

Reasons for Slow Adoption of Mechanical Transplanting of Rice in Punjab

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Abstract: The study was conducted in two districts of Punjab, namely Sheikhpura and Okara, representing core and non-core rice sowing areas, to find out the reasons for the slow adoption of Mechanical Transplanters. A total of 84 farmers, 64 farmers (equivalent to 76.19%) from Sheikhpura district, and 20 farmers (equivalent to 23.80%) from Okara, were interviewed. The interviewed farmers were small (16.67%), medium (21.43%) and large (61.90%) farmers respectively. Amongst the interviewed farmers, 78.75% were adopters, whereas the remaining 21.42% were non-adopters. Amongst the adopters, 72.7% were large farmers having an average area of more than 25 acres, followed by small (18.2%) and medium farmers (9.1%). Amongst adopters, 54.5% were owner cum tenants followed by owners (39.4%) and remaining 6.1% as tenants meaning that Mechanical Transplanting is the technology for large farmers whether they are owners or owner cum tenants. Almost 88% of the MTR adopters had their tractors, whereas 94% had their tube wells as a source of irrigation, meaning resourceful farmers were adopting this technology. There is a significant difference in 1000 grain weight of different varieties falling in the category of fine, coarse and hybrid varieties but in field no distinction is being kept by the service providers as they are using on an average 10kg seed (100 trays per acre/100 gm seed per tray) for all varieties. Five most common reasons of slow adoption of mechanical transplanters by rice growers are i) lack of expertise on the part of machine operators (95.2%) ii) high mortality rate of seedlings (92.9%) iii) high seed rate in mechanical transplanting (85.7%) iv) non-availability of mechanical transplanters in the area (85.7%) v) Mechanical transplanting is not suitable for small holder farming. Almost 61% of the adopters reported increased yields with Mechanical Transplanting as compared to manual transplanting of rice.

Keyword: Mechanical transplanter, Adoption, Tractor, Small farmers, Varieties

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1. Introduction

Student Rice wheat and maize are top most staple food crops as they provide as they provide almost 60% of food energy intake by world population. Pakistan always remained a big contributor for fulfilment of

world population's rice needs. Presently, Pakistan is ranked 10th largest producer of rice in the world with 8.9 million tons of rice production (API GOP, 2024). During the year 2023-24, a handsome increase (36,37,000 ha acres) in rice crop area of

Pakistan was observed, which is 18% more as compared to previous year 2022-23. Ultimately, a better yield of crop was achieved with 4.1 T/ha as compared to last year's yield, i.e., 3.7 T/ha (FAS USDA, 2024). However, the share of all provinces of Pakistan is different in rice production. Punjab is the largest producer of rice, thanks to favorable environment and weather conditions for the production of the rice crop. During the financial year 2022-23, the total area of Punjab under rice cultivation was 2188,000 ha, which was much more as compared to other provinces, such as 603,000 ha for Sindh, 56,000 ha for KPK and 126,000 ha for Balochistan (MNSFR, 2024).

It has been predicted that between 2040 and 2069, the rice yield in Pakistan might fall by 25% if there remains a similar trend of temperature increase in Pakistan (Ahmad *et al.*, 2015). Moreover, the major reasons behind low rice yield in Pakistan include shortage of water, insect pests and diseases, weeds infestation and unsuitable sowing method that ultimately leads to low plant population and ultimately lower yields. Among all these reasons, the major reason is low plant population per unit area, which can be improved by using a proper sowing method (Ehsanullah *et al.*, 2007). In Punjab, there are different methods of rice transplantation, i.e., manual transplantation, direct seeding and

mechanical transplantation. All of these methods have their pros and cons. However, the selection of an effective and modern rice transplantation method with proper weed control gives a higher yield of rice crop (Hossain *et al.*, 2002).

In Punjab, the most common methods of rice cultivation are manual transplantation followed by the direct seeding method. Although, manual transplantation method requires more labour and higher effort, still the majority of farmers prefer the manual transplanting method as compared to direct seeding (Verma, 2010) due to its success rate and effective weed control. Similarly, according to (Kaur *et al.*, 2023), the most practiced method of rice cultivation in Punjab is manual transplantation, even though it demands more water and labor requirements as compared to direct seeding. This is due to a lack of knowledge about the benefits of direct seeding over manual transplantation. On raised beds, water requirement is reduced by 12-60 percent for direct-seeded rice and yield is increased by 10 percent as compared to manual transplanted rice (Gupta *et al.*, 2003). Mitchell *et al.*, (2004) also supported this narrative with the results that direct seeding is a very good alternative to manual transplanting and the potential yield under direct seeding is equal to that of transplanted rice under better weed control conditions, as well as good water

