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RESEARCH ARTICLE

Extent of Adoption of Paddy Residue Management Techniques in Sri Muktsar Sahib District

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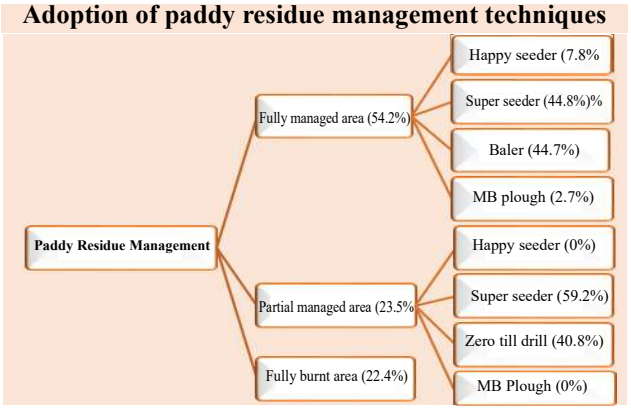
HIGHLIGHTS

- Most farmers either fully manage or partially manage paddy straw.
- In situations of full residue management, the majority of farmers equally utilize Super seeder and Baler methods to manage crop residues.
- In situations where partial burning is practiced, the primary method involves the use of zero till drill, followed by super seeder technology.

GRAPHICAL ABSTRACT



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ABSTRACT

Introduction: Paddy residue is, generally, burnt by the farmers in the combine harvested fields to prepare land for sowing of next crop in the narrow window between paddy harvesting and the next sowing.

Context: Extensive study on farm machinery for in-situ and ex-situ paddy residue management has been carried out by PAU and several technologies have been given to farmers over the last few years.

Objective: The major objective of this study was to evaluate the extent of adoption of paddy residue management techniques in Sri Muktsar Sahib, a south-western district of Punjab.

Methods: A survey-based study was conducted. To execute the study, 200 farmers were randomly selected from all the administrative blocks of the district and data was collected from these farmers. Coefficient of correlation used for adoption index in crop residue management technologies.

Results and Discussion: The study found that 200 farmers, about 49.3% of farmers fully managed the paddy residue, while 25.1% of farmers managed the paddy residue partially. Additionally, 25.7% of farmers resorted to the complete burning of rice residue. The use of super seeders accounted for 44.8% of the area where rice residue was fully managed. In situations where limited burning occurred, 59.2% of the area was accomplished using zero till drills, whereas super seeder machines were utilized in 40.8% of the area.

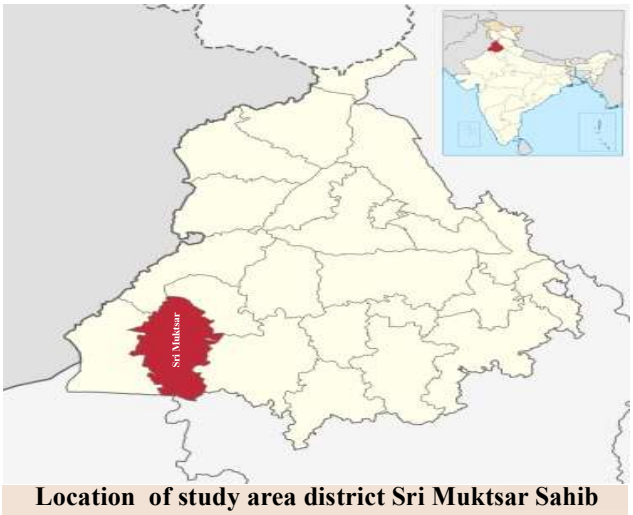
Significance: The study concluded that ex-situ technologies, such as removing paddy straw with a baler and sowing wheat with a zero-till drill, are the most widely adopted techniques in the study area. Among the in-situ paddy straw management methods, the super seeder is extensively used in the Punjab region.

