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Crop Residue Management Alternatives in South Western Punjab- An Economic Analysis

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ABSTRACT

Considering the earnest need for well managed CRM system with good potential of resource use, the present study was carried out for economic evaluation of CRM alternatives in South-Western Punjab. Primary data were collected for the year 2020-21 from 120 farmers using pre-tested schedule through personal interview method. The annual agricultural residue production was 40807.88 quintals (Qtls) with average being 14.66 Qtls per acre. Complete burning (CB) was the major residue management method (RMM) followed in case of paddy (*basmati* and non-*basmati*) while complete removal (CR) was main RMM for cotton, wheat, mustard and guar. ROVC per acre was higher by about ₹ 1200 for complete incorporation (CI) and by ₹ 56 for partial burning (PB) than CB for wheat sown after paddy and was ₹ 1500 for CI of *basmati* residue. Among cotton RMMs, the ROVC was more for CI than CR by ₹ 1500 per acre. Steps like compensation to farmers by integrating the cost of RM in the MSP, assured availability of RM machinery at reduced rates, improved custom hire services and extension services are needed to deal with the state's practice of stubble burning.

Keywords: Crop residue, Generation, Management, Returns and Variable Costs

With huge agricultural production, agricultural waste generation is equally massive in India. The yearly national production of agricultural waste is anticipated to be around 500 million tons (Mt) with major contribution of rice i.e., 34 per cent and wheat being 22 per cent (Bimbraw, 2019). Scientists and policy makers are facing a big problem in effective management of agricultural leftovers as burning of these agricultural wastes has a negative impact on the environment and humans (Raza *et al.* 2019; Nyanga *et al.* 2020). In situ burning of agricultural wastes creates greenhouse gases (GHGs) which contribute to global warming and particulate matter as well as plant nutrients (N, P and K) which have negative impact on soil properties and cost money (Lohan *et al.* 2018). It is reported that burning of one ton of straw accounts for the loss of entire amount of organic carbon, 5.5 kg of nitrogen (N), 2.3 kg of phosphorous (P), 25 kg of potassium (K) and 1.2 kg of sulphur (S). On an average crop residue of different crops contain approximately 80 per cent of N, 25 per cent of P, 50 per cent of S and 20 per cent of K and on retaining the crop residue in the soil itself can enrich the soil with these nutrients (NPMCR, 2019). In a study for NW India, the private cost associated with paddy straw burning is around ₹ 8953 per hectare and the societal cost of burning paddy straw was estimated to be ₹ 3199 crore which was the maximum for Punjab farmers i.e. ₹ 1804 crores (Kumar *et al.* 2019). In Punjab state, the monetary cost to farmers

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because of crop residue burning is estimated to be about ₹ 800-2000 crore as nutritional loss and ₹ 500-1500 crore as government subsidies on fertilizer each year (Alexaki *et al.* 2019). Thus, good agricultural residue management is crucial not just for the long-term survival of the agriculture but also as a source of additional revenue for farmers in terms of lower production costs and increased output.

About half of nation's total residue burnt is from Uttar Pradesh, Punjab, Maharashtra and Madhya Pradesh (Devi *et al.* 2017). Punjab is a symbol of India's grain surpluses, giving India much needed food security. Punjab state has a major share in national crop production i.e. contributing towards 18.2 per cent of wheat, 12.8 per cent of rice and 5 per cent of cotton in the country's production (Punjab Economic Survey, 2020-21) i.e. about 19 per cent of the country's wheat, 11 per cent rice, and 5 per cent cotton. With this production, around 23 Mt of paddy and 17 Mt wheat straw are generated each year and more than 80 per cent of paddy straw and nearly 50 per cent of wheat straw being burned publicly on fields (Kumar *et al.* 2019). CRM machinery are subsidized, small farmers are rewarded for not burning crop leftover, and crop residue burning is simply prohibited (MoAFW, 2018: Rambani, 2019: PTI, 2019: Dutta *et al.* 2022), still residue burning has been reported on more than 50 per cent of the paddy area sown despite several efforts by the government (CREAMS 2020). Therefore, there is a strong need to find out the economically viable alternatives of CRM that are both environmentally benign and boost farm profitability. With this backdrop, the present study was carried out to examine production and management of crop residue along with economic analysis of different crop residue management alternatives followed bythe farmers.

