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Crop production practices and input use pattern in rice (*Oryza sativa* L.) cultivation in sub-mountainous region of Punjab, India

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Abstract

Rice (*Oryza sativa* L.) has been highly input intensive crop of sub-mountainous region of Punjab (India). Farmer's fields are highly diverse with respect to the adoption of contrasting crop production practices, which involve variable input use. We studied long-term (2012-21) changes in crop production practices and input use in rice production at farmer's fields to understand the temporal variation related to management induced change in crop productivity. The survey data revealed that area under un-recommended paddy varieties decreased from 39% in 2012 to 6 % in 2021. Area under direct seeded rice (DSR) has increased marginally from 2012 to 2021. Butachlor was the major herbicide used over the years with 71-82% respondents using it for weed control. Majority of farmers (~60%) apply urea in a range of 91-130 kg/acre, while since 2018 farmers applying 71-90 kg urea are also increasing. Over the years there has been significant decline in the trend of farmers regarding phosphorous application in both rice and wheat crops. The percentage of farmers going for rice residue burning decreased from 68 % to 9 %.

Key words: Input use, residue management, rice, varieties

Introduction

Rice (*Oryza sativa* L.) has been the major cereal grain crop of summer season in entire northwestern India. It has been reported to be highly input intensive (Choudhary *et al*., 2021; Basavalingiah *et al*., 2020) with high energy, carbon (C) and water footprints (Sudhakara *et al*., 2017; Upadhyay *et al*., 2022). The crop production in Punjab (India) has made rapid strides as a result of consolidation of landholdings, reclamation of new agricultural lands, development of irrigation, and high quality biochemical as well as mechanical inputs (Bhatt and Singh, 2021). The food grain production in Punjab has increased from ~3.2million tons in 1960-61 to ~31.7million tons in 2017-18 due to the introduction of high yielding varieties and the adoption of by highly receptive farmers besides the support of the government policies (Anonymous, 2018). Over the last two decades, rice-wheat cropping system has been facing several sustainability issues; amongst which the stagnation of yield, decline in water table, soil degradation and atmospheric pollution has foremost importance (Singh *et al*., 2021; Rajanna *et al*., 2022; Bhatt *et al*., 2023).

Over the past few years, rice cultivation in the study region has experienced a drastic change with respect to the establishment methods, e.g. direct seeded rice (DSR), mechanical transplanting apart from conventional puddled transplanted rice (Bhatt and Singh, 2021). A large scale labor shortage during COVID-19 pandemics has driven the farmers to adopt direct seeded rice also. Nonetheless, there has been a large variation in the selection of rice varieties in Punjab with variable impact on soil management and crop production

practices (Singh *et al*., 2021). Therefore, the present survey was conducted to study the long-term (2012-2021) changes in soil management and crop production practices adopted by the farmers in rice cultivation in Ropar district of Punjab (India). The present study would help in identifying management practices having over-use of agri-inputs and to optimize management practices with the objective ofreducing the wastage of resources, while enhancing productivity and sustainability of the system for long period of time.

Materials and Methods

Description of study region

Ropar (also known as Rupnagar) district lies between 30°-322 and 31°-242 North latitude and 76°-182 and 76°- 552 East longitude. The district adjoins Nawanshahar (SBS Nagar), Mohali (SAS Nagar) and Fatehgarh Sahib districts of Punjab. The district has five blocks, viz. Sri Anandpur Sahib, Ropar, Nurpur Bedi, Chamkaur Sahib and Morinda. Ropar district spans over 138 th.ha. out of which net sown area is 74 th.ha., while 26 th.ha. area is under forest cover. The cropping intensity of the district is 162 percent as compared to 190 percent cropping intensity of Punjab. Texture of the soils in the district varies from loam to silty clay, with the exception of river Sutlej and the *choes* found in the region where sandy patches are present. Chamkaur Sahib block has sodic soil, while the Anandpur Sahib, Nurpur Bedi and Rupnagar blocks are undulating. Ropar district is located in the eastern part of Punjab and is characterized by generally dry weather except for the monsoon period. Two types of soils are found in this district, *viz.* reddish chestnut soils and tropical arid brown soils. Texture of the soil is also highly variable, where blocks Morinda and Chamkaur Sahib have sodic soils, and Rupnagar and Anandpur Sahib have undulating soils. The pH of soils in the district varies from 7.5 to 8.9.