Rice-wheat cropping system is the major cropping system of Punjab. Assured marketing and remunerative prices of these crops give assured income to the farmers of Punjab which encouraged the farmers to adopt this cropping system in large areas in comparison to other cropping systems. India is one of the important manufacturers of rice at the global level (Sharma *et al.* 2015; 2017). The area under rice crops has been increasing continuously for the last five decades and it increased from 16 lakh ha in 1966 to about 31 lakh ha in Punjab during 2020-21 (Kalkat, 2017; Anonymous, 2022a). Presently, about 220 lakh tonnes of straw is produced annually by paddy cultivation in Punjab, management of which has emerged as a serious challenge. The severity of the issue lies in the fact that farmers, after harvesting the paddy crop with a combine harvester, burn the loose straw in the fields to clear them for sowing the next crop, such as wheat (Erenstein, 2011). The majority of farmers, especially the tenant ones considered the straw burning process as the easiest and cheapest way to manage paddy residue which saves time for field preparation (Kaur and Singh, 2023). At present, a large portion of paddy straw (>80%) in the state is burnt in 3-4 weeks during October-November (Singh *et al.* 2010). However, the process of paddy straw burning, by emitting various greenhouse gases (GHGs) (carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O etc.) and fine particles, polluting the air which further affects global climate change and also human and animal health (Singh *et al.* 2008).To the awareness of farmers regarding the ill effects of paddy residue burning and the positive effects of residue retention in the field, a large number of programs are being organized, but despite all these efforts, the farmers prefer to set fire to paddy residue in open fields. A few years ago, farmers were not attentive of the negative effects of paddy straw burning and they had very few options for judicious paddy straw management. Previously, farmers had only one option: burning crop residues. However, agricultural scientists now recommend several techniques for in-situ or ex-situ paddy residue management. These include fitting a super straw management system (SMS) on combine harvesters, as well as using tools like smart seeders, surface seeders, happy seeders, super seeders, zero-till drills, rotavator tillage, reversible mouldboard ploughs, rice straw choppers/mulchers, cutter-cum-shredders, and balers (Kumar *et al.* 2023; Singh *et al.* 2020; Anuradha *et al.* 2021). Many of these methods facilitate the farmers sowing of wheat in the presence of paddy straw without burning or removing it from the field. These methods give higher net returns as compared to the conventional method (Kumar *et al.* 2023). The loose straw and standing stubbles of paddy, after harvesting the crop, need to be managed either by incorporating it into the soil or by removing it from the field for other uses. Paddy residue incorporation in the fields, as an substitute to burning, has been assumed by only a few farmers because they consider paddy residue incorporation a costly as well as energy and time-intensive process (Singh and Sidhu, 2014). Besides, the collection and removal of paddy straw and utilizing it for other uses is the most preferred method in the south western part of Punjab. The present study was showed to assess the extent of the adoption status of various paddy residue management technologies and their impact on the overall management of total paddy residue produced.

METHODOLOGY

A survey-based study was conducted in Sri Muktsar Sahib district of Punjab to extract information regarding the relative adoption of straw management techniques by the farmers during *Rabi* 2021-22. Sri Muktsar Sahib district, a South-Western district of Punjab, located between North Latitude 29˚54’20 and 30˚40’20 and East Longitude 74˚15’ and 74˚19’has dry sub humid climate and grass land type of vegetation. The major cropping systems, that cover most of cultivated area of the district, are rice-wheat and cotton-wheat systems, in which wheat occupied the highest area (~215 thousand ha) followed by rice (~185 thousand ha) and cotton (~29 thousand ha) during 2021-22 (Anonymous, 2022a, b).

As rice-wheat cropping system occupies the



Location of study area district Sri Muktsar Sahib

highest area, management of paddy straw is a big assignment for the farmers. Therefore, the current study aimed to evaluate the relative use of straw management techniques by farmers in the Sri Muktsar Sahib district. To gather the necessary data, 200 farmers were randomly selected using stratified random sampling from all four administrative blocks of the district during the year 2021-22. In each administrative block, five villages were chosen, and data were collected from ten randomly selected farmers in each village. A well-structured and pretested, interview schedule was prepared to elicit responses from the farmers to capture desired information required to meet the objectives. The questionnaire consisted of the name and address of the farmer and the technique followed for paddy straw management during 2021-22 viz. happy seeder, zero till drill, super seeder, rotavator, baler technology, and reversible mould board plough etc.

