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Assessing the Dynamics of Rice Varietal Choices and Consumer Preferences: Implications for Research and Policy

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ABSTRACT

Setting research priorities to evolve new rice varieties should align with farmers' and consumers' demands to optimise income, resource efficiency, and consumer utility. To assess and reset the current rice breeding programs in Tamil Nadu, India, this study examines the farmers' and consumers' preferences for rice varieties released by the Tamil Nadu Agricultural University (TNAU) and non-TNAU varieties. Primary data from 360 respondents, including producers and consumers, along with two focus group discussions involving various stakeholders during 2021-22, reveal that farmers prefer TNAU varieties during the Kuruvai season for high yields, maturity duration, and stress resistance, but shift to non-TNAU varieties in Samba and Thaladi seasons based on grain quality and price. Consumers prefer branded rice for its superior cooking quality and appearance, while some rural consumers opt for unbranded rice due to its affordability and greater availability. Influencing factors for farmers' choice of TNAU varieties include experience, extension services, access to inputs, and education. Consumers' decisions are influenced by factors such as income, market price, household size, and cooking quality. Past breeding programs have focused on yield and stress resistance, neglecting consumer preferences, resulting in only a few varieties, such as CO51, TPS5, CR1009 sub1, ADT51, and ADT54, being widely accepted. The study highlights the need to reorient future rice research by integrating both farmers' and consumers' choices, while ensuring marketability, improving input access and extension services, and branding through Public-Private Partnerships. Additionally, it emphasises the importance of strengthening the seed supply chain via Farmer Producer Organisations (FPOs) to meet the diverse needs of producers and consumers. The findings and policy outcomes apply to real-world situations involving public rice research/ breeding programs.

Keywords: Rice varieties, farmer Preference, consumer behaviour, varietal adoption, probit, regression tree analysis

JEL Codes: C38, D12, O13, Q12, Q16

I
INTRODUCTION

Global efforts in rice breeding have led to the development and cultivation of over 110,000 rice varieties worldwide, with about 40,000 of them being classified as *Oryza sativa* (Rathna Priya et al., 2019). Past research programs in rice have focused on production criteria such as high yields, resistance to biotic and abiotic stresses, and resource efficiency, but have ignored sustainability and the climate crisis during varietal development (Ramasamy et al., 1997). In response to the Sustainable Development Goals (SDGs) to end hunger, rice breeding programs currently prioritise quality, sustainability, and nutrition, in addition to routine priorities of yield and stress tolerance, amid resource scarcity under climate change (Varzakas and Slim, 2024). Subsequently, numerous varieties have been released in different research institutions across the world (Hamilton, 2006). However, farmers have unique preferences for production and market-oriented requirements that may not

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always align with research objectives. These preferences can significantly impact adoption decisions, sometimes causing a disconnect between available technologies and the technologies that farmers actually adopt, due to various factors, including socio-economic and demographic elements (Hossain, 2021; Pingali et al., 2001; Rasheed et al., 2022). Additionally, consumer preferences vary across different locations, which are not taken into account when developing rice varieties (Bin Rahman and Zhang, 2022). This misalignment can result in limited adoption of rice varieties. Tracing back the history, the identification of the dwarfing gene in Dee-Gee-Woo-Gen and the development of the high-yielding rice variety IR8 were key factors in India's green revolution (Hargrove et al., 1980). Subsequently, a collaborative research network involving the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) facilitated continuous improvement in rice production by introducing high-yielding varieties (Pathak et al., 2018; Ramasamy et al., 1997). The supply of these varieties to farmers in India is ensured through a seed multiplication process involving SAUs and the State Department of Agriculture. This seed multiplication chain helps to maintain genetic purity and meet farmers' demand for quality seeds. India's public agricultural research system, comprising ICAR institutes and SAUs, has collectively developed over 1000 modern rice varieties (MRVs). Both the public and private sectors have invested considerably in rice breeding programs, developing and commercialising numerous rice varieties and hybrids. This development has enabled farmers to select cultivars based on their field performance, resulting in stabilised global and regional rice production over the years (van Oort et al., 2015).

The primary responsibility for rice breeding in Tamil Nadu, a leading rice-producing state in India, lies specifically with the Tamil Nadu Agricultural University (TNAU). TNAU has released 190 rice varieties since the introduction of GEB 24[2] in 1921 (Rangasamy et al., 2012). Around 114 varieties are designated for formal seed sales annually in the state of Tamil Nadu, India (https://seedcertification.tn.gov.in/seedcertification/). These varieties are tailored for different growth durations and are primarily adopted by farmers in the rice-rich Cauvery Delta Zone (CDZ) of Eastern Tamil Nadu. This adoption is instrumental in enabling large-scale rice production, aided by the availability of certified seeds. In addition, several private companies and other SAUs in India have introduced popular rice varieties. However, TNAU rice varieties are often considered more important than private rice varieties due to their emphasis on public access, affordability, and adaptability to the local agro-climatic conditions of Tamil Nadu. Further, TNAU varieties are designed to benefit a wider range of farmers, including small and marginal farmers, who may lack the financial resources to purchase seeds from

[2]It was also known as Kichili samba, which was evolved by the Government Economic Botanist (GEB) during the British colonial period at the Paddy Breeding Station, now known as the Department of Rice, which is part of Tamil Nadu Agricultural University in Coimbatore.

private companies (Kumar and Moharaj, 2023). Given the extensive variety of choices, farmers consider multiple factors beyond yield when selecting new varieties or discontinuing older ones. Inputs from many studies carried out to assess farmers' preferences (Suvi et al., 2020), farmer perceptions (Checco et al., 2023; Paris et al., 2008; Sharma et al., 2017) and production constraints faced by farmers in different ecosystems (Dröge et al., 2022; Loko et al., 2022) can pave the way for the development of new rice varieties with increased adoption rates. Hence, farmers' preferences hold great importance and should be thoroughly incorporated into the breeding strategy for developing new varieties.

Similarly, there is a growing need for a deeper comprehension of consumer preferences (Cuevas et al., 2016), which traditionally focused on specific production environments within countries (Custodio et al., 2023; Custodio et al., 2016; Sudha et al., 2013) but now demands a broader perspective considering the dynamic nature of the rice market. The rice value chain connects farmers to final consumers, including local traders, millers, wholesalers, retailers, and exporters, as well as the state-owned Food Corporation of India and the Public Distribution System (Dawe, 2012). Consumer preferences are influenced by various factors, including taste, price, variety, quality, brand reputation, and value addition, alongside crucial considerations such as the physical appearance of raw rice, grain slenderness, fragrance, and cooking quality (Bairagi et al., 2021; Custodio et al., 2019; Peterson-Wilhelm et al., 2022; Sultana et al., 2022). Regional preferences significantly influence marketability (Custodio et al., 2016), making them crucial for rice breeding strategies (Calingacion et al., 2014) in developing and promoting new rice varieties that consumers are more likely to adopt.

