The Indian Journal of Agricultural Sciences 96 (6): 797–803, June 2026/Article
https://doi.org/10.56093/ijas.v96i6.156938

Assessment on therapeutic value and diversity analysis in traditional rice (*Oryza sativa*) landraces of Tamil Nadu

K AMUDHA[1]*, L D ANANDALEKSHMI[2], G ARIHARASUTHARSAN[3] and D UMA[2]

Agricultural Research Station (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Bhavanisagar, Erode, Tamil Nadu 638 451, India

Received: 21 September 2024; Accepted: 02 June 2026

ABSTRACT

The potential health benefits of pigmented rice (*Oryza sativa* L.) landraces are creating interest among researchers towards the biochemical profiling of landraces for therapeutic trait improvement. The field experiment was conducted during rainy (*kharif*) season of 2022 and 2023 at Agricultural Research Station, Bhavanisagar, Erode, Tamil Nadu to assess flowering pattern and yield of landraces, and lab experiment at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu to analyse bioactive compounds and antioxidant activity in 44 rice landraces of Tamil Nadu along with high yielding varieties as checks. Metabolite profiling had shown that the black rice genotypes Burma Black (Total phenol content- 1,336.83 mg GAE/100 g DW; total flavonoid content- 256.15 mg QE/100 g; total anthocyanin content- 129.91 mg CE/100 g DW, and antioxidant activity 2,894.47 µgTE/g), Kavuni (Total flavonoid content- 291.77 mg QE/100 g) and Chitthan Samba (Total anthocyanin content- 158.49 mg CE/100 g DW; antioxidant activity 3,693.32 µgTE/g) were enriched with various bioactive compounds analysed and antioxidant activity, therefore can be used as potential genotypes for therapeutic rice improvement. Diversity analysis has grouped the landraces into five clusters with majority of genotypes falling into Cluster I. Highest intra-cluster distance was shown by Cluster V (24.92) whereas the highest inter-cluster distance was exhibited between Clusters I and II (88.77). Hence, hybridisation between genotypes in these clusters enhances the chances of obtaining transgressive segregants in the segregating generations.

Keywords: Antioxidants, Anthocyanin, Diversity analysis, Flavonoids, Phenols, Rice landraces

Rice (*Oryza sativa* L.) is the staple food for four million people globally accounting for 21% of human per capita energy (Mishra *et al.* 2022). Traditional landraces besides being the richest source of carbohydrate possess several nutritional and therapeutic compounds (Verma and Srivastav 2017). According to clinical studies, the grains of pigmented landraces were more effective against the control of non-communicable diseases. Black rice kernels are due to the presence of anthocyanins which is water soluble pigment classified under flavonoids in phenolic compounds while red rice kernels are due to proanthocyanidins which is condensed tannins produced as an end product of flavonoid biosynthetic pathway. Both these compounds have health promoting properties and antioxidant activity (Zhong *et al.* 2023).

In recent years, consumers are showing interest in consumption of pigmented landraces due to the widespread occurrence of cardiovascular diseases, obesity, diabetes and cancer caused due to oxidative stress resulting from an unhealthy lifestyle and work pressure. So its cultivation is gaining momentum among farmers. Consequently, researchers are focussing on the characterisation of landraces, indigenous to their region for therapeutic trait improvement in rice. In Tamil Nadu, 400 indigenous cultivars comprising of both pigmented and non-pigmented rice landraces had been in cultivation in older days (Amudha *et al.* 2023). But due to green revolution, many of them went out of cultivation. Landraces inspite of its uniqueness, are poor yielders and has to be genetically improved for exploitation against the health issues of the mankind for whom rice is a staple food. For the successful genetic improvement of any trait existence of genetic diversity among the genetic material is essential as it aids in both the retention and exploitation of desirable variation and selection of appropriate parents for breeding programmes. With this background, the current research was undertaken to characterise and explore the genetic divergence for therapeutic traits among the rice landraces of Tamil Nadu for harnessing its genetic potential.

[1]Agricultural Research Station (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Bhavanisagar, Erode, Tamil Nadu; [2]Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu; [3]Agricultural College and Research Institute (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Madurai, Tamil Nadu. *Corresponding author email: amudhakpbg@tnau.ac.in

MATERIALS AND METHODS

Field evaluation: The field trials were conducted during the rainy (*kharif*) season of 2022 and 2023 at Agricultural Research Station (11°29´N, 77°80´E; at an elevation of 256 m amsl), Bhavanisagar, Erode, Tamil Nadu. The genetic material used in the present study comprised of 44 landraces (Table 1) and three checks which are popular rice varieties representing different duration groups in rice. All these experimental materials were raised in randomised block design (RBD) with two replications. Each landrace and check was planted in two rows with a row length of 3 m. Days to 50% flowering for each genotype was recorded on plot basis. At physiological maturity in each genotype, 10 plants were tagged randomly for recording plant yield.

