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Influence of Rice Residue Management under Different Tillage and Weed Management Options on Productivity, Protein Yield and Economics of Wheat (Triticum Aestivum L.)

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ABSTRACT:

A two-year field study was carried out during *Rabi* (winter) seasons of 2021-22 and 2022-23 to find out the influence of rice residue management under different tillage and weed management options on productivity, protein yield and economics of wheat (*Triticum aestivum* L.) at the Agronomy Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.). The experiment was conducted with four residue management under different tillage and five weed management options in split plot design and replicated thrice. The results showed that rice residue retention with zero tillage treatments recorded highest productivity, protein yield and economics of wheat as compared to no residue treatment. While in case of different weed management options, hand weeding at 20 and 40 DAS had a significant impact in maximizing productivity, protein yield and economics of wheat closely followed by post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% WP PoE(60 gm + 4 gm a.i. ha^{-1}). The highest net return and benefit: cost ratio was found in treatment combination, zero tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}).

Keywords: Tillage, Crop residue, Weed management, Wheat, Protein yield

1. Introduction

Wheat *(Triticum aestivum* L.) is one of the most important cereal crops for the majority of world's population. It contributed about 760 million tonnes to the global food grain basket in the year 2020–2021, from an area of about 219.70 million hectares. World-wide India is firmly occupying the second position among the wheat producing countries after China, while in India, this crop occupies about 30.79 million hectares area and accounts for production of about 107.59 million tonnes with productivity of 3494 kg ha^{-1} (Anonymous, 2021). There are various alternatives available for the management of crop residues. These options encompass the removal of residues from the field, leaving them on the soil surface, integrating them into the soil, or utilizing them as mulch for subsequent crops. In tropical regions, the recycling of crop residues within the field is limited, as they are often harvested for fuel, feed, or bedding, or simply burned on-site. This prevalent practice of burning crop residues in the field is primarily attributed to farmers' lack of awareness regarding their value and the absence of suitable technology for incorporating the residues into the soil. Zero tillage with previous crop residue retention results in water saving and excellent suppression of all weed species. It also saves the soil from formation of large crack and also avoids sub-soil compaction (Jat *et al*., 2008). The adoption of resource conservation technologies, such as zero tilled wheat sowing, is considered essential to maintain the productivity of rice-wheat cropping system (Singh *et al.*, 2010).This resource-conserving technique has gained widespread adoption in the Indo-Gangetic Plains (IGP) of South Asia, particularly in India. ZT wheat, which refers to zero-till wheat cultivation after rice, is particularly suitable for the rice-wheat cropping systems in the IGP. By alleviating system constraints, such as allowing for earlier wheat sowing, ZT wheat has proven to be beneficial. It aids in controlling the growth of the weed *Phalaris minor*, reducing production costs, conserving water and increasing the population of beneficial microorganisms and soil organic matter. These advantages have been highlighted in studies conducted by Verma and Singh (2008) and Simon *et al*. (2009). The appeal of these benefits has led to widespread interest among farmers and rapid adoption of this practice across the Indo-Gangetic Plain, facilitated by the broad applicability of this mechanical innovation.