The widening gap between farmers' varietal choices and consumer preferences has an adverse impact on farmer income, as it wastes resources, time, and labour on developing varieties due to low adoption and low demand. There has been strong confirmation that insufficient priority has been bestowed on consumer-preferred traits by breeding programs, which is a major contributing factor to low varietal turnover and the adoption of modern varieties (Thiele et al., 2021). This shift in agricultural research towards market-oriented approaches, with evaluations based on societal impact and relevance (Bantilan and Keatinge, 2007; Sarewitz and Pielke Jr, 2007), underscores the importance of transitioning from supply-focused breeding to consumer-focused programs for the benefit of both farmers and consumers (Custodio et al., 2019; Custodio et al., 2016). To align public rice improvement programs with enhancing the rice value chain, research should focus on understanding market dynamics and integrating novel preference-matching concepts into breeding strategies (Custodio et al., 2023; Peterson-Wilhelm et al., 2022). Current policies should consider consumer preferences for long-term, sustainable production and improving farmers' livelihoods. Therefore, a systematic study addressing the challenges of aligning farmer and consumer preferences is necessary to inform policymakers and guide research priorities for TNAU. Thus, our model and analysis apply to real-world situations involving public rice research/ breeding programs.

In light of these challenges, we attempted a comprehensive investigation into farmers' preferences for TNAU (Public rice research) and non-TNAU rice varieties in the Cauvery Delta Zone (CDZ), evaluating them according to varietal traits preferred by farmers, as well as consumer preferences for unbranded rice *versus* branded rice, considering quality parameters and socio-economic conditions. Our objectives are to understand the specific market requirements for rice and to identify gaps that investment and research must fulfil to ensure the development and adoption of high-yielding varieties with quality traits required by the consumers. The specific objectives of the study are: (i) to examine the extent of adoption of TNAU and non-TNAU rice varieties by farmers (ii) to assess the varietal choice based on farmers' perception and adoption (iii) to examine the consumer's preferences for rice; and (iv) to suggest appropriate policies for reorienting research priorities to increase the market share of TNAU varieties.

II

CONCEPTUAL FRAMEWORK

Figure 1 illustrates the study's conceptual framework, highlighting how traditional rice breeding programs focus on maximising yield for specific ecosystems while often neglecting the preferences of both producers and consumers. Farmers

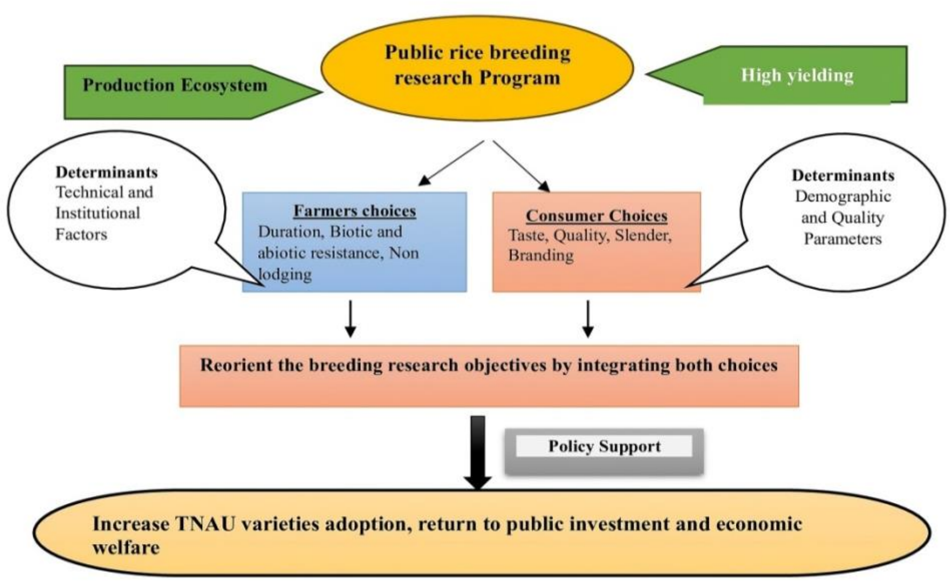

FIGURE 1. CONCEPTUAL FRAMEWORK

select rice varieties based on seed availability, growth duration, and stress resistance (Jin et al., 2020), while consumers prioritise taste, cooking quality, and grain characteristics (Custodio et al., 2019). This mismatch underscores the need to realign breeding objectives to meet the needs of both groups (Chinni et al., 2023). Additionally, socio-economic and institutional factors influence the adoption of variety. This study examines these preferences, evaluates their determinants, and suggests policy instruments to bridge the gap between production goals and market demands, ensuring that new rice varieties are both agronomically viable and commercially attractive. The findings will inform the development of breeding programs that align with the rice production and consumption landscape, thereby fostering greater adoption and economic benefits.

III

METHODOLOGY

2.1 Study Area

The Cauvery Delta Zone (CDZ) in Eastern Tamil Nadu, India, was purposefully selected for this study due to its significance in rice cultivation (Figure 2). CDZ is home to over 400 traditional rice varieties and spans seven districts, of which three districts (Thanjavur, Thiruvarur, Nagapattinam) cover 57 per cent of the CDZ's total area of 14.47 lakh hectares. Rice is a crucial staple, constituting 43 per cent of the total cultivated area in the region (Government of Tamil Nadu, 2021).

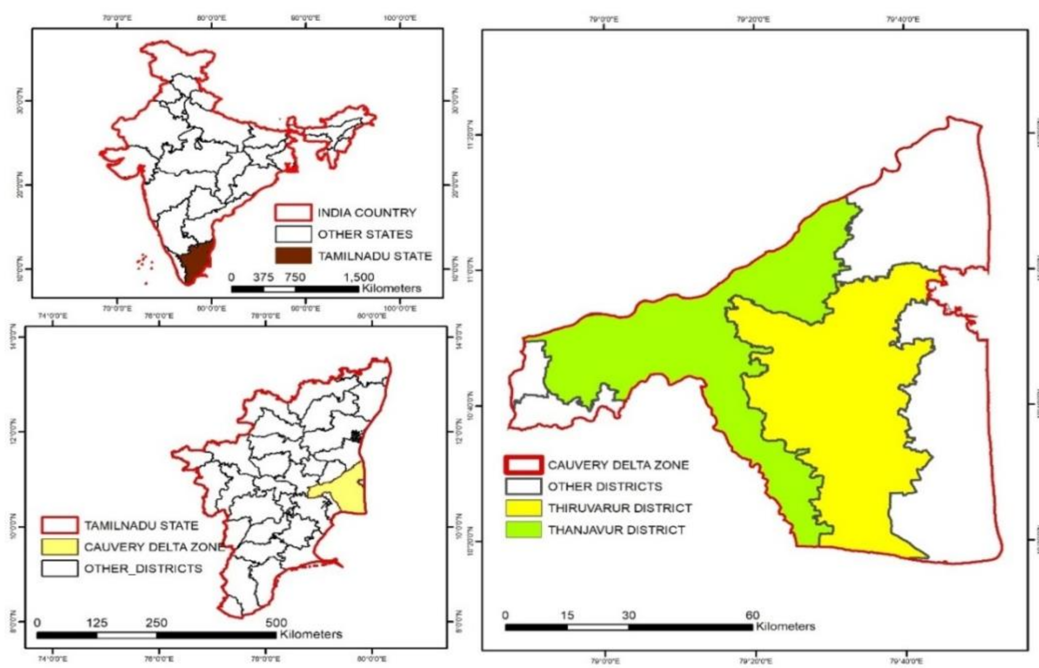

FIGURE 2. STUDY AREA MAP

2.2 Sampling

We employed stratified random sampling (Adenuga et al., 2016), beginning with the selection of Thanjavur and Thiruvarur districts due to their significant paddy cultivation (Figure 2). Next, two blocks were selected from each district, and two villages were chosen from each block. We sampled 22 farmers from each village, resulting in a total of 180 farmers. For the consumer survey, 22 respondents were selected from two municipal corporations and two rural panchayat villages in each district, totalling 180 consumers.

