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Adoption of Improved Rice Technologies in Major Rice Producing Areas of Punjab, India: A Multivariate Probit Approach

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Abstract

For the purpose of increasing productivity in the agricultural sector, notably in the production of rice, the implementation of enhanced agricultural technology packages is absolutely necessary. In this study, the possibility of smallholder farmers adopting improved rice technology was investigated, as well as the factors that influence their decisions towards such adoption. The results of the multivariate probit analysis showed that the factors that influence adoption differed for various technologies, and that the decision to adopt each technology was influenced by a different set of criteria. A number of important elements were taken into consideration, including demographics, institutional characteristics, ownership of resources, plot properties, and finances. In the study, the advantages of combining rice technologies were highlighted, and it was suggested that these technologies be promoted as a package. The use of these technologies among farmers should be encouraged by governments and partners who should assist the accessibility and affordability of these technologies.

Keywords: Gender, Age, Experience, Education, Household size, Rice Area, Mobile

Introduction

Rice is a global staple, especially in Asia. Rice is flexible and can be used in savoury and sweet dishes. It provides calories, fibre, vitamin B, iron, and magnesium as a complex carbohydrate. Long-grain, medium-grain, short-grain, white, brown, and black rice varieties exist. Rice can be boiled, steamed, fried, or baked as a side dish, main entrée, or ingredient in soups, salads, and desserts (Ahmed et al., 2017) Rice cultivation has been important to many cultures and cuisines for thousands of years.

India's staple food, rice, was introduced around 2000 BC. Rice may have come to India from ancient Chinese and Southeast Asian traders. Different Indian areas have developed their own rice types and farming methods. West Bengal, Odisha, Andhra Pradesh, and Tamil Nadu are famed for their ancient rice farming methods (Aryal et al., 2018). India produces and consumes rice in practically every state. West Bengal, Uttar Pradesh, Punjab, Andhra Pradesh, Telangana, Tamil Nadu, and Bihar cultivate the most rice in India (Bannor et al., 2020). India needs rice for food security and rural livelihoods. It sustains millions of farmers, especially in rural areas, and several allied industries like rice milling and processing.

Punjab is a major contributor to India's rice production. It is known as the "Rice Bowl of India" because of its large rice production. Punjab is an ideal region for rice cultivation due to its fertile soil, abundant water resources from rivers such as the Beas and Sutlej, and a well-established irrigation system (Chandio and Yuansheng, 2018). Punjab has consistently produced a large quantity of rice, both for domestic consumption and export. Farmers in Punjab primarily cultivate two types of rice: Basmati rice and non-Basmati rice. Punjab's agricultural practises, which include the use of modern farming techniques, improved seed varieties, and adequate infrastructure, all contribute to the province's high rice productivity (Eliazer et al,. 2019). In addition, the state government has launched a number of initiatives to promote rice cultivation and provide farmers with subsidies, irrigation facilities, and crop insurance. It is important to note, however, that the agricultural landscape is subject to change, and specific production figures can vary from year to year due to a variety of factors such as weather, government policies, market demand, and economic factors.

Rice is one of the commodities that has gotten special attention in the country's efforts to change agricultural production. Rice production has developed rapidly and widely throughout the country since its introduction. In developing nations, increasing agricultural productivity through the adoption and distribution of new agricultural technologies is a critical road to economic growth and agricultural transformation (Kumar et al., 2020). Meaningful change in agricultural productivity, for example, through new technologies, can be one approach of assuring food security through increased production and lower food prices.

To achieve national food security, cut rice imports, and reduce rice market volatility, rice productivity and production must increase. High-yielding crop varieties and other recommended technology packages can boost rice production and boost agro-processing and non-farm sectors. Technology alone does not boost productivity. Farmers need them. Most rice adoption studies were limited to a district or zone and used small sample sizes. No data exists on the adoption and spread of improved rice technology packages and agronomic practises. This study examined rice technology adoption in major production areas in Uttar Pradesh, India and the factors that influence farm households' technology adoption decisions.

Material and Methods

The study was conducted in 4 major rice producing districts i.e Jalandhar, Ludhiana, Kapurthala and Hoshiarpur. Five blocks from each district were selected from which one village was selected randomly. From each village 10 farmers were selected randomly. Thus in total 20 blocks , 20 villages and 200 households were selected. (Figure 1)

