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REVIEW

A century of traditional rice farming in tidal swamplands of South Kalimantan, Indonesia: Its impact on breeding and conservation programs

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ABSTRACT

The current and future tidal swamplands are very strategic as one of the Indonesia national food barns considering the decreasing of productive land. Utilization of tidal swampland for agriculture, especially rice farming in South Kalimantan by local farmers began spontaneously hundreds of years ago. Most of the tidal swampland in South Kalimantan is still planted with local rice (*Oryza sativa* L.) varieties. Various local rice varieties planted by farmers include Siam, Bayar, Pandak, and Lemo varieties. These local varieties have been collected, identified, and conserved ex-situ in the tidal fields of South Kalimantan. The technology of local varieties of rice cultivation from seedling to harvest is carried out traditionally and uses traditional tools. Numerous local varieties collected and conserved, undergo crossbreeding with superior varieties to generate new high-yielding varieties with flavours favoured by the local populace. The Siam Unus serves as local variety for crossbreeding, while the superior varieties include Cisokan and Dodokan. The crossing of Siam Unus with Cisokan yields Margasari variety, and with Dodokan, it produces Martapura variety. Both varieties enjoy significant popularity among farmers and the local communities in the tidal areas of South and Central Kalimantan. This paper reviews research on traditional rice farming of tidal swampland and its impact on breeding and conservation programs in South Kalimantan.

Key words: Breeding programs, conservation, local rice varieties, *Oryza sativa*, tidal swampland, traditional cultivation.

INTRODUCTION

The swamplands consist of tidal and freshwater swamplands. The tidal swampland in Indonesia spans an estimated 20.1 million hectares across four major islands: Kalimantan, Sumatra, Papua, and Sulawesi (Nugroho et al., 1992; Gunawan et al., 2012; Hairani et al., 2024). Although tidal swampland is often considered unsuitable for agriculture, it is currently being extensively utilized to meet the demands of a rapidly increasing global population (Sulaiman et al., 2019; Qurani and Lakitan, 2021). Research indicates that tidal swampland can be made productive for rice (*Oryza sativa* L.) with proper management and innovation (Sulakhudin and Hatta, 2018; Sulaeman et al., 2022).

Tidal swampland is a type of swampland that has unique hydrological and soil properties. It is classified into four types, A, B, C, and D, based on its hydrologic nature or the type of overflow it experiences. Additionally, depending on the soil type, it is categorized as potential soils, acid sulfate, saline, or peat land. Type A land is always waterlogged and experiences daily tidal drainage. Type B land is only affected by large tides but is drained daily. Type C land has never been fully inundated, despite experiencing large tides. It has permanent drainage, and tides affect it indirectly. Groundwater is near the surface, within 50 cm of the ground surface, and drainage is limited (Widjaja-Adhi et al., 2000).

The tidal swamp area in South Kalimantan is home to various plant species, including traditional rice cultivars. Hundreds of germplasms, some with important traits, are found in this region for future breeding (Wijaya et al., 2007). Traditional rice cultivars generally comprise several significant genes related to tolerance of acidity, salinity, and contamination by metals (Ogunbayo et al., 2007). Farmer selection and adaptation to local conditions have shaped this germplasm (Sanghera et al., 2013). Hence, rice has become an integral part of the culture and traditions of Asian rice-growing communities for generations (Thomson et al., 2009). Most of the germplasm is not well-characterized and is disappearing due to adopting high-yielding varieties (HYVs) (Iskandar and Ellen, 1999). Various efforts are necessary to preserve, maintain, characterize, and improve this germplasm.

Local rice cultivars (swamp rice) possess some agronomic advantages such as tolerance to submergence, acidity, salinity, and heavy metal contamination, even though this germplasm has relatively low productivity at only 2 t ha^{-1} (Mursyidin et al., 2021). In addition, this plant has adapted over hundreds of years to different types of stressful abiotic conditions, such as immersion, wave abrasion, water level fluctuation, and low oxygen conditions (Wang, 2020). Swamp rice possesses some useful genes that can be used for rice breeding in the future (Das and Das, 2014). Additionally, it displays certain agronomic traits that could be beneficial for crop yield stability, stress tolerance, adaptability to local conditions, and acceptability factors (Azeez et al., 2018; Hafiz et al., 2020). For instance, it is tolerant to acidity, salinity, metal contamination (Rao et al., 2018; Mursyidin et al., 2021), agromorphological traits, cultivation methods, and enhanced market value (Mursyidin et al., 2019). However, despite its potential, most of this germplasm remains unused, underutilized, and sub-optimally characterized for breeding purposes.

Agricultural development in tidal swampland faces various challenges such as exposure to pyrite layer and generally shallow bottom of less than 50 cm, thick, raw, hydrophobic peat, water stress and seawater intrusion, and attack of plant pests and diseases (Sulaeman et al., 2022). Indigenous varieties of tidal swamp rice are still prevalent in rice fields in South Kalimantan. Local varieties occupy 146.612 ha of the 191 740 ha of tidal swampland used for rice paddy fields (South Kalimantan Agriculture Service, 2006). In 2001, more than 90% of the land was planted with rice local varieties (Zauhari, 2001).

Local rice varieties are widely used by farmers due to their adaptability and ease of cultivation. As per Wiggin's study in 1976, local rice varieties have several benefits that are in line with farmers' interests (Wiggin, 1976). They are easily available in most areas and require minimal maintenance. These varieties have distinct characteristics such as a longer growth period of 9-10 mo, lower yield potential of 2-3 t ha^{-1}, minimized dependence on fertilizers and pesticides, adaptability to challenging environments, and higher market prices. Farmers consider these varieties easier to manage during cultivation and more efficient (Sanghera et al., 2013; Khairullah, 2020; Mursyidin et al., 2021).

Farmers in the tidal swamplands of South Kalimantan have a long history of cultivating diverse local rice varieties. Among the popular local varieties are Siam, Bayar, Pandak, and Lemo. The Bayar variety group, for instance, has been under cultivation by farmers in tidal swamplands since 1920, while the Lemo variety since 1956 (Idak, 1982). Presently, the widely prevalent Siam variety group is known by various names that depend on factors such as the grain's shape, rice's flavour, farmer's name, or specific characteristics embraced by local farmers (Khairullah, 2020). The local varieties conserved ex-situ in tidal swampland and have been utilized as a gene source in crossbreeding between local swamp rice and superior varieties. This paper reviews research on traditional rice farming of tidal swampland and its impact on breeding and conservation programs in South Kalimantan.

TRADITIONAL CULTIVATION OF LOCAL RICE VARIETY

The process of cultivating local rice varieties goes through several stages, including land preparation, nursery, transplanting, fertilization, pest, disease, and weed management, as well as traditional methods for harvesting and post-harvest procedures. Currently, farmers in the tidal rice fields of South Kalimantan continue to use traditional cultivation techniques, primarily in smaller rice fields. Traditional technology is mainly influenced by rainfall patterns, which result in the flooding of land in tidal rice fields.

