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Adoption Pattern of Farm-Machinery based Solutions for *In-situ* Paddy Straw Management in Punjab

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ABSTRACT

Farmers burn paddy residues in the field harvested by combine harvester to prepare fields for sowing of the next crop in the narrow window between paddy harvesting and the next sowing. Punjab Agricultural University has carried out extensive research on farm machinery for *in-situ* paddy straw management and promoted technologies in Punjab from 2018 to 2022 under the "Promotion of Agricultural Mechanization for *in-situ* Management of Crop Residue" scheme. A survey was carried out to assess the adoption pattern of these technologies by Punjab farmers. The adoption of Happy seeder was maximum (16.80%) among different technologies during 2019 while Super seeder was preferred and accepted on a large scale (14.99%) during 2020. Farmers growing potatoes and other winter crops preferred residue incorporation using chopper, rotavator, MB plough, or harrow and adoption varied from 9.17 per cent to 20.4 per cent over five years. Overall, paddy straw management has increased from 20.49 per cent during 2016 to 49.91 per cent during 2023.

INTRODUCTION

The intensive rice-based cropping systems, particularly in north-western India are characterized by the use of combine harvesters on almost entire area and a narrow window of time for sowing of next crop. This system consists of a combination of farming techniques that include rice as the primary crop followed by the cultivation of other crops (Kumar et al., 2022). The situation predisposes farmers to burn paddy stubbles and loose straw in the combine harvested fields. Around 75-80 per cent of the area under paddy is combine-harvested, and loose paddy straw is burnt by farmers in the state to prepare the field for next crop (Singh et al., 2018). Farmers resort to burning to avoid the extra burden of additional tractor operations and heavy machinery. Moreover, burning helps in destroying soil-borne insects, disease-causing organisms, and weed seeds in the surface soil layer. Approximately 23 million tonnes of paddy residue are burned in Punjab, Haryana, and Uttar Pradesh, leading to severe regional pollution. (Ravindra et al., 2019; Singh, 2018; IARI, 2020). Paddy straw, unlike wheat straw is used less as fodder due to its high silica content. Apart from environmental pollution, nutrients (N, P, K and S), precious soil organic carbon and microbial diversity are lost. According to estimates, one tonne of straw contains 400 kg of organic carbon, 5.5 kg of nitrogen, 2.3 kg of phosphorus, 25 kg of potash, and 1.2 kg of sulphur. Moreover, 50–70 per cent of micronutrients are lost through burning of straw, which results in expense of more than Rs. 200 crores (Sidhu et al., 2007).

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Rice residues can be managed using *in-situ* (retention of rice straw on the surface as mulch on surface or incorporation of the residue into the soil by mixing or inverting) or *ex-situ* (use of paddy straw for energy, mulching, biochar, etc.) straw management technologies (Mahal et al., 2019). Among all available paddy straw management options, *in-situ* use of paddy straw is the most feasible, economical and sustainable option (Singh et al., 2020). Punjab Agricultural University has carried out research on farm machinery-based solutions for *in-situ* paddy straw management. The major technologies introduced are Happy Seeder, Super Seeder, Smart Seeder, paddy straw mulcher, cutter-cum-spreader, zero-till seed-cum-fertilizer drill, reversible mould board plough, rotavator etc. One solution module aimed at direct drilling of wheat seed in paddy stubbles, with retention of straw on the surface as mulch while another solution was based on incorporation of straw in the soil, which was an essential requirement for planting of vegetable crops like potato and pea (Singh et al., 2022). There has been significant scaling up of these technologies in the last 5 years. Government of India sanctioned a 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". At this point of time, a re-appraisal of technological and dissemination strategies seems relevant and to understand the adoption pattern of different paddy straw management technologies by Punjab farmers the present study has been undertaken.

METHODOLOGY

Under the patronage of Punjab Agricultural University and ICAR-ATARI, Ludhiana, there are 18 Krishi Vigyan Kendras working in different districts of Punjab (hereafter, PAU-KVKs). PAU-KVKs reached out to all stakeholders (including farmers, school/college students, NGOs, social influencers) through trainings and demonstrations, farmer-scientist interfaces, Kisan Melas, campaigns, literature, mass and social media. Elaborate campaigns were organized by PAU-KVKs for awareness and trainings for paddy straw management throughout October-November of 2018 to 2022 under this project.

