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Adoption Status of Rice Residue Management Technologies in South-Western Punjab

Gurdeep Singh[1]*, Pritpal Singh[2], G.P.S. Sodhi[3] and Devinder Tiwari[4]

ABSTRACT

The present study was conducted during 2019-20 in south-western Mansa district of Punjab. The study aimed to investigate the adoption status of different rice residue management (RRM) technologies. Data were collected from randomly selected 100 farmers, custom hiring centers (CHCs) and co-operative societies of the district. The total area under study was 5350±49.9 ha. Among the studied villages maximum area under RRM (404.0±12.6 ha) was in village Biro KeKalan of Budhlada block which constituted ~30 per cent of the total area under study. The least area under RRM (28.4±3.1 ha) was in village Kallhon of Mansa block which was only 4.6 per cent of the total area. The results of the study revealed that rice residue over about 43 per cent area was managed by farmers through different RRM technologies like mulching, incorporation and residue removal. The rice residue was either managed without burning or partial burning in case of very heavy straw load. Farmers preferred rice residue removal over other technologies of the total are managed, the area under rice residue removal was ~37 per cent which was accomplished by using either rectangular baler or manual labor. Area under residue mulching using happy seeder (HS) technology was ~31 per cent followed by rotavator (RT) (~14%) and super seeder (SS) technology (~7.7%). The manual removal of loose straw comprised only 2.3 per cent area. A number of constraints were faced by the farmers in RRM including yellowing of leaves, attack of pink stem borer, water stagnation and straw loading etc. The constraints reported by CHCs and co-operative societies in RRM were lack of high HP tractor among farmers and lack of skill to use new technology. Based on the results of the study it was concluded that there is significant increase in area under RRM, however, various constraints faced by farmers need to be addressed to further enhance area under RRM.

Keywords: Adoption, Happy seeder, Mulching and incorporation, Rice residue management

INTRODUCTION

Rice-wheat cropping system (RWCS) occupies ~4.1 Mha area in north-western states of India comprising Punjab, Haryana, Uttarakhand and western Uttar Pradesh. These states produce ~34 Mt of rice residue, of which Punjab alone contributes ~20 million tones. The mechanized harvesting of rice using combine harvesters has been a common practice followed in more than 90 per cent of the area in the state. As a result huge quantity of loose straw is left behind by these harvesters in the fields. To manage this quantum of left-over straw through *in-situ* incorporation is not only energy intensive but also costlier and time consuming affair (Singh *et al*., 2010; Singh *et al*., 2020). Of the total rice straw produced, ~5 Mt is managed by different ways, while the remaining ~15 Mt is burnt *in-situ*. Rice residue burning contributes towards emission of greenhouse gases (Gujral *et al*., 2010; Lohan *et al.*, 2013) with serious environmental implications. Nonetheless, residue burning is not a viable option as it leaves high carbon (C) footprints and lowers C sustainability of world's largest cropping system (Singh

[1,2]Assistant Professor, Krishi Vigyan Kendra, Mansa, Punjab
[3]Associate Director (T), Krishi Vigyan Kendra, Mansa, Punjab
[4]Assistant Professor, Krishi Vigyan Kendra, Ludhiana, Punjab
*Corresponding author: gurdeepsingh@pau.edu

et al., 2020). Besides GHGs emissions, residue burning causes nutrient loss of 100% C, 90% N, 60% S and 25% each of P and K. (Dobermann and Fairhurst, 2002). Estimates revealed that burning of one Mg of rice straw leads to a loss of ~400 kg of organic C, 5.5 kg of N, 2.3 kg of P_2O_5, 25 kg of K_2O, 1.2 kg of S and 50-70 per cent of micro-nutrients, which costs more than Rs. 200 crores (Sidhu *et al*., 2007). In the last two decades, significant progress has been made by the State Agricultural University to evolve and disseminate number of technologies for *in-situ* management of loose rice straw using different technologies like straw management system (SMS) on combine harvesters, zero till drill, (ZTD), happy seeder (HS, a modified ZT), super seeder (SS), reversible mouldboard plough (RMBP), rotavator tillage (RT), rice straw chopper and cutter-cum-shredder etc. The Government of India (GOI) has undertaken several initiatives to curb the menace of residue burning by providing crop residue management (CRM) machinery to the cooperative societies, farmers' groups and individual farmers on 50-80 per cent subsidy. The GOI outlaid Rs. 6,950/- millions under a project 'Agricultural mechanization for *in-situ* management of crop residues for the year 2018-19 and 2019-20. The project focused on capacity building and awareness creation among farmers. Besides, numbers of CRM machines were supplied to farmers through cooperatives as well as on individual basis. During the past two years, a significant reduction in farm fires has been observed and farmers are coming forward for the adoption of these RRM technologies. Till date there is no information available regarding the adoption status of different RRM technologies in the study region. The present study was therefore conducted to assess the adoption status of different RRM technologies, their contribution towards the management of total rice residue produced and the advantages and constraints faced by farmers in Mansa district of south-western Punjab.

