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STRATEGIES AND TECHNOLOGIES FOR THE UTILIZATION AND IMPROVEMENT OF RICE

Editors:
Puji Lestari | Karden Mulya | Dwinita Wikan Utami
Dani Satyawan | Supriadi | Mastur

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PREFACE

ASEAN countries are the main consumers of rice with the average consumption per capita of 2.5 times of the world average. Therefore, improving rice production in the region is crucial for ensuring global food security. However, the increase in rice production is confronted with competition in land use that is driving agricultural land to be expanded in marginal areas and the negative impacts of climate change. In addition to growing population, these areas are not easily replaceable either, since climate change can accelerate when land opening and deforestation are carried out. To overcome those of the obstacles need new rice technologies including new environment adaptable varieties.

This book aims to address those challenges, by first conducting a review of the approaches that have been conducted in the past, to identify areas that had been exploited successfully and other approaches that need to be further optimized to address the future challenges more effectively. New techniques that are beginning to be implemented or showing potentials for rice characterization and improvement in the future are also explored. In addition, rice genetic resources, which are the raw materials for rice improvement, also need to be considered. Each rice-consuming country typically has its own breeding program and genetic resource collection, and a closer collaboration for research and exchange of materials needs to be sought to expand the genetic and technological bases in each country. In particular, an important field of technology currently needed by Indonesia is cultivation technology for underutilized lands, with the emphasis on swamplands. Therefore, the potential for productivity gains in these lands is quite significant. Several variables are open to improvement, including the choice of cultivars, agronomic practices, soil amelioration, and water management.

This book constists three chapters covering policies, strategies, and tools on breeding program and use of local rice varieties, the potential of swamps land for the expansion of rice cultivation areas and available technology, and genetic diversity of local rice in swamp area and their use and development for rice production for it's contribution to food security. This book contains articles those have been presented at the national workshop on "Co-development and Transfer of Rice Technologies" held in Banjarbaru-South Kalimantan, Indonesia, 2019, and some others are purposively written for this book. The purpose of this book is to introduce the scientific community and policy maker, the diversity of landraces/local variety and their use in breeding program and in rice production in swamp land.

The chapter one covered the limiting factor in increasing rice production in Indonesia, People Democratic Republic of Lao, Malaysia, and the Philippine, including their policies and strategies in rice breeding program. It was described that landraces/local rice varieties in every country are potential genetic materials that should be stepped forward their genetic by means of a breeding approach in parallel with their conservation activities and preservation purposes. Research on genetic diversity supported molecular markers is required to facilitate the efficient use of local genetic resources.

The chapter two described the characteristics, the limiting factors, and the available technologies for development of swampland as an alternative in expansion of rice farming area. Peatlands in tidal swamp ecosystems are often associated with pyrite layers located in the lower layers, which become acidic during the dry season. Most peat soils from the tidal swamp ecosystem are in the early stage in the decomposition of organic matter in the process of peat formation ("fibric") and even more in the upper layer. Therefore, to develop tidal swampland to be productive land need proper management through the application of appropriate technology.

The chapter three covered research on genetic diversity analysis and breeding program of rice for adaptation to swamp land ecosystem, and practical use both of local and modern varieties in production of rice in swamp area. The development of rice cultivation in tidal swamps has been in effect for a long time. The genetic diversity of rice in this area is rich, presumably due to variations in adaptation to existing natural challenges and local community habits. For this reason, the development of new varieties in swamps is not only a matter of overcoming environmental stresses but also fulfills community preferences.

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Bogor, December 2020

Editors

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PROLOGUE THE URGENCY OF UTILIZATION OF LOCAL GENETIC RESOURCES FOR RICE IMPROVEMENT

Karden Mulya, Dwinita Wikan Utami, and Puji Lestari

Food security issues are the crucial priority for the global economy and people's livelihood. The latest analysis shows that to meet food needs in 2050, cereal production must increase between 26–68 percent from 2014 levels. Recently, Asian Development Bank projected that in Southeast Asia (ASEAN) rice consumption will expand from 100.0 million tons in 2011 to 111.3 million tons in 2021, attaining a growth of 1% annually. The average ASEAN rice consumption per capita is 2.5 times the world average, and at the top is Bangladesh with 171.7 kg/capita/year. The Lao PDR, Indonesia, Philippines and Malaysia consume rice at 162.3, 134.6, 119.4 and 79.9 kg/capita/year, respectively. Therefore, improving rice production is crucial for ensuring global food security.

The rice production system in ASEAN has over recent years challenged by growing population and global climate change impacting the environmental stresses, agricultural land conversion, and the change of consumer's preference for food quality. The number of people suffering from hunger has increased over the last three years, as well as the number of people suffering from obesity. Obesity is often associated with chronic illness such as hypertension, diabetes, heart diseases, and some forms of cancer. Today, more than 670 million adults are obese. Some projections estimate that the number of obese people will very soon overtake the number of people suffering from hunger in the world, which accounted for 821 million in 2017. It costs about US$ 2 trillion per year in direct healthcare and lost economic productivity. This is equivalent to the impact of smoking or the impact of armed conflicts.

According to the FAO, between 2005 and 2015 natural disasters cost the agricultural sectors of developing country's economy staggering of US$ 96 billion in damaged or lost crop and livestock production, and half of the damages occurred in Asia. As such disasters are predicted to be more common due to climate change, it will create even more pressure to improve productivity to compensate for productivity loss during such events, and to create hardier crops that can withstand extreme growth conditions. Taking into account the opportunities for population concentration in urban areas, land shifts due to non-agricultural needs, and the possibility of increasing population income in the future, rice cultivation needs to be supported by new technologies and innovations. Therefore, breeding for rice not only increased in terms of quantity, but also improved the quality of nutrition and diverse consumer preferences. So that the improvement of rice varieties not only meets the objectives of increasing production in new planting areas and is more adaptive to climate change, but also meets consumer tastes.

Generally, there are two ways to increase the rice grain, firstly, increasing cultivation areas, and, secondly, enhancing productivity. Expanding the cultivation area for the rice was focused to the non-arable area such as marginal or suboptimal land. While, enhancing rice productivity is adopting technological innovations. As a consequence, since fertile agricultural land for rice is decreasing due to conversion to non-agricultural uses, rice cultivation was extended to marginal or suboptimal land. To overcome the scarcity of fertile agricultural land, the Indonesian government has planned to use swampland in purpose for increasing rice production. The usage of suitable varieties for swampland ecosystems is the one among the important efforts in using the swamplands for rice production. Importantly, narrowing yield gap in the rice production of suitable varieties according to researcher recommendation and farmer's practice in the field is taken in account to ensure food security.

The importance of the range of local germplasm including local sorts of the plant is being recognized nowadays as a valuable genetic resource for future crop improvement and it's contribution to food security. Varieties must be adaptive to the physical environment of the lands and in accordance with a specific local culture that's to certain sorts of adaptive rice and cultivation methods. Landraces/local rice varieties in every country are potential genetic materials that should be stepped forward their genetic by means of a breeding approach in parallel with their conservation activities and preservation purposes. Research on genetic diversity supported molecular markers is required to facilitate the efficient use of local genetic resources.

Several breeding targets for rice improvement are addressed to unravel the obstacle on increasing rice production under the global climate change condition pressure, like resistance to biotic and tolerance to abiotic stresses. Blast and bacterial leaf blight (BLB) are the one of significantly constrain in lowland rice production in temperate and subtropical Asia, and upland rice in tropical Asia, Latin America, and Africa. Breeding for drought, submergence tolerance and enhanced yield in flash-flood areas has been getting to be a crucial target for abiotic seriously constrain on rice production. In addition, rice plants play a lively role as a medium for transporting methane from the rice fields into the atmosphere. Flooding conditions are ideal conditions for the continual decomposition of organic materials within the swampland. The power of rice plants to emit methane varies counting on the physiological and morphological properties of a spread. Additionally, each variety features a different plant growth and root activity which is closely associated with the quantity of methane emissions.

Recently, the genetic techniques and genomics tools including advances in breeding techniques and precise phenotyping probably reveal the candidate genes and metabolic pathways underlying the trait targets of breeding programs. Certain genes and proteins related to important traits are expressed in rice and alter their expression under the strain condition. Therefore, different disciplines to rise understand rice plant responses to any production constrain and link this understanding with the breeding of improved cultivars associated with the target traits are important to be elucidated.

CHAPTER 1.
STRATEGY AND POLICY ON GENETIC RESOURCES MANAGEMENT FOR RICE BREEDING

Rice is one of leading crops in the world and more than 90% of rice is produced and consumed in Asia. In terms of food consumption, Asia is distinctive from the rest of the world according to its great dependency on rice and as the basic staple for the majority of the population. While other regions rely more heavily on other cereals.

Rice production system in Southeast Asia which has over recent years become newly challenged by growth population and climate change impacting to the environmental stresses, agricultural land conversion, and the change of consumer's preference on food quality. A number of programs addressing in management and evaluation of rice germplasm lines, and breeding have been evolved to pioneer the increased rice production and improved its quality. Landraces/local rice varieties in every country are potential genetic materials that should be improved their genetic by breeding approach in parallel with conservation activity.

To complement with the utilization of local genetic resources, rice breeding in the future must therefore be much more concerned with and oriented towards varietal technology development in the ecosystem perspective. The ecosystem-wise varieties released in Asia, Africa and Latin America in the post-green revolution period are more than two-thirds of efforts and results have focused on favorable agro-ecologies. On the other hand, marginal rice ecosystems, such as swampland, are more important from the point of view of household food and nutritional security, which placec greater emphasis on more rational breeding approaches, such as incorporating wide adaptability in rice genotypes or developing varietal, local farmers participation, and formal policies.

Since fertile agricultural land for rice is decreasing due to conversion to non-agricultural uses, rice cultivation was extended to marginal land. In 2000, marginal land use for agriculture reached 36 percent of the total global agricultural land. To overcome the scarcity of fertile agricultural land, swampland in South East Asean countries including Indonesia could be potential to contribute in increasing rice production. The use of swampland area for agricultural production in Indonesia has been a long history involving local communities. Provision of suitable varieties for swampland ecosystems is one of the important efforts in using the swamplands for rice production. Rice varieties must be adaptive to the physical environment of the lands and in accordance with local culture that is specific to certain types of rice and cultivation methods.

Sustainable rice production is the main goal to secure food globally and needs a well managed genetic materials. However, lack of precise information about the characterization and evaluation of conserved germplasm is the weakest link in many of the national, regional and global collections. Systematic characterization of the collected germplasm is then vital. The genetic resources generated in research institutions/stations - i.e.

released varieties, breeding lines, advanced material evaluated in coordinated trials, mutants, genetic stocks etc. - must be conserved. Many of the mutants developed, discarded and then lost, may have been vital for functional genomics, crucial for future breeding with great velocity and precision.

As the entire genus *Oryza* has been included in the agreed list of crops under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), it has thus become mandatory to facilitate the flow of materials for rice breeding. To support breeders, researchers, and farmers on utilization of plant genetic resources, the exchange of genetic material needs to be accompanied by an adequate exchange of information. The exchange of relevant scientific information of plant genetic resources under the Treaty is regulated in article 17 of the agreement and implemented by the Global Information System of the International Treaty (GLIS). The GLIS provides a standardized automated one-stop shop for plant genetic resources for food and agriculture (PGRFA) information around the world. It facilitates easy access to information on seeds and other crop material for research, training and plant breeding.

In addition to technologies in research and information, future rice breeding will essentially be guided by policy-setting and commensurate instruments for managing the change from the present scenario (focusing on seed for the public good or profit-making in an evenly placed public-private breeding environment showing elaborate responsibilities and contributions) to a future scenario dominated by new concerns and issues. Moreover, networks (of scientists) and consortia (of institutions) will be extremely important in the years ahead by capitalizing on complementarities and harness synergies at national, regional and global level.

This Chapter resumes a number of topics related to the limiting factor in increasing rice production in four ASEAN countries namely Indonesia, People Democratic Republic of Lao, Malaysia, and the Philippine, including their policies and strategies in rice breeding program. In addition, some landraces/local rice varieties in every country potential genetic materials that should be stepped forward their genetic by means of a breeding approach in parallel with their conservation activities and preservation purposes, and studies on genetic diversity supported molecular markers that are required to facilitate the efficient use of local genetic resources are discussed.

RICE VARIETAL DEVELOPMENT IN THE PHILIPPINES

Alvin D. Palanog, Leonilo Gramaje, Cielo Luz Mondejar, Mark Ian C. Calayugan, Marilyn C. Ferrer, Gerald E. Bello, Xavier Greg Caguiat, May Osano-Palanog, and Leo T. Sta. Ines

INTRODUCTION

The demands for rice continues to outweigh its domestic supply and achieving rice self-sufficiency and security have been the long-term goal of the Philippines. Rice production is constantly challenged with environmental, social, and political constraints that hamper its ability to meet its goals. Increasing productivity through increasing yield has been the primary goal to achieve the purpose of the rice sector. Improved yield potential is the priority trait of rice breeding in the country. However, the increasing yield is not only limited to genetic manipulation with several factors influence yield potentials of varieties such as resistance to biotic and abiotic factors and adaptability to varying environmental conditions. Thus, rice breeding is also directed in developing desirable traits not limited only to high yield such as pest resistance, drought, saline, and heat tolerance, good eating quality, and preferred by farmers and consumers (Palanog et al. 2020). Several breeding institutions are involved in varietal development in the country which includes: Philippine Rice Research Institute (PhilRice), International Rice Research Institute (IRRI), University of the Philippines Los Baños

(UPLB), and some private companies and each adopts various breeding strategies and practices. PhilRice is a government research institution tasked to develop technologies including rice varieties aimed at improving productivity and profitability of farmers. It is the leading breeding institution in the country that developed public inbred and hybrid rice varieties suited for various environmental conditions. It combines both conventional and molecular breeding tools to develop improved breeding lines for target ecosystems (Palanog et al. 2020). However, IRRI is considered a premier research institution in the world. Its pioneering work in rice breeding contributed to the Green Revolution in the 1960s (Mackill and Khush 2018). IRRI has been successful in infusing current and state-of-the-art technologies and basic research in developing advanced rice varieties. It works closely with other breeding institutions such as PhilRice and UPLB in developing varieties preferred by rice farmers and consumers. Though numerous varieties have been released, there are only few that have been extensively cultivated and popularized among farmers. This book chapter aims to review rice breeding strategies and programs designed by breeding institutions in the Philippines with special emphasis on the practices of PhilRice; popular varieties preferred by the farmers and their characteristics; current breeding practices being introduced; and the future direction of rice breeding in the country.

RICE SITUATION AND OUTLOOK

Rice is one of the major crops in the Philippines. For the past decade, the volume of rice production ranged from 15,770,000 to 19,280,000 million metric tons (mmt; Figure 1), with the highest volume of production in the year 2017. Harvest area from 2010 to 2019 had ranged from 4,350,000 to 4,810,000 hectares (ha) while

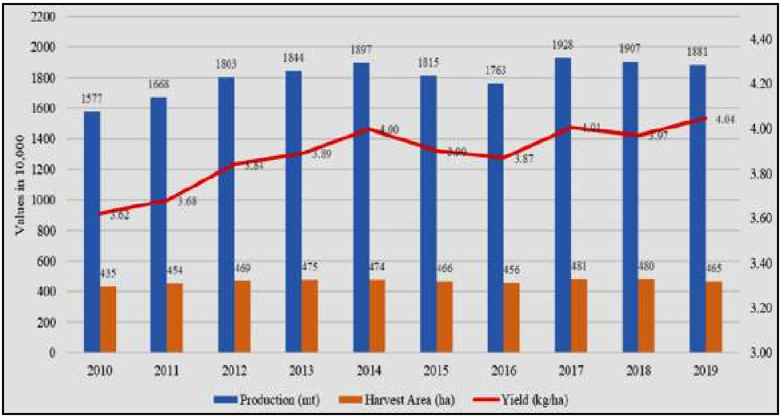

Figure 1. Annual rice production (mt), harvest area (ha) and yield (kg/ha) in the Philippines from 2010 to 2019. Source of data: Philippine Statistics Authority (PSA 2020).

crop yield ranged from 3.62 to 4.04 kilograms per hectare (kg/ha). Rice production increased from 2010 to 2014, then declined in 2015 to 2016, suddenly increased in 2017 [as the year with the highest volume], and decreased in the succeeding two years. From 2010 to 2013, the increase in the volume of production can be attributed to the increased in the harvest area and crop yield, while only the yield had heightened the rice production in 2014. On the contrary, the decreased in rice production in 2015 and 2016 had resulted from the decline in both harvested area and crop yield. Meanwhile, the decline in 2018 was caused by the decrease in crop yield. The highest crop yield was recorded in 2019, however, the harvest area was reduced which resulted to the decline in the volume of rice production that year.

The volume of rice production and rice area map per province in the year 2019 were presented in Figure 2. Pangasinan, Nueva Ecija and Isabela had the highest volume of production of more than 1,000,000 mt (Figure 2a). These three provinces are located in Luzon. These provinces had also the highest rice area in Luzon

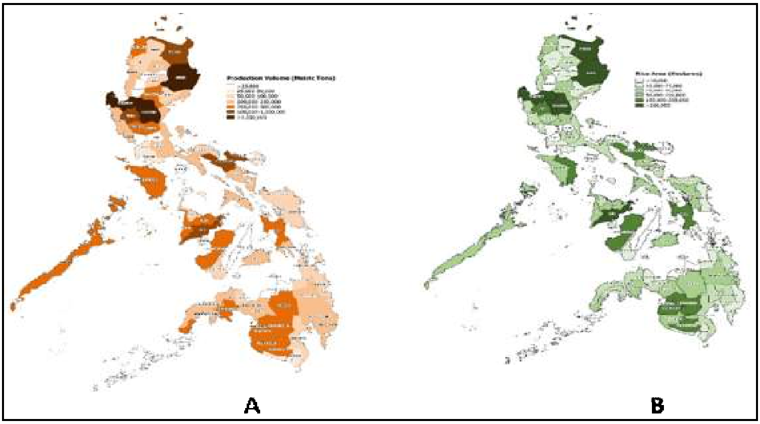

Figure 2. Volume of production in million metric tons (A) and production area (B) of rice per province in the Philippines in 2019. Source: PSA (2020).

including Cayagan with more than 200,000 hectares rice area (Figure 2b). Cagayan had production volume between 500,000 to 1,000,000 mt similar to Tarlac and Camarines Sur. Ilocos Norte, Nueva Viscaya, Pampanga, Bulacan, Occidental Mindoro and Palawan had rice production volume ranged from 250,000 to 500,000 mt, while the remaining provinces in Luzon had less than 250,000 mt volume. In the Visayas, Iloilo had the highest volume of rice production and rice area. Even though Negros Occidental and Leyte had a higher rice area than Antique and Capiz, they were in the same ranged of rice production volume. In Mindanao, the rice production volume of Bukidnon, Zamboanga del Sur, North Cotabato, Maguindanao, Sultan Kudarat and South Cotabato ranged from 250,000 to 500,000 mt. Among these provinces, only Maguindanao, North Cotabato and South Cotabato had the rice areas ranged 50,000 to 100,000 ha.

RICE BREEDING PROGRAMS AT PHILRICE

Being the staple food of the majority of the 100.98 million Filipinos (PSA 2015), the need to increase the rice supply should be given priority especially that the population was projected to increase up to 128 million people. As part of the national government goal of sufficiency by providing available, affordable, accessible and safe and nutritious food for the people, the Philippine Rice Research Institute is fully supportive through its research and development (R&D) program. As an attached agency to DA which aims to have competitive and sustainable rice industry through uplifting income and economic condition of rice farmers (www.officialgazzete.gov.ph), PhilRice maintains its eagerness to help out by developing varieties adaptable to different rice growing ecosystems such as in irrigated lowland, rainfed, upland, saline and flood-prone areas, cool elevated, and heat prone areas. The objective is to identify rice lines that are high yielding, with tolerance to abiotic and biotic stresses, and with good grain qualities. In PhilRice, plant breeding strategies were laid down first in collaboration with other disciplines involved such as the genetic resources, crop protection, agronomy, rice chemistry, engineering and mechanization, seed health, seed production team, and the technology management group.

Among the plant breeding priorities are increasing yield potential by exploiting the diverse germplasm, changing plant architecture, multiple resistance that could withstand to current pest and diseases, superior grain qualities, appropriate growth duration depending on the ecosystem and season, and efficient nutrient uptake and utilization (PhilRice 2016).

BREEDING FOR IRRIGATED LOWLAND (INBRED AND HYBRID RICE)

One of the targets is to develop high yielding inbred rice varieties with an attainable yield up to 10 ton/ha for dry season (DS) and 8 ton/ha during the wet season (WS). This is to up-scale the previous average yield of 5.3 ton/ha, and attainable yield of 8.3 ton/ha for DS and 7.6 ton/ha for WS (PhilRice 2016). To achieve this goal, ideotype breeding by changing the plant architecture, and developing new plant type (NPT) was reconsidered. Active involvement of plant breeders to other divisions like the, "walk through" in which breeders are invited to participate and interact with other researchers at field established by the genetic resource group, and to evaluate possible donor parents of a different trait of interest for line improvement. Apart from it, the combination of conventional and cutting-edge technologies is in place for faster and more target-oriented breeding program. As to date, NSIC 2006 Rc 160, NSIC 2009 Rc 216, NSIC 2009 Rc 218SR, NSIC 2012 Rc 300, NSIC 2015 Rc 402 are some of the PhilRice bred varieties that are famous to farmers because of its outstanding performance in terms of yield and grain qualities.

The exploitation of heterosis by capitalizing hybrid rice is also helpful in increasing rice production knowing that hybrid rice can offer 15%–20% or more yield advantage than the best high yielding inbred of the same growth duration (Virmani 1997; Tran 2004). Improvement of parental lines by marker-assisted backcrossing, and the use of a molecular marker to determine male sterile (MS) lines, and fertility restoring gene are among the activities that hasten the development and improvement of hybrids and parents. Assessing the [general combining ability (GCA) and specific combining ability (SCA)], and the establishment of heterotic groupings are also given much attention (Gramaje et al. 2020). Moreover, seed yield-enhancing traits are also considered to ensure that upcoming hybrids have increased seed production capacity to be commercially viable. Multi-environment trials (MET) are also done to identify best hybrids for nomination to national cooperative test (NCT). Currently, newly developed cytoplasmic male sterility (CMS) and thermo-genic male sterility (TGMS) based hybrids are now in the pre-commercialization stage. NSIC 1997 Rc 72H (M1) and NSIC 2009 Rc 204H (M20) are the two public hybrids that are widely commercialized in the Philippines.

BREEDING FOR RAINFED AND ADVERSE ENVIRONMENT: DROUGHT SUBMERGENCE, AND SALINITY

The need to intensify the breeding effort for rainfed lowland rice is important for its significant contribution in rice production of the country knowing that it covers 27.4% of the 2.76 million hectares rice area (BAS 2010). A lot of limitations could hamper the rice production and poses big challenge to the breeders. Screening the best lines from seeding, vegetative and reproductive stage is crucial because drought, submergence and salinity could occur in any of the stages which reduced yield up to 17 to 50% (Redfern et al. 2012). Understanding the mechanism of resistance is vital in designing a breeding strategy. Drought scape, avoidance and tolerance can be solved by using early maturing varieties, timing of planting, improving the root system and tolerant donor parents.

Submergence is common in low-lying areas in the country that may possibly happen several times in a year that affect rice yield. Flooding might occur at germination, seedling, tillering, and most damaging when reproductive stage. Thus, lines with anaerobic germination and submergence tolerance or with *Sub1* gene, and with regeneration ability are essential in breeding for this purpose. Currently, the improvement of lines using F13A and other donor parents identified with tolerant genes. These were used in marker-assisted breeding and advanced lines were evaluated at field condition.

Moreover, salinity is another threat in rice production especially in saline-prone coastal land in the Philippines with estimated area ranged from 0.4 to 0.6 million ha, of which 0.2 million ha are considered seriously salt-affected soils (IRRI Knowledgebank). A better understanding of the responses of the plant to salt stress and how to deal with it using conventional and modern technologies are the fastest way to develop or improve rice lines with tolerance to salinity. Furthermore, other desirable agronomic traits such as maturity and plant height, and with disease resistance especially to blast, and with good grain quality are part of the selections criteria, and exploitation of Pokkali as donor line is also studied (Mohammadi et al. 2008).

BREEDING FOR HEAT TOLERANT RICE

The breeding for heat-tolerant varieties is getting more attention to address the effect caused by the high-temperatures as a manifestation of global warming that could be a threat in rice production (Manigbas et al. 2018). Current strategies involved was to use Dular and N22 as donor parent of promising inbred varieties but with susceptibility to heat, and to come up with lines with heat tolerance and high yield. In addition, QTLs for high-temperature tolerance was found to be cross-specific depending on the parental combination. Marker-assisted selection can be utilized to hasten the breeding process for high-temperature tolerant rice (Grospe et al. 2016). Moreover, screening of lines using the glass-house is a good strategy. From the crosses made from 'dular' and N22, several advanced breeding lines produced desirable individuals with heat tolerance, resistance to pests and diseases, and high yield potential as exposed in high-temperature environments (Manigbas 2014).

BREEDING FOR A SPECIAL PURPOSE

The demand for special purpose rice has dramatically increased over the past years (Braceros et al. 2014), which resulted in increased demand in the international market. Special purpose rice is aromatic, glutinous, pigmented, and micro-nutrient dense (High Iron and Zinc). The objective is to develop specialty rice that is high yielding, resistant, and with excellent grain qualities (PhilRice 2016). It needs a rigid evaluation of lines from other countries, and existing modern and traditional varieties to select the ideal lines. Some of the important procedures in screening that needs thorough observation are kernel and a sensory evaluation by breeders, and aroma screening done in the laboratory. NSIC 2009 Rc 218SR is one of the most familiar special purpose rice bred by PhilRice because of its aroma and good grain quality.

BREEDING STRATEGIES AND PROGRAMS OF OTHER INSTITUTIONS

Front liners for service-driven rice breeding in the Philippines other than PhilRice include the *University of the Philippines Los Baños (UPLB), International Rice Research Institute (IRRI), and Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG).* Several business-oriented institutions also continued to develop new rice varieties in the country. Government and non-government organizations (NGOs), and private companies design their breeding programs fitted on the need of the target users particularly farmers.

Generally, breeding strategies comprise the following concepts: creating and exploiting genetic variability on the materials or germplasms used, hybridization or crossing pure-line parents which may vary depending on their preferred techniques and pedigree method as the most common selection method used. UPLB Rice Program continues to develop adaptive rice varieties through its Rice Varietal Improvement Program (RVIP). The program has conducted several rice breeding activities to breed desirable rice lines and improved commercially available rice varieties. Thus, UPLB as an academic institution has amassed a huge volume of information related to rice breeding and production such as the discovery of wild rice species, hybrid vigor, genetic and inheritance studies, and pest resistance screening. It also utilized new technologies and molecular-based approaches such as the development of superior thermo-genic male sterility (TGMS)-based hybrids and marker-assisted selection to complement conventional breeding strategies in producing rice varieties. The RVIP of the University of the Philippines Los Baños is a collaborative program of researchers from various disciplines of the College of Agriculture and Food Science and College of Human Ecology which spans for six decades. It researches on rice varietal improvement and technology development; trained undergraduate and graduate students majoring in plant breeding, crop physiology and agronomy; and actively involved in the rice varietal improvement group of the National Seed Industry Council. The objectives of the program were to develop sustainable and climate change-adaptive farming technologies and approaches for rice production through rice varietal improvement and integrated crop management; to enhance agricultural innovation through the participatory development of integrated rice-based agricultural system involving rice breeding, pest management, nutrient and water management; and within the context of integrated rice-based production, to enhance community participation in local governance and decision-making. The program at present have core and basic projects on rice germplasm collection, multiplication, characterization, evaluation, conservation and documentation; use of wild rice species to increase genetic diversity in rice breeding (wide hybridization); mutation breeding; and genetic profiling of UPLB elite breeding lines, parentals and traditional rice varieties (RVIT-UPLB 2019). Its current lead projects include national multi-environment testing (NMET) of drought-prone direct-seeded rainfed; development of rice varieties for rainfed lowland drought-prone environment; and improved resource-use efficient (iRUE) rice varieties for the Philippines (Sigari et al. 2014). The program also has a collaborative projects with PhilRice on the deployment of genetic resistance in the management of rice black bug; development of best management practices (BMPS) for mechanized dry direct seeding technology in rice-based environments in the Philippines; development of TGMS lines and TGMS-based two-line hybrid rice; and the national rice cooperative testing project (NCT). The program currently is gearing towards the application of modern research tools in the conduct of its activities such as molecular tools, rapid generation advance/speed breeding to hasten the development of improved varieties. Lastly, the end goal of the program is to create competitive rice varieties that can produce high yield at lower input cost in the midst of climate-change.

IRRI is known for its work in developing rice varieties that contributed to the Green Revolution in the 1960s. Its variety IR8 established the basic plant-type of the high-yielding varieties

(HYVs) we have today. Presently, IRRI still develops advanced rice varieties with superior grain quality, yield more grain, can withstand better in pests and diseases. HYVs are developed using quantitative genetics to improve the performance of elite breeding pool for key agronomic traits including yield. Rapid generation advance technology is used to accelerate breeding cycles. However, the elite breeding lines are crossed with existing high-yielding varieties to develop improved varieties with the use of genomic prediction to allow selection of superior recombinants in early generation breeding trials. IRRI continues to develop hybrid rice using CMS system. It also works on two-line hybrid rice breeding using TGMS system. Marker-aided selection (MAS) is being used in TGMS. The molecular breeding program in IRRI includes the use of a new gene- editing tool called CRISPR-Associated Protein (Cas)9 System. The rice breeding platform of IRRI develops and deploy innovative breeding strategies, tools, and technologies to sustainably enhance the genetic potential of rice for yield and its ability to tolerate biotic and abiotic stresses while improving the grain/nutritional quality and; help disseminate the new products faster to farmers. It is working on six key research areas (IRRI 2020). The first one is on breeding for marginal environments which aim to develop rice varieties resilient and adaptive to biotic and abiotic stresses for non-ideal growing areas. The second one is to breed for favorable environments that optimize rice varieties and cropping systems for intensive rice-growing areas. The third is breeding driven by emerging trends and market needs that develop product profiles for prioritized pipelines based on maturity, farming practices, and consumer preferences, including grain quality, aroma and nutrition. Fourth is breeding innovations with the goal of accelerating the rate of genetic gain through the adoption of innovative and modern breeding approaches and best practices, including precision phenotyping for key biotic, abiotic, grain and nutrition traits; breeding analytics; germplasm analyses; molecular breeding; pre-breeding; and genotyping support. Fifth is germplasm evaluation, seed system and product management which provides IRRI-bred germplasm and varieties to national agricultural research and extension systems (NARES) partners for testing and release through the national varietal testing and release system to ensure faster delivery of better products to farmers. And lastly, host plant resistance which targets to discover and apply the resistance of rice plants to various environmental stresses.

Rice breeding in MASIPAG has evolved beyond participatory plant breeding. Farmers are breeding their own rice, maintain germplasm in their own farms, select the materials by themselves, do cross-pollination, make selections of segregating lines, evaluate their selections, and share developed varieties with other farmers. Farmers are reinforced by other farmers, scientists and NGO workers. This approach aims to empower farmers when they are able to breed new varieties.

POPULAR VARIETIES IN THE PHILIPPINES

Before the "Green Revolution," the Filipino farmers were using traditional varieties. These varieties were found to be stable, adapted to local growing conditions, and have good eating qualities. At the beginning of the 1950s due to the growing population, the government was forced to shift to modern agriculture mostly increasing the use of synthetic fertilizers. However, since these traditional varieties were tall, applying nitrogen fertilizers make them prone to lodging which resulted to poor yield (Rabara et al. 2014).

The solution to the problem was to develop new varieties as specified by plant physiologists and agronomists. Accordingly, the most relevant traits are low stature, new leaf architecture (slender erect leaves), non-photoperiodic, early maturing, and high-tillering which could result in high yield. With these traits, varieties developed are good in photosynthesis, fertilizer responsive, non-lodging, and could be planted any time of the year since these varieties are non-photoperiodic (De Leon 2011). The first released variety with these characteristics was IR8 by IRRI in 1968. These ushered the Green Revolution or modern farming which relied on heavy use of chemical fertilizers, irrigation water and the use of pesticides.

Presently, the Philippines is using the RCEF program to distribute free seeds to farmers. The guide to this program was to use the top ten most popular varieties selected from among almost 300 varieties released since 1990. These varieties tend to be popular due to their stable high yield, resistance to pests, and popularity among the consumers. Identified as the most popular varieties PSB Rc 10, NSIC 1994PSB Rc 18, PSBNSIC 2000 Rc 82, NSIC 2006 Rc 160, NSIC 2009 Rc 216, NSIC 2009 Rc 222, NSIC 2014 Rc 358, NSIC 2015 Rc 400, NSIC 2015 Rc 402, and NSIC 2016 Rc 480 (PhilRice, 2020a, 2020b, 2020c). The variety PSB Rc 10 released in the 1990s is the oldest among the popular varieties. Its most important characteristic aside from high yield (7.5 ton/ha maximum yield) is its early maturity of 106 days after sowing (DAS), it is also moderately resistant to resistant to most important insect pests and diseases namely stemborer, blast, bacterial leaf blight (BLB), rice tungro virus (RTV), green leafhoppers (GLH), and brown plant hoppers (BPH), however the rice in cooked form is hardly a major drawback for this variety.

NSIC 1994 Rc18 has a quite long maturity of 123 DAS and taller than most varieties at 102 cm, but the maximum yield is 8.1ton/ha higher than the yield of PSB Rc 10. It also have good eating quality intermediate reactions to blast, BLB, RTV, GLH, and BPH, however it is moderately susceptible to stemborer but have high milling recovery of 65.34%. The next most popular older variety is NSIC 2000 Rc82 is an early maturing variety at 110DAS, the important trait of this variety is it a very high maximum yield of 12ton/ha. This yield is very high compared to other inbred varieties. This variety is also resistant to blast, intermediate reaction to BLB, BPH, and stemborer, however it is moderately susceptible to RTV and GLH. Among the most recently released varieties NSIC 2009 Rc 216 and NSIC 2009 Rc 222 are worth noting. NSIC 2009 Rc 216 is a very high yielding variety with maximum yield of 9.7 ton/ha and matures within 112 DAS. Though Tthis variety is though susceptible to RTV, but it is moderately resistant to BPH and GLH and it has good eating quality. NSIC 2009 Rc 222 is worth noting because of its high yield (maximum of 10 ton/ha) and intermediate reaction to RTV and BLB. It is also resistant to GLH very important trait that make it to withstand RTV attack, GLH being the vector or carrier of RTV. NSIC 2009 Rc 222 is very important in case of RTV outbreak in a given area, other varieties may succumb to RTV pressure but not NSIC 2009 Rc 222. A major drawback of this variety is, it is hard in cooked form.

Other varieties of worth mentioning are NSIC 2006 RcC 160 and NSIC 2015 Rc 400. These varieties are not recommended for planting during wet seasons in areas where tungro incidence is very high. Below are the general agronomic characteristics of the 10 popular varieties in the Philippines (Table 1).

Table 1. Agronomic characteristics of current most popular rice varieties in the Philippines (*pinoyrice.com/rice-varieties*).

NSIC registry No.	Agronomic characters					Reaction to insect pests and diseases							MR (%)	EQ
	Ave. Yield (ton/ha)	Max. Yield (ton/ha)	Maturity (DAS)	Height (cm)	Blast	BLB	ShB	RTV	DH	WH	BPH	GLH		
PSB Rc 10	4.8	7.5	106	77	R	I	-	I	R	R	R	MR	66.62	Hard
NSIC 1994 Rc 18	5.1	8.1	123	102	I	I	-	I	MS	MS	I	I	65.34	Medium
NISC 2000 Rc 82	5.4	12.0	110	100	R	I	-	S	I	I	I	MS	65.0	Medium
NSIC 2006 Rc 160	5.6	8.2	107	96	I	I	-	S	MR	MR	S	I	71.1	Soft
NSIC 2009 Rc 216	6.0	9.7	112	96	S	-	-	S	-	-	MR	MR	67.0	Medium
NSIC 2009 Rc 222	6.1	10.0	114	101	I	I	-	I	-	-	MR	MR	65.0	Hard
NSIC 2014 Rc 358	5.4	9.1	114	98	I	S	S	S	I	I	I	S	72.4	Medium
NSIC 2015 Rc 400	5.3	11.3	113	98		S	S	S	-	-	I	I	71.4	Moderately Soft
NSIC 2015 Rc 402	5.5	14.0	114	95	I	I	I	S	-	-	MR	S	69.3	Moderately Soft
NSIC 2016 Rc 480	3.2	4.4	107	96	I	S	S	S	I	I	I	I	71.8	Soft

Note: DAS-days to sowing; BLB-bacterial leaf blight; ShB-sheath blight; RTV-rice tungro virus; DH-deadheart; WH-whitehead; BPH-brown plant hopper; GLH-green plant hopper; MR-milling recovery; EQ-eating quality; NSIC-National Seed Industry Council; R-resistant; I-intermediate; S-susceptible; MR-moderately resistant; MS-moderately susceptible.