2.3 TNAU and non-TNAU rice varieties

On the production side, "TNAU varieties" include rice developed and released by TNAU and its research stations, with prefixes like CO[3], ADT[4], ASD[5], TRY[6], TKM[7] and TPS[8] denoting their origins. Some varieties, such as CR1009[9], CR1009 *sub1*[10], and IWP[11], are direct introductions released under their original names. "Non-TNAU varieties" refer to rice from other SAUs (e.g., BPT[12], NLR[13] and JGL[14]), ICAR (e.g., Swarna *Sub 1*[15]), IRRI (e.g., IR20[16]), and private companies. On the consumption side, preferences are categorised as (i) unbranded rice, including local or farm-grown varieties from both TNAU and non-TNAU sources, and (ii) branded rice, sold under registered brand names.

2.4 Data collection

We collected primary data in 2021-22 using a structured questionnaire to assess varietal preferences, adoption of different rice varieties, and consumer preferences. We also collected secondary data on net sown area and variety distribution from various published sources. Additionally, two Focus Group Discussions (FGDs) were held: one with 20 production stakeholders (rice scientists,

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[3]CO- Rice varieties were released by Tamil Nadu Agricultural University (TNAU), Coimbatore.
[4]ADT- Rice varieties were released by Tamil Nadu Rice Research Institute (TRRI), TNAU, Aduthurai
[5]ASD - Rice varieties were released by Rice Research Station, (RRS), TNAU, Ambasamudram
[6]TRY- Rice varieties were released by Anbil Dharmalingam Agricultural College and Research Institute, TNAU, Trichy.
[7]TKM- Rice varieties were released by Rice Research Station, TNAU, Tirurkuppam
[8]TPS - Agricultural Research Station, TNAU, Thirupathisaram
[9]CR1009 (IET 5897) – was released by TNAU as an introduction in Tamil Nadu in 1982 and subsequently as Savithri by CRRI in 1983 (from Robin et al., 2019)
[10]CR1009 Sub 1 variety, an improved version of CR1009 with the *Sub* 1 gene developed through Marker Assisted Selection (MAS) conferring submergence tolerance, was released by TNAU, Coimbatore.
[11]IWP – Improved White Ponni was released by TRRI, Aduthurai in 1989 through selection from White Ponni which was introduced in Malaysia
[12]BPT 5204 was released from the Agricultural Research Station, Bapatla under the administrative control of Acharya N G Ranga Agricultural University (ANGRAU), Andhra Pradesh.
[13] NLR 34449 was released by Agriculture Research Station, ANGRAU, Nellore.
[14]JGL – Regional Agricultural Research Station, Jagtial coming under Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad
[15]Swarna Sub 1 – Released by Orissa State Seed Sub- Committee on Crop Standards
[15]IR20 rice variety was released by IRRI, Phillippines.

extension officials, input dealers, and farmers) and another with 20 consumption stakeholders (traders, processors, wholesalers, retailers, and consumers) to examine preferences for unbranded and branded rice varieties.

2.5 Tools of Analysis

2.5.1 Rice Preference Index (RPI)

RPI evaluates farmers' preferences for specific rice varieties and consumer preferences for branded or unbranded rice (Sharma et al., 2017). Farmers ranked nine key parameters, including seed availability, crop duration, germination, pest resistance, yield, and drought tolerance. Consumers identified nine parameters, such as grain expansion, colour, price, cleanliness, and aroma. Respondents rated these parameters on a scale of 1 to 5, and stakeholders assigned weights to each. The weighted scores were calculated based on these ratings to determine the RPI for each rice variety, which was then ranked accordingly.

$$RPI = \frac{\sum_{k=1}^{m}\sum_{j=1}^{l}\sum_{i=1}^{n} w_{ij}X_{ijk}}{\sum_{k=1}^{m}} \quad \text{------------- (1)}$$

where, w_{ij}= the weight of the jth characteristic of the ith rice variety, X_{ijk}= farmers/consumer preference score assigned towards jth characteristic of ith rice variety by kth farmer/consumer, i=rice variety ranging from 1 to n, j=characteristic of rice variety ranging from 1 to l, k= number of respondent farmers \ consumers' ranking from 1 to m.

2.5.2 Regression Tree Approach

We used a regression tree approach (RTA) to analyse factors influencing farmers' preferences for rice varieties (Ran et al., 2018). This decision tree algorithm predicts a continuous outcome based on multiple input variables, effectively handling nonlinear relationships (Morgan and Sonquist, 1963). The method recursively partitions the dataset into subsets by selecting variables and split points that best segregate the data into homogeneous groups (Suvi et al., 2020). This process continues until a stopping criterion, such as the maximum tree depth or the minimum number of samples per leaf, is met. Splitting criteria generally aim to minimise mean squared error (MSE). RTA is nonparametric, accommodating both categorical and continuous variables, and it can manage missing data through surrogate splits (Han et al., 2019; Anderson et al., 1999; Feldesman, 2002). We constructed a decision tree regression model to predict the response rate as described in equation (2).

Y= f (EDU, HS, INCOME, EXP, ATE, FV, IRRIG, FPO, ATI) --------- (2)

Where Y refers to '1' if TNAU or '0' if non-TNAU varieties; *EDU* - education (Number of years studied in school); *HS* - household size; *INCOME* - annual family income (in Indian Rupees); *EXP* -experience (in years); *ATE* - access to extension (1-

if yes, 0 - no); *FV* -to frequency of extension visit; *IRRIG* - irrigation (1- irrigated, 0 - otherwise); *FPO* -FPO membership (1- yes, 0 - otherwise); *ATI* - access to inputs (1 - yes, 0 - otherwise). The classification and regression tree (CART) algorithms in IBM-SPSS Modeller 22 (Han et al., 2019) were used to develop a predictive model for farmers' preferences between TNAU and non-TNAU varieties, utilising a minimum of 30 parent nodes and five child nodes.