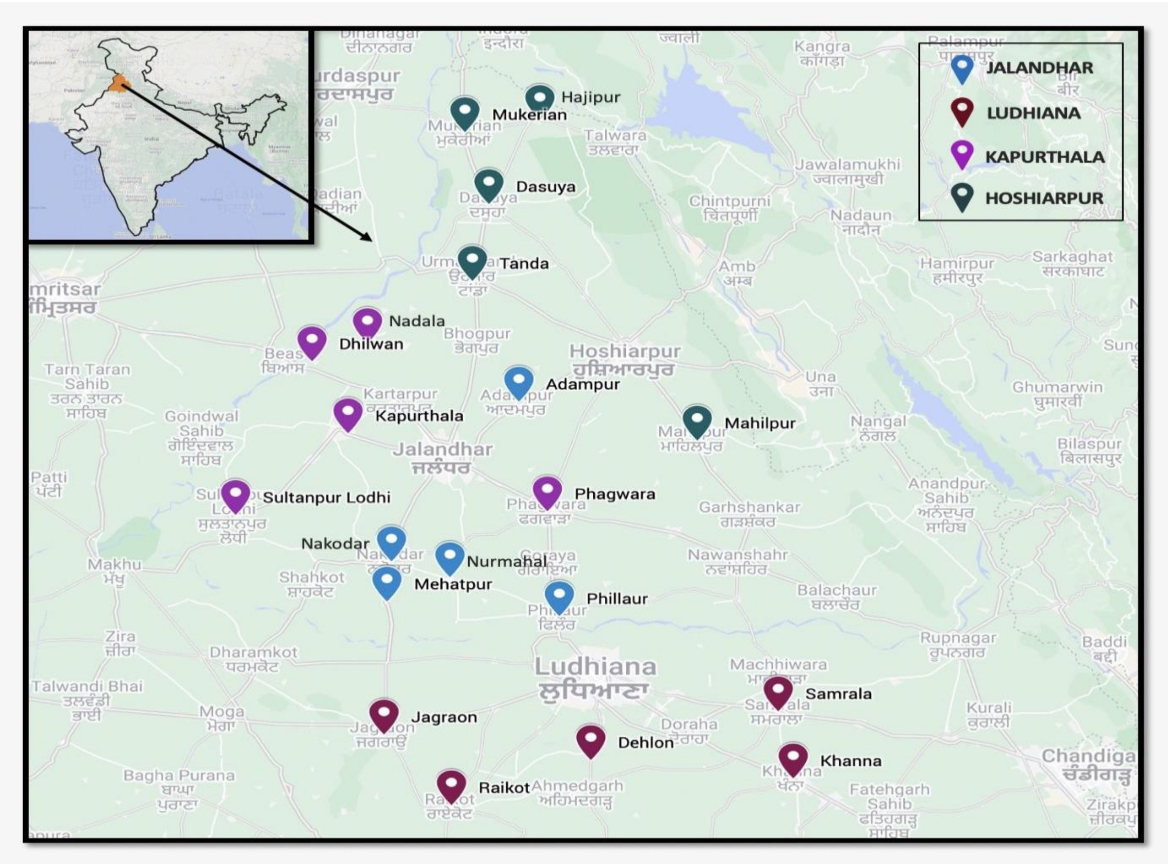

Figure 1. Study area of the household survey

This study was based on cross sectional data collected from rice-based farming systems. The primary data was collected from sample households using structured questionnaires through the interview methods. Relevant secondary data were collected from various government organizations. The sampling technique employed to select samples for the study involved both purposive and random sampling techniques. The multistage sampling approach was followed to identify household in which district were the primary sampling techniques, blocks the secondary and household the tertiary sampling units. Before the actual survey, the questionnaire were pretested in non-sampled villages and relevant modifications were made. Important information such as fertilizer dose and frequency, weeding frequency etc were collected from secondary sources. The community survey was aimed at collecting community level from community leaders and key informants which provided the useful insights (Table 1).

The data were analyzed using STATA 17 and R for descriptive and econometric statistics. The data received through the interview were compiled, summarized and interpreted. Mean, percentage, frequency and chi-square test and standard deviation were used to access socio-economic characteristics and rice technology packages. Multivariate probit (MVP) regression was used to estimate the factors influencing adoption decision of improved agricultural technologies. It helps to determine possible complementarities and substitutability between the improved technology and practices. MVP also accommodates the possibility of correlation between adoption decisions across different technology practices.

In this study, a variety of household, farm, plot characteristics and institutional factors are hypothesized to influence the adoption of improved rice technology by smallholder farmers in rice-based farming systems. Table 1 provides detailed definitions of the explanatory variables and hypotheses regarding the effects on the adoption of technologies.

Table 1. Definition of variables hypothesized to influence the adoption of improved rice technology packages

Variable	Description	Value	Sign
Gender	Gender of household head	0= female, 1= male	±
Age	Age of household head	Years	±
Experience	Experience of household in farming	Years	+
Education	Average education of family	Years	+

Household size	No. of family members	Number	±
Total Cultivated Land	Cultivated Area	Hectare	±
Rice Area	Total area under rice	Hectare	±
Livestock	Livestock ownership	Livestock ownership	+
Rice Income	Income from rice sale	Rupees	+
Mobile	Ownership	1= Yes, 0= No	+
Radio	Ownership	1= Yes, 0= No	+
Non/off farm	Non/off farm income	1= Yes, 0= No	±
Extension	Frequency of extension contact	Count	+
Receive Credit	Credit received last year	1= Yes, 0= No	+
Irrigation Access	Access to irrigation	1= Yes, 0= No	+
Market Distance	Distance from main market	Walking minutes	
Cooperation membership	Membership of cooperatives	1= Yes, 0= No	+
Social Capita Index	Index social capital	Number	+
Soil Fertility	Soil fertility status	0=Fertile, 1=Medium, 2=Infertile	±
Plot distance	Rice plot distance from the residence	Kilometer	-
Crop rotation	Crop rotation practice	1= Yes, 0= No	±
Rice Ecosystem	Rice ecology	1=Lowland, 0=Upland	±

Note: The "+" sign indicates a positive effect on the adoption of improved rice technology, while the "-" sign indicates a negative effect. The "±" sign indicates that the effect could be positive or negative, depending on the specific context or conditions.

