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IMPACT OF MECHANICALLY TRANSPLANTED (MTR) TECHNOLOGY ON RICE PRODUCTIVITY AND FARMERS LIVELIHOODS IN PUNJAB, PAKISTAN

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ABSTRACT

This article tries to find out the adoption and economic benefits of Mechanically Transplanted Rice (MTR) technology among rice-growing small farmers of the Gujranwala district of Punjab, Pakistan. Rice is a primary food and export crop, and any efforts towards increasing the efficiency of rice production are critical to the sustainability of the agricultural sector. The transplanting process is time-consuming as well as intensive labor, involving manual cleaning of the transplant housing; on the other hand, MTR provides a potential approach to alleviate the dependency on labor and optimize crop management. The information was gathered using structured interviews with 120 rice farmers, 60 adopters, and 60 non-adopters of MTR. Descriptive statistics, profitability analysis, and binary logistic regression were also used to evaluate the socio-economic differences, variations in profitability, and influential determinants when making choices regarding the adoption of MTR. The results show that the yields of MTR adopters were very high, the gross profit was significantly higher, and the labor cost was lower as compared to non-adopters. Regression analysis indicated that other variables that were significant in adoption included yield, female labor involvement, availability of machinery, labor cost, and access to training ($p < 0.05$). Even though there are such benefits, numerous farmers do not adopt due to a number of obstacles, such as the costs of machines, inexperienced operators, and the proximity of mat-type nurseries. The analysis of the study draws the conclusion that MTR possesses good prospects to enhance the productivity of rice and the income of farms in the area. To enable it to get wider uptake, some policy interventions that include the provision of training programs, rental subsidies, etc, and access to shared machinery services, particularly to small and medium-scale farmers, are necessary. Promoting MTR can help the modernisation of the Pakistan rice sector and rural livelihoods.

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INTRODUCTION

Agriculture is popularly considered as the backbone of many economies across the world, being pivotal in food production, employment, and rural development. It supplies necessary raw materials to industries, and it makes life viable by producing crops and rearing animals, and therefore it includes the cultivation of agricultural and forest products as well as management of animals and plants, and microbes used as food, fiber, fuel, and medicine, and is pivotal in human life and development. Agricultural science is a multidisciplinary discipline, combining biological, environmental, natural, economic, and social sciences, which helps to know and enhance sustainable farming systems (Yu and Mu, 2022).

In addition to fulfilling dietary needs, it contributes significantly to the industrial sector by supplying raw materials and supporting agro-based industries. In developing countries, the sector plays a vital role in meeting domestic food requirements, supporting employment, and driving national economic growth. A large portion of the population in such countries depends directly on agriculture as their primary source of income and livelihood (FAO, 2021). Furthermore, agriculture is essential for ensuring food security, especially in the face of rising population pressures and increasing demand for food.In the context of Pakistan, agriculture holds even greater significance due to rapid population growth and the increasing need to meet future food demands. The sector is the foundation of Pakistan's economy, contributing approximately 24 percent to the national Gross Domestic Product (GDP) and employing about 37.4 percent of the labor force. Besides providing food and raw materials, agriculture supports several industries, contributes to export earnings, and promotes socio-economic development in rural areas. Strengthening the agricultural sector is, therefore, crucial for enhancing food security and sustaining long-term economic growth (GOPb, 2024).