Monthly rainfall patterns in tidal swampland

The traditional cultivation of local rice varieties in tidal swamplands is closely tied to the water level fluctuations in the paddy fields. These fluctuations are primarily influenced by the rainfall patterns, although tidal movements and ebbs also play a role, especially in tidal areas. Figure 1 illustrates the monthly rainfall and local rice planting patterns in the tidal swamplands of Barito Kuala Regency. During the dry season (April-September), July experiences the highest rainfall while April records the lowest. Conversely, in the rainy season (October-March), November sees the highest rainfall while October experiences the lowest precipitation.

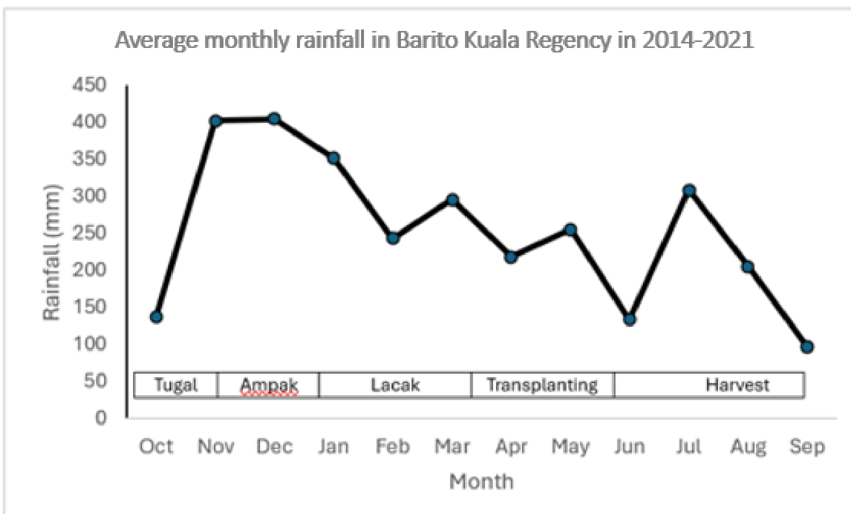

Figure 1. Monthly rainfall and local rice planting patterns in tidal swamplands of Barito Kuala Regency, South Kalimantan (data were processed from BPS-Statistics of Barito Kuala Regency, 2014; 2018; 2021). *Tugal* is the first seeding; *Ampak* (first transplanting of *tugal*'s seedling); *Lacak* (second transplanting of *ampak*'s seedling.

Nursery, transplanting of nurseries, and land preparation

Local rice nurseries usually require transplanting up to two times. Seed nurseries commonly employ the *tugal* or *teradak* method, known as the dry nursery, which is widely practiced by farmers in tidal swamplands, alongside wet nurseries known as *palai*. The dry nursery *tugal* usually begins around October or November. About 5 kg seeds are adequate for cultivating 150 m^2 of land or 1 ha of rice fields. Farmers usually apply husk ash to the holes in *tugal* area. Seedlings are ready for transplanting about 30 to 40 d after sowing (Khairullah, 2020; Mursyidin et al., 2021). The first transplanting of seedlings, known as *diampak* is conducted in 20% of total field area. This process occurs between December and January. Seedlings are divided into 4-5 portions from a planted hill and then placed in the second seedbed, *ampakan*. These seedlings remain exposed for about 40 d before the next transplanting phase. The second transplanting stage, known as *dilacak*, takes place between January and February/March. This stage requires around a third of rice field area, typically located in centre of the fields. The seedlings at the third seedbed (*lacakan*) stage are ready for planting in rice fields after 55-60 d (Figure 2) (Khairullah, 2020; Mursyidin and Khairullah, 2020).

Figure 2. Seedling process via *tugal*, involving the creation of *tugalan* holes on dry soil filled with rice seeds; Tugalan seedlings approximately 3 wk old (left); transplantation at the *ampak* (centre) and *lacak* stage (right). The dry nursery *tugal* usually (October or November), 5 kg seeds are adequate for cultivating 150 m^2 land or 1 ha rice fields. Farmers usually apply husk ash to the holes in *tugal* area. Seedlings are ready for transplanting about 30 to 40 d after sowing. Seedlings are divided into 4-5 portions from a planted hill and then placed in the *ampak* (second seedbed). These seedlings remain exposed for about 40 d before the next transplanting phase. The second transplanting stage, *lacak*, takes place between January and February/March. This stage requires around a third of rice field area, typically located in centre of the fields. The seedlings at *lacak* (third seedbed) stage are ready for planting in rice fields after 55-60 d. Source: Photograph (left) by A. Fahmi, (centre & right) by I. Khairullah.

The process of seedling transplanting can span up to 4 mo. This extended duration is deemed inefficient, especially when considering that within this timeframe, a single planting season of HYVs could be completed. However, the natural conditions of the land, with its depth, prohibit the direct planting of seedlings into the fields. The multiple transplanting serves the purpose of enlarging, fortifying, and proliferating the seedlings. Efforts to address this prolonged nursery duration necessitate proper water management, leveraging the natural ebb and flow of high and low tides to regulate field water levels (Mursyidin and Khairullah, 2020; Puji et al., 2022a).

Land preparation occurs roughly 1 mo after seedlings reach *lacakan* stage in February. Weeds within paddy fields are cleared using a *tajak* tool (scythe-like tool), and the cut weed pieces are left on the water surface for 10-15 d. Subsequently, these weed remnants are twisted into small, round bundles. Periodic reversals in twisting process expedite decomposition. These bundles are evenly distributed across the surface of rice fields while awaiting water to recede (Figure 3) (Anwarhan, 1989; Khairullah, 2020). Land preparation using a *tajak* is non-disruptive to pyrite layer, ensuring plant safety. The cut weeds serve as indirect organic matter, enriching the soil with nutrients. However, the decomposition process of this organic matter is relatively slow. To expedite decomposition, there's a need for decomposers that can hasten the breakdown of organic matter while ensuring environmental safety (Simatupang et al., 2014).

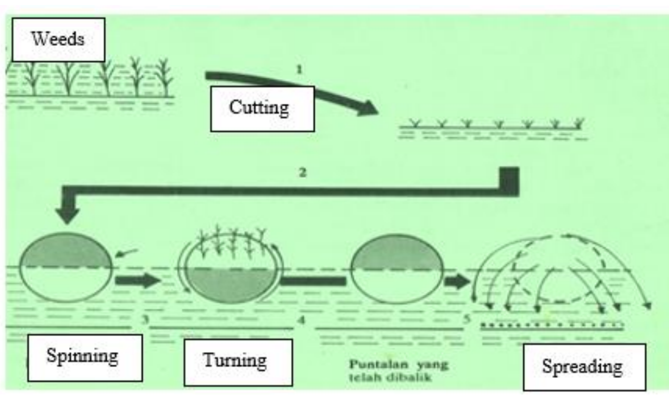

Figure 3. Illustrates the schematic breakdown of weed biomass into organic matter sources through an in-situ process in tidal swamplands. Source: Anwarhan, 1989.