Results and Discussion

Demographic Characteristics of the Household

The Table 2 shows household characteristics in Jalandhar, Ludhiana, Hoshiarpur, and Kapurthala, Punjab. These include the family head's age, farming experience, rice farming experience, education level, average family education, household size, and agricultural practise adoption. Age is the important demographic factors which can influence the adoption rate. According to the finding Jalandhar has the highest average age of the family head at 43.7 years, followed by Kapurthala at 44.8 years, Ludhiana at 39.2 years, and Hoshiarpur at 38.7 years. The average age for all districts is 41.6 years. This suggests that family heads in

Jalandhar and Kapurthala are older than those in Ludhiana and Hoshiarpur. Kapurthala has the highest average of farming experience at 23.8 years, followed closely by Jalandhar at 22.2 years. The average age in Ludhiana and Hoshiarpur is 21.5 years and 19.8 years, respectively. Across all districts, the average farming experience is 21.8 years. Kapurthala has the highest average of 23.8 years of rice farming experience, followed by Jalandhar at 22.2 years. The average rice farming experience in Ludhiana and Hoshiarpur is 21.5 years and 19.8 years, respectively. The average rice farming experience is 21.8 years for overall districts. The result was in line with the results of Baiyegunhi et al., (2019) where the average age, faring experience and rice farming experience were in same trend. The similar results were also found by Mirani et al., (2002), Ahmed et al., (2017), Chandio and Yuansheng (2018), Bannor et al., (2020), and Boon and Anuga (2020). The results were found different in study of Kassie et al., (2015), Kumar et. al., (2016), Jain and Rekha (2017), Islam (2019) and Kumar et. al., (2020).

The education levels of the family heads, as well as the average family education, provide information about the educational background of households which has an immense role for access to basic information and technology update. Ludhiana has the highest levels of education, with family heads having an average education level of 3.9 and families having an average education level of 4.8. Jalandhar, Hoshiarpur, and Kapurthala have lower levels of education. The average education level of family heads for overall is 2.8, and the average education level of families is 3.6. The family size assists for better participation in rice production due to more requirement of labour. Household size varies by district, with Ludhiana having the largest average size of 6.8 members and Jalandhar having the smallest average size of 5.2 members. The average household size in Kapurthala and Hoshiarpur is 4.8 members and 4.5 members, respectively. The average household size for overall is 5.3 people. The similar results were also found by Jha and Kumar (2001), Chandio and Yuansheng (2018), Bannor et al., (2020), Boon and Anuga (2020), Mansaray and Jin (2020). The results were found different in study of Khalid and Mehmood (2010), Mariano et al., (2012), Muzari et al., (2012), Kumar et. al., (2016), Ahmed et al., (2017), Mehar et al. (2017) and Kumar et. al., (2020).

Table 2- Demographic Characteristics of the Sampled Households

Household Characteristics	**Jalandhar**	**Ludhiana**	**Hoshiarpur**	**Kapurthala**	**Overall**	**Adopters**	**Non Adopters**
Age of the Family Head	43.7	39.2	38.7	44.8	41.6	41.2	45.0
Farming Experience	22.2	21.5	19.8	23.8	21.8	23.8	12.4
Rice Farming Experience	22.2	21.5	19.8	23.8	21.8	22.5	20.8
Education Level of the Head	1.8	3.9	3.1	2.5	2.8	2.4	1.8
Average Family's Education	2.5	4.8	3.2	3.7	3.6	3.8	2.7
Household Size	5.2	6.8	4.5	4.8	5.3	5.9	4.9

Economic Characteristics of Sample Households

1. Land Ownership

One of the most important factor influencing crop production is land ownership. The farmers who do not cultivate their land share or rent their land. The Table 3 shows land ownership patterns in four Punjab districts: Jalandhar, Ludhiana, Hoshiarpur, and Kapurthala. It includes the average hectare of land owned, shared, and rented. In Jalandhar, the average household owns 2.18 hectares of land, while the average shared-in land is 1.12 hectares, indicating that some households own land jointly. Furthermore, Jalandhar households rent an average of 1.07 hectares of land. Households in Ludhiana own an average of 2.85 hectares of land and have access to shared-in land averaging 1.10 hectares. Furthermore, households in Ludhiana rent 1.48 hectares of land on average. In comparison to the other districts, Hoshiarpur has a higher average land ownership, with households owning an average of 3.54 hectares of land. Similarly, households in Hoshiarpur have access to 1.25 hectares of shared-in land on average. The renting pattern is also balanced, with Hoshiarpur households renting 1.25

hectares of land on average. Among the four districts, Kapurthala has the highest average land ownership, with households owning an average of 4.52 hectares of land. They also have access to shared-in land, which is 1.38 hectares on average. Furthermore, households in Kapurthala rent 1.85 hectares of land on average, indicating a significant reliance on rented land. The average amount of land owned by households across all districts is 3.27 hectares. The average shared-in land area is 1.21 hectares, and households rent 1.41 hectares of land. This finding is in accordance with the results of studies by Jena and Grote (2012), Kumar et al., (2013), Kumar et al., (2016), Subedi et al., (2019), Kumar et al., (2020) and Takahashi et al., (2020).