To study adoption pattern of different crop residue management technologies, a survey was conducted every year in January month from 2017-18 to 2022-23. For this, five villages from three block of eighteen districts were selected on random. In each village, 10 farmers were selected on random for survey and questions about how crop residues were managed. Therefore, a total of 150 farmers were questioned for assessment of adoption pattern, and to identify the reasons for such adoption behaviour. Farmers employed different crop residue management techniques for retention or incorporation (partial or full) or removal (manual or by baler). Farmers retained the crop residue as mulch using three different machines such as Happy seeder, Smart seeder and Surface seeding. Happy Seeder directly seeds the wheat in residue-retained field without performing any preparatory tillage operations. Super Seeder incorporate the straw at shallow depth and sow wheat seed in lines. Smart Seeder works as a strip till drill and retains benefits of both Happy seeder and Super seeder in a single machine. Smart Seeder places wheat seeds in a well-tilled narrow band of soil and covers seed rows and leave the inter-row area as such with residue on its surface. In surface seeding, wheat seed is broadcasted in the standing stubbles either manual or mechanical followed by chopping of straw by chopper-cum-mulcher. Farmers who managed rice straw by incorporation using chopper, rotavator, mould board (MB) plough, rotavator or harrow was categorized in one method of incorporation. The data about adoption pattern of different paddy straw management technologies was analysed using mathematical tools and weighted-arithmetic means were computed.

The Pearson correlation analysis was performed with the extent of adoption of paddy straw management technologies and profile characteristics of farmers viz., age, education, total land holding, annual income, experience, mass media exposure, extension contacts and social participation. Karl Pearson's product moment correlation coefficient (r) was used to find out the degree of relationship between independent (x) and dependent variable (y).

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

With a participatory approach, reasons for under-utilization of crop residue machinery were recognized and farmers were asked to give them ranking. The econometric analysis of this data was done by calculating Rank Based Quotient (RBQ) using the following formula:

$$\text{RBQ} = \frac{\Sigma fi\ (n+1-ith)}{N \times n} \times 100$$

where, fi= number of farmers reporting a particular reason under i^{th} rank, N = number of farmers, n= number of reasons identified

RESULTS AND DISCUSSION

A total of 430 training camps and 390 farmer-scientist interactions were conducted between 2018 and 2022 under the project (Table 1). Young minds of schools and college students were also sensitized for promotion and adoption of paddy straw management technologies. For mobilization of students, a total of 302 programs (such as *Prabhat Pheris*, poster competition, *nukkad natak*, etc.) were conducted with active participation of 52,061 students during 2018 to 2022 (Table 1). Along with that, several mass awareness programs such as farmers' fairs (*Kisan Melas*) and TV/Radio talks related with benefits of crop residue management and its technologies were organised. Beside this, extension literature related to technologies was distributed among all stakeholders. Various slogans in vernacular language were displayed at common places in the villages and these were written at village bus stop and boundary walls in large fonts for creating awareness and curiosity amongst general public.

Under the project, the states have distributed more than 2.42 lakh machines to individual farmers and more than 0.38 lakh machines to CHCs for the states of Punjab, Haryana, Uttar Pradesh, and Delhi NCR during 5 years from 2018 to 2023. Out of this, a total of 1.10 lakh machines were provided in Punjab only and year-wise details of machine supplied under central sponsored scheme is given in Table 2. PAU-KVKs procured a total of 550 implements related with crop residue management (such as Happy

