZT-ZT tillage system), iv) zero tillage in aerobic rice and zero tillage with preceding crop residues in wheat (ZT-ZT+R tillage system), v) zero tillage with one- third of preceding crop residues in both rice and wheat (ZT+R-ZT+R tillage system), and three weed management treatments in sub plots, *viz*. i) Herbicides in both rice and wheat (H-H), ii) integrated weed management in both rice and wheat (IWM-IWM), iii) two hand weedings at 20-25 and 40-45 DAS in rice and one hand weeding at 30 DAS in wheat (HW-HW). In aerobic rice, pre-emergence application of pretilachlor at 0.9 kg ha^{-1} followed by post emergence application of bispyribac-sodium at 25 g ha^{-1} was applied while in wheat, post emergence application of clodinafop at 60 g ha^{-1} combined with metsulfuron-methyl at 4 g ha^{-1} was applied. In integrated weed management (IWM) practices, rice plots received a combination of hand weeding and herbicide application, while in wheat, intercropping with mustard (sarson) was practiced using a replacement series (2:1) approach alongside chemical and manual weed control methods. Conventional tillage (CT) was performed using ploughing once, followed by two harrowing and levelling. Zero till wheat was sown after the application of paraquat to take care of the existing flush of weeds. Wheat crop variety 'HPW 368' was sown during the first fortnight of November at a spacing of 22.5 cm using a seed rate of 120 kg ha^{-1}. Recommended dose of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} was supplied through urea, single super phosphate and muriate of potash, respectively.

The data on plant height of wheat was recorded at different growth stages of wheat plant. Various yield attributes *viz*. number of effective tillers per unit area, number of grains per panicle and 1000 grain weight were recorded as mean of 5 observations within each sub-plot. Wheat grain equivalent yield (WGEY) was computed by converting yield of intercrop based on prevailing market price at the end of season (MSP for wheat: ≠ 2275 per quintal and mustard: ≠ 5650 per quintal). Economic analysis was done as per the prevailing cost of inputs and selling price of output.

Statistical analysis was done as per the standard procedure described by Gomez and Gomez (1984). The technique of analysis of variance (ANOVA) for strip plot design was used for the interpretation of results. The critical difference (CD) was calculated for parameters whose effects were significant at the 5% confidence level.

Results and Discussions

Tillage treatments where wheat was raised with zero tillage with residues of preceding (rice) crop recorded significantly greater plant height at 60, 90. 120 DAS over conventional and zero tillage without residue treatments (Fig 1). This might be due to the residual impacts of the preceding crop, which enhanced the physical, chemical, and biological



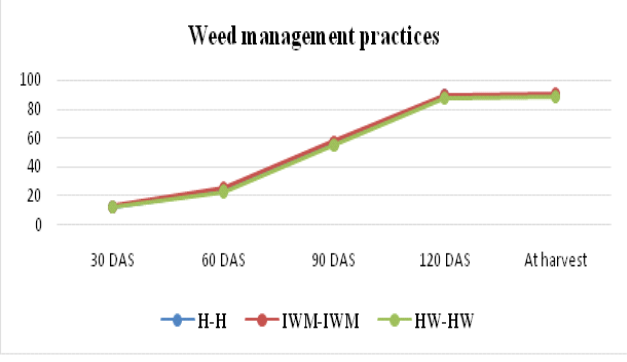


Fig 1. Effect of tillage and weed management practices on progressive plant height of wheat crop

properties of the soil by facilitating moisture retention, maintaining optimal soil temperature and less nutrient losses (Kumari *et al*. 2024). These improved soil conditions support plant growth, ultimately contributing to increased plant height. Weed control methods did not significantly affect the plant height of wheat at all stages of observations (Fig 1). Interaction effect of different tillage and weed management practices were also found non-significant for variation in wheat height.