METHODOLOGY

Mansa district in south-western Punjab has five administrative blocks viz. Mansa, Budhlada, Jhunir, Sardulgarh and Bhikhi comprises of 243 villages. The district lies between 29.6'-36.3' north and 75.2'-34.9' east, and has a total geographical area of ~2.19 thousand ha. Rice-wheat and cotton-wheat are the two major cropping systems prevalent in the district. Wheat dominates the cereal acreage with ~170 thousand ha area, while rice occupied 119 thousand ha area in the district during 2019 (DOA&FW, Mansa). The data were collected from randomly selected 100 farmers, 16 custom hiring centers (CHCs) and 10 cooperative societies during the year 2019-20. The data were collected using stratified random sampling from all five administrative blocks of the district. Within each administrative block, two villages were selected and within each village ten farmers were randomly selected. The survey thus comprised a total of 100 farmers. The data from CHCs and cooperative societies of these selected villages was also collected to study the present adoption status of RRM techniques, their contribution towards the management of rice residue and to study the advantages and constraints faced by farmers. The data were collected through personal interviews of farmers, in-charges of CHCs and inspectors of cooperative societies. For the purpose of data collection, an open ended interview schedule was developed. The data regarding area under various RRM techniques during current (2019) and previous year (2018) was recorded for comparison. Similarly, data regarding area covered by CRM machinery available with CHCs and the cooperative society was also collected. In addition, the advantages and the constraints faced by farmers regarding different CRM technologies was recorded. The rice area under different RRM techniques viz. HS, RT, ZTD, baler technology, SS, RMBP and disc-harrow was recorded during these interviews.

RESULTS AND DISCUSSION

The results of the study revealed that a total of 5350±49.9 ha area was under rice cultivation in the selected villages. Maximum area under RRM was 404.0±12.6 ha in village *Biro KeKalan* of *Budhlada* block followed by 116±4.3 ha in *Karandi* village of *Sardulgarh block*. However, maximum proportion of area was in *Anupgarh* village (35.5%) of *Bhikhi* block followed by Biro KeKalan village (30.4%) of *Budhlada* block. Minimum area under CRM (28.4±3.1, 4.6%) was in *Kallhon* village of Mansa block. Thus, a total of 1098.4±15.2 ha i.e. 20.5 per cent of the total area under rice cultivation was managed through different RRM practices viz; incorporation, mulching or removal during 2019-20, while 1209.1±29.6 ha area was managed with partial residue burning in the district (Table 1). The total area under RRM in the district was ~43 per cent while area under rice residue burning was 56.9 per cent. Among the various RRM practices, the highest proportion of rice residue (37.4%) was managed through manual removal or mechanical removal using rectangular baler technology. The proportion of rice residue incorporation with RT, MBP, disc-harrows and the SS technology was ~32 per cent, while the proportion of area where rice residue was managed as surface mulch with the use of HS technology was~31.0 per cent.