Biochemical profiling of landraces: Rice grains of the 44 landraces and three checks used in the present study were dried to optimum moisture content and dehusked using a satake dehusker. The dehusked rice samples were powdered using mortar and pestle and used for analysis as the landraces are consumed without polishing (Suganthi *et al.* 2025). Biochemical analysis of the genotypes under investigation was carried out at Department of Biochemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu in two replications for the two consecutive seasons of *kharif* 2022 and 2023.

Total phenolic content (TPC): It was estimated according to procedure outlined by Singleton and Rossi (1965) wherein Folin Ciocalteu reagent (0.5 mL) was made to react with crude ethanolic extract of the rice samples (0.2 mL) followed by an incubation and neutralisation with 20% of Na_2Co_3 (1 mL). Spectrometric readings were taken at 640 nm and TPC of the genotypes was expressed in mg of Gallic acid equivalent (GAE)/100 g of rice on dry weight (DW) basis.

Total flavonoid content (TFC): Flavonoid content was analysed as per Woisky and Salatino (1998) method with slight modifications. To methanolic extract of rice sample (0.2 mL), distilled water (2.9 mL), methanol (1.5 mL), 1% aluminium chloride (0.1 mL), and 1 M potassium acetate (0.1 mL) were added with vigorous shaking followed by an incubation for 20–30 min. TFC sample readings were measured at 410 nm and TFC of the genotypes was expressed in mg of quercetin equivalent per 100 grams (mg QE/100 g) of sample.

Table 1 List of genotypes used in the present investigation

S.No.	Genotype	Kernel colour	S.No.	Genotype	Kernel colour
1.	Sarapilli Samba	Red	25.	Arcot Kichalli	White
2.	Manavari	Red	26.	ManjaPonni	White
3.	Panamara Samba	White	27.	Illumpam Poo Samba	Red
4.	Senthooram	White	28.	Aruvatham Kuruvai	Red
5.	Channangi	White	29.	MilaguSamba	White
6.	Sembarai	Red	30.	Vasanai Seeraga Samba	Red
7.	Varigarudan Samba	White	31.	Kuzhiyadichan	Red
8.	Pamani Samba	White	32	Thulasi Vasanai Samba	White
9.	Uppumolagi	White	33.	Thengai Poo Samba	White
10.	Katta Samba	White	34.	Chinna Adukku Nell	Red
11.	Karthigai Samba	White	35.	Kaviya Samba	White
12.	Muthuvellai	Red	36.	Norungan	Red
13.	Chetty samba	Red	37.	Kavuni	Black
14.	Chitthan Samba	Black	38.	Kuruvai Kalanjiam	Red
15.	Ghandhasala	White	39.	Kothamalli Samba	Red
16.	Karuthakar	Red	40.	Nootripathu	Red
17.	Sadai Samba	White	41.	Kallukar	White
18.	Karuppu Kavuni	Deep black	42.	Karunkuruvai	Brown
19.	Mysore Malli	White	43.	Burma Black	black
20.	Kitchalli Samba	White	44.	Rangoon Samba	Red
21.	Atthur Kichali Samba	White		Checks	
22.	Seeraga Samba	White	45.	CO51	White
23.	Thooya Malli	White	46.	CO52	White
24.	Poongar	Red	47.	CR1009 Sub 1	White

Total anthocyanin content (TAC): *p*H differential method, set forth by Fuleki and Francis (1968), was used for the estimation of anthocyanin content. Methanolic extract of rice samples (1 mL) were prepared and taken in two test tubes wherein 0.025 M potassium chloride buffer (9 mL) was added in one test tube and 0.4 M sodium acetate buffer was added in other tube. Test tubes were incubated for 15–20 min. Using UV-visible spectrometer absorbance values were measured at 510 nm and 700 nm and calculated according to the formula given below:

$$\mathrm{TAC} = \frac{A_{abs} \times MW \times DF \times 10^3 \times 100}{\varepsilon \times 1}$$

Where A_{abs}, $(A_{510nm} - A_{700nm})_{pH\,1.0} - (A_{510nm} - A_{700nm})_{pH\,4.5}$; MW, Molecular weight of cyanidin-3- glucoside (449.2); DF, Dilution factor (1:10); ε, Molar absorptivity (26,900). TAC was expressed as milligram of Cyanidin-3-glucoside equivalent (CE)/100 g of sample on DW basis.