Within this land preparation system, there exists a recycling process in situ, utilizing biomass of weeds that grow on the land being ready for cultivation. The recycling process entails the decomposition of dead weed biomass post-planting, which is then composted and returned to the soil. This process serves as a source of in-situ organic matter, enriching the soil's organic content and thereby enhancing soil fertility (Nazemi et al., 2007; Simatupang et al., 2014). The closed nutrient recycling process commences with activities such as weed picking (*menajak*), spinning (*memuntal*), turning (*membalik*), and spreading (*meampar*) the decaying weed biomass (Figure 4). Each phase of the process, from *menajak* to *meampar* is dedicated to producing high-quality and refined organic matter, with each stage lasting between 10 to 15 d (Figure 3) (Anwarhan, 1989). Once the weed biomass has decomposed and transformed into compost, it is evenly distributed across the entire land surface, ready for planting rice seedlings.

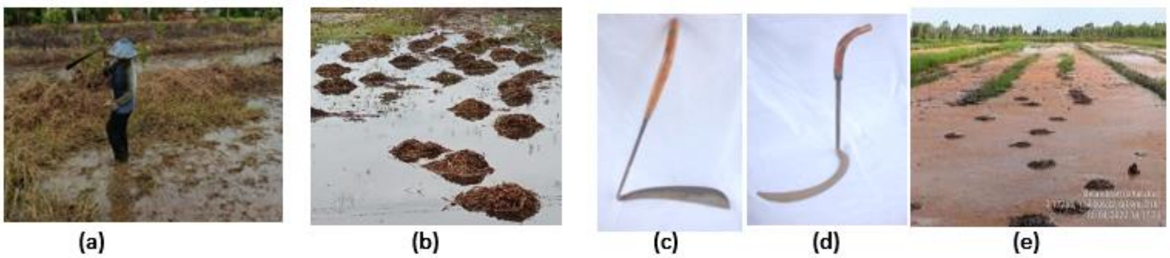

Figure 4. Land preparation using a *tajak* tool, where weeds are cut on the soil surface and left to float on the water surface until they decompose (a); *memuntal* is decomposing weeds in the field as organic matter (b); *tajak surung* tool for clearing the land where the water is receding, (c) and *tajak bulan* tool for clearing the land where the water is deep (d), (e). Lowland cultivated by *tajak*. Source: (a) and (b) from Indonesian Swampland Agricultural Research Institute (ISARI) documentation, (c) and (d) images from ISARI gallery, (e) Photograph by I. Khairullah.

The *tajak* is a traditional tool for preparing rice fields in tidal swamplands (Figure 4). It has been notably recognized for its role in conserving land resources. The *tajak* is particularly effective in soil preparation, especially in areas with shallow pyrite soils (Noor, 1996; Simatupang and Nurita, 2010). The *tajak* comprises a flat iron piece and an iron handle, with the handle's upper part often crafted from wood. Its working capacity is about 3-4 *borong* (1 *borong* equals 17 m × 17 m), approximately 0.1 ha land per day (within an 8 h workday) (Nazemi et al., 2007; Simatupang et al., 2014).

Transplanting, fertilization, weeding, and plant pests-diseases control

Planting the seedling occurs during March-April when the water level has subsided. Farmers exhibit irregular spacing, typically planting about 5 hills per *depa* (1 *depa* = 1.70 m), or approximately 42.5 cm × 42.5 cm. Each hill accommodates 2-3 seedlings, with preference given to large, mature, and sturdy seedlings. The traditional tool used for planting rice seedlings obtained from *lacakan* is *tatujah*, typically crafted from ironwood or *gelam* (*Melaleuca leucadendron* L.) wood (Figure 5). The planting capacity using *tatujah* is tely 3 wholesales (0.08 ha) of rice fields per day (within an 8 h workday) (Khairullah, 2020; Puji et al., 2022b).

The planting time provides indirect advantages for plants due to decreased solubility of Fe (Fe^{2+}), thereby minimizing risk of Fe toxicity stress for the seedlings being planted (Hairani et al., 2023). Iron toxicity usually occurs in dry soil or during a prolonged drought (Shamshuddin et al., 2013). However, local varieties have a tolerance mechanism for Fe toxicity in acid sulphate tidal swamplands (Khairullah et al., 2021). Conversely, when the soil is flooded, the increase in pH can lead to the reduction of ferric to ferrous iron. This phenomenon occurs mainly in actual acid sulphate soils (when pyrite has oxidized) that are re-inundated by rain or tidal water (Khairullah et al., 2021; Shamshuddin et al., 2013). Ferrous iron concentrations of 300-400 mg kg^{-1} ppm are highly toxic to rice plants and cause low nutrient availability (Craft, 2016; Panhwar et al., 2016). However, the irregular spacing poses a significant disadvantage concerning sunlight absorption, leading to suboptimal photosynthesis.

(a) b) (c)

Figure 5. (a) Transplanting is performed using a traditional tool, *tatujah*. Mature and sizable seedlings are separated to allow for approximately 2-3 stems per planting hole; (b) (c) Images of several *tatujah* tools. Planting the seedling occurs during March-April when the water level has subsided. Farmers exhibit irregular spacing, typically planting about 5 hills per *depa* (1 *depa* = 1.70 m), or approximately 42.5 cm × 42.5 cm. The traditional tool used for planting rice seedlings obtained from *lacakan* is *tatujah*, typically crafted from ironwood. The planting capacity using *tatujah* is tely 3 wholesales (0.08 ha) of rice fields per day (within an 8 h workday). Source: (a) and (b) photograph by I. Khairullah, (c) image from Indonesian Swampland Agricultural Research Institute (ISARI) gallery.

Initially, farmers refrained from using inorganic fertilizers like urea, SP36, or KCl. They relied on the decomposition of organic matter, considering it adequate for plant growth. Some farmers occasionally applied table salt in moderate amounts. However, in recent times, a shift has occurred towards inorganic fertilization due to organic matter depletion. Nonetheless, the fertilizers applied predominantly consist of urea and SP36, often in improvised or irregular doses. Farmers rarely use KCl fertilizer, which poses a risk of K deficiency, adversely affecting plant health (Khairullah, 2020; Mursyidin et al., 2021).

Certain farmers utilize husk ash as a method to meet K requirements for rice plants, ensuring their sufficiency. Additionally, farmers frequently apply table salt, which can temporarily benefit paddy fields but poses long-term harm by impairing soil structure. To enhance the yield of local rice varieties, fertilization with 45 kg N, 60 kg P_2O_5, and 60 kg K_2O per hectare is recommended (Khairullah, 2020). In the context of agronomy, efforts to increase crop productivity include improving fertilization methods in terms of dosage, timing, and method of application (Mehner and Tockner, 2022).

Weeding is typically carried out by farmers during the initial stages of growth. However, many farmers tend to forgo weeding due to the extensive coverage of the rice canopy, which effectively suppresses weed growth by shading the soil surface. This natural shading reduces sunlight penetration, limiting weed proliferation. Nonetheless, weeding remains essential for enhancing crop yields (Khairullah and Saleh, 2020).

Control measures for pests and plant diseases are infrequently undertaken. Common pests include rats, stem borers, rice bugs, ground bedbugs (stone javelin), rice leafrollers, and brown planthoppers. Common diseases include neck blasts, brown leaf spots, and leaf midrib blight. Integrated control methods are highly recommended, involving strategies like varying cropping patterns through varietal rotation and encouraging the use of natural enemies. Chemical spraying against invasive pests is occasionally employed; however, the choice of pesticide should align with government recommendations, tailored to the specific type of pest (Susanti et al., 2016).