Different tillage and weed management practices significantly affected the key yield attributes except 1000 grain weight of wheat (Table 1). Wheat sown in zero tillage in presence of rice residues (ZT+R-ZT+R) recorded the significantly higher number of effective tillers (284.8 m^{-2}) and number of grains per panicle (50.6) which was statistically at par with treatment, ZT- ZT+R. Significantly lower no. of effective tillers (252.1) and number of grains per panicle (45.9) of wheat was noted under treatment T_1 (CT-CT) where wheat was cultivated with conventional tillage which was statistically at par with T_3 (ZT-ZT). Higher availability of moisture and plant nutrients due to a smaller weed population may have contributed to the higher values of all yield attributes with zero tillage + residues. This enhanced photosynthetic activity, leading to greater production and translocation of photosynthates to the plant's reproductive parts, resulted in higher yield attributes of crop. In contrast, conventional tillage exposed weed seeds to the surface

Table 1: Effect of tillage and weed management practices on yield attributes and wheat grain equivalent yield

Treatments (Rice-Wheat)	No. of effective tillers/m^2	No. of grains/ panicle	1000 grain wt. (g)	Wheat grain equivalent yield (q ha^{-1})
Tillage				
CT-CT	252.1	45.9	42.82	34.8
CT-ZTR	264.6	47.2	43.64	39.0
ZT-ZT	258.7	46.9	43.25	37.5
ZT-ZTR	270.5	48.6	44.28	40.2
ZTR-ZTR	284.8	50.6	45.05	41.3
LSD (P=0.05)	14.4	2.6	NS	24.3
Weed management				
H – H	290.4	50.8	45.19	41.3
IWM -IWM	201.3	49.3	44.21	35.3
HW – HW	282.6	50.2	44.83	40.2
LSD (p=0.05)	10.6	1.3	NS	18.8
Interaction	**NS**	**NS**	**Ns**	**S**
Tillage at same weed level	-	-	-	**390**
Weed at same tillage level	-	-	-	**352**

CT: conventional tillage; ZT: zero tillage; R: residues; H: herbicide; IWM-IWM: integrated weed management; HW: hand weeding

leading to a higher weed population resulted in increased crop-weed competition, which in turn reduced photosynthetic activity significantly lowered yield attributes (Kumar and Rana 2021).

Turning to impact of different weed control practices on yield attributes revealed that the chemical control method significantly increased the yield attributes *viz*. no. of effective tillers and no. of grains per panicle by 44.26 and 3.04 per cent over integrated weed management method (intercropping with mustard in 2:1 + chemical control+ manual weeding). The replacement series of mustard in wheat could have reduced the number of rows of wheat in integrated method, which subsequently lowers the yield attributing traits (Biswas *et al*. 2020). Interaction of tillage and weed control method was found to be non-significant on wheat yield attributes.

Different tillage and weed management practices significantly affected the wheat grain equivalent yield (Table 2). The minimum wheat grain equivalent yield (34.8 q ha^{-1}) was recorded under CT-CT tillage system, when conventional tillage was done in wheat followed by ZT- ZT tillage system (37.5 q ha^{-1}) which were statistically at par with CT-ZT+R tillage system (39.0 q ha^{-1}). However, maximum wheat grain equivalent yield (41.3 q ha^{-1}) was recorded when zero tillage was done in presence of residues of preceding aerobic rice in wheat under ZT+R-ZT+R tillage system and proved significantly superior over other tillage system. The increase in grain yield under treatment ZT+R-ZT+R over CT-CT was 15.56 per cent, respectively. The higher yield under conservation tillage over conventional tillage was mainly due to lower weed dry weight and higher values of yield attributes including no. of effective tillers, no. of grains per panicle and 1000 grain weight, as these improved yield factors played a significant role in boosting the grain yield of crop. The retention of residues further enhances soil hydrothermal conditions by regulating soil temperature and moisture which promote better root growth, allowing plants to explore a greater soil volume for water and nutrients. Additionally, residue decomposition increases organic matter to the soil, improving soil structure, porosity, and nutrient availability. This favourable condition led to better crop development and higher yields compared to conventional tillage (Ankit *et al*. 2023).

In case of weed control methods, application of clodinafop 60 g ha^{-1} along with metsulfuron- methyl 4 g ha^{-1} in wheat significantly increased the wheat grain equivalent yield by 17.07 per cent in comparison to integrated weed management treatment (IWM-IWM) which involves the intercropping of wheat with mustard along with the manual and chemical control methods of weeds. In IWM treatment, intercropping of wheat with mustard in a 2:1 replacement series reduced the number of wheat rows, which in turn decreased the total number of effective tillers per unit area and ultimately lowered the wheat grain yield. Additionally, crop competition due to mustard led to reduced 1000 grain weight and number of grains per panicle as compared to sole wheat in other weed management practices. Lower mustard yield further contributed to the decline in overall productivity (Biswas *et al*. 2020).