Antioxidant assay (FRAP method): The FRAP test was performed using methanolic extract as suggested by Benzie and Strain (1996) with few modifications. The 500 µL extract was added to 2,500 µL working FRAP solution and incubated in dark at 37°C for 30 min. The blank was made using 500 µL of 80% methanol and treated in the same way as that of samples. Absorbance were performed at 593 nm on the purple-hued compound (ferrous tripyridyltriazine complex) using a double beam UV-VIS spectrophotometer. The unit µg Trolox Equivalents (TE)/g dry matter was used to quantify the reduction of ferric in the antioxidant system.

Statistical analysis: Statistical analysis was carried out with two independent replicates for each data set recorded for the two consecutive years. Mahalanobis D^2 analysis was utilised for working out the genetic distance between the genotypes. Categorisation of germplasm into various Clusters was carried out by Tocher's method (Rao 1952) using INDOSAT software.

RESULTS AND DISCUSSION

Phytochemical profiling of landraces: The TPC, TFC, TAC and antioxidant activity of rice landraces of Tamil Nadu were analysed along with high yielding varieties as checks (Table 2). Significant differences were exhibited by genotypes for various therapeutic traits studied (Table 3). Phenolic compounds grouped as natural antioxidants are medicinally essential compounds for the control of blood lipids and prevention of the cardiovascular problems. Antioxidant property of phenolic compounds is due to phenolic ring which stabilises the unpaired electrons. Rice contains both free and insoluble phenolic acids which are derivatives of hydroxybenzoic and hydroxycinnamic acids (Goufo and Trindade 2014). In the present study, phenolic content was found to be highest in the deeply pigmented landrace Burma Black (1,336.83 mg GAE/100 g DW) followed by the red rice cultivar Kothamalli Samba (1,231.15 mg GAE/100 g DW). In contrast, significantly lower phenolic levels were observed in the non-pigmented landrace Panamara Samba (151.06 mg GAE/100 g DW) and the check variety CR 1009 Sub 1 (152.48 mg GAE/100 g DW). These findings indicate that phenolic content in rice landraces is strongly influenced by the pericarp colour of the grain, which is consistent with earlier reports by Tian *et al.* (2004) and Nandhini *et al.* (2023). Interestingly, Kaviya Samba, despite being a non-pigmented landrace, exhibited a notably high phenolic content (1,064.89 mg GAE/100 g DW), comparable to that of deeply pigmented varieties, suggesting it as an exception to the general trend. In agreement with the present study, Ashokkumar *et al.* (2020) identified several novel phenolic compounds in popular southern Indian rice landraces, including both pigmented and non-pigmented types. These compounds include 3,5-di-tert-butylphenol, 2,4-di-tert-butylphenol, p-cresol, ionol and 2,6-di-tert-butylphenol, with p-cresol being the predominant phenolic compound across these landraces. Therefore, comprehensive metabolomic profiling of Kaviya Samba and Burma Black, which are enriched in phenolic acids, is essential to uncover unique phenolic constituents and to evaluate their potential as therapeutic landraces for the management of lifestyle-related diseases. With respect to flavonoid content, Kavuni exhibited the highest value (291.77 mg QE/100 g), which is approximately 1.4 folds greater than that of the high-yielding check varieties, thereby supporting the findings of Fathima *et al.* (2022). Similarly, Burma Black, Rangoon Samba and Manjaponni also recorded total flavonoid contents exceeding 250 mg QE/100 g. Flavonoids present in natural products have been shown to play a significant role in the management of Type 2 diabetes by modulating insulin activity and associated metabolic pathways (Yi *et al.* 2023). In this context, the elevated flavonoid content in Kavuni substantiates its traditional recognition as an antidiabetic landrace in Tamil Nadu. Previous investigations have revealed that pigmented rice landraces cultivated under the temperate agro-climatic conditions of Kashmir are enriched with diverse flavonoid compounds, including luteolin, apigenin, myricetin and quercetin uronic acid (Bhat and Riar 2015). In contrast, pigmented rice varieties grown in the tropical environments of southern India have been characterised by the presence of flavonoids such as tricin, cirsimaritin, genistein and 7-hydroxyflavones, which are recognised for their notable pharmacological and medicinal properties (Mohanlal *et al.* 2011). Therefore, comprehensive and systematic flavonoid profiling of Kavuni and other identified landraces is imperative to scientifically substantiate the traditional knowledge regarding Kavuni as an antidiabetic rice, and to further elucidate its potential for development and application as a functional food in the management of metabolic disorders. Deeply pigmented rice varieties enriched with anthocyanin pigments were reported to display high antioxidant activity and serve as a good source of antioxidants. The antioxidant potential and therapeutic efficacy of anthocyanins are primarily attributed to their unique structural characteristics, which confer high reactivity toward reactive oxygen species, thereby reducing the risk of lifestyle-related diseases and promoting overall human health (Moko *et al.* 2014). In