Data collection and compilation

A set of 100 farmers was selected randomly from 10 villages (2 villages each from 5 blocks of Ropar district). The information was collected in semi-structured questionnaire through face-to-face interviews. The information on different soil management and crop production practices adopted by the farmers were recorded. The survey was conducted on these farmers each year continuously for 10 years with the help of questionnaire. The information was collected through face to face interviews of these 100 farmers during *kharif* growing season. Information was gathered about the input use and management practices followed by farmers for rice cultivation like variety selection, method of sowing, method of residue management, amount of fertilizers and pesticides used, etc. Changes in the agronomic practices over the years were tabulated and analyzed.

Statistical analysis

The data gathered in interview schedules was entered in Microsoft Excel Spreadsheets (MS Office 2007) and analyzed for frequency distribution. The mean values were statistically analyzed by using Least Significant Difference (LSD) test, and the treatment means significant at $p<0.05$ were denoted using different letters.

Results and Discussion

Temporal changes in selection of rice varieties

Selection of variety is an important decision as the rice varieties available in this region vary not only in terms of time and duration but also in terms of yield potential (Singh *et al.,* 2021). These results revealed that area under un-recommended varieties has decreased from ~39%in 2012 to ~6% in 2021 (Fig. 1). Conversely, the area under PR-118 has decreased from ~37% in 2012, to ~11% in 2014, and almost disappear thereafter. Similarly, the area under PR-114 decreased significantly from ~14% in 2012 to ~8.0% in 2014. Rice variety PR-121 covers ~30-38% of total area under rice during 2015 to 2018. The constant efforts in the form of awareness campaigns by Punjab Agricultural University (PAU) have played a major role in the adoption of recommend rice varieties. Additionally, intensified extension efforts made to provide seed of recommended rice varieties may have helped to increase area under recommended rice varieties. The duration of variety also significantly affects the resource consumption especially irrigation water and also fertilizers and pesticides.

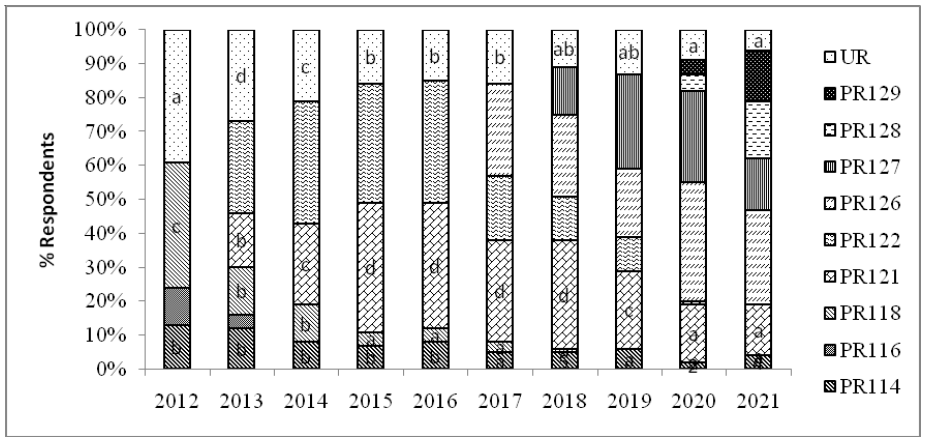

Fig. 1. Temporal change in adoption of rice varieties by farmers of Ropar district of Punjab, India. Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

Crop establishment methods

These survey results revealed that there were three methods of rice establishment being followed by the farmers of the district. Though the main preference of the farmers remains on manual transplanting (i.e. puddled transplanted rice) which was preferred by 85-99% of the farmers during 10-year study (Fig. 2). Only ~1-2 % of farmers preferred the mechanical transplanting. The less preference of farmers for mechanical transplanting methods was ascribed to the limited number of mechanical rice seedling transplanters available in the study region. Nonetheless, eventhe farmers having mechanical transplanters, preferred manual transplanting over mechanical transplanting. The basic reason for farmers' preference for manual transplanting has been related to quick, less, and the difficulties associated with preparation of mat type nursery to be required for mechanical transplanters. The third method i.e. direct seeded rice involves the direct sowing of rice (DSR) with seed drill, and has a mixed response from the users. Some farmers report it to be easy, time saving and cheaper, while some believe DSR crop is difficult to maintain considering the issues of weed management, plant population and yield potential. Normally, ~1-6% farmers tried DSR in their fields during normal years

