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Paddy Residue Management Alternatives in Punjab, India: An Economic Analysis

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***Abstract*:** Farmer's choice of using crop residue management (CRM) method depends on different factors like the quantum of residue generated, accessibility and affordability of CRM solutions and other technical or marketing constraints. Considering the earnest need for well-managed CRM system with good potential for resource use efficiency, the present study was conducted in the Punjab state during the year 2020-21.Among the four prevalent strategies i.e. complete burning (CB), partial burning (PB), complete incorporation (CI) and complete removal (CR), the CI method proved to be the most cost-effective with highest returns (Rs.115274.2 per hectare) because of higher yield though CB was the most preferred by all the farm categories. CR raised the farmers' burden by Rs. 7200 per hectare in comparison to CB. Majority of the respondents faced technical problems related to lack of practical knowledge about operating machines, seed rate, moisture requirements and complicated methods followed by economical, managerial and marketing constraints. Steps like compensation to farmers by integrating the cost of paddy residue management in the MSP, assuring the availability of residue management machinery at reduced rates, improving custom hire services and extension services are needed to deal with the state's paddy straw management.

***Keywords*:** Constraints, Economics, Input use, Management methods, Paddy residue

India is an agrarian economy. An average of 500 million tons of agricultural leftover is produced every year from various crop species, with rice accounting for the majority (34 Percent) of the residue (Bimbraw 2019). Globally, India ranks second in the production of rice, and stands first in the world in terms of paddy straw burning, accounting for around 27 per cent of the total rice residue burnt (Kumaret al 2019). In situ burning of agricultural residues produces not only greenhouse gases which contribute to global warming and particulate matter, but also plant nutrients like N, P and K which have negative effects on soil characteristics and cost money (Lohanet al 2018). Punjab produces approximately, 19 per cent wheat, 11 per cent of rice and 5 per cent of cotton of the country. Around 75 to 80 per cent of the area under paddy is machine-harvested, and approximately 95 per cent of paddy straw is burnt annually in the state (Singh et al 2018). In a study for NW India, the social cost of paddy straw burning was the highest for Punjab (Rs 1804 crores) (Kumar et al 2019). The annual monetary cost of crop residue burning is about Rs 800-2000 crore in terms of nutritional loss and Rs 500-1500 crore in the form of government subsidies on fertilizers to Punjab farmers (Alexakiet al 2019). Therefore, there is an earnest need for well-managed crop residue management (CRM) systems with good potential for resource use efficiency. Although, farmers are expected to use CRM machines for managing the stubble but still its burning has been a common way of managing crop residue even after the imposition of ban on stubble burning by the government. Therefore, it has become very important to find out the economically viable alternatives of paddy residue management. Keeping this in view, the present study was conducted to evaluate the production, management, present status and cost of paddy residue management alternatives along with the related problems faced by the farmers in the Punjab state.

MATERIAL AND METHODS

The present study was carried out in the South Western Punjab during the year 2020-21. Multi-stage random sampling technique was followed to draw a representative sample. At the first stage, two districts namely Sri Mukatsar Sahib and Firozpur were selected and at the second stage, two blocks from each selected district namely, Gidderbaha and Sri MukatsarSahib from district Sri Mukatsar Sahib and Ghalkhurd and Zira from Firozpur district were selected at random (Table 1, Fig. 1). At third stage, two villages from each selected block were chosen and hence total of eight villages were selected to carry out the study. A sample of five farmers from each category (i.e. small, medium and large farmers according to their operational holdings with upto 5acres, 5 to 15 acres and more than 15 acres, respectively) from each village was selected making a total sample 120 farmers.

Data were collected using pre-tested questionnaire regarding production and utilization of paddy residue,

different residue management methods (RMMs) followed along with different constraints faced by farmers in the adopting the RMMs. Statistical techniques like percentage, average, etc. were worked out to analyses the data. Average mean score method was used to rank the problems faced by the respondents in paddy residue management. The different RMMs techniques used on the farms of selected farmers are as follows:

Complete Burning (CB): After harvesting of paddy, the loose straw and stubbles were cut using a straw cutter-cum spreader and the paddy straw was burnt completely. The field was then sown directly with zero till drill technique or prepared by ploughing for sowing wheat.

Partial Burning (PB): The loose straw produced with combine harvesting was burnt directly and wheat was sown in the remaining standing stubbles using tractor drawn zero till drill or after incorporation of standing stubbles by using various tractor drafted implements like disc harrow, cultivator, rotavator, etc. for the tillage.

