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ACCESSING ADOPTION OF IMPROVED RICE AND TECHNOLOGICAL GAPS IN RICE CULTIVATION: EVIDENCE FROM MANIPUR INDIA

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ABSTRACT

Improved agricultural technologies are critical for enhancing crop productivity with efficient resource utilization. Rice, being a staple crop, occupies a significant share of cultivated land in Manipur, with nearly half of the area under improved varieties. The present study employed an ex-post facto research design in Imphal West and Bishnupur districts of Manipur to assess the extent of adoption and technological gaps in the recommended package of practices for three improved rice varieties CAU-R1, RCM-9, and RCM-13. The findings revealed a high technological gap in disease management, seed treatment, and pest management practices. Among the varieties, CAU-R1 emerged as the most widely adopted, followed by RCM-9 and RCM-13. Overall, the majority of respondents exhibited a medium level of adoption of improved rice cultivation practices. To bridge the identified gaps and enhance productivity, need-based training and capacity-building programs focusing on critical practices are recommended for sustainable rice production and income improvement among farmers.

***Key words*:** Adoption, improved rice cultivation, technological gap, Manipur.

Introduction

Improving sustainability on farm production depends on the intervention of potential technology and the choices of farmers to adopt the appropriate technology (Gamage *et al.*, 2024. Adoption of recommended practices and innovative technologies Transformations of the agricultural sector requires adoption of new technology and innovative approaches that support sustainable outcomes. Sustainable farming is the ability to maintain harmony and co-existence of the environment and human civilization (Rai *et al.*, 2022). Technology adoption is possible by adopting good agronomic practices such as land management, effective fertilization, water management, lower plant densities and increasing resources efficiency (Rakholia *et al.*, 202). It is also evident that improved technology adoption has a positive and significant effect on the welfare of households by improving income of 30 to 33% as compared to non-adopters' farmers (Ayenew *et al.*, 2020; Adams and Jumpah, 2021). Adoption of improved technologies in agriculture is the tool for boosting the farm production and productivity thereby helping in poverty reduction and ensuring food security in developing countries (Yokamo, 2020).

In India agriculture is the livelihood source of more than 50% of the rural population and it provide employment to around 58% of the population. Currently the population of India is 1.4 billion as of May 2023 which is equivalent to 17.7% of the total world population (8 billion). Population is growing very fast in India becoming the most populous country expected to reach the total population of 1.7 billion by 2050 (Singh, 2019). To meet the rising demand of foods and to provide livelihood of millions of rural people, agriculture sector urgently requires a transformative change to make it more sustainable (Mohanty, S., & Yamano, T. 2017). In order to overcome the present crisis, it is important to the large growing crops in the country. Rice being one of the most important crops plays a major role in the cultural and economic development of India (Mohanpatra and Sahu, 2022). India has long been ranked as the second largest producer of rice *i.e.*,195 million metric tons after China which has production over 212.8 million metric tons followed by

Indonesia and Bangladesh, against the world total volume of milled rice production of 510 million metric tons of milled rice (Shahbandeh, 2023). In India rice accounts for more than 40 per cent of the food grain production, holding the highest export volume of around 15.5 million metric tons worldwide (Prameela, 2022). In agricultural sector rice cultivation occupied a major segment by promoting foreign exchange, economic growth and employment generation through the rice industrial sector of the country (IIIEM, 2019).

However agricultural land is already scarce and expansion is not an option to increase rice yield. Rice yield needs to be increased to ensure access of rice at affordable market price. In this situation improved technologies can be the primary sources of increasing crop yield without expanding the cultivated area (Hashim *et al.*, 2024). Increasing crop yield is the means of improving the household food security and raising the farmer's income (Addison *et al.*, 2022). Modern agricultural technologies such as diseases resistant varieties reduces pesticides use, biological pest control and others advance technologies brought increase crop productivity, improve incomes and wellbeing of farmers (FAO, 2022). Utilization of improved technologies in an appropriate manner would prove to be beneficial in improving productivity and profitability which enhance in sustaining livelihood of the farmers (Kapur, 2018). The production system of rice in India can be improved as the average rice productivity is only 2.6 t/ha which is much lesser than the neighboring countries like China, Indonesia and Bangladesh (Kumar *et al.*, 2022). With the existing condition the solution to make agriculture more productive and sustainable is by adopting improved technologies. Thus, improved technologies are the solution to feed a continuously growing population against the limited resources, unsustainable practices and climate crisis. Economic efficiency on farm management and commercial feasibility for farmers without disturbing the performance of natural environment will be achieved by adopting improved technologies (Nayak *et al.*, 2023).