Harvest and post-harvest

Harvesting occurs typically between July to August or September, depending on rice variety and planting time. Traditionally, farmers use the *ranggaman* tool for harvesting. The *ranggaman* is constructed from bamboo, measuring approximately 10-20 mm in diameter and around 10 cm in length (Figure 6). The *ranggaman* is specifically employed for cutting panicles of taller local rice varieties. Despite being slower, this method is known to minimize yield losses. Harvesting with *ranggaman* allows farmers to selectively choose ripe panicles, often leading to multiple or staged harvests based on ripening stages. This tool is suitable for smaller agricultural plots or subsistence farming (Khairullah et al., 2021). While using a sickle for harvesting is faster, it tends to result in broken rice during milling. Harvesting with *ranggaman* requires more labour and time due to its manual nature (Khairullah, 2020; Puji et al., 2022a).

(a) (b) (c) (d)

Figure 6. (a) Rice harvesting using *ranggaman*; (b) *Ranggaman* tools; (c) Threshing panicles using feet; (d) Threshing panicles using g*umbaan* tolls. Harvesting occurs typically between July to August or September, depending on rice variety and planting time. Traditionally, farmers use the *ranggaman* tool for harvesting. The *ranggaman* is constructed from bamboo, measuring approximately 10-20 mm in diameter and around 10 cm in length. The *ranggaman* is specifically employed for cutting panicles of taller local rice varieties. Despite being slower, this method is known to minimize yield losses. Source: (a), (c), and (d) photograph by I. Khairullah, (b) image by Indonesian Swampland Agricultural Research Institute (ISARI) gallery.

At the farmer level, processing harvested yields (threshing panicles) is predominantly carried out through traditional methods using feet, known as *diirik*. This threshing requires considerable manpower and time. Following threshing, the grains are dried on a plastic tarp or mats made from *purun plant*, a local plant known for its high acid resistance in tidal swamplands. The *purun* plant often serves as an indicator of acid sulphate land with a pH < 3.5 and high Fe content (Khairullah et al., 2019).

To separate filled grains from empty or half-filled unhulled rice, a traditional tool called *gumbaan* is utilized. The *gumbaan* is employed to differentiate between filled and empty grains. The dried grains are placed into the *gumbaan* and rotated, effectively segregating the filled grains, half-filled unhulled rice, and empty unhulled rice. This tool allows for the separation of different rice grain types based on their fullness (Saleh and Khairullah, 2022; Puji et al., 2022b).

COLLECTION, CHARACTERIZATION, AND CONSERVATION

A collection of local rice varieties was conducted in tidal swamplands of South Kalimantan in 1994. Each collected variety was assigned a registration number. Out of the 143 registered numbers, several varieties shared the same name, resulting in the identification of only 82 distinct local varieties based on their designated names (Sulaiman et al., 1995). Among the well-known local varieties in tidal swamplands of South Kalimantan are Siam, Bayar, Pandak, and Lemo variety groups. The Siam variety group is notably prevalent, known by various names at the farmer level. These variations in nomenclature often relate to differences in grain shape, rice taste, farmer names, or unique characteristics recognized by local farmers (Khairullah et al., 2021).

Characteristics of local rice varieties in tidal swamplands of South Kalimantan are leaf angle ranging from intermediate to horizontal, flag leaf angle varying from erect to intermediate, leaf length measuring between 33-46 cm, while the flag leaf length falls within the range of 24-36 cm, leaf width typically ranges from 0.8-1.2 cm, and the flag leaf width similarly measures 0.8-1.2 cm; culm angle observed as erect to intermediate, tiller numbers varying between 7-19 tillers, with productive tiller numbers ranging from 7-17; ligule shape is cleft, with ligule length ranging from 0.5-2.3 cm; grains are awnless, slender, and translucent, with small and slender brown rice; panicles are well exerted, compact, with a droopy axis, plant height typically ranges from 80-125 cm (Mursyidin et al., 2019; Saleh and Khairullah, 2022).

The most popular local variety highly favoured by the farming communities in the tidal swamplands of South Kalimantan is Siam Unus. Additionally, Karangdukuh and Siam Unus Halus are also among the favourite varieties (Sabur et al., 2021). These rice varieties are renowned for their excellent taste, and small slender grain shape, yet they possess a relatively low yield potential, typically ranging between 1.5-2.0 t ha^{-1}. Moreover, they are susceptible to predation by rats and birds (Noorsyamsi et al., 1984). According to Calingacion et al. (2014), grain shape is also fundamental to developing new rice cultivars for swamp areas within Indonesia because local farmers and consumers have strong preferences for this trait. Most farmers in South Kalimantan Province cultivate and consume medium-sized rice grain, e.g., the so-called Siam group. Another distinguishing characteristic of these varieties is the clear and translucent appearance of the rice and its non-sticky texture (Khairullah and Saleh, 2020; Mursyidin et al., 2022).

Some local rice varieties exhibit relatively higher yields (ranging from 2.0-2.5 t ha^{-1}) and are less susceptible to attacks by rats and birds. These varieties possess greater adaptability but are noted for having less favourable taste. Among these varieties are Bayar Putih, Bayar Malintang, Lemo, Siam Ganal, and Pandak. Notably, the Lemo variety demonstrates resistance to flooding and low pH conditions, while Bayar Malintang exhibits considerable tolerance to salinity (Anwarhan, 1989). Five commonly cultivated local varieties in tidal swamplands of South Kalimantan have been characterized: Siam Unus, Karangdukuh, Pandak, Lemo, and Bayar Palas. Among these varieties, traits such as plant height, leaf length, stem length, 1000-grain weight, productive tillers, panicle length, and the number of primary branches in panicles showed narrow genetic diversity. However, yield and number of secondary branches in panicles exhibited wider genetic diversity (Khairullah, 2020; Sabur et al., 2021).

Several local varieties of tidal swamp rice collected in South Kalimantan underwent testing for resistance against brown planthoppers, stem borers, leaf blasts, midrib blight, and brown leaf spot (Sulaiman et al., 1995). Notably, there were no resistant varieties found against brown planthopper biotype 1; most varieties displayed slight susceptibility to susceptibility. Among the varieties, Siam Adil and Siam Ketumbar exhibited some resistance to stem borers. Regarding leaf blast resistance, the race 002 variety of Siam Arjan was classified as resistant, and Siam Unus showed moderate resistance. There were no resistant varieties found for leaf midrib blight disease, with most varieties classified as moderately susceptible to susceptible. However, Siam Pandak was identified as resistant to brown spot disease, whereas Siam Unus showed the least resistance (Sulaiman et al., 1995; Prayudi, 2000).

Concerning tolerance to submergence, both direct planting and transplanting, only Siam Unus and Pandak displayed the capability to recover after a 30 d submergence period. This information regarding agromorphology, resistance to pests and diseases, as well as submergence tolerance, holds significant importance when considering the utilization of a variety for developing new high-yielding varieties specifically tailored for tidal lands (Gusmiatun et al., 2015). All identified local rice varieties are subsequently conserved ex-situ in acidic sulphate tidal swamp land at the Indonesian Swampland Agricultural Research Institute (ISARI) experimental Installation.