Pakistan has two main cropping seasons: Kharif and Rabi. The Kharif season begins between April and June, with crops harvested between October and December. Major crops grown during this season include rice, sugarcane, cotton, maize, moong, mash, bajra, and jowar. The Rabi season, on the other hand, begins in October and ends with harvests in April and May. Common Rabi crops include wheat, gram, tobacco, barley, rapeseed, and mustard (GOPb, 2024). Among staple food crops in Pakistan, rice, wheat, and maize are the most significant, collectively providing nearly 60 percent of the caloric intake of the global population. In Pakistan, rice holds a particularly important position, being the second most important food crop after wheat. It contributes about 3.0 percent to the agricultural value added and 0.6 percent to the national GDP (GOPb, 2024). In addition to being a dietary staple, rice serves as a commercial crop with high economic and industrial value. It is used as a raw material in the production of goods such as paper, hats, and other products, making it a vital component of both food and non-food supply chains (GOP, 2022). Rice is cultivated as a Kharif crop in Pakistan. It is typically sown from May to June, grown through July to September, and harvested between October and December (Tauseef and Uddin, 2024; Garcia and Gracia, 2022). The crop's significance in terms of food security, income generation, and export potential underscores the need for innovations and sustainable practices in rice production to meet future challenges. Pakistan's two major rice-producing regions are Punjab and Sindh. In Punjab, key rice-growing districts include Gujranwala, Sialkot, Okara, Hafizabad, Sheikhupura, Mandi Bahauddin, and Jhang. In Sindh, rice cultivation is concentrated in areas such as Upper Sindh, the Indus Delta region, Kashmore, Jacobabad, Shikarpur, Larkana, Kambar Shahdadkot, Dadu, Badin, and Thatta (Ashfaq et al., 2024; Akmal et al., 2023). Punjab contributes approximately 65 percent of the country's total rice production, while Sindh accounts for 29 percent. Balochistan and Khyber Pakhtunkhwa (KPK) make smaller contributions, with Balochistan at 4 percent and KPK at 2 percent (GOP, 2024b). Table 1 presents rice sowing time and major cultivated varieties across provinces.

Pakistan has consistently been a significant contributor to the global rice supply. As of 2024, it ranks as the 10th largest rice producer in the world, with an annual production of 8.9 million tons. (GOP, 2024a). During the 2023-24 cropping year, the total area under rice cultivation increased to 3.637 million hectares, reflecting an 18 percent rise compared to the previous year (2022-23). This expansion in cultivated area contributed to improved yield, which rose to 4.1 tons per hectare from 3.7 tons per hectare in the prior year (USDA, 2024). Table 2 shows the cultivated area under rice in Pakistan. In Pakistan, rice yield patterns over the last 10 years have shown both increases and decreases. Production fell from 9,323 million tonnes in 2021-22 to 7.322 million tonnes in 2022-23, recording negative growth of 21.5 percent. However, rice production is lower than last year (GOP, 2024b). The data for the last five years regarding area, production, and yield of Rice crops are shown in Table 3. Wash root rice seedlings are traditionally transplanted by hand in this country. Compared to mechanical transplantation, this process required more time and effort in terms of manual work. The mechanical transplanter required only three man-days per hectare compared to 33 man-days per hectare for hand transplanting (Rahaman et al., 2022; Feng et al., 2024). Plant populations are poorly managed because farmers do not take the hill-to-hill distance into consideration. Reducing time and labor expenses, guaranteeing regular spacing of plants and maximum plant density by placing two to three seedlings per hill, and avoiding seedling movement shock are only some of the advantages of mechanical transplantation (Kamruzzaman et al., 2022; Hayat and Khatoon, 2021).

Table 1. Rice sowing information by province.

Sr. No	Province	Sowing Time	Variety Name	Districts
1	Punjab	May 20 - June 30	Basmati 370, Basmati Pak, Basmati 385, Super Basmati, Basmati 2000, Shaheen Basmati, Basmati 515, KS-282, KSK-133, NIAB IR-9, Basmati 198, rice hybrids	Lahore, Gujranwala, Sheikhupura, Sialkot, Narowal, Hafizabad, Gujrat, Sahiwal, Mandi Bahauddin, Nankana Sahib, Jhang, Chiniot
2	Sindh	April 25 - June 30	IR-6, DR-82, DR-83, DR-92, Sada Hayat, Sarshar, Shahkar, IR-6, Shadab, Shua-92, Khushboo-95, rice hybrids	Larkana, Dadu, Shikarpur, Qambar-Shahdadkot, Jacobabad, Kashmore, Thatta, Badin, Tando Muhammad Khan
3	KPK	May 1 - May 20	IR-6, DR-83, Sarshar, Sada Hayat, Shahkar, rice hybrids	Swat, Dera Ismail Khan, Malakand, Batgram, Kohistan, Mansehra, Mingora, Barikot, Kabal, Matta, Khwazakhela
4	Balochistan	May 15 -June 30	IR-6, KSK-282, KSK-133, JP-5, Kashmir Nafees, Swat-I, Swat-II, Dilrosh-97, Fakher-e-Malakund	Nasirabad

Source: Government of Pakistan. 2025.