Sustainable agricultural development is essential to meet the growing food demand while safeguarding natural resources for future generations. The adoption of appropriate technologies and improved farming practices plays a crucial role in enhancing productivity, reducing environmental degradation, and ensuring food security (Rai *et al.*, 2022). In this context, rice cultivation holds special significance in India, where rice is a staple food and a major contributor to agricultural GDP. India ranks as the second-largest rice producer globally, with an annual production of about 195 million metric tons, accounting for more than 40% of the country's total food grain output (Prameela, 2022; Shahbandeh, 2023). Despite this, the average rice productivity in India is only 2.6 tons per hectare, significantly lower than in neighboring countries such as China and Bangladesh. This indicates an urgent need to adopt modern agricultural technologies and improved agronomic practices to enhance yield without expanding the cultivated area, given land constraints and population pressure.

The North-Eastern state of Manipur represents a unique case in this scenario due to its heavy dependence on agriculture for livelihoods, diverse agro-climatic conditions, and distinct socio-economic characteristics. Agriculture employs nearly 70% of the state's population, and rice is the dominant kharif crop, occupying around 86% of the total cultivated area in both the valley and hill regions (Department of Agriculture, Government of Manipur, 2021). The state has shown considerable progress in the adoption of high-yielding varieties (HYVs), with about 106.18 thousand hectares under HYVs of paddy and an average yield of 3.83 tons per hectare in 2020–21, which is above the national average. However, despite this relatively higher productivity, there remains a significant technological gap in the adoption of improved cultivation practices, such as proper land preparation, seed treatment, integrated nutrient management, and pest control measures (Van *et al.*, 2024). These gaps are influenced by factors such as farmers' socio-economic conditions, access to inputs, knowledge levels, and institutional support.

Governments and development organizations have consistently advocated for agricultural technologies as a means to boost farm productivity and alleviate poverty. Despite their potential benefits, many of these technologies are still adopted at low rates (Ruzzante *et al.*, 2021). Understanding the extent of adoption and the existing technological gaps in rice cultivation in Manipur is critical for designing targeted interventions and extension strategies that can bridge these gaps, improve resource use efficiency, and ensure sustainable production. Given the state's strategic role in ensuring regional food security and its potential to further increase productivity through better technology adoption, this study aims to analyze the current status of adoption of improved rice cultivation practices and identify technological gaps among farmers in Manipur. The findings will provide valuable insights for policymakers, researchers, and extension agencies to formulate region-specific strategies that enhance productivity and sustainability in rice-based farming systems.

Materials and Methods

The present study was carried out in the state of

Table 1: Distribution of respondents based on their extent of adoption of improved paddy cultivation practices of CAU-R1 (Tamphaphou) variety.

Recommended practices of CAU-R1	FAf (%)	PAf (%)	NAf (%)	TAS	AI %	Tgap	Rank
Land preparation	15 (37.50)	17(42.50)	8 (20.00)	47	58.75	41.25	VIII
Seed rate	13 (32.50)	20 (50.00)	7 (17.50)	46	57.50	42.50	VII
Seed treatment	6 (15.00)	10 (25.00)	24 (60.00)	22	27.50	**72.50**	II
Sowing time	14 (35.00)	**22 (55.00)**	4 (10.00)	50	62.50	37.50	IX
Seedling age	**18 (45.00)**	20 (50.00)	2 (5.00)	56	70.00	30.00	X
Nursery fertilizer	11 (27.50)	17 (42.50)	12 (30.00)	39	48.75	51.25	V
Main field fertilizer	9 (22.50)	14 (35.00)	17 (42.50)	32	40.00	60.00	IV
Insect Pest Management	8 (20.00)	12 (30.00)	20 (50.00)	28	35.00	**65.00**	III
Diseases management	4 (10.00)	10 (25.00)	**26 (65.00)**	18	22.50	**77.50**	**I**
Weed management	13 (32.50)	16 (40.00)	11 (27.50)	32	40.00	60.00	IV
Water management	11 (27.50)	**22 (55.00)**	7 (17.50)	44	55.00	45.00	VI

