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Review article

KAIPAD - Unique Rice Tract of Kerala, India

VANAJA, T[1*] AND SRESHMA, C.K.[2]
[1]Department of Plant Breeding and Genetics, [2]Department of Soil Science and Agricultural Chemistry, Regional Agricultural Research Station, Kasaragod, Kerala Agricultural University, Kerala, India
E-mail: vanaja.t@kau.in, cksreshm96@gmail.com
***Author for communication**

ABSTRACT
The *Kaipad* saline tract of India is distributed over the sea coast of Kasaragod, Kannur and Kozhikode districts of Kerala, fringed by mangroves. The *Kaipad* region is an estuarine ecosystem where the land is influenced by tidal action, resulting in brackish water conditions that support specific flora and fauna. This region supports a variety of biodiversity, including mangrove species, salt-tolerant grasses, rice and aquatic fauna adapted to brackish water habitats. It plays a significant role in the coastal ecology of Kerala. Mangroves are particularly important in this region as it maintains biodiversity and ecological balance. The *Kaipad* tract is known for its naturally organic production systems, with rice-fish farming being the predominant agricultural practice. However, the primary agricultural challenge in the *Kaipad* tract is saline and flood soil, which necessitates specialized rice cultivation practices. Traditionally, low yielding and lodging type saline-tolerant indigenous rice varieties having good cooking qualities were cultivated by the farmers. Recently, Kerala Agricultural University has developed five saline-tolerant, high yielding and lodging tolerant rice varieties by adopting the combined strategy of conventional breeding linked with novel strategies of organic plant breeding and farmer participatory plant breeding. 'KAIPAD RICE' has secured the Geographical Indication (GI) tag, and a stakeholders' society and farmer-producer organization have been established to support the conservation and development of this tract, promoting sustainable agricultural practices and enhancing local livelihoods. Products from the tract are available in domestic and export markets. In 2019 the Kerala Government formed an agency named KADS for the conservation and development of this precious ecosystem. This review aimed to discuss the special biodiversity and specific agricultural practices of this area.

Key words: *Kaipad* saline tract, Saline soil, Mangroves, Mound nursery, Organic rice, Rice fish farming, Tidal farming, Organic plant breeding, Participatory plant breeding

INTRODUCTION

Kaipad is a unique coastal wetland tract located along the banks of rivers flowing through three districts of Kerala and joining the Arabian Sea. The term "*Kaipad*" is derived from the Malayalam word "Kayalpaadam", "Kayal," meaning "salt water area," and "Paadam," meaning "rice field". *Kaipad* may be the shortened version of 'Kayalpadam' (Vanaja 2013). This *Kaipad* or "Kayalpadam" terminology highlights the distinctive nature of the region. Being coastal and adjacent to rivers, the *Kaipad* tract experiences flooding during the monsoon and increased salinity during the summer. Tidal currents generated in the sea, cause the saline water to flow into the *Kaipad* fields through the rivers during high tide and flow out during low tide. During high tide, it will carry a higher amount of salts into the field and make the agriculture field more saline. The salinity of the *Kaipad* region ranges from 9.72 to 29.00 dS/m (Shanti et al. 2017).

Under higher soil saline conditions, conventional cultivation practices are not feasible in *Kaipad* ecosystems. Therefore, to address and overcome these challenges, a special agricultural practice is being employed in the *Kaipad* fields, particularly for rice cultivation. Along with river water, the *Kaipad* fields receive fertile organic matter deposits from forest of hill tracts and marine wastes. This, combined with leftover paddy stubbles, excretions from migratory birds and remnants of aquaculture increase the soil organic matter content of the soil. Several species of marine fungi and phytoplankton increase soil organic matter decomposition rate into a greater extent and makes the *Kaipad* ecosystem highly fertile. Consequently, the rice produced in this

ecosystem is entirely organic.

The *Kaipad* system of rice cultivation is an integrated organic farming system in which rice cultivation and aquaculture are practiced together in coastal brackish water marshes which are rich in organic matter (Vanaja et al. 2015). Traditionally farmers mainly used indigenous rice varieties like Orkayama, Kuthiru, Mundon, Kuttadan (of Kannur Kaipad), Orpandy, Orissa, Odiyan (of Kozhikode Kaipad) and Punchakayama, Kandorkutty (of Kasaragod Kaipad). for the cultivation (Vanaja et al. 2009). The traditional varieties are tolerant to moderate and high saline condition and are rich in nutrients and have appreciable cooking qualities, but the drawbacks of these verities are its lodging behavior and less productivity. These are the major limitations for the farmers of the *Kaipad* saline tract for a sustainable rice production, and hence there was a demand from Kaipad farmers for long to develop high yielding, non-lodging and saline tolerant rice varieties suitable to this unique ecosystem without losing the desirable qualities of traditional varieties. The Kerala Agricultural University addressed these issues through development and commercial release of five new rice varieties, satisfying the demand of farmers, christened as 'Ezhome' 1, 'Ezhome' 2, 'Ezhome' 3, 'Ezhome' 4 and 'Mithila' through a sustained efforts of variety development works for a period of 20 years by adopting the combined strategy of conventional breeding linked with novel strategies of organic plant breeding for sustainability and farmer participatory plant breeding for easy and early adoption of research results (Vanaj et al. 2015, 2017, Vanaja and Neema 2021). These new varieties are characterized by their salinity tolerance, non-lodging traits and higher productivity. Their release was highly successful with 60-110% more production than traditional varieties, and has provided substantial relief to the farming community in the *Kaipad* saline tract. A society named 'Malabar *Kaipad* Farmers society' has been formed by Kerala Agriculture University for the socio economic development of farmers in *Kaipad* saline tract in 2010. Different types of ecosystems are there in *Kaipad* region such as marshes, swamps, ponds and paddy fields. These ecosystems are rich in biodiversity with respect to flora and fauna. Among the flora, mangroves are second in importance only to rice. Mangroves have a diverse range of ecological and socioeconomic values. Mangrove forests serve as vital habitats and provide food and shelter for a wide variety of fish and shellfish, contributing significantly to biodiversity (Vanaja et al. 2013). They act as natural buffers between land and shallow seas, preventing erosion. Mangrove crowns serve as resting and nesting sites for birds, while their flowers provide a valuable source of honey. This ecosystem is also well-known for hosting diverse species of migratory birds, further highlighting its unique biodiversity.