Table 2. Rice cultivation in Pakistan – area and yield overview.

Province	Area Under Cultivation
Punjab	2,188,000 ha
Sindh	603,000 ha
Khyber Pakhtunkhwa (KPK)	56,000 ha
Baluchistan	126,000 ha
Total (2022–23)	~2,973,000 ha

Source: GOP (2024a).

Table 3. Area, production, and yield of rice crops in Pakistan.

Year	Area (000 ha)	Percent Change in Area	Production (000 tons)	Percent Change in Production
2018-19	2810	-	7202	-
2019-20	3034	8.0	7414	2.9
2020-21	3335	9.9	8420	13.6
2021-22	3537	6.1	9323	10.7
2022-23	2976	-15.9	7322	-21.5
2023-24	3637	22.2	9869	34.7

Source: GOP (2024a).

MTR is cost-effective, friendly in its operation, helps in maintaining soil physical properties, and is considered useful for effective crop management and productivity point of view. However, compared to traditional transplanting, the adoption of MTR is still bleak due to the high initial investment and farmers' ignorance of producing mat-type nurseries. Effective automation can increase labor and land productivity and efficiency. Enhancing rice production and exports by making it globally competitive and utilizing all existing technologies to their fullest capacity is urgently needed (Basir et al., 2020; Paudel et al., 2021). Crop output can be increased by implementing innovations and contemporary technologies. Individual households' financial circumstances are improved by the use of cutting-edge machinery (Guru et al., 2022; Rouf et al., 2025).

Rice trans-planters can be of two types: manually propelled walk-after type of transplanter, which transplants four lines in one pass, and power-driven riding type of transplanter, which transplants generally six lines at one pass. With good mechanization, both land and labor productivity will improve. In order to expand rice production and exports and enable them to become competitive globally, the usage of modern technologies to their full extent is necessary. New innovations and improved machinery can be incorporated to increase the crop yield, enhance the financial status of farmers and their families (Saha et al., 2021; Guru et al., 2022).

In Pakistan, the adoption of MTR is increasing among farmers due to labor shortage and the increasing cost of labor. It is relatively cheap, simple to implement, and serves to enhance soil health and conditions, therefore, ensuring crop management and productivity. Nevertheless, there are certain complexities that restrict its application. Adoption is hindered since the machine is costly at the initial stage, and farmers are not conversant with growing a mat-type nursery plantation. In order to enhance the MTR, they should consider training in the technical aspects, making the equipment readily accessible, and thus appealing to the custom hiring services. Such actions will contribute to the popularity of mechanical transplanting among farmers (Hossen et al., 2022; Umar et al., 2022).

This paper aims to assess the rate of adoption and advantages/disadvantages of using the mechanically transplanted rice (MTR) technology in Punjab, Pakistan. Namely, it investigates socio-economic profiles of rice farmers, evaluates the effect of MTR on rice productivity and farmers' rice (MTR) technology in Punjab, Pakistan. In particular, it reviews the socio-economic nature of the riposte. The proposed research study will help policymakers encourage the greater spread of MTR by adopting methods like the subsidy of its access to equipment and technical assistance. Promoting the use of modern technologies in farming is core to promoting productivity and sustainability in farming, as well as promoting the livelihood of the rural community.

METHODOLOGY

In this chapter, we give an overview of the research design used to evaluate the effects of the Mechanically Transplanted Rice (MTR) technology on rice production and the livelihood of the farmers in Punjab, Pakistan. The methodology summarises the location of the study, sampling, methods of data collection, and data analysis tools to be used to guarantee the reliability and validity of results. It offers a systematic process to explore the topic of adoption of MTR, its economic and technical advantages, and comprehend related difficulties. The systematic procedure also provides objective, credible, and sensible findings that are aligned with the research commitments.

Study Area

The study was done in the Gujranwala district in the province of Punjab in Pakistan. The annual average rainfall of the district is about 22mm, and the temperature rises as high as 42 o C in summer and as low as 5-7 o C in winter. The area has a large agricultural activity, which is largely supported by irrigation sourced by the Chenab River. The presence of rice as the second dominant rice district in Punjab, Gujranwala, gives a strategic location as a regional centre of mechanized farming, and as a result, Gujranwala is considered as the best venue for determining whether there is adoption of mechanically transplanted technology of rice or not.