Manipur, located in the North-Eastern region of India, covering an area of 22,327 km², which accounts for 0.7 percent of the total geographical area of the country. The state has a population of 2.85 million (IBEF, 2020) and comprises an alluvial valley of 1,820 km² surrounded by hills occupying 20,507 km². Agriculture is the primary source of livelihood for the majority of the population, and rice is the dominant kharif crop, occupying approximately 86 percent of the total cropped area (Department of Agriculture, Government of Manipur, 2021). Considering the predominance of rice cultivation and its importance for food security and farmers' income, Manipur was purposively selected for the present investigation. Among the nine districts of the state, Imphal West and Bishnupur were selected purposively for the study as these districts lie in the central valley region and represent the major rice-growing areas with a high concentration of improved rice varieties and adoption of scientific cultivation practices. Four Community Development (C.D.) blocks Patsoi and Wangoi from Imphal West and Bishnupur and Nambol from Bishnupur district were chosen purposively on the basis of the intensity of improved rice cultivation. From these blocks, a list of villages cultivating improved paddy varieties was obtained, and two villages from each block were selected randomly, making a total of eight villages for the study. A comprehensive list of farmers growing improved paddy was prepared, and from each village, 15 farmers were selected randomly, resulting in a total sample size of 120 respondents. For the purpose of this study, improved paddy refers to high-yielding and stress-tolerant varieties recommended for the state of Manipur. Specifically, the study focused on CAU-R1 (Tamphaphou), RCM-9 (RC Maniphou-9), and RCM-13 (RC Maniphou-13). Primary data were collected using a structured interview schedule through personal interviews with the selected farmers. The interview schedule included questions related to socio-economic characteristics, adoption of recommended rice cultivation practices, and constraints faced in adopting improved technologies. The recommended practices considered for assessing adoption included land preparation, seed treatment, nursery management, transplanting methods, fertilizer application, weed management, pest and disease control, water management, and harvesting. The extent of adoption was measured using a practice-wise scoring system, wherein full adoption (FA) of a recommended practice was assigned a score of 2, partial adoption (PA) a score of 1, and no-adoption (NA) a score of 0. The total score obtained by a farmer was divided by the maximum possible score (*i.e.*, the score obtained if all practices were fully adopted) and expressed as a percentage to compute the Adoption Index (AI) using the formula:

$$Adoption\ Index\ (AI) = \frac{Total\ score\ obtained}{Maximum\ possible\ score} \times 100$$

Where, the total score obtained represents the sum of all scores for adopted practices by the farmers and the maximum possible score equals the number of recommended practices multiplied by the full score.

Technological gap for each practice was calculated using the following formula:

$$Technological\ gap\ (Tgap) = \frac{R - AR}{R} \times 100$$

Where, R represents the full score of each recommended practice and AR denotes the adoption score of the respective practice. The overall technological gap was obtained by averaging the gaps across all practices.

Results and Discussions

Adoption of improved rice cultivation technology Table 1 presents the distribution of respondents based on their extent of adoption of improved paddy cultivation practices for the CAU-R1 (Tamphaphou) variety. The results reveal distinct patterns across different

Table 2: Distribution of respondents based on their extent of adoption of improved paddy cultivation practices of RCM-9 variety (n=40).

Recommended practices of RCM-9	FAf (%)	PAf (%)	NAf (%)	TAS	AI	Tgap	Rank
Land preparation	9 (22.50)	**25 (62.50)**	6 (15.00)	43	53.50	46.50	IX
Seed rate	10 (25.00)	22 (55.00)	8 (20.00)	42	52.50	47.50	VIII
Seed treatment	2 (5.00)	7 (17.50)	31 (77.50)	11	13.50	**86.50**	III
Sowing time	**17 (42.50)**	20 (50.00)	3 (7.50)	54	67.50	32.50	XI
Seedling age: 55days old seedlings	9 (22.50)	21 (52.50)	10 (25.00)	39	48.75	51.25	VII
Nursery fertilizer	6 (15.00)	20 (50.00)	14 (35.00)	32	40.00	60.00	VI
Main field fertilizer	5 (12.50)	16 (40.00)	19 (47.50)	26	32.50	67.50	IV
Insect Pest Management	1 (2.50)	5 (12.50)	34 (85.00)	7	8.75	**91.25**	II
Diseases management	0 (0.00)	4 (10.00)	**36 (90.00)**	4	5.00	**95.00**	**I**
Weed management	7 (17.50)	16 (40.00)	17 (42.50)	30	37.50	62.50	V
Water Management	14 (35.00)	18 (45.00)	8 (20.00)	46	57.5	42.50	X