The presence of crop residue in the soil has been shown to have a significant impact on the emergence of weeds, as highlighted by Verma *et al.* (2016). Not only does residue retention affect weed emergence, but it also plays a role in the growth and population of weeds. Moreover, the management of crop residue and tillage practices can also influence the effectiveness of soil-applied pre-emergence herbicides. This is because the presence of pre-emergence herbicides and ash content from residue burning can potentially impact the activity of these herbicides. Although several interacting factors may determine the extent of this influence including residue nature, height, type and quantity, prevailing weed flora, soil type and weather conditions (Khankhane *et al*., 2009). Application of rice residue at rates of 6 to 7 t ha^{-1} on the surface has been shown to have a significant impact on reducing weed growth and development when compared to other methods such as incorporation and no-residue treatments, as demonstrated by Brar and Walia in 2010. Furthermore, research conducted by Chhokar *et al*. in 2009 indicated that the retention of rice residue at levels of 5.0 and 7.5 t ha^{-1} resulted in a substantial decrease in weed dry weight in both rice and wheat crops, with reductions ranging from 23.4% to 44.1%. In a similar vein, Brar and Walia (2010) found that the surface application of rice residues at rates of 6 and 7 t ha^{-1} not only led to a significant decrease in the growth and development of *Phalaris minor* but also resulted in higher weed control efficiency compared to incorporation and no rice residue treatments. Weeds are a significant threat to the productivity of wheat among various production factors. They compete with crops for essential resources such as water, nutrients, and other growth factors, as highlighted by Khokhar and Nepalia (2010) and Najwa *et al.* (2012). In the absence of effective control measures, weeds can deplete a considerable amount of applied nutrients and water, leading to higher yield losses. This becomes even more severe when there is a scarcity of these resources, as mentioned by Singh *et al.* (2009) and Sharma and Singh (2011). Depending on the density and type of weed flora present, uncontrolled weeds throughout the crop period can result in a reduction of more than 50% in grain yield, as stated by Azad (2003). Several studies have demonstrated the effectiveness of various new herbicide molecules in controlling weeds. For instance, Baghestani *et al.* (2008) and Barros *et al.* (2009) found that herbicides such as clodinafop propargyl, fenoxaprop-p-ethyl, iodosulfuron-methyl-sodium and mesosulfuron-methyl were highly effective in weed control. Additionally, Kumar *et al.* (2011), Singh *et al.* (2012), Malik *et al.* (2013) and Chitband *et al.* (2013) reported that tank mixtures containing clodinafop + metsulfuron, mesosulfuron-methyl + iodosulfuron-methyl-sodium, with or without surfactant provided excellent control of various weed species. With the aforementioned information in mind, the current study was carried out to study the influence of rice residue management under different tillage and weed management options on productivity, protein yield and economics of wheat (*Triticum aestivum* L.).

2. Materials and Methods

The present experiment was carried out during *Rabi* seasons of 2021-22 and 2022-23 in the Agronomy Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) situated at 26°47' N latitude and 82°12' E longitudes with an altitude of 113 meters above the Mean Sea Level. The soil of the experimental field was silty loam in texture, moderately alkaline in reaction, low in organic carbon and available nitrogen but medium in available phosphorus and potassium. The treatments comprised of 4 rice residue management practices, namely conventional tillage without residue, conventional tillage with rice residue @ 3.0 tones ha^{-1}, zero tillage without residue, zero tillage with rice residue @ 3.0 tones ha^{-1} and 5 weed management options, viz. Triallate 50% EC PE@ 1250 gm a.i. ha^{-1}, Triallate 50% EC PE@ 2500 gm a.i. ha^{-1}, Clodinafop propargyl 15% + Metsulfuron methyl 1% WP PoE(60 gm + 4 gm a.i. ha^{-1}), hand weeding at 20 and 40 DAS and weedy check were established in split-plot design replicated thrice. The rice residue management practices were kept in main plots and weed management options in subplots. Treatment combinations were allocated to experimental units randomly employing Fisher and Yates random table method (Panse and Sukhatme, 1985). No preparatory tillage was carried out for zero-tillage with and without residue retained treatment, zero till-cum-ferti-seed drill was used for sowing of seeds. Whereas, in case of conventional tillage with and without residue treatment, preparation of land was done by tractor driven rotavator. Seed-cum-fertilizer drill was used for sowing of seeds. In conventional tillage with residue, the loose rice residues were spread over between the rows in the field after 10 days of sowing.

The wheat variety HD-2967 was sown at the seed rate of 100 kg ha^{-1} in rows 20 cm apart on 21/11/2021 and 22/11/2022, respectively. The crop was fertilized with N: P_2O_5: K_2O @ 120:60:40 kg ha^{-1} in the form of urea (46% N), diammonium phosphate (18 % N and 46% P_2O_5) and muriate of potash (60% K_2O), respectively. Half amount of nitrogen and full dose of phosphorus and potash were applied as basal at the time of sowing and remaining amount of nitrogen was top dressed after first irrigation. Pre-emergence application of herbicide Triallate 50% EC was done as per treatment just after sowing whereas Clodinafop propargyl 15% + Metsulfuron methyl 1% WP was sprayed 30 days after sowing. The crop was irrigated at crown root initiation (C.R.I.) stage (21 DAS), booting stage (70 DAS), flowering stage (90 DAS) and dough stage (110 DAS). The crop was harvested on 10.04.2022 and 11.04.2023 respectively during two years of investigation and was sun dried thoroughly for 3 days in the field. After weighing the total biomass of each net plot, the produce was threshed and the weight of grains was recorded and finally converted into t ha^{-1}. The grain samples of wheat were analyzed for their nitrogen content by modified micro-Kjeldahl's method. Nitrogen content of grains was multiplied by conversion factor (6.25) to get total protein content. The protein yield was calculated by using the formula given below:

Protein yield (kg ha^{-1}) = Protein content (%) x Grain yield (kg ha^{-1})/100

The economic study was carried out by computing the cost of cultivation, gross return, net return and benefit: cost ratio. Cost of cultivation for different treatments were worked out by considering all the expenses incurred in the cultivation of experimental crop and added with variable cost due to treatments. Gross return was worked out by using following formula:

Gross Return (Rs.ha^{-1}) = Grain yield (kg ha^{-1}) × Price (Rs.) + Straw yield (kg ha^{-1}) × Price (Rs.)

The net return was calculated by deducting the cost of cultivation from the gross return of the individual treatments.

Net Return (Rs. ha^{-1}) = Gross Return – Cost of Cultivation

Benefit cost ratio was worked out by dividing the net return by the cost of cultivation of the individual treatment.

$$B:C = \frac{\text{Net return (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

The data recorded were subjected to statistical analysis using analysis of variance (ANOVA) technique for SPD as prescribed by (Gomez and Gomez, 1984). Standard error of mean in each case was calculated at 5% levels of probability.

3. Results and Discussion

Yield (t ha^{-1})

The data related to grain yield (t ha^{-1}) and straw yield (t ha^{-1}) as influenced by rice residue management under different tillage and weed management options are summarized in Table 1 and depicted in Fig. 1.1. It is clear from the data that rice residue management under different tillage and weed management options caused significant variation in grain and straw yield of wheat. The maximum grain yield was recorded under the influence of zero tillage with rice residue (4.55 and 4.79 t ha^{-1}) which remained statistically at par with conventional tillage with rice residue (4.47 and 4.70 t ha^{-1}), but significantly superior to rest residue management treatments during both the years. The variation in grain yield of conventional tillage without residue and conventional tillage with rice residue was also significant. Similarly the significant difference in grain yield of zero tillage without residue and zero tillage with rice residue was also observed. The similar trend in the yield of straw was also noticed in the influence of rice residue management under different tillage and weed management options. The higher yield in zero tillage with rice residue might be due to proper seed placement at the right depth in narrow slit made by zero till-cum-ferti - seed drill as well as emergence of wheat seedlings under favorable moisture content, which responded in term of good crop yield (Gupta *et al*., 2011). This might also be due to the better growth and yield attributes under this treatment which resulted into higher yield. The result is in close conformity with that of Yadav *et al.* (2005), Mitra *et al*. (2014) and Kumar *et al*. (2016). The wheat yield enhanced by 9.8–11.3% under zero tillage wheat with happy seeder with full residue load over residue burning and residue removal plots (Korav *et al*., 2024). The results in this study indicated that a zero tillage system can be as equally effective as a conventional tillage system for wheat production in rice-wheat rotation. Similarly, the results showed positive impacts of rice residue retention on wheat grain yield (Pandey and Kandel, 2019).

Among different weed management options, hand weeding at 20 and 40 DAS recorded maximum grain yield (4.71 and 4.93 t ha^{-1}) being on par with the grain yield (4.64 and 4.85 t ha^{-1}) obtained under the effect of post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}) but significantly higher than rest of the weed management options adopted. Grain yield realized under the effect of pre emergence application of Triallate 50% EC @ 2500 gm a.i. ha^{-1} and Triallate 50% EC @ 1250 gm a.i. ha^{-1} was also significantly higher than weedy check during both the years of investigation. The weedy check recorded the lowest grain yield because of the largest nutrient and moisture removal by weeds and intense crop weed competition, which led to poor source and sink development, poor yield components and thus low yield. The similar trend in straw yield was also noticed due to different treatments. Among the weed management options, two hand weeding exhibited the highest yield attributes and yield, these higher yield attributes and yields of wheat was owing to effective control of weeds and higher growth and development of wheat in less weedy situation under this treatment. This might be probably due to the creation of

Table 1: Effect of rice residue management under different tillage and weed management options on grain and straw yield of wheat (*Triticum aestivum* L.)

