



Crop Residue Management Initiatives in Changing the Farmers Behaviour and Farm Production in Bareilly district

B. P. Singh¹, Madan Singh^{2*}, Vijay Kumar³, M. B. Reddy⁴, Mahesh Chander⁵, Shruti⁶, R. S. Suman⁷ and Vanee Yadav⁸

¹Principal Scientist and Head, Division of Technology Assessment and Capacity Building, ICAR-Research Complex for NEH Region, Umiam, Meghalaya-790103, India

^{2,6}Scientist, ^{5,7}Principal Scientist, Division of Extension Education, ICAR-IVRI, Izatnagar, Bareilly-243122, Uttar Pradesh, India

³Senior Scientist (Extension Education), ICAR-Directorate of Poultry Research, Hyderabad-500030, Telangana, India

⁴Crop Science Expert, ⁸Soil Science Expert, Krishi Vigyan Kendra, ICAR-IVRI, Izatnagar, Bareilly-243122, Uttar Pradesh, India

*Corresponding author email id: madansinghjat@gmail.com

ARTICLE INFO

Keywords: In-situ, Crop residue management, Farmers behaviour, Crop yield, Farm implements, Straw burning

<https://doi.org/10.48165/IJEE.2024.60114>

Conflict of Interest: None

Research ethics statement(s):

Informed consent of the participants

ABSTRACT

The study was conducted in Bareilly District of Western Uttar Pradesh from 2022 to 2023 to ascertain the impact of In-situ Crop Residue Management (CRM) initiatives in changing the farmers' behaviour and improving the farm production on farmers' field. A total of 81 adopted farmers were selected purposively for the study. In-situ crop residue management increased from 13.6 to 92.6 per cent. Further, the manure and fertilizer usage in major crops viz. wheat, sugarcane, and mustard were reduced significantly among the adopted farmers on whose fields the demonstrations of crop residue management were conducted. The crop yield of wheat, mustard, and sugarcane increased significantly by 24.44, 42.48, and 18.31 per cent, respectively among the adopted farmers. Also germination, tillering/branching in plants, moisture in soil, and size of the grain increased due to the in-situ management of crop residue as reported by 70 to 80 per cent of the farmers. Adoption of crop residue management practices in wheat crop reduced the cost of cultivation by 4 per cent and gross and net return increased by 26.8 and 44.3 per cent, respectively.

INTRODUCTION

India has achieved an all-time highest food grain production of about 323.5 million tonnes in 2022-23 (Ministry of Agriculture & Farmers Welfare, 2023). Cereal group (rice, wheat, barley, maize, sorghum, minor millets) contributing highest organic residue of 368 million tonnes (54%), next to cereal group, sugarcane shares 16 per cent (111 million tonnes) of total crop residue. But the next question raised is whether this residue is used productively. Unfortunately, majority of farmers from Punjab, Haryana, and western Uttar Pradesh simply burn valuable crop residues in field itself. The rice and wheat straw are a very rich source of organic

carbon (nearly 45% organic carbon) and several other nutrients (Turmel et al., 2015). Crop residue burning significantly increases the quantity of air pollutants such as CO₂, CO, NH₃, NO_x, SO_x, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs) and PM (Mittal et al., 2009) which basically accounts for the loss of organic carbon, nitrogen, and other nutrients, which would otherwise have retained in soil (NPMCR, 2019). In India, in 2000, CH₄, CO, N₂O, and NO_x emissions from paddy and wheat straw burning were 110, 2306, 2, and 84 Gg, respectively (Meena et al., 2022). The burning of one tonne of paddy straw releases 3 kg particulate matter, 60 kg CO, 1460 kg CO₂, 199 kg ash and 2 kg SO₂ (DAC

