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Identifying Key Barriers to Resource-Conserving Technology Adoption in Punjab Agriculture

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Abstract: This study investigates the adoption of Resource-Conserving Technologies (RCTs) in Punjab's agriculture, focusing on paddy-wheat and cotton-wheat cropping systems. Despite the environmental and economic advantages of RCTs, such as reduced greenhouse gas emissions, improved soil health, and efficient resource use, adoption rates in Punjab remain uneven. The research identifies key barriers to RCT adoption, including high costs of machinery, inappropriate sowing moisture, and limited crop residue management practices. Data collected from 120 farmers across two districts, Mansa and Sri Muktsar Sahib reveals significant gaps, particularly in the cotton-wheat system where adoption is notably low. The study employs a Resource Conservation Index (RCI) to quantify the extent of RCT adoption and utilizes Garrett's ranking technique to evaluate the problems faced by farmers. Findings indicate that while paddy-wheat farmers show moderate to high adoption levels, cotton-wheat farmers lag behind. To enhance RCT adoption, the study recommends financial incentives, increased availability of machinery, and greater awareness about the benefits of crop residue management. Addressing these barriers is crucial for advancing sustainable agriculture in Punjab and ensuring the long-term viability of its farming systems.

Keywords: Adoption, Constraints, Direct seeded rice, Punjab, Technologies

Resource-Conserving Technologies (RCTs) encompass practices and innovations that enhance the efficiency of resource use in agriculture (Ghosh et al 2017). These technologies are pivotal in advancing sustainable agriculture, particularly in regions like Punjab, where traditional cropping systems, such as paddy-wheat and cotton-wheat, are prevalent. These systems have historically bolstered economic growthbut also raised significant environmental concerns, including groundwater depletion, soil erosion, and air pollution from the burning of crop residues. To mitigate these challenges, a range of RCTs has been introduced, including the happy seeder, super seeder, zero tillage, direct seeded rice, crop residue management, and integrated pest management. The happy seeder is a notable RCT that facilitates resource conservation by integrating several processes. This tractor-mounted machine cuts and lifts rice straw, sows wheat directly into the soil, and then spreads the straw as mulch over the sown area. By providing an alternative to burning rice residues, the happy seeder allows for direct drilling of wheat into both standing and loose residues (Gathala et al 2011). Similarly, the super seeder offers an innovative approach by chopping and lifting rice straw, planting wheat, and covering the area with straw. This technology allows for immediate sowing of wheat after rice harvest, bypassing the need for burning rice residues and enabling planting 7-10 days earlier than traditional methods. The super seeder is designed to be environmentally friendly, enhancing soil productivity while avoiding harm to local flora and fauna (Kathapalia et al 2022). Zero-tillage technology represents another key RCT, characterized by minimal soil disturbance. This approach primarily involves controlling unwanted vegetation through non-mechanical methods or using minimal tillage equipment, thereby reducing tillage operations to essential tasks like traffic and seed-bed preparation. Originating in the 1950s in the United States for pasture renovation, zero tillage has since become a widely adopted practice.

Direct seeding of rice is an alternative method that conserves soil and water by sowing seeds directly in the field, bypassing the traditional transplanting of seedlings. This approach addresses labour shortages and avoids the negative impacts of soil puddling, such as soil structure disruption and reduced permeability (Bhardwaj and Sidana 2014). The increasing scarcity of water and labour is driving farmers to adopt direct-seeded rice over conventional transplanting methods (Rakesh et al 2017). Crop residue management is a crucial RCT aimed at addressing agricultural waste. Traditional residue removal methods are often costly and labour-intensive, leading many farmers to burn crop residues. In response, various in-situ straw incorporation technologies have been recommended, including straw management systems, zero till drills, happy seeders, super seeders, reversible mould board ploughs, rotavators, and rice straw choppers/mulchers (Singh et al 2022). However, adoption of these technologies remains limited due to high costs and the energy required for in-situ incorporation (Singh and Sidhu 2014). Alternatively, paddy straw can be collected and removal of paddy straw from field by using rake and baler and utilizing it for animal feed, mulch, paper production, or biomass energy generation.

These RCTs are designed to lower input costs, conserve water, improve soil fertility, and reduce greenhouse gas emissions. However, the adoption of these technologies in Punjab has been uneven due to socio-economic, technical, and institutional challenges. Therefore, the present study is devised to gather information on adoption status of RCTs, and major problems faced by farmers while adopting these RCTs.