MATERIALS 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 Mukatsar Sahib from district Sri Mukatsar Sahib and Ghalkhurd and Zira from Firozpur district were selected at random (Table 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 5 acres, 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 management of crop residue, different residue management methods (RMMs) followed along with cost involved in managing the crop residue by adopting the RMMs.

RESULTS AND DISCUSSION

Crop residue generation and management by the respondents

The type of residue generated varies with the crop. It was observed that 40807.88 quintals (Qtls) of crop residue was generated during 2020-21with 20357.25 Qtls (49.89 %) being from kharif crops and 20450.63 Qtls (50.11%) from rabi crops (Table 1).

Similar results were found in a study based on secondary data for Punjab state (Sangeet and Kumar, 2016). Further analysis revealed that on an average, 14.66 Qtls of crop residue was generated from each acre cultivated and the respective figures for cotton, *basmati*, wheat, mustard, paddy and guar were 25.60, 18, 14.69, 14, 13.72 and 13 Qtls respectively. During *kharif* season, paddy generated most of the crop residue, accounting for about 86 per cent of the total residue produced. Cotton with 2560 Qtls residue generation contributed 12.58 per cent to the total *kharif* season residue. Other minor crops, such as *basmati* and guar, produced 315 Qtls (1.54%) and 3.25 Qtls (0.02%) residue during the season. Among rabi crops, wheat contributed the most with 99.91 percent share i.e., 20433.13 Qtls followed by mustard with mere share of 0.09 per cent (17.50 Qtls) in the total residue generated.

Analysis of data for residue management methods (RMMs) for different crops revealed that farmers were following four main RMMs i.e., complete burning (CB), partial burning (PB), complete incorporation (CI) and complete removal (CR). For paddy, CB

emerged out to be the most preferred method practiced followed by majority i.e., 68 farmers on 623.63 acres (48.95% of total paddy area), followed by PB (35 farmers on 17.80% area), CR (31 farmers on 19.94 % area), and CI (17 farmers on 13.31% area). In the case of Basmati, the chosen farmers utilized CB, CR and CI for residue management only and PB method was not used to avoid delay in following wheat crop sowing. Among the selected farmers, six farmers practiced CB on an area of 11 acres (62.86% of the total *basmati* area), followed by CI on 5 acres (28.57 % area) and CR on 1.50 acres (8.57 % area).

For guar only CR method was followed by the selected farmer across an area of 0.25 acres (100 per cent area). In the context of cotton, the chosen farmers mostly used CR and CI approaches only. Majority i.e., 35 farmers practiced CR on an area of 83 acres (83% of the entire cotton area) among the selected farmers, followed by CI on the rest of 17 acres (2 farmers with 17% cotton area). In case of *Rabi* season crops, the chosen farmers opted only for the CR method. All the wheat and mustard growers had used the CR method for residue management i.e., for wheat (1390.50 acres) and mustard (1.25 acres).

Table 1: Distribution of farmers selected for the study

District	Block	Village	Farm category			
			Small	Medium	Large	Total
Sri Mukatsar Sahib	Gidderbaha	Rokhala	5	5	5	15
		Doda	5	5	5	15
	Sri Mukatsar Sahib	Lambi Dhab	5	5	5	15
		Kanian wali	5	5	5	15
Firozpur	Ghal Khurd	Ghall Khurd	5	5	5	15
		Shakoor	5	5	5	15
	Zira	Lango	5	5	5	15
		Dewa Shahwala	5	5	5	15
Grand Total			40	40	40	120

Economic analysis of different crop residue management practices followed bythe farmers

Comparative economic analysis of the CRM methods adopted by the respondents for different crops has been discussed in this section.

Economic analysis of wheat cultivation under different paddy residue management techniques

Analysis of data revealed that among different components of variable cost involved in wheat cultivation after paddy residue management, the cost of machine use was the highest for all the four methods. Comparison for machine cost among the four RMMs indicated that it was the highest for CR (38%) i.e. ₹ 6355 per acre and the lowest i.e., ₹ 4915 per acre (Table 3 and Fig. 1).