& FW, 2022). Impact of residue burning on soil health is highly disadvantageous and leads to loss of organic matter as carbon-dioxide (CO_2) and conversion of nitrogen (N) into nitrate (NO_3^-) (Kumar et al., 2019). Even though the government began to ban the practice in the 1990s, the farmers in Punjab and Haryana, in particular, burn an estimated 35 million tonnes of crop residue from their paddy fields each year in late September and October. The National Green Tribunal (NGT), based in India's capital, has banned the burning of straw and stubble in the four states that border New Delhi as reported by Meena et al., (2022). In 2018, the Govt of India, launched a central sectoral scheme on promotion of agricultural mechanization for in-situ management of crop residue in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi with the objectives of protecting environment from air pollution and preventing loss of nutrients and soil micro-organisms caused by burning of crop residue; promoting management of crop residue by incorporation into the soil; promoting farm machinery banks for custom hiring; creating awareness among stakeholders. The central sectoral scheme was implemented through the network of Krishi Vigyan Kendras and state agriculture departments on a massive scale. Keeping in view this study was carried out to assess the impact of in-situ crop residue management initiatives in changing the farmers behaviour and improving the farm production.

METHODOLOGY

The study was conducted in Bareilly District of Western Uttar Pradesh during 2022-23. The farmers for the study were selected purposively by taking the list of farmers (81) from the Department of Agriculture, Bareilly and Krishi Vigyan Kendra-IVRI who had participated in campaign for Crop Residue Management (CRM) and on whose field the demonstrations of CRM practices were conducted. Hence, the sample size of the study was 81 respondents. Data was obtained from the farmers using personal interview method with the help of structured interview schedule designed for the study purpose. Structured interview schedule was developed to measure the perceived attributes of farm implements used by the farmers in crop residue management and awareness among the farmers about ill effect of crop residue burning and utilization pattern of crop residue among the farmers. Before-after research design was deployed to carry out the impact of crop residue management practices on the yield of major crops and quantity of manures and fertilizers per acre used in different crops and impact of crop residue management Practices on economics of wheat cultivation. The collected data were analysed using descriptive statistics (Mean, Standard Deviation, frequencies) and inferential statistics (Paired t test and Chi-square test) with the help of SPSS software package.

Paired t test was used to isolate the impact of crop residue management practices on the yield of major crops, quantity of manures and fertilizers per acre used in different crops. Chi-Square test was deployed to measure the change in rice straw utilization with the crop residue management practices over its burnings. Garrett's ranking technique was used to analyse the different constraints faced by farmers in adoption of the crop residue management practices.

RESULTS

Utilization pattern of crop residue among the farmers

Crop residues always have competing uses in many ways. According to TIFAC (2009) rice, wheat, maize, *jowar*, sorghum, finger millet, and *bajra* residue are mainly used as cattle fodder. The residues of cotton, chilli, pulses and oilseeds used as cooking fuel for household needs. Rice husk is mainly used as fuel in boilers and bagasse mainly for paper and plywood industry. Certainly the introducing the CRM practices at farmers field has improved the effective utilization of crop residue among the farmers. From the results (Table 1) it is clear that most (91.40%) of the farmers had followed the In-situ management of crop residue with CRM equipment, followed by those farmers (70.40%) who had used the crop residue for soil mulching. It was further revealed that 69.10 per cent of the farmers utilized the residue as bedding material for the dairy animals and 40.70 per cent farmers converted the crop residue into organic fertilizers which signifies the contribution of extension efforts for the introduction of CRM practices.

Table 1. Distribution of respondents according to the utilization pattern of crop residue

Utilization of crop residues	Farmers utilizing crop residue (%)
Animal feed	39.5
Animal bedding	69.1
Cooking fuel	9.9
Sold for cash	28.4
Soil Mulching	70.4
Used for preparation of organic fertilizer	40.7
Mushroom cultivation	6.2
In-situ management with traditional equipment	40.7
In-situ management with Bio-decomposer	35.8
In-situ management with CRM equipment	91.4