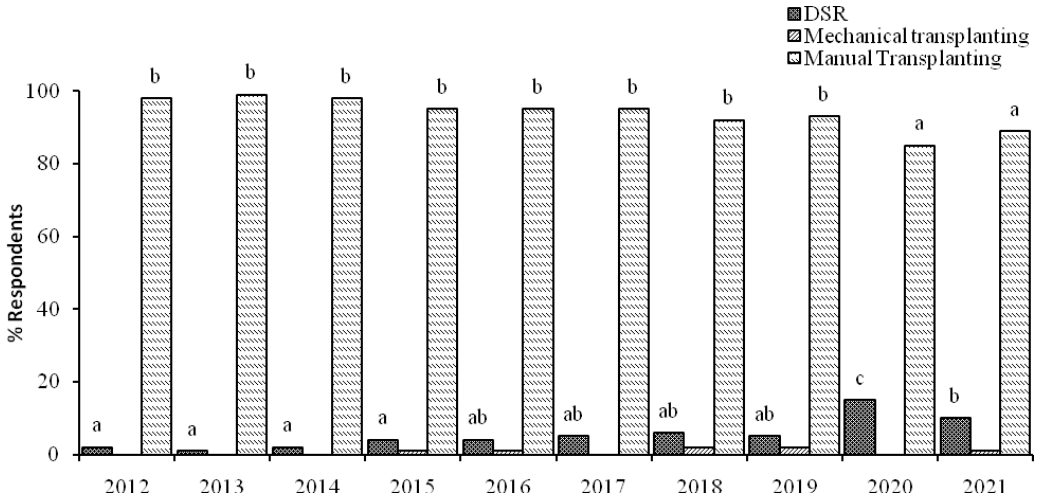

Fig. 2. Relative distribution of respondents based on adoption of different rice establishment methods by farmers over a long period of time (2012-21) in Ropar district of Punjab, India. Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

under the study, but sudden increase up to~15% was observed during pandemic year of 2020 when the seasonal labor was not available till late into the season. Figure 2 illustrates a significant increase in area under DSR by ~3-times from 2019 to 2020. It could be ascribed to the fact that there occurred a large shortage of migratory labor due to COVID-19 pandemics (Bhatt and Singh, 2021). It was important to observe non-significant change in rice area under manual transplanting for the period between 2012 and 2018. A significant decrease in area under manual transplanting decreased during 2020/2021 was ascribed to large scale joint extension efforts carried by the Punjab Agricultural University, Ludhiana and State Department of Agriculture and Farmers Welfare, Punjab, India.

Fertilizer consumption patterns

In general, the urea consumption has declined over the period of study. This can be attributed to increase in awareness level of farmers and crop residue management practices being promoted extensively. The extension scientists of Punjab Agricultural University have been constantly making efforts to educate farmers regarding balanced and optimum use of fertilizers. During 2012, 92 % farmers were applying more than the recommended dose of urea to the rice crop. This trend of high urea application gradually declined over the period of time (Table 1). Major decline was however observed during 2018 when the quantity of urea per bag was reduced from 50 kg/bag to 45 kg/bag.

The Punjab Agricultural University recommends skipping of Phosphorus application to rice crop if the recommended full dose of phosphorus has been applied to the preceding wheat crop. This was extensively promoted by the extension functionaries through campaigns and awareness camps. This educational effort is visible in this study as the percentage of farmers applying phosphorus to rice crop reduced from 78 % in 2012 to 29 % in 2021 (Fig. 3).