Stake holders' society named 'Malabar Kaipad Farmers' Society' (MKFS) was established in 2010 for the development of the Kaipad rice tract and to improve the standard of living of Kaipad farmers by marketing organic rice at better prices under an RKVY project of Kerala Agricultural University. Society is working for the socio-economic development of rice cultivators of Kaipad rice tract and its protection without losing its peculiar nature of the ecosystems. Realizing the need and significance of protection and development of the naturally blessed ecosystem, Kerala government formed an agency for Kaipad, named Kaipad Area Development Society (KADS) in 2019. Realizing the great potential of the tract in production of natural food items and its significance in health, efforts started by Kerala Agricultural University to equip the stake holders' society under its Rebuild Kerala Initiative project since 2020. This RKI project which is going on concentrate on value addition of GI branded Kaipad rice and marketing of organic products, and establishment of a Research and Development Centre for organic wetland ecosystem. As a result, seven products were standardized, being marketed in both domestic, export and also in Amazon. In 2020 the stake holders formed a farmer producer company, named Malabar Kaipad Farmer Producer Company (MKFPC).

The main aim of this review article is to provide detailed information on the biodiversity, ecosystem services and specialized agricultural practices of the *Kaipad* saline tract.

Geographical area of *Kaipad* saline tract

In Kerala, the *Kaipad* saline tract is located approximately between 11.25°N 75.77°E and 12.5°N

75.0°E, and it covers an area of about 3840 ha. The *Kaipad* saline tract is distributed over three districts of Kerala such as Kasargod, Kannur and Kozhikode, in 49 panchayats, 8 municipals and 1 corporation. Even though the gross area is estimated to be 3840 ha, due to various socio-economic reasons only 30-40% of the area is being cultivated and the remaining area is kept as fallow land. The major part of the *Kaipad* tract is in the Kannur district. Kasaragod district is the northernmost district of Kerala, has an average elevation of 19 meters. It is bounded by the Western Ghats in the east and the Arabian Sea in the west, with 12 rivers flowing across its terrain. Most of the *Kaipad* tracts in Kasaragod lie along the banks of the Chandragiri River, in 13 Panchayats and 3 municipalities. Total *Kaipad* tract in Kasaragod district is 1207.5 acres, out of the total area only, 483 acres of land being cultivating and remaining 724.5 acres is kept as fallow.

Kannur district is drained by six rivers, with the Valapattanam River being the longest at 110 km. Other rivers in the district include the Kuppam, Mahe, Anjarakandi, Thalassery, Ramapuram and Perumba rivers. The *Kaipad* rice tracts in Kannur district are primarily located along the banks of the Valapattanam, Kuppam and Kattampally rivers, in 21 panchayats and two municipalities. Total *Kaipad* tract in Kannur district is 5579 acres, out of the total area only 2231.6 acres of land being cultivating and remaining 3347.4 acres of land is kept as fallow.

The Kozhikode district has a coastal elevation of one meter, comprising a sandy coastal belt and a lateritic midland. Rivers originating from the Sahyadri run through the outer areas of Kozhikode city, including the Chaliyar Puzha, Kallayi Puzha, Korapuzha, Poonoor Puzha and Iravanjhi Puzha. The *Kaipad* rice tracts in Kozhikode district are located along the banks of these rivers in 16 panchayats, 2 municipalities and one corporation. In Kozhikode district, the *Kaipad* tracts cover an approximate area of 2789.5 acres, out of these 1115.8 acres is under cultivation and remaining 1673.7 acres kept as fallow.