FUTURE PROSPECTS AND THE WAYS FORWARD

Yield has always been the primary focus of rice breeding in the country and will continue to be a major consideration in variety development along with essential traits such as resistance to a pest, abiotic stresses, and good grain qualities. However, recently, breeding has been directed to increasing the nutritional content of rice through biofortification due to the prevailing problem on micronutrient malnutrition affecting a vulnerable segment of the population (Swamy et al. 2016). Breeding for micronutrient-dense rice such as high in Zinc and Iron, and Vitamin-A rich rice “golden rice” varieties is expected to intensify in the coming years. Molecular breeding has proven to be an effective tool in accelerating breeding cycle and several varieties have been developed with the aid of this technology. However, intensive adoption and inclusion of molecular biology inbreeding are needed to reap its full benefits especially in the case of PhilRice and UPLB. Particularly, in pyramiding the important genes/QTL of the important traits will facilitate in developing a new generation of plant-types. Lastly, innovative and modern breeding practices such as precision phenotyping, breeding analytics, germplasm analysis, gene editing, and other emerging techniques in biotechnology must complement conventional breeding methods in accelerating rate of genetic gains and achieving future rice breeding goals.

CONCLUSIONS

The demand for rice will continue to rise as population growth remains unabated. Rice breeding needs to keep up with the multiple challenges in rice production in order to achieve country's rice security goal. PhilRice being the national agency tasked to develop varieties and technologies to improve rice production of the country should take the lead in the pursuit of rice secure Philippines. It should embrace innovative breeding strategies and forge strong collaborative partnership with other breeding institutions such as IRRI, UPLB, and private organizations. Importantly, strong government support is needed to strengthen rice research and development in the country–our sure ticket to rice sufficiency and security.

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BREEDING STRATEGIES FOR RICE IN MALAYSIA

Asfaliza Ramli and Rahiniza Kamaruzaman

INTRODUCTION

The rice sector has been considered as an important sector and has always been given attention by the Malaysian government. The national rice policy over many decades is focused on four mains objectives, i.e., to ensure food security for the nation, to raise farm income and productivity, to provide a food supply for consumers at reasonable prices and to reduce the foreign exchange resulted from importation (Rosnani et al. 2015). Various production incentives have been introduced, including Guaranteed Minimum Price (GMP), price subsidy, and input subsidies (fertilizer and chemical) due to the high cost of rice-producing in Malaysia. These efforts also indicate the importance of maintaining a 'comfortable' level of self-sufficiency as well as national food security for its growing population.

Research and development (R and D) is a part of the strategies implemented by the government to enhance rice production in Malaysia. Rice varieties play vital roles in determining potential yield and quality. Hence, the Malaysian Agricultural Research and Development Institute (MARDI) was given a mandate in rice varietal development since 1969. However, since 2000, other research institutions and universities start to develop new rice variety to offer more choices to farmers. There are two types of rice cultivation in Malaysia i.e. wetland and dryland. Several modern rice varieties were released for wetland cultivation, and traditional rice varieties were mostly cultivated in Sabah and Sarawak, including upland rice variety. This article aims to describe rice production and its breeding program for desired important agricultural traits in Malaysia

MALAYSIAN RICE PRODUCTION

Rice production areas in Malaysia consist of granary and non-granary with total parcel area of 214,281 ha and 69,766 ha, respectively (Table 1). There are eight main rice granaries in peninsular Malaysia, i.e., Muda Agricultural Development Authority (MADA), Kemubu Agricultural Development Authority (KADA) and Integrated Agriculture Development Area (IADA) Kerian, IADA Barat Laut Selangor, IADA Pulau Pinang, IADA Seberang Perak, IADA KETARA and IADA Kemasin Semarak. Also, four new granaries on the east coast of peninsular Malaysia (Pekan and Rompin), Sabah (Kota Belud), and Sarawak (Batang Lupar) were developed in 2014 and 2017. The national average yield in 2018 is 3.77 ton/ha, while the granary area and non-granary area yields are 4.68 and 2.59 ton/ha, respectively. The high production rate in the granary area was contributed by a proper irrigation system, which allows

Table 1. Malaysian rice production area 2013–2018 (Agrofood Statistics 2018.

Item		2013	2014	2015	2016	2017	2018
Paddy Parcel	Granary	200,505	210,842	211,266	214,015	214,281	214,281
Area (Ha)	Non-granary	89,377	79,040	79,820	72,564	69,881	69,766
Planted Paddy	Granary	369,273	400,733	406,048	417,007	426,249	426,046
Area (Ha)	Non-granary	302,406	278,506	275,511	271,763	259,299	273,934
Average Yield	Granary	5,002	5,212	4,864	4,941	4,496	4,682
(Kg/Ha)	Non-granary	2,715	2,729	2,854	2,755	2,707	2,594

double cropping of rice cultivation practice. The adequate irrigation schemes are constructed with appropriate farm roads to accommodate farm mechanization, particularly for land preparation and harvesting (Toriman and Mokhtar 2012).

The total production of rice in Malaysia showed a declining trend from 2014 to 2018 (Figure 1). Although paddy planted area has shown an increase, however, the paddy production showed otherwise, which may be contributed by decreasing average yield per hectare. Many factors are influencing the rice yield production, and one of the major threats is disease incidence. In 1985, paddy production declined due to pest and disease (rice Tungro disease) and weather conditions (Rajamorthy et al. 2015; Mohamad Aris et al. 2018). Moreover, a severe rice bacterial leaf bight (BLB) disease outbreak, reported in 1988 and 1994, caused more than 40% of Muda planted area was affected, and estimated yield loss was 10–50% (Saad et al. 2000). In late 2016, the disease outbreak was also reported in west coast peninsular Malaysia, where 40% of the area was affected due to cultivation on non-resistance rice variety in most of the regions (Zainal 2017).

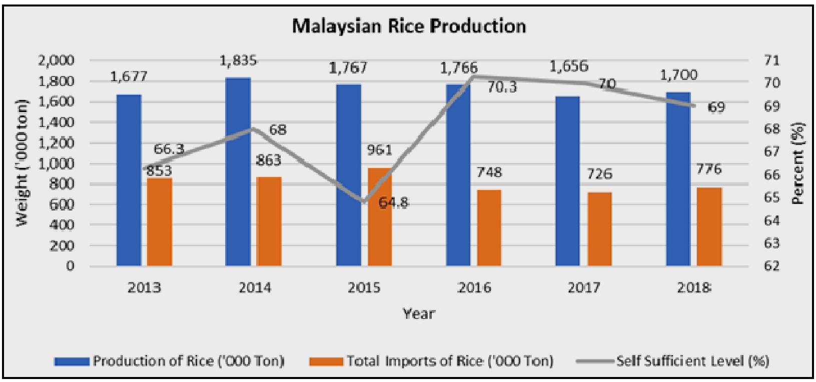

Figure 1. Malaysian rice production in 2013–2018 (Agrofood Statistics 2018).

BREEDING FOR DOUBLE CROPPING

An attempt was made to produce rice variety suitable for double cropping in the early 1950s by performing crosses between indica and japonica varieties. The japonica rice varieties chosen were mostly photoperiod insensitive, while indica varieties were perceived as suitable to the local environment. Malaya joined this program and selected local traditional varieties and send it to Central Rice Research Institute, Cuttack, India, to be crossed with selected Japonica varieties. According to Othman (2017), these breeding materials were known as the Cuttack Hybrids, and the first batch of hybrid seeds arrived back in Malaya was as early as 1951 but mostly came back in or after 1953. The varietal selection was made based on a non-photoperiod sensitive trait, short term maturation period, long grain and non-sticky rice, response to fertilizer, high yield, hight, stiff straw, and lodging resistance (Othman 2017). The success of this program was determined by releasing two varieties, which are Malinja (1964) and Mahsuri (1965).

BREEDING FOR HIGH YIELD VARIETY

As a tertiary level of irrigation and drainage facilities were intensified to improve on-farm water management that enable the cultivation of a high-yielding variety of rice (Toriman and Mokhtar 2012). Other than that, upgraded facilities such as farm roads allow extensive use of farm mechanization, including land leveling and harvesting. In 1990, direct seeding (broadcasting) method was introduced to replace labor-intensive manual transplanting where farm facilities can support this practice. The breeding for high yielding rice was initiated by selecting rice variety with New Plant Type (NPT) characteristics that were designed to maximize solar radiation interception, minimize lodging, and a high response to inputs in order to improve biomass and harvest index that contribute to high grain yield (Dash et al. 2015). The selection process focuses on several traits, mainly semi dwarf, high germination percentage, short maturity, long panicle, and heavy grain weight.

MR 219 was developed to suit direct-seeded practice, and it was widely accepted rice variety and still being planted from 2001 until now. It was considered as elite variety due to its favorable traits and was genetically stable across all types of soils in peninsular Malaysia. Other than that, MARDI also released a high-yielding variety, for example, MR 253, MR 263, MR 220CL2, MR 269, MR 284, MARDI Siraj 297, MARDI Sempadan 303 and MARDI Sebernas 307 with yield potential 7–9 ton/ha. These varieties have their advantages over the locations and soil fertility status. MR220cL2 was developed for Clearfield Rice Production System to solve the weedy rice problem due to direct-seeded practice. This variety becomes the most popular among farmers due to the higher yield obtained in a highly infested weedy rice field. Moreover, the cultivation of this variety across Malaysia was reached up to 54% in 2015 and 2016 (Figure 2) and still become the most cultivated variety to date (Paddy Statistics of Malaysia 2016; Agrofood Statistics 2018).

As the potential yield of inbred variety becomes plateau, hybrid rice technology was explored in 2007 by the exploitation of heterosis for yield enhancement. Local environmental adaptation trial was conducted on the varieties obtained from China, India, and the Philippines and showed yield potential 6–7 ton/ha with unfavorable grain quality (medium grain and sticky). Therefore, the development of the first 100% local hybrid rice variety was made, and MR12H was successfully released in October 2019 with yield advantage more than 20% compared to an inbred line (MARDI Siraj 297). This variety is suitable for low

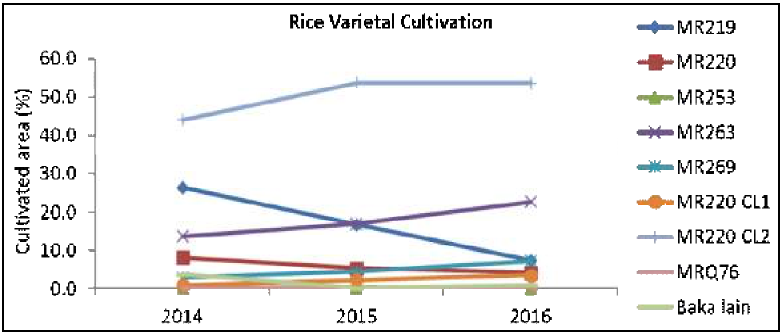

Figure 2. Cultivated rice varieties in Malaysia 2014–2016 (Paddy Statistics of Malaysia 2014–2016).

fertility soil with a 30 kg/ha seed rate and 105 days of maturation (MR12H 2019).

BREEDING FOR PEST AND DISEASE-RESISTANT VARIETIES

Susceptibility of a high-yielding variety to pests and diseases is the limiting factor which led to yield reduction. A severe outbreak of important rice pests and diseases rice plants, such as foliar and panicle blast, bacterial leaf blight (BLB), sheath blight, Tungro, brown planthopper, and bacterial panicle blight will result in dramatic yield and economic losses. Therefore, the development of rice variety with resistance traits toward the pests and diseases become a primary concern in the breeding program. According to Misman and Zakaria (2019), although MARDI has released several varieties with resistance to blast, the amount of the blast resistance has a breakdown from year to year. One of the factors that contribute to pest and disease outbreak is by planting mono variety in a large area for an extended period (Misman and Zakaria 2019). Kogeethavani et al. (2018) reported that near-isogenic line (NILs) carrying BLB resistance genes *Xa5,* *Xa7*, and *Xa11* showed high resistance towards local *Xanthomonas oryzae pv. oryzae* isolates. Hence, identified potential pests and diseases resistance genes can be introgressed into high-yielding variety to improve their resistance trait.

BREEDING FOR HIGH-QUALITY RICE

The demand for high-quality rice or specialty rice is showing an increasing trend that indicates that there are changes in the living standard and lifestyle of the Malaysian consumers (Rosnani et al. 2018). Twenty percent of imported rice is specialty rice, which comprises of fragrant rice (11%), glutinous rice (4%), basmati rice (3%) and japonica and red rice (2%) (BERNAS 2017; Rosnani et al. 2018). The development of high-quality rice in MARDI was carried out and focusing on fragrant or glutinous, long and slender grain, translucent or less than 10% chalkiness, good eating taste, high milling recovery and if possible has added value such as low glycemic index, antioxidant property, and other health properties. In contrast, other traits are taken as a secondary objective (Asfaliza and Othman 2017). Several specialty rice has been released by MARDI, such as MRQ74 (fragrant), MRQ 76 (fragrant), MRM16 (color), MRQ98 (color), Pulut Hitam (black glutinous) and Pulut Siding (glutinous).

BREEDING FOR ABIOTIC STRESSES TOLERANCE

Breeding for abiotic stresses tolerance rice variety becomes a major concern due to climate changes or natural phenomena that pose a threat to rice production. Rice is vulnerable to drought stress at all stages of growth (Shamsul et al. 2018). Moreover, an early reproductive stage drought stress, especially during anthesis, has been found to result in significant yield reduction (Boyer and Westgate 2004). An attempt has been made to introgress major QTLs related to yield under drought stress (*qDTY*) which have been identified to have a genetic gain of 10 to 30%, with a yield advantage of 150 to 500 kg/hectare during reproductive stage (Swamy and Kumar 2013; Shamsudin et al. 2016). Introgression of *qDTY*s was conducted by crossing donor parents such as Vandana harboring $qDTY_{6.1}$ and Morobereken harboring $qDTY_{3.2}$ and $qDTY_{11.1}$ with high-yielding variety, such as MARDI Siraj 297 (Shamsul et al. 2018). The presence of targeted genes was detected along the breeding process using Marker Assisted Selection (MAS), and Marker Assisted Breeding (MAB) was carried out in the backcross population. Also, the improvement of submergence tolerance being carried out by the introgression of *Sub1* gene into a high-yielding variety MARDI Siraj 297 (Rahiniza et al. 2018).

CONCLUSIONS

Rice breeding is a major component of the rice research programs, and the objectives are to increase rice productivity mainly through the development of suitable rice variety for double cropping with high yield and also the development of resistant/tolerant variety towards biotic and abiotic stresses. The success of the breeding program and the growth of new rice varieties results in the transformation of the rice industry in Malaysia from manual transplanting to direct-seeded and from manual harvesting to mechanical harvesting. Other than that, high yielding rice increases farmer's income, less pesticide usage due to resistant varieties, and suitable rice varieties that can be cultivated across different ecosystems.

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BREEDING STRATEGY FOR RICE IN LAO PDR

Phetmanyseng Xangsayasane and Chanthakhone Boualaphanh

INTRODUCTION

Laos is a landlocked nation and located in the middle of the Southeast Asian peninsula. The population is about 6.8 million and divided into 18 provinces. Laos shares borders with Myanmar, Cambodia, China, Thailand, and Vietnam. The total area of Laos is 236,800 kilometers square and approximately 70% of that is mountainous. Rice has been a top priority for the Lao government ever since the first National Socio-Economic Development Plan (NSEDP). National development policies and strategies have emphasized the importance of agriculture in general and rice in particular towards achieving food security and stimulating economic growth. Rice in Laos, as in much of the region, has been of significant importance since ancient times. Rice is not only associated with cultural traditions, but also been of prime political importance throughout the country's history.

According to most accounts, the country was a net rice importer in most of the 1970s and the 1980s and food availability was particularly vulnerable to extreme climate events such as the severe droughts in 1977 and floods the following year. According to Schiller et al. (2006), it was precisely in response to such disasters that the Government initiated its first attempts to improve rice production and achieve a higher level of rice self-sufficiency in 2000. By the 1990s, the adoption rates of improved varieties had expanded considerably, particularly in the central and southern lowland production systems, reaching some 65–80 percent in the wet season and 100 percent in the dry season. Many farmers have adopted these new varieties in response to market demands, while continuing in parallel to cultivate traditional indigenous varieties to meet personal and family taste preferences. This review article aims to explain breeding program for rice improvement in Lao PDR, consisting of information on rice production and its consumption, the rice production constrains, breeding system, recommended varieties and seed production.

RICE PRODUCTION AND CONSUMPTION

Rice production is the main farming activity in Laos, accounting for over 80% of the total cultivated area. Total rice production areas were 863,446 hectares, of which rainfed lowlands were 760,951 ha, covering 88.1% and irrigated lowlands were 102,495 covering 11.8% (DOA 2015). Total rice production in wet season was 3,414,719 tons with an average yield of 4.39 ton/ha, where total rice production in the dry season was 555,037 tones with an average of 4.9 ton/ha (Table 1).

Laos has the highest per capita production and consumption of glutinous rice in the world. Lao people also have a particularly strong cultural affinity for glutinous rice (Schiller et al. 2006). Non-glutinous rice is more popular in the northern part of Laos than any other parts of the country, but about 83% of the rice area was planted to glutinous rice (Lao-IRRI 2005). The highest proportion of glutinous rice (about 91%) is grown in the dry season of irrigated environment, and the lowest proportion of total rice area that is growing glutinous rice (60%) is in the rainfed upland environment in the northern agriculture region

Table 1. Rice areas and production of Lao PDR in 2017.

Province	Total rice areas (h)	Wet season			Dry season		
		Areas (h)	Yield (t/h)	Production (t)	Areas (h)	Yield (t/h)	Production (t)
Northern	116,325	108,012	4.55	491,301	8,313	4.43	38,717
Phongsaly	7,440	7,436	4.92	36,585	4	3.75	15
Luangnamtha	11,888	11,663	4.47	52,134	225	4.44	999
Udomxai	16,338	15,895	4.40	69,938	443	3.84	1,701
Borkeo	16,781	14,761	4.51	66,572	2,020	4.46	9,009
Luangprabang	15,314	13,992	4.39	61,425	1,322	5.30	7,007
Ouphan	13,889	12,313	4.45	54,793	1,576	4.44	6,997
Xaiyaboury	34,675	31,952	4.69	149,855	2,723	4.77	12,989
Center	502,196	434,051	4.48	2,004,704	68,145	5.26	376,585
Vientiane capital	73,491	55,530	4.70	260,991	17,961	5.51	98,965
Xienkuang	19,526	19,526	4.18	81,619			-
Vientiane	60,145	51,590	4.74	244,537	8,555	5.37	45,940
Bolikhamxai	39,355	36,666	4.35	159,497	2,689	5.38	14,467
Khammouan	85,139	74,789	4.40	329,072	10,350	5.80	60,030
Savanakhet	217,178	188,630	4.76	897,879	28,548	5.50	157,014
Xaisomboun	7,362	7,320	4.25	31,110	42	4.02	169
Southern	244,925	218,888	4.15	918,714	26,037	5.00	139,735
Salavan	86,940	74,670	4.30	321,081	12,270	5.30	65,031
Xekong	10,010	9,098	4.40	40,031	912	4.39	4,004
Champasak	125,555	113,055	4.21	475,962	12,500	5.52	69,000
Atthapu	22,420	22,065	3.70	81,641	355	4.79	1,700
Total	863,446	760,951	4.39	3,414,719	102,495	4.90	555,037

Source: DOA 2015.

(Schiller et al. 2006). The preference for glutinous rice by the Lao people was seen in collecting mission in 1995–2000 where over 85% of lowland varieties collected were glutinous.

The consumption estimates for Laos' rural population in 2007/2008 would result in rice accounting for 83% of the average of total dietary energy consumption (Ramasawamy et al. 2012), which is extremely high. If one accounts for rural and urban populations combined, according to such estimates, rice has

Table 2. Urban versus rural per capita rice consumption (in raw milled rice kg) in Lao PDR.

Region	LECS 3 (2002/03)	LECS 4 (2007/08)	% change
Whole country	145.2	179.1	23%
Urban	139.8	130.1	-7%
Rural	147.1	199.0	35%

Source: Ramasawamy et al. FAO (2012).

moved from representing 67 percent of average daily DEC in 2002/2003 to 77 percent in 2007/2008 (Table 2).

CONSTRAINT OF RICE PRODUCTION

Most of rice production areas in Laos is rainfed lowland rice, whereas drought-prone areas for rice production occupies about 60% of the total rice area and it because yield lost up to 53% in the vegetative stage, whereas it reduced up to 85% in the reproductive stage (Fukai et al. 2008). Flood-prone is covered by 20% and causes yield losses of 100%. From 1966 to 2002, the flood occurred 28/37 years or about 76% and drought occurs 17/37 years or about 46% (Rice in Laos 2016). Since 2017, early drought and flood occurred regularly. But, in 2019, an early drought occurred throughout the country and followed by the flood in September, damaging rice production areas of about 139,829 ha in 6 provinces, covering about 16% of total rice production areas in the country (Figure 1).

Climate change is the main constrain that affect directly to rice production in the country. Drought and flood are the major constraints for rice production in Lao PDR. Hazardous weather occurs more frequently at any time during the crop growth in recent years. Flood and drought are occurred year to year, affected national rice production become unstable with varied from year to year up to 20%.

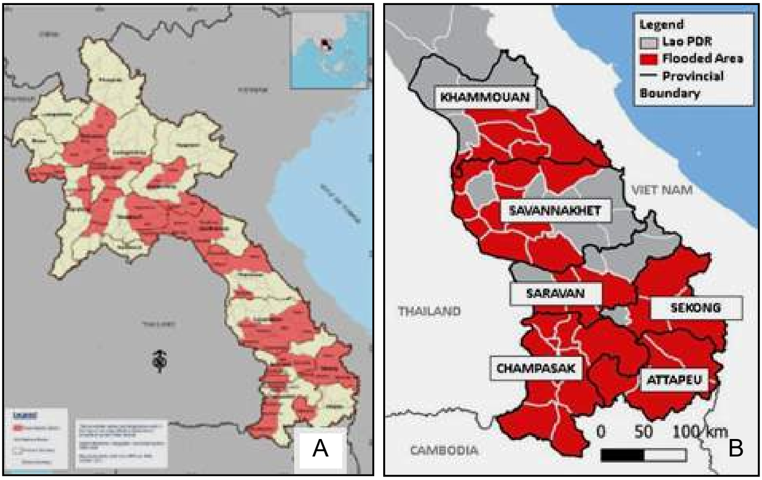

Figure 1. Flood prone areas in Lao PDR (A) and flood in wet season 2019 (B).

RICE BREEDING SYSTEM

The development of the rice sector is always a priority of the Lao's government for economic growth and food security. Rice breeding program was established at Rice Research Center (RRC) in 1991, in collaboration with IRRI, and supported funding by the government of Switzerland. From 1991 to 1998, most of the breeding lines were introduced from IRRI, Philippines and Thai-IRRI program. Out of 1.627 lines of the F2 population, 4 lines were released as TDK and PNG varieties. Out of 64 imported promising lines, 13 lines were released as TDK, TSN, PNG and NTN varieties for different agroclimatic zones in Lao PDR. Hybridization at RRC was started in 1994, since then about 272 crosses were made by the Lao breeders. Out of 272 crosses made, so far 8 clones were released as TDK and TSN varieties and 34 lines were identified as promising lines. Among all parents used in the crossing program at RRC, TDK 1 was the dominant parent for evolving promising lines for Lao PDR.

From 1993 to 2019, Lao national rice research program released 38 improved varieties, of which, 16 is Thadokkham varieties (TDK), 6 is Phon Ngam varieties (PNG), 11 is Thasano varieties (TSN), one is Namtane variety (NT) and is 4 Xebangfai varieties (XBF). These varieties have been widely adopted by farmers throughout the country. By 2005, the variety improvement program had developed a specific variety recommendation for the main lowland rice-growing areas of Laos, the Mekong River Valley. There had been a high level of farmer acceptance and adoption of improved varieties developed and distributed during the 1990s. Adoption was more than 70% during wet season rice cultivation in the Mekong River Valley and 100% in an irrigated environment in the dry season (Inthapanya et al. 2006). Due to using of improved high yielding varieties after release first improved rice variety in 1993, Laos has rice self-sufficiency since 2000.

GENERALLY RECOMMENDED VARIETIES

Varieties generally recommended for different regions are shown first (Table 3). The varieties listed here are widely adapted and potentially high yielding and are recommended for wide use. Several varieties are recommended and encouraged to grow for specific locations to minimize the risk of biotic problems such as brown planthopper and blast. Wet season recommendation is grouped into 4 Regions: Northern Region, Center upper region, Center lower region, and southern region.

The recommendation is further made separately for different terrace positions. The lower terrace position has generally fertile soils and can be flooded during the wet season. The end of the growing period is generally longest in the lower terrace, and late-maturing varieties are generally recommended. The middle

Table 3. Generally recommended rice varieties for wet and dry seasons at different terrace positions in regions of Lao PDR.

Season	Region	Terrace position		
		Lower	Middle	Top
WS	Northern	TDK1, TDK5, TDK6, TDK11, TDK8, RD10, Kai Noi		
WS	Central-upper	RD6*, RD8, TDK10, XBF1, XBF3*, XBF4*	TDK1, TDK8, TDK6, TSN1, VTE450-1*, TDK4, VTE450-2, KDML105, RD15, Hom Nang Nouane, Chao Dok Dou, XBF1, XBF2	TDK9*, TDK11, TDK12, RD10, NTN1, XBF1, XBF2
WS	Central-lower	RD6*, TDK10, XBF1, XBF3*, XBF4*	TDK1, TDK8, TDK6, PNG1, TSN3, TSN1, TSN5, XBF1, XBF2	TDK9*, RD15, TDK11, PNG1, PNG3, TDK12, RD10, NTN1, XBF1, XBF2
WS	Southern	RD6*, TDK10, XBF1, XBF3*, XBF4*	TDK1, TDK8, TDK6, PNG1, TSN3, PNG5, Chao Dok Dou, PNG6, KDML105*, XBF1, XBF2, XBF3*	TDK9*, TDK11, PNG1, PNG3, TDK12, RD10, NTN1, KDML105*, XBF1, XBF2,
DS	Whole	TDK1, TDK5, TDK6, TDK8, TDK11, TSN3, TSN5, PNG1, PNG5, PNG6, NTN1, RD10, XBF1, XBF2		

*Photoperiod sensitive.

terrace position occupies the largest area of rainfed lowland rice in Laos and contains the largest number of recommended varieties. The area can be commonly affected by drought and flood. While TDK lines developed in Vientiane are suitable across most of the country, PNG lines developed in Champassak are popular in the Southern region. Similarly, TSN lines developed in Savannakhet are popular in the Central-Lower region. The top terrace position often has a relatively short growing season and drought may occur commonly in this position. Therefore, the recommended varieties for top positions are commonly quick maturing and possess some drought resistance.

Most varieties can be grown in the wet and the dry season, but photoperiod sensitive varieties (e.g. TDK9, TDK10 and RD6) can only be grown in the wet season. Often the dry season experiences relatively low temperature and the growth of rice plant are prolonged. Therefore, recommended varieties have shorter growing durations and are suitable for dry season.

VARIETY RECOMMENDATIONS FOR SPECIFIC PROBLEMS/TARGETS

Table 4 below provides information on rice varieties recommendation for specific conditions. General recommendation shown in Table 1 should be considered first, but if the field has anticipated problems listed below or varieties with the specific target, the varieties listed in Table 4 may be selected.

VARIETY CHARACTERISTICS

Rice varieties grown in Lao showed varied characters. Some improved and traditional varieties have been identified their resistence/tolerance to pest and diseases that commonly exist in the country. The following Table 5 show key characteristics of popular varieties.

Table 4. Rice **v**arieties recommendation for the potential problem areas/the specific target characters.

Environment	Name
Low temp	TDK5, TDK6, TDK8, TDK11
Flood prone	XBF1, XBF2, XBF3*, XBF4*
Drought-prone	XBF1, TDK11, PNG1, TDK12, PNG3
Salinity areas	KDML105
Fe toxicity areas	TDK10, TDK11, Muang-nga, TDK9, Doktiew, TSN1, RD10
Low soil fertility	TDK9, TDK11, TDK12, TSN1, KDML105
GM problem	Muang-nga, Ta-khiat, Lay-keaw
Aroma G	XBF4, RD6, Kai Noi, Hom-nang-nuan
Aroma NG	XBF2, XBF3, VTE450-1, Homsavane, KDML105

Table 5. Description of widely grown of improved and traditional rice varieties in Lao.

Improved variety	Flowering date	BPH	BI	BLB	NB	BD	GLH	GM	Fe toxicity	Submergence	Aroma
VTE450-2	135-140	S	MR	MR	MS	R	S	S	MT	S	N
VTE450-1	Early Oct	S	MR	MR	MS	R	S	S	MT	S	N
TDK8	135-140	MS	MR	MR	MS	R	S	S	MS	S	N
TSN5	135-140	MS	R	R	R	R	S	S	MS	S	N
TDK12	Early Oct	S	MS	MS	MS	R	S	MS	MT	S	N
TDK11	135-140	MS	R	MR	MR	S	S	S	T	S	N
TDK9	Late Sept	S	R	MR	MS	R	S	S	T	S	N
TDK10	Mid Oct	S	R	R	MS	R	S	S	T	S	N
PNG3	130-135	R	MR	S	MS	R	S	S	MT	S	N
PNG5	125-130	S	S	MR	S	R	S	S	MT	S	N
PNG6	130-135	S	R	MR	MS	R	S	S	MT	S	N
TSN2	130-135	S	MR	MR	MS	R	S	S	MS	S	N
Homsavanh	Mid Oct	S	MR	MR	MS	R	S	MS	MT	S	N
TSN4	125-130	S	S	S	MS	R	S	S	MS	S	N
TDK6	135-140	MS	MS	MR	MS	R	MS	MS	MT	S	N
TDK5	125-130	MS	MS	MR	MS	R	MS	S	MT	S	N
TDK4	Mid Oct	MR	MR	R	MR	R	S	S	S	S	N
TSN1	140-145	MS	MR	MR	MS	R	MS	MS	T	S	N
NTN1	130-135	MS	MS	MS	S	R	MS	S	MS	S	N
PNG2	Mid Oct	S	S	S	S	R	S	S	T	S	N
TDK1	135-140	MR	MR	MR	S	S	S	MS	S	S	N
PNG1	125-130	S	R	MR	S	R	R	MS	T	S	N
RD10	Mid Oct	S	S	S	S	R	S	S	T	S	N
KDML105	Mid Oct	S	S	S	S	R	S	S	T	S	N
RD6	Late Oct	MS	MR	MS	MS	R	S	S	MT	S	N
RD8	Late Oct	S	MR	MS	MS	R	S	S	MT	S	N
TSN3	135-140	MS	R	R	MR	MR	R	S	MT	S	N
RD15	Early Oct	S	MR	MS	MS	R	S	S	MT	S	N
XBF1	135-140	S	MR	MR	S	R	S	S	S	T	N
XBF2	120-130	MS	MR	R	MS	R	MS	MS	MS	T	A
XBF3	Mid-October	MS	MR	R	MS	R	MR	MR	MT	T	A

Traditional variety	Flowering time	BPH	BI	BLB	NB	BD	GLH	GM	Fe toxicity
Nang-nuan	5-10 Oct	S	S	S	S	R	S	S	MT
Hom-nang-nuan	15-20 Oct	S	MS	MS	S	R	S	S	MT
Muang-nga	10-15 Oct	S	R	S	R	R	S	R	T
Ta-khiat	5-10 Oct	S	R	S	R	R	S	R	T
Mak-hing	10-15 Oct	S	S	S	S	R	S	S	T
Dok-mai	10-15 Oct	S	S	S	S	R	S	MS	MT
Lay-keaw	15-20 Oct	S	S	S	MS	R	S	MS	MT
Dok-tiou	Late Sept	S	S	S	R	R	S	S	T
Kai-noi	Late Sept	S	S	S	MS	R	S	R	T
Dodeng	Late Sept	S	R	R	MR	R	S	S	T
Chao Dok Dou	Mid Oct	S	MR	MR	MS	R	S	MS	MT

*non-glutinous; # Number of trials tested in brackets.

A = Aroma, BPH = Brown planthopper; Bl = Blast; BLB = Bacterial Leaf Blight; NB = Neck Blast; BD = Bakanae Disease; GLH = Green Leaf Hopper; GM = Gall Midge; Fe Tox = Iron (Fe) toxicity. Ratings: R = Resistant; MR = Mildly resistant; MS = Mildly susceptible; S = Susceptible; VS = very susceptible; T = tolerant; MT = Moderately tolerant.

SEED PRODUCTION SYSTEM

Rice seed production is classified in two systems: formal and informal (Figure 2). In the formal system, seeds is produced by state institute, private sector and farmer seed production group, while in the informal system, seeds is produced by farmer using their indigenous knowledge. Formal seed system is covering only 12% and use for producing paddy for export under contract farming between farmer and rice miller association. Informal seed system covering about 88%, this seed is used for production for food security and local market.

Limited amount of seed is available from research stations mentioned such: the seed of TSN varieties are available from Tassano Research Station in Savannakhet, while PNG varieties are available from Phone Ngam Rice Research and Seed Multiplication Centre. TDK varieties are available from most research stations. If a large amount of seed is required, then pre-order one season in advance. Research stations are Luang Namtha Research Station, Rice and Cash Crop Research Station (Vientiane Province), Nongheo Research Station (Vientiane Capital), Xebangfai Research Station (Khammone Province), Phone Ngam Rice Research and Seed Multiplication Station

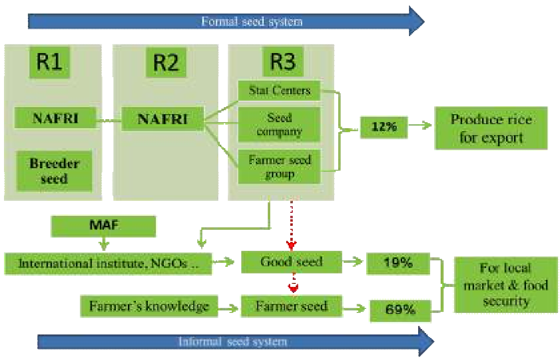

Figure 2. Rice seed system in Lao.

(Champassak Province), Nongdeng Research Station (Saravanh Province), Tassano Research Station (Savannakhet Province) and 30 Ha Research Station (Saiyabouly Province).

OUTLOOK FOR FUTURE RICE BREEDING

Currently, Lao government policy is to promote green agriculture, therefore to support the policy, development of multi tolerance rice varieties to abiotic (drought and flood) and biotic stress (pests and diseases) is the priority of the Lao rice breeding program. The tolerant varieties to pest and diseases can help farmers to reduce pesticide, this is insured environmentally friendly and saving farmer's health as well as consumers. Furthermore, tolerance to abiotic stress can help to alleviate production losses, due to flood, drought. However, there are some constraints for rice breeder to develop a new set of multi-tolerant "drought, flood, pest and disease tolerant" by incorporated flood, drought pest and disease tolerant gene with aromatic flavor into Lao commercial cultivar and disseminate such varieties to grow in target environments to ensure food security in country.

Lao has 2nd biggest rice germplasm conservation in the world after India, and it needs to evaluate these germplasms to identify preference traits for future use either direct use and for breeding purpose. However, rice scientists and breeders are limited, therefore, to achieve goal of the aboved rice breeding program, NAFRI needs future collaboration researches with the rice research institutes in ASEAN and setting up multi rice breeding program to develop a new climate-resilient rice varieties including breeding for submergence tolerance, drought tolerance, aerobic varieties, lodging and shatter-resistant for mechanized harvesting.

CONCLUSIONS

Rainfed lowland is considered as unfavorable rice environment, where some years early drought occurs followed by floods while in other years floods occur followed by terminal drought that affect national yield loss up to 30%. In addition, insect pests and disease (blast and bacterial leaf blight) are affected rice plants more serious. More 500 crosses were made by the Lao breeders and 10 varieties were released as TDK and TSN. However, none of these released varieties are considered as climate resilience rice varieties. To alleviate production losses, due to flood, drought, insect pest and disease, there is a challenging for rice breeder and researchers to develop a new set of multi-tolerant “drought, flood, pest and disease tolerant” by incorporated flood, drought pest and disease tolerant gene with aromatic flavor into Lao commercial cultivar and disseminate such varieties to grow in target environments to ensure food security in country. NAFRI needs future collaboration research with rice research institute in ASEAN and setting up multi rice breeding program to develop new climate-resilient rice varieties including breeding.