Table 3- Land Ownership of the Sampled Households

Districts	Own land (Ha)	Shared in (Ha)	Rented in (Ha)
Jalandhar	2.18	1.12	1.07
Ludhiana	2.85	1.10	1.48
Hoshiarpur	3.54	1.25	1.25
Kapurthala	4.52	1.38	1.85
Overall	3.27	1.21	1.41

2. Access to Institutional Services

The crop production, livestock rearing, adoption of improved technologies is mainly determined by the development of the institutional. The availability of credit is very important factor for poor farmers which increases the farm productivity hence income and adoption of new technologies. The Table 4 provides information on various factors related to institutional services in the district of Jalandhar, Ludhiana, Hoshiarpur, and Kapurthala, as well as an overall comparison. The percentage of individuals in each district who have received credit from institutional services, Jalandhar has the highest percentage at 24.8%, followed by Hoshiarpur (14.5%), Ludhiana (11.8%), and Kapurthala (9.8%). Jalandhar has the highest percentage of coop membership at 54.8%, followed by Kapurthala (35.3%), Hoshiarpur (26.5%), and Ludhiana (25.8%). The average number of extension contacts made by institutional services with individuals, Ludhiana has the highest frequency at 12.2, followed by Hoshiarpur (10.2), Jalandhar (6.5), and Kapurthala (5.2). In case of the average distance in minutes from individuals' locations to the main market Ludhiana has the highest distance at 42.7 minutes, followed by Kapurthala (47.2), Hoshiarpur (38.5), and Jalandhar (34.5). The higher membership index implies greater participation in social institutions which is measured between 0 to 1. Ludhiana has the highest index at 0.78, followed by Jalandhar (0.48), Hoshiarpur (0.68), and Kapurthala (0.35). Overall, the data suggests that Jalandhar has a higher percentage of credit received and coop membership compared to the other cities. Ludhiana has the highest frequency of extension contacts and membership in social institutions. Hoshiarpur has a relatively higher membership index and is closer to the main market compared to the other cities. Kapurthala generally has lower values across the factors examined. This finding is in accordance with the results of studies by Janaiah et al., (2006), Kumar et al., (2013), Kumar et al., (2016), Paltasingh et al., (2017), Paltasingh (2018), Paltasingh and Goyari (2018), Eliazer et al,. (2019) ,Subedi et al., (2019) and Takahashi et al., (2020).

Table 4- Access to Institutional Services of the Sampled Households

Institutional Services	**Jalandhar**	**Ludhiana**	**Hoshiarpur**	**Kapurthala**	**Overall**
Credit Received (%)	24.8	11.8	14.5	9.8	15.2
Coop Membership (%)	54.8	25.8	26.5	34.2	35.3
Frequency of Extension Contacts (Number)	6.5	12.2	10.2	5.2	8.5
Distance to Main Market (Minute)	34.5	42.7	38.5	47.2	40.7
Membership in Social Institutions (Index)	0.48	0.78	0.68	0.35	0.6

Sources of Information

The farmers in the study area received information about the various improved rice technologies from various sources such as farmer, extension worker, Radio/Newspaper/TV etc. The Table 5 provides information on the main sources of information for farmers in Jalandhar, Ludhiana, Hoshiarpur, and Kapurthala, as well as an overall comparison. The percentages represent the proportion of farmers relying on each source. Overall, another farmer is the most common source of information among farmers, with Kapurthala having the highest percentage at 60.5%, followed by Hoshiarpur (58.5%), Ludhiana (48.2%), and Jalandhar (45.2%). Radio/TV/News papers are also widely used, especially in Ludhiana (65.5%), Hoshiarpur (58.7%), and Jalandhar (55.5%). Government extension services play a significant role, particularly in Hoshiarpur (32.5%) and Kapurthala (29.7%). Research centers and NGOs are less frequently utilized sources. The local market is an important information source in Jalandhar (29.5%) and Kapurthala (26.3%). These findings provide insights into the diverse information channels used by farmers in these cities. This finding is in accordance with the results of studies by Kumar et al., (2013), Ghimire et al., (2015), Kumar et al., (2016), Mehar et al., (2017), Paltasingh et al., (2017), Paltasingh (2018), Subedi et al., (2019) and Takahashi et al., (2020).