Climatic conditions of *Kaipad* saline tract

The region experiences three distinct seasons: summer from February to May, monsoon from June to September and winter from October to January. The average temperature in the *Kaipad* region varies, with maximum temperature ranging from 31-35°C, primarily in March and April and minimum temperatures ranging from 19-24°C in December and January (Anonymous 2013). The average total rain fall received in this region is 3438 mm out of which more than 80% is contributed by south west monsoon in the month of June to September and remaining 20 per cent is contributed by north east monsoon in the month of October to November and pre monsoon in April (Anonymous 2013). Rainfall is very heavy in the month of July. Relative humidity is significantly higher in July and September month especially in morning hours (94.57 and 95.29%, respectively) than in the noon time hours (82.86 and 79.29%) (Sowmya 2016).

Physical and chemical properties of soil

Kaipad soil type is saline hydromorphic with sandy loamy to sandy clay loam soil texture (Shanti et al. 2017). The clay loam texture leads to the fluffiness of the soil. This hydromorphic soil is characterized by bluish-black colour with a light grey surface. The saline hydromorphic soils of the Kaipad region are characterized by high clay content, varying between 12.14 and 27.31%. The predominant clay mineral found in the soil is smectite, a 2:1 expanding clay mineral, along with hydroxy-interlayered vermiculite (HIV), mica, kaolinite and gibbsite clay minerals (Unnikrishnan et al. 2022). Due to high clay content the soil become very hard mass and forms wide crack upon drying and become sticky when wet. So only a narrow range of soil moisture level is suitable for cultivation practices. This specific condition along with higher salinity makes the soil suitable for mainly paddy cultivation. Another saline tract, Pokkali, which is seen in mid to southern coastal Kerala, shares similar conditions with *Kaipad* but it is more acidic. This increased acidity in the Pokkali tract is attributed to its higher organic matter content (average 4.15%) and exchangeable aluminium, compared to the *Kaipad* tract (average organic matter content is 1.49%) (Usha 1982). The *Kaipad* saline marshes have an average pH value of 3.40 to 6.48 during the summer months. The relatively less acidic nature of the *Kaipad* soil compared to Pokkali soil may be due to the presence of crustacean shells deposit in *Kaipad* saline tract, during high tidal flows.

These shells, primarily composed of calcium and magnesium carbonate (20-50%), help in neutralization of soil acidity. The exchange acidity, non-exchange acidity and potential acidity of the *Kaipad* tract is 0.69, 15.00 and 15.69, respectively. The *Kaipad* saline marshy area is characterized by highly heterogeneous soil, with varying chemical properties across different locations. The salinity levels in *Kaipad* are particularly diverse, ranging from low salinity (EC value of 2.47 to 5.85 dS/m) to high salinity (EC value of 11.30 to 14.98 dS/m). This variability is largely due to tidal inflow. Despite the salinity, the submerged conditions help mitigate its adverse effects, and rice-fish farming is beneficial for managing salinity (Vanaja 2013).

The soil contains higher level of organic matter in the range of 0.53-3.34% (Shanti et al. 2017). Higher level of organic carbon is due to the incorporation of rice stubbles and straw left in the field after harvest, remnants from the fish cultivation practiced during the high salinity period from November to April, and from the diverse flora and fauna present in the *Kaipad* region. The tract is visited by diverse migratory birds whose excreta also supplements organic richness. The tidal inflow enriches the soils of *Kaipad* with both macro and micronutrients, eliminating the need for external chemical fertilizers. This natural nutrient supply is a key reason why the *Kaipad* saline tract is well-known for organic agricultural production, particularly rice. Tidal inflow and flooding enhance the availability of N, P, K, Ca, Mg, Na, Fe, Si and Mn and causes decrease in availability of Zn and Cu (Anonymous 2013). The available nitrogen content in the *Kaipad* rice tract ranges from 182 to 500 kg/ha, which is considered medium to high range of available nitrogen level in the soil. Phosphorus and potassium levels vary from low to high, with phosphorus ranging from 5.88 to 57.2 kg/ha and potassium ranging from 24 to 592 kg/ha. After rice harvest the rice stubbles are left remain in the field, which later decomposed and release nutrients. As the monovalent potassium ions are rich in the monocot rice plant this will enrich the *Kaipad* soil with potassium content along with the influence of sea water. The rice crop grown in this tract doesn't experience any pest and disease attack, this may be due to high potassium content of the soil and abiotic stress (salinity) induced biotic stress tolerance in the plant (Vanaja et al. 2017). Because of the particular nature of the ecosystems neither chemical fertilizers nor plant protection chemicals are used both rice farming and shrimp farming hence the entire produce from the *Kaipad* tract is exclusively organic.

Rice cultivation in *Kaipad* region

The main agriculture crop in the *Kaipad* saline tract is rice. In this region single crop of rice is being cultivated in the month of June to October followed by fish cultivation from November to April. Similar rice-fish farming systems are being practiced in the Kole and Pokkali wet lands of Kerala. The rice cultivation mainly depends on south west monsoon and sea tides (Anonymous 2013). The rice cultivation method is peculiar in the *Kaipad* tract owing to the salinity and tidal waves (Fig. 1).

Mound preparation

In normal paddy cultivation, the land is puddled using a power tiller or tractor cage wheel. However, this puddling operation is not possible in *Kaipad* rice cultivation as it is marshy. Instead of using puddled soil, seeds are sown on the prepared mounds. These mounds are made to reduce the risks associated with salinity.