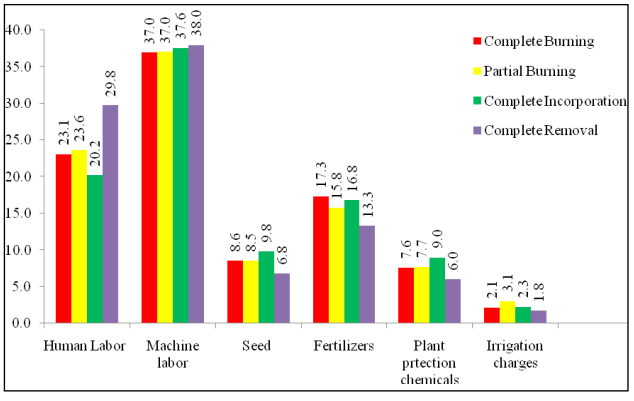

Fig. 1: Cost structure of wheat cultivation different paddy RMMs (% share in total variable cost)

It may be mentioned here that machines 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 along with additional operation of collecting straw and make bales for transportation in CR. 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. Next major input in terms of cost was human labour which was again the highest for CR (29.8%) and the lowest for CI (20.2%). Fertiliser use ranged from ₹ 2215.54 per acre on farms using incorporation technique to 2307.33 kg per acre on fields where paddy straw was completely burned before wheat sowing though in percent share to variable cost it varied from 13 per cent in CR to about 17 per cent for CB. According to PAU recommendations, 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. From fourth year onwards, 20 kg urea can be saved per acre

Table 2: Crop residue generation and management in South-Western Punjab, 2020-21 (Multiple response)

Sl. No.	Crop	Residue Type	Residue Management			Residue generated	
			Method	No. of farmers	Area (Acres)	Total (Qtls)	Average (Qtl/acre)
				Kharif			
1			CB	68	623.63 (48.95)	0	
	Paddy	Straw	PB	35	226.75 (17.8)	0	
			CI	17	169.63 (13.31)	7011.25 (40.11)	13.72
			CR	31	254 (19.94)	10467.75 (59.89)	
		Sub total		151	1274 (100.0)	17479 (85.86)	
2	Basmati	Straw	CB	6	11 (62.86)	0	
			CI	3	5 (28.57)	243 (77.14)	18.00
			CR	1	1.5 (8.57)	72 (22.86)	
		Sub total		10	17.5 (100.0)	315 (1.54)	
3	Guar	Stalk	CR	1	0.25 (100.0)	3.25 (0.02)	13.00
4	Cotton	Stalk	CR	35	83 (83.0)	2120 (82.81)	
			CI	2	17 (17.0)	440 (17.19)	25.60
		Sub total		37	1391.75 (100.0)	2560 (12.58)	
Total (A)					–	20357.25 (49.89)	120
1	Wheat	Straw	CR	120	1390.5 (100.0)	20433.13 (99.91)	14.69
2	Mustard	Stalk	CR	4	1.25 (100.0)	17.5 (0.09)	14.00
Total B					1391.75 (100.0)	20450.63 (50.11)	14.69
Grand total (A + B)					2783.50 (100.0)	40807.88 (100.0)	14.66

Note: (i) CB, PB, CI, and CR means complete burning, partial burning, complete incorporation and complete removal respectively; (ii) No crop residue from Paddy and Basmati was generated in case of CB and PB.

