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Economic feasibility of different options of rice stubble and weed management on performance of late sown wheat (*Triticum aestivum* L.) in western UP

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Abstract
A field experiment at Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUA&T) Meerut Uttar Pradesh (India), Meerut, during the winter (Rabi) seasons of 2020-21 and 2021-22, evaluated economic feasibility of different options of rice stubble and weed management on performance of late sown wheat (*Triticum aestivum* L.) in Western UP. The highest wheat grain and straw yields were achieved with PUSA decomposer-treated residue and brown manuring, followed by Clodinafop Propargyl @ 60 g active ingredient (a.i.) ha^{-1} post emergence (PoE). This treatment also maximized gross and net returns, though the highest benefit-cost ratio occurred with residue burning, which is harmful to the soil, environment, and health. Among weed management practices, Brown manuring followed by Clodinafop Propargyl @ 60 g a.i. ha^{-1} PoE provided the best grain, straw, and economic returns, while the highest benefit-cost ratio was with 100 g + 4 g a.i. ha^{-1} PoE of Fenoxaprop-p-ethyl + Metsulfuron methyl. The combination of PUSA decomposer-treated residue, Brown manuring, and Clodinafop Propargyl @ 60 g a.i. ha^{-1} PoE yielded the highest net return. In contrast, rice stubble removal and two-hand weedings had the lowest yield. Thus, using PUSA decomposer with Brown manuring and Clodinafop Propargyl is recommended for higher yields and return in late-sown wheat under western U.P., India.

Keywords: B:C ratio, grain yield, rice stubble and weed management

Introduction
The "king of cereal," wheat (*Triticum aestivum* L.), is a significant staple crop that has been farmed worldwide since ancient times and is a member of the Poaceae family. In 2020-21, 122 countries and 217 million hectares of land were growing with wheat, yielding 774.8 million tons worldwide (Anonymous, 2021) [2]. The amount of wheat consumed worldwide is estimated to be 759.5 million tons annually, and this amount is predicted to rise over the next several years (Anonymous, 2021) [2]. With an average national productivity of 3424 kg ha^{-1} and a total production of 108.8 million tons, it is the most significant *Rabi* cereal crop in India, grown on an area of 341.57 lakh hectares. (Anonymous, 2021) [2].
A total of 9.85 million hectares are used to farm wheat in Uttar Pradesh, producing 36.21 million tons of wheat per years at an average productivity of 3.68 tons per hectare (Ramadas *et al.*, 2019) [7]. Wheat grain contains significant amounts of vitamins B, minerals (zinc, iron), protein (14.70%), fat (2.10%), and carbohydrates (78.10%), as well as trace minerals (magnesium, selenium), which are vital for overall health. Bread, biscuits, candies, noodles, and essential wheat gluten are all made with wheat flour. In addition, wheat straw is utilized as animal feed, to produce ethanol, to brew beer, as a raw material derived from wheat for cosmetics, to build wheat straw composites, and to replace meat with wheat protein, wheat bran and germ can be a useful source of dietary fiber that aids in the prevention and treatment of several digestive diseases (Kumar *et al.* 2011) [5].
Crop residue is a vital component of the agricultural ecosystem's stability and a rich source of nutrients for plants. Crop residues are potential sources of nutrients since they retain around 25% of the N and P, 50% of the S, and 75% of the K that cereal crops absorb (Dotaniya, 2013) [4].

Crop leftovers from agriculture are produced annually in the range of 500-550 million tons (Mt). In 2011-12, crop production included 93.9 million tons of wheat, 104.6 million tons of rice, 21.6 million tons of maize, 20.7 million tons of millets, 357.7 million tons of sugarcane, 8.1 million tons of fiber crops (cotton, jute, and mesta), 17.2 million tons of pulses, and 30.0 million tons of oilseeds (Anonymous, 2012) [1]. In the rice-wheat cropping system, where weeds can reduce productivity by up to 80%, an intensive cropping strategy combined with improved irrigation and fertilizer treatment has created favorable growing conditions for weeds (Walia and Brar, 2001) [9]. Therefore, to satisfy the food and nutritional needs of India's rising population and to raise farmers' incomes, effective weed management is essential for producing higher crop productivity and improving resource use efficiency (Rao and Chauhan, 2015) [8].