2.5.3 Determinants of Consumer Preferences: Probit Model

We used the probit model to analyse consumer preferences (Y), which takes the value one for unbranded and zero for branded rice (Ehiakpor et al., 2017). This model addresses the heteroskedasticity issue that invalidates Ordinary Least Square (OLS) estimates and aligns with the cumulative normal probability distribution assumption (Gujarati and Porter, 2009; Reardon et al., 2016). Probit analysis reveals how demographics influence consumption probability, with decisions based on utility (Z_i), which depends on several variables (X_i) such as income, age, price, market location, and rice attributes like aroma and cooking ease and calculated using equation (3).

$$Z_i = \beta_1 + \beta_2 X_i \quad \text{-------------------- (3)}$$

When, Z_i exceeds the threshold value assumed as Z_i^* the consumer prefers to purchase unbranded rice (local rice varieties/farm-grown rice) as they obtain maximum utility. Further, Z_i^* is assumed to be normally distributed with a constant mean and variance. The probability P_i of choosing an unbranded rice variety over branded rice varieties is given in (4).

$$Pr(Y = 1) = \int_{-\infty}^{x'\beta} \theta(t)\, dt\, \theta = \Phi\,(x'\beta) = \Phi\, Z_i^* \ldots\ldots\ldots (4)$$

Where,

$\Phi\,(x'\beta)$ is the cumulative density function; θ is the standard normal distribution; x' is a vector of the independent variable; β is a vector of coefficients; Z_i^* is the expected value of the latent variable

We derived the marginal effect[17] using the following equation (5) (Greene, 1999)

$$\frac{\partial p_i}{\partial x_{ik}} = \Phi(x_i'\beta)\beta_k \quad \text{-------------------- (5)}$$

[16]Marginal effects were computed for individual variables while maintaining other variables at their sample mean, providing insights into how independent variables influence consumer preferences for purchasing branded and unbranded rice varieties.

The empirical model used in the present study (Asante et al., 2013) is given in equation (7)

$$Y=\alpha+ \beta_1 AGE+ \beta_2 GENDER+ \beta_3 EDU+ \beta_4 HS+ \beta_5 INCOME+ \beta_6 MS + \beta_7 CLEAN+ \beta_8 AROMA+ \beta_9 EC+ \beta_{10} PRICE+ \beta_{11} MA \quad \text{--------}(7)$$

Where, AGE - respondent age (years); *GENDER* -'1' for male and '0' for female; EDU - formal education; HS - household size; *I*NCOME - Family income (INR/month); *MS* - marital status ('1' if married, '0' if unmarried); *CLEAN* - cleanliness of rice ('1' if yes, '0' no); *AROMA* - fragrance of rice ('1' if yes, '0' no); *EC* -Ease of cooking within 10 minutes ('1' if yes, '0' no); *PRICE* - market price of rice (INR/kg); *MA* - market access *i.e.* distance from household to market (Km). α, β_1 *to* β_{11} are the parameters to be estimated.

IV

RESULTS AND DISCUSSION

We presented the results of the spread and adoption of different rice varieties in the study area, along with the socio-economic factors influencing varietal choices, from the perspectives of both farmers and consumers.

4.1 Spread of rice varieties

Evaluating the adoption and dissemination of TNAU rice varieties over non-TNAU varieties is essential for harnessing the improved traits of these new varieties developed by TNAU. This assessment also plays a vital role in establishing research priorities for rice crop improvement programs. The spread of rice varieties assessed in different growing seasons in CDZ, *viz.,* Kuruvai[18], Samba[19], and Thaladi[20] (Yadav et al., 2014), is presented in Table 1. It was observed that a majority of farmers (90.56%) adopted TNAU varieties during the Kuruvai season. However, this adoption declined to 51.11 per cent in the Thaladi season and 75.56 per cent in the Samba season, with non-TNAU varieties replacing them.

The choice of rice varieties by farmers in the CDZ of Tamil Nadu is significantly influenced by the different growing seasons. Figures 3a to 3c illustrate the adoption of various rice varieties grown by farmers in the CDZ across different seasons. During the Kuruvai season (Figure 3a), 90.56 per cent of farmers grew short-duration TNAU varieties, with CO51, TPS5, and ASD16 making up 66.67 per cent. Farmers preferred TNAU varieties due to their higher yields, shorter duration,

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[18] This season coincides with the southwest monsoon season, typically starting in June and ending in September, cultivating short-duration varieties (115-120 days)

[19]. Farmers who skip the Kuruvai crop opt for the Samba season, which starts in the first week of August and ends in mid-January, cultivating long-duration varieties (150-160 days).

[20] Farmers who raise the Kuruvai crop often changeover to the Thaladi season, cultivating either short (115-120) or medium-duration (130-135 days) rice varieties from September-October to mid-January.

TABLE 1. SPREAD OF RICE VARIETIES IN THE CAUVERY DELTA ZONE

Seasons	TNAU varieties	Share (%)	Non-TNAU	Share (%)
Kuruvai	CO51; TPS5; ASD16; TKM 9; ADT37; ADT45; ADT43	90.56	Local landraces; Private varieties (Sadhana); Jyothi (Ptb 39)[21]	9.44
Samba	CR1009 *Sub 1*; ADT51; TRY3	75.56	CR1009; Swarna *Sub 1;* Local landraces	24.44
Thaladi (Late Samba)	ADT54; ADT39; ADT38; CO(R)50; ADT 46; TKM13; IWP	51.11	BPT5204; NLR34449; IR20; Private varieties like Akshaya, Karnataka Ponni, Uma (MO16)[22]	48.89

Source: Authors' Calculation (2021-2022)

and resistance to biotic and abiotic stresses, including blast, gall midge, hopper infestation, and drought. Approximately 9.44 per cent of farmers selected non-TNAU varieties, including local landraces, Jyothi, and private varieties such as Sadhana. During the Samba season, the largest area of rice cultivation was recorded, coinciding with the onset of the Northeast monsoon. Similar to Kuruvai, TNAU varieties dominated. Figure 3b shows that 60 per cent of farmers grew CR1009 Sub1 and ADT51, while 24 per cent opted for non-TNAU varieties, such as CR1009, Swarna Sub1, and local landraces. Unlike the flood-prone Samba season, the Thaladi season coincides with the Northeast monsoon and faces prolonged dry spells due to intermittent heavy rainfall (Barati et al., 2022; Yadav et al., 2014). This makes rice cultivation more vulnerable, resulting in a reduced cultivated area. Farmers adopt alternate wet/dry irrigation and cultivate varieties adapted to dry conditions to mitigate water stress during critical growth stages (Aryal et al., 2022; Barati et al., 2022; Ishfaq et al., 2020; Wei et al., 2022). During this season, 50 per cent of farmers preferred non-TNAU varieties, such as BPT 5204, NLR34449, IR20, Akshaya, Karnataka Ponni, and Uma.