management. According to Pandey and Velasco (2005), many rice-growing countries are adopting the direct seeding method by leaving the traditional manual rice transplantation due to rapidly increasing water and labour rates and ultimately a rise in the rice production cost. In the direct seeding method of rice transplantation, weed management is still a main limitation. Following successful implementation in several developed countries, mechanical transplantation is increasingly being explored in Asia, including countries such as India, Nepal, and Vietnam, where it is promoted for its labor-saving potential and water-use efficiency (Nawaz *et al.*, 2022; Guru *et al.*, 2018; Paudel *et al.*, 2021). As per findings of a research conducted by Manjunatha *et al.*, 2009, 03 man days are required for transplanting one hectare of rice with self-propelled Mechanical transplanters in comparison to 33 man days required for transplanting manually. Moreover, an increase in labour cost, better yield expectations and labour shortages have compelled the farmers to adopt the mechanical transplanting of rice (Rashid *et al.*, 2018). There are two types of mechanical rice transplanters. One is a power-driven or riding-type mechanical transplanter, while the other is a self-propelled or walk-after type. The riding type can transplant six lines in one pass, as

compared to the walk-after type that can transplant four lines in one pass (Patil & Phate, 2016). On the whole, mechanical transplantation of rice is an economical and user-friendly method that helps in preserving soil properties and is also considered suitable for productivity and crop management (Saha *et al.*, 2021).

However, besides all the benefits of mechanical rice transplantation, very slow adoption of this modern technique has been observed by farmers of Punjab province due to the initial high investment cost and lack of knowledge about growing mat-type nurseries in contrast to traditional transplanting (Guru *et al.*, 2018). The research study has been conducted to find out the reasons for the slow adoption of mechanical transplanting of rice despite its necessity and economic benefits. in Punjab province. In many Southeast Asian countries, the adoption of mechanical rice transplanting has followed a similar trajectory to that observed in Punjab. For instance, in India, constraints such as small landholdings, lack of skilled labor, and limited access to transplanters have slowed adoption despite proven yield and labor efficiency benefits (Guru *et al.*, 2018; Paudel *et al.*, 2021). Similarly, countries like Vietnam and Thailand have reported region-specific barriers, including cultural attachment to traditional methods and inadequate post-purchase support (Pandey

and Velasco, 2005). Guru et al. (2022) also emphasized the need for localized adaptation of machinery and better farmer training programs. Studies in Nepal revealed that bundling transplanter with extension services significantly improved uptake (Paudel *et al.*, 2021). These comparative findings underscore the importance of combining financial, technical, and institutional support mechanisms to accelerate adoption. Linking these insights to the Punjab context allows for a deeper understanding of both shared and unique challenges faced by rice farmers in transitioning to mechanized transplanting systems.

To boost the adaptation of mechanical transplantation of rice in Punjab, a project titled “National Program for Enhancing Profitability through increasing productivity of rice” has been implemented by the Department of Agriculture, Punjab, through “Directorate General of Agriculture (Extension & A.R). The following are the key objectives of this project;

- Productivity improvement of rice crop through balanced use of subsidized Inputs.
- Transformation of manual transplanting of rice into mechanical transplanting through the promotion of mechanical

rice transplanters by involving service-providing units.

Promotion of climate-smart rice residue management and mechanical methods of rice growing.

2. Scientific Methodology

The study was conducted in two representative districts of Punjab: Sheikhpura (core rice-producing area) and Okara (non-core rice-producing area). A total of 84 rice farmers were selected using proportionate stratified random sampling to ensure coverage of different farmer categories. Specifically, 64 farmers (76.2%) were selected from Sheikhpura and 20 farmers (23.8%) from Okara, reflecting the regional distribution of rice cultivation. Farmers were further stratified by farm size category (small: <12.5 acres, medium: 12.5–25 acres, large: >25 acres) and adoption status (adopters vs. non-adopters of mechanical transplanting). The sampling ensured inclusion of both adopters and non-adopters to provide a balanced view of constraints and motivations. Selection was conducted in collaboration with local agricultural extension offices to ensure representativeness and diversity across socio-economic and agro-ecological conditions. The sample structure aimed to capture a range of farming practices and technology exposure across the two

districts. “In addition to structured survey questions, farmers were invited to share open-ended comments, which were recorded to capture their perceptions and lived experiences.”.

3. Results and Discussion

3.1. Basic characteristics of respondent farmers

The study was conducted in two districts of Punjab province of Pakistan, namely Sheikhpura, representing the core rice-producing area of the province and Okara, representing a non-core rice-producing area. District-wise frequency distribution of respondent farmers is given below in Figure 1.

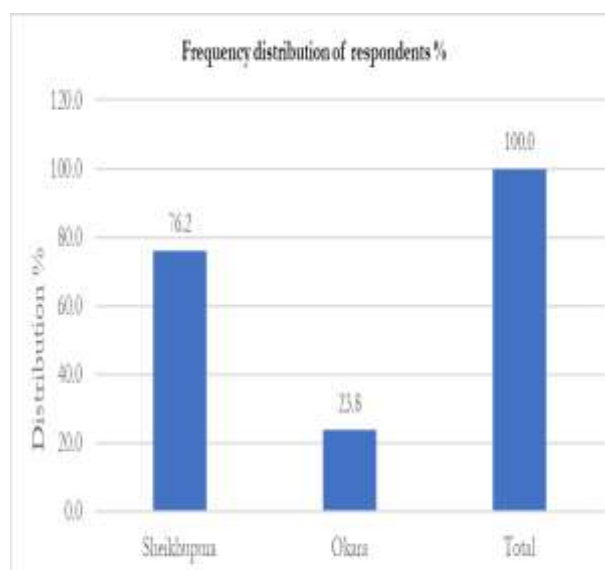


Figure 1. Frequency distribution of respondents

Approximately 16.67% of the respondent farmers were small farmers having less than 12.5 acres of land. This was followed by large farmers (61.90%) and medium