Changes in rice straw utilization with CRM practices over its burnings

The annual gross crop residue production of India is 371 Mt, wherein wheat and rice residues constitute 27–36 per cent and 51–57 per cent, respectively (Venkatramanan et al., 2021). The rice straw is considered to be a poor feed for cattle owing to its high silica content. Chand & Singh (2023) reported that India produces more than 650 million tonnes of crop residue and only a part of this is used as dry fodder for livestock. The introduction of CRM practices open the gate ways for various alternative uses of rice straw. From the data (Table 2) it is clear that introduction of different CRM practices resulted in economic use of rice straw, the number of farmers burning the crop residue had reduced to 6.2 per cent from 45.7 per cent. Great impact created by CRM practices is that farmers became aware about the ill effect of residue burning. These findings are in line with the research outcome of Devi et al., (2017). Further data (Table 2) depicted that the adopter farmers of in situ crop residue management with CRM equipment were significantly increased to 92.6 per cent from 13.6 per cent.

Table 2. Change in the CRM Practices in post harvest of paddy after 2018

Practices before the CRM	Farmers (%) followed the practices before 2018	Farmers (%) followed the practices after 2018	Change (%)	Chi-square value
Burning the crop residue	45.7	6.2	-39.5	22.80**
Making straw from crop residue	63.0	67.9	4.9	0.08
Application of Urea during Pre-sowing irrigation	56.8	70.4	13.6	0.98
Harvesting with Super SMS Combine	12.3	56.8	44.5	21.8**
In-situ management with traditional equipments	54.3	40.7	-13.6	0.20
In-situ management with Bio-decomposer	9.9	33.3	23.4	9.26**
In-situ management with CRM equipments	13.6	92.6	79.0	46.10**

Awareness among the farmers about ill effect of crop residue burning (CRB)

It was found that majority of the farmers were well aware of the ill effects of crop residue burning. Majority of the farmers (91.4%) reported that residue burning over farms causes environmental pollution due to release of harmful gases into atmosphere. Next to it, 86 per cent of the farmers reported that crop residue burning (CRB) will diminish plant, available nutrients and minerals in the soil solution pool. Moreover, 84 per cent of the farmers opined that residue burning kills the farmer's friendly insects and beneficial micro-organisms (Table 3).

Table 3. Awareness among the farmers about the losses due to crop residue burning

Awareness about the losses due to crop residue burning	Farmers awareness (%)
It diminishes nutrients and minerals of the soil	86.4
It causes environmental pollution due to emission of harmful gases	91.4
It causes reduction in crop yield	76.5
It enhances cost of cultivation	70.4
It elevates soil temperature and kills soil organism	81.5
It kills farmers friendly insects and micro organisms	84
It reduces the quality of the produce	66.7
It reduces the water holding capacity of the soil	65.4

Chi-square value: 6.7^{NS}.

All listed issues are equally important for respondents ($p > 0.05$)

Usage and farmers perception about the attributes of farm implements

In fact, CRM practices are highly implement-cum-machine driven technologies and the success of these depends essentially upon their effective usage. In this context, it was found that among various implements the rotavator was the most commonly used as reported by 79 per cent of the farmers (Table 4). Further, due to the attributes of 'easily operate' the farm machineries i.e. 'Chopper / Mulcher / Shredder / Shrub Master' hold second preferences (59.3%) covered 310 acres cultivated area under CRM practices followed by Reversible MB plough as it was frequently used (46.9%) by them. Among the conservation agricultural machineries 'Super Seeder' was used by majority (53.1%) of farmers in comparison to Happy seeder (7.4%).

Table 4. Usage and area covered through farm implements in crop residue management practices on farmers' field

Farm implements usage	Farmers practices CRM	Area under CRM practices (acre)	Average area/ farmer (acre)
Manual harvesting	47(58.0)	155.2	3.3
Harvesting with reaper cum binder	9(11.1)	73.5	8.2
Harvesting by combined with super SMS	39(48.1)	193.0	4.9
Happy seeder	6(7.4)	42.0	7.0
Super seeder	43(53.1)	256.0	6.0
Zero till ferti seed drill	34(42.0)	215.5	6.3
Chopper/mulcher/shredder/shrub master	48(59.3)	310.2	6.5
Reversible mould board plough	38(46.9)	291.7	7.7
Rotavator	64(79.0)	344.7	5.4
Laser land leveller	10(12.3)	70.0	7.0

