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P Sivakumar
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Chitra M
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Vishunu Vyas Gatta
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Harshavardini K
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Karunakaran V
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

A Velayutham
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Corresponding Author:
P Sivakumar
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Eachangkottai, Thanjavur, Tamil Nadu, India

Exploration of traditional rice (*Oryza sativa* L.) land races: Scope for the future sustainable food production

P Sivakumar, Chitra M, Vishunu Vyas Gatta, Harshavardini K, Karunakaran Vand AVelayutham

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Abstract
Traditional landraces have more complex genetic backgrounds, abundant genetic diversity and heterogenecity, as well as strong adaptability to the environment and are the primary source an excellent resistance genes donors for various important pest and diseases. They provide new alleles for the improvement of commercially valuable traits in rice. Global climate change emphasizes the need to use better adapted cultivars of the main crops and traditional landraces as potential donors of useful genes. Traditional rice landraces are pest and disease resistance, and also resistance or tolerance to drought, water logging and flood situation. The traditional rice landraces are being gradually replaced by the incorporation of modern rice cultivars, thereby threatening the existence of many invaluable traits present in such local varieties. A large number of landraces of rice have disappeared from the irrigated field since the adoption of high yielding varieties (HYVs).Existing indigenous traditional rice can play an important role in the development of sustainable agriculture and also valuable for agronomical, social and cultural practices. Conventional breeding techniques are not alone to tap the genetic potential of rice landraces for commercial varietal improvement programme in rice. Molecular breeding programme is highly helpful into the breeders to elucidate the novel genes and QTLs from traditional rice landraces. These genes and QTLS will be introgressed into commercial rice verities through marker aided selection and using other biotechnological tools. This paper reviews the research findings related to improvement in yield, biotic and abiotic stress tolerance in traditional rice landraces.

Keywords: Rice, traditional landraces, biotic stress, abiotic stress, yield

Introduction
Rice is the most important staple food crop consumed by more than half of the world's population. In current scenario, there is a gradual increase in the global population that makes more demand for rice. The use of locally available traditional rice landraces and or indigenous rice varieties are highly helpful to the plant breeders to develops superior verities for various biotic and abiotic stress tolerance. Today only about 8000 botanically different varieties of rice are in existence in the whole world, out of which more than 4000 varieties are identified in India (Bajpai, 2004, Yadugiri, 2010) [4, 34]. To overcome these problems, landraces play a crucial role in local food security and sustainable agricultural development. Landraces are unique source of specific traits for disease and pest resistance, nutritional quality and marginal environment tolerance. They show high resilience under harsh environmental conditions i.e., abiotic and biotic stress and are a trusted source achieving stable crop yield (Oladosu *et al.*, 2020) [23]. The gene pools found in landraces contribute to the conservation of biodiversity and keep the ecosystem stable and functional in a sustainable manner. In addition to preserving biodiversity in agriculture, the cultivation of traditional landraces provides nutrient cycling, carbon sequestration, soil erosion control, reducing greenhouse gas emissions, and regulating hydrological processes. Landraces are crucial germplasm having diverse source of adaptability genes and incorporation of those genes could ensure optimum grain yield (Mondal *et al.*, 2016) [20].
India is the world's second largest producer of rice. Currently, the National Bureau of Plant Genetic Resources (NBPGR) of the Government of India estimates that there are somewhere between 75000 and 100000 landraces of rice in India. Furthermore, there are still a significant number of varieties of rice available with farmers, and these varieties are unrecorded or uncaptured by formal systems. Tamil Nadu is one of the biodiversity centers for rice, where various kinds of traditional varieties were grown in the different places.

In Tamil Nadu, around 233 traditional Rice landraces available and these landraces are come to cultivation due to medical and nutritional properties. Apart from that, several rice landraces are recently used for improve the yield and yield related traits and to develop varieties against biotic and abiotic stress tolerance. Traditional landraces have different characters such as drought tolerance, stress tolerance, water lodging etc. Some few examples are Kalurundai, Kuzhivedichan, Valsivappu, are resistant to drought, pest and disease and salinity. Pichavari, Vaikunda are tolerant to flood and drought. Kuthiraival samba is resistant to lodging. Poongkar and Kalurundaikaar are suitable for coastal sandy soils and drought resistant tall variety. Puzhuthikarnel is dry land rice which is susceptible to lodging. This paper reviews research findings related to improvement in yield, biotic and abiotic stress tolerance traditional landraces.