Table 2 Phytochemical analysis of pigmented and non-pigmented landraces of Tamil Nadu

S.no.	Genotype	TPC (mg GAE/100 g DW)	TFC (mg QE/100 g)	TAC (mg CE/100 g DW)	Antioxidant (µg TE/g)
1.	Sarapillisamba	434.10	53.23	35.05	1,352.77
2.	Manavari	308.18	62.77	30.85	835.52
3.	Panamara Samba	151.06	110.99	19.30	614.23
4.	Senthooram	224.09	125.57	20.52	604.29
5.	Channangi	181.03	122.35	18.67	568.37
6.	Sembarai	278.96	156.75	31.61	1,129.45
7.	Varigarudan Samba	174.95	127.01	19.93	591.49
8.	Pamani Samba	178.10	235.03	18.24	612.77
9.	Uppumolagi	185.55	148.64	21.75	704.48
10.	Katta Samba	186.01	169.68	9.31	507.12
11.	Karthigai Samba	216.55	201.90	19.12	648.55
12.	Muthuvellai	884.72	121.97	129.79	2,920.97
13.	Chetty Samba	985.75	118.20	84.69	2,197.56
14.	Chitthan Samba	991.35	159.30	158.49	3,693.32
15.	Ghandhasala	277.08	84.40	25.68	715.34
16.	Karuthakar	801.54	104.64	42.39	1,450.07
17.	Sadai Samba	208.09	144.36	20.33	546.86
18.	Karuppu Kavuni	645.81	162.56	73.70	2,182.45
19.	Mysore Malli	811.32	145.74	11.47	482.14
20.	Kitchalli Samba	295.55	144.16	17.98	559.57
21.	Atthur Kichali Samba	252.10	142.07	11.42	508.55
22.	Seeraga Samba	357.17	126.00	32.06	775.44
23.	Thooya Malli	314.22	136.36	11.37	531.47
24.	Poongar	675.64	215.02	28.31	1,304.86
25.	Arcot Kichalli	278.62	204.06	25.60	625.24
26.	ManjaPonni	269.88	252.41	26.78	701.96
27.	Illumpam Poo Samba	288.13	229.50	9.71	464.89
28.	Aruvatham Kuruvai	490.37	99.76	32.64	451.11
29.	MilaguSamba	204.62	172.04	6.06	434.48
30.	Vasanai Seeraga Samba	747.68	194.96	40.93	1,509.45
31.	Kuzhiyadichan	774.37	165.18	50.17	1,968.26
32.	Thulasi Vasanai Samba	255.39	213.14	27.93	718.64
33.	Thengai Poo Samba	323.44	202.12	6.56	420.80
34.	Chinna Adukku Nell	937.34	174.41	56.63	1,824.31
35.	Kaviya Samba	1,064.89	161.50	43.49	1,441.73
36.	Norungan	820.79	173.56	33.30	1,114.37
37.	Kavuni	606.45	291.77	37.65	1,731.69
38.	Kuruvai Kalanjiam	867.56	213.48	35.63	1,318.26
39.	Kothamalli Samba	1,231.15	193.61	38.20	1,663.29
40.	Nootripathu	903.33	152.41	37.34	1,409.13
41.	Kallukar	230.40	186.19	5.68	423.70
42.	Karunkuruvai	875.08	169.68	33.79	1,556.52
43.	Burma Black	1,336.83	259.10	129.91	2,894.47
44.	Rangoon Samba	649.26	256.15	32.27	1,332.95
	Checks				
45.	CO51	153.95	127.00	11.08	501.01
46.	CO52	170.72	140.53	20.98	497.05
47.	CR 1009 Sub 1	152.48	143.32	5.31	410.89
	Mean	503.21	163.75	34.82	1,094.14
	SE	8.39	4.82	2.17	40.98
	CD (p=0.05%)	23.47	13.48	6.08	114.61
	CD (p=0.01%)	31.00	17.81	8.03	151.39

TPC, Total phenolic content; TAC, Total anthocyanin content; TFC, Total flavonoid content; CD, Critical difference; SE, Standard error; GAE, Gallic acid equivalent; DW, Dry weight; QE, Quercetin equivalent; CE, Cyanidin-3-glucoside equivalent; TE, Trolox equivalents.