farmers (21.43%) respectively. Almost 78.6% of the respondent farmers had having education of matric and above, followed by primary and middle level education (14.3%), whereas 7.1% were illiterate. Almost (19%) of respondents were between 31-40 years age, followed by 35.7% and 45.3% in the age categories of 41-50 and above 50 years. Distribution of respondent farmers concerning their tenancy status shows that majority of the farmers were owner cum tenant (52.4%) followed by owner (42.9%) and tenants (4.8%).

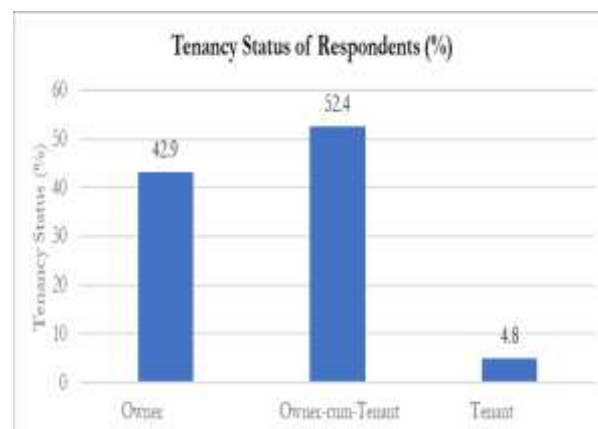


Figure 2. Distribution of respondents regarding tenancy status

The distribution of farmers based on their source of irrigation was analyzed to understand the influence of water availability and management practices on the adoption of mechanical rice transplanters. The majority of the farmers utilize a combination of canal and tube well irrigation (71.4%), followed by tube well irrigation (23.8%) and canal only (4.8%). This dual-

source irrigation system provides flexibility and reliability, potentially making these farmers more responsive to adopting mechanical rice transplanters. The frequency distribution of respondents by source of irrigation is given below in Figure 2.

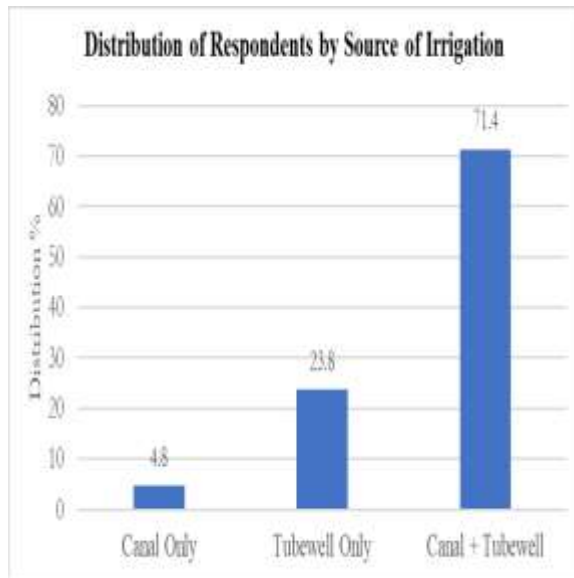


Figure 3. Distribution of respondents

Table 1. Frequency distribution of adoption of mechanical rice transplanters by farm size.

Farm Size Category	Frequency	Percentage (%)
Small	12	18.2
Medium	6	9.1
Large	48	72.7
Total	66	100.0

3.2. Adoption of mechanical transplanting

Among the 84 farmers who were interviewed, 66 farmers adopted mechanical rice transplanting of rice at their

fields. The category-wise distribution of adopters is as follows:

Distribution of adopters of mechanical transplanting of rice was further analyzed to see which of the farmers are more likely to adopt mechanical transplanting. Results reveal that the majority of the adopters were large farmers (72.7%), followed by small farmers (18.2%) and medium farmers (9.1%). Results of the study are in line with those of Hu, Y *et al*, 2022, who reported that large farmers are more likely to adopt new technologies as they have access to financial and capital resources and are well informed regarding positive and negative effects of the new technologies. Several varieties were being grown by rice growers. Not every rice variety is suitable for mechanical transplanting. To know which of the rice varieties are being liked by farmers for mechanical transplanting, the variety analysis is given in Table 2 below:

High Adoption Varieties: LP-18 (non-approved) and other varieties exhibit a 100% adoption rate, suggesting that these varieties may have specific characteristics making them more compatible with mechanical transplanting. PK-386 shows a relatively high adoption rate of 73.3%, indicating its suitability for mechanization. Moderate Adoption Varieties: Kissan Basmati (1509), Basmati-515, and PK-1121 show moderate adoption rates ranging from 54.2% to 59.2%. The study results are

in line with those of Muhammad Umar et al. (2022), as they also highlighted that PK-386 and PK-1121 are the most commonly adopted varieties for mechanical transplanting. Farmers growing these varieties may encounter partial compatibility with mechanized transplanting or face other constraints. Low Adoption Variety: Super Basmati has a 0% adoption rate, highlighting significant barriers to mechanization for this variety, possibly due to its traditional cultivation practices or market preferences.