[21] Jyothi (Ptb39) – Released in the year 1974 from Regional Agricultural Research Station, Kerala Agricultural University, Pattambi, Kerala

[22] Uma (MO16) - Released in the year 1998 from Rice Research Station, Kerala Agricultural University Kerala, Moncompu, Kerala

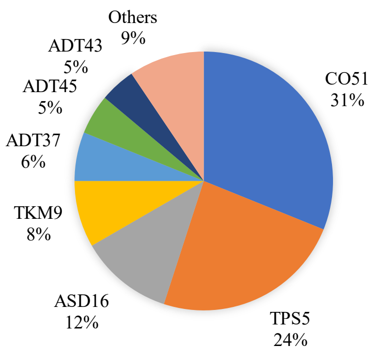

FIGURE 3A. KURUVAI SEASON

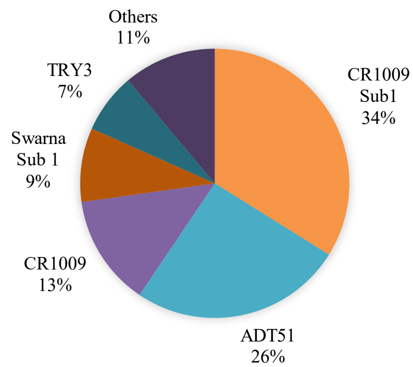

FIGURE 3B. SAMBA SEASON

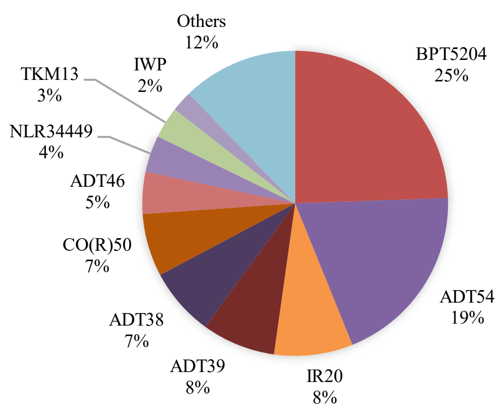

FIGURE 3. SPREAD OF RICE VARIETIES ACROSS DIFFERENT SEASONS

4.2 Consumer choices of rice brands and varieties

Consumer preference for rice varieties varied based on characteristics like aroma, ease of cooking, and whether the rice was raw or parboiled (Figure 4). Most consumers purchased branded rice, though identifying specific varieties is challenging due to packaging and polishing. Common non-TNAU varieties sold as branded rice include Ponni, Improved White Ponni, Karnataka Ponni, IR20, and Akshaya. About 52 per cent of consumers bought branded rice, with 35.5 per cent preferring

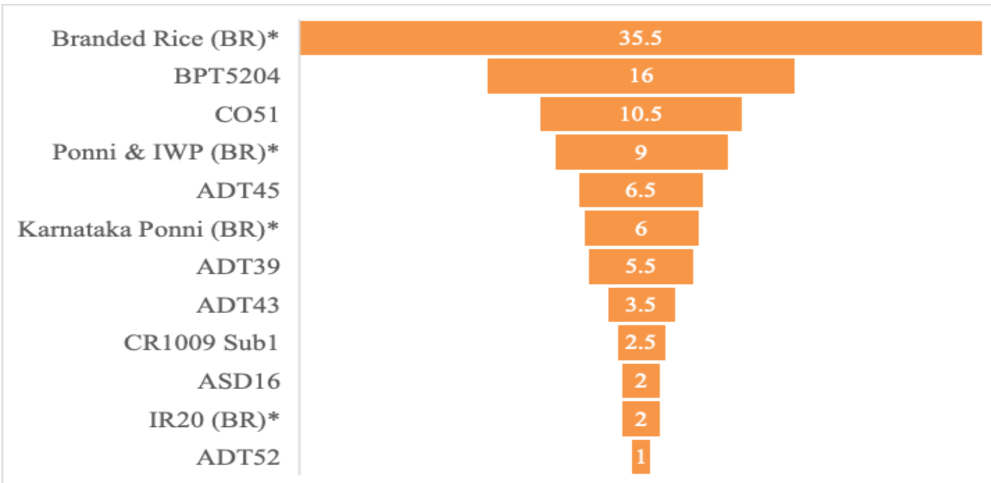

FIGURE 4. CONSUMERS' PREFERENCE FOR RICE VARIETIES
*BR- Branded Rice Category

brands like Vikkiravandi, Vinayaka, and Kitchen King. BPT 5204 was the most preferred unbranded rice (16%) (Reddy Lachagari et al., 2019) due to its palatability, high quality, taste, and grain colour, followed by TNAU varieties such as CO51 (10.5%) and ADT45 (6.5%). Consumers in rural areas favoured farm-grown TNAU varieties, such as ADT43, ADT39, and CO51, while CR1009 Sub1 and ASD16 were preferred for making idlis and snacks (Robin et al., 2019).

4.3 Rice Preference Index

Farmers' preferences for TNAU and non-TNAU rice varieties were evaluated using the Rice Preference Index (RPI), based on nine key traits provided by the State Agricultural University. Weighted scores were assigned to each trait, reflecting their importance in varietal adoption. The farmers' ratings were used to calculate the index, with results shown in Table 2. TNAU varieties scored higher than non-TNAU varieties in the Rice Preference Index, particularly for seed availability (43.92), high yield (51.18), and pest resistance (48.96). TNAU seeds were more accessible, and varieties like TKM16, ADT43, and CR1009 Sub1 showed better yields and resistance to pests, unlike BPT 5204. Similarly, TNAU varieties such as TKM16, ADT43, ADT38, and ADT46, which yield over six tonnes per hectare, are highly favoured by farmers due to their productivity, as demonstrated in multiple studies (Asante et al., 2013; Jin et al., 2020; Sharma et al., 2017). Many studies highlight that farmers prioritise resistance to biotic stresses (Suvi et al., 2020; Thant et al., 2020). TNAU varieties, such as ADT46, TKM13, and CR1009 Sub1, are pest-resistant, particularly against leaf hoppers and leaf folders, whereas varieties like BPT 5204 and private ones are more susceptible (Banumathy et al., 2016; Marimuthu et al., 2005; Singh and Singh, 2017). The overall score for TNAU varieties (351.68) reflected better adaptation to local conditions, with key differences in pest resistance, seed availability, and drought tolerance driving their higher adoption.

TABLE 2. PREFERENTIAL RANKING OF TNAU AND PRIVATE VARIETIES

Evaluation criteria	Weighted score	
	TNAU Varieties	Non-TNAU Varieties
Seed availability	43.92	34.84
Crop duration	34.73	35.27
Germination	30.43	29.76
Number of tillers	33.60	33.59
Pest and disease resistance	48.96	28.86
Milling Outturn	37.60	36.35
High yielding	51.18	49.36
Drought tolerance	39.74	32.58
Non-lodging and non-shattering	31.52	28.84
Total	351.68	309.45

Source: Authors' calculation (2021-22)

4.4 Consumer Preference Index

Consumer preferences for unbranded and branded rice were analysed using the Rice Preference Index (RPI) formula, focusing on various quality attributes. The unbranded category included 'local rice' and 'farm-grown varieties' from both TNAU and non-TNAU sources. The weighted scores for each parameter indicate their significance in purchasing decisions, as shown in the Consumer RPI results presented in Figure 5.