Table 3 Analysis of variance for different therapeutic traits and yield (pooled 2022 and 2023 data)

Source/Trait	dF	Days to 50% flowering	Total phenol content	Total flavonoid content	Total anthocyanin content	Antioxidant	Single plant yield
Mean sum of squares							
Replication (R)	1	12.25	364.59	312.07	307.24	148.70	3.58
Environment (E)	1	0.02	14,61.34**	514.93**	306.97*	18,048.46*	394.62**
Genotype (G)	46	473.30**	4,55,432.578**	10,392.05**	4,162.60**	22,90,727.19**	108.87**
G × E	1	6.14	192.08	2.06	68.31	3,527.91	3.39
Error	138	7.54	281.78	93.03	18.93	6,719.57	14.95

Df, Degree of freedom; G × E, Genotype environment interaction.

line with this, the present investigation revealed that black rice genotypes Chitthan Samba (TAC: 158.49 mg CE/100 g DW; antioxidant activity: 3,693.32 µg TE/g) and Burma Black (TAC: 129.91 mg CE/100 g DW; antioxidant activity: 2,894.47 µg TE/g), which possessed the highest anthocyanin content, also exhibited superior antioxidant activity. In contrast, non-pigmented genotypes such as Thengai Poo Samba, Milagu Samba, Kallukar, and the check variety CR 1009 Sub 1 recorded markedly lower anthocyanin content (TAC: <7 mg CE/100 g DW) and antioxidant activity (<435 µg TE/g). Evidence from *in vitro* cell culture and *in vivo* animal model studies has further demonstrated that anthocyanins derived from black rice genotypes function as potent anticarcinogenic agents, with reported efficacy against breast and liver cancers (Yamuangmorn and Prom-u-Thai 2021). Additionally, extracts obtained from black pigmented rice grains and bran have been shown to exert antidiabetic effects by inhibiting endogenous α-glucosidase activity and thereby reducing glucose release and absorption in the small intestine (Boue *et al.* 2016). Given their exceptionally high anthocyanin content and antioxidant capacity, the black pigmented genotypes Chitthan Samba and Burma Black warrant further investigation for the presence of specific anthocyanin compounds such as delphinidin, which has been reported to exhibit enhanced efficacy against reactive oxygen species. Similar observations have been made in the Manipur black rice landrace 'Chakhao Poireiton', where delphinidin contributes significantly to its functional uniqueness (Bhuvaneswari *et al.* 2020). Nevertheless, red pigmented landraces Muthuvellai and Chetty Samba also possessed high anthocyanin content (129.79 mg CE/100 g DW; 84.69 mg CE/100 g) as that of black pigmented landraces and showed high antioxidant activity (2,920.97 µg TE/g; 2,197.56 µg TE/g). Java red rice was reported to have anthocyanin content equivalent to black rice cultivars with significant antioxidant activity which is in unanimity to the present finding. It was also reported to have antidiabetic activity via α-amylase inhibition (Agustin *et al.* 2021).

Thus, biochemical profiling of indigenous rice genotypes from Tamil Nadu revealed that the black rice genotypes Burma Black (TPC: 1336.83 mg GAE/100 g DW; TFC: 256.15 mg QE/100 g; TAC: 129.91 mg CE/100 g DW; antioxidant activity: 2,894.47 µg TE/g), Kavuni (TFC: 291.77 mg QE/100 g), and Chitthan Samba (TAC: 158.49 mg CE/100 g DW; antioxidant activity: 3,693.32 µg TE/g) exhibited superior levels of pharmacologically important bioactive compounds. Notably, Burma Black, enriched with all the evaluated bioactive constituents along with high antioxidant activity, underscores its potential as a functional medicinal rice for the management of chronic diseases. Further phytochemical investigations in Burma Black are likely to elucidate novel bioactive compounds contributing to its therapeutic efficacy. In line with the present findings, earlier metabolite profiling studies on black, red, and brown rice genotypes from Sri Lanka, Indonesia, China, Manipur, and Assam have consistently demonstrated that highly pigmented rice varieties are rich in phytochemicals, anthocyanins, and free radical scavenging compounds (Sompong *et al.* 2011, Moko *et al.* 2014). The current study also identified red rice genotypes with notable anthocyanin content and antioxidant potential comparable to black rice. Therefore, the pigmented landraces identified in this investigation hold significant promise as potential functional foods for combating non-communicable diseases, warranting further detailed metabolomic characterisation.