In April, complete dewatering of the agricultural field is carried out and allows the land to dry properly. To prevent entering of tidal water into the fields a bund is constructed at the edge of *Kaipad* field where it meets with the river. The bunds are constructed using wild grasses and sticky muds taken from riverbanks. Farmers then clean the field and start to prepare mounds of 60 cm height and 45 cm diameter. This work will be completed by the mid of May. Due to the labor-intensive nature of mound preparation and labour scarcity, the farmers in the *Kaipad* region are in need of machines to assist this arduous task. Once the mounds are created, they are left as it is. During the hot summer months of April and May, salt gets accumulate on the mound surfaces due to high evaporative loss of soil moisture. With the onset of the southwest monsoon in early June, the accumulated salt on the surface is leached out. When rain water in the field gets increases the bund between field and river is completely made open and allows the normal tidal inflow/outflow which will continue up to harvest time without any control.

Figure 1. Rice cultivation practices at Kaipad saline tract. a) Mount prepared in the month of April, b) Seed sowing on mount, c) Mount nursery, and d) Dismantling of mount

Mound Nursery

The nursery on the mounds, known as the mound nursery is primarily adopted in the high saline tracts of *Kaipad*. To prepare the mound nursery, germinated seeds are used. Initially, seeds are tightly tied in a jute cloth and soaked in water for 24 hours. After soaking, the bundle is taken out of the water and placed on the floor, and then a weight will be kept on the top to create high pressure. The high pressure and temperature induce temporary stress on the seeds, leading to germination of seeds within two days. The germinated seeds are then sown on top of the mounds. However, a significant challenge in this method faced recently is the threat posed by migratory birds, which may take away the sown seeds. Hence farmers use to place mud above the sown seeds, but still bird attack exists. In olden days vast area is cultivated, nowadays cultivation get reduced, this may be the reason for more bird attack. This issue is a common concern for farmers during the nursery preparation period. To avoid the bird attack farmers nowadays adopt two methods, i) prepare nursery in non-saline wetland and transplanted 30-35 days old seedlings to raked *Kaipad* soil. In this case some farmers make mound at usual time and dismantle these mounds and transplanted these seedlings. Some farmers simply raise the *Kaipad* field where mounds are not taken and transplanted the seedlings raised in non-saline wetlands. (ii) nursery will be raised in non-saline wetland and 15 days old seedlings will be planted on prepared mounds in *Kaipad*.

Dismantling of mound nursery

30-40 days old mound nurseries are carefully dismantled with spades by skilled labourers without damaging the seedling roots, spreading them apart uniformly. This process is typically completed by the end of July. Following this operation, no further cultivation practices are required until harvesting. The

soil in the *Kaipad* tract is rich in both macro and micronutrients, eliminating the need for external chemical fertilizers or organic manure. Pest and disease attacks are negligible, so there is no need for pesticides usage. Additional, weeding is not practiced in this tract due to the absence of weeds.

Harvest

The crop is ready for harvest between the end of September and mid-October. During harvesting, panicles along with a small portion of the culm are collected, leaving a larger part of the stubble in the field. Decomposition of these stubbles results in providing potassium in the tract through nutrient recycling which provides not only nutrient but also immunity to the crop. The harvested produce from the interior of *Kaipad* is transported to the banks of *Kaipad* using yachts or country boats (Vanaja 2013).

Rice varieties of *Kaipad*

Centuries ago, *Kaipad* farmers cultivated traditional rice varieties adapted to the region's saline conditions. In the Kannur *Kaipad* area, traditional varieties such as Kuthir, Oorkayama, Kuttadan and Mundon were grown. In Kasargod *Kaipad*, varieties like Kandorkutti and Punjakayama were prevalent, while Odiyan, Orissa, and Orpandi were commonly used in the Kozhikode district. Traditional rice varieties in the *Kaipad* saline tract are well-adapted to low to medium saline conditions and are well-known for their high nutritional value and delicious taste. These varieties flourish in the natural ecosystem, exhibiting strong resistance to pests and diseases. However, their commercial cultivation faces challenges due to their lower yield potential, averaging around 2000 kg/ha and their susceptibility to staggered mode lodging because of poor culm strength and excessive culm length particularly during harvest. This makes harvesting labour-intensive and less efficient. While these traditional varieties are valued for their resilience and quality, their reduced productivity and lodging issues limit their profitability for large-scale rice farming in the region. To address these issues, Kerala Agricultural University developed and commercially released five high-yielding, staggered mode lodging tolerant rice varieties specifically for the saline *Kaipad* region. The new varieties are 'Ezhome-1', 'Ezhome-2', 'Ezhome-3', 'Ezhome-4' and 'Mithila' which offer a productivity increase of 60-110% over traditional varieties (Vanaja 2007, 2013, Vanaja et al. 2015, 2017, Vanaja and Neema 2021). These varieties have awn less grains and nutritional rich and taste wise similar to the traditional varieties, providing a more reliable and productive option for local farmers. *Kaipad* rice varieties include both traditional and varieties released by Kerala Agricultural Universities. In 2014 *Kaipad* rice has secured Geographical Indications (GI) tag.