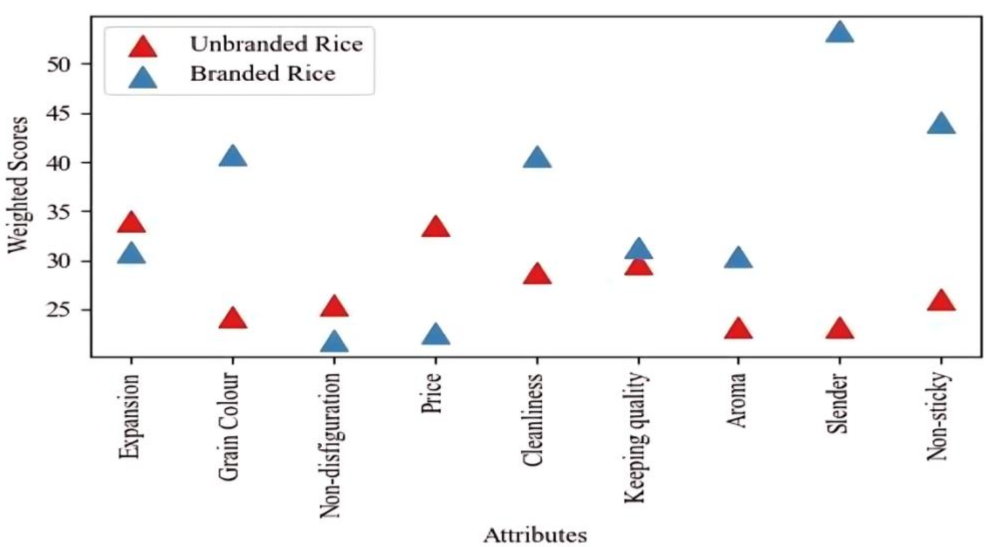

FIGURE 5. PREFERENTIAL RANKING OF BRANDED AND UNBRANDED RICE BY CONSUMERS
Source: Authors' calculation (2021-22)

Consumer preference ranking revealed that unbranded rice had a higher expansion rate (33.92) during cooking compared to branded rice (30.84), which influences consumer choice (Thant et al., 2020). However, branded rice achieved a superior white colour (40.72 vs. 24.2) due to better processing (Dharmalingam et al., 2021) and a higher RPI for non-disfiguration (25.43 vs. 21.76). Unbranded rice scored higher for price affordability (33.6), making it more accessible to budget-conscious consumers. In terms of cleanliness, branded rice scored higher (40.61 vs. 28.75) and showed fewer impurities (41.33). Branded rice also demonstrated better keeping quality and aroma. The survey indicated a preference for slender grains and non-stickiness in branded rice, meeting consumer expectations for colour, texture, and overall quality. Ultimately, 52 per cent of respondents favoured branded rice for its quality and availability, while 48 per cent preferred local varieties, such as BPT5204 and TNAU varieties, for their cost-effectiveness and suitability for meals and idlis.

4.5 Navigating the evolution of TNAU rice varieties and FGD Results

Farmers' preferences for rice varieties were analysed across short-duration, medium-duration, and long-duration categories, as shown in Figure 6. The analysis revealed seven short-duration, ten medium-duration, and five long-duration varieties predominantly grown by farmers. Among these, only four—TPS5, ADT54, TKM13, and CR1009 Sub1—were recently released cultivars (within the last ten years), while the others were released over a decade ago. Additionally, there is a mismatch between consumer preferences and the top-ranking varieties favoured by farmers, highlighting the need for more targeted research to develop rice varieties that meet the needs of both stakeholders.

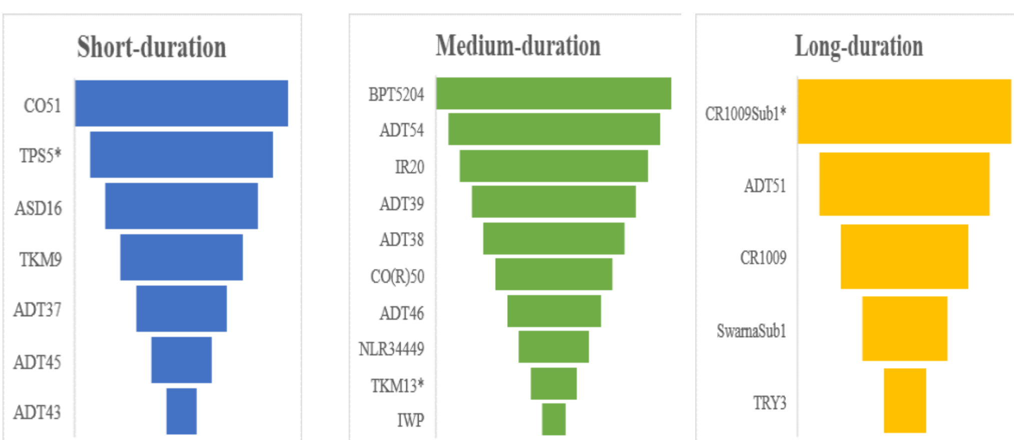

FIGURE 6. ORDER OF PREFERENCE OF DIFFERENT VARIETIES BY FARMERS (*LESS THAN 10 YEARS)

The survey and focus group discussions revealed distinct preferences for rice varieties among producers and consumers. Both groups favored CO51 and BPT5204, while ADT54, ADT39, ASD16, NLR34449, and ADT43 received moderate preference. However, some varieties, such as TPS5, ADT51, TKM13, and CR1009 Sub1, were highly preferred by farmers but not by consumers, while IWP and IR20 were consumer favourites not favoured by producers. Varieties such as ADT45, ADT46, CO(R)50, and Swarna Sub1 were unpopular with both groups. Notably, TPS5 covered 23.89 per cent of the Kuruvai season, ADT51 over 25.56 per cent during the Samba season, and ADT39 and ADT38 accounted for 7.78 per cent and 7.22 per cent, respectively, during the Thaladi season. This indicates the importance of these varieties for ongoing cultivation. While breeders aim to provide quality seeds of notified varieties annually, some may not be economically viable, suggesting a need for improvement or discontinuation of cultivation for certain varieties.

4.6 Farm-level determinants of adoption of rice varieties

To identify the determinants of TNAU variety adoption, we used a regression tree approach with a binary dependent variable indicating whether a farmer adopted a TNAU variety (1) or not (0). The Classification and Regression Tree (CART) method included nine determinants, with five significantly influencing farmers' preferences (Figure 7). Of the 180 surveyed farmers, 60.55 per cent preferred TNAU varieties while 39.55 per cent preferred non-TNAU varieties.

The decision tree begins by dividing farmers based on their farming experience: node 1 for those with less than 27.5 years and node 2 for those with more. Adoption rates increased with experience, aligning with findings by Joshi and Bauer (2006). Access to agricultural extension services was the second most influential factor, with a 70 per cent adoption rate for TNAU varieties (node 3), consistent with studies by Anang and Asante (2020), Cavite et al. (2022), and Emmanuel et al. (2016). Node 2 further divides based on the frequency of extension visits: node 5 for one visit and node 6 for more than one visit, showing that nearly 98.6 per cent of 80 farmers adopted TNAU varieties due to frequent visits from extension officials. Agri-input dealers also served as crucial sources of farm information (Node 8), providing timely inputs and credit (Dadabhau et al., 2015). Node 8 splits based on education level: up to 7th standard (Node 13) and above 7th standard (Node 14), indicating that higher education is associated with a greater adoption of TNAU varieties. The regression tree achieved a predictive accuracy of 96.3 per cent for TNAU preferences and 84.5 per cent for non-TNAU varieties, with an overall accuracy of 91.7 per cent, effectively predicting farmers' preferences for rice varieties.

