

Integrating traditional knowledge and field monitoring to assess insect pest tolerance in indigenous rice varieties of Wayanad, Kerala

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The traditional rice varieties are a crucial part of ecological farming practices in Wayanad, Kerala. The present study combined traditional knowledge with field monitoring to assess the insect pest tolerance of 49 traditional rice varieties in seven panchayats of northern Wayanad, Kerala, for five wet seasons (June to October) from 2019 to 2023. The measurement of pest density and abundance, along with parasitism, was used to calculate a composite Pest Index for each rice variety (0-1; higher values indicate lower tolerance), while farmer perceptions and traditional measures such as leaf strength, aroma, and recovery characteristics were collected through interviews (n = 203). Random Forest analysis revealed that lodging, maturity days, and grain yield were useful predictors of pest incidence (AUC = 0.91; OOB ≈ 8%). While *Jeerakasala*, *Mundon*, and *Gandhakasala* were found to be highly susceptible to pests, *Kanakam*, *Kayama*, *Kunjootti*, *Kunnunkulamban*, and *Marathondi* were found to be most tolerant to insect pests. In addition to the significance of preserving pest-tolerant varieties for sustainable and low-input rice cultivation, the strong agreement between farmer perceptions and results confirms the validity of traditional ecological knowledge.

Keywords: Folk taxonomy, Indigenous knowledge, Pest index, Rice pest, Traditional farming, Traditional rice

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Rice is a major food source for more than half of the world's population¹, and it is a staple crop in India², where it is a backbone of rural economies and a tradition for farmers there. Wayanad District in Kerala is known for preserving traditional rice varieties, which are believed to have greater natural resistance to pests than modern high-yielding varieties, particularly in low-input or organic agricultural settings³⁻⁵. Changes in market pressures and policies have led farmers towards high-yielding varieties, which, though they yield well under optimum conditions, rely on chemical protection for pests, thereby increasing costs as well as upsetting the natural balance^{6,7}. Experiences of traditional farmers, especially *Adivasis* in Wayanad⁸, reveal their precise understanding of stem hardness, leaf toughness, and natural pest tolerance, although these insights have not been scientifically validated.

In Wayanad, traditional rice varieties are cultivated by tribal and marginal farmers⁹, though studies on their insect pest tolerance are scarce and mostly based

on folklore rather than recent research³. Due to climate change and increasing pest challenges, identifying resilient crop varieties is essential^{3,10}.

In view of the above challenges, the study was conducted on the traditional rice varieties grown in northern Wayanad during the pesticide-free kharif periods. The aim of the study was: (1) documenting folk taxonomic knowledge on pest identification (2) estimating farmer perception on traditional characters of pest tolerance (3) estimating farmer perception on pest tolerance in traditional varieties of rice, and (4) estimating varietal variation in pest tolerance through a composite Pest Index (PI) (5 kharif seasons, 2019-2023).

The study promotes agro-ecological practices to enhance crop diversity and reduce pesticide reliance.

Materials and Methods

Study area

This study was conducted in the Wayanad district, Kerala (11.771° N, 75.842° E), which is part of a biodiversity-rich Western Ghats and traditionally known for its rice landraces. The landscape has low-lying valleys called *vayals*. Based on water availability, soil type, fertility, and topography,

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Kurichiya tribe classifies *vayals* into three groups: *Kunivayal* (gentle slope with moderate drainage), which includes drought-tolerant varieties like *Pal Thondi* and *Marathondi*; *Kunduvayal* (flat valley bottom with heavier soils, medium duration) which grows varieties such as *Gandhakasala*, *Jeerakasala*; *Koravuvayal* includes flooded (long duration, waterlogged condition) varieties like *Chettu Veliyan*, and *Mundon*⁹ (Fig. 1).

To minimize variation in climatic and soil factors, field surveys and pest assessments were conducted in the northern part of Wayanad, covering the traditional rice-farming Panchayats of Edavaka (11.7715° N, 75.9637° E), Mananthavady (11.8029° N, 76.0039° E), Panamaram (11.7402° N, 76.0731° E), Thavinjal (11.8488° N, 75.9521° E), Thirunelli (11.9081° N, 75.9971° E), Thondernadu (11.7710° N, 75.8418° E), and Vellamunda (11.7341° N, 75.9376° E). These areas were selected for their prevalence of indigenous rice cultivation, ecological uniformity, and accessibility for repeated seasonal observations (Fig. 2). Study sites within these panchayats were selected based on seed availability and the likelihood that farmers would cultivate the specified rice varieties.