Traditional varieties

Kuthiru

Kuthiru is a traditional rice variety suited for the *Kaipad* saline tract of Kannur district, with medium duration of 120-125 days and photo-insensitive growth. It features light golden-coloured internodes and is susceptible to staggered mode lodging. The rice has deep red kernels with awns and produces a grain yield of about 950 kg/ha. Its hulling efficiency is 81%, with a head rice recovery rate of 69%. Nutritionally, 100 grams of rice contains 12.1 mg of iron, 2.1 mg of zinc, 835.9 mg of potassium, and 10.7% crude fiber. Kuthiru shows moderate tolerance to leaf roller and blue beetle and is resistant to blast in both leaf and plant infections based on visual scoring (Vanaja 2018).

Orkayama

This traditional rice variety has duration of 135-140 days and is photo-insensitive. It has weak lodging resistance and its grains are awn less. The variety yields approximately 2250 kg/ha, with a hulling percentage of 73% and a head rice recovery of 64%. In terms of nutritional content, 100 grams of grains contain 8.81 mg of iron, 3.92 mg of zinc, 3.55 g of protein, 40.8 mg of calcium, 1.29% total sugar, 1.16% crude fat, and 9.65% crude fiber. This variety is also tolerant to saline conditions and suited to *Kaipad* saline tract of Kannur district (Vanaja 2018).

Orissa

The Orissa rice variety has the duration of 130-150 days and is photo-insensitive. It features green-coloured internodes and is susceptible to lodging. The kernels are white, short, and partially awned. This variety yields about 2236 kg/ha, with a hulling percentage of 80% and a head rice recovery rate of 76% (Vanaja 2018).

Developed rice varieties

The high-yielding rice varieties currently available

for the *Kaipad* saline tract of Kerala are 'Ezhome-1,' 'Ezhome-2,' 'Ezhome-3,' 'Ezhome-4' and 'Mithila.' These varieties were developed by Kerala Agricultural University by adopting combined approach of organic plant breeding (Vanaja et al. 2015, Bueren 2003) and farmer participatory plant breeding program (Morris and Bellon, 2004) which is differs from conventional breeding program. In these novel strategies, all filial generations and early trials were grown in the farmers field in the saline, marshy *Kaipad* region. In addition to *Kaipad* saline tract these verities are suitable for non-saline area also. As it is developed through organic plant breeding it has to be managed under organic farming practices for better yield performance in terms of quality.

'Ezhome-1'

The first developed saline tolerant rice variety suited for *Kaipad* saline tract is 'Ezhome'-1. It is a cross between a high yielding and most popular 'Jaya' variety as female parent and traditional land race 'Kuthiru' as male parent (Vanaja et al. 2009). 'Ezhome'-1 is a high-yielding, saline-tolerant variety, producing 3-4 t/ha of grain with a long duration of 135-140 days during *kharif* season. It has a height of 100-110cm during the kharif season. It is not suited for second crop season in *Kaipad* saline tract, but can be cultivate in the non-saline tract during kharif with same long duration period. But during the rabi season, it matures faster with a short duration of 90-95 days and have a height of 70-75 cm may be due to thermos sensitivity. it is thus preferred in areas where farmers need short duration crop during water shortage second crop season. 'Ezhome-1' performs well in non-saline wetland areas also with a yield of 5.82 t/ha under organic management, with the same crop duration as in *Kaipad* fields. The gene recombination from hybridization may have shifted the genetic assembly from stress-induced yield enhancement to epigenetic yield improvement.

In addition to resist the tidal flood condition it can tolerate flooded/submerged condition of non-saline wetland tract immediately after sprouting and at early seedling stage during Kharif season with an average yield of 4 t/ha under organic management. At seedling stage it get decay during submergence but later get rejuvenate when water level get reduce. The cooking quality this hybrid derivative rice variety is same as that of the traditional male parent, *i.e.,* Kuthiru. Colour, texture, flavour and appearance are more acceptable than 'Kuthiru'. 'Ezhome'-1 possess a higher Ca (194 mg/kg), K (10519 mg/kg), Fe (59.8 mg/kg), and Zn (12.9 kg/ha) content than Kuthiru. It has 10.6% crude fiber and 3 g per 100 g protein. There is no pest and disease attack in the saline *Kaipad* ecosystem. This may be due to the high potassium content and salinity induced biotic stress tolerance (Vanaja et al. 2015).

'Ezhome -2'

'Ezhome-2' rice variety was developed through inter-varietal hybridization between 'Jaya' and 'Orkayama'. It can be cultivated in both *Kaipad* saline tract and non-saline area with medium duration of 120-125 days. It is having higher grain (3.2 t/ha) as well as straw yield with higher value of harvest index. It can tolerate low to medium range of salinity (4-6 dS m^{-1}). It has a plant height of 110-120 cm with 15-18 strong tillers and awn less grains. It is suited for both first and second crop seasons in *Kaipad* saline tract as well as suitable for non-saline wetland for both seasons.