Table 1. Extension activities conducted during 2018-2021

Extension activities conducted	2018-19		2019-20		2020-21		2021-22	
	Number	Beneficiaries (No.)	Number	Beneficiaries (No.)	Number	Beneficiaries (No.)	Number	Beneficiaries (No.)
Trainings	181	4,680	68	1,900	100	2,698	81	2,174
Farmer-scientists interface	62	7,943	102	7,335	134	6,176	92	5,850
Mobilization of school & college students	88	18,040	117	21,190	33	1,030	64	11,801
Kisan Melas	18	2,55,287	19	85,134	1	100	4	4,043
Campaigns	390	32,215	150	27,080	73	6,758	89	7,609
TV/radio talks	78	Numerous	31	Numerous	27	Numerous	20	Numerous
Extension articles	45		103		27		22	
Bulletins/manuals	20		9		5		78	
Literature distributed	2,20,750		2,06,624		1,91,481		1,57,056	
Wall painting (Sq Feet)	2,27,351		1,24,664		1,28,415		69,501	
Hoarding-banners	2,592		7,994		1,395		1,111	

Table 2. Machines supplied in Punjab under centrally sponsored scheme during five years

Name of Implements	2018-19	2019-20	2020-21	2021-22	2022-23	Total
Happy seeder	9552	3223	541	224	37	13577
Super seeder	0	963	16734	8608	13324	39629
Paddy straw chopper	1623	4505	811	828	614	8381
Mulcher	2640	1888	1154	553	369	6604
RMB plough	2904	2948	1686	587	373	8498
Zero till drill	3372	7332	2842	2563	4028	20137
Super SMS	3628	695	1607	42	141	6113
Rotary slasher	384	270	7	273	0	934
Shrub Master	69	14	0	0	434	517
Cutter cum spreader	26	944	0	0	0	970
Rotavator	3549	286	0	0	0	3835
Baler	0	0	224	62	336	622
Rake	0	0	205	50	290	545
Reaper/Reaper Binder	0	0	0	6	17	23
Smart Seeder	0	0	0	0	10	10
Total	27747	23068	25811	13796	19973	110395

Source: Department Agriculture & Farmers Welfare, Punjab

seeder, mulcher/chopper, cutter-cum-shredder, mould board plough, rotavator, zero till drill, etc.) during 2018-19 to 2020-21 for demonstrations at farmers' fields. During these years, demonstrations on Super SMS, Happy seeder, Super seeder, Mulcher, MB plough, Zero till drill and Rotavator were conducted on thousands of hectares at the farmers' fields (Table 3). The perusal of data in Table 4 indicated that variables such as education, experience in farming and social participation had positive and significant relationship with adoption index at 1% probability. Mass media exposure and extension contacts had positive and significant relationship with adoption index at 5% probability. On the other hand, age had negative correlation with adoption behaviour of *in-situ* straw management technique.

It was observed that burning of paddy straw is practiced only in combine harvested fields for clearing loose paddy straw and/or standing stubbles (of 25-30 cm height), and to clear the fields for sowing of *rabi* crops (mainly wheat and potato). Only a narrow window of 2-3 weeks is available between harvesting of paddy and sowing of next crop. Innovative farm machinery solutions developed at PAU, including Happy Seeder and Super Straw Management System (Super-SMS) formed the core of the technology dissemination initiative for the management of paddy straw without burning (Mahal et al., 2019). Super-SMS was developed and commercialized by Punjab Agricultural University, Ludhiana, to equip the operational combine harvesters in the state with mechanized straw spreaders, which help in uniform spreading of rice residue as a part of rice harvesting process itself. PAU had developed Happy Seeder in the year 2006 for direct sowing of wheat in the combine harvested paddy field. It was observed that only 0.23 per cent of area was managed by Happy seeder during 2018 which further increased in succeeding years (Table 5). The adoption of Happy seeder was maximum (16.80%) during 2019. Thereafter, Super seeder technology was demonstrated amongst farmers during 2020-21. Farmers accepted this technology on a large scale (14.99%) as this technology resonates well with farmers' psychology of clean cultivation as in conventional agriculture system. Two new mulching technologies viz., surface seeding and Smart seeder was also demonstrated at farmers' fields during 2021-