MATERIAL AND METHEODS

Location and sampling procedure: The study was conducted in Punjab, focusing on farmers from Mansa and Sri Muktsar Sahib district using a multi-stage sampling technique. Initially, districts with the highest proportion of paddy, wheat, and cotton cropped areas were chosen. Mansa and Sri Muktsar Sahib were selected. In the second stage, four villages from each district were randomly selected: Ubha, Uddat Bhagat Ram, Guarangana, and Khialamalkpur from Mansa, and Doda, Roranwali, Bhalaina, and Kot Bhai from Sri Muktsar Sahib. In the final stage, a list of farmers adopting various resource conservation technologies (RCTs) was compiled with assistance from KVK scientists and agricultural development officers. The sample farmers were finalised after focused group discussions were done with various panchayat members and progressive farmers. From this t, 15 farmers per village were chosen, ensuring representation of both RCT adopters and non-adopters. The final sample comprised 120 farm households, with 60 focusing on paddy-wheat sequence, and 60 on cotton-wheat sequence.

Data collection: Data collection involved primary sources. Adetailed interview schedule was prepared to align with the study's objectives. This schedule was pre-tested in the study area, leading to revisions to correct redundancies and address missing information. Primary data were gathered through personal interviews using the revised schedule, focusing on major RCTs and their constraints for paddy, wheat, and cotton crops during the 2021-22 agricultural year.

Construction of resource conservation Index (RCI): Resource conservation index (RCI) was constructed through summative method by taking into account method adopted for sowing in paddy, crop residue management of paddy and method adopted for sowing of wheat in paddy-wheat sequence and method adopted for cultivating cotton, method adopted for sowing wheat in case of cotton-wheat sequence (Table 1).

Resource conservation index for paddy-wheat (RCI_{PW}) = method adopted for sowing in paddy + crop residue management of paddy + method adopted for sowing of wheat)

Resource conservation index for cotton-wheat (RCI_{CW}) = method adopted for cultivating cotton +method adopted for sowing wheat.

Garrett ranking: This method was used to evaluate the problems faced by farmers for adoption of RCTs. The farmers were asked to rank the given problem according to the magnitude of the problem. The orders of merit given by the respondents were converted into ranks by using the following formula:

$$\text{Percent position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij} = Rank given for the ith item by the jth individual

N_j = Number of items ranked by the jth individual

Table 1. Construction of resource conservation Index

Indicators of resource conservation	Assigned score	Minimum score	Maximum score
Paddy-wheat crop rotation			
Method adopted for sowing paddy (A)	0 if puddled transplanted rice 1 if direct seeded rice	0	1
Crop residue management of Paddy (B)	0 if not managed 1 if managed	0	1
Method adopted for sowing wheat (C)	0 if conventional tillage 1 if modern tillage	0	1
Resource Conservation Index for paddy-wheat (RCI_{PW}) = A+B+C		0	3
Cotton-wheat crop rotation			
Method adopted for cultivating cotton (D)	0 if not integrated pest management 1 if integrated pest management	0	1
Method adopted for sowing wheat (E)	0 if conventional tillage 1 if modern tillage	0	1
Resource Conservation Index for cotton-wheat (RCI_{CW}) = D+E		0	2

The percentage position of each rank thus obtained was converted into scores by referring to the table provided by Henry Garrett. Then for each factor the scores of individual sample farmers were added together and divided by the total respondents for whom scores were added. Thus, mean score for each problem was ranked by arranging them in the descending order.

RESULTS AND DISCUSSION

The constructed RCI ranged between 0 (representing entirely non-adopters of modern farming practices for paddy-wheat and cotton-wheat) and 2 (representing complete adopters of resource conservation technologies for paddy-wheat and cotton-wheat). Hence, RCI has as a scale to measure the extent of modern farming practiced by the farmers in the study area. Based on the points scored on the RCI scale, farmers were classified into four groups (Table 2). Farmers were categorized based on their adoption of RCTs for two different cropping systems: paddy-wheat and cotton-wheat. It provides a comparative view of the extent of RCT adoption among farmers in these systems by dividing them into four groups: non-adopters, fair adopters, good adopters, and exceptional adopters.