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BIOTECHNOLOGY ON RICE IN INDONESIA: CURRENT PROGRESS AND FUTURE POTENCY FOR FARMER

Mastur, Dwinita W. Utami, and Puji Lestari

INTRODUCTION

The role of food security is vital for the survival of a country. However, rice productivity is not in line with population growth. FAO (2009) predicts that in 2015–2030, the existing areas of agricultural land in Indonesia will not be able to support the need for food production as population growth increases significantly (Moniaga 2011) and changing in the demographic structure that is less favorable for the agricultural sector (Susilowati 2016). Moreover, frequent and extreme weather significantly affects the level of agricultural production, especially food crops (Ministry of Communication and Information, Republic of Indonesia 2011).

Climate change has an impact on the problem of food security, both directly and indirectly. Direct influence, for example, with the occurrence of climate change, will affect changing the time of uncertain rainfall and the length of the growing season. Meanwhile, climate change on rice production indirectly has an impact on changes in rice prices. Climate influences the rotation of the dry and rainy seasons, which are strongly associated with rice farming patterns, which will ultimately affect the success or failure of rice production (Rohmah 2014). The level of land use balance with the carrying capacity of the land becomes a measure of the feasibility of land use that affects to reduce agricultural land, including paddy field area (Fitriani 2005; Moniaga 2011).

Biotechnology techniques in developing countries, however, have mostly been targeted at increasing yields of food crops (Nyerhovwo and Douglason 2010). Agricultural biotechnology offers opportunities for the overall utilization of rice germplasm, which in turn improves crop productivity and quality. New techniques of biotechnology and genetic engineering have raised very high expectations in terms of the possibility of producing new rice varieties and superior products. Possible methods include *in vitro* plant regeneration, somaclonal variation, mutation, protoplast fusion, gene transfer, and so on (Wijayanto 2013). The genetic modification on rice is a potentially valuable technology whose advantages and disadvantages need to be considered rigorously on an evidential. This technology gains higher public acceptance and can be regarded as one among a set of technologies that may contribute to improved rice (Godfrey et al. 2010). This article describes current progress of biotechnological approach in rice, how it can solve any constrain in rice improvement, and how the delivered products could benefit to farmers in Indonesia.

RICE PRODUCTION IN INDONESIA

Indonesia is the fourth most populous country in the world. At the same time, the program of achieving food self-sufficiency has become one of the work programs in each period of Indonesia's leadership change. Statistic Indonesia (2019) data recorded that population growth in 2010–2016 increased by 1.36%, in addition to the estimated rice production in 2018 of 56.54 million tons, with a total population of 260 million in 2016 (BPS 2019).

Rice production areas in Indonesia are concentrated in Java (53%), then Sumatra (23%), Sulawesi (11%), Kalimantan (7%), Nusa Tenggara (5%), as well as Maluku and Papua (1%) islands. Centralization of the various sectors of development on the island of Java has led to many fields of rice were converted functioned into areas, such as housing, industry, roads, and the other sectors (Rusono 2014). The management of rice cultivation and production should be revised to fulfill national rice production. The management of farming must be based on the season and planting patterns, adopting superior varieties, high seed quality, integrated plant management, intermittent irrigation, balanced fertilizers, and integrategd pest management, as well as controlling of harvest and the period of post-harvest (Nanda 2015).

Converting of paddy fields to other usages inevitable, but needs to be compensated with the opening of new areas. The value of land-use change is considered to be very dangerous for national rice production (Anonymous 2014). Thus, rice has become a political and strategic commodity and controls the livelihoods of the people of Indonesia (Pujiasmanto 2015).

RICE GENETIC MATERIAL MANAGEMENT

Genetic variability for agronomic traits is the crucial component of breeding programs for broadening the gene pool of both rice and other crops. Thousands of accessions of rice germplasm characterized by resistance to major diseases and pests, tolerance to abiotic stresses, and improved quality characteristics to develop the core collection and compile in the integrative database. The genetic variability detected will be used in a breeding program to enhance improved rice lines. Breeders, therefore, search for genetic variability in other gene pools involving wild relatives of *Oryza* and new techniques are applied for the creation and transfer of variability.

The success of breeding depends heavily on genetic diversity as the sources of genes. Therefore, proper management of rice germplasm is vital for supporting the breeding program and other activities. The genetic resources management consists of exploration, conservation, characterization, evaluation, and uses. For germplasm conservation. The government funding research institution, as ICABIOGRAD, is facilitated to conserve plant genetic materials, i.e., GenBank and Plant Genetics laboratory with six deep freezers (set at -18^{o}C), three chillers (0–5^{o}C), and seed storage room (set at 15–20^{o}C with 50% humidity) for storing of rice accessions germplasm, and a computing room for developing food crop germplasm database. The database system of genebank status was available at the ICABIOGRAD website (biogen.litbang.pertanian.go.id/plasmanutfah). For access, exchanges, and benefit-sharing of utilization sharing of the utilization of PGR, several policies and regulations should be followed (Sabran 2016). Characterization and evaluation are required for breeders and other users of PGR to make the most effective use of genebank collection. DNA fingerprint for the barcoding system on core collection was applied for supporting the rice collection management.

Indonesian rice breeding has been recommended for the adoption of high yielding improved varieties (HYVs), using modern cultural practices, and increased investment in irrigation during 1969–1996 (Fagi 2000). Through these approaches, Indonesia was a success in increasing the productivity and sustainability of rice production in 1984. Nevertheless, Indonesia still faced with many challenges, like most farmers yet was poorly resourced with land ownership less than 0.5 ha, considered as small scale farmers. Thus, to optimally and sustainably use our precious rice genetic resources through a good management and molecular breeding approach are required.

BIOTECHNOLOGICAL APPROACHES ON RICE

Agricultural biotechnology is a potentially neat solution to the unfolding scenario (Scoones 2002). Agricultural biotechnology can contribute to food security in developing countries and focuses on the needs of poor farmers and consumers in those countries where the consultation with poor people themselves could be identified (Persley 2000). The utilization of biotechnology in agriculture is marked by many inventions of cultivar plants/new varieties called genetically modified (GM) crops, which have specific characteristics. Among these are plants that are adaptive to various environmental stresses, both biotic and abiotic stresses. Included in this criterion are tolerant plants that grow on marginal lands, which have the potential to be developed to increase agricultural products (Pawiroharsono 2012).

Modern biotechnology is not a silver bullet for achieving food security, but used in conjunction with traditional or conventional agricultural research methods, it may be a powerful tool in the fight against poverty that should be made available to poor farmers and consumers. It has the potential to help enhance agricultural productivity in developing countries in a way that further reduces poverty, improves food security and nutrition, and promotes the sustainable use of natural resources. Solutions to the problems facing small farmers in developing countries will benefit both farmers and consumers (Per and Marc 2000). It is also critical that biotechnology is viewed as one part of a comprehensive sustainable poverty alleviation strategy, not a technological "quick-fix" for world hunger and poverty (Persley 2000).

Biotechnology needs to go hand in hand with investment in broad-based agricultural growth. There is considerable potential for biotechnology to contribute to improved yields and reduced risks for poor farmers, as well as more plentiful, affordable, and nutritious food for poor consumers (Persley 2000). Increasing agricultural productivity from modern biotechnology can reduce the pressure of expanding agrarian land on land demand and directly help prevent or reduce deforestation and preserve natural habitats. Biotechnology will help protect the environment and the multiplication of genetic resources (Susilowati 2001). In addition to supporting improvements in plant material/variety development, biotechnology also plays a role in reducing the input of synthetic pesticides to make the environment safer through the production of biological pesticides and pests and disease-resistant transgenic crops (Sutrisno 2006).

POPULATION DIVERSITY AND SELECTION EFFICIENCY

Somaclonal Variation

Somaclonal variation refers to the genetic changes arising through tissue culture in regenerated plants and their progenies. Somaclonal techniques have been successfully used in various plant species. It occurs for a series of agronomic traits, such as disease resistance, plant height, tiller number and maturity, and for different biochemical characteristics. The technique consists of growing callus or cell suspension cultures for several cycles and regenerating plants from these long-term cultures. The regenerated plants and their progenies are evaluated in order to identify individuals with a new phenotype. Some useful somaclonal variants, including those for disease resistance and tolerant to saline stress, have been selected as the promising rice lines.

Anther Culture

As early as 1968, Niizeki and Oono reported the production of haploids from anther culture of rice. Since then, the anther culture technique has been significantly refined; it is now possible to produce haploids from the anther culture of many japonicas and indicas rice, although the frequency of plant regeneration is lower in indica varieties. Anther culture is essential for the development of "true" breeding lines in the next generation from any segregating population, producing a shorter breeding cycle in new varieties.

One of the released varieties that developed using anther culture technique was Inpari HDB variety, which is resistant to bacterial leaf blight disease. This variety was developed from IR64 as the recurrent parent and wild rice species *Oryza rufipogon* as the donor parents. The Inpari HDB was also resistant to the brown planthopper insect pest.

Genome Sequencing

Recent advances in DNA sequencing and molecular marker technologies have the potential to accelerate research for gene discovery and pre-breeding applications. Whole-genome sequencing technologies were possible to create prosperious data on genetic variants such as insertion/deletion (*indels*) and single nucleotide polymorphisms (SNPs). These provide sample polymorphisms for selecting molecular markers associated with an essential trait for rice improvement (Thomson 2016).

All the genetic information obtained from genome sequencing technology can be the key to various commodities on breeding programs, including in rice. Multiple types of genes, molecular markers, and genome variations can be associated with superior traits and are used as breeding targets. The Indonesian Center for Agricultural Genome (Pusat Genom Pertanian Indonesia/PGPI) is a website (http://genom.litbang.pertanian.go.id/) that has become a data center point and network for genomics and bioinformatics research, especially in agriculture. At this website, whole-genome sequences from various Indonesian agricultural germplasm, including rice, are available, complete with identified gene content and genomic variations.

Molecular Marker-Assisted Selection (MAS)

Molecular marker genotyping becomes more established and routine supported research on rice breeding that can focus more effort into population development and precise phenotyping. Numerous genes of economic importance, such as those for disease and insect resistance, are repeatedly transferred from one varietal background to another by plant breeders. Most genes behave in a dominant or recessive manner, and transfer is a time-consuming process. Screening procedures are sometimes cumbersome and expensive and require a large amount of field space. Tagging such genes by tight linkage with DNA markers means that time and money can be saved in transferring them from one varietal background to another. A molecular marker very closely linked to the target gene can act as a "tag" which can be used for indirect selection of the gene(s) in the breeding program. Several varieties developed by using molecular breeding were released to be commercial varieties, such as Inpari Blast, Inpari40, and Bio Patenggang. Inpari40 is an excellent case of MAS-rice varieties gives beneficial for farmers.

GENE DISCOVERIES AND TRANSGENIC PLANT DEVELOPMENT IN RICE

The breeding approach has significantly contributed to rice productivity by developing new superior rice varieties. These struggles have been supported by the availability of access to plant genetic resources to improve existing varieties for many important traits, such as high yield, resistance to pests or diseases, tolerance to abiotic stresses, or nutritional quality. Current progress in plant genetic engineering allows the effective transfer of important gene(s) across species/taxa for genetic improvement. Gene discovery contributes to the development of trait or phenotype, aiming at the identification of the structure and function of genes. Gene discovery activities, including gene identification, isolation, cloning, and characterization, can be used on transgenic plant development. Based on these activities, ICABIOGRAD has been identified genes related to biotic stress (*CryIAc* for resistance to stem borer) and abiotic stress (NUE and K transporter genes).

One of the current progresses on transgenic rice development is NUE (Nitrogen Used Efficiency) development. To achieve further high crop productivity and high NUE under well-fertilized conditions, ICABIOGRAD has been developed the gene construct contained the *alanine aminotransferase* (*AlaAT*) from tomato combined with *Oryza sativa 2-alkenal reductase-1* as a root-specific promoter (Patent No: S00201702280). This construct transformed into elite rice line Mekongga and based on the efficacy test, Mekongga-transgenic lines showed one third more efficient than wild type based on national doses N fertilizer recommendation.

FUTURE PERSPECTIVE

Recent advances in cellular and molecular biology of rice offer new opportunities to enhance the efficiency of both the pre-breeding and breeding phase on rice. Biotechnology is becoming an essential component of rice breeding. Anther culture has become an important technique for use by plant breeders to shorten the breeding cycle for the development of rice varieties. Several rice varieties have been developed through anther culture.

Molecular markers have been used to the tagging of numerous genes for tolerance to significant biotic and abiotic stresses. MAS has become an essential tool in rice breeding: for introgression genes from one varietal background to another; for pyramiding genes; and for the development of durable pest-resistant cultivars. Fine mapping of QTL should provide a means to pyramid QTLs for tolerance to significant abiotic stresses. Map-based cloning has made it possible to isolate useful genes governing critical agronomic traits and the incorporation of these genes into elite rice cultivars through transformation. The application of the advance tissue culture and molecular markers have been broadening rice gene pools and enhanced the efficiency of the introgression of targeted genes into the plant.

Advances in genetic engineering have facilitated the introduction of cloned novel genes into rice through transformation. Transgenic rice with enhanced resistance to diseases and insects and improved nutritional quality have been produced and will have a significant impact in terms of increasing rice production and improving the nutritional value of rice. Public and private efforts in sequencing the rice genome have added new dimensions for research in functional genomics to precisely reveal the function of rice genes. Identification of genes and their manipulation present another significant breakthrough in rice genetics and breeding.

Many rice cultivars have been developed through the application of biotechnology tools. Many more will be forthcoming. Future food and nutritional security will depend upon the availability of rice cultivars with higher yield potential, durable resistance to diseases and insects, tolerance to abiotic stresses, and higher levels of micronutrients in the grain. Conventional breeding methods and biotechnology tools will help meet these challenges.

CONCLUSIONS

Dynamic changes in climate condition have affected on increasing the biotic and abiotic stresses on rice (*Oryza sativa* L.). Severe threat to the sustainable rice production has made challenge for rice breeders to enhance production and productivity under multiple stresses. This can be done by speeding up discovery of genes and alleles, marker-assisted selection and genetic modification to this crop. In parallel vision, molecular breeding and conventional breeding are harmonized to develop population. DNA markers derived from the fine mapped position of the genes for important agronomic traits could provide opportunities for breeders to develop high-yielding, stress-resistant, and better quality of rice varieties. A significant contribution of molecular markers and in vitro techniques available as a detection tools are to simply assist for selection process. Complete information of the important gene also significant for developing the genetic modification of rice line. Gene editing with CRISPR system will be able to target a certain gene important for crop improvement purpose. Over-expression of gene originated from other species into rice is also applied to increase resistance to biotic stress. Molecular breeding could help to build new rice line constructively to cope the environmental changes. Inpari40, Inpari Blast and Bio Patenggang were good examples of varieties resulted from molecular breeding which beneficial for farmers in Indonesia. Molecular breeding-based findings have been delivered to farmer and other stakeholders, and other researches to establish molecular detection for desired traits in rice are underway.

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RICE BREEDING STRATEGY FOR CLIMATE RESILIENCE AND VALUE ADDITION IN INDONESIA

Priatna Sasmita and Yudhistira Nugraha

INTRODUCTION

Rice is an important food crop for Indonesian. It is not only as the primary source for nutrition (Faharuddin et al. 2016), but also it is related to social and economic aspects (Simatupang and Timmer 2008). In the next few decades, Indonesia still depends on rice. In 2035, the Indonesian population will be projected as much as 305.6 million (Statistic Indonesian 2017). With an assumption of rice consumption of 110 kg per capita per year and considering national reserve, Indonesian should provide at least 50 million tonnes of milled rice in 2035. The task of the Indonesian Government to stabilize rice production becomes more complicated because of the population growth and land competition for non-agricultural purposes. During the last decade, the average of arable land conversion to non-agricultural use was 96.512 ha per year (Purbiyanti et al. 2017). On the other hand, climate change also affects national rice production. Increasing of global temperature induces more often incidence of abiotic stresses for rice such as drought (Khanal et al. 2016), flood (Nugraha et al. 2013), salinity

(Hairmansis et al. 2017), and more often of damage due to pests and diseases (Muslim 2013).

Annual and interannual variations strongly influence agricultural production in Indonesia in precipitation. Its results experience dry climatic conditions, droughts, and flooding, with significant consequences for agricultural production. A map the location through-out the archipelago has been generated, showing the most vulnerable situation which is located in the coastal area (Figure 1). The year-to-year dynamics of climate change over the archipelago failed in crop production, and famines in different parts of the country (Naylor et al. 2006). Over the longer run, rising concentrations of greenhouse gases will likely create additional climate impacts on Indonesian agriculture. Therefore, every resource and opportunity should be managed by the Indonesia government to produce more rice, including the use of innovative technology to enlarge the capacity of production as well as maintaining its sustainability. This paper discusses rice breeding strategy for climate resilience and value addition in Indonesia. Current progress of the rice breeding programs in the country and future strategies to accelerate the impact of the research will be also discussed.

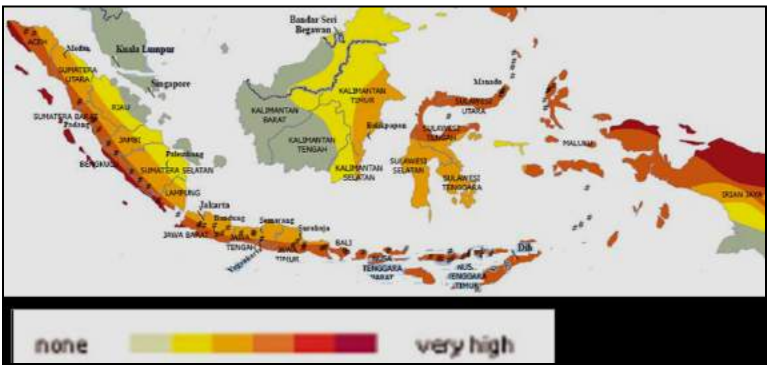

Figure 1. Heat map of Indonesia vulnerable region to climate change condition.

AGROECOLOGICAL ZONE OF RICE AREA IN INDONESIA

Rice in Indonesia is grown in a diverse agroecological zone, from low land (0 m of sea level) to high altitude in mountainous areas (1,200 meters above sea level). Indonesia has four rice agroecological zones, namely irrigated, rainfed, upland, and swampy land (Figure 2). Almost 60% of Indonesian rice production is supported by irrigated-low land environments where mostly it is located in Java Island. Farmers grow rice in different agroecosystems, and the most extensive rice ecosystem is irrigated lowland, which is predominantly in the northern part of Java. In this agroecosystem, rice can be planted three times a year. The rice productivity of this area is quite high, with an average of 5.8–4.8 ton/ha.

Rainfed lowland is the second largest production for rice in Indonesia, where it lies about 2.5 million ha at all main Island in Indonesia with average productivity 4–3 ton/ha. The definition of the rainfed lowland rice is the rice that usually transplanted and

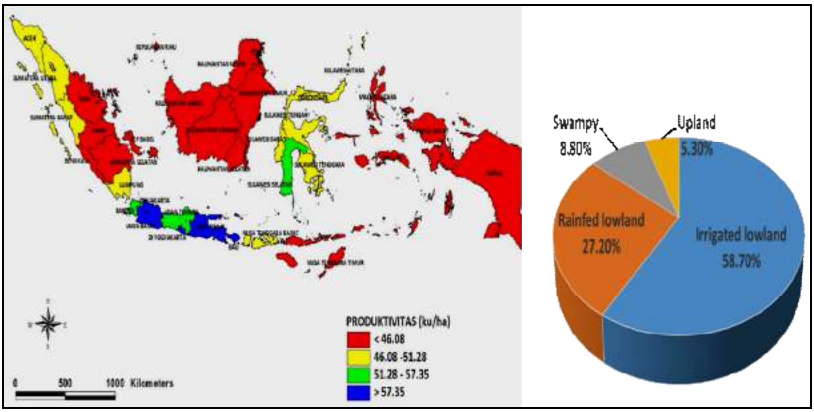

Figure 2. Distribution of rice agroecological zone and productivity of each area in Indonesia.

grown in leveled, bunded fields that are shallowly flooded with rainwater. Rain-fed lowland, which is the land-dependent with rainfall in some area only one season a year and the others can be twice depending on distribution and availability. This diverse area ranges from drought-prone to areas subjected to flash-flooding above several meters during the growing season.

The other agroecosystem zone is upland, where rice is grown in dryland during the wet season without land bundling for reserving water, unlike irrigated or rainfed lowland. Upland rice area occupies about 1.2 million ha, with its productivity ranging 2.0–4.5 ton per ha depending on the soil fertility and the availability of water. Rice is also cultivated under the upland condition as multiple cropping systems with other crops like silviculture or various food crops such as maize, soybean, etc. Most of the upland agroecosystem in Indonesia located in oxisol soil where this kind of land lacks fertility and abundance of metal toxic, such as aluminum oxide. Therefore, the prerequisite of rice varieties for this agroecosystem is having tolerance to aluminum toxicity. Moreover, another constraint for rice production in upland is different strains blast pathogen between location, and need to be addressed as well.

Another agroecosystem is swampy land, where the most significant potential area in Indonesia for agriculture; however, the utilization for rice production remains low (<1 million ha). There are two types of swamp areas, namely tidal swamp ("pasang surut"), where the water regime is depending on the dynamic of tidal in the coastal zone, and the freshwater swamp region where it can be found in the Basin or "Lebak". Lebak is a bundle of land flooded in a particular time at least one month, and the water regime is affected by rain, descend upon nearby the areas.

EXPLOITATION OF SUBOPTIMAL AGROECOLOGICAL ZONE

Most rice production in Indonesia comes from Java, the most populated region; therefore, the expansion of paddy cultivation area should be carried out in the outside Java, such as Sumatera, Kalimantan, and Papua. However, these areas are dominated by swampy land (Rumanti et al. 2018) or upland/dryland areas (Surmaini dan Runtunuwu 2011). The swampland soil has been known as a sub-optimal environment with less production capacity due to the high level of acidity and the toxicity to metal substances, such as aluminum, iron, and manganese (Nugraha et al. 2016). The existing rice varieties grown by local farmers is landrace or local varieties. These varieties are identified as high adaptable to such a harsh environment; however, they have a low yield, tall, and photoperiod sensitive (Sitaresmi et al. 2013).

To increase rice production in the swampy areas, as high as the rice production in the irrigated ones, it needs substantial investment such as irrigation infrastructure to leach toxic metal and to neutralize soil pH by liming. Although there is at least 5 million ha of swampy land and dryland, however, most of this area is located in the forest or wildlife conversation zones (Mulyani and Agus 2017)–related to the problem of water scarcity and excess of salinization of soil in rice fields near coastal areas. As farmers draw increased quantities of water from the ground, the lowering of the water table allows the intrusion of seawater into the groundwater table, thus preventing the cultivation of most varieties of rice. Introducing rice variety suitable under harsh conditions in the sub-optimal environment is the most reliable technology application by the farmers. Since 2012, there are many rice varieties adapted to upland conditions, including for silviculture and low-temperature tolerance in high altitude

(Table 1) and rice varieties adapted to swampy and coastal zone (Table 2).

HISTORY OF RICE VARIETY DEVELOPMENT IN INDONESIA

The utilization of agricultural land should be supported by a high-yielding variety and best agricultural practice for expressing potential genetic of the rice variety. In 1970, when the green revolution was started, the cultivation of the local varieties of rice, which characterize as low-yield, tall plant statue, and long

Table 1. Released rice variety adapted for upland condition.

Varieties	Year released	Yield potential (ton/ha)	Targeted environment
Inpago 10	2013	7.3	Acidic soil, upland
Inpago 11	2016	7.0	Acidic soil, upland
Inpago 12	2017	7.0	Acidic soil, upland
Rindang 1	2017	7.0	50% shade tolerant
Rindang 2	2017	7.4	50% shade tolerant
Luhur 1	2018	6.4	High altitude (1000 m asl)
Luhur 2	2018	6.9	High altitude (1000 m asl)

Table 2. Released rice varieties adapted for the swampy and coastal region.

Variety	Year released	Maturity (d)	Average yield (t ha^{-1})	Stress tolerance
INPARA3	2008	127	4.6	Submergence-tolerant with Sub1 Moderately tolerant of Fe and Al toxicity
INPARA4	2010	135	4.7	Submergence-tolerant with Sub1
INPARI29	2012	110	6.5	Submergence-tolerant with Sub1
INPARA8	2014	115	4.7	Submergence-tolerant with Sub1 Moderately tolerant of Fe toxicity
INPARI34	2014	102	5.1	Moderately tolerant of salinity
INPARI35	2014	106	5.3	Moderately tolerant of salinity
PURWA	2017	111	4.9	Submergence-tolerant with Sub1
INPARA 10	2017	112	5.6	Moderately tolerant to Fe toxicity

duration has been replaced by a high-yield, semi-dwarf statue and short-duration varieties. These new varieties responded to the application of the high level of fertilizer, especially nitrogen, producing more grain than the old rice varieties.

An increase of about 3.3% of rice production occurred during the green revolution in 1970–1980 (Figure 3). During the 1980s, there was an outbreak of brown planthopper (BPH), causing loss of rice productivity of 0.2%. The rice production rose as much as 1.2% after the introduction of the new *Bph* resistance varieties, such as IR64. However, during the 1990s, the *Bph* resistance varieties break their resistance to BPH because of biotype mutations. Therefore, some new rice varieties such as Ciherang, Mekongga, Cigeulis, which carry out the new *Bph* resistance gene, were introduced to overcome. Rice production in Indonesia slightly increased by 1,2% from 2000 to 2016 because of the introduction of some rice new varieties that have better yield production but also adaptive to diverse agroecosystem zone and also to encounter consumer preferences.

The Indonesian Center for Rice Research (ICRR) has released more than 200 varieties for several target environments,

Figure 3. Historical development of rice varieties in Indonesia during the 1970s to 2018.

including irrigated rice fields, rainfed lowlands, swampy areas, and uplands. The success of breeding programs can be identified through adoption varieties by farmers. Almost all varieties grown by farmers in Indonesia are products of the ICRR classical breeding program (Table 1). Seed distribution in 2018 showed that Ciherang predominantly covered cultivation area (30.80%), followed by Mekongga (12.79%), IR 64 (7.00%), INPARI 30 Ciherang Sub1 (5.96%), Situ Bagendit (5.49%), Inpari 32 HDB (3.64%), Ciliwung (3.13%), Cigeulis (2.98%), landrace (8.34%), and others (19.86%) (Directorate General of Food Crops, 2018). The wide distribution of Ciherang is in complement with the national rice program, which addressed to accelerate the dissemination of technology innovation, contributes significantly to increasing national rice productivity as much as 0,5 ton/ha during 2005–2014. Replacement of IR64 by Ciherang gave an economic benefits Rp. 67 trillion in 2014.

Among the known abiotic stresses, submergence is one of the most critical factors in the flash flood-prone in the Asia rice cultivation area, including in Indonesia. Ministry of Agriculture, through the IAARD, portrayed that more than 300 thousand hectares of the rice cultivation areas in Indonesia per year are affected by different types of floods (http:// katam.litbang.pertanian.go.id/main.aspx?lang=en), especially during the wet season. The inundation can be happening at any growth stage of rice from seedling, vegetative stages, through ripening that may cause substantial yield losses.

Developing new rice varieties for the flood-prone ecosystems, considering the quality of improved yield, tolerant to biotic stress, and accepted by the farmer is essential. Therefore, the submergence tolerance gene is introduced using molecular assisted back-crossing (MAB) to improve the most widely cultivated variety in Indonesia, Ciherang. The near iso-genic lines

(NIL) of Ciherang was introduced to Indonesia from the International Rice Research Institute in 2010. Ciherang Sub1 was not significantly different in comparison to the original Ciherang. However, under 15 days, the submerged Ciherang Sub1 surpasses Ciherang yield potential. The development of Ciherang Sub1 could provide more options for farmers to choose for using their favorite varieties and minimize crop losses due to unexpected flooding (Nugraha et al. 2017). In 2012, Ciherang Sub1 was officially released and named INPARI 30 Ciherang Sub1. INPARI 30 Ciherang Sub1 became the top ten largest grown of rice field in Indonesia in 2015, and the distribution then increased in 2018, which covered as much as 969 573.2148 ha or the fourth largest of covered area (Table 3). Although INPARI 30 Ciherang Sub1 is comparable to its parents, the average yield slightly higher as much as 0.5 ton per ha than Ciherang under normal conditions in our demonstration plot. This yield profit contributes equally to 387.9 million tons of rice or US$ 125 million. This benefit is another addition to its tolerance to flash flooding stress.

Table 3. Rice varieties coverage areas in Indonesia (Directorate general of food crops 2018).

Varieties	Year of release	Coverage area (ha)	Percentage (%)
Ciherang	2001	5011967.826	30.80
Mekongga	2006	2081353.95	12.79
IR 64	1986	1139395.174	7.00
Inpari 30 Ciherang Sub-1	2012	969573.2148	5.96
Situ Bagendit	2003	892570.0729	5.49
Inpari 32 HDB	2013	592198.8772	3.64
Ciliwung	1988	509755.1674	3.13
Cigeulis	2002	485630.3723	2.98
Other varieties		3231682.806	19.86
Land Races		1356514.939	8.34
Total		16270642.4	100

The use of biotechnology in rice breeding in ICRR has been initiated on a small scale. The biotechnological approach is useful for rice genetic improvement of particular traits such as high beta carotene (golden rice), Fe/Zn content, the resistance of brown planthopper, and bacterial leaf blight. In particular, molecular marker-assisted could give a tremendous opportunity for the selection process of the transgenic plant with high Fe and Zn content, brown planthopper, and bacterial leaf blight. The handling of the GMO materials follows the regulations, such as the fulfillment of food, feed, and environmental safety.

ICRR's breeding programs gain genetic improvement of rice varieties over for 20 years. This genetic improvement has increased grain yield from rice varieties released in the 2000s (Ciherang group 1997–2007) to the Inpari generation (2008–2018). The grain yield of Ciherang group was 5.62 ton/ha, while Inpari group varieties were 6.47 ton/ha. Thus, Inpari group was higher of 0.85 ton/ha or ± 13% of yield improvement than Ciherang group (Figure 1). Inpari group varieties also improve the capacity to reduce the risk of pest and disease attacks and abiotic environmental stresses such as drought, flooding, salinity, and others (Nugraha and Sitaresmi 2018).

DEVELOPMENT OF SPECIALTY RICE

With the rapid development of economics and the increase in people's living standards, functional foods are being gradually embraced by consumers and have growth potential. Rice plays a vital role in promoting people's health and in improving public nutrition, and therefore there is ever-increasing consumer demand for rice for its functional quality. Developing and marketing of useful rice is becoming a subject of great importance for research and is to be the focus of research in the future.

The Government of Indonesia is implementing rice price policies in achieving domestic rice price stability. The current rice price policies are regulated only for standard rice with acceptance to specialty rice. The term specialty rice is unique rice characters in kind in terms of aroma, color, and chemical composition. With the growing prosperity, demand for such specialty rice is also growing. The need for long-slender grained like Basmati is increasing in India and Pakistan dramatically. The market for pigmented rice (red and black grains) also has increased because of the high nutrient content of antioxidants, and vitamin B. Farmer will get more earned income by planting the specialty rice because of its high price compared to regular rice.

The development of specialty rice, also an effort to meet the needs of micronutrients of people in Indonesia, is considered. A national breeding program conducting biofortification through the rice breeding process is being implemented. Biofortification through breeding will get more efficient results because it is heritable to the next generation of plants, so it is more efficient compared to fortification, which at all times must carry out specific nutritional improvement treatments. Rice breeding for added value purposes is one of the integrated programs under the Ministry of Research and Technology. ICRR has released functional rice variety (added value), with characters of red rice, black rice, red-aromatic rice, and high zinc content. These rice varieties are Inpari 24, Inpari 25, IR Nutri-Zinc Inpari, Jeliteng, Pamera, Paketih, Arumba Inpari, and Pamelen. Besides, varieties with unique rice characteristics such as Tarabas (low amylose and crystal rice) and Baroma (aromatic and Basmati type) also have been released (Table 4).

It has been a big gap between productivity in sub-optimal agroecosystem compared to irrigated condition. Therefore, the rice breeding program strategy should put the focus on:

Table 4. Specialty rice released in Indonesia.

Varieties	Year of release	Yield potential (ton/ha)	Characteristic
Inpari 24 Gabusan	2014	7.7	Red Rice
Inpari 23 Bantul	2014	9.2	Aromatic
Inpari 25 Opak Jaya	2014	9.4	Red, Waxy, Amylose: 5.7%
Inpari IR Nutri-Zinc	2019	10.0	High Zn content: 29.6–34.5 ppm
Jeliteng	2019	9.9	Black Rice
Pamera	2019	11.3	Red-Aroma Rice
Paketih	2019	9.6	Waxy rice
Inpari Arumba	2019	10.5	Red-Aroma Rice
Pamelen	2019	11.9	Red Rice

(1) development of rice varieties with higher yield potential, yield stability, superior cooking quality, and shorter growth duration, and develop specialty rice for increasing added value of rice, for the optimal agroecosystem.

(2) development an improved varieties with higher productivity, yield stability, and tolerance to environmental stresses by combining multiple gene resistance genes to the harsh environment such as drought, salinity, flood, and metal toxicity, for the suboptimal agroecosystem.

The existing resources cannot solve all this challenge, and the breeding program has gained the advantage by efficient technique aided by an integrated molecular/genomic approach and high throughput phenotyping. The next generation of plant breeders needs a unique degree of knowledge and flexibility to react to rapidly changing environments, consumer preferences, and political frameworks. The continuous progress in science and technology revolutionizes the way plant breeding is conducted. New hard skills are required to be able to harness the potential of these developments. The plant breeder of the future has to interact in diverse and interdisciplinary working fields.

CONCLUSIONS

Research development of rice in Indonesia is dynamic. Exploitations of landrace or local rice varieties and marginal zones of potential development areas, such as swampland, also using various advanced breeding technologies have been generating several improved rice varieties that adaptive to submergence conditions or resistance to pests and diseases. Several high-yield, semi-dwarf statue, and short-duration rice varieties have been released and replaced the cultivation of conventional rice varieties. Biofortification through breeding is also implemented to get specialty rice variety having added values, such as red rice, black rice, red-aromatic rice, and high zinc content, as well as, low amylose and crystal rice varieties. Rice varieties with higher yield potential must retain the "good plant-type traits," namely, short stiff (lodging-resistant) culms, erect leaves, and high tillering ability. Moreover, incorporating the following varietal traits should help increase rice yield per crop. It has been a big gap between productivity in sub-optimal agroecosystem compared to irrigated condition; therefore, the effective and efficient rice breeding program strategy should be further prioritized.

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THE CONTRIBUTION OF SWAMPLAND RICE FOR FOOD SECURITY IN SOUTH KALIMANTAN

Rina D. Ningsih, Aidi Noor, and Muhammad Yasin

INTRODUCTION

Food is the main basic needs for a human that must be fulfilled all the time. While food security is "a condition of the availability of sufficient food, both in quantity and quality, safe, diverse, nutritious, equitable, and affordable." Food sufficiency for each person will determine the level of welfare of a community. Sufficient domestic food production ("swasembada") is the most effective way to achieve local food price stability, and, in turn, achieve food security.

Rice is one of the staple foods for the majority of South Kalimantan's people. On the poverty line, rice provides the most significant contribution both in urban and rural areas (BPS 2015). Expenditures on the poor are mostly used to buy food, especially rice commodity. An increase in rice price is parallel with the higher public spending, as a result it has the potential to increase the number of poor people. The previous study (Malian et al. 2004) reported that every 10% increase in rice prices would cause an increase of 1% of poor people. Meanwhile, one of the causes of low food security in Indonesia is poverty (BPS 2014). The low-income household is mainly used for food consumption (Putri et al. 2013), which means its close relationship between economic factors and food security (Wijaya et al. 2013).

South Kalimantan is one of the most significant national rice contributors, accounting around 5% of domestic rice production. The South Kalimantan rice production is 1,439,048 tons, a conversion value from 2,452,365.82 ton grains yielded from the total production from the wetland (506,823 ha) and upland rice areas (63,170 ha) (BPS 2018). Approximately, 58.82% of the rice area is glade and tidal swamps. The rice productivity in the swamps glade is 5.66 ton/ha, whereas in tidal land is 3.85 ton/ha. In the swamps area, generally cultivation is only once for particular tidal swamps dominated by local rice. This article aims to discuss the rice contribution in swampland for food security in South Kalimantan, Indonesia.

FOOD SECURITY IN SOUTH KALIMANTAN

The Food Security Agency formulates nine indicators of the Food Security Index, Ministry of Agriculture (BKP 2018), as follows:

a. The ratio of a normative consumption per capita to the net availability of rice, corn, cassava, and sweet potatoes.
b. Percentage of population living below the poverty line.
c. The percentage of households with a proportion of expenditure on food more than 65 percent of total spending.
d. Percentage of households without access to electricity.
e. The average length of schooling of women over 15 years.
f. Percentage of households without access to clean water.
g. The ratio of total population per health worker to population density.
h. Percentage of toddlers with sub standard height (stunting).
i. Life expectancy at birth.

To complement the indicators, food security index is identified with specific range which differ between district and city. The cut-off point food security index is presented in Table 1. Based on the 9 indicators of food security index for districts and eight indicators for cities, the food security index of South Kalimantan Province is in the range of 5–6, meaning taht the region is in a securing food status (BKP 2018) (Table 2).