The data were subjected to analysis using means, frequencies, percentages, and standard deviation, to get the final results. The Pearson correlation analysis was performed with the extent of adoption of paddy straw management technologies" and profile characteristics of farmers viz., age, education, total landholding, annual income, experience, mass media exposure, extension contacts and social participation." Karl Pearson's product moment correlation coefficient (r) was used to find out the degree of relationship between independent (x) variables i.e. and dependent variable (y) i.e adoption index.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\, n\Sigma x^2 - (\Sigma x)^2 \,][\, n\Sigma y^2 - (\Sigma y)^2 \,]}}$$

Where;

r = Coefficient of correlation

n= the number of data points, i.e., (x, y) pairs, in the data set.

$\sum XY$= the sum of the product of the x-value and y-value for each point in the data set.

$\sum X$= the sum of the x-values in the data set.

$\sum Y$= the sum of the y-values in the data set.

$\sum X^2$= the sum of the squares of the x-values in the data set.

$\sum Y^2$= the sum of the squares of the y-values in the data set.

RESULTS

The data presented in Table 1 showed that the total area under paddy cultivation of the studied respondents was 1417.4 ha, out of which, the highest area was under Malout block (465.2 ha) followed by block Muktsar and Lambi (345.6 and 342.0 ha, respectively) while Gidderbaha block covered the lowest area (264.6 ha) under paddy cultivation during the study period. For paddy residue management, the highest area under fully managed rice residue was found in Muktsar block (269.6 ha) followed by Lambi (247.8 ha), Malout (131.6) and Gidderbaha (118.8 ha). Partial burning of paddy straw is the process, in which only loose straw is set on fire while standing stubbles are managed in the field. The highest area under partial burning was observed in Malout block (166.4 ha) followed by Gidderbaha (87.2 ha) and Lambi (42.2 ha), while Muktsar block recorded the lowest area under partial burning. The highest occurrence of full crop residue burning was observed in the Malout block with an area of 167.2 ha and it was followed by Gidderbaha and Lambi blocks with 58.6 and 52 ha area, respectively while Muktsar block shared the lowest area in full residue burning (39.2 ha).

Out of the total area of 1417.4 ha under study, paddy straw was managed in major portion i.e. 54.2 and 23.5 per cent area was fully and partially managed, respectively while only 22.4 per cent area was under full crop residue burning (Fig.1). Among the different blocks, Muktsar showed the highest proportion of area under residue management (78.0 and 10.6% under fully and partially managed, respectively), followed by Lambi block which showed 72.5 and 12.3 per cent area under fully and partially managed, respectively (Fig. 1). The lowest proportion under crop residue management was observed in Malout block which

Table 1. Allocation of area under various paddy residue management methods in different blocks of the district

Block	Fully Managed (ha)	Partially managed (ha)	Fully burned (ha)	Total (ha)
Gidderbaha	118.8 (8.4)	87.2 (6.2)	58.6 (4.1)	264.6 (18.7)
Muktsar	269.6 (19.0)	36.8 (2.6)	39.2 (2.8)	345.6 (24.4)
Lambi	247.8 (17.5)	42.2 (3.0)	52.0 (3.7)	342.0 (24.1)
Malout	131.6 (9.3)	166.4 (11.7)	167.2 (11.8)	465.2 (32.8)
Total	767.8 (54.2)	332.6 (23.5)	317.0 (22.4)	1417.4