Table 3. Demonstrations conducted during 2018-19 to 2021-22

Demonstrations conducted	2018-19		2019-20		2020-21		2021-22	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Super SMS	1,376	2803.2	1004	2137	733	1166.5	948	2193.4
Happy Seeder	2,402	3224.4	2962	4325	1564	2330.5	879	1304
Super Seeder	-	-	-	-	284	701	840	1071.8
Mulcher	738	2152.4	1458	3173.8	636	1118.3	581	1108.8
MB Plough	469	910	835	1960.4	466	915.1	534	770.4
Zero till drill	-	-	679	959.2	944	1771.4	1155	1422.7
Rotavator	-	-	291	284.2	627	963	327	475.2

Table 4. Relationship of the socio-personal characteristics of respondents with adoption index of in situ management techniques

Independent variables	Karl Pearson (r value)
Age	-0.237*
Education	0.358**
Total land holding	0.111ns
Annual income	0.033ns
Experience	0.412**
Mass media exposure	0.386*
Extension contacts	0.267*
Social participation	0.382**

*Significant at 0.05 level; **Significant at 0.01 level; ns: Non-significant

22 and 2022-23, respectively. Area managed with residue incorporation using chopper, rotavator, MB plough or harrow varied from 9.17 to 20.4 per cent during 2018 to 2022. Farmers growing potato and other winter crops preferred this method over others for rice residue management. The perusal of survey data indicated that 12.44 to 21.30 per cent of rice residues were removed manually or with the help of baler. Overall, paddy straw management has increased from 20.49% during 2016 to 49.91% in 2023 (Table 5).

There are more than 1.0 lakh machines supplied on subsidy in the state of Punjab (Table 3). Out of these machines, about 50 per cent are with individual farmers, 39 per cent with custom hiring centres/farmer groups/panchayats/FPOs and 11 per cent are with cooperative societies. For the management of paddy straw, various machines are to be used in combination for complete operation/ practice. The reasons for low adoption of paddy straw management machines and their under-utilization were also identified in the survey (Table 6). Paddy straw management machines involved high cost, and are available with medium to large farmers. Large farmers who owned such machinery don't go for custom hiring due to various socio-political factors. The long duration varieties are sown on approximately 30 per cent area which leave short window for sowing of next *rabi* crop that also prompt farmers to burn the straw. The marginal and small farmers cannot afford buying these machines due to financial constraints, and mostly hire the services of these machines from CHCs or Co-operative Societies.

In the survey, farmers were asked about any difference in package/production technology and benefits from crop residue management technologies. They were of the view that there was significant reduction (80-90%) in the density of *Phalaris minor* at 25 days after sowing in the fields depending upon amount of straw retained as surface mulch. This is in agreement with the findings of Buttar et al., (2022). Also, wheat crop in which rice residue was retained on the surface as mulch (e.g. Happy seeder/Smart seeder/ Surface seeding) escaped the negative effect of terminal heat stress in 2021-22. This is also reported by Singh et al. (2022).

In order to supplement use of crop residue management machinery, PAU stressed upon cultivation of short duration varieties of rice. Short duration varieties covered 70 per cent of *parmal* rice area and PR 126 was most popular variety covering 22 per cent area during *kharif* 2022. Short duration variety (PR 126) played a significant role in paddy straw management. This variety is recommended for general cultivation in the Punjab state during 2017 which matures in about 93 days after transplanting. Its average paddy yield is 81.9 quintals per hectare and can be transplanted from 25th June onwards taking only 93 days for maturity. PR 126 has 10 per cent less straw load (97.7 quintals per hectare) as compared to Pusa 44 (108.9 quintals per hectare) which take 128 days for maturity after transplanting. It provides a window period of 25-40 days between rice harvesting and wheat