Table 1. Cut off point Food Security Index.

IKP Group	District	City
1	< = 41.25	< = 28.84
2	>41.52–51.42	>28.84–41.44
3	>51.42–59.58	>41.44–51.29
4	>59.58–67.75	>51.29–61.13
5	>67.75–75.68	>61.13–70.64
6	>75.68	>70.64

Table 2. Rank and score of Food Security Index in South Kalimantan Province, 2018.

Rank		District's names	Score	IKP Group
National (416)	Province of South Kalimantan (98)			
District				
9	1	Tanah Bumbu	84.06	6
17	2	Balangan	82.46	6
27	3	Banjar	81.73	6
35	4	Tabalong	81.11	6
57	5	Hulu Sungai Selatan	79.79	6
59	6	Tanah Laut	79.76	6
76	7	Hulu Sungai Tengah	78.69	6
81	8	Kotabaru	78.57	6
85	9	Hulu Sungai Utara	78.42	6
93	10	Barito Kuala	77.99	6
City				
39	11	Banjarmasin	75.82	6
53	12	Banjarbaru	70.,21	5
75	13	Banjar	64.33	5

TIDAL SWAMP RICE CONTRIBUTION TO REGIONAL FOOD SECURITY

The composition of food diversity, which is based on the proportion of energy balance of the main food groups, is called the Hope Food Pattern (PPH) (Gardjito 2009). The ideal food pattern score is 100. The rate of the National PPH score in South Kalimantan Province in 2017 was 86.5, below the ideal score (100), indicating that the quality of community food availability still does not meet the perfect food diversity of each food group (Badan Ketahanan Pangan 2018b).

The level of food security in South Kalimantan is highly food resistant. But related to food diversity PPH score is still lower than the National PPH score, suggesting that more efforts are still needed to increase food diversity (Table 3). The pattern of consumption of staple foods (food sources of carbohydrates) is dominated by grains, at around 62.1%. The level of grain energy consumption has exceeded the recommended composition by 50%, while rice consumption per capita is 261.3 grams/cap/day (95.4 kg/cap/year) (Badan Ketahanan Pangan 2018b).

Table 3. The energy availability based on PPH score in South Kalimantan in 2017.

Food commodities	Recommended calories (kcal/cap/day)	Score max	PPH Score (2017)	
			Indonesia	South Kalimantan
Rices	1,100	25	25	25
Starchy foods	132	2.5	1.7	1.6
Animal Food	264	24	22.3	22.8
Oil and fat	220	5	5	5
Oily fruit/seeds	66	1	0.9	0.5
Nuts	110	10	6.2	5.6
Sugar	110	2.5	2.5	2.5
Fruits and vegetables	132	30	26.8	23.5
Others	66	0	0	0
Total	2200	100	90.4	86.5

Food independence of an area in absolute or full rice self-sufficiency if the community's rice needs are entirely met from domestic production without imports (Suryana and Kariyasa 2008). Adequacy of rice in an area is seen through the existing rice surplus and deficit. A district is considered to have a rice surplus if the rice availability exceeds the need for rice consumption. In contrast, a rice deficit is noted if the availability of rice is lower than the rice consumption requirement. Overall, South Kalimantan has a rice surplus in all districts except the municipalities of Banjarmasin and Banjarbaru where low agricultural land area are predominant.

Paddy production in South Kalimantan, according to Indonesian statistic data in 2018, is 2,313,573.38 tons of MPD, equivalent to 1,466,111.45 tons of rice (63.37% of rice from milled unhusked rice). With a population of 4,055,500 people, South Kalimantan still has rice surplus. Based on national report (BPS 2016), the area of tidal swamps land planted with 166,324 ha of rice spread across seven districts, resulting its rice production of 602,706.19 tons, with the estimation of 26.05% of the total rice production in South Kalimantan. Rice production in South Kalimantan in 2017 is presented in Table 4.

Adaptive rice varieties in tidal swamps land sulfate acid, potentially contain high levels of iron (Fe) and zinc (Zn) because the growth environment is rich in Fe and Zn. In general, local varieties of tidal swamps are adaptive to the environmental conditions facilitating to possess high Fe and Zn in their rice. As reported that the Fe and Zn levels in 71 local rice varieties varied greatly. The content of Fe of broken rice skin of local rice varieties of tidal swamps rice ranges between 11 to 83 ppm. Zn levels range 20–108 ppm Zn. Fe content of superior varieties of Kapuas rice is 20 ppm Fe, and Banyuasin is 44 ppm Fe. Zn levels of an

Table 4. Rice production and consumption in 2017.

Districts/cities	Total residents (x000)	Rice consumption ton/yeac (x 95.4kg/cap/year)	Rice production (ton)	Surplus or deficit
Tanah Laut	329.3	31,415.22	127,540.64	96,125.42
Kotabaru	325.8	31,081.32	57,637.85	26,556.53
Banjar	563.1	53,719.74	176,084.66	122,364.92
Barito Kuala	302.3	28,839.42	211,874.53	183,035.11
Tapin	184.3	17,582.22	215,143.98	197,561.76
Hulu Sungai Selatan	229.9	21,932.46	165,323.36	143,390.90
Hulu Sungai Tengah	263.4	25,128.36	181,629.59	156,501.23
Hulu Sungai Utara	228.5	21,798.90	82,910.53	61,111.63
Tabalong	243.5	23,229.90	69,365.39	46,135.49
Tanah Bumbu	334.3	31,892.22	61,886.41	29,994.19
Balangan	125.5	11,972.70	108,933.70	96,961.00
Banjarmasin	684.2	65,272.68	4,120.46	- 61,152.22
Banjarbaru	241.4	23,029.56	3,609.14	- 19,420.42
Jumlah	4,055.5	386,894.70	1,466,060.24	1,079,165.54

excellent rice variety of Martapura tidal swamps rice is around 65 ppm (Technology Indonesia.com 2019).

The average Fe and Zn levels in superior varieties were 11.7 ppm and 23.9 ppm, respectively. These local varieties of tidal swamp rice proved the high levels of Fe and Zn in broken rice skin. Besides local varieties of rice have low glycemic content, therefore such rice is suitable for people with diabetes (Indrasari et al. 2008, 2010; Marsh et al. 2011; Pangerang et al. 2018; Suryani et al. 2020).

Iron (Fe) is an essential microelement for hematopoiesis (blood formation) synthesized in hemoglobin (Hb). Hemoglobin itself consists of Fe, protoporphyrin, and globin (1/3 Hb weight consists of Fe). Zinc is one of the essential microminerals which has a primary role in the process of accelerating growth and cell division, where zinc involves in the synthesis and degradation of carbohydrates, fats, proteins, nucleic acids, and embryo formation. Zinc also is vital for immune system, and it is proven that zinc is a potential mediator of the body's defense against infection. Moreover, zinc acts as an antioxidant, sexual development, taste, and appetite. Thus, Fe and Zn are two nutrients needed by the body (Indrasari 2006; Hidayati et al. 2009; Wessells et al. 2012; Black et al. 2013; Stevens et al. 2013; Schmidt et al. 2014).

CONCLUSIONS

Food security in South Kalimantan is quite guaranteed, with a high food security index, and is classified as a food security area. Food diversity is still low; the PPH value is lower than the national average. The consumption pattern of staple foods (food sources of carbohydrates) is dominated by grains (62.1%). Tidal swamps rice contributed 26.05% of the total rice production in South Kalimantan. The good nutritional value of tidal swamps rice is high because it contains higher levels of iron (Fe) and zinc (Zn) than rice from other fields. The food security in South Kalimantan from food availability's aspects is secure, which imply that rice adaptive in swampland could give a big impact to food availability in South Kalimantan.

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DOI ASSIGNATION OF INDONESIA PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE TO SUPPORT EXCHANGE IN THE MULTILATERAL SYSTEM

Nurul Hidayatun, Hakim Kurniawan, Endo Kristiyono, and Muhamad Sabran

INTRODUCTION

One of the main components of the International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA) is the Global Information System (GLIS). The participating countries should adopt the GLIS in the utilization of their PGRFA collections, especially for those PGRFA that are included in the annex-1 of the Treaty (FAO 2009).

The GLIS requires the availability of adequate supporting instruments in its implementation, particularly a single unique identity for PGRFA. The identification must be sufficient with some requirements. Local identity, which is mainly used in each genebank to identify its collection, can not be used as a permanent identifier because of the lack of some essential characters. Various solutions had proposed to solve this problem, including the use of the World Information and Early Warning System (WIEWS) code and using the digital object identifier (DOI). The use of WIEWS code is easy to obtain but less recommended because this is not opaque and lack of connection due to different documentation systems between providers and recipients, causing inconsistency in the genetic resource identity. DOI, as one example of Permanent Unique Identifiers, is considered more accurate and permanent. This identifier is guaranteed for fully opaque, compact, unique, and unchanged.

DOI application gives new opportunities to improve the quality and variety of services offered to users of the PGRFA community. The DOI of the PGRFA will include the DOI system prefix, GLIS prefix, and unique value assigned by GLIS. The DOI will be associated with the plant materials and the holder of the plant materials. DOI will not change even there is a change in taxonomy or error correction. DOI assignation can be conducted in different ways such as manually by clicking on the GLIS website or by registering the system to system using the XML protocol by developing and implementing the toolkit on the stakeholder's network. DOI can be used for material publications as bibliographic references or on the dataset and Standard Material Transfer Agreement (SMTA). The DOI is expected to be a global standard for public identification of PGRFA, facilitating linkage between the material and diverse source of information associated with the material (Alercia et al. 2018)

The International PGRFA Community has agreed on a common approach to facilitate the establishment of automated meaning links through the adoption of permanent unique identifiers. The International Treaty has set up the information infrastructure for the operations of the Multi-lateral system (MLS) and that the GLIS is further developed. A multicountry project was funded by Benefit Sharing Fund (BSF) through the under window 3 of the third call for proposal. The multi-country construction of a Test Platform for the Development and Allocation of a Unique Identifiers for Rice Germplasm was aimed to the adoption and implementation of global, permanent and unambiguous identifiers. This established identifiers was beneficial to add value and facilitate the use of PGRFA and the development of a platform to establish automatized system-to-system connections. The purpose of such connection is to add value to the material being transferred within and from the MLS.

The project was targeted to all *ex-situ* of rice (*Oryza* spp.) collection, including either accession conserved in *ex-situ* genebank collections and *ad hoc* dynamic working collections of genetic stocks, pre-breeding materials, other bred, and elite materials developed by researchers and breeders. The exposition of the aggregation of metadata information of accessions in MLS will make the content discoverable, and thus expected to support broader use of PGRFA.

Each ecosystem has its characteristics and capabilities as production systems. In Indonesia, the production systems are differentiated based on the nature of the production in each ecosystem. Based on the type of production, there are four central production systems existed in Indonesia, i.e., aquaculture and fisheries production system, forestry production system, livestock production system, and crop production system.

Indonesia is rich in the ecosystem, and so is the production system. The natural resources and land utilization for the on-farm crop production system are categorized as wetland and dryland. The dryland system occupies 41.12% of the agricultural ecosystem, whereas the wetland system occupies 23.64%. The rest are shifting cultivation areas (11,27%) and temporarily unused land (23.97%) Pusdatin, 2015). Dryland, hold 41% of total agriculture land, existed in almost all provinces. The dryland in

Indonesia is categorized as dryland with dry climate, which is commonly found in Eastern Indonesia and dryland with a wet climate condition, which is widely occurred in western Indonesia, mostly outside Java (Widjaja et al. 2014). The dryland production system consisted of locally known as "gogo rancah", moor, and yard garden (Pusdatin 2015). Wetland system consisted of irrigated and non-irrigated land. The system is widely distributed in South Sumatera, South and West Kalimantan, and South Sulawesi. The structure of this system can be categorized as a rainfed field, swamp, or tidal land.

Indonesia ratified ITPGRFA in 2006 with the issuance of Law Number 12. One of consequences of the adoption of the Treaty is to taking measures to facilitate its implementation in national level. (UU no.4 tahun 2006). In term of legal measures, there is Ministerial Regulation declared to support facilitation of PGRFA access (Permentan No. 15, 2009). Aside of the development of legal aspect, as a participating country, Indonesia obliged to share their PGRFA into the MLS schemes. However, until 2017, these consequences have not been wholly followed up. The objective of this study is to generate an overview of the inclusion of Indonesia PGRFA into MLS. Besides, the expose of those PGRFA is expected to facilitate and support its utilization.

DOI ASSIGNATION OF INDONESIA IPTGRFA

As the contracting party of ITPGRFA, Indonesia must comply with the components of the Treaty. The part IV of the Treaty on The Multilateral System of access and benefit-sharing encourage the Contracting Parties to include their crop collection listed in Annex-1 of the Treaty to the MLS as described in the Article 10–13 (FAO 2009).

Indonesia exposes the PGRFAs to the system by assigning DOI of the country PGRFA collections. The DOI assignations for Indonesia PGRFA were performed during the year 2016–2019 through the participation of the Multilateral BSF-FAO project funded by ITPGRFA and independently outside the project. In 2019, a total of 1366 PGRFA collections were assigned with DOI. Those PGRFA are collected and managed by different PGRFA holders in Indonesia. The whole data preparation for the registration was completed by the PGRFA holders, whereas the process of DOI assignation was conducted through the single account that managed by ICABIOGRAD.

By 2019, a total of 1366 PGRFA accession were assigned with DOI, including 1246 rice accessions. The assignation was started in 2017 through an internship program at the International Rice Research Institute (IRRI), the Philippines. A total of 849 rice accession ICABIOGRAD-IAARD genebank were assigned with DOI. The next assignation on rice accessions was conducted through participation in the DOI training. During the 1st International DOI Training, aside from ICABIOGRAD as the National genebank, there was another rice holder participate for the DOI assignation. With the participation of the Indonesian Center for Rice Research (ICRR), Assessment Institute of Agricultural Technology (AIAT) of Central Kalimantan, AIAT of East Kalimantan, AIAT of West Nusa Tenggara, AIAT of South Sumatera, and AIAT Yof ogyakarta, a total of 110 rice accessions were assigned with DOI. These rice accessions were collected *ex-situ* in each rice holder and on-farm in each administrative area of the five AIATs. Samples of some of those rice accessions were then deposited to ICABIOGRAD genebank. DOI assignation on rice was also performed separately, outside the project programs. A total of 30 rice accessions from breeder collections were assigned with DOI to complement and support the transfer of the materials.

Because rice is the main focus of the project, the DOI registration was initially applied in this crop. A total of 1,246 rice accessions were assigned with DOI. Based on the biological status, those accessions including traditional cultivar/landrace, breeding materials, and improved cultivar (Tabel 1). Most of the traditional varieties are maintained *ex-situ* in ICABIOGRAD genebank, and the rest is maintained in AIAT and on-farm. The advanced/improved materials are supported by the ICRR sub-genebank, whereas the breeder/researcher maintains the breeding materials.

There are some signs of progress in the implementation of participating countries. The Indonesian Agency for Agricultural Development (IAARD) is responsible in handling the rice germplasms maintained in the ICABIOGRAD genebank as national genebank, the ICRR for managing the working collections for rice breeding programs, and the 34 location in the AIAT throughout the country. In the meantime, a total of 1111 accessions of rice accession have been registered with DOI, including 849 rice accessions that were recorded during the internship in IRRI, 111 rice accessions from genebank collection, 96 rice accessions from ICRR, 55 rice accessions from AIAT of South Sumatra. Related on-going activities are: validating the

Tabel 1. Biological status of Indonesia rice accessions assigned with DOI.

Biological status	Number of accessions
Traditional cultivar/landrace	1197
Breeding/research material	28
Advanced or improved cultivar	21
Total	1246

viability of existing accession collections, synchronizing rice accessions with ICRR, acquisitions and registering new rice accessions from AIAT, and continuing DOI registration.

Based on the origin from where the accessions obtained, the majority of the rice accessions are from Kalimantan island, Sumatera, and Java (Figure 1).

The rice accessions are categorized as an anaerobic, irrigated, and non-irrigated wetland, based on the type of production system,. Among the rice accession assigned DOI, only 393 plant accessions are able to be categorized, whereas the rest 722 plant accessions are unknown. Among the 393 rice accessions, 68% is irrigated rice, 27% aerobic rice, and 4% are non-irrigated wetland rice. In the dryland, which is typically upland, rice production is performed in anaerobic plantation with a so-called "gogo rancah" system. This system is usually made with fences and terraces in such a way to avoid erosion. Aside from rice, plants grown are corn and other crops. Some plant accessions are considered anaerobic rice. This type of rice is found in a rainfed field, swamp, or tidal land.

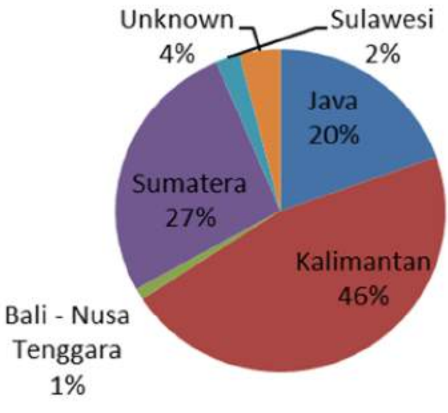

Figure 1. Composition of rice accessions based on its origin.

Aside from rice, some other PGRFA were also assigned with DOI. During the 2nd international DOI Training, seven crop-based research centers participated on the DOI assignation, i.e., the ICRR, the Indonesia Legume and Tuber Research Institute (ILETRI), the Indonesia Tropical Fruit Research Institute (ITFRI), the Indonesian Center for Animal Research and Development (IRIAP), the Indonesian Center for Subtropical Fruit Research Institute (ICSFRI), the Indonesian Center for Vegetable Research Institute (IVEGRI), the Indonesian Cereal for Research Institute (ICERI), and the Agrotechnology Innovation Center–University of Gadjah Mada. With the participation of those institutes, another PGRFA were assigned with DOI. The majority of those PGRFA are a member of Annex-1 crop, whereas the other is a non-annex-1 crop (Table 2).

Table 2. Indonesia PGRFA assigned with DOI.

Crop	Species	Number of accessions	Institution
Rice*	*Oryza sativa*	1246	ICABIOGRAD, ICRR
Maize*	*Zea mays*	22	ILETRI, ICRI
Cassava*	*Manihot esculenta*	6	ILETRI
Sweet potato*	*Ipomoea batatas*	12	ILETRI
Pigeon pea*	*Cajanus cajan*	12	ILETRI
Citrus	*Citrus reticulata blanco*	12	ICSFRI
Banana*	*Musa paradisiaca and Musa acuminata*	10	ITFRI
Animal Feed	*Calopogonium; Centrocema; Clitoria; Gliricidia; Indigofera; Leucaena; Pueraria; Sesbania; Stylosanthes*	18	IRIAP
Pumpkin	*Cucurbita pepo*	5	UGM
Been	*Phaseolus vulgaris*	5	UGM
Winged Bean	*Psophocarpus tetragonolobus*	5	UGM
Yardlong Bean	*Vigna unguiculata*	5	UGM
Snow Pea	*Pisum sativum*	5	UGM
Eggplant*	*Solanum melongena*	5	UGM

*: Annex-1 crop.

ICABIOGRAD genebank manages around 11.000 PGRFA accessions, consisted of cereals, legumes, tubers, and others (Hidayatun et al. 2017). Among those collections, only rice is assigned with DOI and shared with the MLS. Another food crop accessions were maintained in the research institute under the Research and Development Center for Food Crops. ICRR managed rice collections, including traditional cultivar, breeding lines, and improved varieties. During the participation in the project, the institute opens improved rice varieties to be assigned with DOI. The improved rice varieties are basically under the public domain. ILETRI, which is maintaining legumes and tubers crop, included 30 accessions of food crops consisted of cassava, sweet potato, and pigeon pie. Cereals are preserved in ICRI. Among cereals collections in ICRI, only 20 maize accessions are currently assigned with DOI.

A total of 52 accessions of horticultural crops were assigned with DOI. Under the Ministry of Agriculture, horticulture crop is maintained by research institutes under the Research and Development Center for Horticulture Crop. Twelve accessions of citrus and ten accessions of banana were assigned with DOI by ICSFRI and ITFRI, respectively. Thirty vegetable crop accessions were opened and assigned by AIC-UGM.

Together with the conservation of livestock, forage genetic resources are maintained by IRIAP. Nine species of forage were assigned with DOI, i.e., *Calopogonium, Centrocema, Clitoria, Gliricidia, Indigofera, Leucaen, Pueraria, Sesbania,* and *Stylosanthes.* Those species are non-Annex-1 crop.

Through the project of The Multi-country Construction of a Test Platform for the Development and Allocation of a Unique Identifiers for Rice Germplasm, some provision of ITPGRFA are implemented. Serials of workshops and technical trainings that were conducted during the program facilitated the implementation of Multilateral System. Aside of promoting capacity building, the communication among PGRFA stakeholders that was established is also mediated the raising awareness. Those practices are basically part of tool of implementation of ITPGRFA, especially on the development of facilitated access of PGRFA (JCBP 2018).

CONCLUSIONS

DOI system is beneficial to be implemented for supporting germplasm collection management and exchanges. Indonesia assigns DOI for 1366 PGRFA collections. Indonesia complies with the ITPGRFA by exposing some PGRFA in MLS.

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CHAPTER 2.
RICE TECHNOLOGIES ON PEAT-SWAMPY LANDS

ASEAN countries, including Indonesia, faces the challenge of increasing food production for its food security. In the year 2025, 1.4 million ha of additional rice cultivation area needed to produce rice for national food security. As a result, land availability is becoming an important issue. There will be a land-use competition between food production, biofuel production, and human settlement. Considering that the availability of highly productive arable land is limited, the development and optimization of suboptimal or marginal land along with the relevant technologies for food production is a potential alternative.

Peatlands in tidal swamp ecosystems are often associated with pyrite layers located in the lower layers, which during the dry season become acidic. Most peat soils from the tidal swamp ecosystem are in the early stage in the decomposition of organic matter in the process of peat formation ("fibric") and even more in the upper layer. Dynamic modeling can be used to determine the prospect of rice farming in degraded peatland, with the focus on reducing GHG emission and increasing food production. In tidal swamplands, rice cultivations using the ratoon system are mostly implemented for local rice varieties. Ratoon system cultivation of local rice varieties in the tidal swamplands has been practiced for a long time. The ability of rice plants to produce ratoon can be determined by genetic and environmental characteristics, such as water availability, soil fertility, and the presence or absence of pests and plant diseases.

The development of tidal swamplands for rice crops faces several problems, including high soil acidity, low nutrient content, and high concentration of soluble of iron, aluminum, and manganese. Implementing appropriate farming technology, such as improvement of land quality, use of adaptive and high-yielding varieties, and suppression of post-harvest yield loss and pest disturbance, could improve the tidal swampland productivity. The development of the swampland quality can be carried out through water management, water quality improvement, and application of soil ameliorant. Water management is intended to supply the plant requirement, prevent weed growth on the rice field, avoid the formation of toxic materials through leaching, control of water levels, and maintaining water quality in plots and canals.

The development of tidal swamp agriculture is one of the efforts to answer the challenges of increasing agricultural production. With proper management through the application of appropriate technology, tidal swampland has good prospects to be developed into productive land. Technology Package, known as "Jajar Legowo" in the tidal swamp areas, is very feasible. This technology might become a breakthrough in increasing rice production in the tidal swamp areas to sustain food self-sufficiency. As a consequence, intensive management of swampy lands is necessary because it may contain a layer of pyrite, which causes soil acidity and high soluble Fe concentration.

In Indonesia, the area of acid sulfate soil is quite extensive, approximately 6.1 million ha, and plays a vital role in national rice production. Soil fertility is essential for rice cultivation. Rice cultivation acid sulfate soil generally has low productivity due to mostly this soil not suitable for crop cultivation until amelioration. Application of biofertilizer increases soil fertility due to increase soil pH, reduce exchangeable Al and weakly bound-Al. Decreasing of Al and Fe toxicity and also acidity can be strengthening of the soil fertility, nutrient availability, and uptake. Besides, microorganism as biological fertilizer element also produces plant growth promotion substances that can increase plant growth and yield. The use of acid sulfate land with intercropping planting systems to make food shortages due to crop failure can be prevented, and pest and disease attacks can be decreased. Land modification can be done by organizing the water system, plant varieties, and fertilizer technology. The role of peatland and swampy lands need to optimized to support national food security with techniques specific to these environments.

Chapter two is purposed to resume a number of topics such as the characteristics, the limiting factors, and the available technologies for development of swampland as an alternative in expansion of rice farming area; peatlands in tidal swamp ecosystems which are often associated with pyrite layers located in the lower layers, which become acidic during the dry season; and most peat soils from the tidal swamp ecosystem in the early stage in the decomposition of organic matter. More over, to develop tidal swampland to be productive land need proper management through the application of appropriate technology is also described.

ECONOMIC FEASIBILITY ANALYSIS OF RICE FARMING IN SWAMPLAND

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Wahida Annisa Yusuf, and Muhammad Alwi

INTRODUCTION

Swampland suitable for agriculture around 10.87 million hectares consists of a lowland swamp field about 2.34 million hectares and tidal land ranges of 8.54 million hectares (ICALRRD 2014). The area that has been opened by the Ministry of Public Works and Public Housing is around 3.77 million hectares, while the public are is about 3.0 million hectares. Therefore, in total, the swampland area is approximately 6.77 million hectares that can be utilized. Around 1.05 million hectares swampland could be cultivated for rice field with once a year of planting (90%) and productivity of 4–5 ton/ha of dry grain yield. However, the contribution of swampland to national rice production is only 4–5 million dry grain ton/year (Sulaiman et al. 2018).

Swampland is a potential land to be developed as an area of food crops, especially rice. However, swampland faces various shortcomings, such as high soil acidity, deficient nutrient (Widjaja-Adhi et al. 1992), and high intensity of pests, weeds, and diseases (Ismail et al. 1994). Tidal land has a high potential to be cultivated with various food crops.

Swampland is generally cultivated with rice plants once a year using local varieties. The rice production of local rice varieties is usually lower than the superior rice varieties. Nevertheless, rice production can be increased through the improvement in water management, provision of ameliorant, superior rice varieties, and pest control. This paper presents information on the economic feasibility of the most suitable rice farming along with the utilization of local varieties in swamps land to get information of efficient measures of inputs for rice farming in swampland.

THE PERSPECTIVE OF FARMING SYSTEM

Tidal swampland is classified into three types (A, B, and C). Type A is characterized by an area which is absorbed by single or double tide that experiences daily drainage covering coastal areas alng the banks of large rivers; type B is an area covered by single tide and no affectd by the neap tide, and type C is area not completed flooded by spring or small tide. Type B and C are more suitable for some food crops and horticulture crops. The model of rice cultivation in the type B is partly arranged with a "surjan" system. The "sunken bed" is cultivated horticultural crops and food crops, such as oranges, chilies, and maize, whereas, in the ”rice bed” is cultivated by rice crop.

Planting patterns are carried out by farmers in both types, generally once a year, while in some locations, cropping patterns are carried out twice a year. The cropping system adopted is local rice-improved rice varieties and improved varieties-improved varieties of rice or improved varieties-improved varieties of rice-corn and improved varieties of rice-corn. Some varieties are cultivated in tidal swamp of type B and C especially local varieties (Siam Unus, Siam Putih, Siam Saba, Siam Babirik, Siam Mayang, Karang Dukuh, and soon) and improved varieties such as Inpara 2, IR42, Ciherang, and Cilosari.

Local rice is commonly cultivated in the dry season, planted in March-April, harvested in August/September, and local varieties seedlings begin in December. Improved rice is planted in November/December and harvested in March/April. The difference in improved rice varieties cultivation technology is only through one wet nursery, while local rice is carried out in dry seedlings (“teradak” and "ampak").

Farmers generally carry out a specific planting pattern called as "sawit dupa". "Sawit dupa" pattern is a harmonious combination to maintain the culture of local farmers who use local varieties, but also farmers can practice new technologies for the cultivation of improved varieties. The word "sawit dupa" is taken from a series of sentences "sa” and “wiwit” abbreviated as “sawit” (“sa” = one time and “wiwit” = seedling) and “dupa” means "dua kali panen" (twice harvested). With "sawit dupa", the harvest index can be increased from 100% (planting once a year) to 180%. The value of 180% is obtained from 80% of the predominant planting area because 20% of the land area is used for making local rice seedlings, and 100% of the land is for local rice varieties cultivation. One hectar of rice field in the surjan rice model can be only cultivated for 0.8–0.9 ha area since 0.1–0.2 ha is used for bedding. The technology of rice cultivation in potential tidal swampland of type B and type C in 2017/2018 rainy season and middle freshwater of the backswamp in the 2018 dry season, as are presented in Table 1.

The selection of local varieties must consider the condition of the water system that has not yet fully controlled by farmers. Local rice is cultivated in simple ways, including seed preparation, seeding for 2–3 stages (seeding-"ampak"-trace), land preparation, planting, maintenance, and harvest. The local rice harvest time was done at the same time as the farmers could shorten the planting period and increase the labor efficiency. Rice

Table 1. Rice farming systems in tidal swampland of type B and C, and freshwater backswampland, South Kalimantan and West Kalimantan, 2018 planting season.

Description	Type B[1]		Type C[2]	Freshwater backswamp[3]
	Rainy season 2017/2018	Dry season 2018	Rainy Season 2017/2018	Dry season 2018.
Seed (kg/ha)	25–30	10–15	63	50–72
Age planted (day)	25–30	60–90	25–30	15–30
Tillage	tractor	tractor	Slash-burn	Without Grounding
Method/Planting distance (cm)	Square/20×20	Square/25×30	Square/20×25	Square/25×25
Amount of fertilizer (urea, PONSKA, organic fertilizer) per hectare	Dosage varies (given 2-3 times)	Dosage varies (given 1-2 times)	300-300-300	Varied, low dose, and liquid fertilizer
Lime (kg/ha)	Dosage varies	Dosage varies	-	-
Weeding	once	0-once	1–2	1–2
Herbicides (ltr)	2–4	2–4	4	4
Harvest method	Sickle	Sickle/combine Harvester	Traditional/sickle	Sickle/combine Harvester
Threshing	Thresher,	Thresher	Thresher	Thresher
Productivity (ton/ha)	2.0–3.75	2.2–3.0	2.4–3.4	4–5.5

Source: [1)]Sulaiman (2018), [2)]Alwi (2018), [3)]Sosiawan (2018).

production in Karang Dukuh in 2019 dry season using 30 day-old seed revealed around 4.4 ton/ha, 12 day-old seed produced 3.52 ton/ha, and accounting 3.080 ton/ha using the conventional practice (personal communication).

The technology of rice cultivation in potential tidal swampland of type B is different compared to those in type C in West Kalimantan. On type "C," farmers generally cultivate rice once a year in the dry season, using particular variety (Cilosari), which has been adaptive both in technical, social, and economic aspects.

Rice cultivation technology applied by farmers in potential tidal swampland of type B in Karang Buah Village in South Kalimantan is more advance than that in type C land located in Matang Danau village, West Kalimantan. The potential tidal swampland of type B accompanied with an adjustable water system are preferable by farmers using agricultural machinery, especially hand tractors and combine harvester. In contrast, the water system/channel in potential tidal swampland of type C land has not been practices yet.

Rice plantations in the freshwater of backswamp consist of "Rintak" rice and "Surung" rice. The "Rintak" rice is freshwater of backswampland, swamp rice, which is planted at the end of the rainy season and harvested in the dry season. However, several problems are faced in the adoption of the "Rintak" rice system, i.e., irregular water that causes difficulties in determining the right planting time and delayed planting rice. "Surung" rice is planted at the end of the dry season and harvested at the beginning of the rainy season. Farmers generally do "Rintak" rice.

RICE FARMING IN TIDAL SWAMPLAND

Rice production facilities

The average rice production of IR42 variety in potential tidal swampland of type B in 2017/2018 rainy season was 3.11 ton/ha or around 2.5–3.5 ton/ha. In contrast, the average rice production of Cilosari variety in potential tidal swampland of type C was 3.00 ton/ha or about 2.5–3.5 ton/ha. The difference in average rice production achieved by each type is generally due to differences in the level of land fertility and the application of rice cultivation technology. Meanwhile, the average rice yield of Siam Unus in potential tidal swampland of type B ranges 2.2–3.0 ton/ha (average 2.35 ton/ha). The production of local rice depends on the rice variety, typology, and type of overflow. Wardah et al. (2012) reported that there was character diversity among local varieties grown by farmers in South Kalimantan. Local rice is quite tolerant and grown well in acid sulfate soil ($pH<3.5$). Khairullah

(2007) reported that the cultivation of local rice varieties on tidal land required low inputs for fertilizers and pesticides as well as being adaptive to uncertain environments.

Rice production facilities needed in one hectare for improved varieties and local rice farming in potential tidal swampland of type B and type C are presented in Table 2. The seeds of improved variety needed per hectare is quite high, for example 32.0 kg/ha for potential tidal swampland of type B, and 63.0 kg/ha for type C. The high amount of seed used for the potential tidal swampland of type C is as the result of lw quality of the seeds collected from previous harvest. Urea and NPK fertilizers are used by farmers in all locations, while farmers cultivate in the potential tidal swampland of type B only use lime for rice plant cultivation. Insecticides used by farmers to control improved rice farming in tidal swampland of type C is higher than that of the tidal swampland of type B due to the high attacks of pest such as plant hopper and stem borer found in such land.

The average seed requirement for local rice per hectare in tidal land is 12 kg. The rice production facilities such as urea, SP36, and KCl are used by farmers to conduce local rice farming in all land typologies but at low doses. Farmers use urea fertilizer in addition to fertilizing track nurseries and are also used for planting on paddy fields. Fertilizer for local rice in tidal land is intended to maintain soil fertility or vegetative growth.

Cost and revenue analysis

Analysis of the cost and income of one hectare of improved varieties and local rice farming in potential tidal swampland types B and C is presented in Table 3. The average production cost of the improved variety per hectare in the potential tidal swampland oftype B field was IDR 6,541,947/ha or 46.7% of

Table 2. The use of production facilities in one ha of improved varieties and local rice farming in one tidal swampland oftype" B" and type C, South Kalimantan, and West Kalimantan, 2018 planting season.

Production facilities	Type" B[1]"		Type" C[2]"
	2017/2018 Rainy season	2018 Dry season	2017/2018 Rainy season
Seed (kg)	32.0	12.0	63.0
Urea (kg)	141.5	65.0	300.0
Ponska (kg)	223.0	167.0	300.0
Lime/dolomite (kg)	188.0	200.0	-
Solid organic fertilizer (kg)	337.0	150.0	300.0
Liquid organic fertilizer (litre)	1.8	-	6.0
Insecticide (IDR)	70,775	166,500.0	220,000
Herbicide (litre)	3.20	3.0	5.0
Human labor (man days)	38.5	64.7	106
Tractor labor (work days)	2.0	2.0	-

Source: [1)]Sulaiman (2018), [2)]Alwi (2018), processed.
Type B: an area covered by single tide and no affectd by the neap tide.
Type C: an area which is not completed flooded by spring or small tide.

revenue, while type C field needed IDR 11,050,000 or 81.8%. The average local rice production cost per hectare in potential tidal swampland of type B was IDR 6,982,800/ha or 49.5% of revenue. Compared to the three farming, the most considerable rice production costs were found in the potential tidal swampland of type C. The amount of this total cost came from labor costs of 60.9% and production facilities around 20.9% of revenue.

The economic profits from rice farming from potential tidal swampland of type C are lower than that from the type B (Table 3), possibly due to low rice production with high costs. This is in good agreement with previous study (Wahyuningsih and Zuraida(2018), which reported that the local rice profit was IDR 7,518,879/farmer and R/C value of 1.85. Nevertheless, three farming is profitable and efficient.

Table 3. Cost and income analysis of improved varieties and local rice farming in two types of tidal swampland in South Kalimantan, an West Kalimantan, 2018 planting season*.

Production facilities	Type" B[1]"		Type" C[2]"
	2017/2018 Rainy season	2018 Dry season	2017/2018 Rainy season
Production (ton/ha)	3,115	2,350	3,000
Receipts (IDR/ha)	14,017,500	14,100,000	13,500,000
Production cost (IDR/ha)			
Production facilities	1,961,947 (14.0)	1,202,800 (8.5)	2,825,000 (20.9)
Family labor	4,580,000 (32.7)	5,780,000 (41)	8,225,000 (60.9)
Total cost (IDR/ha)	6,541,947 (46.7)	6,982,800 (49.5)	11,050,000 (81.8)
Profit (IDR/ha)	7,475,553 (53.3)	7,117,200 (50.5)	2,450,000 (18.1)
R/C	2.14	2.02	1.22

Note:
*Based on one-hectare rice farming.
Numbers in parentheses are the percentage of production value.
Source: 1) Sulaiman (2018), 2) Alwi (2018).

RICE FARMING IN FRESHWATER BACKSWAMP

Use of rice production facilities

The average production of superior rice in the freshwater backswamp was 5185 ton/ha or around 3.5–6.5 ton/ha. Rice production in the freshwater backswampland is quite varied due to the rough rice field conditions. The production facilities for rice farming in the freshwater backswamp field is presented in Table 4.