Table 5- Sources of Information of the Sampled Households (%)

Main Source of Information	**Jalandhar**	**Ludhiana**	**Hoshiarpur**	**Kapurthala**	**Overall**
Government Extension	25.2	27.5	32.5	29.7	28.7
Another Farmer	45.2	48.2	58.5	60.5	53.1
Research Center/ KVK/ SAU	15.5	18.3	24.5	27.8	21.5
NGOs	8.5	9.2	6.4	2.4	6.6
Radio/TV/News Paper	55.5	65.5	58.7	49.5	57.3
Local Market	29.5	25.7	19.8	26.3	25.3

Adoption Status of Improved Rice Technology Packages

Various improved agricultural technologies of rice such as improved seeds, recommended use of fertilizers, recommended irrigation frequency etc. are been used by the farmers to improve the rice productivity. The Table 6 represents the adoption rates of various technologies and practices in rice cultivation across Jalandhar, Ludhiana, Hoshiarpur, and Kapurthala, with an overall average. Improved seed adoption ranges from 24.5% in Jalandhar to 32.7% in Kapurthala, with an overall adoption rate of 28.0%. Row planting, where crops are planted in rows instead of broadcasted, has lower adoption rates, ranging from 17.8% in Hoshiarpur to 28.9% in Kapurthala, with an overall adoption rate of 22.0%. Row planting, one of the agronomic practices that can increase rice productivity, has lower adoption rates across all regions. Adoption rates range from 17.8% in Hoshiarpur to 28.9% in Kapurthala, with an overall adoption rate of 22.0%. The extension workers motivates the farmers to go for recommended doses of fertilizers, thus it shows some variation across the regions. Ludhiana has an adoption rate of 48.6%, Jalandhar has 56.5%, Hoshiarpur has 57.8%, and Kapurthala has the highest adoption rate of 61.2%. The overall adoption rate for recommended use of fertilizers is 56.0%.

Weed management is more demanding in rice as compared to other cereal crops. As it is sown at close spacing, which makes mechanical weeding difficult resulting in less yield. Recommended weeding frequency shows significant variation, with adoption rates as low as 7.6% in Ludhiana and as high as 52.3% in Kapurthala. The overall adoption rate for recommended weeding frequency is 30.5%. Recommended irrigation frequency exhibits higher adoption rates, ranging from 54.2% in Hoshiarpur to 72.4% in Jalandhar, with an overall adoption rate of 65.5%. Recommended pest/disease management has adoption rates ranging from 35.7% in Jalandhar to 48.3% in Kapurthala, with an overall adoption rate of 41.6%. Recommended post-harvest management practices have adoption rates ranging from 49.3% in Kapurthala to 59.2% in Hoshiarpur. The overall adoption rate for post-harvest management is 55.3%. Overall, the adoption rates indicate varying levels of implementation of these practices, highlighting the need for targeted interventions and extension services to promote the adoption of improved rice technologies consistently. This result confirms the finding by Kumar et al., (2013), Kumar et al., (2016), Mehar et al., (2017), Paltasingh et al., (2017), Aryal et al., (2018), Beuermann et al., (2018), Paltasingh (2018), Subedi et al., (2019), Bannor et al., (2020) and Takahashi et al., (2020).

Table 6- Adoption Status of Improved Rice Technology Packages of the Sampled Household

Improved Technologies and practices	**Jalandhar**	**Ludhiana**	**Hoshiarpur**	**Kapurthala**	**Overall**
Improved	24.5	28.7	26.2	32.7	28.0

Seed					
Row Planting	22.7	18.5	17.8	28.9	22.0
Recommended use of Fertilizers	56.5	48.6	57.8	61.2	56.0
Recommended Weeding Frequency	33.2	7.6	28.9	52.3	30.5
Recommended Irrigation Frequency	72.4	65.4	54.2	70.1	65.5
Recommended Pest/Disease Management	35.7	39.4	42.8	48.3	41.6
Recommended Post-Harvest Management	55.2	57.3	59.2	49.3	55.3

Returns from improved rice technologies

The Table 7 provides data on the impact of improved technologies and practices on rice yield and income in a given context. The study compares the outcomes between adopters and non-adopters of these practices. The table shows that adopters of improved seed achieved a higher rice yield of 41.2 q compared to 33.5 q for non-adopters. The t-statistic of -5.24 suggests a significant difference between the two groups. Adopters also earned a higher income of Rs 75,124 compared to Rs 63,253 for non-adopters. Adopters of row planting achieved a higher yield of 38.2 q compared to 33.4 q for non-adopters. The t-statistic of -6.35 indicates a significant difference. However, in terms of income, adopters earned Rs 72,152, while non-adopters earned slightly more at Rs 70,127. Adopters of recommended fertilizer use achieved a higher yield of 39.4 q compared to 32.6 q for non-adopters. The t-statistic of -6.87 suggests a significant difference. In terms of income, adopters earned Rs 74,258, while non-adopters earned Rs 69,248. Adopters of recommended weeding frequency achieved a yield of 36.4 q compared to 33.2 q for non-adopters. The t-statistic of -5.82 indicates a significant difference. Adopters earned Rs 73,247 in income, while non-adopters earned Rs 68,779. Adopters of recommended irrigation frequency achieved a yield of 37.2 q compared to 31.2 q for non-adopters. The difference in yield is statistically significant (t-stat = -4.57). Adopters earned Rs 74,248 in income, while non-adopters earned Rs 66,457. Adopters of recommended pest/disease management achieved a yield of 38.6 q compared to 29.2 q for non-adopters. The difference in yield is statistically significant (t-stat = -5.87). Adopters earned Rs 71,247 in income, while non-adopters earned Rs 65,454. Adopters of recommended post-harvest management achieved a yield of 39.2 q compared to 28.4 q for non-adopters. The difference in yield is statistically significant (t-stat = -6.85). Adopters earned Rs 73,452 in income, while non-adopters earned Rs 66,748.