Varietal selection and survey design

We surveyed 203 rice farmers in Wayanad, and the contact information was collected from the Farmer Address Book published by the M.S. Swaminathan Research Foundation and from biodiversity events. The surveyed farmers included 65 growers of traditional varieties, 92 of high-yielding varieties, and 46 of both, consisting of 26 tribal and 177 non-tribal families. Our survey aimed to reach tribal farmers through voluntary participation and informed consent.

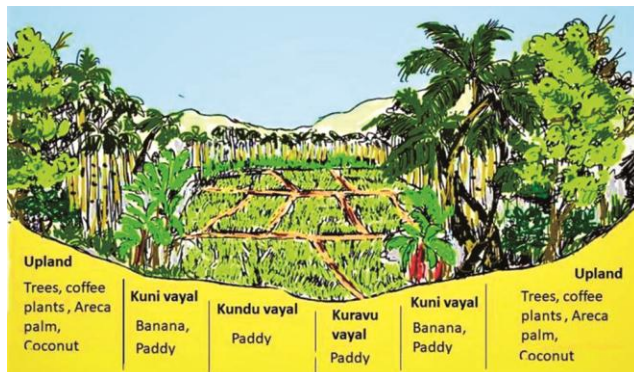


Fig. 1 — Paddy landscape of Wayanad, North Kerala (Adapted from Girijan *et al.*⁹)

Field experiments were conducted in pesticide-free areas across 19 locations in five kharif seasons from 2019 to 2023. We selected 49 traditional rice varieties based on recommendations from farmers. Each location had two to four plots (10 m × 2 m = 20 m²) with different varieties grown in natural conditions. Each variety had at least three independent locations and season observations.

Insect pest surveillance was done during the kharif season (July to October), with weekly observations during the vegetative, booting and ripening phases, when pest prevalence is at its peak. Data were collected through semi-structured interviews in Malayalam, along with participatory field observations. The interview questions included farmers' perceptions on pest tolerance, pest identification, and indicators of pest tolerance. Folk names of pests were recorded and validated against entomological references.

Information on traditional ecological knowledge (TEK) regarding pest tolerance was collected through focus group discussions, semi-structured interviews, and field walks. To ensure participatory validation, the farmer's observations on pest symptoms, varietal tolerance, lodging, and seasonal patterns of pest prevalence were compared with empirical pest field observations conducted at the exact locations. The

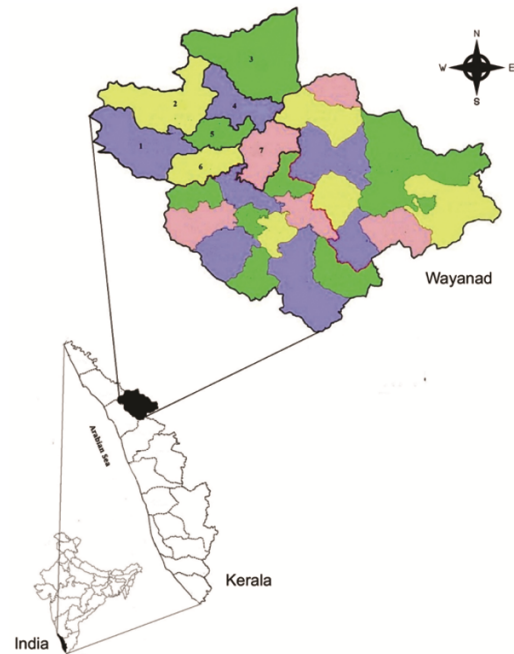


Fig. 2 — Panchayats selected for the sampling in traditional rice varieties of Wayanad, Kerala. 1-Thondernadu; 2- Thavinhal; 3- Thirunelli; 4- Mananthavady; 5- Edavaka; 6- Vellamunda; 7- Panamaram. Exact site locations are not shown to maintain farmer privacy and because specific sites varied slightly across years

reason for simultaneous observation of the fields was to determine the pest’s prevalence and identify it using pictorial guides and expert validation. The differences, if any, were addressed through village feedback sessions. The validated information was then used to integrate the TEK with pest monitoring.

Folk taxonomy and pest identification

Indigenous knowledge of rice insect pests was documented using a folk taxonomic approach, integrating visual elicitation and participatory interviews. High-resolution photographs assisted, farmers in identifying 23 common pest species, with descriptions of symptoms and vernacular names in Malayalam. Data were recorded verbatim and translated into English, resolving inconsistencies through follow-up validations with neighbouring farmers. Vernacular names were cross-referenced with scientific taxonomy through expert consultation and identification keys^{2,11}. Diagnostic traits, including leaf folding and larval morphology, were used for verification, confirmed against the ICAR-National Bureau of Agricultural Insect Resources database¹² and national checklists. Voucher specimens and representative photographs (Supplementary Fig. S1) were archived at the Insect Ecology & Ethology Laboratory, Department of Zoology, University of Calicut, for future reference.