The data regarding area covered by different RRM techniques revealed that maximum area (~35%) was covered by rectangular baler technology as farmers preferred removal of rice residue over other strategies for fine seed bed preparation in order to facilitate sowing of ensuing wheat crop. Singh *et al*. (2017) reported baler as socially and environmentally feasible technology in managing loose paddy straw from combine harvested rice crop fields. Next preferred technology was HS and the area under this technology was ~31 per cent. Farmers operated HS in full load of rice residue after one operation of mulcher or chopper or in partial burnt rice straw fields. The area under RT technology was ~14 per cent (13.7%) which was involved both wet and dry incorporation of rice residue. Newly introduced SS technology and RMBP covered an area of 7.7 and 7.6 per cent, respectively. Both the technologies were used for *in-situ* incorporation of loose straw. The incorporation of loose straw using conventional disc-harrows was only 2.7 per cent, however, the incorporation by disc harrows resulted in enhanced cost of cultivation due to high diesel fuel consumption on extra tillage operations required to incorporate heavy paddy straw load. Earlier, Gajri *et al*. (2002) had reported that in Punjab ~25 per cent of farmers had to perform more than five tillage operations for incorporation of rice residues, while, ~50 per cent of farmers used more than five tillage operations to

Table 1: Village wise description of RRM in selected area

Administrative block	Village	Total area under rice cultivation (ha)	Total area under RRM (ha)	Total area with *in situ* open field rice burning (ha)	
				Partial	Complete
Budladha	Ralli	792±25.9†	145.4±13.5 (18.4)¶	246.0±37.1 (31.1)	400.6±56.2 (50.6)
	BeeroKeKalan	1330±35.2	404.0±12.6 (30.4)	292.0±24.4 (22.0)	634.0±49.4 (47.7)
	Budladha pooled data	2122±34.9	549.4±12.9 (25.9)	538.0±30.4 (25.4)	1034.6±53.9 (48.8)
Mansa	BurjRathi	640±9.9	60.0±4.9 (9.4)	51.4±4.4 (8.0)	528.6±13.3 (82.6)
	Kallhon	620±8.9	28.4±3.1 (4.6)	120.0±14.3 (19.4)	471.6±20.0 (76.1)
	Mansa pooled data	1260±11.7	88.4±5.1 (7.0)	171.4±7.9 (13.6)	1000.2±17.6 (79.4)
Bhikhi	AtlaKhurd	410±13.1	104.8±4.3 (25.6)	19.6±3.9 (4.8)	285.6±14.5 (69.7)
	Anupgarh	282±8.7	100.2±4.0 (35.5)	60.0±4.9 (21.3)	121.8±9.6 (43.2)
	Bhikhi pooled data	692±8.9	205.0±4.0 (29.6)	79.6±5.4 (11.5)	407.4±12.4 (58.9)
Sardulgarh	Krandi	420±8.9	116.0±12.6 (27.6)	230.0±15.0 (54.8)	74.0±23.7 (17.6)
	Tibbi Hari Singh	260±6.7	64.0±4.8 (24.6)	97.0±4.7 (37.3)	99.0±9.0 (38.1)
	Sardulgarh pooled data	680±10.1	180.0±5.4 (26.5)	327.0±10.4 (48.1)	173.0±15.7 (25.4)
Jhunir	Talwandi Aklia	332±5.3	33.8±3.4 (10.2)	57.0±4.2 (17.2)	241.2±6.4 (72.7)
	Khiali ChehlanWali	264±15.7	41.8±2.8 (15.8)	35.0±4.2 (13.3)	187.2±19.0 (70.9)
	Jhunir pooled data	596±10.1	75.6±3.1 (12.7)	72.0±6.9 (15.4)	448.0±23.1 (71.9)
District	—	5350±49.9	1098.4±15.2 (20.5)	1209.1±29.6 (22.6)	3043.6±67.4 (56.9)

†Values indicate standard error (S.E.) of mean; ¶Values in the parenthesis indicate percent of total area under rice cultivation

incorporate loose straw after partial burning. Manual removal of loose straw used as dry fodder for animals was only 2.3 per cent. This small proportion under manual removal of paddy straw was due to heavy involvement of labor, which is already scarce and costly in the study area. Moreover, manual removal of loose straw was mostly in case of basmati rice which is used as animal fodder.