The farmers of freshwater backswamp area used relatively high seeds number, on average of 62 kg/ha. Farmers sow rice seeds more than once because it is challenging to estimate planting time. The use of fertilizers in both urea and NPK Ponska is still low under the recommendation. Some farmers stated that their land has been fertile. Insecticides needed by farmers to

Table 4. The use of production facilities in 1 ha of improved varieties of rice farming in the freshwater of backswampland, Hulu Sungai Utara Regency, South Kalimantan, 2018 dry season.

Production facilities	Hambuku Raya	Hambuku Pasar	Hambuku Hulu	Average
Seed (kg)	63.0	60.0	63.0	62.0
Urea (kg)	5.0	10.0	5.0	6.7
KCl (kg)	13.2	15.0	13.2	13.8
Ponska (kg)	13.4	10.0	13.5	12.3
Liquid organic fertilizer (litre)	1.03	1.0	1.7	0.98
Insecticide (litre)	4.06	4.0	4.09	4.05
Herbicide(litre)	3.54	4.0	4.0	3.85
Human labor (man days)	66.17	73.18	67.1	68.8

Data source: Sosiawan (2018), processed.

control improved varieties of rice farming in freshwater backswamp field is higher than those in potential tidal swampland type of B.

Cost and revenue analysis

Analysis of the cost and income of one hectare for improved varieties of rice farming in the freshwater of the backswamp is presented in Table 5. The average production cost of Mekongga variety in the freshwater of the backswamp field was IDR. 14,327,805.7/ha or 50.2% from receipts. The cost consisted of 46.6% labor costs and 3.6% production facilities. The profit gained from rice farming in the freshwater of the backswamp field was IDR 14,193,361/ha. The rice farming of Mekongga variety is profitable and efficient. The similar value of rice farming profits around IDR 12,546,326/ha, with an R/C value of 2.79 was done in the previous report (Rina 2015).

Table 5. Analysis of costs and income of rice farming in freshwater backswamp field, Sungai Pandan District, Hulu Sungai Utara Regency, 2018 dry season.

Description	Hambuku Raya	Hambuku Pasar	Hambuku Hulu	Average
Production (kg)	4,975	5,527	5,055	5,185.67
Receipts (IDR)	27,362,500	30,398,500	27,802,500	28,521,166.7
Cost (IDR)				
Production facilities	1,002,555 (3.7)	1,032,140 (3.4)	1,080,000 (3.9)	1,038,231.7 (3.6)
Labor	11,798,722 (43.1)	14,460,000 (47.6)	13,610,000 (48.9)	13,289,574 (46.6)
Total cost (IDR/ha)	12,801,277 (46.8)	15,492,140 (51.0)	14,690,000 (52.8)	14,327,805.7 (50.2)
Profit (IDR/ha)	14,561,223 (53.2)	14,906,360 (49.0)	13,112,500 (47.2)	14,193,361 (49.8)
R/C ratio	2.13	1.96	1.89	2.01

Data Source: Sosiawan (2018).
Note: Numbers in parentheses are the percentage of production value.

RECOMMENDED RICE CULTIVATION TECHNOLOGY

The integrated crop management technology, i.e., water management, rice variety selection, balanced fertilization, biological fertilizer, and pest management of Inpara 2 variety rice cultivation in potential tidal swampland of type B, yielded 5.7 ton/ha dry grain or around 5.2–6.4 ton/ha. Socially farmers had positive perception of cultivation technology and financially improved rice cultivation technology had good prospects for development on a broad scale supported by R/C>1 and MBCR>2 (Annisa 2018).

The Inpara 2 rice variety had adapted well in tidal swamps, especially to acidity and iron toxicity (Koesrini et al. 2014; Rina and Koesrini 2016). The Inpara 2 variety was one of the varieties favored by tidal swamp farmers. Javanese ethnic farmers preferred the Inpara 2 variety in terms of plant type, productive tillers, panicle length, grain color, and rice quality (Rina and Koesrini 2018). The Inpara 2 was released in 2008 by the Indonesian Center for Rice Crops with a potential yield of 6.08 ton/ha and tolerant to Fe and Al (Suprihatno et al. 2010). The yield of Inpara 2 and Inpara 3 varieties in swamps was relatively stable between 4.12–6.20 ton/ha (Adri and Yardha 2014; Helmi 2015).

Recommended rice cultivation technology in potential tidal swampland of type C using Inpari 32, water management, land preparation (tractor), Jarwo 2:1 planting system, nutrient management of 1 ton/ha dolomite, 100 kg urea and 250 kg NPK Ponska per ha, maintenance and harvest using a combined harvester produced 5,330 ton/ha or around 3.3–5.6 ton/ha. The rice farming is financial profitable and can be developed on a large-scale with positive farmers' perception. In addition, farmers' preferences for the most preferred varieties such as Inpara 3, Cilosari, Inpara 1, Margasari, Inpara 6, Inpara 9 and Inpari 32 is complement to the recommended technology (Alwi 2018). Both recommended rice cultivation technologies from two types of overflows need to be disseminated to users in order to assist farmers to adopt and increase rice production in swamps.

CONCLUSIONS

Rice cultivation on farmers' level with "sawit-dupa" planting patterns in potential tidal swampland of type B showed that the average production of IR42 varieties was 3.1 ton/ha dry grain yield and Siam Unus 2.35 ton/ha dry grain yield. In contrast, in potential tidal swampland of type C field, Cilosari variety yielded 3 ton/ha of dry grain. In the freshwater backswamp, the average yield of Mekongga was 5,185 ton/ha of dry grain. Financially, IR42 variety rice farming in the rainy season and Siam Unus in the dry season in potential tidal swampland of type B and Cilosari variety during the rainy season in potential tidal swampland of type C field were quite profitable and efficient (R/C>1). Overall, rice farming in the freshwater backswampland in the dry season is cost-effective and efficient.

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RATOON SYSTEM ON LOCAL RICE CULTIVATION IN TIDAL SWAMPLAND

Susilawati

INTRODUCTION

Tidal swamplands in Central Kalimantan cover a vast area, and most of them are used for traditional rice farming. Local rice varieties planted in tidal swamplands typically are late maturiy varieties that are planted once per year. Their numbers are numerous and vary between regions. Domestic rice cultivation by farmers mostly used the ratoon system. Ratoon, or "Turiang" in Banjar language, or "Singgang" in Javanese, is allowing rice plants to regrow after harvesting the main crops (Nair and Rosamma 2002). Many farmers in tidal swamplands of Central Kalimantan commonly use the ratoon system, by allowing local rice plants that have been harvested to grow and harvested again after 1.0–1.5 month. The advantage of the ratoon system is to provide additional rice production per planting season, with little extra input, cost, labor, and preparation time for planting (Susilawati 2011).

Several local rice varieties recommended to be planted in tidal swamplands and can be harvested after ratooning are Brenti, Siam Saba, Siam Epang, Siam Mutiara, Umbang Bilis, Siam Kupang, Siam Sarai, and Umbang Inai. Although the level of ratooned local rice production is not too high, averaging between 0.3–0.5 ton/ha, it can still provide additional production and income. The extra yield potential of ratooned local rice can be increased by adding fertilizers, water management, and optimizing the cutting height after harvesting the main crop (Susilawati et al. 2012).

The ability of rice plants to produce ratoon can be determined by genetic and environmental characteristics, such as sunlight, temperature, water availability, soil fertility, and the state of pests and diseases (Mahadevappa 1988). Also, the cutting height of the main crops and the addition of fertilizers also influence the ability of rice plants to produce ratoon (Susilawati et al. 2012). Importantly, local rice that has a kinship with wild relative species can be ratooned and roduce secondary tillers. The wild rice species if *Oryza perennis* Moench is the ancestor of *Oryza sativa* L., which is commonly found in Asia, especially in the tidal swamp area. This species is a perennial type with high ratoon potential and can produce a lot of vegetative growth (Oka 1974 in Susilawati et al. 2011). Likewise, *Oryza minuta* can produce productive tillers by up to >50 tillers after secondary tillers, while *Oryza nivara* and *Oryza glumaepatula* can produce >20 tillers. Some varieties have a small number of tillers in the initial planting, usually less than ten, and then followed by secondary tillers so that the number of tillers becomes large (Suhartini et al. 2003).

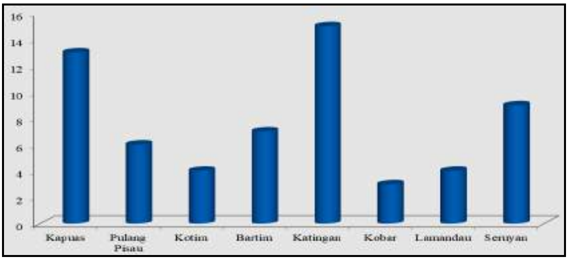

Figure 1. Number of local rice varieties suitable for tidal swamplands that have been collected from each regency in Central Kalimantan.

Table 1. Local rice varieties specific for tidal swamplands that have been registered and known its Digital Object Identifiers (DOI).

Sample Id	Holder views	Holder pid	Holder name	Creation method	Taxonomy	DOI
05020-30509	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Karang Dukuh	10.18730/J7XHH
05020-30518	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Kumpang Omas	10.18730/J7XTT
05020-30522	IDN179	00AQ17	ICABIOGRAD	Acqu	Oryza *sativa* L. Glinti	10.18730/J7XYY
05020-30540	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Siam Cantik	10.18730/J7YGB
05020-30551	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Gedagai	10.18730/J7YTN
05020-30555	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Siam Unus	10.18730/J7YYS
05020-30557	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Siam Kupang	10.18730/J7Z0V
05020-30558	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Gilai	10.18730/J7Z1W
05020-30571	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Siam Epang	10.18730/J7ZE4
05020-30572	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Sibung rendah,	10.18730/J7ZF5
05020-30578	IDN179	00AQ17	ICABIOGRAD	acqu	*Oryza sativa* L. Cirendah	10.18730/J7ZNB
05020-30579	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Kencana	10.18730/J7ZPC
05020-30587	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Balimau	10.18730/J7ZYM
05020-30588	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Banyu Bilis	10.18730/J7ZZN
05020-30589	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Barinsai	10.18730/J800P
05020-30590	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Humbang Inai	10.18730/J801Q
05020-30591	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Humbang Inai	10.18730/J802R
05020-30592	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Lawai	10.18730/J803S
05020-30593	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Lentera	10.18730/J804T
05020-30594	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Mangbetik	10.18730/J805V
05020-30595	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Pahakung	10.18730/J806W
05020-30596	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Pentet	10.18730/J807X
05020-30598	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Pikat	10.18730/J809Z
05020-30599	IDN179	00AQ17	ICABIOGRAD	Acqu	*Oryza sativa* L. Serumpun	10.18730/J80A*

This paper is to review some in-house research results and studies of literature. The objective of this review paper was to provide information about local rice cultivation using the ratoon system in tidal swamplands and to discuss technological improvements to increase the productivity of the ratoon system.

LOCAL RICE VARIETIES IN TIDAL SWAMPLANDS

The total of tidal swampland area in Central Kalimantan is about 5.5 million hectares, and 4,131,360 ha of which have the potential for agriculture and fisheries. Approximately, 1,195,771 ha of the swampland had been reclaimed and included in the area of the ex-mega rice project (called PLG) (Alihamsyah et al. 2000). Common problems that are found in tidal swamplands are nutrient deficiency, high soil acidity, flood-prone, and pyrite poisoning (Suriadikarta 2007). Tidal swampland management for rice plants is generally carried out traditionally, using a tool called “tajak”, which is a long-handled and curved earth-moving tool with a front part that resembles a machete. The “tajak” is used for weeding and turning the top of the soil and around the roots of weeds. At present, many farmers cultivate the land by using both two-wheeled and four-wheeled tractors. Tillage is usually done after the rainy season or before the dry season. A number of local rice varieties can grow well in tidal swampland in Central Kalimantan. For future utilization, some of them were collected from regencies as presented in Figure 1.

Rice farming carried out in tidal swamplands utilizes late maturing local rice varieties (days to harvest >6 months) that are only planted once a year. This option could be related to the condition of the tidal swamplands, which experience high tides resulting in high waterlogging. Consequently, tall plants are more suited to this kind of environment, even though tall plants are generally late-maturity type.

Numerous local rice varieties are being planted in tidal swamplands in Central Kalimantan. Farmer's preference differs between regencies, but some of them are the same as those grown in South Kalimantan (Table 1). Some popular local varieties are Siam Unus, Siam Busu, Brenti, Siam Saba, Siam Epang, Siam Mutiara, Umbang Bilis, Siam Kupang, Siam Sarai, Umbang Inai, and Sekonyer. Local consumers prefer to consume rice with specific taste and shape of grains characterized similarly to the local varieties, so the selling price of local rice varieties is higher than improved rice varieties. Therefore, local rice varieties are always planted by farmers every year. The seeds are easy to obtain, mainly because farmers always save some seeds from harvest with extra storage space. Another characteristic of local rice is the lack of response to fertilizers, so they are more efficient in terms of inputs. Their tall stature allows them to tolerate the the water level, and they are easily harvested. The average local rice productivity ranges from 1.0–1.2 ton/ha on newly opened lands and 2.0–2.8 ton/ha on existing lands (Susilawati et al. 2014). Longer planting duration and the low productivity of local rice varieties do not decrease farmers' interest to plant them (Aswidinnor et al. 2008). Considering the importanc of these local genetic resources, some of the local rice accessions have been registered to obtain international Digital Object Identifiers (DOI) (Table 1).

LOCAL RICE CULTIVATION SYSTEM IN TIDAL SWAMPLAND

Tidal swamplands are classified based on the flooding types, and they can be divided into four categories, namely flooding type A, type B, type C, and type D. A type A tidal swampland, either huge tides or low tides can inundate the land area. In type B, the land area can only be overwhelmed by huge tides, while water from low tides cannot overflow into the land. In type C, the surface area is not affected by waves, but the tides only change the depth of the ground water level at less than 50 cm from the ground surface. A type D tidal swampland is also not affected by tides at the surface, and the waves only change the groundwater level at a depth of more than 50 cm from the ground surface (Ar-Riza and Alkusumah 2008).

Local rice cultivation in tidal swamplands of Central Kalimantan is generally carried out in three stages. The first stage is called *Ampak*, which is germinating the seeds by placing it on a nursery that is specially made from mud media, in an area around 10–15% of the total cultivation area. The nursery is maintained until the tillers can be split, which generally occurs in around 30 days. The second stage is *Lacak*, when the rice tillers taken from *Ampak* bunches are split and replanted in 20–25% of the total area in order to become more numerous. This stage typically has a duration of 30–60 days, which is expected to obtain a lot of saplings with vigorous stems to cover the whole cultivation area. The last step is planting in the field. At this stage, the bunches from *Lacak* stage are cut off from the top in order to obtain the remaining two-thirds of the plants. Subsequently, the tillers are separated to select around We wish to thank the secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) for funding the conference and the preparation of this book and the Director General of the Indonesian Agency of Agriculture Research and Development (IAARD) for publishing the book through the IAARD press and the Director of Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGRAD) for funding the final printing and multiplication of the book. 3–4 rice tillers to be planted per hole (Susilawati 2016).

Farmers mostly do local rice cultivation using the ratoon system in tidal swamplands, but not all areas produce good yield. The rice yield from ratoon cultivation on tidal lands with flooding of types A and B is higher than that on the flooding type of C and D because water availability on the type A and type B is more sufficient.

For local rice varieties, the required water level needed is 100–120 mm deep, which is higher than that for improved varieties, which is only 50–75 mm. Provision of water or discontinuous inundation can change the microclimate around the plant, such as increasing soil moisture and reducing temperature fluctuations during the day and night (Rohmat and Suardi 2007).

Besides the water flooding types and water availability, the ratoon system in tidal swamplands also depends on the type of local rice varieties. Not all local rice varieties respond well to ratooning. Observations and dialogues with local farmers revealed that the types of local rice cultivated using the ratoon system are those that are not too tall, have large stem size, and have high tillers number (Ramesha 2011; Susilawati 2018). The local varieties of rice, such as Siam Epang, Brenti, Siam Saba, Cirendah, Siam Kupang, Umbang Bilis, Beautiful Siam, and Siam Mayang, have plant heights range of 117–143 cm (Table 2). Local

Table 2. The characters of some local rice varieties cultivated using the ratoon system.

Accession name	DOI registration	Origin (Regencies)	Days to harvest (days)	Plant height (cm)
Brenti	10.18730/J7XYY	Pulang Pisau	135	117
Cirendah	10.18730/J7ZNB	Katingan	133	123
Siam Saba	10.18730/J7XHH	Kapuas	151	141
Siam Cantik	10.18730/J7YGB	Barito Timur	137	127
Siam Epang	10.18730/J7Z0V	Kotawaringin Timur	147	125
Siam Kupang	10.18730/J7YGB	Barito Timur	144	125
Siam Mayang	10.18730/J7YYS	Kapuas	153	143
Umbang Bilis	10.18730/J7ZZN	Katingan	134	125

rice cultivation using the ratoon system begins with the planting of the main crop. Almost all types of local rice are planted using the traditional method, except for the Siam Epang variety from East Kotawaringin Regency, which is cultivated using the same way as improved varieties, i.e., using seedbed, transplantation, and complete applications of fertilizers. For other local varieties that are traditionally grown, the fertilizers are applied at a very minimal level, and most are not fertilized at all. As well known that fertilizer is one of the most critical inputs for the growth and yield of rice. Several studies have shown that ratoon growth is highly dependent on the composition and dosage of fertilizers (Jason 2005).

The planting schedule for local rice varieties in tidal swamplands begins in February, with harvesting time from July to August. Harvesting is done using a tool called *"ani-ani",* so that a large portion of the rest of the plants are remained. The productivity of some local rice varieties shows between 1.3–3.6 ton/ha. Siam Epang is the highest-yielding variety since its cultivation uses the same methods as improved varieties. The study proves that although local rice is commonly non-responsive to fertilization, the fields assays demonstrate that fertilizer application can increase domestic rice production. In particular, nitrogen being one of the main fertilizers applied to the main crop, would be able to increase yield with a good practice (Islam et al. 2008; Petroudi 2011).

Farmers in the districts of Katingan and East Barito generally leave the rest of the crop after harvest by cutting off parts of the plants and leave around 30–40 cm of stems from the ground. On the other hand, farmers in the Kapuas and Pulang Pisau districts mostly cut the remaining crop stumps with sickles, to allow rice plants remain around 20–25 cm of stems, which is then simply abandoned. In September or October, they generally harvest the ratoons, and by the rainy season, farmers left the lands again because floods often occur in the rainy seasons. Some farmers immediately make land preparations and commonly use their area for rice planting for improved varieties. Maincrop and ratoon yields of local rice varieties are summarized in Figure 2 (Susilawati et al. 2017).

TECHNOLOGICAL IMPROVEMENT OF RICE CULTIVATION USING RATOON SYSTEM ON TIDAL SWAMPLANDS

Rice cultivation currently using a ratoon system in tidal swamplands has been widely carried out, especially in areas planted with improved rice varieties. Since 2015, through the a national program of food self sufficieny (called UPSUS) for rice, corn, and soybeans, a lot of assistance has been provided to farmers in the form of seeds, fertilizers, and agricultural machineries such as two-wheeled and four-wheeled tractors, rice

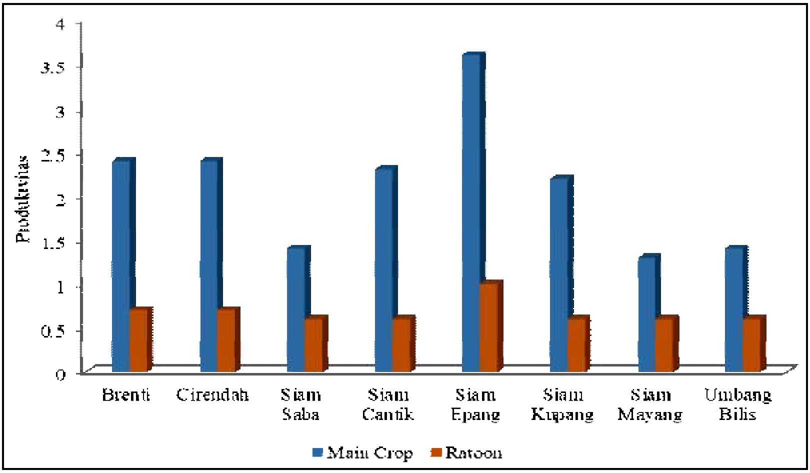

Figure 2. Rice yield of the main crops and ratoon of several local rice varieties in Central Kalimantan.

planting equipment, and harvesting equipment (Kemtan 2015; Kemtan 2018). One of the goals of this program is to increase the rice cropping index from once to twice or more a year. The crop index of rice is adjusted to twice a year. The cropping pattern used is local rice–improved varieties, with the planting period from April to September (the dry season) used for local rice, and the rainy season from October to March assigned for improved rice varieties. This program also has an impact on local rice cultivation practices. There were very few farmers who applied fertilizers to local rice varieties, but todays many farmers fertilize their crops, albeit with a minimal amount.

For rice cultivation using ratoon system in tidal swamplands, the use of harvesting machines such as combine harvesters helps speed up harvests and cuts the stems at a uniform height. On tidal lands that are still wet, the remaining stems of rice plants begin to grow new tillers 3–7 days after harvest. Although the farmers do not provide specific inputs, the yield of the ratoons is relatively high, at about 1.0–1.1 ton/ha for Inpari 30 and Inpari 9 varieties, which can be harvested at 45–55 days after the main harvest. To improve the ratoon system on tidal lands, the most influential factors are genetic and environmental factors. One of the technological innovations that needs to be developed is how to boost the genetic potential of rice plants to produce ratoons, both in local and superior rice varieties. Currently, superior rice varieties are better in producing ratoons than local rice varieties. However, if ratooning can be applied effectively in local rice, it will provide additional production of local rice and close the yield gap between local and superior rice varieties. Environmental factors, such as sunlight, temperature, water availability, soil fertility, plant pest, and disease conditions, fertilization, and cutting height, also affect the ability of plants to produce ratoons (Susilawati et al. 2012; Mahadevappa 1988).

These factors need to be considered to improve the cultivation practices of the ratoon system in tidal swamplands.

Cutting height can determine the number of shoots that grow, but the growth is greatly influenced by the remaining assimilate reserves in the stems that can be used for ratoon growth, and the level of ratoon vigor (Jichao and Xiaohui 1996). Cutting height can also affect the number of tillers and seed yield (Harrel et al. 2009). Jichao and Xiaohui (1996) proposed that a higher cutting site from the ground surface allows for more carbohydrate reserves to be available from the main crop and can be utilized by the ratoons. However, Susilawati et al. (2018) reported that higher cutting heights in local rice varieties could inhibit the growth of ratoon shoots and reduce the number of ratoons that produce seeds. Instead, cutting heights of 15–20 cm resulted in well-developed shoot buds and panicles compared to higher cuts.

Nakano and Morita (2007) found that the number of saplings and ratoon panicles increased, and the percentage of dead ratoon shoots decreased at an ideal cutting height of 15–20 cm. In contrast, in a research conducted on the irrigated land where water conditions can be controlled, the best cutting height is shallow at 1–3 cm. Under such circumstances, the ratoons morphologically grow like new plants and are called Salibu rice (Merize et al. 2016). This cultivation method reduces the use of seeds and labor, but in terms of plant age, "Salibu" plants will be the same as new plants since the newly formed ratoon shoots also enter the initial vegetative stages.

Fertilization is believed to increase the productivity of ratoon plants, and one of the fertilizers given to the main crops that are very influential on the yield of ratoons is N (Islam et al. 2008). In superior rice varieties, the application of N to the main crop significantly increased IR36 ratoon height, increased the number of tillers in IR42 ratoons, and increased the yield of both varieties

(De Datta and Bernasor 1988). The element N in fertilizers is a constituent of amino acids, nucleic acids, and chlorophyll, which can accelerate growth and increase the number of productive tillers (Dobermann and Fairhurst 2000). In hybrid rice, the application of N fertilizer at a dose of 96–125 kg/ha N resulted in an additional 5.0–5.6 ton/ha of yield (Charoen 2003). Increasing N application from 100 kg/ha to 140 kg/ha increased yield by 12.8–16.1% (Charoen 2003). The time of N application on the main crop in the ratoon system also affected rice yield (Jason 2005).

Technological improvements through the provision of organic materials, setting the cutting height, and fertilizer application to the local rice Siam Epang showed that with a cutting height of 5 cm, and N fertilizer use at 50% of the recommended dose on the main plant, as well as providing liquid organic material at 2 cc/liter of water can induce ratoons to grow like a new plant, with 14 productive tillers and productivity of about 2.6 ton/ha. This result could be obtained because the main crop was planted using "Jarwo Super" spacing technology in a swampland. Another local rice variety, Siam Saba, which is managed under the same conditions in Kapuas district, produced a yield of 0.8 ton/ha (Table 3). The technological package being applied here is designated as "*Jajar Legowo Super* Tidal Land-Specific Technology", with the major technological components listed in Table 4. The selection of Siam Epang local rice for testing the application of this technology was based on farmers' familiarity with planting Siam Epang local rice together with improved rice varieties.

Table 3. Growth performance and production of Siam Epang and Siam Saba rice local varieties in ratoon system.

Character	Accession			
	Siam Epang		Siam Saba	
	Main crop	Ratoon	Main crop	Ratoon
Plant height (cm)	127	99	141	122
Number productive tiller	47	14	12	8
Panicle length (cm)	25	14	19	16
Number grains per panicle (g)	229	113	121	87
1000 grain weight (g)	17	17	16.98	16,5
Yield (ton/ha)	6,4	3,6	2,4	0.8

Table 4. Technological components of "Jarwo Super" for Siam Epang variety in tidal swamplands.

Technological components	Recommendation
Variety	Siam Epang
Volume of seeds	25–30 kg/ha
Age of seedling	15–17 days
Planting type	Jajar legowo 2:1 or (25 x 15) x 40 cm
Lime	500–1.000 kg/ha/season, applied a week before planting
Biotara	25 kg/ha, applied at cultivation
Biochar	20 sac/ha, mix with lime
Agrimeth	10 pack/25 kg seed
Liquid organic matter	4 litter/ha
Urea	100–150 kg/ha
NPK	150–300 kg/ha
Integrated Pest Management	Organic and Chemical

CONCLUSIONS

Local rice cultivation using a ratoon system has long existed in tidal lands, especially on the flooding of type A and B areas. The traditional method in a cultivation and simple ratoon management of rice plants without additional input and maintenance yielded rice production of 0.15–0,17 ton/ha. With better cultivating management of the main crops, the yield increased to 0.3–0.4 ton/ha. Further improvement in planting distance and local rice variety of Siam Epang increased yield of 0.56 ton/ha. Selection of more adaptive and high yielding local rice varieties is necessary to gain better rice yield in the tidal swampland in Central Kalimantan.

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IMPROVEMENT OF SOIL PROPERTIES TO INCREASE RICE PRODUCTIVITY IN TIDAL SWAMPLANDS

Eni Maftu'ah, Ani Susilawati, and Anna Hairani

INTRODUCTION

To realize the vision of the Indonesian government to become a world food source in 2045, it is necessary to take strategic steps that include the optimization and expansion of food production areas. Food, according to most Indonesian people means rice, because rice is a staple food that fulfills about 45% of food intake or about 80% of the main carbohydrate sources in foods consumed by Indonesian people (Mamat 2007). One of the potential areas for the development of rice production areas is the tidal swampland. Cultivation of rice plants in tidal swamplands faces several constraints, such as low soil fertility, high soil acidity, pyrite, high concentrations of Al, Fe, Mn, and organic acids, deficiency of P, Ca, K, Mg, and microbial activity (Arsyad et al. 2014). In fact, the tidal swamplands in Indonesia are large and should be explored further their potential to be developed as an area of food production. Since less optimal utilization and development of such swamplands, it is necessary to increase the cropping index, productivity, and product quality, which in turn will improve farmers' income.

Rice productivity in tidal swamplands is generally low, approximately 3.2 ton/ha in Central Kalimantan and 4.5 ton/ha in South Kalimantan (Arsyad et al. 2014). Rice productivity on acid sulfate soils in tidal swamplands can be increased through several approaches, such as improving the growing environment, using adaptive and high-yielding varieties, increasing planting index, and suppressing post-harvest yield loss and pest disturbances. The most critical factors of low rice productivity in tidal swamplands due to pyrite oxidation are Fe toxicity, Al toxicity, a high acidity of soil and water, and inhibition of macro and micro-nutrient uptake. Poor water management will increase uncontrollable pyrite.

Application of soil ameliorants could improve the fertility of tidal swampland, as proven by the results of several studies. Application of 2 ton/ha of rice straw compost and 60 kg/ha of P_2O_5 fertilizer increased rice productivity by up to 5.73 ton/ha in a tidal swampland at Pelalawan, Riau (Masganti et al. 2017). Straw compost and *Eleocharis dulcis* with 75% of recommended fertilizer dosage in acid sulfate soil yielded 3.4 ton/ha or increased yield by 40% compared to no applied organic matter (Annisa and Nursyamsi 2015). This paper describes the potential of tidal swamplands, their characteristics, and the efforts to improve the fertility of acid sulfate soil to increase rice productivity.

POTENTIAL OF TIDAL SWAMPLANDS FOR RICE CULTIVATION AREA

A tidal swampland is a land where its water regime is affected by water tide from the sea or river. There are two types of soil in tidal swamplands: mineral soils and peat soils. Acid sulfate soils are mineral soils that develop from pyrite-rich (FeS_2) precursor materials. Pyrite accumulates in submerged lands that contain some amount of organic matter and dissolved sulfate, which usually comes from seawater. When drainage carries oxygen through the stagnant soil, pyrite is oxidized to sulfuric acid. Acid sulfate soils develop if acid production exceeds the neutralization ability of the precursor material, so the soil pH decreases to less than 4. Peat soils in the tropics are formed due to anaerobic environmental conditions which facilitate the very slow decomposition process. In contrast, peat soils in cold climates are formed due to the inhibition of the decomposition process at low temperatures. The rate of peat accumulation in the tropics is relatively faster than in temperate climates.

The tidal swamplands for agriculture is a strategic choice to substitute fertile lands that have been converted to nonagricultural purposes. According to the most recent data, it is estimated that the total area of tidal swamplands in Indonesia is 8.92 million ha, consisting of 7.55 million ha of acid sulfate soils and 1.37 million ha of peat soils (Ritung et al. 2015). Most tidal swampland areas are spread over the island of Sumatera (3.02 million ha), Kalimantan (2.99 million ha), Sulawesi (0.32 million ha), and Papua (2.43 million ha). Tidal swamplands are mostly located in wet climate regions, suggesting their enormous potential for rice cultivation. Since rice is the most widely cultivated crop in tidal swamplands, this prospective lands need supporting technologies for soil improvement to increase rice productivity.

Rice is suitable in tidal swamps because of some factors as follows (1) abundant swamp water for most of the year, with shallow groundwater levels, (2) flat land topography, (3) clay and soft texture and (4) cultural heritage of the rice farmers. The area of tidal swamplands suitable for rice farming reaches 6.10 million ha, of which 3.42 million ha are located in tidal swamps, and 0.2 million ha are on peatlands (Ritung et al. 2015). Rice field development can be carried out mainly in the tidal swamps with tidal types B and C. By improving land fertility, rice production in each typology of tidal swamps could be increased by up to 6.3–7.0 ton/ha (Alwi 2014).

FERTILITY CONSTRAINTS OF TIDAL SWAMPLANDS

Some problems in tidal swamplands that limit rice crop productivity include high soil acidity, low nutrient availability, shallow layers of pyrite, thick and raw peats, floods, and drought (Anwar et al. 2016). In acid sulfate soils, the main problem is the presence of pyrite (FeS_2). Enio et al. (2011) stated that the oxidation of pyrite resulted in a high amount of H^+ ions, which cause acid sulfate soils to become very acidic. High soil acidity increases the solubility of Fe, Al, and Mn up to toxicity level, accompanied by P deficiency due to fixation by Fe and Al, and lack of base cations because of leaching. Pyrite oxidation causes changes in ion contents in soil solutions and sorption complexes. Oxygen and Fe^{3+} ions in the soil can act as oxidizing agents for pyrite, which causes the land to become extremely acidic, and the very acid soil (pH 2–3) (Priatmadi and Haris 2009). Kochian et al. (2004) reported that acid sulfate soils in tidal lands are classified as acidic to extremely acidic, ranging from pH 4 (Sulfaquents) and pH <3.5 (Sulfaquepts), and only a few plants can adapt to such conditions.

Under oxidative conditions, a high concentration of Al in the soil solution causes adverse effects on plant growth, both directly and indirectly. Al toxicity reduces and damages the root system, causing plants to be more susceptible to drought stress and nutrient deficiency (Kochian et al. 2004). Early symptoms can be seen in the root system of plants that do not develop as a result of the disruption of root cell lengthening (Roslim 2011). Plant roots become thickened, curled, and shortened, even cell division will be inhibited (Matsumoto 2000).

Under reductive conditions, the acidity of acid sulfate soils affects Al solubility, but this condition can increase the solubility of Fe^{2+}, H_2S, CO_2, and organic acids, which are toxic to plants (Ryan and Delhaize 2010). A high concentration of Fe^{2+} ions will be present in the soil solution. The level of Fe^{2+} ions in the soil that causes toxicity for rice plants varies from 100 ppm at the pH of 3.7 to 300 ppm at the pH of 5.0 (Sahrawat 2004), whereas in plant tissues it ranges 300–500 ppm (Sahrawat 2004) and 500–2000 ppm (Nozoe et al. 2008).

In peat soils, the problems that commonly arisen are high soil acidity, low availability of macro and micronutrients, and a high concentration of organic acids. Ameliorants are needed for soil management to reduce the effect of these organic acids. Organic acids that are toxic to plants are from phenolic acid groups, such as hydroxybenzoic acid, vanillic acid, syringic acid, p-fumaric acid, and ferulic acid. However, these acids are also the active parts of the soil that determine the ability of peat to retain nutrients. The characteristics of these organic acids will determine the chemical nature of peat (Sabiham et al. 1997).

TECHNOLOGY TO IMPROVE SOIL PROPERTIES OF TIDAL SWAMPLANDS

Improvement of soil properties of tidal swamplands can be carried out directly and indirectly. Indirect intervention can be done through water management and the development of water quality in *inlet* canals to improve soil properties. In contrast, direct response is made trough amelioration and fertilization. Ananto et al. (1998) suggested that the development of tidal swamps requires proper planning, management, and utilization and application of appropriate technology, especially for soil and water management.

Water Management

Improvement of water infrastructure is one aspect that must be considered in the efforts to improve the soil on tidal swamplands and support rice growth. Water management, in principle, is meeting water requirements during land preparation and plant growth, is also to improve the soil physicochemical conditions. The utilization of tidewater for irrigation needs according to plant needs; preventing the intrusion of saltwater; leaching toxic substances for plants, reducing as much as possible the occurrence of pyrite oxidation in acid sulfate soils; and preventing irreversible drying processes on peat. Suryadi et al. (2010) reported that water management is not only to reduce or increase the water level, but also to lower soil acidity, prevent soil acidification due to the oxidation of pyrite layers, prevent risk of salinity, flooding, and flushing of toxic compounds that accumulate in the rhizosphere. Water level control is intended to maintain the groundwater level so that it is always above the pyrite layer and leaching it out through a controlled drainage system. A conventional water management system in tidal swampland is the two-way water flow system, where water enters and exits through the same channel. Hence, the irrigation channel for the entry of water during high tides also functions as a drainage channel for the discharge of water when the tide is receding. Water management system that separates the influx channel and the drainage channel and directs the flow on one path is called a one-way flow system.

Water management in tidal swamplands that is more effective in improving the properties of acid sulfate soils is the one-way flow system. To adjust the water level, flood gates are needed, and the model depends on the typology of the land. In overflow type A tidal lands, the flapgate system is more suitable, whereas in overflow of types C and D and the block system use the stop-log system, and for type B overflow uses a combination of one-way and tabat flow systems (Sarwani 2001). These systems can reduce organic acid poisoning or sulfuric acid and iron from pyrite oxidation in swamps.

In tertiary canals with typology A, water is managed by opening the floodgate at low tide for drainage and closing floodgate to hold in the tide, while in typology C, in addition to holding the tide the floodgates also hold rainwater, so it functions as a long storage. Water management application increased soil quality on tidal land types A/B and C (Table 1). High iron and aluminum solubility is a major soil problem in tidal swamplands. Improved water management, especially soil leaching, had proven to be effective in reducing iron and aluminum solubility and had no negative effect on nutrient availability in the soil (Imanuddin and Armanto 2012). Improved water management can increase rice production from an average level of 2.5 ton/ha to 5 ton/ha on typology C in the Delta Saleh in Kalimantan, and

Table 1. Effects of water management on soil chemical properties in tidal land type C (Delta Saleh) and tidal land type A/B (Telang I).