Sampling and Data Collection

A sample size of 120 rice farmers was sampled in three of the 16 tehsils as identified: Kamoke, Gujranwala City, and Nowshera Virkan, employing a stratified random sampling technique. The case was a sample of 60 adopters and non-adopters of a mechanically transplanted rice (MTR). Mechanized farmers had the advantage of transplanting, spraying, and harvesting machines, as compared to the non-mechanized farmers who depended on manpower to a greater extent.

The structured questionnaire was developed and administered through data collection instruments, as varied in English but interpreted in Punjabi to guarantee the understanding of the respondents. The final questionnaire was pretested in order to adjust the structure and wording of the questionnaire. Initial reluctance in participation was noted among some farmers with regard to the fear that they might be affiliated with the government; this fear was, however, pacified during the interviews.

Statistical and Economic Analysis Techniques

The researchers applied descriptive statistics to make comparisons of socio-economic traits of individuals who took and did not take the MTR. Economic viability of MTR was evaluated through profitability analysis, Total Cost, Total Revenue, Gross Profit, and Benefit-Cost Ratio. A binary logistic regression was used to determine important aspects of adoption, and variables such as yield, labor cost, and access to training were found to be crucial. A combination of these approaches gave a clear image of MTR employment effects and adoption motivators. Analysis of data was undertaken with the use of the following technique.

Descriptive statistics:

Descriptive statistics came into place to give an overview of the fundamental attributes of the data in a factual manner. This involved the formulae of percentages, frequencies, and the mean value in order to analyse the variables, which included the age of the farmers, level of education, extent of land holdings, labour inputs, and output in the form of rice product. These figures allowed us to get a clear picture of the socio-economic profile of the MTR adopters and non-adopters, contributing to finding the patterns and differences in the sample.

Average

The mean, which is also known as the average, is a statistical expression that portrays the midpoint of a given data collection or set. The calculation is made by summing all the numerical values and dividing the result by the number of observations. This study involved computing means of variables like age, education, farm size, rice yield, and input costs to enable distinguishing of general trends between MTR users and those who are not users. This assisted in comprehending some of the normal values and making some important distinctions between the two groups.

$$AM = \frac{\sum X}{N} = \text{sum of all} \frac{\text{observations}}{\text{numbers}} \text{of observations} \quad (1)$$

Whereas,
AM = Arithmetic Mean
ΣX = Sum of Xi observations
N= Total Number of observations

Percentage

The percentage is a method that depicts the amount used by a part in the whole, and it is easy to compare the part across various categories. In this study, the percentage formula was applied to analyze various variables such as socio-economic factors, soil types, water sources, and training access.

$$P = \frac{F}{N} \times 100 \quad (2)$$

Whereas,
F = Frequency
N = Total Number of observations

Net income

Net income represents the financial gain a farmer receives after deducting all production costs from the total revenue. It reflects the overall profitability of rice production and is calculated using the following formula:

$$NI = TR - TC \quad (3)$$

Whereas,
NI=Net income of the farmer
TR =total revenue
TC =Total Cost

Gross Profit (GP)

Gross profit is found by subtracting total cost from its revenue. The following formula has been used to find out gross profit.

$$GP = TR - TC \quad (4)$$

Whereas,
GP =gross profit
TR =total revenue
TC =Total Cost

Benefit-Cost Ratio (BCR)

The Benefit-Cost Ratio (BCR) will be calculated as the ratio of present worth benefits to present worth costs. Machinery will be considered profitable if the BCR exceeds one.

$$BCR = \Sigma Present\ worth\ Benefit / \Sigma Present\ worth\ Cost$$

$$BCR = \frac{TR}{TC} \quad (5)$$

Whereas
TR =total revenue
TC =Total Cost

Regression Model

The binary logistic regression model has been used for analyzing the data. This model used by Casinillo et al. (2024) in his research to extract influencing predictors of the level of rice production and tested its significance on the other hand the in Salam et al. (2024) research paper the causal effect model of input factor allocation on maize production: Using binary logistic regression in search for ways to be more productive. In my model, I give zero for the method of rice, namely mechanical transplantation, and one is for transplanted rice, and take it dependent variable. Independent variables in my model are age of respondents, family size, education years, tube well ownership, no of irrigations, seed rate, number of visits of extension worker, and area under rice.