For paddy-wheat farmers, more diverse range of adoption levels. The 26.67% of farmers are non-adopters, meaning thereby that they do not engage with RCTs. The 23.33% of the farmers are fair adopters, showing moderate use of these technologies. The largest group, comprising 35% of the farmers, are classified as good adopters, indicating that a significant number of farmers have integrated RCTs well into their practices. The remaining 15% are exceptional adopters, representing the highest level of commitment to resource conservation. In contrast, the adoption of RCTs in the cotton-wheat system is less advanced. More than half (55%) of the farmers fall under the non-adopter category, indicating a limited embrace of RCTs. Only 45% of the cotton-wheat farmers came under the category of are considered fair adopters. There are no farmers in the cotton-wheat system who qualify as good or exceptional adopters. This contrast suggests that while paddy-wheat farmers in the study area are making more substantial strides in adopting RCTs, cotton-wheat farmers are lagging behind. This indicates clear need for targeted efforts to improve RCT adoption in cotton-wheat cultivation, possibly through increased awareness, technical support, or incentives.

Table 2. Categories of paddy-wheat and cotton-wheat growers on the basis of extent of resource conservation technologies adoption

Categories	Paddy-wheat		Cotton-wheat	
	RCI_{PW}	Percentage	RCI_{CW}	Percentage
Non adopters	0	26.67	0	55
Fair adopters	1	23.33	1	45
Good adopters	2	35	2	0
Exceptional	3	15	-	-

In DSR in paddy, only 23.33% of farmers adopted the technology, leaving 76.67% still relying on traditional methods. For crop residue management (CRM) in paddy, the adoption is slightly better, with 35.83% of farmers implementing it, but a majority (64.17%) have not. Modern tillage in wheat shows an equal adoption rate, where 50% of farmers have adopted the technique and 50% have not. High level of adoption among farmers regarding Super Seeder which constitute of 53.33 per cent was seen in Haryana also (Kathpalia et al 2023). For IPM for cotton, 38.33% of farmers have adopted the practice, while the remaining 61.67% have not. This variation in adoption rates highlights the challenges in promoting RCTs, particularly in paddy and cotton cultivation, and underscores the need for further interventions to improve technology uptake among farmers.

Problems Faced in Adoption of RCTs in Paddy-Wheat and Cotton-Wheat Crop Rotation

Happy seeder / super seeder: Among the sample data, based on farmer's experience, the major problem encompassed by the farmers for adoption of happy seeder/super seeder was high cost of machinery and high inappropriate moisture at sowing. Inappropriate moisture at sowing is also correlated with another main problem i.e., lower seed germination indicated by 47.75 Garrett's score (Table 3). Singh et al (2022) stated in their study that 35 per cent farmers were facing the problem of shortage of hired machinery.

Zero till drill: In adoption of zero till drill, the major problem reported by farmers was low germination of seed having

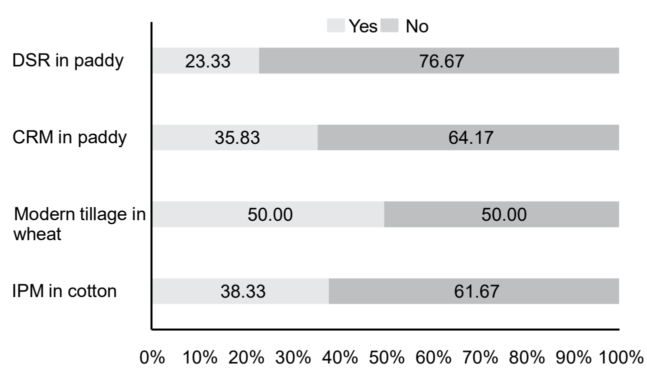

Fig. 1. Paddy, wheat and cotton cultivators with respect to indicators of resource conservation technologies

57.75 average score followed by non-availability at the time of sowing. Inappropriate moisture at sowing was observed to be the least problematic parameter in adoption of zero till drill with an average score of 38.50, followed by high cost of zero till drill with 48.08 Garrett's score.

Direct seeded rice technology: Among various DSR problems faced by sample farmers, less yield of crop was observed to be top ranked with 68.83 Garrett's average score. The second and third rank was given to increased cost of production due to more requirements of herbicides and low seed germination. More pesticide requirement was another problem in adoption of direct seeded rice.