Genetic divergence studies: Existence of genetic diversity in breeding material has got a potential impact on genetic improvement. Genotypes with broad genetic base exhibit wide array of genetic variation in recombinants and provide opportunities for the recovery of transgressive segregants (Roy *et al.* 2023). As a result, genetic diversity was assessed in the landraces of Tamil Nadu to understand its genetic nature. Based on their D^2 values, diversity analysis has categorised the landraces into five different clusters. Cluster I contained the larger number of genotypes followed by Cluster III with five genotypes while Cluster IV had the least number with two genotypes (Fig. 1). Landraces of same geographic location were observed to be distributed among different clusters suggesting substantial genetic diversity in the landraces. Genetic dissimilarity among genotypes is measured using the intra-cluster distance whereas genetic distance between genotypes in any two clusters is measured using inter-Cluster distance. The intra-cluster distance varied between 3.47 (Cluster IV) to 24.92 (Cluster V) (Table 4).

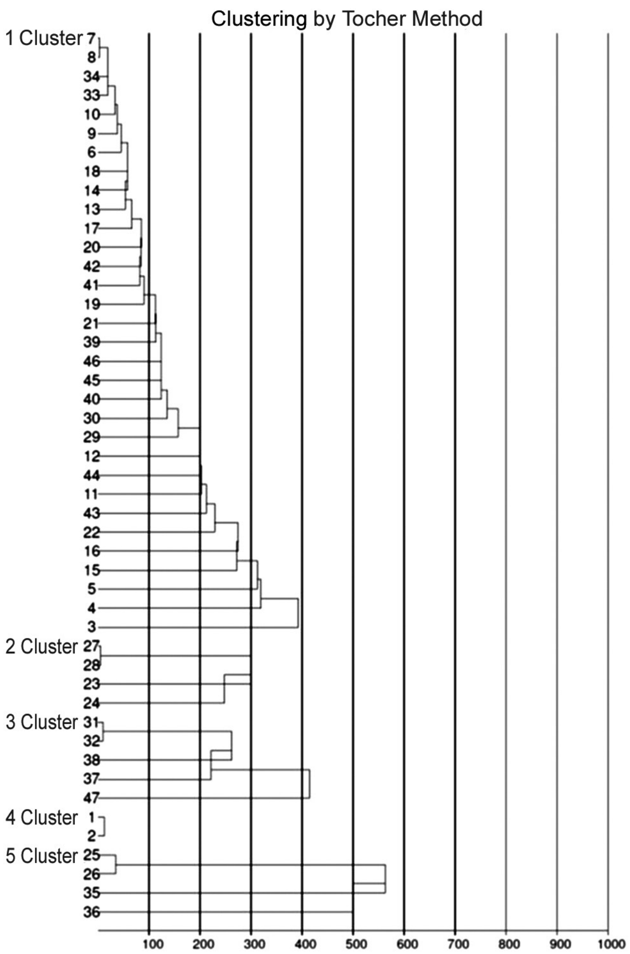

Fig. 1 Genotypic clusters based on genetic divergence.

Table 4 Inter- and intra-cluster (diagonal) distances for different therapeutic traits and yield in rice landraces of Tamil Nadu

Clusters	I	II	III	IV	V
I	14.08	88.77	49.49	26.89	63.13
II		17.78	59.37	70.29	36.42
III			19.39	35.43	32.87
IV				3.47	45.23
V					24.92

Inter-Cluster distance was observed to be highest between Cluster I and Cluster II (88.77) followed by Cluster II and Cluster IV (70.29) while it was lowest between Cluster I and Cluster IV (26.89). High inter-cluster distance specify that the landraces within those clusters exhibit significant genetic differentiation. Therefore, hybridisation between landraces from distant clusters is expected to throw away huge genetic variation and ultimately segregants with desirable traits would be recovered in the segregating generations (Pathak *et al.* 2024). Average performance of all genotypes within a specific cluster for a particular trait is represented by the cluster mean (Table 5). All the five groups showcased a wide range of mean values for the different traits studied expressing the large magnitude of diversity amongst the genotypes. Cluster III expressed maximum Cluster mean value for various traits such as total flavonoid content (205.37), antioxidant (1,229.54) and single plant yield (25.88). Cluster I exhibited the highest for total anthocyanin content (37.68) whereas Cluster V for total phenol content (608.54). Cluster IV possessed genotypes for earliness (78.75). Landraces with all positive traits were not found in any one of the clusters. Hence, landraces of distant clusters can be used in recombination breeding for obtaining desirable segregants (Banumati *et al.* 2010).