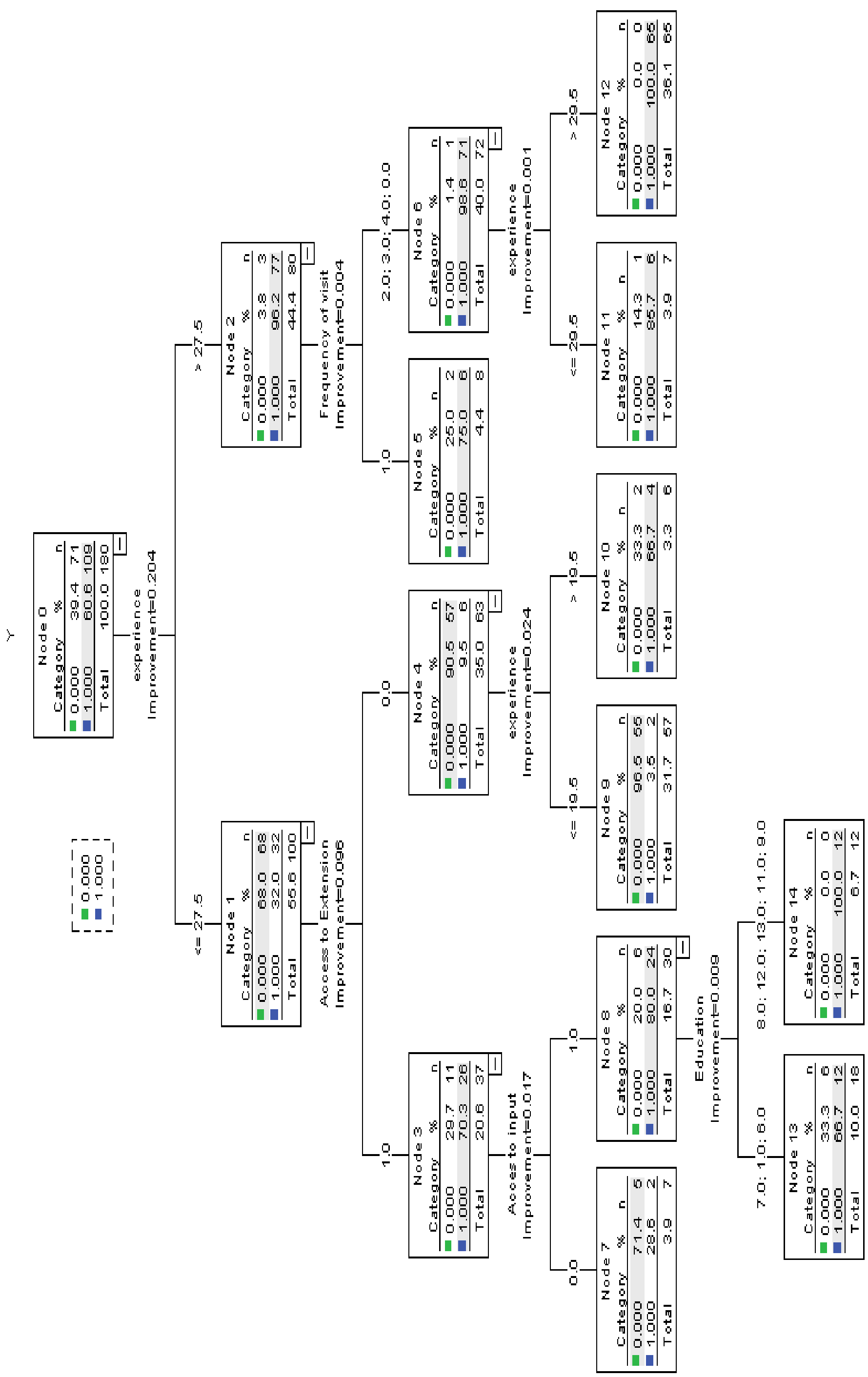

FIGURE 7. REGRESSION TREE ANALYSIS: DETERMINANTS OF FARMER'S PREFERENCE OF RICE VARIETIES

4.7 Determinants of consumer preferences for rice varieties: Probit regression results

We employed the probit model to analyse the determinants of consumer preferences for unbranded versus branded rice. The model demonstrated a good fit at a 1 per cent significance level (Table 4), with McFadden's Pseudo R^2 of 0.71, indicating that the independent variables explain a significant amount of variation in preferences. A positive correlation was found between age and preference for unbranded rice, especially TNAU varieties, with older consumers favouring options from farmers and local millers, while younger individuals preferred branded rice from retail outlets. This aligns with Afonso et al. (2017), who emphasised the impact of age on purchasing behaviour. Education showed a negative relationship with unbranded rice preference; less-educated consumers favoured local rice, while those with higher education preferred branded varieties. Household income was a significant factor, as lower-income households were more likely to purchase farm-grown rice, whereas higher-income households opted for branded rice (Cuevas et al., 2016; Rezai et al., 2011). Specifically, a Rs. 10,000 income increase correlated with a 9.1 per cent decrease in the likelihood of preferring unbranded rice.

TABLE 4. ESTIMATES OF PROBIT MODEL: DETERMINANTS OF CONSUMER PREFERENCE

Description	Coefficient	Std. Error	Z score	Marginal effect	Std. Error	Z Score
Age	0.024*	0.012	1.923	0.003*	0.001	2.018
Gender	-0.647	0.453	-1.430	-0.007	0.050	-1.453
Education	-0.086*	0.052	-1.669	-0.010*	0.006	-1.691
Household size	-0.067	0.110	-0.612	-0.008	0.012	-0.616
Income	-0.816***	0.238	-3.433	-0.091***	0.023	-3.949
Martial status	0.390	0.355	1.098	0.044	0.039	1.122
Cleanliness	-0.823**	0.377	-2.184	-0.092**	0.041	-2.246
Aroma	0.227	0.473	0.481	0.025	0.053	0.482
Ease of cooking	-2.203***	0.510	-4.323	-0.246***	0.043	-5.691
Price	0.136***	0.036	3.826	0.015***	0.003	4.675
Market Access	0.035	0.057	0.611	0.004	0.006	0.613
Constant	-1.079	0.960	-0.550	-		
LR Chi^2				178.193***		
Pseudo R^2	0.714			-		
Log-likelihood	-35.62			-		
N		180				

**** P<0.01; **P<0.05; * P<0.1.* Source: Authors' calculations, 2021-22

Price significantly influenced consumption behaviour, with consumers being price-sensitive. A 1 per cent increase in market price led to a 1.5 per cent decrease in the probability of consuming branded rice, particularly among lower-income and rural households, emphasising affordability concerns. This price sensitivity aligns with findings from Cuevas et al. (2016) and Rezai et al. (2013). Among the quality attributes, aroma significantly influenced consumer preference for rice varieties, with a marginal effect indicating that an increase in aroma raises preference probability by 2.5 per cent. Traditional and local rice varieties require longer cooking times compared to branded white rice (Abukari et al., 2019; Sudha et al., 2013). The ease of cooking, defined as shorter cooking time, is crucial, and our study found a negative significance: longer cooking times decrease the likelihood of consuming local varieties by 25 per cent. Additionally, cleanliness emerged as a key determinant, with buyers being 9.2 per cent less likely to consume unbranded local varieties due to concerns about cleanliness.