Table 3: Cost-Return structure of wheat cultivation under different paddy straw management methods in South-Western Punjab (₹/acre)

Particulars	Paddy straw management technologies			
	Complete Burning	Partial Burning	Complete Incorporation	Complete Removal
Human Labor use	3073.56	3336.03	2659.46	4982.87
Machine labor use	4915.17	5229.69	4948.24	6355.01
Cost of seed used	1139.18	1204.74	1287.29	1139.55
Cost of fertilizer used	2307.33	2228.74	2215.54	2228.67
Cost of plant protection measures	1010.00	1083.82	1182.50	1011.50
Irrigation charges	283.57	431.04	297.04	294.36
Interest on variable cost @ 9 per cent pa for half the period of crop season	572.80	608.13	566.55	720.54
Total variable cost	13301.61	14122.19	13156.62	16732.50
Yield (qtl)	20.60	20.99	21.07	20.87
Returns-main-product	40675.13	41455.25	41613.25	41208.38
Returns-by-product	4377.31	4474.17	4496.42	4377.77
Gross returns	45052.44	45929.42	46109.67	45586.15
Returns over variable cost (ROVC)	31750.83	31807.23	32953.05	28853.65
Difference of ROVC in comparison to complete burning	–	56.39	1202.22	-2897.18

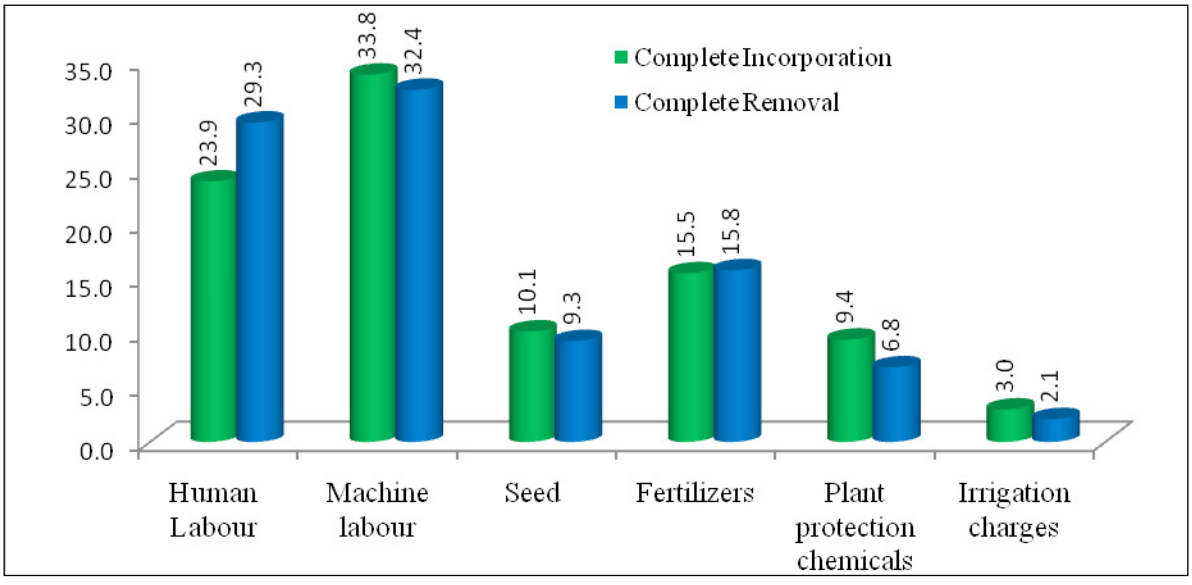

Fig. 2: Cost structure of wheat cultivation different cotton RMMs (% share in total variable cost)

(PAU, 2021-22). Further, it was found that plant protection costs were the lowest on farms that used the traditional technique of paddy straw for wheat sowing i.e. complete burning (₹ 1010), and the highest (₹ 1084) on farms that used partial burning of paddy. In terms of share in TVC, it was the highest for CI (9%). Time devoted to irrigation was again the lowest for farms following CB (19.5 hrs/acre) than other methods. The reasons for higher irrigation hours in case of PB (31 hrs/acre) was to boost the decomposition of remains left after partial burning to avoid their interference in sowing operation of wheat.

As regards seed rate, farmers' perceptions were the major reason for variable seed rate use. They believed that paddy straw incorporation caused germination issues, necessitating the use of higher seed rates to compensate for the poor germination. The seed cost per acre ranged from ₹ 1287 for CI to ₹ 1139 for CB. Further, due to lesser time devoted to irrigation for farms following complete burning (19.5 hrs/acre) than other methods the irrigation cost was the least i.e. ₹ 284 per acre as compared to PB i.e. ₹ 431 per acre with higher irrigation hours (31 hrs/acre) to boost the decomposition of remains left after PB to avoid their interference in sowing operation of wheat.