*Figures in parentheses indicate percent

Perceived attributes of farm implements/machineries adopted by the farmers

Perceived attributes of farm implements / machineries as adopted by the farmers for the use in crop residue management practices were studied and results (Table 5) which depicts that in terms of "easy to operate" majority of the farmers (87.65%, 56.79% and 51.8%) reported that the 'rotavator', 'chopper / mulcher / shredder / shrub master' and the 'super SMS', respectively, were use in management of crop residue. Further, majority of the farmers (72.84%, 58.02%, 54.32% respectively) considered 'rotavator', 'combine with super SMS' and 'chopper / mulcher / shredder / shrub master' as "perfect in work". In terms of "consumption of more fuel" the 'rotavator' and 'chopper / mulcher / shredder / shrub master' were reported by 44.44 and 34.57 per cent of the farmers, respectively.

Demerits of CRM implements as perceived by the farmers

The implements and machinery for the use in CRM should be farmer friendly for their effective usages which are the reasons for adoption. To delineate the major issues facing by the farmers for using various CRM machinery and implements it was found that majority of the farmers (60% for Happy Seeder, 56.3% for combine with super SMS and 50% for reaper cum binder) reported that most of the CRM machinery and implements involved higher maintenance cost (Table 6) which also demands high skill for their

Table 5. Perceived attributes of farm implements used by the farmers in crop residue management

Farm implements used in CRM	Attributes for using farm implements (Response in %)					
	Easy to operate	Consume more fuel	Perfect in its work	Repair cost is very less	Tractor compatible	Implement is very sturdy
Combine with super SMS	51.85	29.63	58.02	35.80	41.98	53.09
Reaper cum binder	2.47	3.70	1.23	0.00	1.23	1.23
Happy seeder	7.41	4.94	6.17	3.70	7.41	6.17
Super seeder	41.98	19.75	45.68	28.40	48.15	44.44
Zero-Till-Ferti Seed drill	41.98	18.52	41.98	34.57	40.74	40.74
Chopper/Mulcher/Shredder/Shrub Master	56.79	34.57	54.32	46.91	56.79	54.32
Reversible Mould Board Plough	37.04	25.93	34.57	24.69	37.04	37.04
Rotavator	87.65	44.44	72.84	65.43	86.42	77.78
Hay Rack	1.23	0.00	1.23	0.00	1.23	0.00
Baling machines	0.00	0.00	0.00	1.23	1.23	1.23

Table 6. Demerits of the farm implements used for the adoption of CRM practices as perceived by the farmers

Name of the Implements/machinery used	Demerits of the farm implements/machinery (response in %)				
	Difficult to operate/handle	Very expensive to use	Not very effective	Maintenance cost is very high	Non availability
Combine with super SMS	6.3	52.1	0.0	56.3	4.2
Reaper cum binder	0.0	50.0	0.0	50.0	0.0
Happy seeder	20.0	60.0	0.0	60.0	40.0
Super seeder	7.7	30.8	0.0	33.3	5.1
Zero-Till-Ferti Seed drill	10.0	46.7	0.0	36.7	3.3
Chopper/Mulcher/Shredder/Shrub Master	3.8	37.7	0.0	28.3	7.5
Reversible Mould Board Plough	3.6	17.9	0.0	17.9	10.7
Rotavator	6.8	35.6	5.5	30.1	5.5

effective usage. Further data revealed that the CRM machinery and implements are very expensive to use (60% for happy seeder, 52.1% for combine with super SMS and 50% for reaper cum binder).

Effect of CRM practices on usage of manures and fertilizers in cultivation of major rabi crops (wheat, sugarcane and mustard)

Crop residues are the important source of various plant nutrients and moreover they are the cheapest source of plant nutrients. With this intent the effect of CRM practices on manure and fertilizer usage in major crops were analysed (Table 7). The results revealed that CRM practices significantly reduce the usage of organic and inorganic fertilizer on the farmer's field. In wheat crop, the percent change of farmers using organic manure, NPK, DAP, Urea and MOP were -7.4, -22, -29.7, -26.2 and -15.5 percentage, respectively. Whereas, in sugarcane, the percent change of farmers for usage of organic manure, NPK, DAP, Urea and MOP were -9.9, -18.4, -14.6, -24.3 and -19.1 percent, respectively. Further in mustard, the percent change in usage of organic manure, NPK, DAP and Urea were -29.8, -24.6, -29.4, and -6.9 percentage respectively.

