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On Farm Testing of Rice Residue Management Techniques for Wheat (*Triticum aestivum* L.) Establishment in Punjab

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ABSTRACT

Rice residue management (RRM) has been the key component of systems' sustainability. The paper reports the effect of different RRM and wheat (*Triticum aestivum* L.) establishment methods on productivity and yield contributing attributes through farmer participatory mode in south-western Punjab. Different RRM technologies including rice residue removal, residue incorporation and residue retention on soil as surface mulch were evaluated. Wheat grain yield was significantly (p<0.05) higher with happy seeder method of wheat establishment following chopping of loose rice stubble, which acts as surface mulch, compared with the other RRM technologies. Wheat grain yield in other RRM technologies viz. rice residue incorporation and removal did not differ significantly. The yield contributing attributes viz. plant height, number of effective tillers m^{-1} row length, 1000-grain weight, ear length and the number of grains ear^{-1} were significantly higher in happy seeder method of wheat establishment. The weed count (*Phalaris minor*) was significantly lower than the other compared methods of RRM. The correlation matrix exhibited a linear positive relationship between the grain yield and plant height (r=0.951*; p<0.05), ear length (r=0.941*), 1000-grain weight (r=0.853*) and number of grains ear^{-1} (r=0.771*). All economic indices viz. average net (Rs. 74, 840/- ha^{-1}), gross returns (Rs. 1,00,620/- ha^{-1}) and benefit-cost (B:C; 3.9) ratio were significantly enhanced because of low cost of cultivation (Rs. 25,780/- ha^{-1}) under happy seeder method of wheat establishment.

INTRODUCTION

The rice-wheat cropping system is practiced on 13.5 million ha (Mha), comprising of 85 per cent of cultivated area in the Indo-Gangetic Plains (IGPs) (Ladha et al., 2009; Bhatt *et al*., 2019), which are home to 1.6 billion people (Balasubramanian et al., 2012). Among others, rice residue management (RRM) has become the major issue threatening the long-term sustainability of the ecosystem and the environment (Singh et al., 2020a; Bhatt et al., 2021; Singh et al., 2021a,b). In north-western India, 2.5 million farmers burn the left-over rice stubbles in their fields before making seed beds for wheat establishment (Keil et al., 2020). Rice residue burning not only results in environmental pollution (Singh et al., 2020a; Sharma et al., 2021), but can also adversely affect soil health through reduced carbon (C) input to the soil (Sharma et al., 2020; Singh et al., 2021a,b). The Indian IGPs annually produce ~620 million tons (Mt) of crop residue with 1/3rd being contributed by rice-wheat cropping system alone (Singh et al., 2019). Nonetheless, residue burning is not a viable option as it leaves high C footprints (Singh et al., 2020a), reduced the net ecosystem C budget (Singh and Benbi, 2020; Singh et al., 2021b), and lowers C sustainability of world's largest cropping system (Singh et al., 2020a). Over the

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years, several robust RRM technologies have been advocated by the research system and disseminated among farmers through extension system. The suggested technologies for *in-situ* management of loose rice straw include straw management system on combine harvesters, zero till drill, happy seeder, super seeder, reversible mould board plough, rotavator tillage, rice straw chopper and cutter-cum-shredder etc. (Singh et al., 2020a,b). Therefore, it becomes important to study the economics of different RRM techniques for wheat establishment in farmer's participatory mode for large scale adoption of different site-specific RRM technologies. A field experiment at farmer's field to investigate the effect of residue removal, incorporation and surface retention on wheat yield and the economic indices was conducted.

METHODOLOGY

The study area is located in Ubha village of Mansa district (Latitude of 29° 59' and longitude of 75 23', 212 m above sea level) in south-western zone of Punjab. Mansa district is divided into five blocks and have 1.8 lakh ha of arable land. A survey study showed that total area under residue mulching using happy seeder technology was 31 per cent, followed by rotavator tillage 14 per cent and 7.7 per cent under super seeder technology (Singh et al., 2020b).

A field experiment was conducted during *rabi* 2020-21 in Mansa district, and three different RRM options including rice residue removal, residue incorporation and residue retention on soil as surface mulch were evaluated. The treatments included rice residue removal with baler technology followed by wheat establishment either by zero till drill (ZTD) or by conventional sowing (CS), rice residue incorporation with mould board plough (MBP) and rotavator tillage (RT) and wheat establishment, residue incorporation under super seeder (SS) method after cutting the lose straw with chopper, residue retention at surface with happy seeder (HS) after cutting the lose straw with chopper and using mulcher followed by broadcasting (BC) the wheat seed. The wheat variety (var. HD 3086) was sown using a seed rate of 100 kg ha^{-1}. Wheat received recommended doses of fertilizer 120 kg N ha^{-1} + 26 kg P. All other crop production and protection practices were adopted as per recommendations of Punjab Agricultural University.