UTILIZATION FOR BREEDING PROGRAMS

Genetic diversity is indispensable in forming a baseline population for natural selection and the evolutionary process (Govindaraj et al., 2015). In other words, this parameter has an essential role in the future evolutionary direction or as a precondition for future adaptive changes. Hence, it has important implications for future conservation and breeding programs (Lloyd et al., 2016). Understanding genetic diversity is essential for conservation by increasing the effectiveness and efficiency of the program. Some aspects of the program, such as loss of genetic diversity, are only addressed by extensive population genetic studies (Luan et al., 2006). For plant breeding, genetic diversity becomes more important in the context of climate change (Govindaraj et al., 2015).

Some of local varieties, known for their distinct characteristics, are utilized as crosses in the breeding program. The crossbreeding between local varieties of tidal swamp rice and superior varieties was first carried out in the tidal swamplands of South Kalimantan. The local varieties used include the Siam Unus variety, which is highly popular and favoured by farmers in South and Central Kalimantan (Sulaiman et al., 1995; Khairullah et al., 2021). Employing the single-cross method between Siam Unus and Cisokan and Dodokan (both high-yielding varieties of irrigated rice), a series of selected lines were developed. This initiative commenced in 1994 and, following various integrated breeding processes, led to the release of two new high-yielding varieties specifically tailored for tidal swamplands in 2000. These two swamp-specific high-yielding varieties were named Margasari (a cross between Siam Unus and Cisokan) and Martapura (derived from Siam Unus and Dodokan) (Sulaiman et al., 1995; Hidayani, 2023).

The Margasari and Martapura varieties were derived from crosses involving Siam Unus with Cisokan and Dodokan, respectively. Siam Unus, a locally favoured variety in South and Central Kalimantan, is known for its rice taste preferred by consumers and its tolerance to Fe toxicity. However, it has low yield potential and a longer growth (photoperiod sensitive) lasting 10 mo. On the other hand, Cisokan and Dodokan are HYVs of non-tidal swampland rice that possess a shorter growth duration (not sensitive to photoperiod) but demonstrate higher yield potential (Khairullah et al., 2019).

The crossing (Siam Unus and Cisokan or Dodokan) was conducted at Experimental Installation Banjarbaru in 1994 (Sulaiman et al., 1995). During the rainy season, the initial generations were planted using the Rapid Generation Advance procedure, involving 8 h of light and 16 h of darkness to hasten flowering. In the dry season, planting occurs in the field within a screen house. This approach allowed for the generation of two breeding cycles annually, thereby expediting the breeding period (Ikehashi et al., 1979), both Rapid Generation Advance (RGA) and field plantings utilized close spacing. Selection criteria were primarily focused on grain type, eliminating plants susceptible to pests and diseases. Harvesting was conducted in bulk to retain genetic variability while promoting increased homozygosity in the population (Khairullah et al., 2021; Puji et al., 2022a).

Individual plant selection commenced in the F_4 generation. The segregation of photoperiod-sensitive and insensitive genotypes was achieved by planting cross-generation populations during the rainy season, characterized by longer daylight periods compared to the dry season. The chosen plants were cultivated in a panicle-row system in the field to establish pedigree lines. The pedigree selection primarily focused on plant morphology, tolerance to Fe toxicity, slender grain shape, and resistance to pests and diseases under field conditions on acidic sulphate soil (pH 4) at the Experimental Installation Belandean, Barito Kuala Regency (ISARI, 1998).

The selected and promising lines were subsequently subjected to observation in the acidic sulphate soils of Belandean and Handil Manarap potential fields. The lines demonstrating favourable characteristics, including good acceptability, tolerance to Fe toxicity, and resistance to pests and diseases, were further evaluated in yield trials conducted on prospective lands encompassing peaty soil and acidic sulphate soil. The yield trials progressed in stages, initially starting with non-replicated trials, followed by replicated trials with plot areas measuring 1 m × 5 m, 3 m × 5 m, and 4 m × 5 m (ISARI, 1999).

To facilitate field testing, the lines underwent assessments for resistance against brown leafhopper, blast, and midrib blight, as well as evaluations for yield quality conducted by the ISARI pest research group (ISARI, 1998). The taste test data for rice underwent analysis using the Friedman test, a non-parametric statistical method based on ranking. These promising lines were also incorporated into a national multi-location test utilizing a randomized complete block design across acidic sulphate soils, peat soils, and potential lands (ISARI, 1999). In 2000, Margasari and Martapura varieties were introduced as novel HYVs specifically tailored for tidal swampland rice (Hidayat and Khairullah, 2018; Khairullah et al., 2019; ISARI, 2021). After the release of Margasari and Martapura varieties, further research was conducted by crossing other local rice with HYVs. This resulted in the development of new varieties such as IPB Batola 5R, IPB 1R Dadahup, IPB 2R Bakumpai, IPB Kapuas 7R, Inpara 1 Siam Hizinc, and Inpara 12 Siam Mayas (Table 1).

The two new HYVs Margasari and Martapura have promising potential for adoption and development in the tidal swamplands of South and Central Kalimantan, traditionally dominated by various local varieties. The two new HYVs Margasari and Martapura show potential for adoption and development in the tidal swamplands of South and Central Kalimantan, traditionally been dominated by various local varieties. This is partly due to the rice taste and grain shape, which are comparable to those of the local Siam Unus variety. The characteristics of Margasari and Martapura plants include scattered leaves, full panicle stalks that are prone to easy detachment, and a slightly sticky rice texture. However, a notable weakness of these superior varieties is their susceptibility to lodging, particularly during the harvest season in watery conditions and strong winds (Hidayani, 2023; Khairullah et al., 2021). In breeding programs, lodging is a limiting factor on potential yields because it can reduce the canopy for photosynthesis, increase respiration and susceptibility to disease, and limit the translocation of nutrients and C to the grain (Wu et al., 2011). Ünan et al. (2013) report that lodging is correlated with plant height. At the molecular level, the plant height variations are controlled by a gene regulator, i.e., rice plasticity 1 (RPL1), located on chromosome 6 (Nayar, 2014).

The leaf structures of Margasari and Martapura, which are not too erect or scattered, are anticipated to inhibit weed growth. The long panicle stalk facilitates easier harvesting for farmers using the *ani-ani* tool (Khairullah, 2020). The grains' tendency to easily detach is preferred by farmers employing traditional threshing methods. The slender grain shape, bright colour, and desired rice taste are expected to command higher prices. Their moderate maturity allows for a biannual planting system. Genetically, the shape of the rice grain is determined by several traits, e.g., weight, length, width, and thickness (Zheng et al., 2015). At the molecular level, several genes (QTL), such as *Dwarf1* (D1), *GS3*, and *GW2*, control this trait (Fu et al., 2015; Zhou et al., 2015). Zhou et al. (2015) reported that *GS3* affects the grain length and weight, whereas *GW2* is related to grain width and weight.