Effect of CRM practices on crop performance as perceived by the farmers

It is clear from the data (Table 8) that various CRM practices had significant effect on various growth parameters of the crops.

In case of wheat, it was found that 98.8 per cent of the farmers reported that adoption of CRM practices increased the germination rate, 95.1 per cent of the farmers reported the increased in tiller and grains per ear, 91.4 per cent of the farmers had reported that adoption of CRM practices resulted in increased soil moisture. Further, in case of sugarcane, 97.8 per cent of the farmers perceived that CRM practices increased germination rate, 95.7 per cent of the farmers reported the increase in tiller production, 91.3 per cent reported increase in soil moisture and 93.5 per cent of the farmers reported that number of irrigations reduced. In case of mustard crop, majority of the farmers reported increased resource use efficiency, 76.5 per cent of the farmers reported increased in branching, no. of grains increased per flower head reported by 70.6 per cent of the farmers, increased seed size/weight reported by 82.4 per cent of the farmers. Whereas, decreased in number of irrigation as well as in labour usage in mustard cultivation were reported by 76.5 per cent and 47.1 per cent of farmers, respectively.

Crop yields of wheat, mustard and sugarcane

The ultimate goal of any technology is to increase crop yield and profitability to the farmers which play a key role in the rate of adoption. An attempt was made to ascertain the effect of recommended CRM practices on crop yields (Table 9). The economic yields of wheat, mustard and sugarcane increased significantly by 24.44, 42.48 and 18.31 per cent, respectively after the adoption of CRM practices by the farmers. It was found that

Table 7. Quantity of manures and fertilizers per acre used in different crops (before and after CRM Practice)

Crop	Manure and fertilizers	Before RCM practices	After RCM practices		
		Mean $\pm$ SD	Mean $\pm$ SD	Percent change	Percent change in no. of farmers
Wheat	Organic Manure	3904.2 $\pm$ 1841.4	3615.2 $\pm$ 1978.6	-7.4	11.3
	NPK	68.03 $\pm$ 32.6 ^a	53.05 $\pm$ 18.9 ^b	-22	0
	DAP	61.02 $\pm$ 19.9 ^a	42.9 $\pm$ 18.1 ^b	-29.7	5.1
	Urea	77.4 $\pm$ 33 ^a	57.1 $\pm$ 24.6 ^b	-26.2	-3.9
	MOP	40.6 $\pm$ 27.1	34.3 $\pm$ 15.1	-15.5	-22.2
Sugarcane	Organic Manure	5968.2 $\pm$ 2390.1	5375.6 $\pm$ 2015.6	-9.9	2.2
	NPK	86 $\pm$ 55	70.2 $\pm$ 38.6	-18.4	0
	DAP	67.8 $\pm$ 25.3	57.9 $\pm$ 19.6	-14.6	-12.9
	Urea	128.2 $\pm$ 67.7 ^a	97.1 $\pm$ 56.3 ^b	-24.3	-2.3
	MOP	45 $\pm$ 21.3	36.4 $\pm$ 15.8	-19.1	11.1
Mustard	Organic Manure	5437.5 $\pm$ 4978.2	3818.7 $\pm$ 2392.1	-29.8	0
	NPK	65.5 $\pm$ 21.1	49.4 $\pm$ 10.1	-24.6	-10
	DAP	50.6 $\pm$ 11.5 ^a	35.7 $\pm$ 11.5 ^b	-29.4	0
	Urea	56.4 $\pm$ 22.1	52.5 $\pm$ 21.5	-6.9	-9.1
	MOP	20	20	0	0