Complete Incorporation (CI): After harvesting paddy, wheat was sown in the loose straw and standing stubbles using Super seeder, Happy seeder and Mulcher run by tractor. No separate preparatory tillage is required as the seed-bed preparation and sowing along with straw management is done in a single operation.

Complete Removal (CR): After paddy harvesting, straw was chopped with straw cutter cum spreader. Then the tractor run rotary rake is used to collect straw into windrows which is next turned into straw bales by tractor operated straw baler. The straw bales are then collected from the field manually and transported/stored and the field was prepared for sowing wheat.

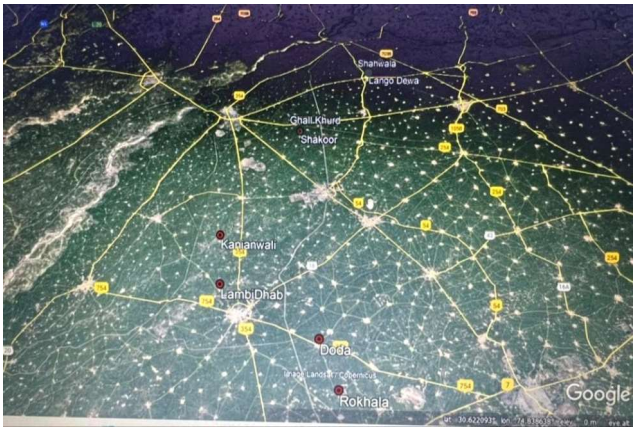

Fig. 1. Geographical distribution of the selected villages in the study

RESULTS AND DISCUSSION

Status of paddy residue management in Punjab: The complete burning (CB) emerged out to be the most preferred method by majority i.e. 68 farmers (48.95 % of total paddy area), followed by partial burning, complete removal and complete incorporation (Table 2). Farm category wise analysis indicated that among all the farm categories, CB was the most preferred method for paddy residue management. Large farmers opted for CR (21.91 %) while PB emerged to be the second most adopted RMM for small farmers (30.93 %) and medium category (17.78 %).

Input use under different residue management methods : The input use pattern for wheat following the paddy crop revealed that the seed rate was the highest (118.6 kg/Ha) on farms where wheat was sown after CI of paddy straw (Table 3), followed by PB,CB and CR. Respondents believed that paddy straw incorporation caused germination issues, necessitating the use of higher seed rates to compensate for the poor germination (Table 3). Plant protection costs were lower (Rs. 2525 and 2528) on farms following CB and CR technique respectively than on farms that used PB and CI (Rs. 2709.and Rs.2956 respectively). The fertiliser use ranged from 445 kg per hectare on farms using CI technique to 478 kg per hectare on fields following CB. Different studies indicate that unlike removal or burning of crop residue which put the adverse effect on soil climate and micro-organisms,

Table 1. Distribution of farmers selected for the study

District	Block	Village	Latitude	longitude
			N	E
Sri Mukatsar Sahib	Gidderbaha	Rokhala	30.29	74.64
		Doda	30.38	74.64
	Sri Mukatsar Sahib	LambiDhab	30.53	74.50
		Kanianwali	30.62	74.52
Firozpur	Ghal Khurd	Ghall Khurd	30.86	74.81
		Shakoor	30.83	74.76
	Zira	Lango Dewa	30.97	74.99
		Shahwala	31.00	75.04

incorporation of straw increases soil organic matter and N, P and K contents in soil (Adam 2013, Lohan et al 2018). According to PAU recommendations also, incorporation of paddy straw or its retention through Happy Seeder for more than three years helps in increasing the wheat productivity and improves soil health and from fourth year onwards, 20 kg urea can be saved per acre (PAU, 2021).

Comparison of time devoted to irrigation revealed that the irrigation hours were the highest for PB than other three methods of RRM. In terms of human labour involved, CR was most labour intensive (170 hours per hectare). In terms of machine labour though almost same time was involved in harvesting paddy with combine and making wheat straw (turi) yet the tractor use for CI method was the least. CR required higher machine use in order to collect straw and make bales for transportation (4 hours). The average yield was marginally high (52.7 auintals/Ha) for CI method in comparison to CB (51.5 quintals/Ha), PB (52.5 quintals/ha) and CR (52.2 quintals/ha). As a consequence, it can be concluded that straw management technique has no direct impact on wheat crop production, except in cases where wheat was seeded after paddy straw incorporation, which enrich soil by providing food to soil friendly organisms and aids in increasing soil fertility (Gill and Singh 2020) which benefit the farmers directly