Nutritional quality of the rice grain is higher than that of the traditional land race Kuthiru. It has Ca (156 mg/kg), K (9558 mg/kg), Fe (87.6 mg/kg) and Zn (116.5 mg/kg), and 11.3% crude fiber, 4 g protein in the rice grain. The incidence of the pest and disease in the *Kaipad* saline tract was not reported in 'Ezhome'-2. It shows resistance against gall midge, leaf folder and moderate resistance against whorl maggot, case worm, and blue beetle. It is also moderately resistant to sheath blight and bacterial blight (Vanaja et al. 2017).

'Ezhome-3'

The 'Ezhome-3' hybrid derivative rice variety was developed by crossing Mashuri (female parent) with Kuthiru (male parent). It is a medium-duration variety, maturing in 120-125 days during both *kharif* and *rabi* season. The average yield is 3.99 t/ha with approximately 21 panicles per plant. Each panicle contains around 178 grains. The plant grows to an average height of 110-115 cm and having deep red kernels. This awn less variety has closely arranged grains, with a milling percentage of 63.7% and a head recovery rate of 62.6%. Among developed varieties, 'Ezhome -3' is the most suitable variety for rabi season in *Kaipad*.

Compared to the traditional Kuthiru variety, 'Ezhome-3' contains 206 mg/kg calcium, 11610 mg/kg potassium, 20 mg/kg zinc, 65.6 mg/kg iron, and 13.4% by wt. crude fiber. In the *Kaipad* ecosystem, it exhibits strong resistance to pests and diseases, showing complete resistance to gall midge, case worm and blast and bacterial blight diseases. In conventional rice cultivation fields, it demonstrates partial resistance to case worm and brown spot (Vanaja et al. 2015).

'Ezhome -4'

It is a long-duration variety (130-135 days) known for its high grain and straw yield, along with a high harvest index. This variety is tolerant of low to medium salinity (4-6 dS m{ [1]) and is also well-suited for non-saline, flooded areas. Unlike the popular local cultivar 'Kuthiru' of the *Kaipad* ecosystem, it has an intermediate plant height of around 110 cm with strong, sturdy culms and a wide-angle orientation, making it resistant to lodging. The panicles are compact, containing about 176 grains each.

The healthy flag leaf and high stay-green index during the reproductive stage reflect its strong photosynthetic capacity and efficient source-sink relationship. Developed as an organic variety for naturally organic environments, it follows the principles of organic plant breeding. Therefore, when cultivating it in non-saline *Kaipad* tracts, organic management practices should be followed. If farmers wish to apply fertilizers, recommendations suited for local cultivars should be used instead.

'Ezhome-4' contains Ca (199.6 mg/kg), crude fiber (1.39% by wt.), Fe (66.0 mg/kg, K (2010 mg/kg), Zn (12 mg/kg) and protein (2.28 g/100 g). In the *Kaipad* ecosystem, it exhibits strong resistance to pests and diseases. In conventional rice cultivation fields, it exhibits resistance to leaf folder, BPH, WBPH and GLH, and moderate resistance to gall midge, stem borer, case worm, whorl maggot, sheath blight, BLB and sheath rot (Vanaja et al. 2018).

'Mithila'

The Mithila rice variety was developed by crossing Jaya (female parent) with Orkayama (male parent). It is a medium-duration variety with a maturation period of 125-130 days. Mithila has a superior milling percentage of 81.8% and a head rice recovery rate of 73%, compared to 69.7 and 68.9%, respectively, for the local check variety 'Kuthiru'. The cooked rice of Mithila is non-sticky and delicious, similar to 'Kuthiru', but with a swollen and tender texture, unlike Kuthiru's split and firm consistency. Mithila having brown-colored kernels and, upon evaluation, has been found to contain higher levels of calcium, magnesium, and protein. It also possesses desirable grain qualities, such as being awn less, moderately shattering, and having medium-bold grains, unlike the awned, shattering, and bold grains of traditional landraces.

All the above five varieties were tested in National Saline Alkaline Screening trials of AICRP (NSASN) during 2011 at 16 locations and found superior to the local check (Table 1). The comparison of five developed varieties with respect to various characteristics is given in Table 2. As these varieties were developed under naturally organic tract by adopting the concepts and strategies of organic plant breeding when cultivation is doing in non-saline tract, the best management is organic.

If any farmer wants to integrate manuring, the fertilizer dose can be that of traditional varieties. The view of the naturally organic *Kaipad* tract before execution of variety development programme with staggered mode lodging plants with excessive culm length and poor culm strength, panicles with loosely arranged less number of grains compated to that of *Kaipad* tract after execution of the project with lodging tolerant varieties with strong culm, compact panicle with more number of grains is shown in Figure 2.

Aquaculture in *Kaipad* region

At the end of October, the rice harvest in the *Kaipad* region will be completed. Only single rice crop cultivation is practiced in this area, the agricultural land is then converted for aqua culture. After the rice is harvested and the northeast monsoon has passed, the bunds around the fields are strengthened, and a sluice gate is installed. During tidal inflow, a conical net with an opening at the end is fixed inside the sluice gate valves. This net allows fingerlings of prawns, crabs and other fish to enter the field. Once the tide retreats the net is removed and a draining filter is placed at the sluice's mouth to prevent the escape of fingerlings from the field (Vanaja 2013, Vaiga and Joseph 2016). The quantity of fingerlings

depends on the force and duration of the tidal current. Maximum water is allowed to enter *Kaipad* during two tides, and then it is kept in the field for two to three months to allow the fingerlings to mature. The main feed for these organisms consists of the leftover rice stubbles, algae and other wastes in the field. Both decomposed rice stubbles and fish waste improve the organic matter content of the *Kaipad* soil, thus enhancing its fertility.