*Figures bearing superscript differ significantly in same row

Table 8. Perceived impact of crop residue management on growth parameters of major crops

Growth parameters	Wheat (N=81)			Sugarcane (N=46)			Mustard (N=17)		
	Increase	Decrease	No effect	Increase	Decrease	No effect	Increase	Decrease	No effect
Germination	80(98.8)	0	1(1.2)	45(97.8)	0	1(2.2)	15(88.2)	0	2(11.8)
Tillering/Branching	77(95.1)	1(1.2)	3(3.7)	44(95.7)	1(2.2)	1(2.2)	13(76.5)	0	4(23.5)
Soil moisture	74(91.4)	2(2.5)	5(6.2)	42(91.3)	2(4.3)	2(4.3)	12(70.6)	3(17.6)	2(11.8)
Pest/disease	3(3.7)	37(45.7)	41(50.6)	1(2.2)	20(43.5)	25(54.3)	0	11(64.7)	6(35.3)
No. of grains/ear	77(95.1)	2(2.5)	2(2.5)	-	-	-	12(70.6)	3(17.6)	2(11.8)
Weight/size of grains	70(86.4)	2(2.5)	9(11.1)	-	-	-	14(82.4)	2(11.8)	1(5.9)
No. of irrigation	9(11.1)	69(85.2)	3(3.7)	3(6.5)	43(93.5)	0	3(17.6)	13(76.5)	1(5.9)
Labour use	4(4.9)	69(85.2)	8(9.9)	6(13)	21(45.7)	19(41.3)	4(23.5)	8(47.1)	5(29.4)

Figures in parentheses indicate percent

Table 9. Yield per acre of major crops after following the CRM Practices

Major crop	Number of farmers	Yield (q/ha)	Yield (q/ha)	Percent increase
		Before CRM Practices (Mean $\pm$ SD)	After CRM Practices (Mean $\pm$ SD)	
Wheat	81	18.13 $\pm$ 2.4 ^b	22.56 $\pm$ 3.27 ^a	24.44
Mustard	17	4.18 $\pm$ 1.5 ^b	5.95 $\pm$ 1.7 ^a	42.48
Sugarcane	46	302.17 $\pm$ 58.2 ^b	357.5 $\pm$ 59.08 ^a	18.31

Figures bearing superscripts differ significantly in same row

adoption of CRM practices in wheat crop has reduced the cost of cultivation by 4 per cent and increased Gross and Net Returns by 26.8 and 44.3 per cent respectively.

Constraints and suggestions in adoption of the crop residue management practices

Even though the CRM practices had significant effect on crops yield still these are not much popular among the farmers specifically among non-adopter farmers due to several constraints as observed during data collection. An attempt was made to delineate the major constraints in adoption of CRM practices at farmer's level, among various constraints only six were identified as the

major constraints viz. shorter time window for sowing of next crop (1st rank), CRM equipment (2nd rank) and practices are very expensive (3rd rank), lack of knowledge about the ill effect of crop residue burning (4th rank) and non-availability of CRM equipment/ machinery timely (5th rank) and farm machinery banks are not sufficient in area (6th rank).

Along with the constraints certain suggestions were also provided by the farmers for the successful implementation of CRM practices. Majority of the farmers (93.83%) suggested increasing the availability of number of subsidized equipments and 87.65 per cent of the farmers suggested that government must bear the entire cost involved in application of CRM practices at field

level. Apart from it, 83.95 per cent of farmers suggested to organize effective trainings to impart knowledge and skill on in-situ CRM practices. Further, 83.95 per cent of the farmers suggested for similar strictness and actions for waste burning to keep the pollution free environment.