$$Yi = \beta o + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6\, \beta 7X7 + \beta 8X8 + \varepsilon i \quad (6)$$

Whereas:
Y = Use of different sowing method of r ice (1 = Yes, 0 = No)
Xi = A vector of explanatory variables, which includes:
X1 = Farming experience in the rice area
X2 = Total rice land for the adopter of Mtr
X3 = Total rice land for non-adopters of MTR
X4-=Seeding cost
X5= Fertilizer cost
X6=Labor cost
X7= Land preparation cost
X8 = Harvesting cost

RESULTS AND DISCUSSION

The findings of the empirical analysis of primary data gathered from 120 rice farmers in Punjab, Pakistan's Gujranwala area, are presented in this chapter. The purpose of this section is to interpret the descriptive statistics and assess the socioeconomic conditions, farming practices, and technology adoption behavior of the respondents. The discussion is contextualized with prior studies and theoretical concepts related to agricultural modernization and technology diffusion.

Socioeconomic Characteristics of the Farmers

The socioeconomic characteristics of the 120 rice farmers surveyed in the Gujranwala district of Punjab reveal several key patterns. Table 4 shows that the most respondents (45 percent) were between 41 and 60 years of age, indicating that middle-aged farmers are the dominant group, followed by 32.5 percent aged 25-40 and 22.5 percent above 60. The sample was predominantly male (89.2 percent), with only 10.8 percent female participants, reflecting the male-dominated nature of farming in the region.

Education levels varied, with 5.8 percent having no formal education. A majority had some level of schooling: 25.8 percent received 1-5 years, 27.5 percent had 5-10 years, 26.7 percent attained 10-12 years, and 14.2 percent had 12-16 years of education, suggesting a moderate overall literacy rate among farmers. In terms of family size, 65 percent belonged to medium-sized households (6-10 members), while 20 percent were from small families (1-5 members), and 15 percent had large households (11-15 members).

A strong reliance on household labor was evident, with 87.5 percent of farmers reporting family labor involvement in farming activities. Farming experience was diverse: 27.5 percent had 11-20 years of experience, 22.6 percent had 41-60 years, and smaller groups had either more or less experience, showing a mix of traditional and mid-career farmers. Regarding rice-specific experience, 37.5 percent had 11-20 years of experience, and 24.2 percent had 21-30 years, suggesting a considerable level of specialization in rice cultivation among respondents.

Landholding Status of Respondents

Landholding significantly affects farmers' capacity to adopt technologies like Mechanically Transplanted Rice (MTR). Table 5 has a clear picture of the frequency and percentage of farmers in which the most farmers (59.2 percent) cultivating 6-10 acres, favoring medium-scale mechanization. Only 4.2 percent were cultivated under 5 acres, while 8.3 percent worked on 30-50 acres. About 26.7 percent rented land, primarily 1-5 acres, allowing smallholders to expand operations, though 73.3 percent relied solely on owned land. For rice cultivation, 55.8 percent allocated 6-10 acres, making mechanization more feasible due to labor intensity. MTR adoption stood at 50 percent, indicating the technology is in a transitional adoption phase among farmers.

Farm-Level Characteristics

The farm-level characteristics of respondents provide key insights into their capacity to adopt Mechanically Transplanted Rice (MTR) technology. Most farmers in the study had favorable land and irrigation conditions. A large majority (96.7 percent) used private tube wells, allowing flexible irrigation, though none conducted water testing, indicating a lack of water quality monitoring. Similarly, 91.7 percent had loamy soils, and 96.7 percent used laser land leveling, both supporting uniform field conditions essential for MTR. Fertility levels were generally moderate to high, and salinity was low in most cases, further enhancing suitability for rice cultivation. However, none of the farmers reported soil testing, reflecting a gap in scientific nutrient management. Seed sourcing showed that 70 percent used their own saved seeds, with limited use of certified or public sources, potentially affecting crop performance. The wet nursery method was most common (58.3 percent), aligning with MTR needs, though 37.5 percent still used the dry method. Table 6 explains the farm-level characteristics.

Table 4. Socioeconomic characteristics of the farmers.