Treatments		**Yield (t ha^{-1})**			
		Grain		**Straw**	
		2021-22	**2022-23**	**2021-22**	**2022-23**
A. Rice Residue Management					
Conventional tillage without residue	**C_1**	3.91	4.08	5.45	5.50
Conventional tillage with rice residue @ 3.0 t ha^{-1}	**C_2**	4.47	4.70	5.94	6.18
Zero tillage without residue	**C_3**	4.05	4.22	5.51	5.79
Zero tillage with rice residue @ 3.0 t ha^{-1}	**C_4**	4.55	4.79	5.98	6.33
SEm ±		*0.07*	*0.04*	*0.10*	*0.13*
CD (P= 0.05)		*0.25*	*0.15*	*0.36*	*0.45*
B. Weed Management Options					
Triallate 50 % EC PE (1250 gm a.i. ha^{-1})	**W_1**	4.08	4.25	5.50	5.76
Triallate 50 % EC PE (2500 gm a.i. ha^{-1})	**W_2**	4.15	4.42	5.68	5.88
Clodinafop Propargyl 15% + Metsulfuron Methyl 1% WP PoE (60 gm + 4 gm a.i. ha^{-1})	**W_3**	4.64	4.85	6.29	6.57
Hand weeding at 20 and 40 days after sowing	**W_4**	4.71	4.93	6.31	6.61
Weedy Check	**W_5**	3.65	3.80	4.83	4.93
SEm ±		*0.14*	*0.14*	*0.20*	*0.23*
CD (P= 0.05)		*0.41*	*0.40*	*0.57*	*0.67*

modified micro-climate due to mechanical manipulation of soil and lower crop weed competition which had led to better yield components and thus resulted in higher yields. The yield obtained under the effect of post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}) was on par with two hand weeding because of better weed control in this treatment. These findings are in close agreement with those of Tomar *et al.* (2017), Singh *et al.* (2019), Kundu *et al.* (2020), Yadav *et al.* (2022) and Para *et al.* (2022).

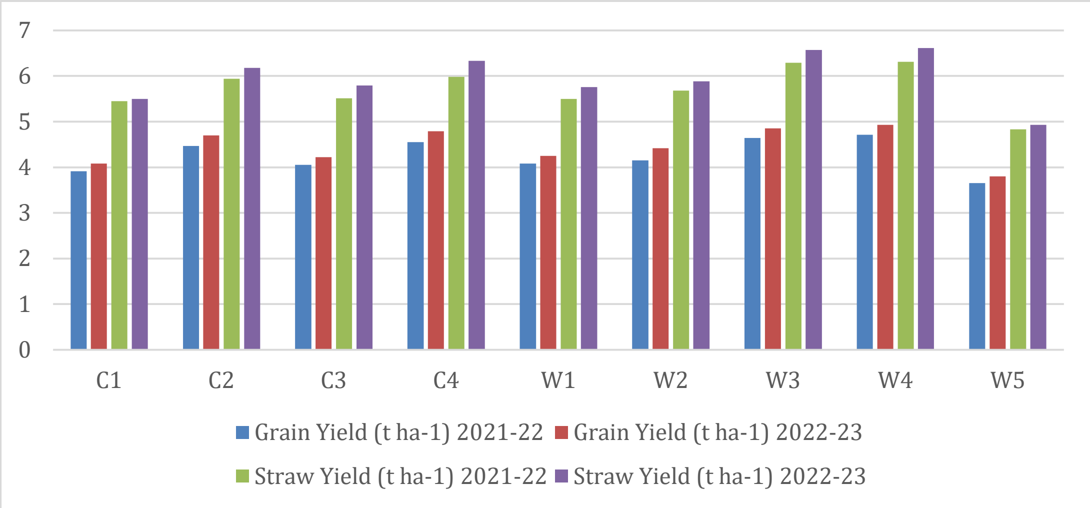

Fig. 1.1: Grain and straw yield of wheat (*Triticum aestivum* L.) as influenced by rice residue management under different tillage and weed management options