The average wheat yield per acre for farmers practicing CI of paddy residue was marginally high (21.07 qtls/acre) as compared to CB of paddy residue (20.60 qtls/acre) and it was 20.99 quintals per acre and 20.87 quintals per acre under PB and CR practices respectively 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 which benefit the farmers directly in terms of main product as well as the by-product of wheat crop through which farmer can get extra cash on selling it. Thus, the incorporation of paddy residue not only reduces energy costs but also reduces adverse impact on the environment. Similar results were found in an earlier study where wheat sowing with happy seeder reduced tillage operations as compared to the conventional method of sowing which resulted in saving of time and fuel (Roy and Kaur, 2016: Tiwari *et al.* 2019).

As the cost components for different residue management technologies varied, particularly in terms of variable cost involved, it resulted in different Returns over variable cost (ROVC) under different straw management strategies. ROVC were the highest (₹ 33151.78 per acre) on farms where wheat was planted with Happy seeder or super seeder and lowest (₹ 28506.04 per acre) on farms that followed complete removal practices. In the case of the incorporation technique, ROVC were roughly higher by ₹ 1194.88 per acre than in conventional CB

Table 4: Cost-Return structure of wheat cultivation under different cotton management methods in Sri Mukatsar Sahib (₹/acre)

Particulars	Cotton residue management technologies	
	Complete Incorporation	Complete Removal
Human Labor use	3184.65	4212.18
Machine labor use	4491.33	4644.88
Cost of seed used	1350.00	1330.12
Cost of fertilizer used	2061.94	2263.60
Cost of plant protection measures	1250.00	983.00
Irrigation charges	395.30	300.02
Interest on variable cost @9 per cent Pa for half the period of crop season	572.99	618.02
Total variable cost	13306.21	14351.82
Yield (Qtl)	19.52	19.35
Returns-main-product	38552.00	38216.25
Returns-by-product	3340.55	3210.00
Gross returns	41892.55	41426.25
Returns over variable cost (ROVC)	28586.34	27074.43

method and this figure was only about ₹ 80 per acre for PB method. In case of complete removal method, the ROVC were about ₹ 3451 per acre less than for the CB method.

The gross returns were the highest (₹ 46109.67 per acre) on farms employing the incorporation practices and the lowest (₹ 45052.44 per acre) on farms following CB of paddy straw. Furthermore, farmers that follow complete removal or partial burning obtained nearly identical gross returns with minor variations. Returns over variable cost (ROVC) were highest (₹ 32953.05 per acre) on farms where wheat was sown using Happy seeder or super seeder and the lowest (₹ 28853.65 per acre) on farms that followed CR practices. In the case of the incorporation technique, ROVC were roughly higher by about ₹ 1200 per acre than in conventional method of CB of paddy straw method and this figure was only about ₹ 56 per acre for PB method. In case of CR, the ROVC were about ₹ 2900 per acre less than for the complete burning method.

Comparative analysis of wheat cultivation under different *basmati* residue management techniques

Among *kharif* crops along with paddy, *basmati* was also one of the crops grown in both the selected districts. None of the selected farmers followed PB method for management of the *basmati* residue as the farmers opined that the wheat planting was already delayed on *basmati* fields. So, employing PB for straw management would further delay it affecting the wheat production.

An examination of the variable cost structure for the wheat sown after *basmati* indicated that the machine use expenses were around ₹ 4639, ₹ 4477.91 and ₹ 5896.29 per acre for CB, CI and CR, forming about 37, 36 and 39 per cent of the TVC respectively (Table 5 and Fig. 3) i.e. it was the highest for CR method of *basmati* RMM. *Basmati* straw incorporation resulted in a machine use cost reduction of ₹ 161.09 per acre when compared to the traditional method of full straw burning. Despite the modest cost savings, this also aids in the reduction of emissions from residues burning. Further, the human labour cost was the highest for CR (₹ 3983 forming 26.3% of the TVC) and the least for CI (₹ 2547 forming 21% of the TVC). Similarly, the cost of fertilizer use was the least for CR (14.3%) and the highest for CB (17.3%). The cost of seed use as well as plant protection chemicals was the highest for CI method i.e. ₹ 1307 forming 10.5% of the TVC and ₹ 1200 forming about 10 per cent of the TVC respectively. Cost for irrigation was almost the same for the three methods of *basmati* residue management.