V
CONCLUSIONS AND POLICY IMPLICATIONS

Globally, the development of high-yielding, stress-tolerant rice varieties has doubled yields and increased production by 140 per cent (IRRI, 2020; FAO, 2021). While improved rice varieties are widely adopted in most Asian countries, their adoption is slower in Africa, Latin America, and some parts of Asia due to supply-driven development programs (Abebrese and Yeboah, 2020; Laborte et al., 2017). Access to preferred varieties is crucial for food security (Baroña-Edra, 2013; Custodio et al., 2016). For instance, South Korea's 'Tongil' hybrid rice was discontinued due to consumer preference issues (Choi et al., 2016; Kim and Sumner, 2005). To improve varietal adoption and the rice value chain, breeding approaches must prioritise consumer preferences and strengthen farmer-consumer linkages (Custodio et al., 2016; Demont and Ndour, 2015). Recognising that varietal attributes are vital for market intelligence, a global market segment analysis is necessary for targeting traits in breeding pipelines. The IRRI's 'OneRice' breeding program aims to develop demand-driven varieties through a unified breeding framework (Heredia et al., 2022). The successful promotion of NERICA (New Rice for Africa) hybrids highlights the importance of aligning breeding with consumer preferences, as farmers are willing to pay premium prices for these varieties (Britwum and Demont, 2021). International case studies show that tailoring varieties to specific regional preferences is replacing traditional landraces with improved options.

Field surveys and focus group discussions revealed the impact of the research on varietal preferences and the challenges of adoption. CR1009, a high-yielding variety introduced by TNAU in 1982, suffers up to 50 per cent losses due to flooding (Robin et al., 2019). In contrast, CR1009 Sub1, developed through marker-assisted selection, was enhanced with flood resistance, leading to its rapid adoption. Farmers using BPT5204 encountered longer harvest times, a lack of subsidies, and reliance on private seed suppliers. Its vulnerability to pests raised production costs, prompting evaluations of TNAU varieties, such as ADT39, CO52, and TKM13, as potential replacements. TKM13, suitable for both Thaladi and Samba seasons, offers broad-spectrum biotic resistance.

Our study examines the alignment between research priorities and the demands of farmers and consumers for rice varieties at Tamil Nadu Agricultural University (TNAU). During the Kuruvai and Samba seasons, about 91 per cent of farmers adopted TNAU varieties, while preferences were nearly equal between TNAU and non-TNAU varieties during the Thaladi season. Farmers prioritised traits like high yield, crop duration, and pest resistance, whereas consumers focused on grain quality, appearance, branding, and price. Key factors influencing the adoption of variety included farming experience and access to agricultural services for farmers, while age, income, market price, and cooking quality were significant factors in consumer purchasing decisions.

Based on the results, we propose the following recommendations for enhancing research priorities and the reach of public rice varieties:

1. **Assured Market**: TNAU rice varieties dominate the Kuruvai season, while CR1009 Sub1 and CO(R)50 are popular in the Samba/Thaladi season, primarily due to guaranteed markets from TNCSC's Direct Procurement Centres (DPCs). To improve access to preferred varieties and farmer livelihoods, DPCs should procure fine-grain TNAU varieties that have higher consumer preference, positively impacting adoption rates and profitability.
2. **Strengthen Seed and Supply Chain**: To compete with non-TNAU varieties like BPT5204, efforts should focus on enhancing the grain quality of TNAU varieties such as CO51, ADT39, ADT43, and TKM13. Improving timely access to TNAU seeds and inputs through initiatives like TNAU's
3. **Enhance Agricultural Extension Services**: The frequency of extension services has a significant impact on the adoption of TNAU varieties. Ensuring input availability alongside effective extension services, such as training and demonstrations, will enhance adoption rates. Timely information and advisory services are essential for promoting TNAU varieties.
4. **Importance of Branding**: Consumers often prefer branded rice due to better packaging and labelling. Investing in branding local varieties can help them compete with branded options, emphasising quality standards to stabilise the local market against global fluctuations.

In conclusion, rice breeding programs since the Green Revolution have focused mainly on yield and abiotic stress resistance, aligning with farmers' priorities. However, many TNAU varieties, even those released a decade ago, dominate fields, while some recent releases risk becoming obsolete due to a lack of preference from farmers and consumers. This underscores the need to reset breeding objectives. We advocate for participatory breeding that integrates feedback from farmers, supply chain actors, and consumers, emphasising preference-matching to develop rice varieties that address the needs of both groups amid climate change. Strengthening public-private partnerships and connecting farmers with Farmers' Producer Organisations can effectively meet future demands.

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APPENDICES

TABLE 1A. DESCRIPTIVE STATISTICS FOR FARMERS' PREFERENCE FOR REGRESSION TREE ANALYSIS

Variable	Variable Definition and Measurement	N	Mean	SD	Min	Max
Y	Y (1 if TNAU varieties were preferred, 0 if non-TNAU varieties were preferred)	180	0.61	0.49	0	1
Education	Education (Number of years spent in school)	180	5.89	4.18	0	16
HH Size	Household size (Number of household members)	180	3.66	1.63	1	8
Income	Income (Annual income of the farmer)	180	41119	20671	10000	176700
Experience	Experience (Farming Experience in years)	180	23.89	13.44	3	49
Access to Extension	Access to Extension (1- if yes, 0 - otherwise)	180	0.5	0.5	0	1
Frequency of visit	Frequency of visit (Number of times visited by the extension officials)	180	2.16	1.33	0	4
Source of Irrigation	Source of Irrigation (1- rainfed, 0 - otherwise)	180	0.69	0.92	0	11
Member of FPO	Members of FPO (1- yes, 0 - otherwise)	180	0.56	0.5	0	1
Access to input	Access to input (1 - yes, 0 - otherwise)	180	0.61	0.49	0	1

TABLE 2A. DESCRIPTIVE STATISTICS FOR CONSUMERS' PREFERENCE FOR PROBIT ANALYSIS

Variable	Variable Definition and Measurement	N	Mean	SD	Min	Max
Y	Represents consumer preference for rice varieties ('1' for unbranded rice (local / farm-grown rice and '0' for branded rice).	180	0.51	0.5	0	1
Age	Number of Years	180	41.98	13.78	17	80
Gender	Gender status of the household head ('1' for male and '0' for female)	180	0.66	0.47	0	1
Education	Number of Years spent in school	180	5.77	3.66	0	13
HH Size	Number of Household members	180	3.66	1.63	1	8
Income	Annual income of the farmer	180	4.05	1.43	2	8.71
Marital Status	0 Unmarried 1 Married	180	0.49	0.5	0	1
Cleanliness	Cleanliness status of rice while purchasing ('1' if yes, '0' otherwise)	180	0.47	0.5	0	1
Aroma	Aroma content/fragrance of rice ('1' if yes, '0' otherwise)	180	0.48	0.5	0	1
Ease of cooking	Ease of cooking within 10 minutes ('1' if yes, '0' otherwise)	180	0.52	0.5	0	1
Price	Market price of rice (Rs/kg)	180	40.46	7.62	19	59
Market Access	Distance from household to market (in Kilometers).	180	5.9	2.86	1	11