Table 2. Variety-wise adoption of mechanical transplanting.

Rice variety	Mechanically transplanted area (%)
Kissan Basmati (1509)	55.1
Basmati-515	59.2
PK-1121	54.2
Super Basmati	0.0
PK-386	73.3
LP-18	100.0
LP-2	28.2
Other	100.0

3.3. Reasons for the slow adoption of mechanical transplanting

The Agriculture Department, Govt. of Punjab, introduced mechanical transplanters during

Table3. Reasons behind the slow adoption of mechanical transplanting in rice crop.

Sr. No	Reasons	Yes	No	Total
01	Service providers lack enough expertise on their part	95.2	4.8	100.0
02	The mortality rate is high in the case of rainfall just after mechanical transplanting	92.9	7.1	100.0
03	Seed rate used in mechanical transplanting is higher as compared to traditional method of transplanting	85.7	14.3	100.0
04	Mechanical transplanter is not available in our area	85.7	14.3	100.0
05	Smaller fields create problems in turning around with the Mechanical Transplanter	83.3	16.7	100.0
06	Nursery raising in mechanical is a laborious method	78.6	21.4	100.0
07	Seedling size is very small at the time of transplanting	78.6	21.4	100.0
08	Mechanical transplanting is not successful in rainy areas	73.8	26.2	100.0
09	Farmer fields are not precisely leveled	73.8	26.2	100.0
10	Nursery in trays is weaker as compared to nursery raised for manual transplanting	69.0	31.0	100.0
11	Mechanical transplanting is not cost-effective	61.9	38.1	100.0
12	Unavailability of spare parts of the mechanical transplanter.	59.5	40.5	100.0

the year 2019 through a development project for the promotion of the transformation of manual transplanting of rice into mechanical transplanting, given in the human nature of labour work for transplanting of rice and for increasing rice productivity. A handsome amount of subsidy was offered for its speedy adoption, but despite concerted efforts, mechanical transplanting did not gain momentum as was expected by its planners. To find out the reasons behind the slow adoption of mechanical transplanting, a field data collection was done from adopters and non-adopters. Their responses against each of the factors are given in Table.3. Farmers in Punjab are well versed with nursery raising method for manual transplanting of rice but mechanical transplanting of rice is a new technology which has some pre-requisites for harvesting good yields which include trained machine operators, well prepared mat type rice nursery of younger age as compared to manually transplanted seedlings, well prepared and precisely levelled fields with thin layer of irrigation water. The main reasons quoted by farmers for their slow adoption of mechanical transplanting of rice.

3.4. Lack of expertise on the part of machine operators

According to survey results, a lack of technical expertise on the part of service

providers/machine operators is one of the main causes of slow adoption of mechanical rice transplanters. Just 4.8 percent of respondents disagreed with the vast majority (95.2%) who cited this problem as a serious obstacle. There is a difference in the objectives of service providers and the host farmer. The service provider wants to cover maximum acreage, whereas the farmer's main objective is profitability, which is only possible if proper plant population is ensured. On one side, there are seed germination issues in trays and at the time of transplanting with mechanical transplanters, gaps remain in the field which need to be refilled manually, leading to increased cost of transplanting. A significant shortage of skilled operators or service providers who can efficiently help farmers in using mechanical transplanters is highlighted by this research. Resolving this lack of experience may be essential for increasing the technology's rate of adoption. Paudel et al. (2022) suggested that a shortage of skilled operators and improving training programs for both service providers and farmers is crucial for boosting the adoption of mechanical rice transplanters.

3.5. Higher rates of seedling mortality in the case of mechanical transplanting

The survey findings indicate that 2nd major reason for slow adoption of mechanical

transplanting in rice is a higher mortality rate of seedlings. A significant i.e. 92.9% of the responses highlighted this issue, stating that mechanical transplanting results in a higher seedling mortality rate compared to traditional methods. Only 7.1% of respondents disagreed with this response. Rice is a water-loving crop and farmers wait for the rainy season to set in for it transplanting. In case of mechanical transplanting, 20-25 days old seedlings are transplanted, whereas in case of manual transplanting, 30-35 days old seedlings are transplanted by farmers. Mechanically transplanted rice seedlings need more time for establishment in the field as compared to manually transplanted seedlings. If there is rainfall just after mechanical transplanting, water level increases in the fields and seedlings float free, leading to increased mortality as Liu *et al*, 2017 also suggested that the age of the seedlings plays a crucial role in influencing the growth stages of rice when using mechanical transplantation methods. This concern suggests that farmers may view mechanical transplanting as a risk to crop establishment and yield stability, discouraging its widespread adoption. Addressing this challenge, such as by improving the calibration and operation of transplanters or providing training to minimize mortality rates, could help build farmer confidence in

this technology and increase its acceptance in the field.