Table 5: Cost-Return structure of wheat cultivation under different *basmati* management methods in South-Western Punjab (₹/acre)

Particulars	Complete Burning	Complete Incorporation	Complete removal
Human Labor use	2669.40	2546.53	3982.81
Machine labor use	4639.00	4477.91	5896.29
Cost of seed used	1318.75	1306.61	1269.00
Cost of fertilizer used	2192.55	2054.50	2172.53
Cost of plant protection measures	1032.00	1200.00	900.00
Irrigation charges	278.01	290.00	287.70
Interest on variable cost @ 9 per cent pa for half the Period of crop season	545.84	534.40	652.87
Total variable cost	12675.55	12409.95	15161.20
Yield (Qtl)	19.63	20.13	19.80
Returns-main-product	38759.38	39756.75	39105.00
Returns-by-product	3375.00	3637.50	3600.00
Gross returns	42134.38	43394.45	42705.00
Returns over variable cost (ROVC)	29458.83	30984.50	27543.80
Difference of ROVC in comparison to complete Burning	–	1525.67	-1915.03

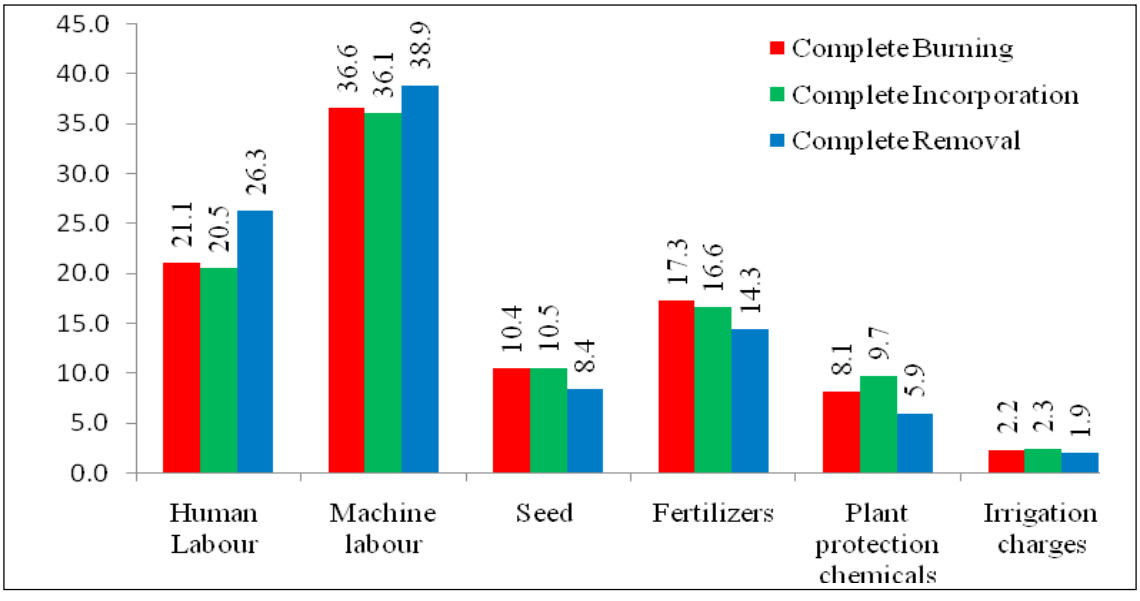

Fig. 3: Cost structure of wheat cultivation different paddy RMMs (% share in total variable cost)

The gross returns were the highest (₹ 43394.45 per acre) on farms using incorporation procedures and the lowest (₹ 42134.38 per acre) on farms adopting complete *basmati* straw burning. Further, for farmers that followed total removal method, the gross returns were ₹ 42705 per acre. The highest ROVC existed on farms following residue incorporation and sowing of wheat with a Happy seeder or super seeder (₹ 30984.50 per acre) while the lowest (₹ 27543.80 per acre) on farms practicing CR method. ROVC were about ₹ 1525.67 per acre higher in the incorporation technique than in traditional CB method of residue management.