The interaction of different tillage and weed management practices showed significant variation on

Table 2. Impact of tillage and weed management practices on economics of wheat

Treatment (Rice – Wheat)	Cost of cultivation(≠ ha^{-1})	Gross return(≠ ha^{-1})	Net return(≠ ha^{-1})	B:C
Tillage				
CT – CT	46185	115518	69333	1.50
CT – ZTR	45915	129386	83470	1.82
ZT – ZT	43815	123459	79643	1.82
ZT – ZTR	45915	132575	86660	1.89
ZTR – ZTR	45915	126734	80819	1.76
Weed management				
H – H	40691	129847	89156	2.19
IWM – IWM	50191	101751	51560	1.03
HW – HW	45766	126811	81045	1.77

CT: conventional tillage; ZT: zero tillage; R: residues; H: herbicide; IWM-IWM: integrated weed management; HW: hand weeding

wheat grain equivalent yield (WGEY). WGEY was minimum under treatment where integrated weed management practices were followed after conventional tillage in wheat under the CT-CT tillage system. However, higher WGEY was observed with the application of clodinafop 60 g ha^{-1} along with metsulfuron- methyl 4 g ha^{-1} after zero tillage in the presence of preceding crop residues of rice in wheat under ZT+R- ZT+R tillage system and proved significantly superior over the rest of treatments. Shekhar *et al*. (2014) also reported higher grain yield of wheat under zero tillage system after the use of post-emergence herbicides.

When wheat was grown with zero tillage system (ZT-ZT), low costs of production was observed (Rs. 43815 ha^{-1}) which were mainly due to absence of preparatory tillage unlike conventional tillage (CT-CT), which requires 2-3 preparatory tillage operations before seeding (Jat *et al*. 2019). Application of crop residue needs an extra labour which increased the cost of cultivation (Rs. 45915 ha^{-1}) in zero tillage along with the crop residue treatments *viz*. CT-ZT+R, ZT-ZT +R and ZT+ R (Table 2). Net returns of any crop and cropping system are directly related to variable cost and economic yields of crops (Jat *et al*. 2019).

Net returns were highest in ZT-ZT+R (Rs. 86660 ha^{-1}) which was followed by CT-ZT+R (Rs. 83470 ha^{-1}) while lowest was recorded in CT-CT (Rs.69333 ha^{-1}). Jat *et al*. (2019) also reported that conservation agriculture-based management system had higher net return than conventional tillage production system. Similarly, maximum benefit: cost was observed in ZT-ZT+R (1.89) as compared to other tillage systems.

Among weed management practices, intercropping of wheat with mustard and post-emergence application of clodinafop @ 60 g ha^{-1} along with one hand weeding at 45-50 (IWM-IWM) recorded higher cost of cultivation (Rs. 50191 ha^{-1}). As integrated weed management involves hand weeding practices in addition to herbicide application, raising labour costs. Higher gross return (Rs. 128947 ha^{-1}), net return (Rs. 89156 ha^{-1}) and B:C ratio (2.19) was recorded with chemical control treatment (H-H), followed by manual weed control (HW-HW) and integrated weed management (IWM-IWM).

Conclusion

The study concluded that zero tillage with surface retention of rice residues improved yield attributes, wheat grain equivalent yield, net returns and benefit cost ratio. Contrary, conventional tillage led to reduced the grain equivalent yield by 15.80 per cent, and net returns by 14.21 per cent over zero tillage in presence of residue treatment. Efficient weed control practices, particularly with the post emergence application of clodinafop 60 g ha^{-1} along with metsulfuron- methyl 4 g ha^{-1} further boosted yield by increasing plant height and yield attributes which ultimately increased the net returns and benefit cost ratio. The combined approach of conservation tillage and efficient chemical weed control is recommended to optimize productivity and economic gains in the rice-wheat system. Therefore, findings of present study suggest to adopt zero tillage practices in presence of residues along with the herbicide application, ZTR+H-ZTR+H to optimize productivity and economic gains in an aerobic rice-wheat system.

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