Table 1. Superior varieties resulting from crossing local rice and high-yielding varieties (HYVs), or purification of local rice in tidal swampland in South and Central Kalimantan. Source: Data were processed from the description of new HYVs (Sastro et al., 2021).

Nr	Superior varieties	Crossing/Promising Line/Purification	Main characteristics	Year released
1	Margasari	Siam Unus/Cisokan KAL9414d-Bj-63-1	Plant duration 120-125 d, grain shape slender, yield 3-4 t ha^{-1}, tolerant to Fe toxicity and pH 4, moderately resistant to brown planthopper 2	2000
2	Martapura	Siam Unus/Dodokan KAL9420d-Bj-276-3	Plant duration 120-125 d, grain shape slender, more length than Margasari, potential yield 3-4 t ha^{-1}, tolerant to Fe toxicity and pH 4, moderately resistant to blasts	2000
3	IPB 1R Dahahup	Siam Mutiara/Fatmawati IPB100-F-25-DJ-1	Plant duration 112 d, grain shape slender, yield 4.7 t ha^{-1}, moderately tolerant to Fe toxicity, moderately resistant to brown planthopper 1	2010
4	IPB 2 R Bakumpai	Siam Mutiara/Fatmawati IPB100-F-25-DJ-2	Plant duration 110 d, grain shape slender, yield 5.1 t ha^{-1}, moderately tolerant to Fe toxicity, moderately resistant to brown planthopper 2-3, blasts	2010
5	IPB Batola 5R	Siam Sapat/Fatmawati IPB107-F-7-9-DJ-1	Plant duration 116 d, grain shape slender, yield 5.3 t ha^{-1}, moderately tolerant to Fe toxicity, moderately resistant to brown planthopper 1, blasts	2012
6	IPB Batola 6R	Siam Sapat/Fatmawati IPB107-F-18-4-DJ-1	Plant duration 117 d, grain shape slender, yield 4.9 t ha^{-1}, moderately tolerant to Fe toxicity, moderately resistant to blasts 133	2012
7	Inpara 11 Siam Hizinc	Mendawak/Siam Rukut//Cisantana B14746E-KA-20-1-1-MR-1	Plant duration 122 d, grain shape medium, yield 6.07 t ha^{-1}, zinc content 33.9 ppm, moderately tolerant to Fe toxicity and salinity, moderately resistant to brown planthopper 1, 2, 3 and to blasts 073	2022
8	Inpara 12 Mayas	Mutation Siam Mayas by gamma rays 200 Gy	Plant duration 117 d, grain shape slender, yield 8.4 t ha^{-1}, moderately tolerant to Fe toxicity, moderately resistant to brown planthopper 1, 2, 3, resistant to blasts 173	2022
9	Inpara IPB Kapuas 7R	Siam Sapat/Fatmawati IPB107-F-60-1-1	Plant duration 112 d, grain shape slender, yield 5.1 t ha^{-1}, moderately tolerant to Fe, Al toxicity, resistant to blasts 033.	2012
10	Siam Mutiara	Purification of local tidal Siam Mutiara rice variety	Plant duration 255 d, grain shape slender, yield 5.68 t ha^{-1}, tolerant to Fe toxicity	2008
11	Siam Saba	Purification of local tidal Siam Saba rice variety	Plant duration 240 d, grain shape slender, yield 5.5 t ha^{-1}, tolerant to Fe toxicity	2008
12	Siam Epang	Purification of local tidal Siam Epang rice variety	Plant duration 135-140 d, grain shape slender, yield 7.0 t ha^{-1}, moderately tolerant to Fe toxicity	2018
13	Argo Pawan	Purification of local tidal Argo Pawan rice variety	Plant duration 135-140 d, grain shape slender, yield 6.47 t ha^{-1}, tolerant to Fe toxicity	2020

CONCLUSIONS

A significant portion of tidal rice fields in South Kalimantan, Indonesia, is still used for growing local rice varieties. The presence of these varieties is closely tied to their adaptability and acceptability among farmers. Various local rice varieties planted by farmers include Siam, Bayar, Pandak, and Lemo varieties. These local varieties have been collected, identified, and conserved ex-situ in the tidal fields of South Kalimantan. The technology of local varieties of rice cultivation includes seeding, transplanting, land preparation, fertilizing, maintaining, and controlling pests, harvesting, and post-harvest processing carried out traditionally. Numerous local varieties, collected and conserved, undergo crossbreeding with superior varieties to generate new high-yielding varieties with flavours favoured by the local populace. Siam Unus serves as the local variety for crossbreeding, while the superior varieties include Cisokan and Dodokan. The crossbreeding of Siam Unus with Cisokan yields Margasari variety, and with Dodokan, it produces Martapura variety. These varieties enjoy significant popularity among farmers and local communities in tidal areas of South and Central Kalimantan.

Author contribution

Conceptualization: I.K., M.N., A.H. Methodology: I.K., A.N., Y.Y., A.F., S.N. Validation: I.K., H.S., H.SS. Formal analysis, Investigation: I.K., S.N., A.F., R.B.H., A.H. Resources: I.K., I.G.K., Y.R., N.S.S. Writing-original draft: I.K., A.H., S.N, A.F., M.N., H.SS. Writing-review & editing: I.K., Y.Y., Y.R. H.S., R.B.H., I.G.K. Funding acquisition: A.H., Y.R. Visualization: I.K., N.N.S, A.F., S.N., A.N. All co-authors reviewed the final version and approved the manuscript before submission.

References

Anwarhan, H. 1989. Tidal and swamp rice cultivation. p. 551-577. In Ismunadji, M., Syam, M., Yuswandi. (eds). Rice Book 2. Food Crop Research Center. Indonesian Agency for Agricultural Research and Development, Bogor. (In Indonesian)

Azeez, M.A., Adubi, A.O., Durodola, F.A. 2018. Landraces and crop genetic improvement. p. 1-20. In Grillo, O. (ed.) Rediscovery of landraces as a resource for the future. IntechOpen, London, UK.

BPS-Statistic of Barito Kuala Regency. 2014. 2018. 2021. Monthly rainfall in Barito Kuala Regency in 2014, 2018, 2021. BPS-Statistic of Barito Kuala Regency, Marabahan, Indonesia. (In Indonesian)

Calingacion, M., Laborte, A., Nelson, A., Resurreccion, A., Concepcion, J.C., Daygon, V.D., et al. 2014. Diversity of global rice markets and the science required for consumer-targeted rice breeding. PLOS ONE 9(1):e85106.

Craft, C.B. 2016. Creating and restoring wetlands: From theory to practice. Elsevier, New York, USA.

Das, T., Das, A.K. 2014. Inventory of the traditional rice varieties in the farming system of Southern Assam: A case study. Indian Journal of Traditional Knowledge 13:157-163.

Fu, J.R., Zhu, L.X., Sun, X.T., Zhou, D.H., Ouyang, L.J., Bian, J.M., et al. 2015. Genetic analysis of grain shape and weight after cutting rice husk. Genetics and Molecular Research 14(4):17739-17748.

Govindaraj, M., Vetriventhan, M., Srinivasan, M. 2015. Importance of genetic diversity assessment in crop plants and its recent advances: An overview of its analytical perspectives. Genetics Research International 2015:431487. doi.org/10.1155/2015/431487.