Ethnobiological survey on pest tolerance in rice varieties

To assess pest tolerance among traditional rice cultivators in Wayanad, a qualitative ethnobiological study was incorporated into the field study. The study was conducted to collect information on the unique features of insect pest tolerance in traditional rice varieties.

Farmer perception of pest tolerance in traditional rice varieties

This study involved conducting interviews and group discussions with rice farmers to assess 62

traditional rice varieties for insect pest tolerance, grouping them as tolerant, non-tolerant, or unspecified. Specific agronomic characteristics, such as maturity days, grain yield, height, lodging, and aromatic traits (Supplementary Table S1), were also taken into account. The susceptibility of traditional varieties to major rice pests, such as *Leptocorisa oratorius* Fabricius (rice bug), *Cnaphalocrocis medinalis* Guenée (leaf folder), or *Scirpophaga incertulas* Walker (yellow stem borer) was also considered.

Pest monitoring protocol

The data collection process included visual observation of the incidence and severity levels of the pests on the 49 traditional rice varieties. Weekly data collections were done throughout the crop growth stage to determine the diversity and frequency of insect pests and their natural enemies. The parasitized and unparasitized caterpillars obtained from the rice field were maintained in a controlled laboratory setup at 28°C and 70 to 80% relative humidity to facilitate the possible emergence of parasitoids and adult insects.

The study used both qualitative observation and quantitative methods to assess varietal tolerance to pests in a field setting. The information was gathered using a structured observation method that included a questionnaire and a documentation method for systematic ranking. The criteria used for the quantitative method included three aspects: density, abundance, and parasitism rate. The criteria allowed the application of a composite index technique, which was similar to that used in the Important Value Index (IVI) in ecology¹³.

Each parameter was then measured as a proportion to enable comparison among rice varieties (Table 1). By combining measures of species diversity (density), population intensity (abundance), and natural

Table 1 — Pest Index (PI) formula and description of all elements

Index	Equation	Element description
Pest Density (D _i)	$D_i = (S_i / S_{total}) \times 100$	S _i = Number of pest species in variety <i>i</i> S _{total} = Total pest species recorded across all varieties
Pest Abundance (Ab _i)	$Ab_i = (\sum_s N_{i,s} / \sum_j \sum_s N_{j,s}) \times 100$	N _{i,s} = Number of individuals of pest species <i>s</i> in variety <i>i</i> $\sum_s N_{i,s}$ = Total pests in variety <i>i</i> $\sum_j \sum_s N_{j,s}$ = Total pests across all varieties
Parasitism (P _i)	$P_i = (\sum_s P_{i,s} / (\sum_s N_{i,s})) \times 100$	P _{i,s} = Number of parasitized individuals of species <i>s</i> in variety <i>i</i> $\sum_s N_{i,s}$ = Total pest individuals in variety <i>i</i>
Surviving Pest Pressure	100 - P _i	Represents remaining pest individuals not parasitized (higher value = higher pest pressure).
Final Pest Index (PI _i)	$PI_i = [D_i + Ab_i + (100 - P_i)] / 300$	Sum of three percentage-based pest pressure components. Dividing by 300 standardizes PI from 0 to 1, where: • PI → 0 = high tolerance / low pest impact • PI → 1 = low tolerance / high pest impact

suppression (parasitism), the Pest Index (PI) provides a biologically valid, multidimensional evaluation of pest tolerance. The PI represents a holistic concept of pest pressure and plant or ecosystem-assisted pest tolerance. Pest density indicates the number of pest species infesting each variety and thus the susceptibility of each variety to several pest species. Pest abundance is the actual number of pests that each variety supports, indicating the ability to regulate pest build-up.

Parasitism was added as a measure of natural biological control and functional tolerance. Since the parasitized pests do not add to crop damage or pest reproduction, the measure of the proportion of pests alive (unparasitized) can be used to approximate the measure of actual pest pressure. Thus, the methodology is biologically accurate, as parasitism is a major determinant of realized field tolerance and is influenced by a combination of plant attributes, such as herbivore-induced volatiles and secondary compounds, that attract parasitoids^{14,15}. In rice ecosystems, pest-parasitoid relationships have been widely observed^{16,17}. The three components of the PI were then standardized and combined to give a composite score normalized to range from 0 to 1. Higher scores on the scale reflect a lesser tolerance (or susceptibility), and vice versa.