3.6. Seed rate is higher in mechanical transplanting

The study results indicate that another significant reason for the slow adoption of mechanical rice transplanters is the higher seed rate being used by service providers as compared to manual methods. In case of manual transplanting, 816 to 1088 Square feet of nursery equivalent to 3 to 4 kg seed per acre is used, whereas in mechanical transplanting, on average, 10Kg seed of rice paddy is being used irrespective of fine, coarse, or hybrid varieties. This increase in seed cost, combined with other risks associated with the mechanical transplanting method of growing rice, is causing hinderance in the way of speedy adoption of mechanical transplanting of rice. Currently, 100 to 120 trays are being used for mechanical transplanting of one acre with 90 to 120 gm of seed per tray, irrespective of varietal differences in 1000 grain weight. A slight lower side variation in seed rate was observed for hybrid seed usage under mechanical transplanting, given the higher cost of the seed; otherwise, service providers do not differentiate between fine, coarse and hybrid seed usage. A substantial 85.7% of respondents pointed out this concern, while only 14.3% disagreed. Feng, Y et al, 2024 found that

higher seeding rates do not necessarily improve mechanical transplanting quality. Although a higher seeding rate results in more seedlings per hill, it also affects seedling health, leading to weaker seedlings contributing towards higher mortality rates and ultimately affecting the yields per unit area. Service providers provide higher seed rates to hide their inefficiency rather than needed. There is a need to research optimizing seed rates for the mechanical transplanting of rice. The research conducted so far by our research institutes does not base their seed rates on 1000-grain seed weight, which ranges from 23 g to 40 g for different varieties falling under fine and coarse categories. Moreover, training in establishing mat-type nursery for mechanical transplanting is very much needed of the hour to promote mechanical transplanting of rice. Narrowing down the gap between the seed rate being used in mechanical transplanting and manual transplanting will ultimately lead to increased adoption of mechanical transplanting of rice.

3.7. Non-availability of mechanical transplanters

Currently concentration of mechanical transplanters is higher in the core rice area as compared to the non-core rice area. The average land holding in the core rice area is less than compared in the non-core rice

area. Moreover, fine rice varieties are grown more in the core area (covering Lahore, Gujranwala and Gujrat divisions), whereas in the non-core rice area, coarse rice varieties having short duration are grown, which fit the cropping pattern. Mechanical transplanter owners find more business opportunities in non-core rice areas as compared to core rice areas, so they prefer to provide their services in non-core rice areas, leading to a shortage of mechanical transplanters in core rice areas. Moreover, service providers shift their focus from one area to the other over time, leaving the adopters helpless to do mechanical transplanting consistently. One of the biggest obstacles in the way of the adoption of mechanical transplanting is the non-availability of mechanical rice transplanters locally. Around 85.7% of the respondents said that mechanical transplanters were not available to the farming community in their areas, while just 14.3% disagreed.

The lack of availability of mechanical transplanters locally shows a gap in the distribution network and supply chain for mechanical transplanters, prohibiting farmers from even considering this technology as a possibility. To overcome this issue, efforts must be taken to build a stable supply network, incentivize dealerships in underserved areas, and explore rental or cooperative models to

boost access for farmers. Expanding the availability of these machines, combined with other factors, could considerably boost their adoption by rice growers. Improving farm machinery is key to growing the agriculture sector. One of the main challenges to improving agricultural productivity is the lack of access to quality tractors and other farming equipment at reasonable prices when needed for farmers. GOP, 2020.

3.8. Mechanical transplanters do not suit to smaller fields

One of the main reasons preventing the use of mechanical transplanting is the perception that technology is not suitable for smallholder farmers, according to the study results. Significantly, 83.3% of responses were that small-scale farming operations are not a good fit for mechanical transplanting, with only 16.7% disagreeing. Large farmers minimize their cost in terms of time required for transplanting of rice, especially in non-core rice areas where they grow short-duration coarse rice varieties or hybrids. More time is required for manual transplanting as compared to mechanical transplanting. So, they prefer to opt for mechanical transplanting of rice through rental services or they manage their transplanters.

The small and dispersed landholdings typical of smallholders, which might not be

compatible with the operational needs of mechanical transplanters, are probably the root cause of this impression. Additionally, this segment finds the technology less enticing due to its high initial cost and lack of economies of scale for small plots. Customized solutions like smaller, less expensive machines, cooperative ownership arrangements, or leasing services should be taken into consideration to encourage uptake among smallholders. Naseer, M. et al, 2020 found that one of the key challenges to farm mechanization is the prevalence of smallholdings, making them unsuitable for the adoption of new technologies. Small farmers don't own and utilize farm machinery effectively.

Since small farmers do not take risks and follow progressive farmers in their agricultural practices, so is the case with the mechanical transplanting method of growing rice, as small farmers were only 18.2% amongst adopters of mechanical transplanting. Moreover, smaller fields of small farmers create operational difficulties for mechanical transplanters, suggesting that mechanical transplanting is big farmer technology.