Soil characteristics	C tidal type		A/B tidal type	
	Before water management	After water management	Before water management	After water management
Soil pH	3.83	4.04	4.21	4.72
C-organic (%)	3.13	3.73	4.50	5.02
N-total (%)	0.24	0.25	0.37	0.37
P-Bray I (ppm)	26.14	20.64	29.29	29.85
K-exc (me/100g)	0.22	0.14	0.18	0.17
Al-exc (me/100g)	5.33	4.45	2.10	1.60
Fe (ppm)	76.68	41.31	78.59	39.24

Source: Imanuddin and Armanto (2012).

from 4 ton/ha to 6–7 ton/ha on land typology A in Delta Telang I. One-way system water management could also increase rice yield from 1.43 ton/ha to 2.34 ton/ha in the dry season and increased yield from 1.26 ton/ha to 3.19 ton/ha in the rainy season (Table 2).

Improvement of Water Quality

Water quality in tidal swamps is relatively low, as indicated by pH <3.5 and the presence of toxic substances that are dominated by Fe, Al, and SO_4. Improving water quality in tidal swamps land can be done using a plant-based filtering system called "biofilter" or other materials that can absorb or neutralize metals. Plants that can be used as biofilters include *purun tikus* and *bulu babi*. Many of these plants can be found in tidal lands. *Purun tikus* and *bulu babi* have been shown to improve water quality. *Purun tikus* was more capable of absorbing iron and sulfate than other plants (Table 3). Its saplings were more effective in absorbing Fe and sulfate than young and old plants. *Purun tikus* plants could also raise the pH of water by about 0.1−0.3 units and reduce Fe by 6−27 ppm and SO_4 by 30−75 ppm. In addition, the *purun tikus* root tissue contained Fe and SO_4 respectively 2.115% and 1.534% as well as stems 0.65% and 1.71% (Indrayati 2011).

Table 2. Effects of one-way flow water management on rice yields in acid sulfate fields.

Water management system	Rice yield (ton/ha)		
	Dry season	Rainy season	Average
Two–way flow	1.43	1.26	1.35
One–way flow	2.34	3.19	2.77

Note: without lime, 90 kg N, 60 kg P_2O_5 and 50 kg K_2O/ha was the basal fertilizer.
Sources: Noor and Saragih (1993).

Table 3. Concentrations of iron (Fe) and sulfate (SO_4) in plant tissue at several age stages.

Plants	Element (ppm)	Concentration (ppm)		
		Sapling	Young plant	Old plant
Purun tikus (*Eleochoris dulcis*)	Fe	1.559.50	347.40	303.70
	SO_4	12.63	13.68	11.91
Bulu Babi (*Eleochoris retroflata*)	Fe	833.99	952.12	873.09
	SO_4	10.25	12.11	13.07
Rumput segitiga (*Cyerus rotundus*)	Fe	80.00	191.91	956.13
	SO_4	5.41	8.28	8.63
Hiring–hiring (*Rynochospora cocymbosa*)	Fe	-	-	-
	SO_4	7.88	8.51	4.62

Source: Jumberi et al. (2004).

Other materials can improve water quality through absorption (e.g. biochar) or through neutralization (e.g. lime). Thus, water quality improvement in tidal swamplands can also be done using filters made from biochar. The performance of biochar filters was significantly better over an entire experiment compared to woodchips and gravel filters with respect to COD, TOC, turbidity, and FIB removal, indicating the superior performance of biochar for wastewater treatment (Kaetzl et al. 2018). The effect of biochar and zeolite application on Fe concentration in water depends on the initial pH, as shown in Table 4. The initial concentration of Fe was 10 mg/l (0.18 mmol l/1) with an initial pH of 2, 3, 4 or 5. The experimental results showed that the adsorption of Fe^{2+} to the sorbent was highly dependent on the initial water pH. Biochar increased water pH by up to 2.5 times higher than zeolite, and biochar absorbed Fe by up to 2.5 times more than zeolite.

Table 4. Changes of water quality before biochar application and after application.

Parameters	sorbents	Intial pH			
		2	3	4	5
Final pH	Biochar	7.19 ± 0.01	7.38 ± 0.04	7.63 ± 0.1	8.06 ± 0.06
	$Mg(OH)_2$-Biochar	8.43 ± 0.06	8.90 ± 0.08	9.44 ± 0.04	10.13 ± 0.03
	Zeolite	2.79 ± 0.01	3.92 ± 0.04	5.11 ± 0.06	6.82 ± 0.08
Fe Sorption (%)	Biochar	94.20 ± 1.6	94.50 ± 0.9	95.80 ± 1.2	97.70 ± 1.0
	$Mg(OH)_2$-Biochar	99.60 ± 0.1	99.40 ± 0.5	99.70 ± 0.2	99.60 ± 0.06
	Zeolite	26.00 ± 1.6	68.70 ± 1.2	82.70 ± 0.6	95.50 ± 1.2

Source: Usman et al. (2013).

Soil Amelioration

Ameliorations is intended to improve the physical, chemical and biological properties of the soil, indicating their benefit for crop cultivation. Some ameliorating materials that can be used in tidal swamplands include lime, manure, compost, biochar, and rock phosphate. The effectiveness of these soil ameliorants is highly dependent on the type of material and land conditions. Lime should be added in an amount that is able to increase relative yield efficiency and not for achieving a neutral pH. Excessive applications of lime to peat soils can increase peat decomposition, whereas in acid sulfate soils excessive application of lime will not be effective. Suswanto et al. (2007) explained that about 4–6 ton/ha of lime was needed for growing plants and increasing rice yield in tidal swamplands. However, on acid sulfate soils that have been intensively managed, the dosage of lime for rice only ranges 1–2 ton/ha.

Provision of ameliorants, such as lime, biochar and manure, have been proven to increase the productivity of acid sulfate soils, but the effect of rice straws on such soil type varies. Rice straws that are being added to the soil must be in a relatively decomposed condition (composted), because in that condition rice straws can also be a source of nutrients and have a higher ability to chelate Fe. The use of rice straw compost has a very important role in increasing the productivity of acid sulfate soils because rice straw residues can be a source of plant nutrients, increase the efficiency of P fertilization, and reduce the level of Fe poisoning (Susilawati and Nursyamsi 2012). The addition of rice straw and *purun tikus* compost plus fertilizers at 75% of the recommended dosage in acid sulfate soil produced 3.4 ton/ha yield, or an increase of about 40% compared to the control without the provision of organic matter (Annisa and Nursyamsi 2015).

Biochar was able to improve the soil through its ability to increase pH, increase water holding capacity, add nutrients, and increase the activity of biota in the soil and reduce pollution (Laird et al. 2010). However, biochar provides nutrients indirectly by reducing nutrient losses through leaching, asa a consequence, fertilization efficiency could be increased. The results of research by Masulili et al. (2010) indicated that rice husk biochar was able to improve soil physical and chemical properties, namely pH, C, total P, Ca-dd, Mg-dd, K-dd, CEC, and reduce the concentration of Al and Fe in acid sulfate soils and increase rice production (Table 5 and Table 6).

According to Subowo et al. (2013), manure could increase rice production in acid sulfate soils at about 1 ton/ha higher than control, as well as increasing Fe content in rice. However, the provision of raw straw (not decomposed) actually decreased rice production (Table 7). According to Masganti et al. (2017), there was an interaction between the dose of straw compost and the dose of P fertilizer. The highest productivity of Inpara 5 rice in a tidal swampland in Pelalawan, Riau, was 5.73 ton/ha upon the application of 2 ton/ha straw compost combined with 60 kg/ha P_2O_5 fertilizer.

Table 5. Effect of soil ameliorant types on acid sulfate soils.

Soil Amandements	pH	C (%)	Total P (%)	CEC	K	Ca	Mg	Al (%)	Fe (%)
				(cmol/kg)					
Control	3.36	0.54	0.21	6.64	0.20	0.24	3.55	3.84	3.60
Rice straw	3.68	3.58	0.30	7.32	0.22	0.23	3.45	3.42	3.34
Rice husk	3.96	3.73	0.31	7.20	0.34	0.45	3.43	3.47	3.22
Rice husk ash	3.98	2.78	0.27	7.79	0.43	0.44	3.56	3.57	3.34
Rice husk biochar	4.40	4.09	0.32	8.03	0.51	0.44	3.57	2.96	3.10
Cromolaena	4.06	3.22	0.29	7.15	0.25	0.22	3.45	3.31	3.28

Source: Masulili et al. (2010).

Table 6. Effect of types of soil ameliorant on rice growth and biomass.

Soil additive	Plant height (cm)	Number of tillers	Number of productive tillers	Total dry biomass (g)
Control	75.17 a	9.00 a	5.00 a	29.53 a
Rice straw	85.67 b	12.00 b	7.33 b	50.93 b
Rice husk	84.00 b	14.33 bc	8.00 b	64.97 bc
Rice husk ash	78.33 a	14.00 bc	8,00 b	57.87 b
Rice husk biochar	86.17 b	17.33 d	9.67 c	75.93 c
Cromolaena	85.00 b	15.00 cd	10.00 c	76.50 c

Source: Masulili et al. (2010).

Tabel 7. Rice production and Fe contents of rice after first milling in potential acid sulfate soil, Muara Telang, Banyuasin, Sumatera Selatan.

Soil amendment	Production of dry grain on field (ton/ha)	Fe contents of rice after first milling
Control	7.28	3.27
Straw (10ton/ha)	6.77	3.59
Manure (10 ton/ha)	8.25	5.24
Lime 2 ton/ha	7.30	4.26

Source: Subowo et al. (2013).

In peat soils, slag and dolomite ameliorant applications have a significant effect in increasing the pH, base saturation, and nutrient levels of Ca and Mg. However, slag application is better in improving the chemical conditions of peat soils, since it also increases silica levels, ash content, and Fe as a polyvalent cation. The application of slag ameliorant has a significant effect in increasing biomass dry weight and grain dry weight in rice plants (Septiyana 2017). Biochar could increase plant height, the number of tillers and the number of panicles compared to controls on peatlands (Maftu'ah and Indrayati 2013). On degraded peatlands, adding 4.85 ton/ha manure + 5,960 ton/ha lime + 119 kg urea/ha + 119 kg/ha SP-36 + 80 kg/ha KCl can improve the chemical properties of peat soils, including increased soil pH, available P, Ca-exc, Mg-exc, decreased exchanged acidity (H^+ exc and Al-exc), and increased IR-66 rice yield to 4.1 ton/ha, which was higher than Martapura variety rice yield of 2.91 ton/ha.

CONCLUSIONS

As a marginal land, tidal swampland productivity is limited by the high degree of variations in biophysical characteristics. The tidal swampland productivity can be improved by several approaches such as thoroughly implementing appropriate farming system technology, improving soil properties and water management to increase rice productivity in tidal swampland, improving water quality, and providing soil ameliorant. Water management functions to supply the plant requirement, prevent weed growth in swampland rice cultivation, prevent the formation of materials that are toxic to plants through leaching, regulate water levels, and maintain water quality in plots and canals. Improvement of water quality can be done by filtering water at inlets, while soil ameliorants can suppress soil acidity and the solubility of poisonous elements. The combination of good water management and the provision of appropriate ameliorant is expected to improve soil properties and increase productivity of tidal swamps.

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SOIL PROPERTIES AND PRODUCTIVITY OF PADDY FIELDS IN THE TIDAL SWAMPLANDS OF KALIMANTAN

Muhammad Noor, Hendri Sosiawan, and Izhar Khairullah

INTRODUCTION

The total area of swamps in Indonesia is around 34.43 M ha, consisting of tidalswamps at approximately 21.16 million hectares and inland wetland swamps at around 13.27 M ha (ICALRRD 2014). However, the report of ICALRRD (2015) stated that the area of swamps was around 34.12 M ha, consisting of 8.92 M ha tidal swamps and 25.21 M ha inland wetlands. Among those, swamplands that have the potential for agricultural development are only around 14.18 M ha. Tidal swamplands, suitable for rice plants, are only around 1.05 M ha (ICALRRD 2018). According to other data, however, about two up to five millions hectares are tidal swamplands (Directorate of Swamps and Coastlines 2006; Subagio et al. 2016).

Research and development of tidal swamps have been initiated since 1970s along with the Tidal Rice Opening Project (P3S) in 1969–1994, which was spread across South Kalimantan, South Sumatra, Jambi, Lampung, Riau, Central Kalimantan, and West Kalimantan (Ismail et al. 1993). The Indonesian Swampland

Agricultural Research Institute (ISARI) is a technical implementation unit of the Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, which was established in 1964 to research various aspects of swampland agriculture, including land and agronomy. According to previous reports (Hatta 2014; Susilawati et al. 2014; Noor et al. 2020), tidal swamplands have diverse soil characteristics and hydrology or water system. Tidal swamplands can be classified into four types, namely types A, B, C and D. While based on biophysical, chemical, and fertility constraints, as well as development opportunities, swamps can be grouped into four land typologies, namely potential land (non-acid mineral soil and saline), acidic sulfate land (sulfuric acid mineral soil), peatlands (acidic peat soils), and saline soils (saline mineral soils).

In order to develop swamplands for food crops or rice fields, the soil properties of swamps need to be considered. For this reason, the technological approach and land cultivation management should take into account of water overflow and land typology. This review paper summarized the information of rice productivity in tidal swamplands, which is related to the dynamics of physical and chemical aspects of soil fertility based on overflow type and land typology especially in Kalimantan (Noor et al. 2020).

RESEARCH PROGRESS ON TIDAL SWAMPLAND IMPROVEMENT FOR RICE CULTIVATION

Research on tidal swamps has proceeded in parallel with swamp reclamation by the government and independent farming communities since the 1970s. The studies on tidal swamps in South Kalimantan and Central Kalimantan had been carried out from 1995 to 2015, including surveys and research activities. Tidal swamplands have been distinguished based on their hydro-topography or tidal overflows (types A, B, C, and D) and land typology (potential land, acid sulfate, peat, and saline), which are related to rice crop productivity. Each location has a unique historical record of opening and development or usage as a lowland swampy paddy.

Tidal swamps in South Kalimantan are mostly spread over four districts and one city, with the broadest area located in Barito Kuala Regency, followed by Banjar, Tapin, and Tanah Laut Regencies (Table 1). Whereas in Central Kalimantan, most of them are spread in Kapuas, Pulang Pisau, East Kotawaringin, and Seruyan Regencies (Table 2). The reclamation of tidal swamps for rice fields firstly was conducted by the government project of "Tidal Paddies Opening Project (P4S)" in 1969–1994, then supported by the project of the "Million Hectare PLG Project" in 1996–2000. A few paddies already existed prior to Indonesian independence (between 1930–1955).

Table 1. Distribution of tidal swamps according to types in South Kalimantan Province.

Districts/City	Area of tidal types (ha)				Total[1)]	Other sources 2014[2)]
	A	B	C	D		
Tanah Laut	9,649	37,751	53,300	3,369	104,069	12,819
Pulau Laut	31,356	9,891	15,141	0	56,388	1,640
Banjar	1,977	9,270	106,696	2,685	120,628	33,272
Barito Kuala	27,762	49,365	132,007	4,367	213,501	94,970
Tapin	0	0	54,926	0	54,926	19,060
Tanah Bumbu	41,840	26,801	2,151	2,074	72,866	3,676
Banjarmasin	476	0	6,790	116	7,382	1,755
Banjarbaru	-	-	-	-	-	1,634
Total	113,060	133,078	371,011	12,611	629,760	168,826

*) Remaining five districts, i.e. Hulu Sungai Utara (HSU), Balangan, HSS, HST, and Tabalong have no tidal swamplands.

Source: [1)]Anwar et al. (2017); [2)]ISARI (2014).

Table 2. Distribution of tidal swamps according to types in Central Kalimantan Province.

Districts/City	Area of tidal types (ha)				Total
	A	B	C	D	
Kapuas	0	0	132.415	54.559	186.974
Kotabar	0	0	12.350,00	9.750	22.100
Sukamara	4.213	1.974	1.720,00	0	7.907
Seruyan	0	0	0	31.354	31.354
Kotatim	1.350	12.352	13.728	2.578	30.008
Katingan	0	0	16.540	0	16.540
Pulang Pisau	15.361	39.822	6.350	0	61.533
Barito Selatan	0	0	5.340	0	5.340
Total	20.924	54.148	188.443,00	98.241	361.756

Sources: Anwar et al. (2017).

A number od studies in land characterization and analysis of physical and chemical properties and soil fertility have been carried out. The land characterizations included pyrite depth, peat thickness, depth of groundwater level, and other land characteristics. The analysis of physical properties comprised soil texture, soil fertility, and chemical properties such as pH, electrical conductivity, total P, total K, available P, available K, exchangeable bases (Ca, Mg, K, and Na), organic ingredients, N total, exchangeable Al, exchangeable H^+, exchangeable Fe, and percentage of pyrite. In addition, growth and yields of rice from each location have been observed. A simple correlation test has been performed to elucidate the relationship between fertility, physical, and chemical properties of paddy soil productivity.

DYNAMICS OF RICE FIELD SOIL PROPERTIES ON TIDAL SWAMPLANDS

Physical Soil Properties of Swamplands

Several swamp sites showed that the clay content is categorized high to very high. While the soil texture is generally smooth to very fine, and contains various components such as clay which positioned the greates, followed by silt, and sand. But the composition is reversed in swamps in particular, the coastal swamp (saline) agroecosystem, where sand is the major component, followed by silt and clay. In saline swamps close to the coast, enrichment from seawater overflows is universal so that the sodium level is high, the pH is rather neutral, and the level of anions is also high, resulting in high electrical conductivity values. Another condition that also dramatically influences the productivity of swamplands is the presence of pyrite layers. The depth of the pyrite layer in swamps varies greatly, and the limit allowed for cultivated land is >50 cm depth. Studies showed that the type A tidal area depth ranges 40–60 cm, while in type B land, it is between 80–120 cm, and in type C land, sometimes it can be found under the peat layer between 30–50 cm (Table 3).

In peat swamps, which have high porosity, water can pass through them quickly. The rawer the peat (fibric), the higher the porosity. The horizontal hydraulic conductivity of peat is higher than the vertical hydraulic conductivity. Land subsidence is widespread at the beginning of the peatland conversion and use, which then decreases with increasing uses (compaction). One of the main characteristics that distinguish peat soil from other soil types (mineral soil) is that the bulk density of peat soils is very low, between 0.05–0.5 g/cm^3, compared to mineral soils density ranging 1.0–2.0 g/cm^3 (Noor 2001).

Table 3. Soil texture and other physical properties of swampland soils.

Tidal Type/Location*	Clay (%)	Silt (%)	Sand (%)	EC (uS/cm)	Pyrite Depth (cm)	*Bulk density* (g/cm^3)
Tipe A[1)]	56	43	1	530	40–60	-
Tipe B[2)]	36	61	3	172	80–120	-
Tipe C[3)]	54	44	2	-	-	-
Tipe C[4)]	-	-	-	-	30–50	0,14

Notes*: [1)]UPT.Tabunganen; [2)]KP. Unit Tatas, Kapuas [3)]Handil Manarap, Banjarmasin, [4)]Suryakanta, UPT.Sakalagun.
(-) = data not available.
Sources: Noor (1996); Anwar et al. (2017); Noor et al. (2020).

Table 4. Chemical properties and fertility of swamplands based on land typology.

Land Typology/location	pH-H_2O	N total (%)	C org (%)	P total (mg/100 g)	K total (mg/100 g)	Aldd (cmol (+)/kg)	CEC (cmol (+)/kg)	SO_4 (ppm)
Potential[1)]	4.43	0.17	3.5	60	9.2	7.4	18.5	224
sulfate Acid [2)]	3.89	0.24	6.8	190	9.7	10	17.5	781
peat[3)]	4.33	0.35	28.1	30	7.9	8.4	32.5	242

Notes: [1)] UPT Terantang; [2)] KP. Belandean; [3)] UPT.Pangkoh.
Sources : Noor et al. (2010), Anwar et al. (2017).

SOIL CHEMICAL PROPERTIES AND FERTILITY OF TIDAL SWAMPLANDS

The chemical properties and fertility of soil samples from several study sites according to their land typology are shown in Table 4. In contrast, similar studies on soil samples obtained from various tidal flow types are shown in Table 5. Based on acidity and nutrient status, potential land has the best characteristics for farming, followed by peat and acid sulfate land type. Cation exchange capacity (CEC) is an indicator of base cation load, and both potential and acid sulfate soils have a similar level of CEC, which is much lower than peat soils. This does not mean that peatlands are better, because H ions are dominant in peatlands and reflect to higher CEC when it is measured. Acid sulfate land has the most significant total P (190 mg/100 g), but Al and sulfate

Table 5. Chemical properties and fertility of swamps based on their tidal types.

Tidal type/Location	pH-H_2O	N total (%)	C org (%)	P total (mg/100 g)	K total (mg/100 g)	Aldd (cmol (+)/kg)	CEC (cmol (+)/kg)	SO_4 (ppm)
Mineral Soils								
Type A[1)]	5.12	0.18	3.70	-	-	0.6	24.3	-
Type B[2)]	3.94	0.59	9.75	-	-	7.5	28.1	-
Type C[3)]	4.15	0.28	3.43	35.9	10.1	3.6	32.5	119
Peat Soils								
Type B[4)]	3.42	0.21	48.89	-	-	5.21	211	-
Type C[5)]	4.22	0.11	28.90	25.3	9.82	6.0	47.5	104

Locations: [1)]UPT.Tabunganen; [2)]KP. Unit Tatas; [3)]Kolam Kiri, UPT.Barambai; [4)]Suryakanta, UPT.Sakalagun; [5)]Kanamit Jaya, UPT.Pangkoh.
(-) = data not available.
Sources : Noor et al. (2010); Anwar et al. (2017).

levels are also higher in this soil type compared to the overall potential of land and peat soils (Table 5).

Water or hydrological conditions significantly affect chemical properties and soil fertility (Noor et al. 2020). The acidity and nutrient status of tidal swampland (mineral soil) type A is better than type C and type B, respectively (Table 3). Type B overflow is more acidic than type C overflow because of the effect of pyrites in the lower layer, which is often oxidized during the dry season and cause acidification.

LAND PROPERTIES IMPORVEMENTAND RICE PRODUCTIVITY

Improvement of Tidal Swampland Properties

The physical and chemical properties of various soil types (Tables 3, 4, and 5) indicate that there is a need to improve soil properties to make the swamplands productive. Improvement of soil properties can be made, among others, by providing ameliorants and fertilizers (Noor 2004; Noor et al. 2009; Noor et al. 2020). The provision of lime as an ameliorant has been shown

Table 6. Effects of lime and manure amelioration on the chemical properties of acid sulfate and peat soils.

Amelioration	Acid sulfate land					Peatland				
	$pH-H_2O$	C org (%)	N-tot (%)	P tot (mg/100 g)	K tot (mg/100 g)	$pH-H_2O$	C org (%)	N (%)	P tot (mg/100 g)	K tot (mg/100 g)
Lime	4.13	3.81	0.13	53.39	11.97	4.72	33.02	0.48	45.26	11.10
Manure	4.16	3.39	0.13	58.94	13.23	4.74	32.80	0.42	51.98	11.46
Lime+manure	4.29	3.28	0.12	52.10	14.02	4.63	27.45	0.34	26.42	6.89

Source: Noor et al. (2009).

Table 7. Effects of fertilizers on the chemical properties of acid sulfate and peat soils.

Fertilizer level	Acid sulfate land					Peatland				
	$pH-H_2O$	C org (%)	N-tot (%)	P tot (mg/100 g)	K tot (mg/100 g)	$pH-H_2O$	C org (%)	N (%)	P tot (mg/100 g)	K tot (mg/100 g)
Std 1	4.23	3.67	0.12	57.62	12.77	4.72	31.84	0.43	48.77	10.09
Std 2	4.18	3.27	0.12	32.30	12.89	4.70	30.96	0.43	38.05	8.79
Std 3	4.16	3.54	0.14	74.51	13.56	4.70	30.49	0.38	40.44	9.42

Notes: Std-1 = NPK (100 kg urea+30 kg SP36+100kg KCl)/ha; Std-2 = NPK (150 kg urea+45 kg SP36+150kg KCl)/ha; Std-3 = NPK (200 kg urea+60 kg SP36+200kg KCl)/ha.
Sources: Noor et al. (2009).

to increase soil pH, while the combination of lime with animal manure can increase pH and decrease the C/N ratio. Response to lime and manure was more positive on peatlands compared to acid sulfate lands (Table 6), while the application of fertilizers produced different responses (Table 7).

Improvement of Soil Properties on Rice Production

Tidal swamps are mainly used for food crop cultivation. However, swamps were known to be very acidic, have low nutrient status, and contain some elements and compounds in excessive levels (toxic) (Tables 4 and 5). Consequently, rice plants in swamps often have stressed growth and low yields (Noor 2004; Noor et al. 2009; Noor et al. 2020).

Animal manure application increases rice yields on both potential and peatlands, but giving a combination of lime and animal manure decreases rice yield. The potential land at the UPT Tarantang has a peat thickness of 20–25 cm, depth of pyrite layer at 80–90 cm, field-measured pH 4.5 (laboratory-measured pH 4.43), mature soil, and acid sulfate land. KP Belandean soil is characterized by a peat thickness of 20–30 cm, depth of pyrite layer at 60–70 cm, field-measured pH 4.5 (laboratory-measured pH 3.89), and half-ripe soil. In comparison, the peatland at Pangkoh has a peat thickness of 30–85 cm, depth of pyrite layer at more than 100 cm, field-measured pH 4.4–4.7 (lab-measured pH 4.33); and half-ripe peat (hemist). Lime is needed to level soil at pH to 4.5 (laboratory pH 3.89) on acid sulfate soils.

Although the achieved soil acidity was the same at pH 4.43 (with lime/dolomite), each land according to typology would produce a different response in terms of rice yield. The provision of large quantities of ameliorants in acid sulfate land resulted in the highest rice yields, ranging from 5.34 to 6.72 ton/ha of dry milled grain (DMG) compared to peatlands, which only reached 2.80–3.23 t/ha of DMG. Manure does not produce good responses in acid sulfate soils, but it is quite good on peatlands (Table 8). The decreased rice yield on peatlands is probably an over-liming phenomenon, but further research is needed (Noor 2004; Noor 2010).

The effects of tidal overflow type on rice productivity are related to water availability and quality. In tidal swamp type A, leaching is very intensive compared to type B and C. In tidal land type C, and leaching is very slow because it is not flooded and often experiences drought (Table 5). Many type C tidal swamps are degraded or abandoned by farmers because of it (Noor 2004; Noor et al. 2020). Table 9 shows the variation of rice yields in tidal swamps based on their overflow type and water management system. With a one-way water management system, DMG yield can reach 5.9 ton/ha or at least 3.2 ton/ha, whereas in

Table 8. Effect of lime and manure on acid sulfate and peat swamplands soils on the dry milled grain yield of rice.

Ameliorant/Fertilizer	Acid sulfate soils				Peatland			
	Std1	Std2	Std3	Rerata	Std1	Std2	Std3	Rerata
Lime	6.72	5.66	5.79	6.06	2.80	2.90	2.91	2.87
Manure	0.73	0.74	1.44	0.97	3.05	3.30	2.74	3.03
Lime+manure	6.34	6.38	5.34	6.02	2.60	2.75	3.25	2.86

Notes: ASL: Lime (pH 4,52); Manure (pH 3,71); Lime+Manure (pH 4,52); PL: Lime (pH 4,81); Manure (pH 4,68); Lime+Manure (pH 4,81).
Source: Noor et al (2009).

Table 9. Effect of different water management systems in tidal swamp types A, B, and C on the dry milled grain yield of rice in Kalimantan.

Tidal type	One way follow system		Two way follow system	
	West Kal	Central Kal/South Kal	West Kal	Central Kal/South Kal
Tipe A	5.4[1)]	4.47[3)]	3.3[1)]	-
Tipe B	5.9[2)]	3.19[4)]	4.1[2)]	1.43[4)]
Tipe C	-	-	-	3.4[5)]

Notes: [1)] Sungai Kakap, Kubu Raya (West Kal); [2)] Sungai Rengas, Kubu Raya (West Kal), [3)] UPT Tabunganen, Barito Kuala (South Kal), dan [4)] Unit tatas, Kapuas (Central Kal),[5)] Handil Manarap, Banjarmasin (South Kal).
Sources: Hatta and Hartono (2012); Hatta (2014).

overflow type A with a one-way follow system can only produce between 3.3–5.4 ton/ha, dependening on the water management system. The yield of rice in one-way follow system is on average higher than the two-way follow system (Table 9). The yield of rice in overflow type B with sufficient lime and NPK fertilizer, as well as good level can reach 4.0–6.0 ton/ha of DMG (Noor 2004; Subagio et al. 2016).

CONCLUSIONS

Surveys and research results show that there is a relationship between rice productivity and chemical properties and soil fertility of tidal swamps. Higher rice yield is achieved from the swamps that have a soil pH of 3.5–5.02 than at lower pH soil (3.0–4.5). Peatlands in tidal swamp ecosystems often have pyrite layers in the lower layers, which becomes acidic in dry seasons. Most of peat soils from tidal swamp ecosystems are fibric and have thicker peat (fibric) in the upper layer. Nutrient status of N, P, and K in tidal lands ranges from moderate to very low. Tidal swamp soil has a low exchanged cations (Ca, Mg, K, and Na); therefore, required lime or dolomite enrichment. However, an excessive lime, especially in peatlands, can cause symptoms of over-liming, which can decrease rice yield. Rice yield is also affected by land typology. On acid sulfate land with sufficient lime and fertilizer, yield can reach 6.0 ton/ha of DMG, whereas yield in peatlands can only reach around 3.0 ton/ha. Rice yields are also affected by overflow type. Rice yield in overflow type B with a one-way water system is between 3.2–5.9 ton/ha of DMG, while in type A with a one-way water system, the yield is between 3.3–5.4 ton/ha of DMG, depending on the water management system. Rice yield in overflow type C (3.4 ton/ha) is relatively lower then in the types A and B. Overall, the soil properties in this tidal swampland in this area could be beneficial information to recommend the suitable rice varieties along with the proper management to produce optimal grain yield.

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BENEFITS AND DISTRIBUTION OF MUD AND ITS EFFECT ON RICE (*Oryza sativa*) PLANTS IN THE BARITO RIVER SWAMP AREA

Mawardi, Bambang H. Sunarminto, Benito H. Purwanto, Putu Sudira, and Totok Gunawan

INTRODUCTION

Tidal characteristics for an area differ from one region to another. Pariwono (1985) classifies the characteristics of tides in Indonesia to single tides, which dominate western Indonesian waters, and double tides in the eastern Indonesian waters. The features of the tides need to be understood by conducting field observations (Hydrographic Services 1987) using automatic tidal recording devices or visual signs (Unesco 1994). The data is then calculated to understand the tidal characteristics of the sea (Hydrographer of the Navy 1969).

The potential of tidal swamps in Indonesia suitable for agriculture is still quite extensive. However their use for agriculture is still limited, as a result of high pyrite layer which can reduce rice yield (Suriadikarta 2012). Pyrite layers (FeS_2) can be found at a depth of 30–60 cm from the surface of the soil, and they often undergo oxidation, especially in the dry seasons, which causes acidity and high solubility of Fe (Shamsuddin et al.

2004). In the sufficiently large neutralizing compounds of oxygen hydroxide ions and lime ($CaCO_3$), the bases can be exchanged, and silicate minerals decay rapidly at the proper PH. Thus, the presence of marine clay containing enough smectite clay minerals which are highly saturated with bases can neutralize soil acidity (Subagyo 2006).

Mud is important for rice roots because this plant requires muddy and fertile soil with a thickness of 18–22 cm. Additionally, mud serves as a nutrient provider and can absorb iron to ovoid poison the plant. Mud is attributable to protect rice from the pyrite. The soil mud can be very important in supporting the success of rice farming in tidal lands, especially in the downstream area of the Barito River. The amount of river mud sedimentation from the Barito river is around 3,073,511.74 m^3/year (Mawardi 2018). Every year an environmental impact analysis (EIA) must be updated due to an increasing amount of the mud.

The siltation of the Barito River occurs due to the upstream and downstream areas of the Barito River experiencing quite a rapid sedimentation (Antaranews.com 2019), which makes it difficult for ships to pass and requires huge costs for dredging. There is not enough studies data on the unique benefits of mud from the Barito area and its spatial distribution. This paper aims to present information explored from researche based-literatures on soil mud and its benefits, especially in Barito River Swamp area, to be useful as a basis to formulate technological recommendations to increase rice production.

BENEFITS AND CONTENTS OF MUD

Barito River is meander-shaped. It has a lot of mud deposition in the downstream area, and several well-known deltas are formed there, such as the Kembang and Kaget islands. Mud that is deposited in the swampy downstream region of the Barito River is quite fertile because it is originated from sea mud, and deposits from the upstream area of the river.

The application of sea mud on paddies significantly affected phosphorus uptake, potassium uptake, and dry weight of the top of the plants (Hadari et al. 2013. Similar results were also obtained by Sulakhudin et al. (2017), the application of coastal sediments at a dose of 40 ton/ha significantly increased the Ca and Mg content. Mud can also reduce iron poisoning in rice plants, as demonstrated by Mawardi (2018) that some soil mud taken from different locations in the tidal swamp area of the Barito River can absorb iron by up to 500 ppm (Figure 1). Thus, soil mud can be an alternative substitute of lime, especially the ones that originated from sea mud that are obtained from marine sediments (Suswati et al. 2012).

SWAMP AND COASTAL MUD COMPOSITION

The mud composition from different locations in the tidal swamp area downstream of the Barito River varied. Table 1

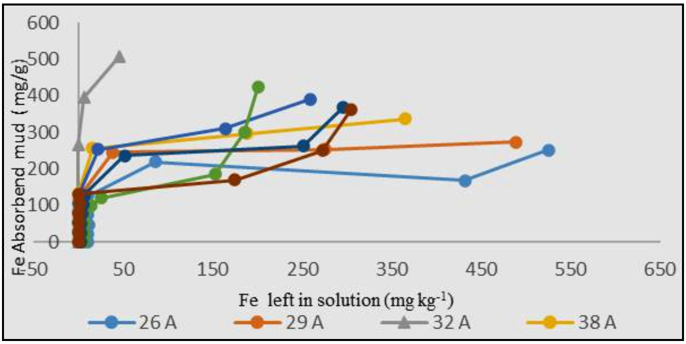

Figure 1. Fe absorbent properties of mud originating from several different locations in the Barito River swamp area.

Table 1. The characteristics of coastal sediment and swamp sediment.

Properties	Coastal sediment (Pontianak)	Swamp sediment (Barito River)
pH H2O 1:2	8.13	5,.9
pH HCL 1:2	7.94	4.27
C.Org (96)	1.96	7.18
N Total (%)	7.26	4.8
C/N Ratio	0.27	8.04
Pbray (mgkg-1)	3.45	2.68
K(cmol(+)kg)	1.71	4.2
Ca (cmol+)kg	14.62	10.41
Mg (emol(+)kg)	1.73	15.7
Na (cmol+)kg	2.65	0.51
KPK(cmokg-1)	15.33	110.41
Texture		
Sand (%)	10.2	0.68
Silt (9)	51.85	18.21
Clay (%)	37.95	81.11

Source: Mawardi (2018) and Suswati (2017).

shows the chemical and physical properties of mud from coastal sediments on the Pontianak Beach of Kijing and swamp sediment from Barito River. Seawater influences the characteristics of sea mud, resulting deposit is rich in salts, such as NaCl, Na_2SO4, $CaCO_3$, and $MgCO_3$ (Tan 1993). These minerals can neutralize organic acids (Stevenson, 1994), increase soil pH; therefore, sea muds tend to be alkaline. Besides, the cation will increase the percentage of base saturation (KB) of the colloidal complex and directly cause an increase in soil pH. On the other hand, swamp mud tends to be acidic because it is influenced by organic acids and the presence of an oxidized pyrite layer in acid sulfate soils, which cause the pH to go down.

DISTRIBUTION OF BARITO RIVER MUD

The quality and amount of deposited mud vary greatly, depending on the source of the river mud and the amount of water (Hardjowigeno el al. 2004). Three factors play the most crucial role in the formation of river mud (alluvial) in tidal lands. The first factor is tidal dynamics, namely the daily tidal frequency or overflow type. The second factor is the difference between the maximum tides and minimum tides (Δ tides), which fluctuates every month (Anwar and Mawardi 2009) although the changes are relatively small. Flow velocity can be influenced by tides, especially the speed of incoming water flow, and the flow of water that comes out and affects the amount of mud being deposited. The deposition of materials or organic materials is also influenced by inflows and outflows (Piirsoo et al. 2012). The third factor is the sediment dissolved in water, and it will affect the thickness of the mud. The depth of the mud reflects the interaction of various factors. Fertility (nutrient) is strongly influenced by the use of green fertilizer from water hyacinth, peat, and soil mud (Sittadewi 2008).