Data were recorded for 9 different yield attributes viz. plant height (cm), number of effective tillers per meter row length, number of grains per ear, 1000-grain weight (g), maturity time (days) and grain and straw yields. Wheat crop was harvested at physiological maturity in the first week of April. For yield measurement, a net plot area of (2.0 m x 2.0 m) was harvested. In manually harvested plots (4 m^2), yields of wheat were reported at 10 per cent grain moisture content. Average cost of cash inputs was estimated as a sum of expenditure incurred for the purchase of cash inputs (Rs. ha^{-1}) like seed, fertilizers, insecticides, fungicides herbicides etc. and labour cost for different field operations, according to equation (1).

Average cost of cultivation (Rs. ha^{-1}) = $\Sigma_{1,2,3,......n}$ ….(1)

Where, $C_{1,2,3.....}$, represents cost for different inputs and labour cost

Average gross returns were estimated as a product of wheat grain yield (Mg ha^{-1}) under happy seeder and conventional tillage and wheat selling price (P) (Rs. Mg^{-1}), according to equation (2).

Average gross returns (Rs. ha^{-1}) = Grain yield x Price ….(2)

Average gross returns were estimated by using minimum support price (MSP) decided by Government of India for the year. The estimations were based on average (2 study years) MSP of wheat. The average net returns were estimated as a difference in AGR and ACCI, according to equation (3).

Average net returns (Rs. ha^{-1}) = Average gross returns - Average cost of cultivation …. (3)

Statistical analysis was performed with SPSS for Windows 16.0 (SPSS Inc., Chicago, USA). Wheat grain yield and related attributes under different RRM treatments were compared using Least Significant Difference (LSD) test. Difference in treatments' mean at $p<0.05$ was considered statistically.

RESULTS AND DISCUSSION

Yield contributing attributes

Table 1 reports that mean plant height didn't differ significantly ($p<0.05$) among different RRM technologies adopted for wheat establishment. The number of effective tillers was significantly higher in wheat established with super seeder technology followed after using chopper for cutting the loose rice straw, while the lowest in the treatment involving rice residue incorporation using mould board plough + rotavator tillage following wheat seeding with conventional drill. Similar result was reported by Singh et al., (2014). As compared with residue removal using baler and wheat establishment using zero till drill, number of effective tillers were significantly increased by 5.4%, in rice residue retention and wheat establishment with happy seeder technology. Weed count (*Phalaris minor*) was significantly reduced by 13.1-times with happy seeder technology, compared with intensive tillage practiced using reversible mould board plough and rotavator tillage for rice residue incorporation.

Happy seeder ensures timely wheat establishment with several benefits in terms of economic gains, enhanced water use efficiency and decreased weed emergence along with sustained wheat grain yields (Chakraborty *et al*., 2008; Singh *et al*., 2011). Singh *et al*., (2020a) reported that the lowest herbicide energy in happy seeder method of wheat establishment was ascribed to reduced infestation of grassy and broad leaved weeds which remained suppressed under residue mulch, because residues retained on soils surface exert physical hindrance on weed germination (Teasdale and Mohler, 2000). It was interesting to observe that although weed count was significantly reduced under zero tillage establishment of wheat following rice residue removal from the field, but was still significantly higher by 150 per cent as compared to happy seeder technology with surface retention of rice residue. Chhokar et al., (2007) reported that ZT method reduces *Phalaris minor* infestation. The 1000-grain weight and the ear length significantly increased under happy seeder technology for wheat establishment, compared with other treatments which did not different significantly from each other. The results revealed that the number of grains ear^{-1} were significantly lower in zero tillage treatment, and was highest with happy seeder technology, highlighting the positive influence of rice residue retention (Table 1).

Table 1. Effect of different wheat establishment technologies on yield attributes of wheat in Punjab

Treatments	Plant height (cm)	No. of effective tillers m^{-1} row length	Weed count (no. m^{-2})	1000-grain weight (g)	Ear length (cm)	Number of grains ear^{-1}
Baler + ZTD	$83.2^{a\dagger}$	67.2^{b}	2.33^{a}	41.3^{a}	10.0^{a}	56^{a}
MBP + RT + CS	84.8^{a}	62.6^{a}	1.66^{a}	41.6^{a}	10.3^{a}	62^{b}
Baler + CS	84.6^{a}	69.3^{c}	12.3^{b}	41.8^{a}	10.4^{a}	65^{b}
Chopper + SS	83.1^{a}	88.0^{d}	11.2^{b}	41.3^{a}	10.1^{a}	57^{a}
BC + Mulcher	85.7^{a}	70.5^{c}	12.6^{b}	41.8^{a}	10.5^{a}	66^{b}
Chopper + HS	88.2^{a}	70.8^{c}	0.94^{a}	42.2^{b}	11.2^{b}	69^{c}

†Mean values followed by different letters are significantly different from each other at $p<0.05$ by Least Significant Difference (LSD) test.

Grain and straw yield and the harvest index

Table 2 shows that wheat grain yield was significantly higher in the happy seeder sown wheat after chopping the loose rice straw followed by wheat establishment using broadcasting method followed by mulcher in comparison to all other technologies. The results corroborate earlier research findings showing that surface mulch enhances wheat grain yield (Singh et al., 2011; Ram et al., 2013). Straw load was significantly highest for chopper + happy seeded wheat followed by broadcasting + mulcher and lowest for chopper + super seeder. Wheat establishment with happy seeder technology recorded significantly higher total energy output, net energy gain, energy use efficiency and energy productivity than the conventionally tilled wheat after residue burning due to grain yield advantage in happy seeder sown wheat (Virk et al., 2020).