Table 3. Problems faced by farmers for adoption of RCTs in paddy-wheat and cotton-wheat crop rotation, Punjab (2021-22)

Problems	Garrett's average score	Rank
Problems in adoption of happy seeder / super seeder		
High cost of machinery	67.50	I
Inappropriate moisture at sowing	54.42	II
Low seed germination	47.75	III
Lack of technical know how	40.67	IV
Loose straw affects functioning of machinery	39.50	V
Problems in adoption of zero till drill		
Low seed germination	57.75	I
Non availability of machineat the time of sowing	54.58	II
Unwillingness to adopt	54.08	III
High cost of zero till drill	48.08	IV
Inappropriate moisture at time of sowing	38.50	V
Problems in adoption of direct seeded rice technology		
Less yield of crop	60.83	I
Increased cost of production due to more requirement of herbicides	51.92	II
Low seed germination	51.00	III
Requirement of specific machinery	44.25	IV
DSR requires more pesticides	43.08	V
Problems in adoption of IPM in cotton		
Does not fulfil the complete insecticide requirement	55.22	I
More infestation of Insect pests	54.83	II
Less knowledge	50.17	III
Labour intensive practice	48.97	IV
Complicated procedure	42.97	V
Problems in adoption of crop residue management		
Extra cost involved	70.42	I
Shortage of hired machine	59.17	II
No market value of paddy straw	46.50	III
Delays sowing of preceding crop	43.75	IV
Shortage of skilled labour	29.17	V

IPM in cotton: According to Garrett's ranking technique IPM in cotton does not fulfill the complete insecticide requirement occupied the first rank with an average score of 55.22 followed by the problem of more infestation of insect pests. Labour intensive practice and complicated procedure were perceived as general problems by the farmers in IPM adoption. Previous studies have highlighted similar challenges with IPM adoption, noting increased risks of inadequate pest control, higher labour costs, and the need for new equipment (Kudusk Per 2023).

Crop residue management: Problems faced by the sample farmers in adoption of crop residue management varied with a huge difference in its average score. Non-adopter farmers reported that extra cost involved in crop residue management was one of the major constraints. Shortage of machines like bailer, paddy chopper and others were ranked second with an average score of 59.17. Absence of paddy straw's market value and delay in sowing of proceeding crop was regarded as other challenges faced by the farmers. Shortage of skilled labours with an average least Garrett's score of 29.17 was accounted as other issue among the farmers. Chopra and Bansal (2022) mentioned that labour shortage at the time of harvesting and the costly process of cleaning the field after harvesting paddy crop are other vital determinants leading to crop residue burning cases in Punjab.

Policy implications: To encourage the rapid adoption of this technology financial help should be provided to farmers for motivating them to adopt RCTs and timely-availability of machinery for ex-situ management for reducing the carbon footprint. Low availability of ex-situ machines such as balers and storage infrastructure is another reason for low adoption of ex-situ management practices. Efforts should be made for increasing the demand of paddy straw as a raw material for industries, new inventions and alternative technologies e.g. bio char production, raw material for power generation and paper mill industry, bedding material for livestock. For maximum adoption of paddy residue management technology, there should be more availability of paddy residue management machines at co-operatives, raising awareness among farmers regarding importance of crop residues in conservation agriculture and providing incentives to the adopter farmers who adopt stubble management technology. Similarly, for modern tillage of wheat, super seeder and happy seeder shall have to be made available to the farmers especially among small and marginal farmers on custom-hiring basis through co-operatively managed machinery service centres. There is a need for capacity building of farmers for effective management of weed and pest in DSR. There is a need to improve efficiency of agricultural pump sets to improve water use efficiency which lowers carbon emissions, increasing fertilizers N use efficiency by reducing the use of N based fertilizers, reducing fossil fuels by doing less tillage and prevention of paddy residue burning by using various ex-situ and in-situ technologies. These all mitigation strategies will help reduce agricultural GHG emissions in the state.

CONCLUSION

The study identifies critical gaps in the adoption of RCTs in Punjab's paddy-wheat and cotton-wheat cropping systems. Despite their clear advantages such as reducing environmental impact, improving resource use efficiency, and enhancing soil health, RCT adoption remains suboptimal. Key challenges include high machinery costs, suboptimal moisture levels at sowing, and inadequate crop residue management. Adoption trends in the paddy-wheat system show progress, particularly with practices like direct seeded rice and happy seeder gaining wider acceptance among farmers. However, adoption in the cotton-wheat system lags, highlighting the need for targeted interventions. Addressing barriers through financial incentives, improving machinery access, and raising awareness about the benefits of crop residue management are essential for wider RCT adoption. Supporting innovations in crop residue utilization and improving water use efficiency can further reduce emissions and promote sustainability. By implementing these strategies, Punjab can progress toward a more sustainable agricultural system, balancing environmental, economic, and resource conservation goals.

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