recommended practices. A considerable proportion of respondents (45.00%) fully adopted the recommended seedling age, whereas partial adoption was most pronounced in sowing time (55.00%) and water management (55.00%). Conversely, the highest level of non-adoption was observed in disease management practices, with 65.00% of respondents reporting no adoption. In terms of the Adoption Index (AI), disease management recorded the lowest score (22.50%) with a Total Adoption Score (TAS) of 18, while land preparation achieved the highest AI (58.75%) with a TAS of 47. Analysis of the technological gap (Tgap) highlights critical shortcomings: disease management exhibited the largest gap (77.50%, Rank I), followed by seed treatment (72.50%, Rank II), and insect-pest management (65.00%, Rank III). The relatively high technological gaps in disease and pest management suggest persistent barriers to adoption. These may stem from farmers limited technical knowledge, difficulties in implementing preventive and control measures, and weak linkages with extension services and agricultural experts. Such constraints hinder the effective transfer of scientific recommendations, leading to partial or non-adoption of critical components of the technology package. Addressing these gaps through targeted farmer training, improved extension communication, and accessible integrated pest and disease management strategies is essential for enhancing adoption of improved paddy cultivation practices in Manipur.

Table 2 presents the distribution of respondents according to their extent of adoption of improved paddy cultivation practices for the RCM-9 variety. The findings indicate notable variation across practices. Full adoption was most prominent for sowing time, reported by 42.50% of respondents, while partial adoption was highest for land preparation (62.50%). In contrast, non-adoption was strikingly high for disease management, with 90.00% of respondents not following the recommended practice. An examination of the Adoption Index (AI) and Total Adoption Score (TAS) further underscores these disparities. Disease management recorded the lowest TAS (4) and AI (5.00%), while land preparation achieved the highest TAS (43) and an AI of 53.50%. Analysis of technological gaps revealed that disease management exhibited the widest gap (95.00%, Rank I), followed by seed treatment (86.50%, Rank II) and insect pest management (91.25%, Rank III). These results highlight critical weaknesses in

Table 3: Distribution of respondents based on their extent of adoption of improved paddy cultivation practices of RCM-13 variety (n =40).

Recommended practices of RCM-13	FAf (%)	PAf (%)	NAf (%)	TAS	AI	Tgap	Rank
Land preparation	11 (27.50)	19 (47.50)	10 (25.00)	41	51.25	48.75	VIII
Seed rate	12 (30.00)	17 (42.50)	11 (27.50)	41	51.25	48.75	VIII
Seed treatment	0 (0.00)	7 (18.50)	**33 (82.50)**	7	8.75	**91.25**	**I**
Sowing time	9 (22.50)	12 (30.00)	19 (47.50)	30	37.50	62.50	VI
Seedling age	**13 (32.50)**	16 (40.00)	11 (27.50)	42	52.50	47.50	IX
Nursery fertilizer	8 (20.00)	19 (47.50)	13 (32.50)	35	43.75	56.25	VII
Main field fertilizer	6 (15.0)	12 (30.0)	22 (55.00)	24	30.00	70.00	IV
Insect Pest Management	4 (10.0)	10 (25.00)	26 (65.00)	19	23.50	76.50	III
Diseases management	2 (5.0)	6 (15.00)	32 (80.00)	10	12.50	**87.50**	**II**
Weed management	7 (17.5)	13 (32.50)	20 (50.00)	27	33.75	66.25	V
Water management	10 (25.0)	**24 (60.00)**	6 (15.00)	44	55.00	45.00	**X**

Table 4: Distribution of respondents based on their level of overall adoption of recommended rice cultivation technology of CAU-R1, RCM-9 and RCM-13 (n=20).

Level of adoption	Frequency	%	Mean	SD
Low (<5.22)	27	22.50	7.77	2.55
Medium (5.22- 10.32)	82	68.33		
High (>10.32)	11	9.17		
Total	**120**	**100**		

the adoption of plant protection practices. The pronounced technological gaps in disease and pest management suggest systemic challenges faced by farmers in implementing these practices. Limited knowledge of crop diseases, inability to identify symptoms, and lack of access to appropriate control measures contribute significantly to non-adoption. Furthermore, weak interactions with agricultural experts and inadequate extension support exacerbate these issues. Consequently, farmers fail to adopt the recommended practices, particularly those requiring specialized knowledge and technical skills. Addressing these constraints through strengthened extension services, capacity-building programs, and farmer-friendly diagnostic and management tools is imperative for narrowing the adoption gap and enhancing the effectiveness of RCM-9 cultivation practices in Manipur.