Fish filtration at the sluice begins three to four days before the full moon and continues until three or four days after the full moon. During this period, a net is placed at the outlet of the sluice gate early in the morning to filter prawns and fish during the tidal outflow. This process is locally known as Kandi Koodal. Intensive prawn and fish filtration occurs until April 14th, which marks the beginning of the new agricultural year, commonly referred to as *Vishusankranthi* day in Hindu mythology. Until this day, bund owners and leased fish harvesters engage in intensive fishing. To maximize the prawn and fish harvest, bund owners allow anyone to fish two to four days before *Vishusankranthi*, provided that half of the harvest is given to the bund owners. This practice is locally known as *Kandi Kalakkal,* meaning churning the field.

After *Vishusankranthi* day, the resource becomes open to the public, allowing anyone to fish from private paddy fields. During the aquaculture season, skilled individuals handle prawn filtration and all related tasks on the bunds. As most activities are carried out at night, small huts are constructed on the bunds and a watchman is engaged for security and to prevent poaching. There is also fish filtration during the monsoon season, known as *Varsha Kettu*, when the crop is in *Kaipad*, but the quantity of the catch is usually less (personal observation of authors).

Mangroves in *Kaipad*

These salt-tolerant trees and shrubs are commonly found along the fringes of backwaters and estuaries. Mangroves play a crucial role in stabilizing the shoreline, preventing erosion and providing habitats for a variety of aquatic and bird species (Vanaja 2013). The mangroves seen in the *Kaipad* saline tract has a significant relation with the aquatic organisms like fish, prawns, crabs and other shell fish. Mangroves provide ideal breeding sites, shelter as well as feed to the juvenile phase of these organisms (Bagust and Tout-Smith 2005). The mangroves grown in this area are the main reason for the richest aquatic biodiversity in the *Kaipad* saline tract. It also absorbs poisonous materials coming in the tract. Even certain variety of mangrove can reduce salt from the tract . Generally there are three types of mangroves such as true mangroves, semi mangroves and mangrove associates (Vaiga and Joseph 2016). True mangroves can grow only in the intertidal zone and couldn't survive in the land. Semi-mangroves and mangrove associates can grow both in the intertidal zone and in the terrestrial area.

A social issue faced by rice farmers of this region is that if they keep the tract fallow for one or two years, the viviparous seedlings of the mangroves come inside rice tract through tidal inflow, establish and convert rice tract to mangrove area. When the farmers do remove these trees for cultivation they

Table 1. Mean yield (kg/ha) of developed rice verities tested at various alkaline-saline tracts of India

Name of culture/ variety	IET No	Alkaline normal	Alkaline	Coastal saline	Coastal saline normal	Inland saline
Ezhome-1(JK 70)	22604	3058	4342	3677	3617	1094
Ezhome -2(Jo 345)	22607	2321	4332	3210	4512	1044
Ezhome-3 (MK 22)	22610	2752	4525	3942	3967	3662
Ezhome-4 (JO 532-1)	22608	2384	3754	3118	1857	1726
Mithila (JO 583)	22609	2415	4929	3781	2468	2203
coastal check (CST 7-1)	-	2644	3538	3321	2466	1709

Source: Vanaja et al. (2015, 2017, 2018, 2021) and state variety release documents

Table 2. Comparison of five developed varieties with respect to various characteristics (After Vanaja et al. (2015, 2017, 2018, 2021)

Item	Ezhome -1	Ezhome-2	Ezhome -3	Ezhome -4	Mithila
Parentage	Jaya x Kuthiru	Jaya x Orkayama	Mahsuri x Kuthiru	Jaya x Orkayama	Jaya x Orkayama
Agronomic traits					
Duration (days)					
Kharif	135-140	120-125	120-125	130-135	125-130
Rabi	90-95	120-125	120-125	125-130	120-125
Average grain yield (t/ha) in saline *Kaipad* during *Kharif*	3.50	3.20	3.99	5.2	5.2
Plant height (cm)	100-110	110-120	110-115	110	117
Average straw yield (t/ha)	5.82	4.55	5.61	10.7	9.7
Number of tillers	19.0	16.5	16.3	15.4	9.8
Performance in saline *Kaipad* soil					
Kharif season	Good performance	Good performance	Good performance	Good performance	Good performance
Rabi season	Poor performance	Average performance	Good performance	Poor performance	Poor performance
Lemma and palea colour	Straw	Straw	Brown furrows on straw back ground	Golden yellow	Straw
Average length of panicle (cm)	25.5	29.4	24.2	27.9	28.3
Average number of grains panicle^{-1}	150	215	178	175.5	145.6
Average 1000 grain weight (g)	28.3	25.6	26.0	29.8	27.2
Physico-chemical and cooking qualities					
Kernel colour	Brown	Speckled brown	Deep red	White	Brown
Awning	Awn less	Awn less	Awn less	Awn less	Awn less
Shattering	Non-shattering	Non-shattering	Non-shattering	Non-shattering	Non-shattering
Hulling (%)		79.1	77.5	75.9	77.8 78.5
Milling (% in commercial mill)	69.0	68.0	63.7	80.0	81.8
Head rice recovery (%)	62.0	63.0	62.6	76.0	73.0
L/B ratio of grain	2.76	2.7	2.8	2.6	2.5
Classification	Medium	Medium	Medium	Medium bold	Bold
Volume expansion	3.4	3.3	2.0	2.8	4.3
Kernel elongation ratio	1.45	1.5	1.45	1.4	1.52
Water uptake	1.60	1.9	2.61	1.68	2.11
Nutrient qualities					
Fe content (mg /kg)	59.8	87.6	65.6	66.0	31.0
Zn content (mg/kg)	12.9	16.5	20.0	12.0	11.0
Ca (mg/kg)	194	156	206	199.6	316.1
K (mg/kg)	10519	9558	11610	2010	2350
Crude fiber (% wt.)	10.6	11.3	13.4	1.39	9.9
Protein (g/100 g)	3.0	4.0	2.0	2.28	2.13