3.9. Nursery raising for mechanical transplanting is a tedious job

Nursery raising for traditional manual transplanting is a farmer-friendly method, whereas some pre-conditions have to be

fulfilled for opting for mechanical transplanting of rice and one such pre-condition is nursery raising which requires a skill and close supervision of germination for which majority of the farmers is not used to.

According to the survey results, one of the biggest obstacles to the widespread use of mechanical transplanting is the labor-intensive nature of nursery raising process. Majority (78.6%) of the responses were that preparing seedlings for mechanical transplantation is more time-consuming than for traditional method of manual transplanting of rice. Additional effort and specialized knowledge are required for nursery preparation, which may deter farmers from adopting the technology. Service provision model is the ultimate solution for promotion and adoption of mechanical transplanting as it will create business opportunities for service providers and ease of growing rice mechanically for farmers. Spandana Bhatt, et al., (2022) observed that nursery production technologies seem to be a significant barrier to the effective utilization of transplanting machinery.

3.10. Seedling size is very small at the time of transplanting

In case of mechanical transplanting of rice, 20-25 days old nursery is transplanted which is delicate as compared to the

nursery strength in case of manual transplanting where 30-35 days old nursery is used. According to the survey results, farmers are somewhat concerned about the small seedling size at the time of transplanting. Zhang *et al* 2008 revealed that the optimal age for rice seedlings used in mechanical transplanting is generally considered to be under 25 days. According to the majority of responders (78.6%), seedlings used in mechanical transplanting are significantly smaller than those utilized in manual transplanting techniques. When nursery is transplanted in field either through mechanical transplanter or manually, it faces some stress. In core rice area of Punjab spread over Lahore, Gujranwala and Gujrat divisions, farmers wait for moon soon rains for rice transplanting. Farmers have less faith in this technique of rice transplanting as they believe that smaller seedlings are more susceptible to illnesses, pests, and environmental stress like heavy rains leading to increased mortality. This issue emphasizes the necessity of training and awareness-raising initiatives to inform farmers about the feasibility of smaller seedlings and their capacity to grow successfully in the field. This problem might be further resolved and adoption encouraged by enhancing mechanical transplanting techniques to guarantee the

successful establishment of smaller seedlings.

3.11. Mechanical transplanting is not successful in rainy areas

Mechanical transplanting and rainfall concentration have negative correlation as small seedlings are more prone to failure while establishing in the field. If rainfall comes immediately after mechanical transplanting of rice seedlings, then small seedlings float in rain water leading to increased mortality and ultimately to low plant population. In rice growing areas of Punjab, 50-70% of annual rainfall comes in monsoon season. According to the survey results, one of the main obstacles to the adoption of mechanical transplanting in wet regions is the perception that mechanical transplanting is not successful in rainy areas. Abbas, S., *et al*, emphasized erratic rainfall and seasonal shifts in wet areas hinder the scheduling of mechanical transplanting. While 26.2% of respondents disagreed, the majority of 73.8% of respondents stated that mechanical transplanting is not successful in areas with high rainfall. This is the reason that extent of adoption of mechanical transplanting in core rice areas is less as compared to non-core rice areas.

Rainy weather can cause problems including soggy fields, which can make it difficult for mechanical transplanters to

work and interfere with seedlings' ability to establish themselves properly. Farmers in these regions might be deterred from implementing the technology by these restrictions. In order to solve this problem, mechanical transplanters' functioning and design must be modified to better accommodate wet field conditions, and farmers in high-rainfall areas must receive professional assistance. Pilot studies that show how beneficial these changes are could help shift attitudes and promote wider use.

3.12. Farmer fields are not precisely leveled

One major obstacle to the use of mechanical transplanters is the absence of exactly levelled areas, according to the survey results. A significant majority of responses (73.8%) cited uneven field levelling as a primary factor in the sluggish adoption of this technology. Finally prepared puddled soil with precise levelling, thin layer (1-2 cm) of irrigation water and well-trained machine operators are the pre-requisites of mechanical transplanting.

Mechanical transplanters require flat fields for reliable transplanting and efficient operation. Uneven fields can result in inconsistent crop establishment, poor seedling placement, and potential output losses. This challenge is particularly

apparent in areas where traditional levelling methods are still often employed. By creating the field conditions necessary for mechanical transplanters to function properly, encouraging the use of laser land levelling technology and providing farmers with levelling tools could aid in the solution of this issue. Thus, this could encourage wider adoption of technology and increase farmer's trust. Akmal *et al* 2023 explained that lack of precise land leveling was a major obstacle for mechanical transplanting, making it difficult to achieve the required accuracy for optimal results.

"Nursery in trays is weaker as compared to nursery raised for manual transplanting.

Based on the results of the survey, farmers are quite worried about the perceived lack of mechanical transplanting capacity of tray-grown nurseries. Nurseries cultivated in trays for mechanical transplantation produce worse seedlings than nurseries set up for manual transplanting, according to most respondents (69%). Feng, Y *et al*, 2024 found that an increase in seed rate leads to increased seedlings per hill but weaker seedlings, ultimately leading to lesser yields with mechanical transplanting of rice.