Nutritional value of traditional rice landraces

Traditional rice landraces have different nutritional properties such as cooking and eating qualities. Some well-known landraces are Mapillai samba is one of the varieties known for strength and Poongar is red rice which will help to overcome health problems in women. Total Protein is rich in Kalanamak and Kuzhiyadichan and total fat content is rich in Kuzhiyadichan, Neelan samba. Potassium content is rich in Kaivari samba, Kaatuyanam, Navara and Poovan samba. Sivappukuruvikaar and Sanna samba shows extraordinarily high value of iron. Calcium is high in Kullakar, Kalian samba and Sivappukuruvikaar and Kattuyanam rice landraces having high Magnesium. Zinc is rich in KalarpalaiKarunkuruvai rice varieties. Phosphorus is rich in Poovan Samba, Kattuyanam and Soorankuruvai. The rice landraces like Karungkuruvai, Mappilai Samba, Kudhaivazhai, Kalanamak, Perungkar, Kovuni, Kullakar and Neelam Samba recorded low glycemic index values. These rice landraces are valuable and potential donor for developing high yielding rice varieties with low glycemic index.

Physiological traits associated with drought tolerant

Crop productivity is increased by developing rice plants resistance to drought. This approach requires an understanding of physiological mechanisms at different developmental stage and duration of drought period. The accumulation of proline and glycine betaine represents a basic strategy used by plants to protect against osmotic stress. Similarly, the consequences show that drought influences metabolite levels differently in a genotype-dependent manner. Proline is to play a positive role in maintaining membrane integrity under various stresses. Usually, proline accumulation is considered to be higher in stress-tolerant plant species. Analyses of rice plants in response to drought stress and recognition of drought tolerance mechanisms for the production of drought-adapted crops will potentially result in higher crop yields per unit of water input. Swapna*et al.* (2017) [31] selected and screened 42 rice genotypes for osmotic stress resistance under drought. It was taken place under hydroponic conditions by using polyethylene glycol. Among those varieties, 2 varieties Swamprabha and Kattamodan which was tolerant to drought stress. Islam *et al.* (2018) [14] screened of 100 genotypes and were tested against 5 levels of drought stress by PEG 6000. The result showed that increasing water stress germination in all genotypes decreases. The genotypes Ratoil, Chinisakkar, Kumridhan, Pusur, and Somondori showed in good performance under drought conditions. Amaravel*et al.* (2019) [2] examined 97 traditional landraces under salt stress with hydroponics and a nutrient medium of EC 8 dSm^{-1} with 4 replications. In which 5% were tolerant, 21% were moderately tolerant, 54% were susceptible 18% highly susceptible. The genotypes such as Pokkali, Kuliyadichan, Gurukot, and IR 12L showed a significant level of tolerance to salt stress. Navya*et al.*(2019) [22] reported that, the physiological characters like chlorophyll content, relative water content, proline content, root length, root to shoot ratio and volume are studied using 49 traditional rice landraces. Out of 49 landraces Sannavaalya, Manjakaime, JGL-1798, Gangadace, Madras sanna and Najarbad exhibited superior yields than others. Pravinkumar*et al.* (2019) [24] studied 50 indigenous rice genotypes from rice growing regions of Tamil Nadu for drought tolerance under hydrophonics with varying levels of osmotic potential. 30% of landraces tested was highly susceptible and 12% genotypes are highly tolerant in nature. Genotypes like Kuliyadichan and Rajalakshmi recorded high germination percent. Anupriya *et al.* (2020) [3] worked on 85 traditional rice landraces and 15 cultivars were used to screen drought tolerance under *in vitro* hydroponics. Seven distinct cluster were formed in which cluster I showed more drought tolerance such as Chenkayama, Kuliyadican, Rajalakshmi, Chandaikar, Oheruchitteni, AathurKichadi Samba, Arikiraavi and Sahabhagidan with drought tolerant check IR 64 Drt 1. Umego*et al.* (2020) [33] has evaluated 11 rice genotypes under induced drought conditions using morphological and physiological parameters. Data were taken on plant height, number of tillers, leaf length, number of green leaves, number of dead leaves, leaf rolling score, and rate of water loss. Of the evaluated genotypes 4 genotypes shows tolerant to drought namely Faro 44, Nerica 2, Nerica 8, and Nerica 5.

Molecular Breeding approaches for crop improvement using traditional rice landraces

The genetic diversity of improved rice varieties has been substantially shaped by breeding goals, leading to differentiation between Indica and Japonica cultivars. The landraces with different origins possess unique genetic backgrounds and the rice germplasm provides diverse genetic variation for association mapping to unveil useful genes and is a precious genetic reservoir for rice improvement (Hour *et al.*, 2020) [13]. The molecular characterization of these land races are of value for their identification, preservation, and potential use in breeding programes (Yesmin *et al.* 2014) [35]. Rice microsatellite (RM) or simple sequence repeat (SSR) markers are robust and co-dominant (*i.e.*) they can detect heterozygous loci, exhibit high allelic variation, and are widely distributed throughout the *Oryza* genome (Mc Couch *et al.* 1997) [18]. More than 1000 microsatellite markers have been characterized in rice. DNA-based markers have the potential to improve the efficiency and precision of breeding programmes based on the marker assisted selection (Rai*et al.* 2015) [26]. Brondani*et al.* (2006) [8] characterized the allelic diversity of 192 traditional varieties of Brazilian rice using 12 simple sequence repeat markers. The germplasm was divided into 39 groups by common name similarity and a total of 176 alleles were detected. The number of alleles per marker ranged from 6 to 22, with an average of 14.6 alleles per locus. Bajracharya *et al.* (2006) [5] assesses the forty two qualitative and quantitative traits in rice landraces using 39 microsatellite markers. All the accessions are showed low morphological diversity with an average Shannon Weaver diversity index of