Protein content (%) and Protein yield (kg ha^{-1})

Data on protein content and protein yield as influenced by rice residue management under different tillage and weed management options during both the year of experimentation are presented in Table 2 and depicted in Fig. 2.1. It is evident from the data that variation in protein content in grain of wheat was found non-significant due to various rice residue management under different tillage options during both the year. Though the variation among treatments were found non-significant but numerically the maximum content of protein was observed in zero tillage with rice residue closely followed by conventional tillage with rice residue and the lowest in conventional tillage without residue. The data related to protein yield showed significant variation due to different rice residue management under different tillage options during both years. Zero tillage with rice residue recorded highest protein yield being on par with conventional tillage with rice residue but significantly higher to conventional tillage without residue and zero tillage without residue. The minimum protein yield was recorded in the treatment where conventional tillage was practiced without residue.

Data indicated significant variation in protein content in grain of wheat due to different weed management options. Significantly highest protein content in grain was recorded under the effect of treatments where hand weeding at 20 and 40 DAS was executed followed by post emergence application of Clodinafop propargyl 15%+ Metsulfuron methyl 1% (60 gm+ 4 gm a.i. ha$^{-1)}$ during both years. The lowest protein content in grain was associated with weedy check treatment. More or less similar trend was obtained in protein yield also.

Table 2: Effect of rice residue management under different tillage and weed management options on Protein content and Protein yield of wheat (*Triticum aestivum* L.)

Treatment		**Protein Content (%)**		**Protein Yield (kg h^{-1})**	
		2021-22	**2022-23**	**2021-22**	**2022-23**
A. Rice Residue Management					
Conventional tillage without residue	**C_1**	9.62	9.68	377.96	397.37
Conventional tillage with rice residue @ 3.0 t ha^{-1}	**C_2**	9.87	9.93	442.35	468.54
Zero tillage without residue	**C_3**	9.67	9.79	394.39	416.21
Zero tillage with rice residue @ 3.0 t ha^{-1}	**C_4**	9.89	10.01	449.84	479.93
SEm±		*0.09*	*0.10*	*4.41*	*4.58*
C.D.(P=0.05)		*NS*	*NS*	*15.55*	*16.14*
B. Weed Management options					
Triallate 50 % EC PE (1250 gm)	**W_1**	9.56	9.65	389.53	411.19
Triallate 50 % EC PE (2500 gm)	**W_2**	9.70	9.79	402.90	433.77
Clodinafop Propargyl 15% + Metsulfuron Methyl 1% WP PoE (60 gm + 4 gm a.i./ha)	**W_3**	10.10	10.17	468.55	492.41
Hand weeding at 20 and 40 days after sowing	**W_4**	10.24	10.36	481.93	510.28
Weedy Check	**W_5**	9.21	9.30	337.78	354.91
Sem±		*0.09*	*0.10*	*13.31*	*15.67*
C.D.(P=0.05)		*0.27*	*0.30*	*38.51*	*45.35*