Random forest model

The random forest classifier was employed to identify the most significant crop characteristics for predicting pest occurrence across various rice varieties. Six predictor variables were considered for the model: crop duration, grain yield (in kg per acre), straw yield (in kg per acre), plant height, lodging, and aroma. The performance of the classifier was gauged on multiple parameters. The confusion matrix helped to determine the sensitivity and specificity of the classifier. The receiver operating characteristic (ROC) curve and the area under the curve are used to assess the discriminant power of the classifier. The out-of-bag error estimate was used to assess whether the classifier was over fitting. The reproducibility of the classifier was found using ten-fold cross-validation, and the average accuracy of the classifier was calculated. The Mean Decrease Accuracy and Mean Decrease Gini values of the importance of the variables, calculated using the Random Forest classifier, assisted in finding the most important factors for the prediction of pest occurrence, as the Mean Decrease Accuracy values are directly related to the accuracy of the classifier and assist in finding

the most important parameters. The Mean Decrease Gini scores are supplementary and reported. The analysis was done using the Random Forest package¹⁸ in R software version 4.4.0.

Results and Discussion

Folk taxonomy and pest identification

The study records local folk name for various insect species, based on traits such as morphology, behaviour and ecological role. For example, “*Ila Churutti*” or “*Ila Madakki Puzhu*” for leaf-rolling insect larvae and beetles, “*Pulchaadi*” or “*Pacha Kuthira*” for grasshoppers, which denote their green colour and ability to jump. Others named “*Pattala Puzhu*” denote dark-coloured and abundant caterpillars found to be armyworms. Names given to stem borers include “*Thandu Thurappan*,” which translates to damage to stems, and “*Chaazhi*,” which denotes unfilled grains. The naming systems for the pests directly reflect their biological attributes and reflect the indigenous knowledge of species classification. More than 85% of local pest species have been identified scientifically, providing validation of the ability of local taxonomy to assist in the development of indigenous methods for managing pests^{19,20} (Supplementary Table S2).

Another important outcome of this study is the strong correspondence between folk pest classification and scientific identification. Farmers used colour, feeding behaviour, damage symptoms and movement patterns to differentiate insect pests. Detailed comparison between farmer-recognized (folk) and scientifically validated pest identities revealed strong correspondence. Out of 27 vernacular pest names documented from farmers, 23 could be accurately matched ($\approx 85\%$) with scientific taxa based on characteristic morphology, feeding behaviour, and crop damage symptoms. These correspondences are presented in Supplementary Table S3, which lists each local name alongside its verified scientific identity, diagnostic field traits, and supporting literature or expert confirmation^{2,4,19,21,22}. This alignment demonstrates the precision and reliability of farmer knowledge in pest recognition and its potential value for community-based pest surveillance.

Folk indicators of pest tolerance in traditional rice cultivation

Farmers assessed the pest tolerance of traditional rice varieties (Fig. 3) through experiential/visual/ecological methods. Long-term performance of rice varieties was

of utmost importance. Varieties known as *Edavaka* and *Marathondi* were consistently cited for their pest tolerance, owing to their consistent performance over different seasons. Direct observation of crop damage, if any, in the form of folded leaves, discoloured grains, or bored stems was another important method. *Chomala*, for example, was readily identified as being highly vulnerable to pest damage in these respects. The ability to recover from an attack is also worth noting, especially in *Veliyan* and *Aayiramkana*, which can tiller and grow back. Contrarily, the taller, more fragrant rice varieties, *Gandhakasala* and *Jeerakasala*, were found to be relatively vulnerable to stem borer attack. The most desirable agro-characteristic traits may therefore increase the susceptibility to pests.

The farmers reported that landraces such as *Thondi* and *Veliyan* showed tolerance to biotic and abiotic stresses, including drought and floods. Varietal adaptability is related to ecological factors:

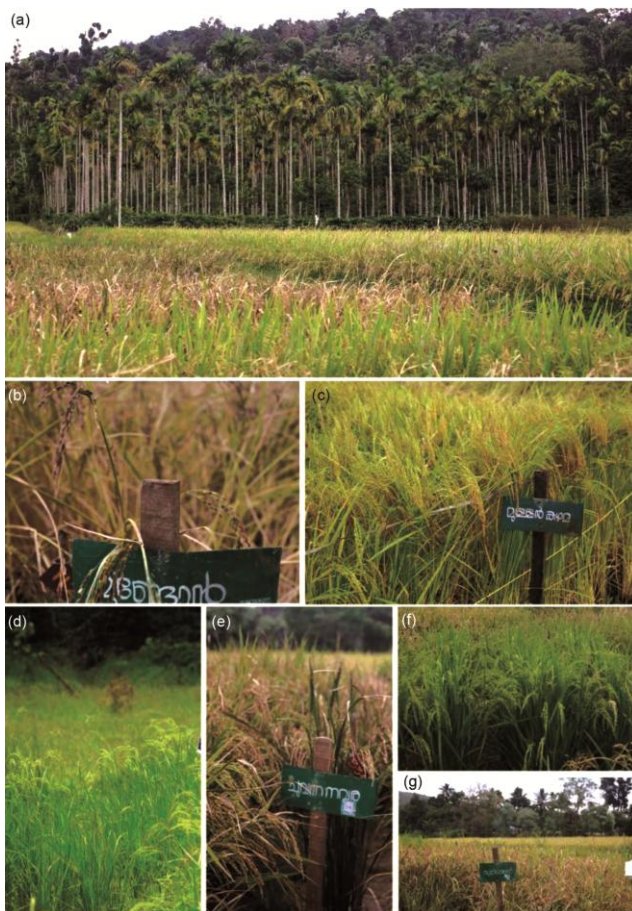


Fig. 3 — Traditional rice fields of Wayanad with indigenous rice varieties, (a) *Vayal*, (b) *Mundon*, (c) *Mullan Kayama*, (d) *Gandhakasala*, (e) *Chuvanna Njavara*, (f) *Jeerakasala*, (g) *Kalladiyaran*

Kalladiyaaran is drought-tolerant, while *Veliyan* is flood-tolerant. The farmers stated that plant height, deep root systems, tillering capacity, and leaf hardness are key factors associated with drought tolerance. Leaf colour is associated with pest tolerance; varieties with purple-coloured leaves, such as *Nasar bath* and *Kaalabathi* (Fig. 4 b & c), were more vulnerable to leaf folders and yellow hairy caterpillars. Other factors associated with pest tolerance include leaf glossiness, stem hardness, and the presence of natural insect enemies, such as spiders and ants, which act as natural pest control agents. Some varieties, such as *Kanakam* and *Velumbala*, were less preferred by pests even when grown together with preferred varieties. In addition, the farmers used traditional pest indicators, such as leaf folder damage and frass, to assess pest tolerance in specific rice varieties. This approach uses an integrated method that combines experience, physical signs, ecological information, and community feedback to measure pest tolerance in traditional rice varieties (Supplementary Table S4).



Fig. 4 — Traditional indicators of pest incidence, (a) farmers observing traditional indicators in *Gandhakasala* fields, (b) incidence of *Psalis pennatula* (yellow hairy caterpillar) in purple-coloured leaves of *Nasar bath*, (c) leaf folder infestations in purple-coloured leaves of *Kalabathi*

Farmer perception of pest tolerance in traditional rice varieties

Farmers in the study area knew of pest-tolerant traditional rice varieties, especially in pesticides free regions. Varieties like *Adukkkan*, *Edavaka*, *Kuruvatti*, *Chenthadi*, *Njavara*, and *Thondi* are reported to be pest-tolerant and possess desirable agronomic characteristics, including medium to long duration (120-180 days) and moderate to high yield potential (above 2500 kg per acre). Mainly, *Adukkkan* and *Njavara* (Fig. 5 a & b) can yield above 6000 kg per acre, which is ideal for low-input, ecologically sustainable agriculture.

Major pest-tolerant rice varieties in the study site are usually medium- to tall-cropping varieties, examples include *Valiya Chennellu* and *Velumbala*. Some tall varieties, such as *Kothandan* and *Marathondi*, are often susceptible to lodging, suggesting they have trade-offs in crop strength. These observations are in line with previous studies^{3,23} that documented a list of traditional varieties with pest- and disease-tolerance, including *Adukkkan*, *Chenthadi*, *Kodiyam*, *Mullanchanna*, *Pokkali*, and *Odachan*.

Most pest-tolerant traditional rice varieties studied were non-aromatic, indicating that farmers valued their tolerance and productivity over the grain's aroma when cultivated in regions where pests were a challenge. However, varieties like *Njavara*, which are tolerant to pests, have aromatic grain and possess medicinal properties, were highly prized. Conversely, some aromatic traditional varieties included in this category were also known to be susceptible to pests, including *Jeerakasala*, *Gandhakasala*, *Chomala*, *Kayama*, and *Kochuvithu*.

More than 60% of farmers who cultivated these varieties reported that their crops were susceptible to damage by leaf folders, stem borers, and rice bugs. One farmer said, “*We like Gandhakasala for its smell, but it is not resistant to pests; it is too risky without using insecticides.*”

Evidence provided by farmer experiences in rice fields indicates that most traditional varieties of improved yield, high straw yield, and adaptation to ecological farming are also tolerant to pests. The Kerala Agricultural University directory compiled the farmer perception of the characteristics of traditional rice varieties in Malayalam. Most of the traditional pest-tolerant varieties reported in the present study, including *Kanakam*, *Edavaka*, *Kavungin Poothali*, and *Chenthadi*, are also listed in the Kerala Agricultural University directory²⁴.