0.23. Lenka *et al*. (2011) [16] worked on comparative analysis of drought stress responsive transcriptome between drought tolerant landraces and drought sensitive modern rice cultivars revealed the genetic mechanism involved in stress tolerance. Gene ontology suggested that drought tolerance of N22 attributable to enhanced expression of several enzyme encoding gens. Rekha*et al.* (2011) [28] used RAPD to study the genetic diversity of rarely traditional landraces in rice varieties from tribal area of Kerala, India. A total number of 664 DNA bands amplified by 15 primers exhibited 72.9% polymorphism (an average of 32.3 polymorphic bands per primer). The varieties like Jeerakasala and Kalladiyaran exhibited the highest percent (50.19%) polymorphism, while Thondi and Adukkan showed the lowest (9.85%) polymorphism. Chakravorty *et al.* (2012) [9] given the assessment of genetic divergence was done for 51 landraces of rice based on 18 agro morphological traits. Among the genotypes, maximum contribution towards genetic divergence came from the characters *viz*., culm length, culm diameter and grain length. Cluster VII recorded highest mean value for plant height, ligule length, culm length, culm diameter, culm number, panicle length and maturity. Hybridization among the genotypes from the cluster I, III, IX and X had maximum inter- cluster distances and desirable values for flag leaf angle, grain breadth, grain weight, kernel weight, number of primary branches per panicleand number of grains per panicle is likely to produce heterotic combinations and wide variability in segregating generations Chakravorty *et al.* (2013) [10] work on the interrelationship among the agro- morphological traits with a view to exploiting them directly in the field (if possible) and forming a base for using these landraces in breeding programme. The study analysed the diversity of phenotypic traits of the landraces of rice. The analysis of variance found significant variability in eighteen quantitative traits used in distance analysis. All the traits except ligule length, culm length, number of grains/panicle and number of primary branches/panicles exhibited positive and significant correlation coefficients with kernel weight. Leaf length was positively and significantly correlated with leaf breadth, plant height culm length; plant height showed similar association ship with flag leaf angle, culm diameter, Culm number and panicle length identified the existence of inherent variability in the landraces of rice that could be used to exploit the variability directly or through crop improvement programmes. Das *et al.* (2013) [11] calculated the genetic distances among the 91 landraces collected from different places by using 23 SSR markers. Among the 91 landrace, 182 alleles were identified which included 51 rare and 27 null alleles. In this study, they found that the non-aromatic landraces from West Bengal were most diverse followed by the aromatic landraces from the same state. Ali *et al.* (2014) [1] evaluated 33 landraces of rice used for salt stress tolerance at the seedling stage. The shoot length, root length, plant biomass were measured and recorded. Genotypes that showed differentiation were assessed by SSR markers. Out of 11 markers, RM 8094, RM336, RM8046 which showed higher PIC that coupled with higher marker index values capable of differentiating salt tolerance. Freeg *et al.* (2016) [12] used SSR markers to examine the genetic diversity among 41 rice genotypes from different geographical areas. Through the MAS approach, the primers RM20A, RM302, RM212, and RM286 were found to be useful for selecting drought tolerant plants. The application is to identify major QTL for drought tolerance and collect favourable alleles. Ramchander *et al.* (2016) [27] conducted experiment in 101 Backcross inbred lines of rice for drought tolerance derived from cross combination of Norungan. Traits like photosynthetic rate, transpiration rate and stomatal conductance were observed using IRGA, and the population was phenotypic for other traits. Among 167 SSR markers surveyed, around 15 were identified and found to be linked to at least one of the investigated traits. Sahu *et al.* (2017) [30] estimated the components of genetic variability and associated statistical parameters for grain quality traits in 215 indigenous rice landraces of Chhattisgarh, India. High heritability with high genetic advance as percent mean was observed for all the grain quality traits except for hulling percent and milling percent. It has been observed that sixty-nine genotypes had short slender type grain characteristics whereas forty-seven genotypes have short bold type grains. Thirty genotypes showed more than 80% hulling percent, fifty-six genotypes showed more than 70% milling percent and fourteen genotypes showed more than 65%.Mishra *et al.* (2018) [19] selected six rice landraces for drought tolerance capacity and used for detailed physiological and molecular assessment under control and simulated drought stress conditions. After imposing various levels of drought stress, compared to the drought-susceptible variety IR64, significant positive attributes and varietal differences were observed for all the above physiological parameters in drought-tolerant landraces. Genetic diversity among the studied rice landraces was assessed using 19 previously reported drought tolerance trait linked SSR markers Based on the result; two rice landraces (Pandkagura and Mugudi) showed the highest similarity index with tolerant check variety. However, three rice landraces (Kalajeera, Machhakanta and Haldichudi) are more diverse and showed the highest genetic distance with N22. These landraces can be considered as the potential genetic resources for drought breeding programme. Genetic parameters of thirteen yield and yield attributing traits in 40 landraces of rice was estimatedwith a view to select better yield attributes in rice (Saha*et al.*, 2019) [29]. The higher value of phenotypic co-efficient of variation (PCV) compared to the corresponding genotypic coefficient of variation (GCV) for all the studied traits indicated that there was an influence of the environment. The studied landraces of rice has the potential for incorporating certain important and valuable traits. Estimation of genetic parameters, correlation analysis and path coefficient analysis revealed that the flag leaf area, number of effective tillers per hill, pollen fertility and number of grains per panicle were the most reliable traits for yield improvement in rice. So, the utmost importance should be given to these characters during the selection for yield improvement in rice.