The distribution of mud in the Barito River swamp area varies both in terms of thickness and quality, and it is affected by position on the sea, topography, and the rainy or dry season. Geographical factors also significantly contribute the sedimentation process, as happened in the Mekong River, where the formation of deltas from river sediments was influenced by several factors such as rainfall, temperature, and geographic characteristics (Thuy and Anh 2015). The total suspension of sediment carried by water also ultimately affect the sedimentation process at a location (Hariyanto et al. 2017).

The characteristics of the Barito River strongly support the occurrence of mud deposition. Still, the factors that influence the removal of mud in each location differ, resulting in different distribution patterns as well (Figure 2.). The amount of sedimentation in a place that allows rice to grow well, such as in the Anjir sub-district, has mud with a thickness of 10–20 cm. That

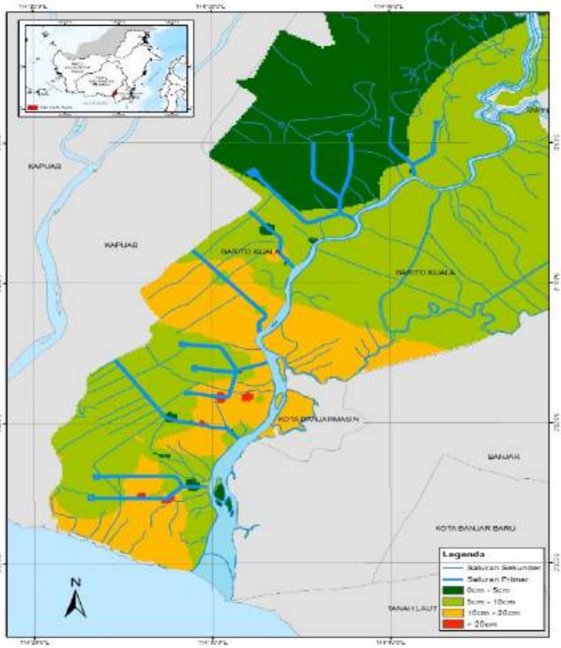

Figure 2. Distribution of mud thickness in low tide area of Barito River (Source: Mawardi 2018).

area became the largest rice producer in Baritokuala Regency since 2011–2015, with an annual production of 34,234, 32,409, 27,205, and 30,431 tons, respectively (BPS 2017). It can also be seen that the thickness of mud in each location is different, and the most dominant ones are 5–10 cm and 10–20 cm thickness.

THE EFFECT OF MUD ON RICE (*Oryza sativa*)

Mud, as an ameliorating material, absorbs Fe and acts a nutrient source, which in turn increases the production of crops like rice, sorghum, and corn. Mawardi (2018) reported the effects of providing mud to vegetative growth of rice, and a summary of his findings can be found in Table 2.

Table 2. Effects of enrichment of four types of Barito river mud at various dosages to the number of tillers and rice plant height

Treatment (ton/ha)	Vegetative growth parameters	
	Number of tillers	Plant height (cm)
Control	11.63ab	61.1a
L1 (10)	12.8abc	71.3a
L1 (20)	15.33c	72.2a
L1 (40 ton ha-1)	15.13c	68.3a
L2 (10 ton ha-1)	12.73abc	68.7a
L2 (20 ton ha-1)	14.87bc	69.1a
L2 (40 ton ha-1)	12.13abc	64.9a
L3 (10 ton ha-1)	12.6abc	61.6a
L3 (20 ton ha-1)	12abc	59.5a
L3 (40 ton ha-1)	14.07bc	64.6a
L4 (10 ton ha-1)	10.27a	72.8a
L4 (20 ton ha-1)	11.47ab	64.7a
L4 (40 ton ha-1)	12.27abc	73.9a

Description: Numbers followed by the same letters in one column are not significantly different based on LSD 5% .
Locations were depicted as L1-L4: L1 = Baramba; L2 = Anjir, L3 = Tinggiran Darat Baru L4 = Sei Kajang.

The number of tillers is significantly different in treatments with varying dosages and mud types (Table 2). The enrichment of mud dosage of 20 ton/ha and 40 ton/ha could produce 13.42 and 13. 40 tillers per plant, respectively. The result is in good agreement with Annisa et al. (2014) that the provision of organic materials has an effect on the number of rice tillers. When added to acid sulfate soils, organic matter has the function of maintaining a reductive environment in order to suppress pyrite oxidation. Ăcai et al. (2009) reported that humic acid found in soil organic matter could adsorb pyrite, allowing the soil supports an optimal rice growth. The addition of mud produced a very close correlation between mud dosage and the harvested grain yield (Figure 3). The higher the dose of river mud, the higher the grain yield being produced. At the dose of 40 ton/ha, mud application

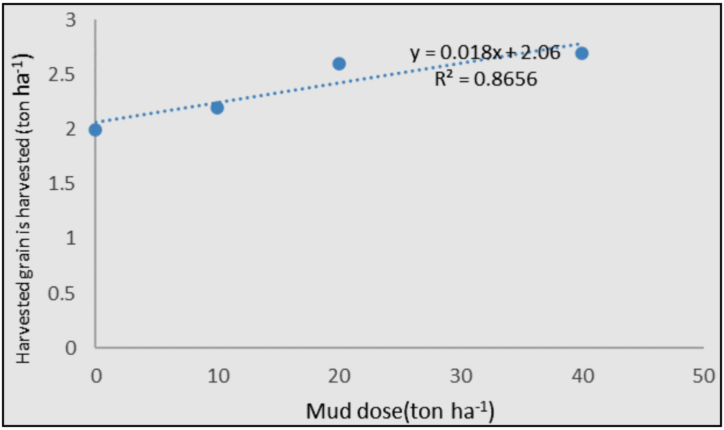

Figure 2. Relationship between dry harvest and mud dose.

can increase dehusked rice production to an average of 2.7 ton/ha, which is much higher than the controls, which only produced an average of 2 ton/ha of dehusked rice.

The effect of mud on other food crops was also reported by Hadari et al. (2017). The application of marine mud produced a positive response in terms of plant dry weight, possibly because the dry weight of plants not only comes from just P and K, but it s the results of an accumulation of various macro and micronutrients. The more nutrients being absorbed by plants will increase the nutrients being accumulated into plant tissues, thus increasing the dry weight plant. According to Lakitan (2010), plant dry weight reflects the accumulation of organic matter that has been successfully synthesized from inorganic compounds, especially water and carbon dioxide. Thus, nutrients available in the soil that is being absorbed by the plant roots will have an effect on the increased dry weight of plants.

CONCLUSIONS

The Barito river swamp area is rich in mud that can benefit fo rice plants. The river mud contains essential source of nutrients and as a lime substitute. It affects the absorption of phosphorus, potassium uptake, the availability of Ca and Mg, and even reduce Fe poisoning in rice plants. The distribution of mud varies both in quantity and quality, and it is affected by its position from the sea, topography, rainfall, temperature, and geographic characteristics. The utilization of mud is the right solution to the problems associated with the Barito River. The soil mud can be improved in its ability to absorb Fe toxins and enriched with other nutrients. Under such conditions, it can function optimally as a soil ameliorant to increase rice production.

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PROSPECT OF RICE FARMING FOR DEGRADED PEATLANDS MANAGEMENT IN CENTRAL KALIMANTAN, INDONESIA

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INTRODUCTION

Land availability is becoming an important issue as a result of the increasing human population. There will be land-use competition between food production, biofuel production, and human settlement (Godfray et al. 2010; Smith et al. 2013). Global estimates suggest that 80% of the needed expansion in food production will be expected from increasing yields and cropping intensity, while about 20% will be from expanded crop area (FAO 2003); therefore, it will require an additional 120 million hectares worldwide.

Indonesia, the world's fourth most populous country, faces the challenge of increasing food production for its food security. In 2010, the population of Indonesia reached 237.56 million, with an annual growth of 1.49% (BPS 2011). It will be challenging to provide enough food in the future. Approximately 34 million tons of rice will be needed, assuming an annual consumption of 139.15 kg per capita (BPS 2011). A proximately, 1.4 million ha of additional rice cultivation will be required to ensure national food security in 2025 (Haryono 2013). Considering that the availability of highly productive arable land is limited, development and optimization of suboptimal or marginal land for food production is an option. One type of marginal land with great agricultural development potential is peatlands.

Indonesia's peat area is 14.9 million ha, which is mainly distributed in islands of Sumatra (35%), Kalimantan (32%), Papua (30%), and Sulawesi and other islands (3%) (Ritung et al. 2011; Mulyani et al. 2012). As much as 4.4 million ha of peatlands in Indonesia are categorized as degraded land (Agus et al. 2014). Similarly, in Central Kalimantan Province, 1.1 million ha are classified as degraded land (Wahyunto et al. 2013). Logging, land conversion, and other improver activities on the peatlands have degraded peatlands; as a result, the physical, biological, and chemical properties changed (Silvius and Diemont 2007; Jaenicke et al. 2008; Anshari et al. 2010). Degraded tropical peatlands are a significant source), which arises from the decomposition of peat (Agus et al. 2010) and fires (Page and Hooijer 2016). Therefore, degraded peatlands should be managed wisely to minimize their impact on CO_2 emission and reinstate their environmental and economic functions (Page et al. 2009).

The development and optimization of degraded peatlands for food production is an option to ensure national food security. Economically, peatlands play an important role since they can be reclaimed for agriculture. However, as reported by Mulyani et al. (2012), only 33 percent of the peatland area can be used as an agriculture area; therefore, the main idea is only to utilize a relatively small portion of the peat which is suitable for crop production. Shallow peat (<1 m thickness) is recommended for food crops (e.g., rice, corn, soybean, cassava, and vegetables) as shallow peat is more fertile and less environmentally risky than other peats (Nursamsi et al. 2016). Mawardi (2007) reported that there is 0.16 million ha of potential area for rice farm development in Central Kalimantan peatlands in the former Mega Rice Project (MRP). The advantages of utilizing degraded peatlands for rice fields are the availability of abundant water, relatively flat topography, and extensive landholding and farming, which is ideal for agricultural machinery deployment (Noor 2001). This paper describs the exploration of the prospect of developing rice farming in degraded peatlands as an option to maintain food security and food sufficiency, as well as to minimize CO_2 emission.

DEGRADED PEATLANDS FOR AGRICULTURE

The utilization of peatlands for agriculture is still being debated among experts. On the one hand, environmentalists expect that peatland should be used for conservation, but on the other hand, the need for agricultural land for food security is also urgently required. The peatlands are not only valued for their ecosystem services (water quality and storage, biodiversity, carbon, etc.) but also have fulfilled many human needs, including food, energy, construction material, livestock bedding, and health (Clarke and Jack R 2010). For further peatland development, due to the high diversity and characteristic of peatlands, it is necessary to do land suitability evaluation. Land resources data and information, such as soil, climate, and another biophysical environment, are essential resources for conducting land suitability evaluation. Las et al. (2009) stated that the suitability of peatlands for agriculture and the level of the environmental impact of peatlands are determined by (1) peatlands thickness; (2) peatlands maturity level; (3) peatlands formation and soil substratum content; (4) degree of peat and mineral association; (5) land clearing, water management system and drainage; and (6) application of crop technology (varieties, fertilizer, soil, and water management). Shallow peatland (<100 cm thickness) is recommended for the cultivation of food crops, such as rice, corn, soybean, cassava, and many other vegetables (ICALRRD 2008), while a deeper peatland (2–3 m) is for perennial crops (Sabiham 2008). The shallow peatland is more fertile and less environmentally risky than deep peats. Moreover, the utilization of degraded peatlands for agriculture creates the opportunity to reduce CO_2 emissions from peatlands through carbon sequestration by plants as a consequence of land-use change from shrubs to other productive plants (Wahyunto and Dariah 2013). Additionally, Noor (2001) stated that the development of peatlands for new agricultural expansion area has several advantages such as: (1) the availability of abundant water, (2) relatively flat topography, (3) proximity to rivers as water sources and for discarding excess water (4) ideal for the deployment of agricultural machinery due to extensive landholdings.

Dealing with peatland's limiting factors is also an essential issue in the development of peatlands for agriculture. As peat soils have inadequate physical and chemical characteristics related to the land and water management, developing both main and sub canals for water management system is an essential element that needs to be done. Construction of main canals is necessary for the cultivation of food crops on peatlands. The function of drainage is to remove excess water, creating an unsaturated condition for plant root respiration, and wash most organic acids in the soil. In the peatland water management system, a hydrodynamic equilibrium between peatlands and surrounding areas is an essential factor in preventing over-drainage, excessive drying, as well as fire risks. Soil management for the peatlands is also crucial because peat soils are acid and infertile. Amelioration efforts are needed to increase the pH and improve crop rooting media. Lime, mineral soil, manure, and ash are ameliorant materials that can be used to increase soil pH (Subiksa et al. 1997).

Innovative technologies have an important role in the development of peatland agriculture in Indonesia. Low soil fertility and water management are the most common problems in peatlands research and development. There are a lot of innovations which are generated by research institutions, including university and Non-Government Organization (NGO), which are available for improving agricultural practices in peatlands.

In the Ministry of Agriculture, specific research related to peatlands is done by the Indonesian Agency for Agricultural Research and Development (IAARD) and its research centers and research institutes. The Wetland Research Institute in Banjarbaru, South Kalimantan, has the mandate to perform specific research related to crop and soil management in peatlands. This institute has also collaborated with other research centers and research institutes under IAARD, such as with the Indonesian Center for Agricultural Land Resources Research and Development (ICALRRD) in terms of mapping peatlands suitability, with the Indonesian Center for Food Crop Research and Development (ICFCRD) in terms of food crop varieties for peatlands, and with the Indonesian Agricultural Environment Research Institute (IAERI) in terms of mitigating GHG emission. Those research institutions have innovated several innovative technologies for peatland development, such as soil and water management technologies (micro water management and landscaping), soil amelioration and fertilization technology, adaptive variety development, pest, and disease control technologies, agricultural machinery, and institutional empowerment of farmers. Besides those innovative technologies from research institutes and universities, indigenous technology, which has been applied by farmers for a long time for peatland agriculture, should also be recognized. This technology can be improved by the innovation of technology to get better production, but should still be environmentally friendly (Noor 2011).

RICE FARMING IN CENTRAL KALIMANTAN PEATLANDS

The average rice yield in Central Kalimantan is 2.13 and 1.89 ton/ha with a B/C ratio of 1.49 and 1.77 for the rainy and dry season, respectively (Surahman 2017). Rina et al. (2007) stated that the average rice yield in peatlands in Kalimantan is 2.3 ton/ha for superior variety and 1.8 ton/ha for local rice varieties. Economically, rice farming in the peatlands is quite profitable, with a profit of US$ 446.50 per hectar in rainy seasons and US$ 507.19 per hectar in dry seasons. The higher profit in dry seasons is caused by higher rice prices even though local variety is used in that season. Most farmers plant rice twice a year. Rice varieties that are usually used by farmers in Central Kalimantan are Siam Unus, Siam Mutiara, Siam Karukut, and Pandak, which are local rice varieties, and Inpara 1, Inpara 2, and Inpara 3, which are superior rice varieties.

Rice productivity in Central Kalimantan is categorized as low because the yield potentials of the superior varieties planted by farmers (Inpara1, Inpara2, and Inpara3) are 5.6–6.7 ton/ha (Simatupang et al. 2013). Soehardi (2014) also reported that in swampy peatlands, rice yield could reach 5.5–6.5 ton/ha for superior varieties while Firmansyah and Harmini (2014) reported that a local variety of rice could produce 3.9 ton/ha in the swampy peatlands of Central Kalimantan. Low rice productivity was likely caused by applications of fertilizers at more economical than the recommended dosage. According to

Firmansyah and Harmini (2014), the recommended dosage of fertilizers in Kapuas District of Central Kalimantan province is 138–36–75 kg/ha for N, P (P_2O_5) and K (K_2O) per crop, respectively. However, farmers in the study area only applied 75–13–13 kg/ha for N, P, and K, respectively (Surahman 2017). Peat soils generally have low fertility, characterized by low availability of macronutrients (K, Ca, Mg, P) and micronutrients (Cu, Zn, Mn, and Bo), as well as the problems of toxic organic acids (Najiyati et al. 2005). Simatupang et al. (2013) reported that fertilization at 90–60–60 kg/ha of N, P, and K dosage would increase rice yield in peatlands by as much as 14.1% compared to typical farmer fertilization dosages.

Pests and diseases, drought in dry seasons, and flood in rainy seasons are the significant problems of rice farming in peatlands. According to Prayudi (2001), the main pests and diseases of rice plants in the peatlands are rats, stem borers, brown planthoppers, blast, tungro, and bakanae. Simatupang et al. (2013) suggested that new rice varieties, which are tolerant of the main pests and diseases in peatlands, such as Inpara1, Inpara2, Inpara3, Inpara4, Limboto, Situ Patenggang, and Batutegi, should be introduced to the farmers in the peatlands. The other problems in peatland rice farming are flood and drought, which are caused by malfunctions of the water channels (both macro and micro). Considering that most of the rice farming in the peatlands of Central Kalimantan was located in the swampy area, water management (both macro and micro) is one of the most critical factors in the peatlands as it is designed to control water as well as preventing floods in rainy seasons and drought in dry seasons (Najiyati et al. 2005).

RICE FARMING FOR REDUCING GREENHOUSE GAS EMISSION

Rice farming can be selected as a land-use option in degraded peatlands. Lowland rice fields have been shown to be a better agricultural system in peatlands in terms of carbon sequestration and greenhouse gas emission since carbon loss in lowland paddy fields was one-eighth of other upland crop systems (Furukawa et al. 2005). There are three scenarios to reduce the rate of land degradation. The first scenario is reducing peatland degradation rates by 0%; the second scenario is reducing peatland degradation rates by 50%; and the third scenario is reducing peatland degradation rates by 100%. The utilization of 0.16 million ha of degraded peatlands for rice farming in Central Kalimantan province can reduce cumulative CO_2 emissions by 12.68% for the first scenario. In contrast, the second scenario reduces 17.30%. In contrast, the third scenario reduces 21.42% under the conditions of no management of the degraded peatlands, which equal to 143.61 million tons of CO_2 for the first scenario is 195.98 million tons of CO_2 for the second scenario, and 242.74 million tons of CO_2 for third scenario (Figure 1).

A significant aspect of CO_2 emission reduction in rice farming systems in degraded peatlands is water table depth. CO_2

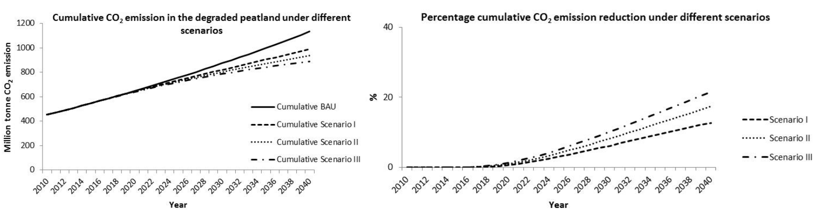

Figure 1. Cumulative CO_2 emissions reduction under BAU, Scenarios I, II, and III, expressed as percentages of reduced cumulative CO_2 emissions under different scenarios by introducing a rice farming system on degraded peatlands (Surahman 2018).

emission rates are lowered as the water table rises towards the peat surface (Hooijer 2010). Similarly, Agus et al. (2012) suggested that the CO_2 emission factor for land use changes depending on the water depth. CO_2 emission could be reduced by minimizing a water table depth from 40 cm (shrub) to 0–30 cm. As a result, CO_2 emission reduced (65.8%) in the reforestation area, rice field (48.8%), and agroforestry (40.7%) (Surahman 2017). Therefore, the rice field is a better option if the conversion of peatlands to agriculture (Furukawa et al. 2005).

SUSTAINABILITY OF RICE FARMING IN DEGRADED PEATLANDS

Farming system sustainability was scored from a combination of Rapfish analyses in different dimensions. Rice farming in Central Kalimantan has a sustainability index score of 52.14. However, in ecology and economic dimension, its score can be categorized as unsustainable (Table 1).

Even though rice farming can be sustainable in degraded peatlands, appropriate measures need to be taken to increase its sustainability. According to the leverage results, improvement of farmer's knowledge about the mitigation of GHG emissions is the most important attribute. Plant productivity is also a highly influential factor in the economic dimension. Currently, rice productivity is still quite low. The implementation of innovative technology is considered a priority and should be done by

Table 1. Raffish scores of rice farming system in Central Kalimantan.

Farming System	Dimension					Mean
	Ecology	Economic	Social	Institutional	Technology and infrastructure	
Rice	48.51	49.65	56.71	52.25	53.59	52.14

farmers under the supervision of agricultural field extension agents. Another important factor for supporting agricultural production is agricultural infrastructure improvement. Better irrigation systems, farm roads, and markets are needed. Local governmental agencies' support in this regard is crucial.

The strategies for sustainable peatland agriculture are improvement in soil fertility and suitability for agriculture, improvement of infrastructures related to peatland agriculture, improvement of institutions related to peatland agriculture, improvement of innovative technology and dissemination, improvement of farmers' knowledge in sustainable peatland agriculture, and improvement in plant productivity (Surahman et al. 2018). Those strategies are expected to lead towards sustainable peatland agricultural conditions as well as improving the farmers' welfare, protecting biological diversity, and maintaining the ecological systems in the target area.

STRATEGIES FOR IMPROVING SOIL FERTILITY AND SUITABILITY

The development of peatlands for agriculture has various constraints in both physical and chemical aspects. The main physical constraint of peat soil is irreversible drying. In this condition, the peat becomes flammable and easily washed away by water flow (Widjaja-Adhi 1988). Under such conditions, peats also lose their ability to absorb water and nutrients (Dariah et al. 2014). Chemical constraints of peatland agriculture include soil fertility, which is characterized by low pH (acidic), and low availability of macro and micronutrients, especially P and K (Najiyati et al. 2005). Amelioration and fertilization can be done to improve soil pH, increase nutrient availability, and enhance soil adsorption. Ameliorant is a material added to marginal soil to improve soil fertility by improving both the physical and chemical properties of peat soil. Lime, mineral soil, manure, and ash residue can be added as ameliorants to raise the soil pH (Subiksa et al. 1997; Najiyati et al. 2005). Application of ameliorants is reported to have a good impact on growth and NPK uptake of sweet corn (Maftu'ah et al. 2013), growth, and yield of rice (Nevia 2014) and production of oil palm (Subiksa et al. 2014). Mineral soil and basic slag as ameliorants for rice cultivation decreased the total C-emission from peat by about 28 to 31%.

Peat soil fertility is also determined by peat depth. Shallow peats have relatively higher fertility and lower environmental risk than deep peats (ICALRRD 2008). Thus, peat depth maps are important for determining the suitability of the peatland agriculture area based on peat depth. The role of spatial data on peatland distribution is getting increasingly important, which is in line with the increased attention on peatland management. Peatland maps have strategic importance in the peatland management for planning both the production and conservation aspects. During the peatland map development, peat depth is differentiated according to the usage objectives. For the development of peatland agriculture, peat depth is classified into <1 m, which is directed for rice field development, 1–2 m for other food crops, 2–3 m for horticulture, perennials, and estate crops, and >3 m for conservation. While for sustainable degraded peatland management, peat depth is divided into four classes: <100 cm, 100–<200 cm, 200–<300 cm, and >300 cm (Wahyunto et al. 2014). From the past 30 years, peatland mapping was done only at 1:250,000 scales, since information on peatland characteristics, are very dynamic and limited. Therefore, to get accurate data, the existing peatland maps should be updated regularly, preferably every 5–10 years, depending on the availability of survey data (Wahyunto et al. 2014). Furthermore, higher resolution peatland maps (1:50,000 scale or less) should be created to obtain more precise data for peatland management planning, especially for the mitigation of GHG emission.

STRATEGIES FOR IMPROVING INFRASTRUCTURE RELATED TO PEATLANDS AGRICULTURE

Water and land management are the keys to success for developing sustainable peatland management. Improper drainage and land management cause serious environmental impacts on the peatlands ecosystem. Those impacts include peat subsidences, fires, and GHG emissions. Therefore, steps taken for improving infrastructures in peatland agriculture should also enhance the water management system. Hoijer et al. (2010) described a linear relationship between groundwater depth in peatlands and CO_2 emission; CO_2 emission increases as groundwater depth increases, due to peat decomposition. Water should be controlled in a balance between a level optimum for supporting crop and a level adequate for preventing peat subsidence and decomposition (Ritzema 2008), such as by constructing water gates in each channel, especially in the development of large-scale peatlands agriculture (Dariah et al. 2014). The major benefits of the canal blocking system are increased water table depth, reduced water runoff through the canal system, and reduced flow velocity to prevent erosion (Ritzhema et al. 2014). Furthermore, Dohong and Lilia (2007) stated that the construction of dams in the canal blocking system is important to stabilize the hydrological properties of peatlands and prevent peatland degradation resulting from fires and peat subsidence.

STRATEGIES FOR IMPROVING INSTITUTIONS RELATED TO PEATLAND AGRICULTURE

Institutional support is crucial in the development of degraded peatlands. It has a role in stimulating and facilitating increased peatland productivity. As reported by Rina and Noorginayuwati (2013), farmers' institutions that exist in peatland agriculture usually consist of farmer groups, water management institutions, farm input institutions, financing institutions, marketing institutions, and agricultural extension institutions. Agricultural extension institutions in the peatlands have not been working well since field agricultural extension activities were still limited in quantity as well as their scopes (Rina and Noorginayuwati 2013). According to Chamala and Shingi (1998), agricultural extension agents should help farmers through four important roles, i.e., empowerment role, community-organizing role, human resources development role, and problem-solving and education role. Strengthening agricultural extensions institutions should be done with more emphasis on farmers' need in the agricultural extension programs, in addition to strengthening farmers' groups. Revitalization of agricultural extension systems through agriculture extension agents for village programs should also be implemented in the development of peatland agriculture.

Village-level cooperatives are alternative farmer support institutions. The cooperatives can serve as farm input institutions, marketing institutions and also financing institutions. As a legal entity, village cooperatives can create several business services that are specially catered to farmers. Village cooperatives can facilitate farmers to get services on agricultural credit through rural micro-banking, distribution of agricultural inputs, and agricultural processing and marketing (Rahmawati 2014). Furthermore, the village cooperatives should also be encouraged to develop their role as channels of government programs (Suradisastra 2006). Due to their function in supporting farmers in the farming system, institutional strengthening and the empowerment of relevant institutions in the sustainable peatland management are also vital for sustainability and to sustain farmers' welfare in peatland agriculture development.

STRATEGIES FOR IMPROVING INNOVATIVE TECHNOLOGY AND DISSEMINATION

Various constraints in both physical and chemical aspects are common in developing peatlands for agriculture, but it is still possible to overcome them by introducing innovative technology (Dariah et al. 2013). Innovative technology for the development of peatlands comprises soil and water management, adaptive varieties, pest and disease control, agricultural machinery, as well as institutional empowerment of farmers (Suriadikarta 2012). These innovations may help to solve peatland issues relating to GHG emissions and peatland's fertility. Soil and water management technologies are important for the development of peatland agriculture (Suriadikarta 2012). A water management system that is appropriate and well-tested in peatland tidal areas is a combination of a one-way flow system and a blocking system (Suriadikarta 2012; Dariah et al. 2013). Additionally, Dariah et al. (2013) explained that in this system, a flap gate (automatic watergate) is installed at the mouth of tertiary channels while semi-automatic water gates are installed in the irrigation channel, which opens in high tide and closes in low tide water condition.

Crop varieties selected for peatlands should be adaptive to peatland conditions. For rice cultivation, plant varieties that are suitable for peatlands include Ciherang, IR42, IR64, IR66, Kapuas, Cisadane, Punggur, Inpara 1, Inpara 2, Inpara 3 and Inpara 4 (Simatupang et al. 2013). However, farmers in the surveyed site still used local varieties for rice cultivation, such as *Siam Unus, Lemo, and Pandak,* because they are favored by the local community, which has higher selling prices. Therefore, it is suggested to plant a combination of both local and superior varieties with 200% rice cropping intensity. Superior varieties are proposed because of their advantages in terms of yield, early maturity, and a high response to fertilizer application (Najiyati et al. 2005).

Even though technological innovations in peatland management have been developed, their adoption rate by farmers is still relatively low. Sarwani et al. (2011) stated that the low rate of dissemination was caused by poorly-planned research and dissemination without having the interlocking agenda, including no assessment to accelerate the dissemination of innovative technologies. With regard to this issue, the Indonesian Agricultural Agency for Research and Development (IAARD) has designed a multi-channel dissemination system to achieve effective dissemination. The innovation of agricultural technologies can be quickly disbursed to all users, such as farmers groups, local governments, agricultural extension agents, the private sector, and decision-makers, as well as directly to individual farmers through various dissemination media (IAARD 2011). However, there are some barriers to the adoption of new technology that should also be considered. Lakitan and Gofar (2013) feared that applications of new technology usually increase farming input costs and thereby reduce farmers' profit. Thus, the challenge of recommending new innovative technology in peatlands lies in limiting the initial investment and farm cost by seeking local raw materials, to make it cheaper and more likely to be applied on a massive scale by farmers.

Improving knowledge, especially in sustainable peatland agriculture, can be done through farmers' capacity building. Field agricultural extension agents can be involved in farmer capacity building programs, especially for GHG emission awareness, through the non-formal learning process (by interacting with the farmers) and also through the formal learning process (by farmer training and farmer field school) in sustainable peatland management (Anantyanu 2011). Resosudarmo and Yamazaki (2011) suggested that among these two methods, training and visit program is more suitable to be implemented in less-developed regions than field school programs for farmers.

STRATEGIES FOR IMPROVING PLANT PRODUCTIVITY

Improving plant productivity can be considered as an intermediate output of sustainable peatland agriculture since plant productivity in peatlands is directly affected by peat soil characteristics and management level. Peatlands are marginal lands for various types of food crops, with several dominant limiting factors such as water and soil conditions, rooting medium, organic acid content, and low nutrient status, which make them less conducive for plant growth. Therefore, strategies and efforts to improve plant productivity must be aligned with other strategies to improve peatland conditions. By implementing all strategies of peatland management, such as improving soil fertility and suitability for agriculture, improving infrastructures related to peatland agriculture, improving institutional support related to peatland agriculture, and improving innovative technology and dissemination, the plant productivity can also be improved eventually. The productivity of rice plants in the peatland could be improved by better management of water, soil fertility, and plant varieties, as well as by reducing the GHC emissions by regulating groundwater depth, nonburning tillage, planting a cover crop, and cropping pattern (Subiksa and Wahyunto 2011). Those strategies are expected to result in sustainable peatland agricultural conditions, as well as improved farmers' welfare, protected biological diversity, and maintenance of ecological systems to reduce GHG emissions. A maximum rice yield could also be made by crop management in peatlands should be done by managing water, using minimum tillage and herbicide application, amelioration and fertilization, and using adaptive rice varieties. Proper fertilizers and ameliorants applications could increase rice plant productivity and reduce GHG emissions in peatland (Agus et al. 2014). Application of ameliorant in peatlands has shown positive impacts on growth and NPK uptake of sweet corn (Maftu'ah et al. 2013), growth, and yield of rice (Nevia 2014), and production of oil palm (Subiksa et al. 2014). Therefore, strategies for improving farmer's knowledge in GHG emission should be aligned with the strategy for strengthening agricultural extension institutions.

CONCLUSIONS

Considering limitations in the availability of highly productive arable land, development and optimization of suboptimal or marginal land for food production is an option. Rice farming for degraded peatlands management in Central Kalimantan could be improved by proper management of land and environments. Farmers' understanding of GHG emission is important since peatlands are fragile ecosystems that can be damaged by improper management. Increasing farmers' knowledge is also intended to improve their profit in the farming system. Dynamic modeling was used to determine prospect of rice farming for degraded peatland management focused on reducing GHG emission and increasing food production. Overall, rice farming has potential for reducing CO_2 emission on degraded peatland as well as increasing rice production in Central Kalimantan province.

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SUSTAINABILITY INDEX AND STATUS OF PADDY RICE FARMING TECHNOLOGY IN SIAK REGENCY, RIAU PROVINCE, INDONESIA

Rachmiwati Yusuf, Indra Fuadi, Ida Nur Istina, and Masganti

INTRODUCTION

Paddy fields have a great significance in efforts to maintain food independence, as overtime of growing populations and economic demands have begun to disturb the existence of agricultural lands. One serious issue related to farmlands today is land degradation, which causes declines in production and land productivity as well as increasingly widespread land-use changes to other purposes (Armanto 2005; Armanto et al. 2007; Lemhanas 2013). As stated by Saragih (2003), the main challenge of agricultural development in Indonesia is the rising disinclination of farmers to grow food commodities, including rice, especially to challenge with low productivity and competitiveness of those cultivated crops. The low productivity of rice in Indonesia is mainly due to limited harvest yields and areas, insufficient capacity of irrigation for water supply, the utilization of varieties with low productivity, suboptimal fertilization, inadequate planting systems, and high yield losses.

All of these factors have contributed to rice production decreases of up to 70% (Irawan et al. 2003).

Decreasing in paddy rice harvest areas is predominantly influenced by climatic anomalies and conversions of farmlands to non-agricultural lands (Irawan et al. 2001). While, The lack of rice harvest areas is prompted by restricted farm power caused by a shortage of funds, labor and agricultural machinery, short supplies of quality seeds due to their late arrival, incompatible varieties and nursery failures, attacks of disturbing plant organisms as a result of suboptimal control, natural disasters such as floods or droughts due to extreme climate changes, and unused lands (Wayan 2005; Haryono 2013; Masganti et al. 2014). Besides, farmers do not apply the recommended technology, although they are aware that the technology is profitable (Adnyana and Suhaeti 2000). Another contributing factor is the degraded fertility of paddy fields, which is mainly caused by subsiding organic content in the soil and the absence of nitrogen-fixing microorganisms, aside from uneven macronutrients and micronutrients in the soil. All of them are triggered by excessive usage of chemical fertilizers (Setyorini 2004).

The Indonesian Ministry of Agriculture (2016) reported that the national average productivity of paddy rice in 2015 was 5.450 ton/ha with a range of 2.650–6.210 ton/ha. The average rice productivity in Riau was 4.007 ton/ha ranging 2.667–5.457 ton/ha. Of twelve cities and regencies in Riau Province, Siak Regency had the highest average rice productivity of 5.457 ton/ha with a range of 4.363–6.096 ton/ha, which is similar to the national average in Indonesia (Distanak Riau 2016).

Rice farming in Siak Regency has enormous potential for development, bearing in mind the availability of potential lands for new production centers and the support of government programs to increase production and the willingness of farmers to produce more rice (Masganti 2013; Sarlan 2014; Ritung et al. 2015). Rice extensification in Pusako, Kandis, Tualang, Koto Gasip, and Mempura Subdistricts, and rice intensification in Bunga Raya, Sungai Apit, Sabak Auh and Sungai Mandau Subdistricts, could be encouraged for food security in the regions. However, efforts to boost rice production by elevating productivity are hampered by inadequate technology and infrastructure, the achievement of the maximum potential yields of varieties, land quality decrease by degradation, increasingly limited water resources, climate variability, and escalating plant disturbing organisms attacks. This phenomenone would weaken food security in Siak Regency. Considering the vital role of existing paddy fields in the rice production centers of the four subdistricts to meet demands for rice in Siak Regency, analysis on the dimension of current sustainable technology is required to raise sustainable rice production and high productivity for the future.

The sustainability index of paddy rice technology and its influencing factors need to be determined to evaluate sustainability to solve the problem on paddy rice farming in Siak Regency. This study aimed to analyze the sustainability index and status of the technology dimension of paddy rice farming and the role of its attributes to its management for future development of rice farming in Siak Regency.

APPROACH TO ASSESS RICE FARMING TECHNOLOGIES IN SIAK REGENCY

The data in this study are classified into primary and secondary data. Primary data were obtained from field observations, and in-depth interviews with 203 farmers and 20 stakeholders in Siak Regency in four paddy rice center subdistricts, namely Bunga Raya, Sabak Auh, Sungai Apit and Sungai Mandau Subdistricts. The informers were chosen by purposive sampling, and the stakeholders were identified using snowball sampling, which stakeholders recommend other stakeholders as respondents (Wildemuth 2009). The analysis was determined using Slovin's equation (Ryan 2013) with an error margin of 7%. Secondary data were collected from documents published by the government of Siak Regency, the Agriculture Agency of Siak and the Statistics Indonesia office of Siak Regency as presented as subdistrict profiles, monographs, agricultural census books, research reports and other documents concerning legislations, primary duties and functions, and strategic management plans held by every related agency.

The sustainability index of rice could be evaluated by using a Rap-Rice approach with multidimensional scaling (MDS) sustainability status of the paddy rice technology dimension. This method is adapted from the Rapid Appraisal for Fisheries (Rapfish) program developed by the Fisheries Centre of the University of British Columbia (Kavanagh 2001; Fisheries Centre 2002; Fauzi and Anna 2005). MDS is a statistical analysis technique that transforms every dimension and multidimensional sustainability of paddy rice farming (Rao and Rogers 2006). According to Nurmalina (2008), MDS maps two similar points or objects into points in immediate proximity, whereas differing objects or aspects are depicted as distant points. The similarities and dissimilarities between objects could be measured from a distance between dots illustrated in the model (Kavanagh 2001).