Farmers frequently hand weed their fields, but it takes a lot of time, labor, and money because labor is scarce at busy times and labor prices are high because people from the agricultural sector are moving to other industries in search of higher and more stable pay. It is also advantageous to use an integrated weed management approach, since no single technology can provide comprehensive and efficient weed control during the crop season. A small number of remaining weeds can yield enough seeds to keep the species a live (Walia *et al.*, 1997) [10]. According to recent research on weed management, tank mixes or the sequential use of two or more herbicides may be required to effectively manage weeds, as a single herbicide application may not be adequate to eliminate all weed species present in the field (Chand *et al.* 2004) [3]. Herbicide resistance is a concern as a result of relying solely on one herbicide for a very long time to manage weeds in wheat (Walia *et al.*, 1997) [11]. To increase wheat productivity, production, and farmer income, weed control is essential. In order to determine the best weed control and residue management strategies for wheat production, this study was carried out to comprehend the relationship between rice stubbles and weed management in field conditions.

Materials and Methods

A field experiment conducted on the "Economic feasibility of different options of rice stubble and weed management on performance of late sown wheat (*Triticum aestivum* L.) in Western UP" in the *Rabi* seasons of 2020-21 and 2021-22 at the Crop Research Centre (CRC) campus of Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUA&T) in Meerut, Uttar Pradesh. The campus is located at latitude of 29°4° north and a longitude of 77°41' east and it is elevated to a height of 237 meters above mean sea level. Eighty to ninety percent of the 862 mm of yearly rainfall occurs between June and September. As the wheat crop was seeded, the highest and lowest temperatures steadily decreased before rising again until harvest time. The soil's texture was sandy loam, with a pH of 7.8, an organic carbon content of 0.48 percent, and available N, P, and K contents of 214.1, 12.08, and 180.5 kg ha^{-1}, respectively. Two important factors and three replications of the experiment were set up in a Split Plot Design (SPD). The five weed control alternatives for rice stubble management were R_1 (residue burning), R_2 (residue removal), R_3 (residue treated with PUSA Decomposer), and R_4 (residue treated with *Trichoderma*). W_1 (Weedy) W_2, or two manual weedings at 25 and 45 DAS W_3 (25 gram active ingredient ha^{-1} of sulfosulfuron. W_4 (Metsulfuron methyl + Fenoxaprop-p-ethyl @ 100 g + 4 g post emergence) W_5 (using brown manuring fb Chlodinofop @ 60 g active ingredient ha^{-1}) crop sowing took place in the first week of December in both years. Using 125 kg of seed ha^{-1}, variety DBW 173 was sown 20 cm apart. Following the first irrigation and crown root initiation stages, fertilizer was applied according to treatment using urea, diammonium phosphate, and muriate of potash. A third of the nitrogen dose and the entire dose of potassium and phosphorus were applied as a basal.

The crop was irrigated more than twice, spaced 20 to 25 days apart after the first irrigation at the crown root stage, in order to avoid any kind of water stress. Using a hand-operated knapsack sprayer with a flat fan nozzle and 250 liters of water per hectare, herbicides were applied post-emergence, or 30 DAS. The first round of manual weeding was finished at 25 and 45 DAS. The Division of Microbiology at ICAR-IARI, New Delhi, has developed the Pusa Decomposer, a microbial solution available in liquid and capsule forms. Four capsules can be converted into a 25L liquid formulation, which is sufficient for in-situ application on one hectare of rice fields containing 5-6 tonnes of paddy straw, promoting rapid decomposition. Using the current local market prices for the various inputs utilized in crop cultivation, the observationally recorded cost of cultivation (in rupees per hectare) was computed for each crop treatment. Using the minimum support prices for grains and the current local market prices for straw, the monetary values of grain yield and straw yield were calculated in rupees per hectare. By aggregating the grain and straw yields monetary worth in rupees per hectare, treatment-wise, the gross return was calculated. The net returns per hectare were computed for each treatment by subtracting the cultivation cost from the corresponding gross returns. The benefit cost ratio was computed using the following formula to get the net return per rupee investment:

$$\text{Benefit Cost (B:C) ratio} = \frac{\text{Net return}(Rs/ha)}{Cost\ of\ cultivation(Rs/ha)}$$

After threshing to determine the grain yield ($q.ha^{-1}$) of the net plot, the grains were cleaned, weighed, and winnowed. The yield was translated from kg plot-1 to qha-1. The experiment data was statistically analyzed using the Split Plot Design hypothesis as put out by Cochran and Cox (1970) and online programming software called Programmer, Computer Section, CCSHAU, Hisar, created by O.P. Sheoran.