DISCUSSION

The findings related to the changes in rice straw utilization with CRM practices over its burnings are in line with Singh et al., (2020) who stated that the area under CRM with Happy Seeder technology increased from 358.5 hectare to 713.4 thousands hectare. Findings of the awareness among the farmers about ill effect of crop residue burning are in line with the findings of Singh et al., (2020). Regarding the usage and farmers perception about the attributes of farm implements used in crop residue management practices, super seeder was used by the majority of the farmers due to its better performance under heavy residue condition (>8t/ha) even if the residue is moist. The results are not in agreement with the findings of Singh et al., (2020) who reported that wheat sowing using Happy Seeder is completed in single operation after combine harvested paddy field, which saves time and diesel i.e. 4-7 lit per ha. Whereas, Jambagi et al., (2023) reported that adopter of Happy Seeder were good for in-situ management of paddy straw, incurred less inputs in wheat cultivation and also got 4 quintals higher yield of wheat in comparison to the non-adopters of Happy Seeder. In terms of "low repairing cost", the use of rotavator was reported by the majority (65.43%) of the farmers which may be due to the easy accessibility and availability of mechanics for the repairing work. Hey racks and bailing machine could not be used may be due to their non-availability in the market.

About the demerits of the implements, the happy seeder, combine with super SMS and reaper cum binder involved higher maintenance cost and also demands high skill for their effective usage which are supported with the findings of Singh et al., (2020) that CRM machinery are costly and need highly skilled persons for their usage and also have more wear and tear. The results of effect of CRM practices on usage of manures and fertilizers in cultivation of major rabi crops made it clear that the adoption of CRM practices significantly reduced the dependency on manure and chemical fertilizers for crop nutrient supplementation. Mandal et al., (2004) has also reported that in-situ residue incorporation increased the soil organic matter (SOM), plant available N, P and K which ultimately reduced the consumption of organic (FYM) and inorganic chemicals in crop cultivation.

The results of the effect of CRM practices on crop performance as perceived by the farmers are in line with the report of Jambagi et al., (2023) & Judice et al., (2007), whereas Saha et al., (2010) have reported that in-situ management of crop residue resulted better performance of mustard as compared to the conventional method (non-residue) treatment. Further, the findings related to the crop yields of wheat, mustard and sugarcane in crop residue managed field are in line with the results of Jambagi et al., (2023) who stated that adoption of CRM with happy seeder resulted in increased wheat grain yields of approximately 4 quintal per ha. Also Judice et al., (2007) reported that harvestable cane yield in the mulch treatment greater than in the burn treatment.

Saha et al., (2010) reported that in-situ incorporation of residue increased the grain yields of mustards over non-residue incorporated treatment. Chatterjee (2013), also reported that practice of returning crop straw to soil can enrich soil organic matter which is important for maintaining soil quality and to increase agricultural productivity. The results of the effect of CRM practices on economics of wheat cultivation are supported with the findings of Shyamsundar et al., (2019), that straw management system (SRM) involving the use of rice straw as mulch augmented with happy seeder yielded highest profits under rice-wheat cropping system. Whereas Jambagi et al., (2023) had reported that Happy Seeder adopter and non-adopter farmers incurred a total input cost of Rs. 47,145 and Rs. 49,015 per ha in wheat cultivation.

CONCLUSION

CRM practices have full potential to generate wealth from the waste, the successful management of crop residue is a sustainable means for enhancing soil health and soil quality without impeding its biological balance. The crop residues can reduce the bio-availability of certain soil pollutants, alleviate several soil-borne pests and diseases, and also improve the saline-alkali soils. Besides, CRM practices helped to reduce chemical fertilizer usage and increase the input use efficiency. Above all, the major challenging task of climate change mitigation can be achieved by following CRM practices which checks the cases of crop residue burning on farmer's fields. Thus, as an agricultural scientists, it is our prime objective to understand the farmers need and make them aware regarding the importance of crop residue management practices and the ill effects of straw burning.