Relationship between yield and related attributes

The correlation matrix exhibited a linear positive relationship between the grain yield and plant height (r=0.951*; $p<0.05$), ear length (r=0.941*), 1000-grain weight (r=0.853*) and no. of grains ear^{-1} (r=0.771*) (Table 3). Straw yield was significantly positively correlated with plant height, grain yield, ear length, 1000-green weight and no. of grains ear^{-1}. The no. of grains ear^{-1} were found to exhibit a significant positive correlation with 1000-grain weight, plant height and ear length. The ear length was found to be positively correlated with plant height and 1000-grain weight.

Economic indices of wheat establishment following RRM

The results (Table 4) revealed that average cost of cultivation was significantly lower in the happy seeder sown wheat, which was at par with broadcasting and mulcher. The use of mould board plough, rotavator and conventional drill for wheat establishment following rice residue incorporation resulted significantly higher cost of cultivation, compared with other RRM technologies. The average gross returns were significantly higher in wheat establishment done using happy seeder after chopper, while significantly lower returns were observed under super seeder sown wheat after the use of chopper which could be attributed to high cost of cultivation and yield losses due to lodging problem. The happy seeder sown wheat showed significantly higher average net returns followed by wheat establishment done using broadcasting method after mulcher in comparison to other technologies. The B-C ratio was significantly higher in happy seeder sown wheat after the use of chopper and broadcasting after use of mulcher in comparison to other RRM technologies. The higher net returns recorded under conservation agriculture based management practices were associated with lower

Table 2. Effect of different wheat establishment technologies on harvest index of wheat in Punjab

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Baler + ZTD	4.62^{ab}	5.13^{ab}	0.47^{a}
MBP + RT + CS	4.65^{ab}	5.55^{c}	0.46^{a}
Baler + CS	4.60^{ab}	5.23^{b}	0.47^{a}
Chopper + SS	4.55^{a}	5.03^{a}	0.47^{a}
BC + Mulcher	4.85^{b}	5.73^{d}	0.46^{a}
Chopper + HS	5.20^{c}	6.13^{e}	0.46^{a}

†Mean values followed by different letters are significantly different from each other at $p<0.05$ by Least Significant Difference (LSD) test.

Table 4. Effect of different rice residue management (RRM) and wheat establishment technologies on economic indices

Treatments	Average cost of cultivation (Rs. ha^{-1})	Average gross returns (Rs. ha^{-1})	Average net returns (Rs. ha^{-1})	B:C
Baler + ZTD	$26,070^{b}$	$89,397^{b}$	$63,327^{b}$	3.4^{b}
MBP + RT + CS	$28,465^{d}$	$89,978^{b}$	$61,513^{a}$	3.2^{a}
Baler + CS	$27,310^{c}$	$89,010^{b}$	$61,700^{a}$	3.3^{ab}
Chopper + SS	$27,440^{c}$	$88,043^{a}$	$60,603^{a}$	3.2^{a}
BC + Mulcher	$25,425^{a}$	$93,848^{c}$	$68,423^{c}$	3.7^{c}
Chopper + HS	$25,780^{a}$	$1,00,620^{d}$	$74,840^{d}$	3.9^{c}

†Mean values followed by different letters are significantly different from each other at $p<0.05$ by Least Significant Difference (LSD) test.

Table 3. Correlation matrix between different yield attributes of wheat.

Parameter	Plant height	Effective tiller	Weed count	1000-grain weight	Ear length	No. of grain ear^{-1}	Grain yield
Effective tiller	-0.293						
Weed count	-0.300	0.498					
1000-grain weight	0.960*	-0.313	-0.127				
Ear length	0.983*	-0.162	-0.256	0.958*			
No. of grain ear^{-1}	0.914*	-0.321	0.023	0.978*	0.894*		
Grain yield	0.951*	-0.182	-0.379	0.853*	0.941*	0.771*	
Straw yield	0.971*	-0.360	-0.368	0.884*	0.917*	0.852*	0.945*

*Significant at $p<0.05$

cost involved in tillage, crop establishment and irrigation, besides higher crop yields (Singh et al., 2021b).

CONCLUSION

Wheat grain yield was significantly higher following RRM with happy seeder technology, compared with other compared technologies. Number of effective tillers, 1000-grain weight, ear length and number of grains ear^{-1}were significantly higher in happy seeder technology. Weed count (*Phalaris minor*) was significantly reduced by 13.1-times with happy seeder technology, compared with intensive tillage practiced using reversible mould board plough and rotavator tillage for rice residue incorporation. Average gross returns, average net returns and B:C ratio were significantly higher, while the cost of cultivation was significantly lower in happy seeder sown. The results on different parameters highlighted the positive influence of rice residue retention using happy seeder technology in comparison with other technologies.

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