Since weaker seedlings may be viewed as less resilient during transplanting and early growth stages, casting doubt on their ability to establish effectively in the field and deterring farmers from using mechanical

transplanting methods, two solutions to the problem are to improve tray nursery management practices to ensure healthy, robust seedlings and to implement awareness programs to demonstrate the effectiveness of tray-raised seedlings in achieving satisfactory crop performance.

3.13. Mechanical transplanting is not cost effective

Mat type nursery raising needs fine soil which is prepared after sieving the field soil for filling the trays used for growing nursery in case of mechanical transplanting which is a laborious work and farmers are not used to it as compared to traditional method of nursery raising for manual transplanting. Special management practices have to be done for doing mechanical transplanting. Moreover, in core rice areas, soil has high water retention capacity due to high clay content whereas the opposite is the situation in non-core rice areas where clay content is less and soils are loamy in nature which are easily sieved with less effort. The results of the survey show that one of the main causes of the slow adoption of mechanical transplanters is the perceived lack of cost-effectiveness. 61.9% of the responses are that mechanical transplantation is not economically feasible when compared to conventional techniques.

Smallholder farmers in particular may be deterred from adopting the technology because of financial concerns about the machinery's high initial investment cost, higher operating costs, or additional input requirements (like higher seed rates or specialized nurseries), which they perceive to outweigh the potential benefits. Smallholder farmers encounter several obstacles when it comes to adopting new technologies. Agricultural innovations should be introduced, like training and infrastructure development, to help farmers overcome these challenges. (FAO,2023)

This issue could be resolved and the financial burden on individual farmers reduced by the use of financial incentives such as leasing services, subsidies, or cooperative ownership structures. Additionally, demonstrating the long-term financial benefits—like labour savings and potential yield increases—might sway farmers' decisions and hasten adoption.

3.14. Unavailability of spare machine parts

Availability of machine spare parts is very much important for smooth adoption of the technology. Since mechanical transplanting has not gained momentum in our conditions as machine spare parts are not available locally. Machine owners have to make specialized arrangements for keeping their machines operational in distant areas.

Machine owners are mostly based in upper Punjab whereas they have to proceed in central and southern Punjab for providing mechanical transplanting service to the farmers of these areas as they have large landholdings which are lucrative for proliferation of their business opportunities. If there is any kind of machine disorder during the field operation, it takes time for rectification of the defect leading to wastage of time and ultimately sowing coverage is affected. The survey's findings demonstrate that a major barrier to the use of mechanical transplanters is the lack of availability of spare parts. Although 40.5% of respondents disagreed, a significant 59.5% of respondents stated that access to spare parts is a major obstacle. Currently service providers are overcoming this deficiency through their own back up arrangements. When it comes to maintaining or repairing their machinery, farmers face delays and challenges due to a lack of readily available spare parts. This issue not only increases downtime but also raises the total cost of ownership and damages user confidence in the system.

This challenge requires a robust spare parts supply chain, which could include repair facilities at local levels, incentives for local dealerships to stock essential parts, or partnerships with manufacturers to ensure timely availability. Improved access to spare parts would significantly boost the

reliability and attractiveness of mechanical transplanters to farmers. Paudel et al, 2021 found that slow adoption of mechanical transplanting is the scarcity of spare parts in local markets. Without access to these parts, it's difficult to repair existing machines, which negatively impacts the effectiveness of the technology and hinders its wider adoption. (Umar et al., 2022) also found high initial cost of mechanical rice transplanters, compulsory use of laser land levelers, higher maintenance cost of mechanical rice transplanters, untrained labour & machine operators, and insufficient training of farmers are the major constraints behind fast adoption of mechanical transplantation of rice in Punjab.

4. Cultural and psychological barriers to adoption

In addition to technical and financial constraints, several cultural and psychological factors contribute significantly to the slow adoption of mechanical rice transplanting. Many farmers in Punjab exhibit a deep-rooted trust in traditional manual transplanting methods, which they have used successfully for generations. This attachment to conventional practices creates a psychological barrier to trying new methods, even if they offer potential benefits. Furthermore, smallholder farmers

in particular tend to be risk-averse, preferring familiar systems that guarantee predictable outcomes over innovations that require new skills or appear uncertain. One farmer shared, “I’ve always done it this way. Why should I change something that works?” This mindset reflects a broader hesitation rooted in fear of crop failure, mistrust in machine efficiency, and a lack of confidence in their own ability to operate or manage new technologies. As noted by Guru et al. (2018) and Paudel et al. (2021), addressing these psychological barriers requires more than technical training—it also demands trust-building, demonstration trials, and peer-led awareness programs that empower farmers through exposure to success stories and gradual learning.

4.1. Comparative insights from other regions

The challenges observed in Punjab are not unique; similar barriers have been reported in various rice-producing regions across Asia. For instance, in India, despite government subsidies and mechanization schemes, adoption of mechanical transplanting has remained limited among smallholders due to fragmented landholdings and cultural reliance on manual methods (Guru et al., 2018). In Nepal, Paudel et al. (2021) found that slow adoption was attributed to poor access to machinery, lack of skilled operators, and

psychological resistance—mirroring the findings from this study. In Vietnam and the Philippines, adoption rates have improved where governments bundled machinery subsidies with training programs and established cooperative models for shared equipment use (Pandey & Velasco, 2005). These examples underscore the importance of integrating context-specific financial, institutional, and educational support to enable adoption, particularly among small and risk-averse farmers. Drawing lessons from these countries, Punjab's policy and extension efforts could benefit from a more holistic approach that addresses not just infrastructure, but behavioral and socio-economic constraints as well.