Comparative analysis of wheat cultivation under different cotton residue management techniques

Cropping pattern followed in the two selected districts revealed that cotton was grown as *kharif* crop only in Sri Mukatsar Sahib as it was not grown

in Firozpur district. Analysis of input use pattern for the wheat crop sown after following the two residue management methods followed by the respondents revealed that seed rate was marginally higher on farms where wheat was sown by incorporating cotton residues (50 kg/acre) than for complete removal of cotton sticks (49.22 kg/acre) method. The seed rate was higher in the fields where wheat followed cotton than for fields having paddy-wheat rotation because the sowing of wheat on cotton planted lands gets delayed as the cotton crop is still not harvested by the time best suited for wheat sowing. So, the farmers used higher seed amount to compensate for the poor germination problem. Similar results were found in a study for Pakistan (Ahmad *et al.* 2004) where wheat yields under rice-wheat rotation were higher (3146 Kg/ha) than under cotton-wheat rotation (2054 Kg/ha) because of lower yield of wheat mainly attributed to delayed planting. This overlap between sowing and harvesting period not only creates considerable pressure and strain but also affect the wheat yield due to delayed sowing

Analysis of the cost-return structure for wheat followed by cotton revealed that cost of machine use was higher on farms following residue removal method (₹ 4644.88 per acre i.e., 34 % share in TVC) than on farms following incorporation (₹ 4491.33 per acre i.e. 32%) as shown in Table 4 and Fig. 2. Also, higher labour use (29% share in TVC) led to higher labor charges for CR (₹ 4214.18 per acre) than CI (₹ 3184.65 with 23.9% share in TVC). Fertilser use formed about 16 per cent share in TVC for both the methods though in absolute terms it was again higher for CR (₹ 2263.6 per acre). Higher share of TVC was observed for cotton seed as well as plant protection chemicals existed for CI method only.

The expected gross returns did not differ substantially between the two options though it was higher (₹ 41892.55 per acre) on farms using incorporation procedures and lower (₹ 41426.25 per acre) on farms using complete cotton stick removal method. Furthermore, with small differences, farmers who followed total removal or incorporation had roughly comparable gross returns. ROVC were around ₹ 1500 per acre higher in the incorporation technique (₹ 28586.34 per acre) than in the total removal technique (₹ 27074.43 per acre).

CONCLUSION

The total variable cost per acre for wheat cultivation was found to be lower for farmers practicing CI of paddy straw as compared to CB and CR method of residue management. Also, the average wheat yield per acre for farmers practicing CI of paddy residue was marginally high (21.07 qtls/acre) as compared to CB of paddy residue (20.60 qtls/acre) and it was 20.99 quintals per acre and 20.87 quintals per acre under PB and CR practices respectively which led to higher ROVC (by about ₹ 1200 per acre for CI and by ₹ 56 per acre for PB) than CB. Among the two methods followed for cotton residue management, the gross returns were again higher on farms using incorporation procedures (CI) than on farms using complete cotton sticks removal method. The average wheat yield for farmers practicing CI of cotton residue was 19.52 qtls/acres compared to 19.35qtls/acre for CR of cotton residue leading to higher ROVC for CI (₹ 28586.34) than CR (₹ 27074.43). For wheat sown after *basmati*, the wheat yield for CI of *basmati* residue was marginally high i.e. 20.13 qtls as compared to CB (19.63 qtls/acre) and CR (19.80 qtls/acre) and ROVC for CI were higher by about ₹ 1500 per acre than CB method.

Among different residue management practices followed by the farmers, complete burning has been the most common way of managing crop residue in paddy and *basmati* even after the imposition of ban on stubble burning by the Government while wheat sown after 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 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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