Overall, the table highlights that adopting these improved technologies and practices can significantly increase rice yield, resulting in higher income for farmers. The t-statistics demonstrate that the observed differences in yield between adopters and non-adopters are statistically significant for all the practices mentioned. However, the income differences may not always align with the yield differences, indicating that factors other than the specific practices may also influence income outcomes. This result confirms the finding by Kumar et al., (2013), Kumar et al., (2016), Mehar et al., (2017), Paltasingh et al., (2017), Aryal et al., (2018), Chandio and Yuansheng (2018), Subedi et al., (2019), Bannor et al., (2020), Boon and Anuga (2020) and Takahashi et al., (2020).

Table 7- Yield and Income Mean Differences Across Technology Adopters

Improved technologies and practices	**Rice Yield (Overall Mean= 35.1 q)**			**Rice Income in Rs (Overall Mean= 70271)**		
	Adopters	Non-adopters	t-stat	Adopters	Non-adopters	t-stat
Improved Seed	41.2	33.5	-5.24	75124	63253	-4.24
Row Planting	38.2	33.4	-6.35	72152	70127	-5.68
Recommended use of Fertilizers	39.4	32.6	-6.87	74258	69248	-4.72
Recommended Weeding Frequency	36.4	33.2	-5.82	73247	68779	-4.87
Recommended Irrigation	37.2	31.2	-4.57	74248	66457	-5.68

Frequency						
Recommended Pest/Disease Management	38.6	29.2	-5.87	71247	65454	-4.81
Recommended Post-harvest Management	39.2	28.4	-6.85	73452	66748	-4.74

Determinants of Adoption of Improved Rice Technologies Packages

Several factors determine the adoption of improved rice technologies packages. We have modeled seven dependent variable and 22 explanatory variable in multivariate probit regression framework (Table 8). Before running the model the variables were tested for existence of outliers and collinearity. The variance inflation factor for all variables were less than 5, showing multi-collinearity is not a serious problem. The MVP model is significant, because the null hypothesis that the adoption of seven rice technologies are independent were rejected at the 1% significance level. The model result revealed that the Wald test is significant at 1% level, which indicates that the subset of coefficients of the model is jointly significant and that the explanatory power of the factors included in the model is satisfactory. The table 8 presents the model results and the conditional and unconditional marginal effect results of the MVP model on the adoption of improved rice technology packages.

Table 8- Multivariate Probit Simulation Result for Adoption of Rice Technology Packages

Variable	Improved seed **Coef. (Rob. S.E)**	Row planting **Coef. (Rob. S.E)**	Recommended use of fertilizers **Coef. (Rob. S.E)**	Recommended weeding frequency **Coef. (Rob. S.E)**	Recommended irrigation frequency **Coef. (Rob. S.E)**	Recommended pest/disease management **Coef. (Rob. S.E)**	Recommended post-harvest management **Coef. (Rob. S.E)**
Gender	0.218 (0.236	0.005 *	0.478** (0.258)	0.247 (0.242)	0.287 (0.257)	0.327 (0.198)	0.292** (0.201)

	)	(0.278)					
Age	-0.007 (0.005)	0.008* (0.004)	0.007* (0.002)	0.009 (0.005)	0.010 (0.006)	0.008 (0.007)	0.011* (0.0060
Experience	0.015* (0.014)	0.008 (0.012)	0.014 (0.014)	0.175* (0.018)	0.172 (0.017)	0.125** (0.165)	0.162 (0.160)
Household size	-0.047 (0.027)	-0.058 (0.028)	-0.055* (0.031)	-0.065* (0.032)	-0.068** (0.039)	-0.048 (0.024)	0.052 (0.025)
Education	0.102* (0.038)	0.105 (0.036)	0.108 (0.029)	0.114 (0.037)	0.117 (0.039)	0.112** (0.038)	0.103** (0.033)
Total Cultivated Land	0.254 (0.121)	0.124 (0.125)	0.278** (0.128)	0.187 (0.124)	0.175 (0.130)	0.217 (0.131)	0.198* (0.127)
Rice Area	0.212 (0.112)	0.114 (0.125)	0.216** (0.128)	0.177 (0.124)	0.144 (0.130)	0.226 (0.131)	0.177* (0.127)
Livestock	0.122 (0.048)	-0.115 (0.039)	-0.114 (0.022)	-0.117 (0.034)	0.114 (0.038)	0.111 (0.032)	0.113** (0.023)
Rice Income	0.007* (0.02)	0.006 (0.002)	0.008 (0.003)	0.007** (0.002)	0.011* (0.003)	0.008** (0.003)	0.010* (0.003)
Mobile	0.292* (0.146)	0.128 (0.135)	0.132* (0.140)	-0.121 (0.125)	0.110** (0.129)	-0.138 (0.132)	0.128* (0.119)
Radio	0.018*	0.028	0.027*	0.039	0.046*	0.049	0.042*