Variable	Category	Frequency (percentage)
Age Group (Year)	25-40	39 (32.5)
	41-60	54 (45)
	Above 60	27 (22.5)
Gender	Female	13 (10.8)
	Male	107 (89.2)
Education Level (Year)	No education	7 (5.8)
	1-5	31 (25.8)
	5-10	33 (27.5)
	10-12	32 (26.7)
	12-16	17 (14.2)
Family Size member	1-5	24 (20)
	6-10	78 (65)
	11-15	18 (15)
Family Labor Involvement	No	15 (12.5)
	Yes	105 (87.5)
Farming Experience (Years)	1-10	14 (11.7)
	11-20	33 (27.5)
	21-30	24 (20)
	31-40	18 (15)
	41-60	27 (22.6)
	Above 60	4 (3.3)
Rice Cultivation Experience	1-10	15 (12.5)
	11-20	45 (37.5)
	21-30	29 (24.2)
	31-40	21 (17.5)
	41-50	10 (8.3)
	Above 50	1 (0.8)

Table 5. Landholding status of respondents.

Variable	Category/Range	Frequency (percentage)
Total Cultivated Land (Acres)	1-5	5 (4.2)
	6-0	71 (59.2)
	11-15	22 (18.3)
	16-20	7 (5.8)
	21-25	2 (1.7)
	25-30	3 (2.5)
	30-50	10 (8.3)
Land Rented-In (Acres)	None	88 (73.3)
	1-5	24 (20)
	6-10	3 (2.5)
	11-15	1 (0.8)
	16-20	1 (0.8)
	20-30	3 (2.5)
Land Under Rice (Acres)	1-5	23 (19.2)
	6-10	67 (55.8)
	11-15	13 (10.8)
	16-20	4 (3.3)
	20-25	2 (1.7)
	25-30	3 (2.5)
	Above 30	8 (6.7)

MTR Adoption Status	Non-Adopter	60 (50)
	Adopter	60 (50)

Comparison of Adoption Status, Yield, and Market Price:

The use of Mechanically Transplanted Rice (MTR) in the study area has a current level of 50 percent, which implies the study area experiences a period of change as adoption of mechanization is on the rise, but still is not extensive beyond the study site. Such an equal distribution will enable an equitable comparison between adopters and non-adopters. The average yield of 44.05 maunds per acre took adopters ahead of non-adopters (37.53) by a margin of more than 6 maunds per acre. Adopters reported a bigger maximum yield, but the minimum yield (33 vs. 38) was a little smaller, following the pattern of variability on farm conditions and management behavior how much high-yielding crops can be realized on a particular farm. As indicated in Table 7, the Adopters likewise obtained marginally higher prices in the market; the average market price was Rs. 4130 per mound as compared to the non-adopters with Rs. 4086. While the cost difference is minimal, it counts for a lot with large quantities. These data demonstrate that MTR improves productivity and price performance, yet the steady success requires sufficient training, effective usage of machinery, and field support services.

Comparative Profitability Analysis of MTR Adopters and Non-Adopters

To understand the economic implications of adopting Mechanically Transplanted Rice (MTR), a comparative profitability analysis was conducted between adopters and non-adopters. This involved assessing key financial indicators: Total Cost (TC), Total Revenue (TR), Gross Profit (GP), and the Benefit-Cost Ratio (BCR). The analysis revealed that MTR adopters had significantly lower average total costs (Rs. 124,472) compared to non-adopters (Rs. 152,986), primarily due to savings in manual labor and input optimization through mechanization. At the same time, adopters achieved higher average revenues (Rs. 185,020 vs Rs. 179,675), largely driven by improved yields and slightly better prices. As a result, gross profit among adopters was more than double that of non-adopters (Rs. 60,548 vs Rs. 26,689), with a Benefit-Cost Ratio of 1.49, compared to 1.17 for non-adopters. This indicates that each rupee invested by adopters generated Rs. 1.49 in returns, compared to Rs. 1.17 among those using traditional methods. Table 8 represents a clear image of profitability analysis.

Table 6. Farm-level characteristics.