Table 2. Paddy residue management methods followed by the farmers in Punjab

(Multiple response)

Residue management method/Farm category	Small		Medium		Large		Overall		
	No.	Area	No	Area	No.	Area	No.	Area	Residue
Complete burning (CB)	18	20.85 (54.65)	21	71.20 (49.44)	29	157.4 (48.07)	68	249.45 (48.95)	0.00
Partial burning (PB)	13	11.80 (30.93)	10	25.60 (17.78)	12	53.3 (16.28)	35	90.70 (17.80)	0.00
Complete incorporation (CI)	1	0.60 (1.57)	7	22.25 (15.45)	9	45.00 (13.74)	17	67.85 (13.31)	7011.25 (40.11)
Complete removal (CR)	4	4.90 (12.84)	10	24.95 (17.33)	17	71.75 (21.91)	31	101.60 (19.94)	10467.75 (59.89)
Total	36	38.15 (100.0)	48	144.0 (100.0)	67	327.45 (100.0)	151	509.60 (100.0)	17479.0 (100.0)

Note: I. Figures in parentheses are percentages from respective totals
ii. No crop residue from Paddy and Basmati was generated in case of CB and PB.
iii. Area in hectares and Crop residue is in Quintals;
Source: Field Survey

Table 3. Input use pattern under different paddy straw management techniques in Punjab

(Per hectare)

Particulars	Paddy straw management technologies							
	CB		PB		CI		CR	
	Q	V	Q	V	Q	V	Q	V
Seed (kg)	105.7	2848.0	111.6	3011.9	118.6	3218.2	106.0	2848.9
Fertiliser (kg)	478.2	5768.3	462.8	5571.9	445.3	5538.9	469.7	5571.7
Plant protection	0.0	2525.0	0.0	2709.6	0.0	2956.3	0.0	2528.8
Irrigation (hrs.)	50.7	708.9	76.7	1077.6	53.1	742.6	52.6	735.9
Human labor (hrs)	146.8	7683.9	153.1	8340.1	126.1	6648.7	170.0	12457.2
Combine harvesting (hrs)	1.5	3146.0	1.6	3096.6	1.7	3063.7	1.5	3128.1
Straw Reaper (hrs)	2.4	3978.8	2.6	4062.0	2.6	4090.2	2.5	4031.8
Tractor use (hrs)	14.1	5163.1	16.6	5915.7	7.8	5216.7	13.3	5151.0
Other machinery use*							4.0	3576.6
Yield (qtl)	51.5	101687.8	52.5	103638.1	52.7	104033.1	52.2	103021.0

Note: (i) CB, PB, CI, CR means complete burning, partial burning, complete incorporation and complete removal respectively , (ii) Q is the quantity and V is value in Rs., (iii) *other machinery use includes use of raker and baler.
Source: Field Survey

in terms of main product as well as the by-product of wheat crop through which farmer can get extra cash.

Cost-return structure of different residue management methods: The cost of machine use was the highest i.e.Rs 6355 per acre for CR and lowest i.e. Rs 4915 per acre for CB method (Table 4). Machine use was observed for tractors along with different implements for paddy straw management, sowing of the wheat crop, for transportation/marketing on farm and for manufacturing of wheat straw and combine harvester for harvesting of the wheat crop. For all of these farm activities, custom hiring rates and own machinery costs common in the research region were utilized to calculate the cost of machine usage.

The gross returns were the highest (Rs 115274.2 per Ha) on farms employing the CI and the lowest (Rs 112631.1 per Ha) on farms following CB. Furthermore, farmers that follow CR or PB obtained nearly identical gross returns with minor variations. Returns over variable cost (ROVC) were highest (Rs 82382.6 per Ha) on farms where wheat was sown following CI and lowest (Rs 72134.1 per ha) on farms that follows CR practices. CI technique, ROVC were roughly higher by about Rs 3000 per Ha than in conventional method of CB and this figure was only about Rs 140 per Ha for PB.In case of CR, the ROVC were about Rs 7200 per Ha less than for the CB method. In a similar study, the CI method using happy seeder proved to be the most cost-effective method of treating paddy straw before seeding wheat crops while other straw management techniques raised the burden on farmers from Rs 2000 to 5100 per hectare (Singh et al 2022).