Zahra *et al.* (2020) [36] found that modern cultivars have a narrow genetic base compared to landraces. Therefore, exploring the genome of landraces at a large scale to identify the genes responsible for stability and adaptation to abiotic stresses can help design varieties that can survive vulnerable climates. Characterization of 97 rice landraces was carried out for 24 different morphological traits using DUS characters (Priyanga *et al.* 2020) [25]. The DUS characterization for these characters will be useful for rice breeders to restore the superior genes and use it in crop improvement programmes. Presence of uniform purple colour in whole plant including ligule and auricles was observed in purple puttu and Chitansamba and is used as morphological markers. The land races namely Ayyan samba and Red sirumani were found to be the early maturity types. The short stem length and erect culms were observed in Senthooram and Seevansamba and these genotypes withstand lodging. Hence, these landraces would be used as donors for the development of short duration and lodging resistance respectively in rice improvement programme. Barik *et al.* (2020) [6] stated that stress tolerance is associated with many physiological and morphological traits. For the detection of physiological traits, robust molecular markers are needed. Identification of gene controlling reproductive stage under drought tolerance is prerequisite one. QTL analysis using inclusive composite detected 3 QTL of physiological traits like relative chlorophyll content, chlorophyll a, proline content in studied RIL population. These 3 QTL will be useful for the enhancement of terminal drought stress tolerance through marker assisted breeding approach in rice. Osmotic stress related morpho-physiological and ISSR markers characteristics were implemented among 23 rice landraces by Nahar*et al.* (2020) [21]. Among 23 rice landraces, eight germplasm collected from various agro-climatic zones exhibited speculated level of tolerance, better adaption and resistance under osmotic stress treatment (Manjunatha *et al.*, 2021) [17]. Used 86 SSR markers used for molecular characterization, 44 markers were polymorphic and remaining 42 were monomorphic one. Nearly 21 markers distinguished Basmati from traditional aromatic landraces of Wayanad *viz*., Gandhakasala and Jeerakasala. Seven SSR markers distinguished Gandhakasala from Jeerakasala, whereas 23 markers distinguished Basmati from Jeerakasala. Twenty-two markers distinguished Basmati from Gandhakasala and 23 markers distinguished aromatic group from non-aromatic group. Beena *et al.* (2021) [7] evaluated 90 rice landraces for various physio-morphological traits in completely randomized design with two treatment levels, i.e. control and high-temperature stress (3–5 °C) more than the ambient condition with three replications each. Based on the performances of various physio-morphological traits under control and heat stress conditions, it is identified that Karuthacheera, LN-9956-Vellakaravala (Pavumba) and Pokkali were recorded the highest number of fertile grains under high temperature. Tu *et al.* (2021) [32] evaluated the drought tolerance ability of 170 rice landraces in the laboratory in net house conditions which revealed high tolerance and attained yield over 80% to compare with the controls in the tillering and ripening stages.

Conclusion

Traditional Rice landraces have very good nutritive value when compared with available cultivable varieties and hybrids. They are potential donor for development of high yielding rice varieties with low glycemic index. Most of the traditional rice varieties are drought tolerant and heat stress tolerance for the incorporation of desirable genes in plant breeding. There is a future scope for the researchers to develop new rice varieties against various biotic and abiotic stresses in crop improvement.

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