The percentage contribution of different traits to total divergence ranged between 1.39–57.35% (Table 5). Total phenol content contributed the maximum (57.35%) to genetic divergence, followed by total flavonoid content (17.48%). Therefore, traits with the highest contribution to genetic divergence can be further studied and explored to better understand the diversity present in the landraces.

Thus, it can be concluded that rice landraces of Tamil Nadu exhibited considerable diversity for therapeutically relevant traits, and the present study serves as a preliminary effort to identify promising genotypes for detailed profiling and validation of traditional knowledge for medicinal food applications. Pigmented landraces such as Burma Black, Chitthan Samba, Kavuni, and Muthuvellai, enriched with diverse bioactive compounds and strong antioxidant potential, were identified as ideal candidates for comprehensive metabolomic investigations and therapeutic rice improvement. These elite genotypes after comprehensive profiling can be effectively utilised as donor

Table 5 Cluster means for different characters and per cent contribution to total divergence among 47 rice genotypes

Trait	Clusters					Contribution (%)	Times ranked first
	I	II	III	IV	V		
Days to 50% flowering	92.17	81.81	101.85	78.75	91.93	11.29	122
Total phenol content (mg GAE/100 g DW)	501.58	442.09	531.25	371.14	608.54	57.35	620
Total flavonoid content (mg QE/100 g)	158.73	170.16	205.37	58.00	197.88	17.48	189
Total anthocyanin content (mg CE/100 g DW)	37.68	20.50	31.33	32.95	32.29	2.87	31
Antioxidant (µgTE/g)	1,140.01	688.08	1,229.54	1,094.14	970.82	9.62	104
Single plant yield (g)	22.34	18.31	25.88	22.48	23.06	1.39	15

parents in hybridisation programmes with high-yielding, quality cultivars to develop improved varieties that combine high yield, non-lodging habit, photoperiod insensitivity, enhanced therapeutic value and desirable cooking quality traits for wider consumer acceptance. Cluster I and Cluster II (88.77) exhibited the highest inter-cluster distance. Hence, genotypes from these distant clusters could be utilised in hybridisation programmes for increasing the likelihood of obtaining desirable segregants through recombination breeding

REFERENCES

Agustin A T, Safitri A and Fatchiyah F. 2021. Java red rice (*Oryza sativa* L.) nutritional value and anthocyanin profiles and its potential role as antioxidant and anti-diabetic. *Indonesian Journal of Chemistry* **21**: 968–78.

Amudha K, Geetha S, Manimekalai M and Ganesamurthy K. 2023. Rice landraces of Tamil Nadu – A review. *Indian Journal of Traditional Knowledge* **22**: 17–29.

Ashokkumar K, Govindaraj M, Vellaikumar S, Shobhana V G, Karthikeyan A, Akilan M and Sathishkumar J. 2020. Comparative profiling of volatile compounds in popular south Indian traditional and modern rice varieties by gas chromatography–mass spectrometry analysis. *Frontiers in Nutrition* **7**: 599119. https://doi.org/10.3389/fnut.2020.599119

Banumati S, Manimaran R, Sheeba A, Manivannan N, Ramya B, Kumar D and Ramasubramanian G V. 2010. Genetic diversity analysis of rice germplasm lines for yield attributing traits. *Electronic Journal of Plant Breeding* **1**: 500–04.

Bhat F M and Riar C S. 2015. Health benefits of traditional rice varieties of temperate regions. *Medicinal Aromatic Plants* **4**: 198.

Bhuvaneswari S, Gopala Krishnan S, Bollinedi H, Saha S, Vinod K K, Singh I M, Prakash N, Bhowmick P K and Nagarajan M. 2020. Genetic architecture and anthocyanin profiling of aromatic rice from Manipur reveals divergence of Chakhao landraces. *Frontiers in Genetics* **11**: *e*570731.

Benzie I F and Strain J J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of antioxidant power: The FRAP assay. *Analytical Biochemistry* **239**: 70–76.