Table 5. Adoption of paddy straw management (area in lakh ha) in Punjab

Practice	2016	2017	2018	2019	2020	2021	2022
Mulching (Happy Seeder)	0.69(0.23)*	0.25(0.85)	4.74(15.8)	4.98(16.80)	3.04(10.20)	3.04(10.26)	2.54(8.17)
Mulching (Smart Seeder)	-	-	-	-	-	-	0.14(0.47)
Mulching (Surface Seeding)	-	-	-	-	-	0.30(1.01)	0.34(1.10)
Partial Incorporation (Super Seeder)	-	-	-	-	4.46(14.99)	5.48(18.48)	4.50(14.47)
Incorporation (Chopper, Rotavator, MB, Harrow etc)	0.05(0.17)	0.18(0.61)	6.11(20.4)	6.19(20.90)	5.08(17.08)	3.63(12.22)	2.85(9.17)
Collection/ Removal with balers, manually etc (including Basmati)	6.03(20.09)	4.37(14.57)	6.41(21.3)	6.75(22.80)	4.72(15.83)	3.69(12.44)	5.15(16.53)
Total	6.15 (20.49)	4.81 (16.03)	17.25 (57.50)	17.92 (60.50)	17.30(58.10)	16.14(54.41)	15.52(49.91)

*Figures in parenthesis denote per cent area under each technology

Table 6. Ranking of reasons for low adoption of paddy straw management machinery by farmers

S.No.	Reasons	RBQ	Rank
1.	High cost of inputs/ machinery for marginal/small farmers	85.50	I
2.	Machines are available with medium to large farmers only	45.52	IX
3.	Individual farmers don't practice custom hiring services	55.56	VIII
4.	Lack of empathy for environment	40.60	X
5.	Socio-political factors	78.90	II
6.	No benefit of subsidy scheme to small farmers	52.00	VI
7.	Cultivation of long duration varieties	75.10	III
8.	Less involvement of Co-operative Societies for machinery hiring	60.60	V
9.	Non-availability of complete set of machines	68.20	IV
10.	Non-availability of matching tractor	49.50	VII

sowing as compared to 0-5 days of Pusa 44. Cultivation of short duration rice varieties saves 5-6 irrigations (~3000 cubic m per hectare), which in turn saves 740 crores of electricity subsidy. Further, it was observed that application of additional microbial decomposers did not improve the rate of decomposition in the available window, and no yield advantage in wheat was achieved.

Farmers were satisfied with crop residue management technologies. Keeping in view the global warming, it is important that farmers should be encouraged to adopt climate resilient agricultural technologies. This is in line with findings of Pabba et al., (2022). Farmers were of the opinion that residue retention or incorporation resulted in the improvement of soil structure and fertility. The continuous experiments related with crop residue management are being conducted in the Punjab Agricultural University (Gupta et al., 2022; 2023) and it is confirmed that there is almost 25, 35, 14 per cent increase in nitrogen, phosphorus and potassium, respectively in residue managed (incorporation/ surface retention of residue) plots as compared to residue removed plots. The decrease in bulk density was observed with *in-situ* management of residue which reflected the improvement in soil structure and porosity. Survey data indicated that adoption rate of Happy seeder and Super seeder is increasing in past few years. Residue retention or incorporation continuously for 13 years increased soil organic carbon from 0.42 to 0.68-0.75 per cent. An increase in quality and quantity of soil organic carbon will finally improve the soil and crop productivity as soil organic matter acts as a source of plant nutrients and restorer of soil structure. It was observed in the continuous experiments that there was 8-10 per cent increase in productivity of rice-wheat cropping system from fourth year onwards. In Punjab, fire events successively decreased by 18.9-51.2 per cent in successive years from 2017 to 2022 compared to 2016. It has been observed that stubble burnt area was reduced by 79.51 to 69.44 per cent from 2016 to 2021. To reduce residual crop burning for sustainable agriculture, the government of India is also taking many lucrative and punitive measures (Rohilla et al., 2022). Air quality index (AQI) was also improved over these years from 'poor' (201-300) to 'moderate' (101-200) quality.

CONCLUSION

The implementation of paddy straw management technologies has gained great relevance with imposition of ban on the burning of paddy straw by the governments and restrictions imposed by the Courts/National Green Tribunal. There are so many management alternatives available including *in-situ* and *ex-situ* management of crop residue. Different rice straw management techniques were used to manage 49.91 per cent area without burning during 2022. The *in-situ* residue management methods are sustainable solution for maintaining soil organic carbon, aggregate stability and porosity. The provision of monetary compensation for farmers or by ensuring the timely availability of residue management machines through custom hiring services or by ex-situ uses of paddy straw can prove to be better alternatives for addressing the State's paddy straw management problem. Additional extension services, active participation of all stakeholders and policy support is required to reduce the paddy straw burning further.