Key agronomic predictors of rice pest presence (Random Forest classification model)

The Random Forest classification model effectively predicted pest tolerance in traditional rice varieties, demonstrating high sensitivity and specificity between tolerant and susceptible rice varieties, as indicated by a confusion matrix. The ROC (Receiver Operating Characteristic) curve assessment revealed an area under the curve (AUC) of 0.91, which reflects an outstanding discriminative power. The model exhibited a low average out-of-bag error rate of less than 8%, thus indicating good classification accuracy. Meanwhile, tenfold cross-validation yielded an average classification accuracy of 88%, indicating that the model is highly reliable.



Fig. 5 — High grain yielding traditional rice varieties, (a) *Adukkkan*, (b) *Karutha Njavara*

The variable-importance analysis identified lodging, crop duration, and grain yield as the main variables influencing pest infestation. The mean decrease accuracy (MDA) indices for these variables were 4.07, 2.52, and 2.26, respectively. Lodging contributes to increased canopy humidity and reduced airflow, creating favourable microclimatic conditions for pests²¹. Rice varieties with longer growing periods face greater cumulative damage from successive pest generations, while very short-duration varieties can avoid peak pest activity windows^{21,22}. Mean decrease Gini (MDG) values, reflecting the structural importance within decision trees, were highest for grain yield (3.67) and straw yield (3.66), indicating their frequent use as split variables during model construction, but not necessarily indicating the highest predictive accuracy. The negative MDA values recorded for plant height terms indicate that the inclusion of these variables marginally reduces prediction accuracy, and hence that they contribute little to the discrimination of pest tolerance (Table 2).

Random forest analysis thus provides empirical support for farmers' observations through the quantification of the relationship between key agronomic traits and pest incidence. The integration of validated TEK with multi-season field data and machine learning analysis provides a replicable, data-driven approach for identifying pest-tolerant landraces.

Comparison of Pest Index with farmer-perceived pest tolerance

Traditional rice varieties were evaluated for their pest tolerance using a Pest Index (PI) shown in Table 3. This PI placed them into three groups: those with high tolerance ($PI \leq 0.20$), medium tolerance (0.21 to 0.50), and low tolerance ($PI > 0.50$). Among these, *Kanakam*, *Kayama*, *Kunjootti*, *Kunkumasali*, *Kunnumkulamban*, *Marathondi*,

Onachanna, *Pal Kayama*, *Raktasali*, and *Thondi* scored high in pest tolerance, with PI values ranging from 0.0040 to 0.0175. Even though these varieties showed strong tolerance in the field, farmers might not have paid much attention to them or might have considered them generally tolerant without specifying the extent of tolerance. In the study, *Velumbala* and *Chennellu*, chosen by farmers for their pest tolerance, showed strong tolerance. *Velumbala* had a PI of 0.0240, indicating high tolerance. Meanwhile, *Chennellu*'s PI was 0.2180, placing it in the medium tolerance category. Farmers also noted that *Chenthadi* showed high pest tolerance, with a PI score of 0.2450, which is in the medium range.

There were some discrepancies between farmer perception and field data on pest tolerance. Farmers reported that *Adukkkan* was tolerant, which matched its high tolerance levels observed in the field. Contrarily, farmers also considered *Kothandan*, and *Njavara* to be tolerant, but these varieties showed only medium tolerance when tested. This suggests that farmers might base their judgments on factors beyond just pest damage, perhaps considering how well crops recover after damage or certain grain qualities. Meanwhile, *Kayama* and *Kunjootti* were not seen as tolerant or were left unspecified by farmers. However, their low PI values of 0.0060 and 0.0070 suggest they are actually quite tolerant to pests. This difference indicates that past experiences with pests and visible crop symptoms can strongly influence how farmers assess crop tolerance. For example, farmers view *Veliyan* as tolerant to pests, especially against yellow stem borer, leaf folder, and rice bug. However, Pest Index ($PI = 0.3250$) classifies it as moderately susceptible, which seems contradictory. Farmers reported that *Veliyan* recovers quickly after a pest infestation, keeping yields consistent. Field observations showed that *Veliyan* deals with pest issues just like other varieties do. However, *Veliyan*'s strong stem and capacity to grow new tillers help reduce yield loss. This distinction explains why farmers assess it differently from what empirical PI data suggests (refer to Table 3).