Variable	Category	Frequency (Percent)
Irrigation Ownership	Canal	4 (3.3)
	Tube well	116 (96.7)
Tube Well Water Quality	Fit	104 (86.7)
	Marginal Fit	16 (13.3)
Water Testing in the Last 5 Years	No	120 (100.0)
	Yes	0 (0.0)
Rate of Tube Well Water (Rs/hour)	Min: 45, Max: 800	Mean: 230.17 ± 88.9
Irrigation Cost per Acre (Rs)	Min: 4,000, Max: 40,000	Mean: 24,320 ± 8,500.78
Land Leveling Technology	Laser	116 (96.7)
	Traditional	3 (2.5)
	Not Leveled	1 (0.8)
Soil Type	Loamy	110 (91.7)
	Clay	7 (5.8)
	Sandy	2 (1.7)
	Miscoded	1 (0.8)
Soil Fertility	Low	12 (10.0)
	Medium	63 (52.5)
	High	45 (37.5)
Soil Salinity	Low	111 (92.5)
	Medium	5 (4.2)
	High	4 (3.3)
Soil Testing in the Last 5 Years	No	120 (100.0)
	Yes	0 (0.0)
Seed Source	Own Saved	84 (70.0)
	Purchased (Private)	24 (20.0)
	Dealer	9 (7.5)
	Public Sector	3 (2.5)
Nursery Raising Method	Wet Method	70 (58.3)
	Dry Method	45 (37.5)
	Raab Method	5 (4.2)

Table 7. Comparison of adoption status, yield, and market price.

Indicator	Adopters (N = 60)	Non-Adopters (N = 60)
Proportion in Sample (percent)	50.00 percent	50.00 percent
Maximum Yield (maunds/acre)	48	42
Minimum Yield (maunds/acre)	33	38
Average Yield (maunds/acre)	44.05	37.53

Maximum Price (Rs/maund)	4300	4300
Minimum Price (Rs/maund)	3900	3800
Average Price (Rs/maund)	4130	4086

Logistic Regression Model

A binary logistic regression model was used to study the reasons why the Mechanically Transplanted Rice (MTR) technology was adopted. This procedure assists in determining what factors will be important in the choice of a farmer to opt into MTR because the dependent variable is the adoption status (adopter =1, non-adopter = 0). The model used a combination of economic, agronomic, and demographic factors, and they are as follows: farming experience, educational level, yield, the cost of labor, and availability of transplanting machinery. Findings of the model indicated that the technical and resource-related variables had an impact that was many times more significant compared with the basic demographic characteristics.

Using the logistic regression analysis, it was determined that a number of variables were statistically significant in affecting the adoption of the mechanically transplanted rice (MTR) technology. Experience in farming was positively and significantly related to adoption, which means that the more farming experience, the more likely they were to use MTR. On the same note, yield per acre was considered very significant, implying that farmers with high productivity had more chances of investing in mechanization. Education level also had a significant positive relationship with adoption. The more educated the farmers were, the more capable they became of comprehending the technical demands and advantages of MTR, and the more inclined they were to use this method.

The size of the land and the availability of labor became significant aspects. The larger the area that farmers farmed and the case whereby farmers would run out of labor during the transplanting season, the higher the chances of a farmer using MTR to decrease labor dependency. Costs of male and female labor were heavily weighted positively. Farmers became less reluctant to implement mechanized substitutes to reduce the total cost of production since the labor expenses were on the rise. Access to transplanting machinery was the most determining factor. Availability in the form of ownership or rental granted farmers a vast odd of adopting MTR, and this factor highlights the significance of gearing the availability of machinery to prompt its adoption. Conversely, the socio-demographic factors like the age, gender, and the size of the family were not significant implying that the socio-demographic factors were not important to the decisions to adopt relative to considerations on operational and economic factors.

Table 9 represents the findings of the binary logistic regression model, indicating that there are major factors that have an impact on the adoption of the mechanically transplanted rice (MTR) technology among the farmers in Punjab. Experience Farming experience has a positive correlation with the adoption of MTR since a more experienced (years of farming) farmer is better placed to consider the benefits of mechanization, thus there would be more likelihood of him adopting new ideas. The other strong determinant is rice production per acre; more productive farmers are likely to be open to using MTR, showing that farmers who have already been more productive are more open to technological growth. The level of education is also significant, since more educated farmers tend to be better informed, more ready to restart their innovations, and more able to establish and trade with the methodical modes of modern farming. Adoption decisions are further determined by the amount of land and labor supply. Farmers with bigger land under production and those that undergo labor lapse during seasons are more likely to mechanize to lessen the reliance on manual labor. Also, the unexpected increasing cost of labor, both male and female, will influence adoption significantly since the traditional transplanting is growing increasingly costly. With all the factors, the most significant predictor comes out as access to transplanting machinery. MTR technology is far more likely to be embraced when there is a farmer who owns or has access to rented rice transplanters. These conclusions emphasize the role of economic reason and availability of resources in the decisions people make regarding adoption, and this just shows that favorable policies that improve the situation with the technical accessibility of resources and lower the cost of operation to the farmers should be encouraged.