Area under different RRM techniques in comparison to previous year

There was significant increase in area under RRM management techniques during 2019-20 as compared to 2018-19 (Table 2). Area under HS mulching technology increased from 358.5 hectare to 713.4 thousand hectare an increase of ~100.0 per cent. Similarly, area under baler technology which is used for mechanical removal of rice residue increased from 491.3 hectare to 809.4 hectare with an increase ~65 per cent. SS technology for rice reside management was introduced for the first time in study area during 2019-20 and area under this technology was 176.2 hectare. Area under RT used for paddy straw incorporation increased to 256.5 to 315.4 hectare and area under disc harrows for straw incorporation increased from 55.4 to 61.6 hectare an increase of 23.0 per cent and ~11 per cent, respectively. Manual removal of basmati rice straw was also adopted by farmers for using as fodder for dairy animals and manual removal witnessed increase of 41.4 per cent from 37.5 hectare to 53 hectare. The overall increase in area under RRM was from 1249.2 ha during 2018-19 to 2305.9 thousand hectare during 2019-20, by ~85 per cent.

Contribution of individual farmer, CHCs and co-operative societies in RRM

The CHCs established by farmer groups played an important role in rice residue management. More than half of the total area (~55%) under RRM was covered by CHCs followed by individual famers. The contribution of co-operative society in RRM was small (~6%) but significant (Table 3). The contribution of CHCs in management of rice residue using RMBP technology was ~81 per cent while individual farmer’s contribution was ~19.0 per cent. The individual farmer’s contribution in RRM using RT was ~83 per cent as majority of the medium and large farmers owned RT which is preferred by farmers in the study area for fine seed bed preparation. The co-operative societies’ contribution in RRM was ~17.0 per cent as small and marginal farmers hired RT from co-operative societies for tillage operations and rice residue incorporation.

Opinion of farmers’ about different RRM techniques

Farmers reported various advantage of surface retention of paddy straw using HS technology over conventional sowing. Majority of the farmers reported less diesel consumption requirement (4-7 per ha) for sowing wheat using HS technology. Farmers also reported that wheat sowing using HS is completed in single operation after combine harvested paddy field, which saves time. Similarly, farmers also reported advantages of labor saving, irrigation water saving (1-2 irrigation),

Table 2: Increase in area under various rice residue management (RRM) technologies, Punjab.

RRM technology	Area (000’ ha) 2018-19	Area (000’ ha) 2019-20	Difference (A-B)	% Increase in area over 2018-19
Happy seeder (HS)	358.5	713.4	354.9	99.0
Baler technology + zero tillage (ZTD)	491.3	809.4	318.1	64.7
Super seeder (SS)	0.0	176.2	176.2	
Mould board plough (MBP)	50.0	176.9	126.9	253.7
Rotavator tillage (RT)	256.5	315.4	59.0	23.0
Disk harrow	55.4	61.6	6.2	11.1
Manual removal	37.5	53.0	15.5	41.4
Overall	**1249.2**	**2305.9**	**1056.7**	**84.6**

Table 3: Percent contribution of individual farmers, CHCs and Co-operative societies in RRM in Mansa district

RRM technology	Individual farmers	CHCs	Co-Societies
Happy seeder (HS)	33.1	60.7	6.2
Baler technology+ zero tillage (ZT)	22.3	70.7	7.0
Mould board plough (MBP)	19.1	81.0	0.0
Rotavator tillage (RT)	83.1	-	16.9
Others (Super seeder (SS) and mulcher etc.)	37.5	62.5	0.0
Overall contribution (%)	**39.0**	**55.0**	**6.0**

increase in soil fertility and less weed infestation. HS technology also ensured early sowing of wheat which also helped in checking the *gullidanda* (*Phalaris minor* Retz.) weed infestation. Malik *et al.* (2004) has also reported that earlier sowing improves the ability of wheat to compete against its major weed *Phalaris minor*, which was responsible for lower wheat yield and herbicide resistance. Increase in wheat as well as rice yield in next season due to residual effect of straw was also reported by the farmers.

It has been reported that surfaced retained crop residues decompose slowly on the surface, increasing the organic carbon and total N in the top 5-15 cm of soil, while protecting the surface soil from erosion (Rasmussen and Collines, 1991). Retention of residues on the surface increased soil NO_3^- concentration by 46 per cent, N uptake by 29 per cent, and yield by 37 per cent compared to burning (Bacon *et al.*, 1987; Bacon *et al.*, 1985a; Bacon *et al.*, 1985b).