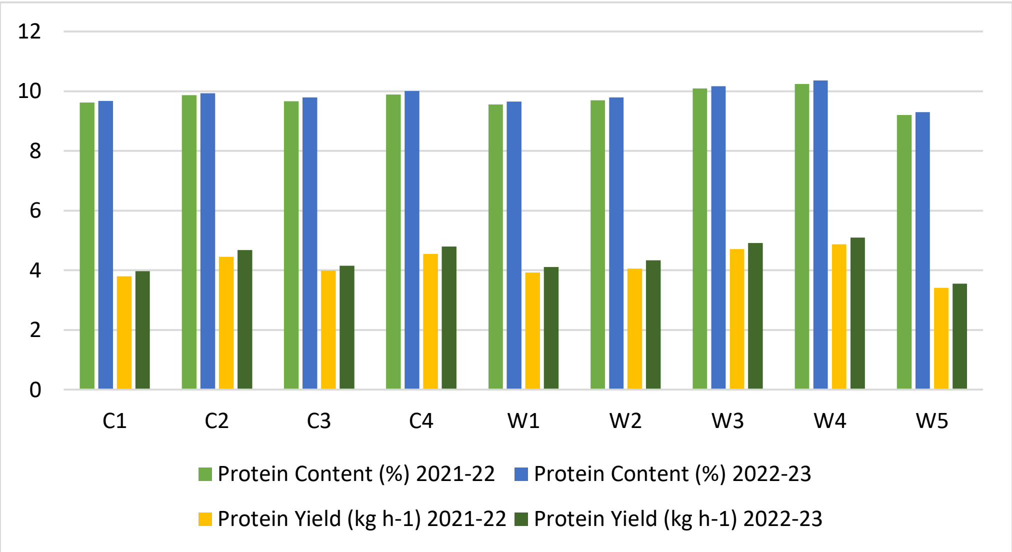

Fig. 2.1: Protein content and protein yield of wheat (*Triticum aestivum* L.) as influenced by rice residue management under different tillage and weed management options

Economics

The pooled data pertaining to economics of different treatments as influenced by rice residue management under different tillage and weed management options are presented in Table 3.

Total cost

The data revealed that the cost of cultivation varied with variation in rice residue management under different tillage and weed management options. The highest total cost of cultivation for wheat occurred under the treatment combination of C_2W_4 (conventional tillage with rice residue + hand weeding at 20 and 40 DAS) during the course of study. The lowest total cost of cultivation was recorded in C_1W_5 (conventional tillage without residue + weedy check).

Gross returns

The data on gross return, calculated under different treatment combination varied with variation in rice residue management under different tillage and weed management options. The highest gross return was recorded with treatment combination of C_4W_3 (Zero tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}) whereas lowest was found in C_1W_5 (conventional tillage without residue + weedy check).

Net returns

Data revealed that highest net return was recorded in treatment combination of C_4W_3 (Zero tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}) followed by C_2W_3 (conventional tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}). Lowest net return was found in treatment combination C_1W_5 (conventional tillage without residue + weedy check).

Benefit: cost ratio

The highest benefit: cost ratio was observed in treatment combination C_4W_3 (Zero tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}) followed by C_2W_3 (conventional tillage with rice residue + post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm + 4 gm a.i. ha^{-1}).

Table 3: Economics of wheat as influenced rice residue management under different tillage and weed management options

Treatment Combinations	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit:Cost ratio (Rs Re^{-1} invested)
C_1W_1	75293	150304	75011	1.00
C_1W_2	80293	152586	72293	0.90
C_1W_3	75233	176752	101519	1.35
C_1W_4	86291	184043	97752	1.13
C_1W_5	69451	134265	64814	0.93
C_2W_1	76556	176559	100003	1.31
C_2W_2	81556	181384	99828	1.22
C_2W_3	76496	198432	121936	1.59
C_2W_4	87554	197951	110397	1.26
C_2W_5	70714	160341	89627	1.27
C_3W_1	75335	157357	82022	1.09
C_3W_2	80335	164032	83697	1.04
C_3W_3	75245	179939	104694	1.39

$C_3 W_4$	86333	187552	101219	1.17
$C_3 W_5$	69493	136116	66623	0.96
$C_4 W_1$	75335	179944	104609	1.39
$C_4 W_2$	80335	186273	105938	1.32
$C_4 W_3$	75245	201752	126507	1.68
$C_4 W_4$	86333	199405	113072	1.31
$C_4 W_5$	69493	164164	94671	1.36

4. Conclusions

Based on the two years research it might be concluded that zero tillage with rice residue @ 3.0 tones ha^{-1} proved to be more effective in improving the productivity, protein yield and economics of wheat followed by conventional tillage with rice residue @ 3.0 tones ha^{-1}. Among the weed management options, hand weeding at 20 and 40 DAS showed maximum improvement in productivity and protein yield of wheat being on par with post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm+ 4 gm a.i. ha^{-1}) at 30 DAS. But when it came to economics, then post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm+ 4 gm a.i. ha^{-1}) at 30 DAS was found more beneficial. Therefore, zero tillage with rice residue @ 3.0 tones ha^{-1} coupled with post emergence application of Clodinafop propargyl 15% + Metsulfuron methyl 1% (60 gm+ 4 gm a.i. ha^{-1}) at 30 DAS may be recommended for the wheat crop to achieve better productivity, protein yield and profit.

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