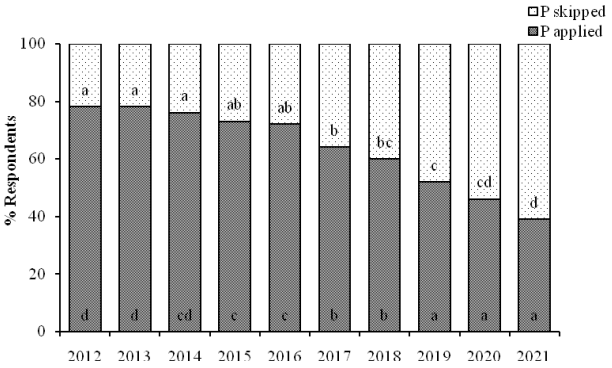

Fig. 3. Distribution of respondents based on application of fertilizer-P in rice over a long period of time (2012-21) in Ropar district of Punjab, India. Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

The use of micronutrients, however, has been increasing. This can be attributed to imbalanced use of fertilizers and lesser application of organic manures (Choudhary *et al*., 2022). The percentage of farmers who needed to apply zinc to their rice crop increased from 44 % to 57 % during the study period (Fig. 4). Likewise, the proportion of farmers applying iron fertilizer increased from 6 % to 13 % during the study (Fig. 5). It peaked to 16 % during 2020 when the area under DSR crop increased, as the DSR crop is more prone to iron deficiency. This indicates the need for organic manures and in-situ crop residue management.

Table 1. Change in pattern of fertilizer-N (urea) application rate over a long period of time (2012-21) in Ropar district of Punjab, India.

Urea (kg/acre)	% of respondents									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
<51	0	0	0	0	0	0	0	0	0	0
51-70	0	0	0	0	0	0	1	1	1	1
71-90	8	8	8	8	8	8	19	23	24	28
91-110	18	17	18	20	24	27	24	25	27	31
111-130	46	45	45	46	43	42	38	35	34	30
131-150	21	23	22	20	19	17	14	12	12	8
>150	7	7	7	6	6	6	4	4	2	2

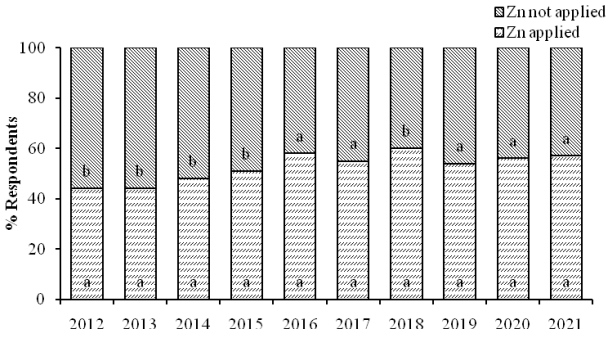

Fig. 4. Distribution of respondents based on application of fertilizer-Zn in rice over a long period of time (2012-21) in Ropar district of Punjab, India. Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

Herbicide use pattern in rice

These results revealed that all the surveyed farmers said that they depend upon weedicides for weed control in rice crop. More than three-fourth of the surveyed farmers were using butachlor as their preferred choice of herbicide (Table 2), and this proportion has been constant over the years of survey. From the survey data it can be observed that there has been a considerable increase in the use of post emergence herbicides like Bispyribac sodium and Cyhalofop butyl. This can be deciphered into increase in the area under DSR and may be some change in weed flora also. As we observe the method of application of weedicides, 68 to 76 % farmers apply the weedicide with a bottle having a solution of weedicide plus water, directly sprinkled into the standing water in the rice crop. The number of farmers following this method of application has been more or less constant during this study period. Others apply this as mixed with sand or fertilizer while the post emergence herbicides have been sprayed with spray pumps (Table 3).

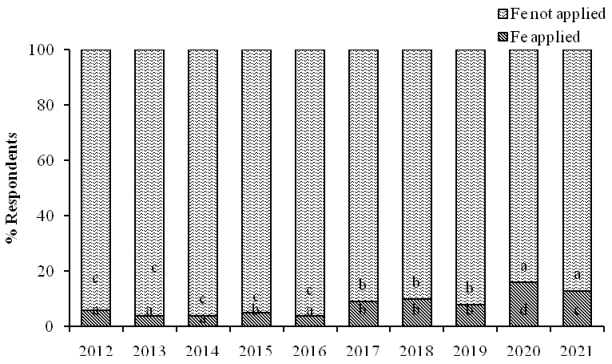

Fig. 5. Distribution of respondents based on application of fertilizer-Fe in rice over a long period of time (2012-21) in Ropar district of Punjab, India. Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

Rice residue management

Rice residue management has gained tremendous attention of government, farmers and general public because of the amount of pollution it is causing. Continuous efforts are being made to solve this problem with machinery and creating other uses for rice straw (Korav *et al*., 2022). These efforts have started showing the results. In this survey during 2012, 68% farmers were burning the rice straw (Fig. 6). This proportion reduced to 9% in 2021, when 91% farmers were keeping the straw in their fields as incorporated or as mulch with the help of implements like happy-seeders, rotavators and super-seeders.