Gunawan, H., Kobayashi, S., Mizuno, K., Kono, Y. 2012. Peat swamp forest types and their regeneration in Giam Siak Kecil-Bukit Batu Biosphere Reserve, Riau, East Sumatra, Indonesia. Mires and Peat 10(5):1-17.

Gusmiatun, Rujito, Suwignyo, A., Wijaya, A., Hasmeda, M. 2015. Increasing submergence tolerance of local swamp rice by introgression of *Sub1* gene. Indonesian Journal of Agronomy 43(2):99-104.

Hafiz, M., Hidayat, T., Yanti, N.D. 2020. Rice farming analysis between local and advanced varieties in Martapura Barat District, Banjar Regency. Frontier Agribisnis 1(4):84-88. (In Indonesian)

Hairani, A., Noor, M., Alwi, M., Saleh, M., Rina, Y., Khairullah, I., et al. 2024. Freshwater swampland as food buffer during El Niño: Case study in South Kalimantan, Indonesia. Chilean Journal of Agricultural Research 84:132-143. doi:10.4067/S0718-58392024000100132.

Hairani, A., Alwi, M., Noor, M., Khairullah, I., Saleh, M., Wakhid, N. 2023. Rice productivity on the swampland flooded tide: The case of Terusan Karya Village. E3S Web of Conferences 444:04013 doi:10.1051/e3sconf/202344404013.

Hidayani, S. 2023. The development of local rice variety in South Kalimantan province. Journal of Development Policy 18(2):225-238.

Hidayat, A.R., Khairullah, I. 2018. The Margasari and Siam Mutiara varieties: national superior and local varieties of tidal rice from South Kalimantan. p. 170-17. In Yusriadi et al. (eds.) Proceedings of the National Seminar on Utilizing Specific Local Potential for Sustainable Agriculture. Lambung Mangkurat Universitas Press, Banjarmasin, Indonesia. (In Indonesian)

Idak, H. 1982. Development and history of rice fields in South Kalimantan. South Kalimantan Regional Government, Banjarmasin, Indonesia. (In Indonesian)

Ikehashi, H., HilleRisLambers, D., Vergara, B.S., Eunus, Rd. 1979. Manual for rapid generation advance. International Rice Research Institute (IRRI), Los Baños, Philippines.
ISARI. 1998. 1999. 2001. 2021. Research Results Report for 1997, 1998, 2000, 2020. Indonesian Swampland Agricultural Research Institute (ISARI). Banjarbaru. (In Indonesian)
Iskandar, J., Ellen, R. 1999. In situ conservation of rice landraces among the Baduy of West Java. Journal of Ethnobiology 19(1):97-125.
Khairullah, I. 2020. Indigenous knowledge cultivation of local rice varieties "Siam Mutiara" and "Siam Saba" at tidal swampland. BIO Web of Conferences 20:01007. doi:10.1051/bioconf/20202001007.
Khairullah, I., Asim, Azwar, Hayati, I. 2019. Yield stability of rice lines at acid sulfate soils and peaty soils to increase tidal swampland productivity. Jurnal Pertanian Agros 21(2):182-190. (In Indonesian)
Khairullah, I., Saleh, M. 2020. Traditional cultivation technology of local rice varieties at tidal swampland. Jurnal Pertanian Agros 22(2):168-179. (In Indonesian)
Khairullah, I., Saleh, M., Mawardi. 2021. The characteristics of local rice varieties of tidal swampland in South Kalimantan. IOP Conference Series: Earth and Environmental Science 762:012009. doi:10.1088/1755-1315/762/1/012009.
Lloyd, M.M., Makukhov, A.D., Pespeni, M.H. 2016. Loss of genetic diversity as a consequence of selection in response to high pCO_2. Evolutionary Applications 9:1124-1132. doi.org/10.1111/eva.12404.
Luan, S., Chiang, T.Y., Gong, X. 2006. High genetic diversity vs. low genetic differentiation in *Nouelia insignis* (Asteraceae), a narrowly distributed and endemic species in China, revealed by ISSR fingerprinting. Annals of Botany 98:583-589. doi.org/10.1093/aob/mcl129.
Mehner, T., Tockner, K. (eds.) 2022. The best management practices in agriculture for protection of inland water ecosystems - Encyclopedia of Inland Waters. 2nd ed. Elsevier, New York, USA. doi:10.1016/B978-0-12-819166-8.00042-6.
Mursyidin, D.H., Khairullah, I. 2020. Genetic evaluation of tidal swamp rice from South Kalimantan, Indonesia based on the agro-morphological markers. Biodiversitas 21(10):4795-4803.
Mursyidin, D.H., Khairullah, I., Syamsuddin, R. 2022. Genetic diversity and relationship of Indonesian swamp rice (*Oryza sativa* L.) germplasm based on agro-morphological markers. Agriculture and Natural Resources 56:95-104. doi:10.34044/j.anres.2021.56.1.09.
Mursyidin, D.H., Purnomo, Daryono, B.S. 2021. The ligule ultrastructure of the tidal swamp rice (*Oryza sativa*) landraces of South Kalimantan, Indonesia, and their genetic diversity and relationship. Biodiversitas 22(12):5280-5285.
Mursyidin, D.H., Purnomo, Sumardi, I., Daryono, B.S. 2019. Phenotypic diversity of the tidal swamp rice (*Oryza sativa* L.) germplasm from South Kalimantan, Indonesia. Australian Journal of Crop Science 13(3):386-394.
Nayar, N.M. 2014. Origins and phylogeny of rices. Academic Press, Oxford, UK.
Nazemi, D., Saragih, S., Annisa, W., Mukhlis. 2007. In-situ organic matter management in the *Tapulikampar* system land preparation to support environmentally friendly agriculture on acid sulfate land. p. 446-449. In Rostini, N., et al. (eds). Symposium and Seminar Proceedings and Congress of the IX of Indonesian Agronomic Association. Padjadjaran University, Bandung, Indonesia. (In Indonesian)
Noor, M. 1996. Marginal land rice. Penerbar Swadaya Publisher, Jakarta, Indonesia. (In Indonesian)
Noorsyamsi, H., Anwarhan, H., Sulaiman, S., Beachell, H.M. 1984. Rice cultivation in the tidal swamps of Kalimantan. In Workshop on Research Priorities in Tidal Swamps Rice. International Rice Research Institute (IRRI), Los Baños, Philippines.
Nugroho, K., Paidi, A., Wahidin, W., Abdulrachman, Suhardjo, H., Widjaja Adhi, I.P.G. 1992. Map of potential areas for agricultural development of tidal swampland, swamplands, and coastal areas. Land Resources Research Project. Soil and Agroclimate Research Center, Bogor, Indonesia. (In Indonesian)
Ogunbayo, S.A., Ojo, D.K., Popoola, A.R., Ariyo, O.J., Sie, M., Sanni, K.A., et al. 2007. Genetic comparison of landraces rice accessions by morphological and RAPDs techniques. Asian Journal of Plant Sciences 6(4):653-666.
Panhwar, Q.A., Naher, U.A., Shamshuddin, J., Radziah, O., Hakeem, K.R. 2016. Management of acid sulfate soils for sustainable rice cultivation in Malaysia. p. 91-104. In Hakeem, K.R., Akhtar, J., Sabir, M. (eds.) Soil science: Agricultural and environmental prospectives. Springer International Publishing, Cham, Switzerland.
Prayudi, B. 2000. Tolerance of local tidal swamp rice to rice leaf sheath blight (*Rhizoctonia solani*). Agronomy Bulletin 77(2):37-40. (In Indonesian)
Puji, H.K., Deasy, A., Ismi, R. 2022a. Preserving the sustainability of natural resources and agro-ecosystems in tidal swampland through local wisdom in Indonesia. Journal of Sustainability Science and Management 17(5):77-97. (In Indonesian)
Puji, H.K., Sumarmi, Budijanto, Utama, D.H. 2022b. Ethno agriculture of the Banjar Tribe in tidal swampland. MNC Publishing, Malang, East Java, Indonesia. (In Indonesian)
Qurani, I.Z., Lakitan, B. 2021. Inland swamp agriculture: Opportunities and challenges. TJF Brief April 2021, Tay Juhana Foundation, Jakarta, Indonesia.
Rao, I.S., Neeraja, C.N., Srikanth, B., Subrahmanyam, D., Swamy, K.N., Rajesh, K., et al. 2018. Identification of rice landraces with promising yield and the associated genomic regions under low nitrogen. Scientific Reports 8(1):9200.