Boue S M, Daigle K W, Chen M H, Cao H and Heiman M L. 2016. Antidiabetic potential of purple and red rice (*Oryza sativa* L.) bran extracts. *Journal of Agricultural and food Chemistry* **64**: 5345–53.

Fathima A M, Geetha S, Hemalatha M, Amudha K, Ananda Lekshmi, Ariharasutharsan G and Devasena N. 2022. Identification and validation of genetic locus linked to flavonoid and anthocyanin content in rice using bulk segregant analysis. *The Indian Journal of Genetics and Plant Breeding* **82**: 299–303.

Fuleki T and Francis F. 1968. Quantitative methods for anthocyanins. 2. Determination of total anthocyanin and degradation index for cranberry juice. *Journal of Food Science* **33**: 78–83.

Goufo P and Trindade H. 2014. Rice antioxidants: Phenolic acids, flavonoids, anthocyanins, proanthocyanidins, tocopherols, tocotrienols, γ-oryzanol, and phytic acid. *Food Science and Nutrition* **2**: 75–104.

Mishra A K, Pede V O, Arouna A, Labarta R, Andrade R, Veettil P C, Bhandari H, Laborte A, Jean Balie J and Bouman B. 2022. Helping feed the world with rice innovations: CGIAR research adoption and socioeconomic impact on farmers. *Global Food Security* **33**: 1–10.

Mohanlal S, Parvathy R, Shalini V, Helen A and Jayalekshmy A. 2011. Isolation, characterization and quantification of tricin and flavonolignans in the medicinal rice Njavara (*Oryza sativa* L.), as compared to staple varieties. *Plant Foods for Human Nutrition* **66**: 91–96. https://doi.org/10.1007/s11130-011-0217-5

Moko E M, Purnomo H, Kusnadi J and Ijong F G. 2014. Phytochemical content and antioxidant properties of coloured and non-coloured varieties of rice bran from Minahasa, North Sulawesi, Indonesia. *International Food Research Journal* **21**: 1017–23.

Nandhini D U, Anbarasu M and Somasundaram E. 2023. Evaluation of different traditional rice landraces for their bioactive compounds. *Indian Journal of Traditional Knowledge* **22**: 483–90.

Pathak V, Prasuna C H, Umakanth B, Surekha K, Subbarao L V and Padmavathi G. 2024. Genetic variability, association and diversity analysis of yield and its component traits in rice germplasm. *The Indian Journal of Agricultural Sciences* **94**: 786–90.

Rao C R. 1952. *Advanced Statistical Methods in Biometric Research*. John Wiley and Sons, New York.

Roy A, Lakshmi H and Sanghamitra R. 2023. Diversity analysis for cooking quality traits in north east Indian landraces. *Oryza* **60**: 388–96.

Singleton V L and Rossi J A. 1965. Colourimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture* **16**: 144–58.

Sompong R, Siebenhandl-Ehn S, Linsberger-Martin G and Berghofer E. 2011. Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. *Food Chemistry* **124**(1): 132–40.

Suganthi S, Rashmi J and Kavitha S. 2025. A survey analysis of perceptions and consumption patterns of traditional rice varieties among different age groups in Tamil Nadu. *Indian Journal of Natural Sciences* **16**: 92675–83.

Tian S, Nakamura K and Kayahara H. 2004. Analysis of phenolic compounds in white rice, brown rice and germinated brown rice. *Journal of Agricultural and Food Chemistry* **52**: 4808–13.

Verma D K and Srivastav P P. 2017. Proximate composition, mineral content and fatty acids analyses of aromatic and non-aromatic Indian rice. *Rice Science* **24**: 21–31.

Woisky R G and Salatino A. 1998. Analysis of propolis: Some parameters and procedures for chemical quality control. *Journal of Apicultural Research* **37**: 99–105.

Yamuangmorn S and Prom-u-Thai C. 2021. The potential of high-anthocyanin purple rice as a functional ingredient in human health. *Antioxidants* **10**: 833.

Yi X, Dong M, Guo N, Tian J, Lei P, Wang S, Yang Y and Shi Y. 2023. Flavonoids improve Type 2 diabetes mellitus and its complications: A review. *Frontiers in Nutrition* **10**: 1192131.

Zhong Y, Zhang Y, Zhu Z, Wang Y, Zeng Z and Liu C. 2023. Comparative study on physicochemical and nutritional properties of black rice influenced by superheated steam, far infrared radiation and microwave treatment. *Innovative Food Science and Emerging Technologies* **84**: *e*103282.