	(0.142)	(0.137)	(0.129)	(0.132)	(0.141)	(0.138)	(0.135)
Non/off farm income	-0.017* (0.157)	0.018 (0.142)	-0.024 (0.147)	0.165* (0.148)	-0.122 (0.148)	0.105** (0.165)	0.112 (0.160)
Extension	0.012* (0.004)	0.008 (0.002)	0.014 (0.004)	0.175*** (0.005)	0.172 (0.005)	0.125 (0.003)	0.162** (0.002)
Receive Credit	0.102 (0.138)	-0.105 (0.129)	-0.124 (0.112)	-0.127 (0.124)	0.104 (0.128)	0.121** (0.122)	0.113 (0.113)
Irrigation Access	-0.072 (0.118)	0.115 (0.119)	-0.113 (0.122)	-0.142 (0.114)	0.101 (0.117)	0.114** (0.113)	0.110 (0.117)
Market Distance	-0.002 (0.2)	0.004 (0.005)	-0.006* (0.003)	-0.007** (0.004)	0.004 (0.001)	-0.006 (0.001)	0.007* (0.002)
Cooperation membership	0.067 (0.122)	0.054 (0.128)	-0.058* (0.131)	0.056* (0.132)	0.086** (0.129)	-0.084 (0.124)	0.025 (0.125)
Social Capita Index	0.229 (0.246)	0.182* (0.235)	0.123* (0.240)	-0.112 (0.225)	0.101 (0.229)	-0.183 (0.232)	0.182** (0.219)
Soil Fertility	-0.017* (0.107)	0.118 (0.102)	-0.124** (0.107)	0.245 (0.108)	-0.142 (0.108)	0.145** (0.105)	0.142*** (0.107)
Plot distance	-0.002 (0.001)	-0.003 (0.00	-0.003* (0.001)	-0.002* (0.001)	0.004 (0.002)	0.002 (0.002)	0.003* (0.001)

		2)					
Crop rotation	0.118 (0.152)	0.128 (0.157)	0.125** (0.159)	0.139 (0.152)	0.146 (0.151)	0.149 (0.158)	0.142* (0.155)
Rice Ecosystem	-0.182 (0.136)	-0.177 (0.135)	0.123* (0.130)	-0.127 (0.135)	0.118 (0.139)	-0.128 (0.132)	0.117* (0.139)
Constant	0.718 (0.552)	0.628 (0.457)	0.725 (0.469)	1.139** (0.453)	1.146 (0.471)	0.849** (0.657)	0.542* (0.659)

The results showed that gender, age and social capital index has the significant and positive effect on row planting, recommended use of fertilizers and recommended post-harvest management which enhances the farmers willingness to adopt these technologies. The experience of rice cultivation has significant and positive effect on improved seed, recommended weeding frequency and recommended pest/disease management. This shows that more experience in rice cultivation leads to more adoption of improved technologies. The size of household have the significant and negative effect on recommended use of fertilizers, recommended, weeding frequency, and recommended irrigation frequency which shows that the bigger family do not adopt recommended use of fertilizers, recommended, weeding frequency, and recommended irrigation frequency.

The education have significant and positive effect on improved technologies such as improved seed, recommended pest/disease management and recommended post-harvest management implies that higher education level leads to higher adoption rate. The total cultivated land, rice area, soil fertility, crop rotation and rice ecosystem have significant and positive effect on recommended use of fertilizers and recommended post-harvest management. The number of livestock have significant and positive effect on recommended post-harvest management which shows that the more livestock leads to higher adoption of improved technologies. The income from rice have significant and positive effect on improved seed, recommended weeding frequency, recommended irrigation frequency, recommended pest/disease management and recommended post-harvest management showing that the higher income from rice leads to higher adoption of improved rice technologies.

The mobile and radio ownership have the positive and significant effect on improved seed, recommended use of fertilizers, recommended irrigation frequency and recommended post-harvest management visualising that the higher mobile and radio ownership leads to higher adoption rate. The non farm income shows that it has positive and significant effect on recommended weeding frequency and recommended pest/disease management where as negative and significant difference in improved seeds. Frequency of extension services shows that there is positive and significant impact on improved seeds, recommended weeding frequency and recommended post-harvest management. It is clear that higher is the frequency of extension services higher is the adoption rate.

The credit received and irrigation access have significant and positive effect on recommended pest/disease management which means more credit and irrigation access leads to higher adoption of improved technologies. The distance from closest market and plot distance have positive and significant impact on recommended post-harvest management and negative and significant effect on recommended use of fertilizers and weeding frequency. The cooperation membership have negative and significant effect on recommended use of fertilizers where as positive and significant effect on recommended weeding frequency and irrigation frequency. This result confirms the finding by Sarap and Vashist (1994), Sall et al., (2000), Addison et al. (2018), Aryal et al., (2018), Awuni et al., (2018), Chandio and Yuansheng (2018), Baiyegunhi et al., (2019), Subedi et al., (2019), Bannor et al., (2020), Boon and Anuga (2020) and Takahashi et al., (2020).