Different rice varieties exhibit a wide range of pest tolerance in the field. *Kunnumkulamban* (0.0090) and *Kunkumasali* (0.0085) exhibited high tolerance levels. In addition, varieties, such as *Onamottan* (0.1500) and *Chennel Thondi* (0.1900), are nearly at the threshold for pest tolerance. There are also varieties with moderate tolerance, such as *Thonnuram Punja* (0.2100) and *Okka Veliyan* (0.2850), which farmers

Table 2 — Variable importance measures from Random Forest classification of pest incidence across traditional rice varieties. The Mean Decrease Accuracy (MDA) values were used as the primary ranking criterion, with higher MDA values indicating greater predictive significance. The Mean Decrease Gini (MDG) values indicate the relative importance of the variables in the model.

Variable	Mean Decrease Accuracy (MDA)	Mean Decrease Gini (MDG)
Lodging (Yes)	4.07	0.97
Height. L	-2.55	0.84
Height. Q	-2.71	—
Grain Yield (Kg/Acre)	2.26	3.67
Straw Yield (Kg/Acre)	-0.69	3.66
Crop Duration	2.52	2.57

did not mention. Some rice varieties do not stand up well to pests. For example, *Valichoori* (0.6000), *Mundon* (0.7100), *Jeerakasala* (0.7300), and *Gandhakasala* (0.7800) all have pest tolerance indices

above 0.50, which align with farmers' reports. This study shows how important it is to consider both farmers' opinions and field-based pest indices when evaluating pest-tolerant rice varieties.

Table 3 — Ranking and grouping of pest tolerance of traditional rice varieties based on Pest Index (PI). Lower PI values indicate higher pest tolerance. Farmer-perceived tolerance (based on interviews) and empirical PI-based classifications are shown separately to highlight areas of agreement or difference. PI categories: High tolerance (≤ 0.20), Medium tolerance (0.21 to 0.50), Low tolerance (> 0.50).

Sl. No.	Rice variety	Pest index (PI)	Empirical category (based on PI)	Farmer-perceived tolerance	Concordance (Agree / Differ)
1	<i>Kanakam</i>	0.0040	High	Yes	Agree
2	<i>Kayama</i>	0.0060	High	Unspecified	—
3	<i>Kunjootti</i>	0.0070	High	No	Differ
4	<i>Kunkumasali</i>	0.0085	High	Unspecified	—
5	<i>Kunnumkulamban</i>	0.0090	High	Unspecified	—
6	<i>Marathondi</i>	0.0100	High	Yes	Agree
7	<i>Onachanna</i>	0.0125	High	Unspecified	—
8	<i>Pal Kayama</i>	0.0140	High	Unspecified	—
9	<i>Raktasali</i>	0.0150	High	Unspecified	—
10	<i>Thondi</i>	0.0175	High	Yes	Agree
11	<i>Thonnuran Thondi</i>	0.0190	High	Unspecified	—
12	<i>Uruthi Kayama</i>	0.0215	High	Unspecified	—
13	<i>Velumbala</i>	0.0240	High	Yes	Agree
14	<i>Koduveliyar</i>	0.0900	High	Unspecified	—
15	<i>Kalladiyayan</i>	0.1000	High	Unspecified	—
16	<i>Vethandam</i>	0.1120	High	Unspecified	—
17	<i>OkkanPunja</i>	0.1250	High	Unspecified	—
18	<i>Adukkam</i>	0.1300	High	Yes	Agree
19	<i>Chuvanna Njavara</i>	0.1380	High	Unspecified	—
20	<i>Kovumbali</i>	0.1450	High	Unspecified	—
21	<i>Onamottan</i>	0.1500	High	Unspecified	—
22	<i>Velli Muthu</i>	0.1580	High	Unspecified	—
23	<i>Kothambari Kayama</i>	0.1620	High	Unspecified	—
24	<i>Kuruva</i>	0.1700	High	Unspecified	—
25	<i>Chembakam</i>	0.1820	High	Unspecified	—
26	<i>Chennel Thondi</i>	0.1900	High	Unspecified	—
27	<i>Pal Thondi (Vella)</i>	0.1950	High	No	Differ
28	<i>Thonnuram Punja</i>	0.2100	Medium	Unspecified	—
29	<i>Chennellu</i>	0.2180	Medium	Yes	Agree
30	<i>Kunjikayama</i>	0.2250	Medium	Unspecified	—
31	<i>Karimbala</i>	0.2320	Medium	Unspecified	—
32	<i>Karanjan</i>	0.2380	Medium	Unspecified	—
33	<i>Chenthadi</i>	0.2450	Medium	Yes	Agree
34	<i>Punnaadan Thondi</i>	0.2480	Medium	Unspecified	—
35	<i>Nasar bath</i>	0.2600	Medium	No	Differ
36	<i>Pal Thondi (Matta)</i>	0.2650	Medium	No	Differ
37	<i>Okka Veliyan</i>	0.2850	Medium	Unspecified	—
38	<i>Kanni Chennellu</i>	0.2950	Medium	Unspecified	—
39	<i>Kothandan</i>	0.3050	Medium	Yes	Differ
40	<i>Chettu Veliyan</i>	0.3080	Medium	Unspecified	—
41	<i>Veliyan</i>	0.3150	Medium	Yes*	Partially Agree †
42	<i>Chomala</i>	0.3250	Medium	Yes	Differ
43	<i>Njavara</i>	0.3350	Medium	Yes	Differ
44	<i>Thavalakamma</i>	0.3600	Medium	Unspecified	—
45	<i>Pal Veliyan</i>	0.4150	Medium	Unspecified	—
46	<i>Valichoori</i>	0.6000	Low	No	Agree
47	<i>Mundon</i>	0.7100	Low	Yes	Differ
48	<i>Jeerakasala</i>	0.7300	Low	No	Agree
49	<i>Gandhakasala</i>	0.7800	Low	No	Agree