Sowing of wheat was also performed after removal of rice residue using baler technology. After removal of loose rice straw sowing was done using ZTD. Like HS, ZTD is also zero till technology yet there is no surface retention of loose paddy straw, however, the farmers reported similar advantage of ZTD, yet, they did not report an increase in soil fertility and yield advantage in next season rice crop. No tillage technology for wheat after rice proved better in terms of saving of fuel, cost of cultivation and advancing sowing time than RT and conventional tillage (Chuhan *et al.*, 2000). In an estimate, it has been found that adoption of no-tillage in 5 million ha would represent a saving of 5 billion cubic meter of water each year. In addition annual diesel fuel savings would come to 0.5 billion liters equivalent to a reduction in CO_2 emissions by nearly 1.3 million ton per year (Mehla *et al.*, 2000).

The farmers following straw incorporation do not reported advantage of less diesel consumption, water saving and reduction in weed infestation, however, they reported increase in soil fertility due to addition of organic matter in soil It has been reported that unlike removal or burning, incorporation of straw increases SOM and soil N, P and K contents (Mandal *et al* 2004). The farmers in this study also reported an increase in yield where straw was incorporated using RT, Disc-harrow or RMBP. It has been reported earlier also that in contrast, rice straw incorporation gave significantly higher wheat yields of 3.5 t ha^{-1} compared to 2.91 t ha^{-1} with straw removal (RWC-CIMMYT, 2003). Being adopted for the first time, the farmers did not report any yield advantage or disadvantage in SS technology.

Constraints faced in adoption of RRM techniques

The major disadvantage in adoption of RRM techniques was attack of pink stem borer which resulted in mortality of plants leading to yield loss. The attack of pink stem borer was reported in all RRM techniques except in RMBP perhaps due to very small area under this technology during study year. While lodging of wheat crop was reported in RT techniques, poor wheat yield was reported in HS, ZTD and RT sowing techniques. Yellowing of plants due to N deficiency was reported by farmers in HS, RT and SS techniques. It has been reported that immobilization of inorganic N occurs due to incorporation of straw and it results in N-deficiency among the plants. Incorporation of rice straw into the soil after its harvest leads to slow down the decomposition and soil nitrate is immobilized (Bacon, 1987), reducing the N uptake and yield of subsequent wheat crops by about 40 per cent (Bacon 1987, Sidhu and Beri 1989). Poor seed germination was reported in HS sown fields where there was heavy straw load of long duration rice varieties and also in fields where loose straw could not be uniformly spread out due to lack of SMS fitted combine harvesters. Chocking of seed drill was also reported in HS and SS techniques in fields where straw load was more. The large volumes of crop residue on the soil surface often lead to machinery failures, thus affecting sowing of seeds of the following crop (Mandal *et al.*, 2004). Wider row spacing in HS techniques (22.5 cm as compared to 16-20 cm in ZTD and conventional drills) was also a constraint in adoption as reported by farmers. Farmers reported that seed rate need to be enhanced in HS, ZTD, RT and SS for ensuring proper plant stand. All the RRM techniques required high HP (>45 HP) tractor and therefore, it was common constraint in adoption of all RRM techniques as majority of the farmers were small and marginal. Poor wheat yield in HS and RT also reported by farmers due to attack of pink stem borer, poor crop stand and yellowing of wheat.

The constraints faced by co-operative society involved lack of high HP tractors among farmers, lack of tractor drivers in societies and low paying capacity of the farmers or delayed payments by farmers. They also reported more wear and tear of machinery due to lack of knowledge about maintenance of RRM machinery among farmers. As a short term constraint, the CHCs and co-operatives society also reported late receipt of purchased RRM machinery during sowing season. They also reported that some farmers did not show interest in managing crop residue due to lack of awareness.

CONCLUSION

Farmers need to be made more aware regarding the importance of *in-situ* rice residue management and ill effects of straw burning. Majority farmers preferred removal of loose straw over incorporation and mulching due to various constraints in residue incorporation as well as mulching. Being a new technology, the area under super seeder technology may increase in the coming years. Farmers need to be trained in operations of RRM techniques, insect pest management, rodent control and fertilizer application to ameliorate nutrient deficiency. The area under RRM can be enhanced if the constraints faced by farmers, CHCs and co-operatives societies are addressed in time. So, it can be concluded that there was significant increase in adoption of RRM technologies in comparison to 2018-19. However, RRM required both short term as well as long term measures for its sustainable solution.

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