In terms of share of different inputs used in wheat cultivation after adopting the RMMs, human labour (29.8%) and machine labour (38%) was the highest for CR method (Fig. 1); seed and plant protection chemicals use was maximum for CI (9.8%) while fertilizer use was maximum for CB (17.3%) and irrigation share (3.1%) was the highest for PB. Thus, the CI method not only reduces energy costs but also reduces adverse impact on the environment. In an earlier study for wheat sowing with happy seeder, reduced tillage operations as compared to the conventional method of sowing resulted in saving of time (95 minutes/ha) in comparison to conventional method of sowing (220 minutes/ha) along with saving of cost involved i.e. Diesel (Tiwari et al 2019).

Constraints in adoption of different residue management methods: Study of different problems faced by the respondents in following RMMs indicated that the technical problems related to lack of practical knowledge about operating machines, seed rate, moisture requirements and complicated methods occupied the first rank with an average mean score (AMS) of 158.80 followed by economic problems of high cost/hiring charges of implements and labour and price differences in subsidized and non-subsidized implements and management problems related to timely availability of required machinery/implements) respectively (Table 5). Marketing problems related to lack of nearby markets for selling the paddy residue, low demand for paddy residue had AMS 64.80 while the other problems such as lack of extension exposure, unwillingness and lack of interest scored the last rank with an AMS of 52.80. However,

Table 4. Cost-Return structure under different paddy straw management methods in Punjab

(Rs/Ha)

Particulars	Paddy straw management technologies			
	CB	PB	CI	CR
Human Labour	7683.9	8340.1	6648.7	12457.2
Machine labour	12287.9	13074.2	12370.6	15887.5
Seed	2848.0	3011.9	3218.2	2848.9
Fertilisers	5768.3	5571.9	5538.9	5571.7
Plant protection measures	2525.0	2709.6	2956.3	2528.8
Irrigation charges	708.9	1077.6	742.6	735.9
Interest on variable cost @ 9 percent for half the period of crop season	1432.0	1520.3	1416.4	1801.4
Total variable cost	33254.0	35305.5	32891.6	41831.3
Returns-main-product	101687.8	103638.1	104033.1	103021.0
Returns-by-product	10943.3	11185.4	11241.1	10944.4
Gross returns	112631.1	114823.6	115274.2	113965.4
Returns over variable cost (ROVC)	79377.1	79518.1	82382.6	72134.1
Difference of ROVC in comparison to complete burning		141.0	3005.6	-7243.0

Source: Field survey

Table 5. Ranking of the constraints faced by the farmers in management of crop residue in Punjab

Constraints	Total score	Average mean score	Rank
Technical	794	158.80	1
Economic	567	113.40	2
Management	487	97.40	3
Marketing	324	64.80	4
Others	264	52.80	5

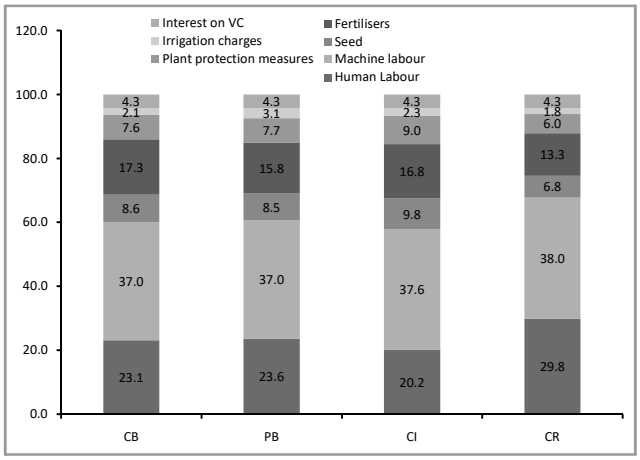

Fig. 1. Shares of inputs used in wheat cultivation after following different RRMs

in another study for Punjab the management related problems for paddy straw was ranked the highest followed by technical, financial and other issues (Roy et al 2018).

CONCLUSIONS

Among different paddy residue management practices followed by the farmers, complete burning has been the most common way of managing crop residue even after the imposition of ban on stubble burning by the Government while wheat sown after paddy residue incorporation method has proved to be time and cost saving without any compromise in terms of yield. Thus, there is a strong need to overcome the constraints in rapid adoption of different technologies for effective management of paddy residue to curb the practice of residue burning. Compensation for farmers by including the cost of paddy residue management in the minimum support price, ensuring the timely availability of residue management machines at subsidized rates, better custom hiring services and promoting the diversified uses of paddy straw in paper mills, energy generation plants, and other industries can prove to be better alternatives for addressing the state's paddy straw management problem

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