Sabur, A., Qomariah, R., Mailen, L. 2021. Marketing analysis of “Siam” local rice in South Kalimantan during the pandemic of Covid-19. Proceeding E3S Web of Conferences 306:02017. doi:10.1051/e3sconf/202130602017.

Saleh, M., Khairullah, I. 2022. The performance of grain yield and variability of ten high-yielding varieties of rice at tidal swampland. IOP Conference Series: Earth and Environmental Science 1025:012032. doi:10.1088/1755-1315/1025/1/012032.

Sanghera, G.S., Kasyap, S.C., Parray, G.A. 2013. Genetic variation for grain yield and related traits in temperate red rice (*Oryza sativa* L.) ecotypes. Notulae Scientia Biologicae 5(3):400-406.

Sastro, Y., Suprihanto, Hairmansis, A., Hasmi, I., Satoto, Rumanti, I.A., et al. 2021. Description of new high-yielding rice varieties of 2021. Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture, Jakarta, Indonesia. (In Indonesian)

Shamshuddin, J., Elisa, A.A., Shazana, M.A.R.S., Fauziah, I.C. 2013. Rice defense mechanisms against the presence of excess amounts of Al^{3+} and Fe^{2+} in the water. Australian Journal of Crop Science 7(3):314-320.

Simatupang, R.S., Nurita. 2010. Conservation soils tillage technology and its implementation in increasing rice production in tidal swampland. p. 863-876. In Abdulrachman, S. et al. (eds.) Book 2. Proceedings of the National Seminar on Rice Research Results. Center for Rice Research, Indonesia Agency for Agricultural Research and Development, Sukamandi, Indonesia. (In Indonesian)

Simatupang, R.S., Nurita, D., Nazemi. 2014. Technological innovation in structuring and preparing tidal swampland. p. 49-72. In Nursyamsi, D., Noor, M., Khairullah, I., et al. (eds.) Tidal swampland innovation technology supports national food sovereignty. Indonesia Agency for Agricultural Research and Development (IAARD) Press, Jakarta, Indonesia. (In Indonesian)

South Kalimantan Agriculture Service. 2006. Annual Report for 2005. Food Crop Agriculture Service of South Kalimantan Province, Banjarbaru, Indonesia.

Sulaeman, Y., Maftu’ah, E., Mukhlis, Anwar, K., Karolinoerita, V., Wakhid, N., et al. 2022. Tidal rice yield assessment in central Kalimantan, Indonesia, under different cultural practices. Resources 11:116. doi:10.3390/resources11120116.

Sulaiman, A.A., Sulaeman, Y., Minasny, B. 2019. A framework for the development of wetlands for agricultural use in Indonesia. Resources 8(1):34.

Sulaiman, S., Sutami, Rosmini, Murjani, Khairullah, I., Nurlaila, et al. 1995. Improvement of superior varieties of photoperiod-sensitive swamp rice. p. 133-171. Report on Research Results of Banjarbaru Food Crop Production Techniques Research and Development Project on 1994/95. (In Indonesian)

Sulakhudin, S., Hatta, M. 2018. Increasing productivity of newly opened paddy fields in tidal swampy areas using a local-specific technology. Indonesian Journal of Agricultural Science 19(1):9-16.

Susanti, M.A., Tamrin, M., Asikin, S. 2016. Management of insect major pest of rice in tidal swampland. Proceedings of National Seminar on Wetlands 1:170-179. (In Indonesian)

Thomson, M.J., Polato, N.R., Prasetiyono, J., Trijatmiko, K.R., Silitonga, T.S., McCouch, S.R. 2009. Genetic diversity of isolated populations of Indonesian landraces of rice (*Oryza sativa* L.) collected in East Kalimantan on The Island of Borneo. Rice 2:80-92.

Ünan, R., Sezer, İ., Şahin, M., Mur, L.A.J. 2013. Control of lodging and reduction in plant length in rice (*Oryza sativa* L.) with the treatment of trinexapac-ethyl and sowing density. Turkish Journal of Agriculture and Forestry 37:257-264.

Wang, Y. 2020. Wetlands and habitats. CRC Press, Boca Raton, Florida, USA.

Widjaja-Adhi, I.P.G., Suriadikarta, D.A., Sutriadi, M.T., Subiksa, I.G.M., Suastika, I.W. 2000. Management of utilization and development of swamp land. p. 127-164. In Adimihardja, A., Amien, L.I., Agus, F., Jaenuddin, D. (eds.) Indonesia’s land resources and management (Bogor Soil and Agroclimate Research Center) (In Indonesian)

Wiggin, G. 1976. Buginese agriculture in the tidal swamps of South Sumatra. Central Agricultural Research Institute, Bogor, Indonesia.

Wijaya, Bernard, C.H., Purnomo, E., Hashidoko, Y. 2007. Physico-chemical properties, sensory characteristics and glycemic index of tidal peat swamp rice grown in South Kalimantan. ASEAN Food Journal 14(1):37-43.

Wu, L-L., Liu, Z-L., Wang, J-M., Zhou, C-Y., Chen, K-M. 2011. Morphological, anatomical, and physiological characteristics involved in development of the large culm trait in rice. Australian Journal of Crop Science 5(11):1356-1363.

Zauhari, R.M. 2001. Wetland development in regional autonomy. Paper at the 8th lustrum of Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, Indonesia. 13 October 2001. (In Indonesia)

Zheng, J., Zhang, Y., Wang, C. 2015. Molecular functions of genes related to grain shape in rice. Breeding Science 65(2):120-126.

Zhou, Y., Miao, J., Gu, H., Peng, X., Leburu, M., Yuan, F., et al. 2015. Natural variations in SLG7 regulate grain shape in rice. Genetics 201(4):1591-1599.