Table 3 presents the distribution of respondents based on their extent of adoption of improved paddy cultivation practices for the RCM-13 variety. The results highlight considerable variation in adoption across different recommended practices. Full adoption was highest for seedling age (32.50%), while partial adoption was most prominent in water management (60.00%). Conversely, non-adoption was notably high in seed treatment, with 82.50% of respondents reporting no adoption. With respect to the Adoption Index (AI), seedling age achieved

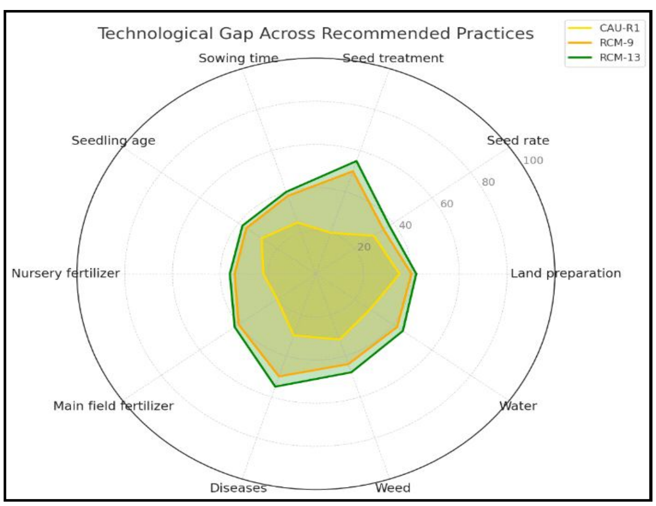

Fig. 1: Technological gap of the recommended practices of improved rice varieties CAU-R1, RCM-9 and RCM-13 cultivation.

Table 5: Relationship between profile of the rice cultivators and extent of adoption of technology of CAU-R1, RCM-9 and RCM-13.

Variables	Coefficient of correlation 'r'	P value
Age	0.152	0.054
Gender	-0.062	0.433
Family size	0.023	0.772
Education	0.113	0.156
Total agriculture land holding	0.214**	0.007
Total land under improved paddy	0.216**	0.006
Annual income	0.0.082	0.304
Annual income from paddy	0.197*	0.012
Training exposure	0.165*	0.037
Information source utilized by paddy growers	0.147	0.995
Social participation	0.001	0.039
Knowledge level	0.164*	0.039
Attitude towards improved paddy cultivation	0.091	0.251
Experience in paddy cultivation	0.192*	0.015
*Significant at 5 per cent; **Significant at 1 per cent		

the highest TAS (42) corresponding to an AI of 52.50%, whereas seed treatment registered the lowest TAS (7) with an AI of only 8.75%. Analysis of technological gaps (Tgap) further indicates that seed treatment exhibited the highest gap (91.25%, Rank I), followed by disease management (87.50%, Rank II) and insect pest management (76.50%, Rank III). The extremely low adoption of seed treatment practices suggests limited awareness among farmers regarding its significance. Many cultivators appeared to lack knowledge about the protective role of seed treatment against seed-borne pests and diseases, leading them to bypass this step and directly sow untreated seeds. Additionally, misconceptions regarding the necessity of seed treatment, combined with weak extension outreach and inadequate farmer training, may have reinforced the perception that the practice is dispensable. This highlights the urgent need for targeted interventions to improve farmers' knowledge and conviction regarding seed treatment and other plant protection measures. Strengthening training programs, improving accessibility of fungicides and treatment facilities, and enhancing communication between farmers and extension agents could help bridge these critical technological gaps in RCM-13 adoption.

Table 4 revealed that the majority (68.33%) of the respondents belonged to medium level of adoption category whereas 22.50 per cent belonged to low level adoption category and 9.17 per cent belongs to high level adoption category. The result was found supported with the findings of (Dhinesh, *et al.*, 2022) reported that majority respondents had medium level of adoption of farm mechanization practices in rice cultivation. Thus, it can be inferred that majority of the respondents had medium level of technology adoption.