Table 8. Comparative profitability analysis of MTR adopters and non-adopters:

Group	Average TC (Rs)	Average TR (Rs)	Average GP (Rs)	BCR (TR/TC)
Adopters (MTR)	124,472.22	185,020.37	60,548.15	1.49
Non-Adopters	152,985.71	179,675.00	26,689.29	1.17

Table 9. Logistic regression model.

Variable	Score	Df	Sig. (p-value)
Farming Experience	8	1	0.005
Yield	77.692	1	0
Education	23.956	1	0
Land and Labor	68.113	1	0
Male Labor Cost	18.39	1	0
Female Labor Cost	64.609	1	0
Transplanting Machine	112.101	1	0

CONCLUSIONS AND RECOMMENDATIONS

Rice is a major food crop in Pakistan (especially in Punjab and Sindh), and thus it plays major roles in food security and rural livelihoods, and income in the context of export earnings. The traditional transplantation of rice is time-consuming, labour-intensive as well and financially costly. Perhaps it should be elevated to allude to particular times when the wages are on the increase among the rural population, as well as the seasonal labour shortages that occur. The result of such losses is a negative impact on productivity and an increase in the costs of production to small and medium-scale farmers. In this paper, it has resolved these problems with its Mechanically Transplanted Rice (MTR) technology intervention. Improved use of MTR technology brings into focus the average yield (44.05 and 37.53 maunds per acre), greater consistency of crops, increased selling prices of crops through the lesser dependence on manual workforce, and a notable improvement in crop uniformity in general production by the MTR using farmers. In addition, MTR provides a significant amount of input and labour cost savings, that is, a large gross profit, and a more desirable Benefit-Cost Ratio (1.49 vs. 1.17) compared with conventional practices associated with a more cost-effective nature. Moderate adoption, however, is observed, and some barriers affect the level of adoption: initial machinery installation is extremely expensive, transplanting machines are unavailable, lack of training in preparation for the mat type nurseries, and inadequate extension. The others also do not bother because of the lack of awareness or technical skills among a section of the smallholders. Logistics regression of the study proves that important variables that drastically affect the decision to adopt are the farming experiences, the level of education, the yield, female and male labor costs, and the availability of a transplanting machine. The socio-demographics, such as age or gender, or the size of the family, were not as pertinent to demonstrate that practical, economic considerations determine the decision to utilize the technology. Research institutes, policymakers, and individuals privately connected ought to collaborate so that the mechanization is more widespread. It may be crucial to speed up the adoption by offering subsidies, services of machinery rental services, training, and awareness campaigns. The move toward a more intensive culture of rice could be supported by a decision to scale up the use of MTR, which should help not only in rice intensification but also lead to the increased profitability of the farms, the alleviation of drudgery, and the sustainable transformation of agriculture in Pakistan.

Mechanical transplanters should be made affordable to small and medium-scale farmers, partially subsidized or loaned at no interest, by the government. The Custom Hiring Centers (CHCs) must also be set up in rice-producing regions, so that access to the transplanting equipment would be shared, which would subtract the economic cost of owning the equipment for a farmer and spread it to other farmers. Campaigns on awareness and training on technical trainings must also be initiated to enable the farmers to be enlightened on the method of preparing mat-type nurseries required to adopt MTR. On-ground technical advice, troubleshooting, and constant support to farmers in using MTR technology need to be established through the strengthening of public extension services. It is desirable to have local youth and service providers invest in and manage the rice transplanting services as an environmentally sustainable business model, which generates employment and enhances service delivery. Promoting MTR should be in line with national agricultural modernization and food security strategies to achieve long-term and broad effects.

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