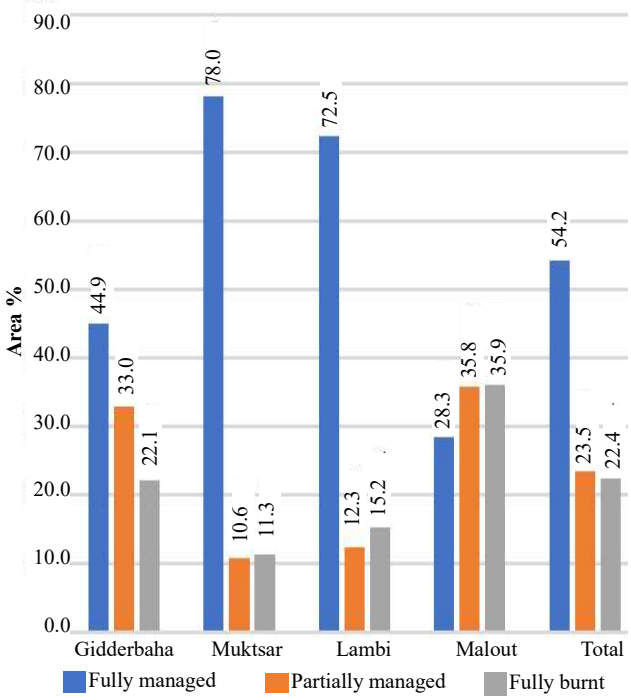


Fig 1. Area distribution under paddy residue management

showed 28.3 and 35.8 per cent area under fully and partially management, respectively, while having the highest proportion under open field burning (35.9%). Thus, a total of 767.8 ha was fully accomplished using different paddy residue management follows viz. super seeder, happy seeder, and straw removal followed by sowing with zero till drill, while rice straw on 332.6ha area was moderately managed for sowing of wheat in the district. Fully rice straw burning was performed on a 317.0ha area to prepare field for wheat sowing. The distribution of respondents (%) under paddy residue management is presented in Fig 2. It revealed that a major portion of respondents (49.3%) fully managed the paddy straw adopting different straw management

Table 2. Area under various paddy residue management methods in the district

Particulars	HS	SS	MMR	B	ZTD	Total
Fully managed						
Area managed (ha)	60.0	344.0	20.4	343.4	-	767.8
% of total	7.8	44.8	2.7	44.7	-	100.0
% of GT	4.2	24.3	1.4	24.2	-	54.2
Partially burning						
Area managed (ha)	0	135.8	0	0	196.8	332.6
% of total	0	40.8	0	0	59.2	100.0
% of GT	0	9.6	0	0	13.9	23.5

HS-*Happy seeder*; SS-*Super seeder*; MMR-*Mulcher + MB Plough + Rotavator*; B-*Baler*; ZTD-*Zero Till Drill*

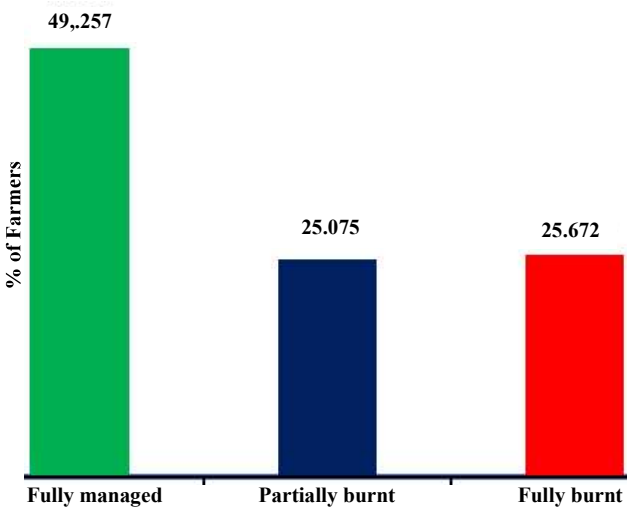


Fig 2: Distribution of respondents under paddy residue management

methods followed fully burning (25.7% of respondents) and partial burning (25.1% of respondents) of paddy residue. Overall, 54.20 per cent of the total area is fully managed, 23.50% is partially managed, and 22.40 per cent is fully burned.