Fig. 1 indicates that the CAU-R1 variety recorded the lowest technological gap across recommended rice cultivation practices, whereas RCM-9 and RCM-13 exhibited comparatively higher gaps. This suggests that CAU-R1 is the most widely adopted improved variety among paddy farmers in Manipur. The higher adoption of CAU-R1 may be attributed to its superior yield potential, tolerance to climatic stress, and favorable grain quality characteristics. Farmers reported continued preference for this variety due to its performance and market acceptability.

These observations are consistent with the findings of Jyothi and Devarani (2019), who reported that CAU-R1 performs well under local agro-ecological conditions and provides an average yield of 5–6 t/ha, compared to 3–4 t/ha for other improved varieties. In contrast, RCM-9 and RCM-13 were least adopted, which could be due to the perceived complexity of recommended practices and limited technical knowledge among farmers. Major technological gaps were observed in critical practices such as seed treatment, fertilizer application, pest and disease management, and water management. Bridging these gaps is essential to enhance productivity and sustainability in rice-based farming systems. Targeted capacity-building interventions, such as farmer training and participatory demonstrations, can significantly improve the adoption of recommended practices. Previous studies (Kumar *et al.*, 2020) have established that farmers who receive technical training demonstrate higher adoption rates compared to non-trained farmers. Addressing these gaps through farmer-centric extension strategies will contribute to sustainable rice production and improved farm incomes. Adoption of science-based practices in land preparation, input management, and crop protection should be prioritized to achieve higher productivity, resource-use efficiency, and long-term livelihood security. Correlation of selected independent variables with the dependent variable 'Extent of adoption of recommended rice cultivation technology.'

Table 5 presents the relationship between selected socio-economic and personal variables of rice cultivators and their extent of adoption of improved rice cultivation technologies across CAU-R1, RCM-9, and RCM-13 varieties. The correlation analysis revealed that certain variables exert a significant influence on adoption behavior. Among the variables, total agricultural landholding ($r = 0.214$, $p < 0.01$) and total land under improved paddy cultivation ($r = 0.216$, $p < 0.01$) exhibited a positive and highly significant association with adoption at the 1% level. This indicates that farmers with larger landholdings were more likely to adopt improved cultivation practices. Similarly, annual income from paddy ($r = 0.197$, $p < 0.05$) showed a positive and significant relationship, suggesting that higher earnings from paddy encouraged greater adoption of recommended technologies. This finding aligns with earlier studies (Mikias, 2020; Mihretie *et al.*, 2022), which also reported income as a driver of technology uptake. In addition, training exposure ($r = 0.165$, $p < 0.05$), knowledge level ($r = 0.164$, $p < 0.05$), and experience in paddy cultivation ($r = 0.192$, $p < 0.05$) were all positively and significantly associated with adoption. These results imply that farmers who had greater access to training programs, possessed higher knowledge, and had more years of experience were more inclined to adopt improved rice cultivation practices. Similar observations were made by Kumar *et al.*, (2020), who highlighted the role of training, farming experience, and adoption of crop management practices in enhancing household income and technology adoption. Moreover, Zegeye (2021) emphasized that positive and significant variables influencing technology adoption also contribute to poverty reduction, reinforcing the broader development implications of these findings. Overall, the results suggest that farmers' resource base, economic returns, knowledge, and training opportunities are critical determinants of adoption. Hence, interventions to scale up improved rice technologies should prioritize capacity-building through training, knowledge enhancement, and targeted support to resource-constrained farmers, thereby accelerating adoption and improving productivity outcomes.

Conclusion

The study revealed that among the improved rice varieties examined, CAU-R1 recorded the highest extent of adoption across recommended cultivation practices, particularly in seed treatment and disease management, followed by RCM-9 and RCM-13. A majority of farmers were found to have a medium level of overall technology adoption. The analysis further indicated that factors such as landholding size, area under paddy cultivation, training exposure, access to information sources, knowledge level, and farming experience were positively and significantly associated with the extent of adoption. These findings underscore the need for targeted interventions to promote the adoption of scientifically recommended practices for sustainable rice production. Strategies should focus on capacity building through farmer training, improved access to extension services, and participatory demonstrations to enhance knowledge and skills. Policies that support the wider dissemination of promising varieties like CAU-R1, along with eco-friendly technologies, can help reduce the environmental footprint while improving productivity and profitability. Ensuring sustained technology adoption will be crucial for achieving long-term sustainability, food security, and income stability in rice-based farming systems of Manipur.

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