† *Veliyan* is perceived as tolerant by farmers but ranks as moderate by PI due to measurable pest incidence despite strong recovery capacity

In addition, the study examined how frequently the pests *Cnaphalocrocis medinalis* and *Scirpophaga incertulas* appeared across five kharif seasons from 2019 to 2023. It was observed that pest abundance was much higher in years with more rainfall, such as 2019 and 2021. On the other hand, pest activity went down in drier years, such as 2020 and 2022. Even though there were these ups and downs each season, the ranking of rice varieties that could handle pests did not change. This suggests that their tolerance comes from the varieties themselves, not from changing seasons. This finding matches what has been observed in traditional rice-growing areas, where pest-tolerant varieties usually perform well regardless of how much rain falls during the monsoon season of Kerala^{2,3}. In earlier work, Gopi and Manjula³ documented a range of local cultivars, such as *Thekkan Cheera*, *Thekkan*, and *Karindon*, that resist pests under organic or low-input farming. Now, the present study confirms similar tolerance in *Marathondi*, *Thondi*, and *Adukkkan*. Furthermore, it provides new evidence of pest tolerance in varieties such as *Kanakam*, *Kayama*, and *Kunjootti*, which have not been previously validated.

Hence, this study examines how farmers' opinions align with scientific validation in assessing pest tolerance. Farmers provide field-based experience, whereas composite pest indices provide precise scientific data on pest tolerance. Sometimes, farmers might not always remember things correctly or could mistake one thing for another. To address this challenge, the study combines farmers' perspectives with practical approaches, including in-person field visits and discussions with specialists.

Traditional farmers in Wayanad have cultivated indigenous rice varieties with varying levels of pest tolerance through their long-standing farming practices. Combining this local wisdom with modern tools in this study, such as Random Forests, help pinpoint which rice varieties are pest-tolerant. Moreover, it is essential to conserve these traditional rice varieties for both ecological and cultural reasons. Thus, robust pest management strategies are essential in a climate change scenario.

Conclusion

The study scientifically validated the insect pest tolerance in 49 traditional rice varieties. Using ecological indicators such as leaf damage and plant recovery, folk taxonomy is consistent with scientific

methodologies for identifying pest tolerance. Important variables that affect pest populations are identified via Random Forest analysis, including lodging and yield. The 'Composite Pest Index' confirms the high pest tolerance of native rice cultivars such as *Kanakam* and *Marathondi*, validating farmers' observations. We developed a solid strategy to identify pest-tolerant rice varieties for sustainable farming by combining scientific methodologies with field experience.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at [https://nopr.niscpr.res.in/jinfo/ijtk/IJTK_25\(2\)\(2026\)160-169_SupplData.pdf](https://nopr.niscpr.res.in/jinfo/ijtk/IJTK_25(2)(2026)160-169_SupplData.pdf)

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Author Contributions

The first author collected the data and wrote the manuscript. The second and third authors designed study and edited the manuscript.

Conflict of Interest

The authors have no conflicts of interest.

Ethics Statement

The traditional knowledge was handled with utmost respect during documentation. This was done to ensure the representation was accurate without disclosing anything sacred or proprietary.

Informed Consent

The participant farmers were informed about the objectives of this study in advance; participation in this study was voluntary, and all personal information provided was anonymized.

Data Availability

Data available to support the conclusions drawn from this study can be accessed from the corresponding author upon reasonable request.

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