The present study revealed that under the conditions of fully managed paddy residue, the major portion of paddy straw was managed by using super seeder (44.8%), a machine used for incorporation of crop residue at the time of sowing (Table 2). Super seeder technology was closely followed by rice straw removal using baler technology (44.7%). Happy seeder technology was adopted on 7.8 per cent of the studied area and a occupied freight of paddy straw was managed using this knowledge. Incorporation of paddy residue by using a mulcher followed by MB plough covered the lowest area (2.7%) among the paddy residue management technologies. In case of partial burning of rice straw, the highest area (59.2%) was managed by zero till drill. In this condition, loose straw was burnt while the remaining standing stubbles were *in-situ* managed by sowing wheat crop using zero till drill. Super seeder was the second most preferred technology (40.8%) for managing standing stubbles after burning loose straw. Wheat sowing with happy seeder and incorporation with MB plough was not adopted by the farmers in partial residue burning conditions. If we consider the total of fully managed and partially managed rice residue area (1100.4 ha), zero till drill covered the highest proportion (49.1%) followed by the super seeder technology (43.6%).

Based on the number of respondents who accomplished the rice residue, it was found that paddy

Table 3. Number of respondents adopted different paddy residue management techniques in Sri Muktsar Sahib District of Punjab

Technology	Partial burning		Fully managed		Fully burnt	
	No.	% of GT	No.	% of GT	No.	% of GT
Happy seeder	-	-	14	4.2	-	-
Super seeder	26	7.8	66	19.7	-	-
Mulcher + MB Plough + Rotavator	-	-	12	3.6	-	-
Removal	-	-			-	-
i) Baler	-	-	73	21.8	-	-
ii) Zero Drill	58	17.3			-	-
Total	84	25.1	165	49.3	86	25.7

straw was fully managed by 49.3 per cent and partially managed by 25.1 per cent of the respondents using different methods (Table 3). A total of 25.7 per cent of farmers did not adopt any straw management methods and fully burnt the paddy straw. Out of the total farmers who fully managed rice straw, the highest number of farmers (21.8%) managed rice straw using baler technology followed by 19.7 per cent of farmers adopting super seeder, 4.20 per cent of farmers adopting happy seeder and 3.6 per cent of farmers adopting MB plough. Among the farmers who opted for partial management of rice residue, 17.3 per cent managed rice straw using zero till drill while 7.8 per cent of farmers used super seeder. According to Bhattacharjee *et al* (2021), majority (89%) of the farmers had a medium adoption level of practicing organic farming.The adoption of various paddy residue management techniques among respondents in Sri Muktsar Sahib District. The majority of respondents fully managed their paddy residue, with a significant number using balers and super seeders. Partial burning was less common, primarily involving super seeders and zero drills. A smaller portion of respondents opted for fully burning the residue.

The Table 4 shows the relationship between the socio-personal characteristics of respondents and their adoption index of paddy straw management technologies, as measured by the Karl Pearson correlation coefficient (r-value). The findings suggest that various characteristics have a significant relationship with the adoption of technologies.

Firstly, age showed a negative correlation with the adoption index, indicating that younger farmers were more likely to adopt crop residue management

Table 4. Relationship of the socio-personal characteristics of respondents with adoption index of in crop residue management technologies

Independent variable	r value
Age	-0.328*
Education	0.422*
Total Land Holding	0.125
Annual Income	0.113
Farming experience	0.211
Extension contacts	0.488*
Mass media exposure	0.342*
Social Participation	0.362*
Risk bearing capacity	0.452*

* Significant at 5 percent level

techniques. Education, extension contacts, mass media exposure, social participation, and risk-bearing capacity all showed positive correlations with the adoption index. This suggests that farmers with higher levels of education, more extension contacts, greater exposure to mass media, higher levels of social participation, and a greater risk-bearing capacity were more likely to adopt crop residue management technologies.

On the other hand, total landholding, annual income, and farming experience did not show a significant relationship with the adoption index. This implies that factors such as education, access to information through extension services and mass media, social connections, and willingness to take risks play a more significant role in technology adoption in crop residue management.

Overall, the findings highlight the importance of socio-personal characteristics in influencing farmers' decisions to adopt these technologies and suggest that targeted interventions in these areas could help promote the adoption of crop residue management technologies. These results were inconformity with the results of Hussain *et al*. (2009).