The adoption of mechanical rice transplanting in Punjab can also be examined through the lens of Rogers' Diffusion of Innovations theory, which offers a valuable framework for understanding the varying pace of technology uptake. According to Rogers (2003), the adoption of innovations follows a predictable pattern involving innovators, early adopters, early majority, late majority, and laggards. In this context, large-scale farmers with access to resources and higher risk tolerance tend to behave as early adopters, while smallholders—constrained by limited capital, lack of technical knowledge, and higher risk aversion—fall into the late majority or laggard categories.

The five key attributes that influence adoption—relative advantage, compatibility, complexity, trialability, and observability—are particularly relevant here. For instance, while mechanical transplanting offers clear labor-saving advantages (relative advantage), its low compatibility with small, uneven fields, and the complexity of mat-type nursery preparation deter many potential users. Furthermore, limited opportunities for trial and a lack of visible local success stories restrict its observability and trialability, slowing diffusion. Aligning policy and extension strategies with these attributes can help accelerate the adoption curve by addressing not just economic constraints, but also behavioral and contextual barriers faced by farmers.

5. Conclusion

This study investigated the underlying reasons for the slow adoption of mechanical rice transplanting in Punjab, Pakistan, by surveying a representative sample of rice growers across core and non-core rice-producing regions. The findings reveal that adoption is significantly higher among large farmers and those operating in non-core areas, largely due to favorable land conditions, lower rainfall concentration, and greater financial capacity. In contrast, smallholders and farmers in core rice zones face multiple interrelated challenges that

hinder adoption. These include limited access to transplanters, poor availability of spare parts, lack of trained machine operators, insufficient knowledge on raising mat-type nurseries, and the perception that mechanical transplanting is not suitable for small and fragmented fields. Additionally, a considerable gap in seed rate requirements between mechanical and manual transplanting contributes to increased costs and operational inefficiencies, further discouraging uptake. Beyond these technical and financial barriers, the study also highlights critical psychological and cultural factors such as risk aversion, trust in traditional practices, and low confidence in new technologies that play a pivotal role in shaping farmer behavior. These insights align with Rogers' Diffusion of Innovations theory, which emphasizes how adoption is influenced by perceived complexity, compatibility, and observability of new technologies. The observed trends in Punjab mirror similar challenges documented in other rice-producing countries in South and Southeast Asia, underlining the need for a more integrated, context-specific approach to technology promotion. For mechanical transplanting to gain broader acceptance in Punjab, especially among small and resource-poor farmers, a combination of targeted policy interventions, capacity-building programs, and infrastructure

support is essential. Public-private partnerships should be encouraged to establish rental and service delivery models, training centers, and robust supply chains for machinery and spare parts. Equally important is the need to foster behavioral change through farmer-led demonstration trials, peer learning, and localized extension strategies. Only through such a multifaceted and inclusive approach can the potential of mechanical rice transplanting be fully realized to enhance productivity, reduce labor dependence, and ensure sustainable agricultural transformation in the region.

Policy implications and recommendations

The findings of this study highlight the need for a more structured and targeted policy approach to enhance the adoption of mechanical rice transplanting, particularly among small and medium-scale farmers. Firstly, the government should extend and customize its subsidy programs to specifically benefit smallholders. This could include providing partial grants or interest-free loans to help farmers either purchase or lease mechanical transplanters. Additionally, establishing custom hiring centers (CHCs) or cooperative service units across rural areas can ensure that resource-poor farmers have affordable access to machines without the financial burden of ownership. Alongside this, there is an

urgent need for comprehensive training and capacity-building initiatives. These programs should target both farmers and machine operators and cover aspects such as mat-type nursery preparation, machine calibration, maintenance, and efficient field operation.

Furthermore, demonstration trials at the village or union council level should be conducted to build confidence among skeptical farmers. Such localized evidence of success can play a powerful role in shifting farmer perceptions and encouraging broader acceptance. Another critical area for intervention is improving the availability of spare parts and repair services. Strengthening partnerships between the public sector, manufacturers, and local vendors can help ensure timely access to parts and minimize downtime during the transplanting season. Equally important is the promotion of laser land leveling, which is essential for effective mechanical transplanting. Incentivizing land leveling, either as a standalone policy or bundled with machinery support—can help improve field conditions and transplanting efficiency. Lastly, the implementation of regular monitoring and farmer feedback mechanisms will allow policymakers to evaluate the effectiveness of these initiatives and make timely adjustments based on the practical challenges faced in the field. Collectively,

these policy measures, if well-coordinated, can reduce the adoption barriers for small farmers, enhance the operational ecosystem for mechanical transplanting, and contribute to greater productivity and sustainability in rice cultivation across Punjab.

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