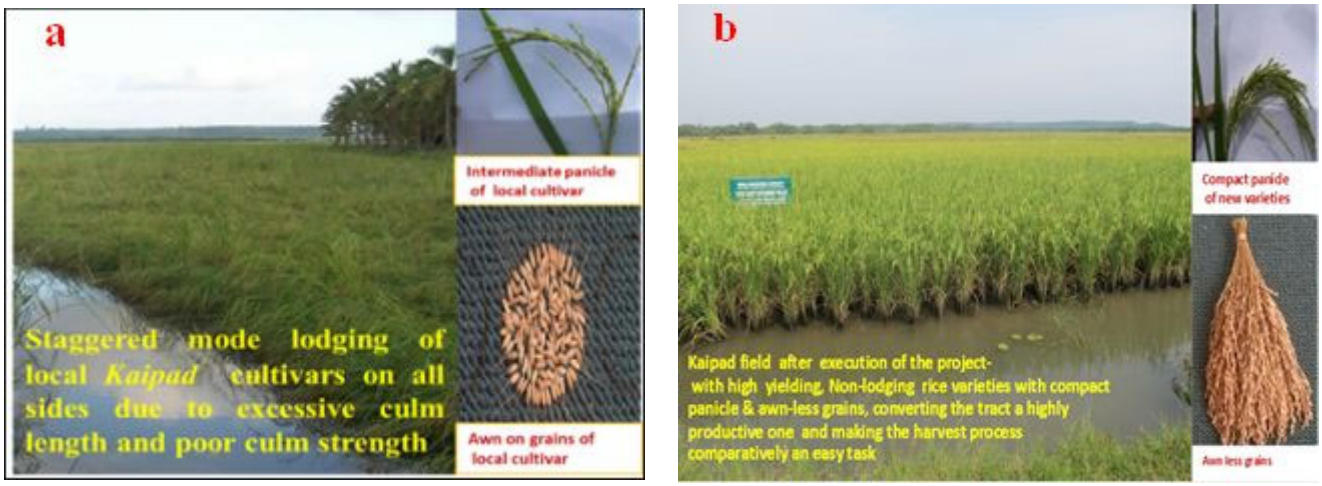

Figure 2. Kaipad tract before and after execution of variety development project of Kerala Agricultural University

face threat from mangrove protectors. This competing interest on the resources should be addressed to protect rice farmers, as well as to safe gourd food and nutritional security, and to protect the balance of the ecosystem considering the significant multifaced roles of *Kaipad* wetland tract.

CONCLUSIONS

The *Kaipad* region of North Kerala is a unique and ecologically rich coastal wetland that has evolved specialized agricultural practices to thrive in its saline conditions. Historically, farmers in this area cultivated traditional rice varieties that were well-adapted to the saline environment but faced challenges such as lower productivity and susceptibility to lodging. Recent advancements, particularly the development of high-yielding, lodging tolerant rice varieties by Kerala Agricultural University, have significantly improved agricultural output and sustainability in the region. The *Kaipad* ecosystem is characterized by its rich biodiversity, including mangroves, saline-tolerant grasses, migratory birds, and various aquatic fauna. The tidal inflow and outflow maintain the ecological balance and nutrient richness of the soil, eliminating the need for chemical fertilizers and minimizing pest and disease issues. The integration of rice and fish farming further enhances the productivity and sustainability of this unique agricultural system. The main product, KAIPAD RICE secured GI tag which opened avenue even for international market. Formation of stakeholders society, government agency and FPO for the conservation, protection, and development is a model for sustainable development mode of a tract based on 4C concepts - Conservation, Cultivation, Consumption and Commerce. In conclusion, the *Kaipad* region exemplifies a harmonious blend of traditional knowledge and modern agricultural innovations, ensuring sustainable and organic rice production while preserving the rich biodiversity and ecological integrity of the coastal wetlands.

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