Grain yield

Average yield of rice of the sampled farmers

Table 2. Distribution of respondents based on herbicide use pattern in rice over a long period of time (2012-21) in Ropar district of Punjab, India.

Herbicide	% of respondents									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Pretilachlor	17b	15a	17b	23c	18b	21bc	22b	23c	20bc	20bc
Butachlor	79c	82c	80c	75ab	74ab	80c	75ab	75ab	71a	72a
Anilogard	4b	3b	3b	2a	4b	3b	7b	4b	5b	6b
Bispyribac sodium	-	-	1a	1a	4b	8b	8b	9b	14c	12c
Cyhalofop butyl	-	-	1a	1a	2a	4b	2a	1a	6b	5b

Mean values for each variety followed by different letters were significantly different at $p<0.05$ by Least Significant Difference (LSD) test.

Table 3. Distribution of respondents based on method of herbicide use pattern in rice over a long period of time (2012-21) in Ropar district of Punjab, India.

Method of treatment	% of respondents									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bottle sprinkle	68a	70ab	76c	72b	72b	75c	72b	72b	74bc	73bc
Mixed with DAP	17b	10a	9a	10a	9a	10a	8a	9a	10a	9a
Mixed with sand	13a	16b	15b	16b	13a	15b	13a	12a	12a	13a
Applied with spray pump	1	1	0	1	1	1	1	1	1	1
Mixed with urea	1	1	0	0	0	0	0	0	0	0

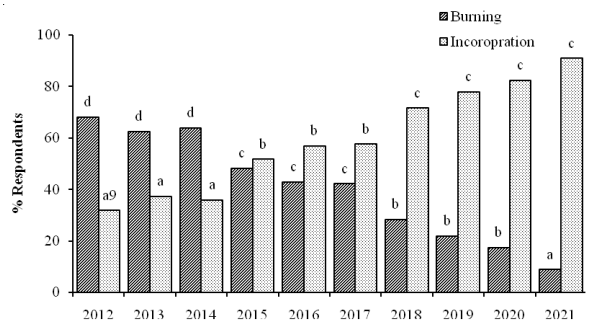

Fig. 6. Periodic shift in crop residue management practices in riceover a long period of time (2009-21) in Ropar district of Punjab, India.

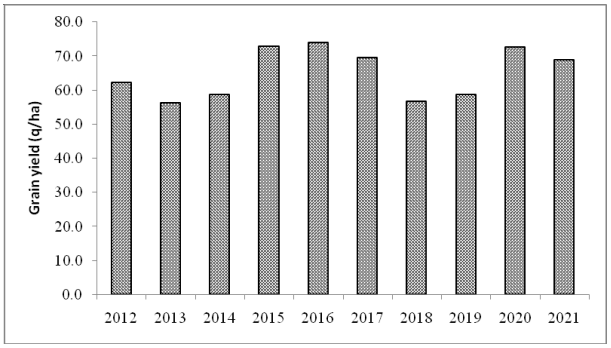

Fig. 7. Average rice grain yield over a long period of time (2012-21) in Ropar district of Punjab, India.

ranged from 56.3 q/acre to 7.9 q/ha during the study period (Fig. 7). The years of 2015, 2016 and 2020 were good in terms of productivity of rice crop among the surveyed farmers.

Conclusion

The farmers are differential in perceiving the new ideas which influence the adoption of new technologies and management practices. This can affect the realization of full potential of a crop. The role of extension agencies is important in convincing the farmers for adoption of improved technology. This study highlights the effects of extension functionaries in positively influencing the farmers for adopting new technologies. This helped in increasing the productivity of crop while reducing input costs.

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