Table 9- Correlation Matrix of the Technologies from the Multivariate Probit Model

Variable	Improved seed **Coef. (Rob. S.E)**	Row planting **Coef. (Rob. S.E)**	Recommended use of fertilizers **Coef. (Rob. S.E)**	Recommended weeding frequency **Coef. (Rob. S.E)**	Recommended irrigation frequency **Coef. (Rob. S.E)**	Recommended pest/disease management **Coef. (Rob. S.E)**	Recommended post-harvest management **Coef. (Rob. S.E)**
Row planting	0.491** (0.089						

	)						
Recommended use of fertilizers	0.392* (0.090)	0.224** (0.082)					
Recommended weeding frequency	0.342*** (0.087)	0.385** (0.072)	0.290* (0.051)				
Recommended irrigation frequency	0.322*** (0.074)	0.2485** (0.061)	0.332* (0.041)	0.351** (0.081)			
Recommended pest/disease management	0.322*** (0.074)	0.2485** (0.061)	0.332* (0.041)	0.351** (0.081)			
Recommended post-harvest management	0.322*** (0.074)	0.2485** (0.061)	0.332* (0.041)	0.351** (0.081)	0.0221* (0.071)		
Recommended post-harvest management	0.322*** (0.074)	0.2485** (0.061)	0.332* (0.041)	0.351** (0.081)	0.421** (0.067)	0.281** (0.072)	
Predicted Probability	0.1987	0.1952	0.3872	0.3248	0.4214	0.5142	0.4124

Joint probability (success)				4.98%			
Joint probability (failure)				21.24%			
Number of observations				200			
Number of simulations				100			
Log-likelihood				-1542.5748			
Wald Chi2 (degree of freedom)				627.81*** (110)			

LR test of overall significance of correlation coefficients $\chi2$ (10) = 138.249, Prob > $\chi2$ = 0.000.
Robust standard errors in parentheses, ***p < 0.01, **p < 0.05, and *p < 0.1

After running the MVP regression, post estimation was done to look the pairwise correlation among the dependent variables. The correlation matrix also showed that farmers ave adopted number of improved technologies simultaneously. The finding was tested using pairwise correlation coefficient across the MVP. The coefficient measure the correlation between the adoption decisions of rice technologies. The result support the hypothesis that error terms of multiple improved technology adoption decision equations are correlated. All pairwise coefficient were positively and significantly correlated, indicating complementarity among the improved rice production technologies (Table 9). This result confirms the finding by Kumar et al., (2013), Kassie et al., (2015), Kumar et al., (2016), Jain (2017), Mehar et al., (2017), Paltasingh et al., (2017), Aryal et al., (2018), Awuni et al., (2018), Chandio and

Yuansheng (2018), Subedi et al., (2019), Bannor et al., (2020), Boon and Anuga (2020) and Takahashi et al., (2020).

Conclusions

The adoption of enhanced agricultural technology packages is crucial for increasing productivity and production in the agricultural sector. Specifically, in the case of rice production, combining various rice technologies offers greater benefits compared to using them individually. This study aimed to assess the likelihood of smallholder farmers adopting improved rice technologies and practices and identify the factors influencing their adoption decisions. Data from 200 rice-producing households were collected, and a multivariate probit model was employed to estimate the factors affecting the adoption of improved agricultural technologies for rice cultivation.

The study found that the variables influencing farmers' decisions to adopt improved technology packages varied among different technologies and practices. Some factors strongly influenced the adoption of specific improved rice technology packages, while they might have been insignificant for other packages. Thus, each rice technology package's adoption decision was influenced by different sets of factors, with varying levels of significance for the same factor. Overall, the results of the multivariate probit analysis showed that most of the estimated parameters aligned with expectations and had an impact on the adoption of improved rice technology packages in the study area.

Key factors affecting the adoption decisions included demographic and institutional characteristics of households, such as gender, age, rice farming experience, average education level of family members, extension services, membership in social institutions, credit use, cooperative membership, and distance to the main market. Additionally, resource ownership and plot characteristics, such as rice area, distance to rice plots, crop rotation practices, soil fertility status, access to irrigation, livestock ownership, access to non-farm income, mobile ownership, total cultivated land, rice income, and rice ecology, played significant roles with different implications across improved rice technology packages. Notably, farmers with larger plots tended to compromise on recommended practices due to capital or labor constraints, leading to the underutilization of resources, such as land. To address this, technologies that save labor or provide access to finance should be designed to facilitate the adoption of improved practices.

The study also highlighted the importance of complementarity among improved rice technologies, implying that policy instruments influencing one technology could also impact related technologies. Therefore, promoting these technologies as a package can facilitate their scaling and adoption. Furthermore, other institutional and economic factors, such as input prices and accessibility, may also influence the adoption of improved technology packages. Thus, it is crucial for governmental and developmental partners to support and promote improved rice technology packages by ensuring the accessibility of improved technologies at affordable prices. Additionally, the national rice-research program should focus on developing varieties that align with farmers' preferences, taking into account factors like yield, marketability, straw yield, and other important traits. Researchers should work on enhancing varieties based on the characteristics preferred by local farmers and incorporated into local varieties. These insights can be valuable in encouraging agricultural technology adoption among smallholder farmers.

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