DISCUSSION

The study revealed the highest proportion of area and farmers was under paddy residue management. The prominent prevalence of paddy residue management in the study area can be attributed to the implementation of cutting-edge agricultural machinery solutions pioneered at Punjab Agricultural University. The crop residue management machinery has played a central role in the technology dissemination efforts aimed at effectively managing paddy straw without resorting to burning (Mahal *et al*. 2019). Besides this, the adoption

of paddy straw management technologies has become increasingly significant following the governmental ban on burning paddy straw and the restrictions imposed by courts or the National Green Tribunal (Buttar *et al.* 2023). Sharma *et al.* (2022) also reported the similar results.

Among the various *in-situ* paddy residue management practices, super seeder shared the major contribution as compared to happy seeder and MB plough. This might be due to fact that after exposure to super seeder machines during 2020-21, farmers adopted this technology on a large scale as this technology resonates well with farmers' psychology of clean cultivation as in conventional agriculture system (Buttar *et al.* 2023). Although, happy seeder technology for wheat sowing ensures timely sowing, economic benefits, improved water use efficiency and decrease in weed problem along with the sustained wheat productivity (Gupta *et al.* 2021; Singh *et al.* 2020), however, Singh *et al.* (2021) found that the complexity of the machine has significant negative effects on the rate of adoption. For ex-situ management, removal of rice residue with baler is the most used technology which is generally followed by wheat sowing by zero till drill. Baler technology is adopted for removing paddy straw from the combine harvested fields (Venkata *et al.* 2020) and has social and economic viability in South-Western part of Punjab (Singh *et al.* 2017). Sharma *et al.* (2022) also It was reported that the majority of areas with fully managed rice residue utilized baler technology. The lower adoption of MB plough technology may be due to the increased cultivation costs associated with its use, as it requires more than five tillage operations to integrate the heavy rice residue load, leading to higher diesel fuel consumption. (Singh *et al.* 2021). In scenarios of partial burning, where only loose straw is burnt, leaving standing stubbles in the field, the feasibility of baling the straw diminishes. However, the use of a zero-till drill remains practical, as it can operate smoothly without any choking during the sowing operation. Earlier studies reported that zero tillage technology, being a technically feasible technique, satisfy the farmers by giving yield advantage, reducing the irrigation and cultivation cost, maintaining soil health, reducing labour requirement and Phalaris minor infestation (Kumar *et al.* 2016; Singh *et al*. 2007).The higher adoption of some specific technologies might be due to the fact that the beneficiary farmers in the study area have gained more experience regarding particular techniques through demonstrations, trainings, and other extension programs which improved their adoption and skill. The results of the study are inconformity with the findings of Raghav *et al.* 2021; Marbaniang *et al*. 2021 and Kumbhare and Singh (2011).

CONCLUSION

As paddy straw burning has several adverse effects such as environmental pollution, soiled gradation, health problems etc., there is immense need to stop the paddy straw burning in open fields. Farmers have different alternatives for in-situ and ex-situ paddy residue management. Removal of straw using baler technology has helped the farmers in study area to solve the problem of rice residue burning. After removal of straw, farmers generally sow the crop with zero till drill. Similarly, the farmers, who wish to partially manage paddy straw, also found zero till drill technology the most suitable one. Thus, zero-till drilling has primarily been adopted by farmers in fields where straw has been partially burnt or removed using baler technology. Super seeder has been found the second preferred option after zero drill in fully and partially residue managed fields. Farmers adopted happy seeder and straw incorporation with MB plough only at smaller scales. Hence, the study concluded that ex-situ technologies i.e. removing of paddy straw by baler and sowing of wheat with zero till drill are the most adopted techniques in the study area. Among the in-situ paddy straw management techniques, super seeder is being adopted at a large extent in the study area of Punjab.

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Declaration of competing interest: Authors have no competing interests.

Data availability: Data would be made available on request

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Appendix: Supplementary data : The supplementary data, table, graph in jpeg format for online visibility to the readers are submitted as an appendix.

Author's contribution: The first author conceptualized operationalized, collected, collated, analyzed the data and interpreted the data and contributing to text and the content of the manuscript. The second and third author participated in conceptualized, operationalized,

contributing to text and the content of the manuscript, including revisions and edits.

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