Results and Discussion

The culmination of growth and yield components is the grain and straw yield. According to the most recent research, wheat straw and grain production are significantly impacted by residue and weed management (Table 1). The next stage, if weed control is required, is to apply it according to table 2's cost of cultivation, gross returns, net returns and B:C ratio. PUSA decomposer-treated rice stubble outperformed residue treated with *trichoderma* (RTT) and residue burning (RB) in terms of grain and straw yields, as compared to other rice stubble treatments. Due to reduced weed density and total weed dry matter; these results also demonstrated that residue treated with PUSA decomposer had superior yield-contributing attributes and yields than conventional rice stubble management treatments. The results of the study on the effects of herbicide treatments on grain and straw yields showed that Brown manuring fb Clodinafop Propargyl @ 60 gram active ingredient ha^{-1} ha^{-1} was more effective. The notable gains in yield qualities and weed control effectiveness are responsible for this outcome. The non-competition of weeds throughout the growth stage may have allowed the wheat to make the most use of moisture, light, nutrients, and space, improving growth and yield components. This could account for the treatments with higher weed control efficiency. Due to insufficient metabolite transfer, significant weed-induced loss of moisture, light, space, and nutrients, and intense rice weed competition, poor source and sink development with subpar yield components resulted in the lowest grain yield being reported in the weedy check.

The ultimate goal may not necessarily be to maximize production. In contemporary farming, greatest profit takes precedence over maximum production. The only true criterion for comparing various treatments is their economic feasibility. Based on a two-year average, the economic analysis of various treatment combinations demonstrated that residue treated with PUSA decomposer yielded the highest gross and net returns, while treatment with residue burning demonstrated the highest benefit cost ratio. Numerous studies have shown that burning residue degrades the physical, chemical, and biological health of the soil as well as the environment's quality and people's health. These outcomes were supported by (Kumar *et al.*'s 2011) [5].

The two hand weeding treatments at 25 and 45 DAS produced the highest gross return among the weed control treatments, and the cultivation cost was likewise the highest compared to the other treatments. 100 g + 4 g *a.i.* ha^{-1} of Fenoxaprop-p-ethyl + Metsulfuron methyl @ and Brown manuring fb 60 g *a.i.* ha^{-1} of Clodinafop Propargyl were the herbicide treatments that yielded the highest gross and net returns. Using 100 g + 4g a.i. ha^{-1} of Fenoxaprop-p-ethyl + Metsulfuron methyl had the highest B:C ratio. However, Brown manuring with fb 60 g a.i. ha^{-1} of Clodinafop Propargyl was statistically comparable to the treatment. That being said, Brown manuring fb Clodinafop Propargyl @ 60 g a.i. ha^{-1} improves soil fertility more than application of 100 g + 4 g a.i. ha^{-1} of Fenoxaprop-p-ethyl + Metsulfuron methyl because of the increase of organic carbon. These findings may be related to variations in wheat yields under various conditions. As a result, the treatment that saw better yields also saw more profit. On the other hand, the treatment with lower yields made less money. These results are consistent with those that Nanher *et al.* (2015) [6] reported.

Table 1: Impact of rice stubble and weed management on grain yield, straw yield, biological yield and harvest index of wheat crop:

Treatment	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2020-21	2021-22	2020-21	2021-22
RB-Residue Burning	45.18	42.68	58.56	55.88
RR-Residue Removal	40.23	37.81	53.51	51.67
RTD-Residue treated with PUSA decomposer	47.59	46.28	61.00	59.34
RTT-Residue treated with *Trichoderma*	46.34	43.93	59.75	59.20
S.Em±	*1.05*	*1.05*	*1.12*	*1.39*
C.D.(P=0.05)	*3.71*	*3.69*	*3.93*	*4.91*
W_1-Weedy	38.65	36.76	52.01	48.67
W_2-Two hand weeding's at 25 & 45 DAS	48.22	46.22	61.75	60.18
W_3-Sulfosulfuron @ 25 g active ingredient (a.i.) ha^{-1} PoE	43.16	41.38	56.44	55.00
W_4-Fenoxaprop-p-ethyl + Metsulfuron methyl @ 100 g + 4g active ingredient (a.i.) ha^{-1} PoE	46.42	43.83	59.70	56.63
W_5-Brown manuring *fb* Clodinafop Propargyl @ 60 g active ingredient (a.i.) ha^{-1} PoE	47.72	45.17	61.25	58.38
S.Em±	*1.42*	*1.02*	*1.47*	*1.39*
C.D.(P=0.05)	*4.10*	*3.77*	*4.26*	*4.91*

Table 2: Cost of Cultivation, Gross Returns, Net Returns (Rs ha^{-1}) and B: C ratio of wheat crop as influenced by different rice stubble and weed management practices:

Treatment	Economics							
	Total Cost (Rs ha^{-1})		Gross return (Rs ha^{-1})		(Net return Rs ha^{-1})		(B:C Ratio)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Rice stubble management								
RB-Residue Burning	42654	43227	136161	141886	89650	94802	1.94	2.02
RR-Residue Removal	45844	46417	122255	127853	72554	77579	1.46	1.54
RTD-Residue treated with PUSA decomposer	48194	48767	142781	152594	90730	99972	1.75	1.90
RTT-Residue treated with *Trichoderma*	48244	48817	139327	144707	87226	92032	1.70	1.75
S.Em±	-	-	2969	3433	2969	3433	0.06	0.06
C.D.(P=0.05)	-	-	10473	12112	10472	12110	0.20	0.23
Weed management								
W_1-Weedy	42364	42937	117944	122735	71711	75928	1.56	1.63
W_2-Two hand weeding's at 25 & 45 DAS	53964	54537	144629	153319	86796	94912	1.50	1.63
W_3-Sulfosulfuron @ 25 g active ingredient (a.i.) ha^{-1} PoE	43709	44282	130395	138382	82816	90230	1.74	1.88
W_4-Fenoxaprop-p-ethyl + Metsulfuron methyl @ 100 g + 4g active ingredient (a.i.) ha^{-1} PoE	44689	45262	139432	144955	90873	95823	1.88	1.95
W_5-Brown manuring *fb* Clodinafop Propargyl @ 60 g active ingredient (a.i.) ha^{-1} PoE	46379	46952	143255	149408	93006	98586	1.86	1.94
S.Em±	-	-	3974	4614	3974	4614	0.08	0.09
C.D.(P=0.05)			11410	13354	11500	13354	0.23	0.26

Conclusion

The results of this study shown a significant improvement in production when cultivating wheat grain and straw yield with residue PUSA decomposer treated residue + Brown manuring fb Clodinafop Propargyl @ 60 g a.i. ha^{-1}. The treatment that involved burning the waste produced the highest benefit-cost ratio, whereas the treatment that used residues treated with PUSA decomposer produced the highest gross and net returns. However, burning leftovers has a negative impact on human health, the environment, and soil health. The treatment including brown manuring with Clodinafop Propargyl @ 60 g a.i. ha^{-1} PoE yielded the highest gross and net returns when it came to weed management measures. The treatment with Fenoxaprop-p-ethyl + Metsulfuron methyl at 100 g + 4 g a.i. ha-1 PoE had the highest benefit-cost ratio; this was similar to brown manuring followed by treatment with Clodinafop Propargyl @ 60 g a.i. ha^{-1} PoE. The highest net returns were obtained by treating the residue with PUSA decomposer and brown manuring, then applying Clodinafop Propargyl @ 60 g a.i. ha^{-1} PoE. On the other hand, during the two years of the wheat crop research, the lowest grain and straw yields were noted under the conditions of rice stubble removal and two manual weedings at 25 and 45 DAS. Based on these results, it is proposed that farmers could benefit from using residues treated with PUSA Decomposer in conjunction with brown manuring and Clodinafop Propargyl @ 60 g a.i. ha^{-1}. This would provide efficient and cost-effective weed management as well as increased yields and profits for late-sown wheat crops in western Uttar Pradesh.

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