REFERENCES

- Chand, R., & Singh, J. (2023). From green revolution to amrit kaal: lessons and way forward for Indian agriculture. NITI Working Paper 02/2023, 1-44.
- Chatterjee, A. (2013). Annual crop residue production and nutrient replacement costs for bioenergy feedstock production in United States. *Agronomy Journal*, 105(3), 685-692.
- DAC & FW (2022). Operational Guidelines of Central sector scheme on promotion of agricultural mechanization for in-situ management of crop residue in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi. Government of India, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare (Mechanization & Technology Division) Krishi Bhawan, New Delhi-110001.
- Devi, S., Gupta, C., Jat, S. L., & Parmar, M. S. (2017). Crop residue recycling for economic and environmental sustainability: The case of India. *Open Agriculture*, 2(1), 486-494.
- Hiloidhari, M., Das, D., & Baruah, D. C. (2014). Bioenergy potential from crop residue biomass in India. *Renewable and Sustainable Energy Reviews*, 32, 504-512.
- Jambagi, R., Singh, D. R., Singh, A., Venkatesh, P., Nain, M. S., & Panghal, P. (2023). Are happy seeder and pusa decomposer potential options for sustainable ways of paddy straw management. *Indian Journal of Extension Education*, 59(3), 132-137.
- Judice, W. E., Griffin, J. L., Etheredge, L. M., & Jones, C. A. (2007). Effects of crop residue management and tillage on weed control and sugarcane production. *Weed Technology*, 21(3), 606-611.

- Kumar, V., Gathala, M. K., Saharawat, Y. S., Parihar, C. M., Kumar, R., & Nayak, H. S. (2019). Impact of tillage and crop establishment methods on crop yields, profitability and soil physical properties in rice–wheat system of Indo-Gangetic Plains of India. *Soil Use Manage*, 35, 303-313.
- Mandal, K. G., Misra, A. K., Hati, M. K., Bandyopadhyay, K. K., Ghosh, P. K., & Mohanty, M. (2004). Rice residue-management options and effects on soil properties and crop productivity, *Food, Agriculture & Environment*, 2(1), 224-231.
- Meena, H. N., Singh, S. K., Meena, M. S., Narayan R., & Sen, B. (2022). Crop residue: waste or wealth? Technical Bulletin 2022, published by ICAR-Agricultural Technology Application Research Institute, Zone-II, Jodhpur, Page No. 1–30.
- Ministry of agriculture & farmers welfare, 2023. <https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1899193>
- Mittal, S. K., Susheel, K., Singh, N., Agarwal, R., Awasthi, A., & Gupta, P. K. (2009). Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. *Atmosphere and Environment*, 43, 238–244.
- NPMCR. [(accessed on 6 March 2019)]; Available online: http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf
- Porichha, G. K., Hu, Y., Rao, K. T. V., & Xu, C. C. (2021). Crop residue management in India: Stubble burning vs. other utilizations including bioenergy. *Energies*, 14(14), 4281.
- Saha, S., Chakraborty, D., Sharma, A. R., Tomoar, R. K., Bhadraray, S., Sen, U., & Kalra, N. (2010). Effect of tillage and residue management on soil physical properties and crop productivity in maize (*Zea mays*)–Indian mustard (*Brassica juncea*) system. *Indian Journal of Agricultural Sciences*, 80(8), 679-685.
- Shyamsundar, P., Springer, N. P., Tallis, H., Polasky, S., Jat, M. L., Sidhu, H. S., & Somanathan, R. (2019). Fields on fire: Alternatives to crop residue burning in India. *Science*, 365(6453), 536-538.
- Singh, G., Singh, P., Sodhi, G. P. S., & Tiwari, D. (2020). Adoption status of rice residue management technologies in south western Punjab. *Indian Journal of Extension Education*, 56(3), 76-82.
- TIFAC (2023, September 11). Availability of Indian biomass resources for exploitation. <https://tifac.org.in/index.php/reports-publications/reports-2010-onwards/other-reports/8-publication/240-availability-of-indian-biomass-resources-for-exploitation?start=1>
- Turmel, M. S., Speratti, A., Baudron, F., Verhulst, N., & Govaerts, B. (2015). Crop residue management and soil health: A systems analysis. *Agricultural Systems*, 134, 6-16.
- Venkatramanan, V., Shah, S., Rai, A. K., & Prasad, R. (2021). Nexus between crop residue burning, bioeconomy and sustainable development goals over North-Western India. *Frontiers Energy Research*. 8, <https://www.frontiersin.org/articles/10.3389/fenrg.2020.614212/full>