REFERENCES

Anonymous. (2021). Consortium for research on agroecosystem monitoring and modelling from space. Indian Agricultural Research Institute Retrieved from http://creams.iari.res.in.

Buttar, G. S., Kaur, S., Kumar, R., & Singh, D. (2022). *Phalaris minor* Retz. infestation in wheat crop as influenced by different rice straw management practices usage in Punjab, India. *Indian Journal of Weed Science, 54*(1), 31-35.

Gupta, R. K., Kaur, J., Kang, J. S., Singh, H., Kaur, S., Sayed, S., Gaber, A., & Hossain, A. (2022). Tillage in combination with rice straw retention in a rice–wheat system improves the productivity and quality of wheat grain through improving the soil physio-chemical properties. *Land 11*, 1693.

Gupta, R. K., Sraw, P. K., Kang, J. S., Kaur, J., Kalia, A., Sharma, V., Manhas, S. S., Al-Ansari, N., Alataway, A., Dewidar, A. Z., & Mattar, M. A. (2023). Influence of 11 years of crop residue management on rice productivity under varied nitrogen levels in the rice-wheat cropping system. *Plant, Soil and Environment*, *69*(7): 333-343.

Indian Agricultural Research Institute (IARI). (2020). Monitoring paddy residue burning in north India using satellite remote sensing during 2020. Consortium for Research on Agroecosystem Monitoring and Modelling from space, New Delhi.

Kumar, N., Chhokar, R. S., Meena, R. P., Kharub, A. S., Gill, S. C., Tripathi, S. C., Gupta, O. P., Mangrauthia, S. K., Sundaram, R. M., Sawant, C. P., Gupta, A., Naorem, A., Kumar, M., & Singh, G. P. (2022). Challenges and opportunities in productivity and sustainability of rice cultivation system: a critical review in Indian perspective. *Cereal Research Communications*, 50, 573-601.

Mahal, J. S., Manes, G. S., Singh, A., Kaur, S., & Singh, M. (2019). Complementing solutions and strategies for managing rice straw and their impact in the state of Punjab. *Agricultural Research Journal, 56,* 588-593.

Pabba, A. S., Naik, V. R., & Rani, V. S. (2022). Adoption of climate resilient agricultural technologies by farmers in Nalgonda district of Telangana state. *Indian Journal of Extension Education, 58,* 30-34.

Ravindra, K., Singh, T., Mor, S., Singh, V., Mandal, T. K., Bhatti, M. S., Gahlawat, S., Dhankhar, R., Mor, S., & Beig, G. (2019). Real-time monitoring of air pollutants in seven cities of North India during crop residue burning and their relationship with meteorology and transboundary movement of air. *Science of the Total Environment, 690,* 717-29.

Rohilla, E., Sehal, B., & Rohila, A. K. (2022). Awareness of paddy residue utilization in Karnal and Kurukshetra district of Haryana state. *Indian Journal of Extension Education, 58,* 180-83.

Sidhu, H. S., Singh, M., Humphreys, E., Singh, Y., Singh, B., Dhillon, S. S., Blackwell, J., Bector, V., Singh, M., & Singh, S. (2007). The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian Journal of Experimental Agriculture, 47*, 844-854.

Singh, G., Sachdeva, J., & Walia, G. S. (2022). Paddy straw management in Punjab: An economic analysis of different techniques. *Indian Journal of Ecology, 49*, 301-307.

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*, 76-82.

Singh, J. (2018). Paddy and Wheat blazing in Haryana state of India: A menace for environmental health. *Environmental Quality Management, 28*, 5-10.

Singh, R., Kaur, S., Murari, A. S., Brar, N. S., Brar, P. S., Kumar, A., & Singh, A. K. (2022). Heat wave in Northern India: farmer's perspective. Division of Agricultural Extension, ICAR, New Delhi, India, 76p.

Singh, R., Mahajan, G., Kaur, S., & Chauhan, B. S. (2018). Issues and strategies for rice residue management to unravel winter smog in north India. *Current Science, 12,* 2419.