Rap-Rice ordination analysis is performed through the stages of (1) setting attributes, (2) scoring every quality in an ordinal scale, (3) Rap-Rice ordination analysis to establish ordination and stress value by the ALSCAL algorithm, (4) rotating to position of the sustainability index and status of rice farming management, and (5) conducting sensitivity analysis (leverage analysis) and Monte Carlo analysis. Sustainability indicators are used to provide direct or indirect information on the future viability of a system on various purpose levels, where usage is deemed essential in informing the planning and development of the next operation. Stress value of <25% is acceptable.

Determination of the sustainability index of paddy rice farming follows set Rapfish systematics. As stated by Nababan et al. (2017), sustainability index and status are identified through 1) studying the attributes of each dimension of sustainability and assessing them according to actual data from field observations, interviews with experts, and literature reviews, 2) scoring those attributes and analyzing them on Microsoft Excel using templates prepared in advance to obtain a value known as the sustainability index, 3) categorizing the sustainability index according to sustainability intervals to determine the sustainability status. The ranges of sustainability scores for each dimension are as follows: poor (0.00–25.00), inadequate (25.01–50.00), adequate (50.01–75.00), and good (75.01–100.00). Other outcomes of MDS analysis are leverage factors, which are strategic factors for future paddy rice management (Pitcher and Preikshot 2001).

SUSTAINABILITY INDEX OF PADDY RICE TECHNOLOGY IN SIAK REGENCY

The sustainability index of the dimension of paddy rice technology in the Siak Regency is established based on data collected with score of each attribute obtained from field assay and interviews with farmers in Siak Regency. Attributes with sensitivity to the sustainability status of paddy rice farming management in terms of technology are identified using leverage analysis. The score of technology dimension is affected by the availability of tilling equipment, planting tools, combine harvesters, and post-harvest machines, as well as a planting index, rice varieties, fertilizer types, pests and diseases control tools, and accessibility to water pump engines (Table 1).

All subdistricts generally still lack farming machinery. Farmers have anticipated this limitation with more workhours for the use of those machines and performing tillage, cultivation, and harvesting manually of rice. The tilling and harvesting

Table 1. Scores of technology dimension and attributes of sustainability of paddy rice farming management in four subdistricts of Siak Regency.

Attribute	Status		Note	Score			
	Good	Bad		BR	Sau	SAp	SM
Availability of tilling equipment	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	1	1	1	1
Availability of planting tools	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	1	1	1	1
Availability of combine harvesters	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	2	1	1	1
Availability of post-harvest machines	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	2	1	1	1
Rice planting index	3	0	(0) 100 (1) 200 (2) 250 (3) 300	2	1	1	1
Variety used	2	0	(0) Local seed (1) Uncertified superior (2) Certified superior	1	1	1	1
Fertilizer type	2	0	(0) Inorganic (1) Organic (2) Organic-inorganic combination	2	2	2	2
Availability of OPT control tools and materials	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	2	1	1	1
Availability of water pump engines	2	0	(0) Not available (1) Available but insufficient (2) Available and sufficient	1	1	1	1

Note. BR = Bunga Raya, SAu = Sabak Auh, SAp = Sungai Apit, SM = Sungai Mandau.

instruments is compensated by using hoes and sickles, respectively. Clearly, agricultural machinery is now highly needed to increase rice productivity. The contribution of mechanization in the region of study, particularly Bunga Raya, is marked by the rising need for the workforce in tillage. Furthermore, the cultivation of superior rice varieties requires planting date uniformity in one area in order to control pests attack. This kind of method could disrupt the life cycle of pest. In addition, augmenting the work volume, shortening the time for tillage, and increasing the number of workers could help reduce the workload on rice cultivation without advance machinery. Each rice farming subsystem necessitates the contribution of agricultural equipments and machines as technical input to enhance the productivity and efficient resources as well as the quality and added value of the farming output.

The application of farming machinery is expected to be one way to overcome problems emerging from the paucity of human resources in the agricultural production process. By utilizing tools and engines appropriate for field conditions, the planting and production indices expectedly improve due to paddy rice low yield losses. As a response to the issue of increasingly limited and costly farmworkers in the study site, agricultural machines are applied to elevate land and labor productivity, to be more effective, and low costs for farming. Notable, one plausible means to raise farming productivity is the development of agricultural and post-harvest mechanization (Effendi et al. 2014). Moreover, rice field tillage by hand tractor allows to be more efficient with the most significant cost difference in employment, which practically accounts for 30% of the total expenditure for manual farming (Amrullah and Sholih 2016).

SUSTAINABILITY STATUS OF PADDY RICE TECHNOLOGY IN SIAK REGENCY

MDS analysis provides sustainability indexes for the technology dimension of 56.70% in Bunga Raya Subdistrict, 53.90% in Sungai Apit, and 51.40% in Sabak Auh and Sungai Mandau, which of all of them imply adequate sustainability for having a value of >50% (Figure 1). To optimize the sustainability of paddy rice farming, the advancement of technology ought to escalate, as technology is an absolute prerequisite for today's agricultural development. This study demonstrates that farmers will quickly embrace technology if its implementation gives economic profits, aligns with the local cultural and physical environment, is easy to carry out, saves labor and time, and does not require high costs.

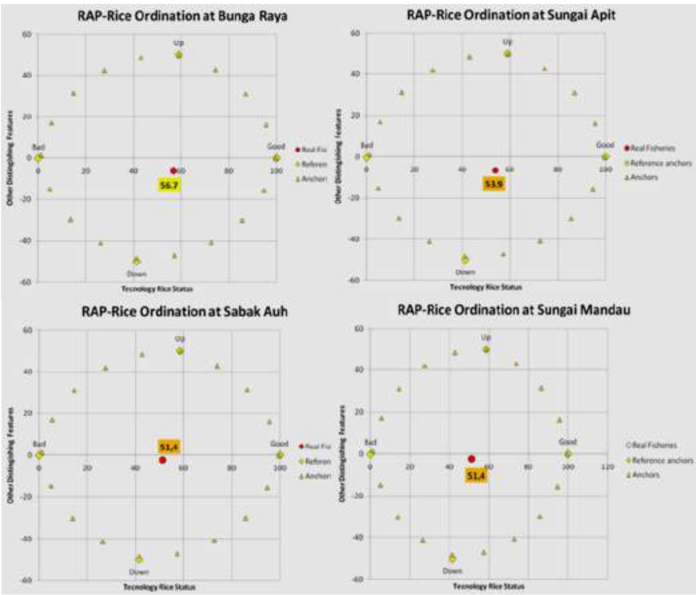

Figure 1. Sustainability index of technology dimension in four subdistricts of Siak Regency.

Figure 1 describes that technology has bolstered paddy rice management in Siak Regency. As delineated by Martina (2017), technology encompasses all methods which rationally aim to provide features of efficiency in every domain of human activities. The technique incorporates the development and application of instruments, machines, materials, and processes that help humankind solve their problems and represent processes that promote the value-added of products, including fertilizers, varieties, farming machinery, cultivation, and institutions. Haryanto et al. (2015) stated that new technology in rice cultivation substitutes or supplements the existing technology, which is why it hardly occurs that new technology entirely replaces a predecessor adaptive to specific agroecology. Therefore, the latest technology has to be compatible with components of the preceding technology.

The implementation of various components of technology calls for decent management to apply the technique correctly, accurately, effectively and profitably, so that the objective of optimal production growth by conservation of agricultural resources is attainable within a sustainable farming system. The Rap-Rice analysis also provides leverage of attributes as an output (Figure 2). The fertilizer type attribute demonstrates high sensitivity in all subdistricts. The characteristic of rice plant disturbing organisms control materials is only sensitive in two subdistricts, namely Bunga Raya and Sungai Apit. At the same time, the planting index (IP) attribute is sensitive in Sabak Auh, Sungai Apit, and Sungai Mandau Subdistricts. Comprehensive and balanced administration of fertilizers mainly affects the growth and yield of rice plants since it provides and restores nutrients that have been either washed away or carried away during harvest.

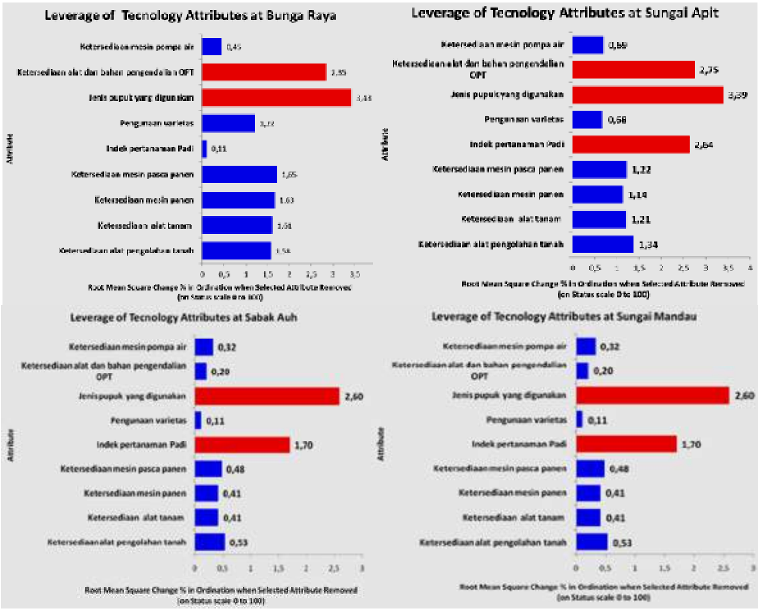

Figure 2. Rice attribute of technology dimension in four subdistricts of Siak Regency expressed in root mean square (RMS).

The use of organic fertilizers improves water-holding capacity, enriches the soil, allows roots to penetrate the ground more quickly, supplies food for microorganisms that decompose organic substances in the land, and augments the percentage of full grains (Rochmah and Sugiyanta 2010). Similarly, Ramadhan (2014) and Dalimunte et al. (2017) state that organic and inorganic fertilizers enhances the agronomic effectiveness of rice plants compared to the sole usage of mineral fertilizers. The appropriate and balanced combination of fertilizers used on the plants would cut down fertilizing costs.

Research findings indicate that farmers typically plant and harvest rice twice a year, except those in Bunga Raya Subdistrict, who do so five times in two years on average (IP 250). Rice IP can be extended from 200 to 300 by planting early-ripening superior varieties (VUSG) aged 90–104 days and using hand tractors to till to expedite tillage time. The rice varieties cultivated by farmers to date are improved varieties with days to maturity of 105–124 days, such as Logawa, Ciherang, Inpari 30, and Inpago 9. In contrast, one variety with early maturity is Dodokan or Silugonggo. This rice variety might be utilized as an alternative to upgrading rice IP as it is preferable by consumers in Siak Regency.

Tillage in Siak Regency is commonly conducted in an interval of two to four weeks, a duration attributed to the restricted number of hand tractors and farmers' habit of tilling perfectly. This relatively long period does not help for better IP since the time needed for simple soil tillage to gain an IP of 300 is at most one week. Hence, the adequacy of equipment, such as tractors, or workers for soil tillage must be taken into account. The lack of tractors can be tackled by collective capital procurement.

Interviews and field observations reveal that irrigation, the seed/variety, pests, and technology strongly impact on IP growth in Siak Regency. This means that if irrigation is expanded and the necessary technology and superior seeds are available in the field, IP will go up, but if pests thrive then, IP will drop. The planting index is greatly influenced by factors of year-round water supply, pests, seeds, technology, and price (Prabandari et al. 2013; Anggraini et al. 2015).

STRESS VALUE, COEFFICIENT OF DETERMINATION AND INFLUENCE OF ERROR IN TECHNOLOGY DIMENSION

The coefficient (R^2) of the dimension capacity of each attribute could determine the sustainability of the reviewed system presented in Table 2.

Table 2. Stress value, coefficient of determination, and influence of error in technology dimension.

Subdistrict	Sustainability Index (MDS)	Stress	R^2	Monte Carlo Analysis*	Difference (MDS-MC)
Bunga Raya	56.70	0.15	0.95	56.00	0.70
Sabak Auh	51.40	0.15	0.94	51.20	0.20
Sungai Apit	53.90	0.15	0.95	53.50	0.40
Subdistrict	Sustainability Index (MDS)	Stress	R^2	Monte Carlo Analysis*	Difference (MDS-MC)
Sungai Mandau	51.40	0.15	0.94	51.30	0.10

Note. An index of 25.01–50.00 is categorized as less sustainable. An index of 50.01–75.00 is categorized as fairly sustainable. Stress value of <0.25 signifies goodness of fit. R^2 >80% or approaching 100% signifies excellent contribution.
*Error at 95% confidence level.

Table 2 clarifies that the stress value of the four subdistricts is 0.15, and the R^2 lies between 0.94 and 0.95. In Rapfish, a stress value is seen as useful if it falls below 0.25. Kavanagh (2001) states that a sustainable stress value is <20%, suggesting that this model is highly acceptable, with a 15% stress value. The goodness of fit test also shows that an ecological sustainability index estimation model is practicable with a squared correlation value (R^2) of 0.94–0.95 or nearing 1. The closer the R-square value to 1, the more perfectly data mapped. This score illustrates that 94–95% of the model can be well construed while the remaining 4–5% is ascribed to other factors. Kavanagh (2001) mentions that an R^2 greater than 80% indicates that the sustainability index estimation model is excellent and viable to use.

There is no significant different between MDS indices and outcomes of Monte Carlo analysis, both in distribution and influence of error at 95% confidence. It can thus be ensured that scoring errors, score variation, the stability of repeated MDS analysis, and faults or loss of data input do not pose any meaningful effect. Kavanagh and Pitcher (2004) assert that Monte

Carlo's report may be employed as a simulation to evaluate the impact of random errors in statistical analysis.

Outcomes of the Rap-Rice analysis are justifiable since validation test outputs show gaps between technology sustainability index and Monte Carlo scores ranging from 0.10 to 0.70, which are minor differences of less than 5. These values imply that the influence of scoring errors is rather small, thereby confirming the Rap-Rice model for paddy rice management as a feasible sustainability index predictor. As stressed by Kavanagh and Pitcher (2004), if the gap between the results of Rap and Monte Carlo analyses is >5, they are considered impractical for the estimation of the sustainability index.

CONCLUSIONS

The current sustainability index and status of paddy rice farming management in Siak Regency in terms of technology are reasonably sustainable (>50%) for all subdistricts (56.70% in Bunga Raya, 51.40% in Sabak Auh, 53.90% in Sungai Apit and 51.40% in Sungai Mandau). The average stress value of the technology dimension in all subdistricts is 0.15, and the R^2 values varied from 0.94 to 0.95. The technology dimension model is acceptable because the obtained stress value is lower than 20%, and the assessed attributes on each dimension are accountable for and contribute to 94–95% of the examined sustainability system. MDS and Monte Carlo sustainability indices within a 95% confidence interval hold discrepancies of 0.10 to 0.70, denoting insignificant differences (<5), which substantiate that the analysis results reliably predict the sustainability index. These study results suggested that the rice farming technology accompanied with the suitable management is reasonable to be applied in some districts in Siak Regency for rice production.

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BIOFERTILIZER FOR IMPROVING THE FERTILITY OF ACID SULFATE SOIL ON THE RICE CULTIVATION

Yuli Lestari and Mukhlis

INTRODUCTION

Being as a staple food of most Indonesians, rice demand in Indonesia is higher because of the increasing population. In the tropics, the area of acid sulfate soil in Indonesia is quite extensive, approximately 6.1 million ha, and plays an essential role in national rice production. Additionally, the availability of sufficient water throughout the year contributes to the success of rice cultivation specialized in acid soil, in particular overflows A and B. Acid sulfate soil of type A is the land that gets large and small tides overflow. In contrast, acid sulfate soil that only gets significant tidal overflowed is called type B. Both acid soil types are found in Indonesia.

Utilization of acid sulfate soil for agricultural development, however, encountered various problems due to extreme chemical characteristics and fragile ecosystems. The mains problems of rice cultivation in acid sulfate soil are acidity associated with aluminum, iron, and hydrogen sulfide toxicity and phosphate deficiency. In 3–4 weeks after planting of rice plants, symptoms of Al toxicity occur when the concentration reaches 35 mg/l (Suastika et al. 2014). Aluminum toxicity can reduce rice yield by about 30–40%. At high levels of Al, the root of the surface was ruptured and lead to cell collapse (Panhwar et al. 2016). The stunt root growth caused by nutrient uptake could be inhibited, allowing to reduce the growth and yield.

Another nutritional disorder that limits rice yield in acid sulfate soil is iron toxicity. According Sahrawat (2006), iron toxicity reduces rice yield by 12–100%. Iron toxicity occurs in flooded land with pH below 5.8 and under 6.5 when aerobic and anaerobic, respectively. In addition to flooded conditions and soil pH, iron toxicity is related to a high concentration of iron in soil solution, oxidation-reduction potential, tolerance of rice, uptake of iron by plants, plant growth phase, and another nutritional status in soil (Frageria et al. 2008). High organic matter in this acid soil, rice plants often exist H_2S toxicity as a result of sulfate reduction. The rice plant in the H_2S toxicity will be susceptible to plant diseases (Suastika et al. 2014), such as a stunted plant with black root rooting and yellowish foliage (Wamishe et al. 2018) and reduce nutrient uptake (IRRI 2000).

The success of rice cultivation in acid sulfate soils is also limited by the low availability of P and uptake by plants because of the high P-fixation capacity of the soil due to the presence of a high concentration of Al and Fe (Suwanto et al. 2007). Lack of available-P in the soil would cause stunted growth, reduced tilling, and reduction of the panicle. Thus, it is essential to maintain the P level which could be represented by available P about 7–20 ppm to support optimal rice production.

To face problems commonly exist in the acid soil, the use of appropriate management technology can hopefully improve soil fertility and optimize rice production in this soil. One of these technologies is the use of biofertilizers. The advantage of biofertilizers to improve soil fertility are eco-friendly approach, low cost and efficient, nutrient uptake, maintaining soil health, remediate land degradation, and increase plant growth and yield. This review aims to explain an effort of how biofertilizer can be used to improve the fertility of acid sulfate soil to increase rice production.

THE STATUS OF ACID SULFATE SOIL FERTILITY

Soil fertility is closely related to the chemical, physical and biological properties of the soil. One of the chemical properties of soil that determines soil fertility is its acidity (pH). Generally, acid sulfate soil pH has a low influence on agricultural development. Reclamation of tidal swampland mainly on the acid sulfate soil by canals construction cause a decrease in the groundwater level below the pyrite layer. This causes pyrite to be exposed to oxygen and oxidized. Pyrite oxidation resulted in high acidity in water and soil. As reported by Anda and Siswanto (2002), the reclamation has been done for rice cultivation in the backswamp in Dadahup and Palingkau, Central Kalimantan. After three years, the network canals construction affects the soil pH to be more acidic. The soil pH before reclamation is about 4.5–6.5 but declines to 3.5–4.5 after reclamation. The acid sulfate soils in Kelantan Plain (Malaysia) that have been reclaimed since 1982 also show acid reactions (pH 3.9–4.9) (Suswanto et al. 2007).

The amount and composition of water-soluble ion largely influence soil fertility and productivity. Acid sulfate soil becomes infertile due to a high concentration of acid sulfate (Shamsuddin et al. 2017), and Al^{3+}, Fe^{2+}, H_2S, and low available-P (Suastika et al. 2014). According to Shamshuddin and Auxtero (1991), the low pH (<3.5) promote the weathering of clay mineral and released large amounts of Al and/or Fe. The reaction of clay mineral weathering is (Maas 1989):

$$\text{Silicate} + H^+ \rightarrow Si(OH)_4 + Al^{3+} + Mg^{2+} + Ca^{2+} + Na^+ + K^+ + Fe^{2+} + Fe^{3+}$$

During the weathering process of clay minerals, the presence of Al and Fe^{2+} in the soil solution also comes from the hydrolysis of Al-hydroxide and iron-oxides, respectively. On the other hand, hydrolysis of Al hydroxide is at pH <5 and the pKa of Al is 5. At pH below 5, Al in the water is $Al^{3+,}$ which is toxic to plants. The results of the study show that soil pH is negatively correlated with aluminum/iron concentration (Figure 1).

In acid sulfate soil, drying and reflooding increased the amount of iron in soil solution and acidity (Sahrawat 1979). Drying causes pyrite minerals to be oxidized and produces Fe^{2+} that can make them to be dissolved when reflooding due to high concentrations of Fe. Sahrawat (1979) reported that the water regime influenced iron concentration in acid sulfate soil. The iron concentration at drying treatment was folded ten times (585 ppm), higher than in the continuous waterflood (50 ppm). Fe^{2+} concentration in experimental field station of Belandean reached 444–445 mg/kg. Notable, compounds affecting iron concentration in acid soil solutions other than FeS_2 are $Fe(OH)_2$ and $FeCO_3$.

Available–P was controlled by soil pH, Fe, and Al (Figure 2). Mustafa and Sammut (2007) reported the increase of soil pH, which causes a significant increase in available-P. Moreover, the soil available-P had a very substantial negative correlation (P=0.007) with the soil Fe and a significant negative correlation

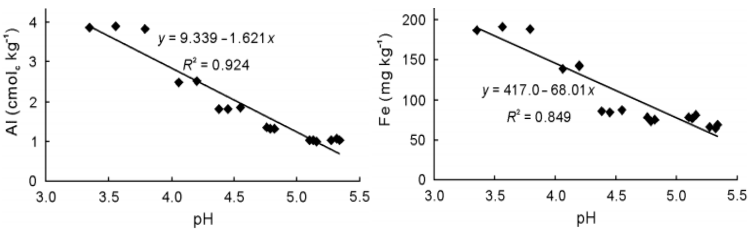

Figure 1. Relationship between soil pH and Al and Fe concentration (Panhwar et al. 2015).

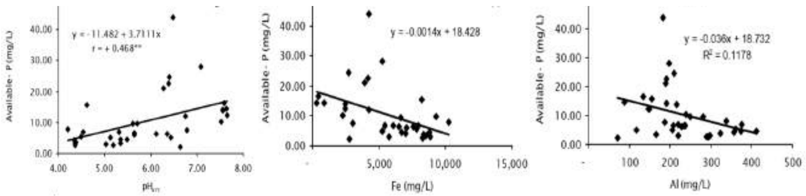

Figure 2. Relationship between soil available-P with pH, iron (Fe) and aluminium (Al) in acid sulphate soil.

(P=0.040) with the soil Al. This suggests that available-P would increase very significantly with a decrease in the Fe concentration while available-P would dramatically increase with the reduction of soil Al.

Available–P was controlled by soil pH, Fe, and Al (Figure 2). Mustafa and Sammut (2007) reported the increase of soil pH, which causes a significant increase in available-P. Moreover, the soil available-P had a very substantial negative correlation (P=0.007) with the soil Fe and a significant negative correlation (P=0.040) with the soil Al. This suggests that available-P would increase very significantly with a decrease in the Fe concentration while available-P would dramatically increase with the reduction of soil Al.

The availability of P in acid sulfate soils ranges from very low to high. The P content available in acid sulfate fields in Karang Bunga Village (South Kalimantan) and Sidomulyo Village (East Kalimantan) are found 6.7 ppm and 5.7 ppm respectively and are classified as very low (Mukhlis 2012). The level of P in acid sulfate soil type B overflows in Sungai Solok Village, Kuala Lumpur District, Palalawan Regency, Riau was 7.8 ppm and is classified as low (Masganti et al. 2017). On the other hand, soil P is identified to be moderate (14–17.3 ppm) in type B of acid soil in Belandean Experiment Station, Barito Kuala Regency, South Kalimantan (Fahmi et al. 2009).

BIOFERTILIZER

Biofertilizer was used a long time ago in rice cultivation. Biofertilizer usually contains one or more living species of microorganism mixture of biodegradable substances to improve fertility and productivity of soil and plants. Biofertilizer applied to seed, plant surface or soil will colonize the rhizosphere, interior part of the plant and promote plant growth by increasing the supply or availability nutrient to the plant (Itelima et al. 2018).

Microorganisms contribute directly and indirectly to soil fertility through their activities. Some types of microbes potentially as biofertilizers, can increase the productivity of acid sulfate soils in rice cultivation. Biofertilizer formula usually only contains one type of microbial, but at present, a biofertilizer could contain multifunction microbes. A multistrand biofertilizer with different functions has more efficacy than a single strain (Naher et al. 2015). A multifunction biofertilizer might contain a mixer of decomposer, nitrogen-fixer, phosphate solubilizer, and growth-promoter microbes. Several bacteria have been identified their potency, especially nitrogen-fixing bacteria such as *Azospirillum, Azotobacter* and *Rhizobium*, and Phosphate solubilizing microorganisms (*Bacillus, Pseudomonas, Burkholderia, Aspergillus, Penicillium*). Fungi such as *Trichoderma, Aspergillus and Penicillium,* and bacteria *like Corynebacterium* dan *Aeromonas* are well known for their role in the decomposition of organic matter.

APPLICATION OF BIOFERTILIZER ON THE RICE CULTIVATION

Rice cultivation in acid sulfate soil is subjected to aluminum toxicity. The effect of aluminum toxicity can be reduced by microbial biofertilizers such as *Stenotrophomonas, Bacillus,* and

Burkholderia. The concentration of exchangeable Al and weakly-bound Al due to the application of biofertilizer with or without basalt and ground magnesium limestone (GML) is lower than control. In contrast, strongly-bound Al will be higher than the control. The lowest of exchangeable Al and weakly-bound Al was obtained from the treatment of Bio fertilizer+GML. Application of Bio fertilize+GML resulted in the highest of strongly-bound Al. These results suggest that the use of biofertilizer decrease the exchangeable Al and weakly-bound Al in contrast to the strongly-bound Al, which will increase (Table 1). The main mechanisms involved would release organic acid that chelate Al (Panhwar 2015).

Application of Biotara (Biofertilizer) increases total N, available P, exchangeable K, Ca, and Mg (Table 2). Increasing nutrient content occurs due to *Trichoderma* sp, which can decompose organic residue (rice straw and weed) to be available for plants. Nitrogen-fixing bacteria have the capability to N fixation by non-symbiotic, whereas phosphate solubilizing bacteria dissolves P-insoluble to soluble-P (Mukhlis and Saleh 2014). All of these bioprospecting microbes are important to increase rice yield.

Table 1. The effect of biofertilizer, basalt, ground magnesium limestone (GML), and the combination to exchangeable Al weakly-bound Al and strongly-bound Al in acid sulfate soil.

Treatment	Exchangeable Al	Weakly-bound Al	Strongly-bound Al
		(Cmol.kg^{-1})	
Control	2.09a	3.04a	4.78f
Biofertilizer	0.11b	2.03b	11.69a
GML	0.03d	1.13f	7.23d
Basalt	0.07d	1.65c	9.02b
Biofertilize + GML	0.01e	1.34e	6.34e
Biofertilizer + Basalt	0.04d	1.42d	8.53c

Source: Panhwar et al. (2015).

Table 2. Changes in chemical properties of acid sulfate soils collected from experimental station Belandean because of biofertilizer application.

Treatment	Total N (%)	Available P (mg.kg-1)	Exchangeable cation (cmol.kg-1)		
			K	Ca	Mg
Biotara+NPK 400 kg+straw/in situ weed 5 ton/ha	0.28a	62.17a	0.69a	5.32a	4.62a
NPK 600 kg+straw/gulma in situ 5 ton/ha	0.27a	59.76a	0.69a	5.11a	4.62a
Urea 124 kg/ha-1+SP-36;17 kg/ha	0.20b	41.23b	0.46b	4.73b	4.11b

Source: Mukhlis and Saleh (2014).

The application of biofertilizer with or without basalt or GML increase the rice yield significantly, as demonstrated by the highest rice yield produced by the combination of biofertilizer with GML. GML caused a reduction of Al, increased soil pH, thus need to supply more Ca and Mg for rice plant growth. The application of biofertilizer containing phosphate solubilizing and N-fixing bacteria increased the availability of P and N. Organic acids secreted by microbes in biofertilizers can also chelate aluminum in the soil. Biofertilizer and GML, or a single application of one of them, can fertility in acid sulfate soil, allowing increased rice yield as presented in Figure 1 (Panhar 2015).

In good agreement with this study, a previous study reported the positive effect of biofertilizer on rice growth and yield in acid sulfate soils. The biofertilizer has increased plant height, the number of tillers, grain yield, and straw yield of rice. A mixed application of P (75%), K + biofertilizer 5 ton/ha and N, P (50%), K + biofertilizer 10 ton/ha produced higher rice yield than its single components. Interestingly, the highest plant height, number of tillers, grain yield, and straw yield were generated at the treatment of N, P (50%), and K + biofertilizer 10 ton/ha (Table 3). This study clearly showed that biofertilizer could reduce the dosage of N and P fertilizer to 50% (Naher et al. 2016).

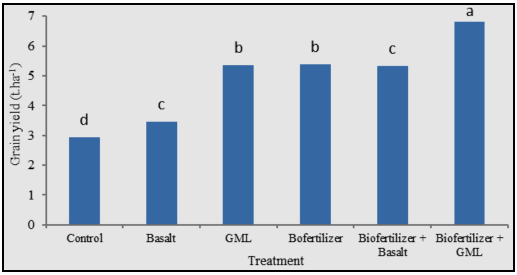

Figure 2. Effect of basalt, GML, with or without biofertilizer to rice grain yield in acid sulfate soil (Mustafa and Samut 2007).

Table 3. Agronomical characters of rice applied with fertilizer in the acid sulfate soil, Kelantan Plain Malaysia.

Treatment	Plant height (cm)	Number of tillers plant-1	Grain yield (t. ha-1)	Straw yield (t. ha-1)
Control (without fertilizer)	76.33c	14.13d	2.89d	6.79d
N, P, K (full rate)	93.31b	25.51c	5.48c	10.85c
N, P (75%), K + biofertilizer 5 t. ha-1	96.62a	27.81b	6.54b	12.82b
N, P (50%), K + biofertilizer 10 t. ha-1	97.45a	29.36a	7.26a	13.96a

Source: Naher et al. (2016).
Note: N-P-K (full rate) = 120–30–60 kg. ha^{-1}

CONCLUSIONS

Rice grown in acid soils generally has low productivity due to lack of supporting technologies. In acidic conditions, the activity of Al^{3+} and Fe^{2+} increases and causes the growth of rice roots is retarded. Biofertilizer ameliorant can be used to increase the fertility of acid sulfate soils is biofertilizer. Application of biofertilizer increase soil fertility as a result of increasing soil pH reduced exchangeable Al, and weakly bound-Al. In increased Al, on the contrary, Fe and Al toxicity decrease. Decreasing of Al and Fe toxicity, as well as the acidity, can be enhanced by soil fertility, nutrient availability, and uptake. In addition, microorganism as biological fertilizer element produces plant growth promotion substances that can increase plant growth and yield.

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INCREASING RICE PRODUCTIVITY USING TECHNOLOGY PACKAGE OF "JAJAR LEGOWO SUPER" IN TIDAL SWAMP AREAS OF SOUTH KALIMANTAN

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INTRODUCTION

Swampland is one of the potential agro-ecologies for agricultural development. The area of swamps in Indonesia is estimated at 33.4 million hectares, consisting of 20.12 million hectares of tidal land and 13.28 million hectares of *lebak bog* farm (freshwater), and as much as 9.53 million hectares suitable for agricultural cultivation activities (Nugroho et al. 1993; Susilawati et al. 2017).

A swampland is defined as an area alongside a coastal, river, lake, or swampy regions that protrude into the seafront to about 100 km or as far as the tidal movement felt. Thus, swamps are lands that are affected by tides or rivers around them. In Indonesia, swamplands are divided into peat swamps, tidal swamplands, and *lebak bog* (freshwater) (Noor 2004). Tidal swamps are defined as swamp areas that get a direct or indirect influence of the tidal flow of the surrounding sea or river. In contrast, the swampy marsh is a swamp area that experiences inundation for more than three months with the lowest inundation height of 24–50 cm (Noor 2007).

The potential distribution of swamps in South Kalimantan starting from the widest is tidal swamps around 1,032,184 ha (49.08%), peat swamps around 800,257 ha (38.05%) and 270,547 ha of tidal swamps (12.87%) (Hatmoko et al. 2007). One of the centers of rice production in South Kalimantan Province is Barito Kuala Regency, which has the broadest tidal land, accounting about 287,922 ha (96.07%) and approximately 95,869 ha could be used for rice farming (ISARI 2014). In this area, rice production increased by an average of 330,687 tons of dry grain, which contributed around 17.83% to rice production in South Kalimantan.

The development of tidal swamp farming is one of the efforts in responding to the challenges of increasing agricultural production. With proper management through the application of appropriate technological innovations, tidal swamps have a good prospect of being developed into productive land (Arsyad et al. 2014). To support the development of agriculture in swamps, technological innovation is needed. Indonesian Agency for Agricultural Research and Development (IAARD) has produced a variety of technological innovation products to increase productivity and farm income. The innovative products include newly improved rice varieties, *jajar legowo* planting system, bio-decomposer capable of accelerating straw composting, biological fertilizers and balanced fertilization, biological pesticides, and machine tools agriculture (IAARD 2016). This review paper describes the information to increase the production of new superior rice varieties (VUB) using technology package “Jajar Legowo Super” in South Kalimantan.

TIDAL SWAMP AREAS

Based on the type of soil and development constraints, tidal swamps are divided into four land typologies, namely peatland, acid sulfate, saline, and potential. According to the high and low tide overflows of the sea/river in general, tidal swampland can be divided into four types of overflow, namely types A, B, C, and D. Arrangement of land with overflow type A and B is generally indicated by submerged in water, while type C is usually arranged with a *surjan* system. The system is made to the depth of pyrite in type A and B, which are possible to be shallow, whereas C overflow is more than 100 cm dept from the ground surface (Noor 2004; Kusumowarno 2014).

The main characteristics of tidal swamps that determine the success of rice farming include content and depth of pyrite, maturity and thickness of peat and salinity. Common problems often arisen in rice farming in the tidal swamps are exposure of pyrite layers located at shallow depth (<50 cm) containing pyrite (FeS_2) because the pyrite is stable under anaerobic conditions. However, pyrite is easily oxidized with H^+ ion layers and sulfuric acid, thereby creating very high soil acidity. Because the pyrite compound is in the lower layer, the effort to maintain the water level at the limit above the pyrite layer is the key to the success of rice farming. The acidification of the soil is followed by an increase in the excess solubility of Al, Fe and Mn, causing poisoning which can be a factor in inhibiting the growth and development of rice plants (Nugraha and Rumanti 2017). Pyrite can also be oxidized in the long dry season which causes a layer of soil to break or crack and to overcome these cracks by applying agricultural lime ($CaCO_3$) (Kusumowarno 2014).

RICE CULTIVATION IN THE TIDAL SWAMP AREA

The development of high yielding varieties in tidal swamps is still unsatisfactory to support national production including to maximise the utilization of local rice varieties. With the benefit of better condition land at present, agricultural technology continues to develop many superior varieties adaptive for swamps such as IR64, Kapuas, Margasari, Sei. Lalan, Sei Lilin, Lematang, Dodokan, Mekongga, and many others. The IAARD has released many improved varieties for swamps, including eight varieties from Inpara 1 to Inpara 8 Agritan.

Factors influencing the selection of rice varieties on tidal land are high yield potential, tolerance to abiotic stress, market demand, preferences, plant age, plant height, and pest and disease resistance (Khairullah 2016). Assessment of plant performance with supporting factors must be considered, namely the availability of nutrients in the soil, land suitability for rice plants, and the availability of sufficient water to assist the plant development as expected. However, a number of problems affect reduced rice yield. Common factors causing unsuccessful cultivation of superior rice varieties at present include: 1) unproper land preparation, such as a tractor allows e very deep of rice field soil where the pyrite ($FeSO_4$) in the lower layer could be lifted out which can increase the soil pH; 2) very high pest attacks like rat; and 3) less consideration of water system which allow excessive drainage to give a chance of pyrite oxidation which can be harmful to the plants.

JAJAR LEGOWO SUPER PACKAGE TECHNOLOGY INNOVATION

One of the breakthroughs to increase plant production is to optimize tidal land. The key to manage tidal land is the functioning of water channels. To provide a good place to grow rice plants, a technology of “jajar legowo super” (*jarwo super*) package cultivation is one of alternative. The word *legowo* comes from the words *lego* (leisure, wide, loose) and *dowo* (long) which means "lego tur dowo" or “wide and long”. *Legowo* row system includes new technology in tidal land which can provide better results due to side effects of the wider root range, temperature in stable plantations, more even beam exposure, and increased population. This system has several types, namely *legowo* type 2: 1, *legowo* 4: 1 or *legowo* 5: 1. For example, *legowo* 2: 1 system has a spacing of 20 cm x 20 cm, two rows in a row set with a distance of 10 cm in a row, and 20 cm between rows, then the distance between the first two rows with the second two rows is 2 folds of the spacing (40 cm), and some others in order to increase plant population. The spacing for *jarwo* 2:1 in rice cultivation is presented in Figure 1.

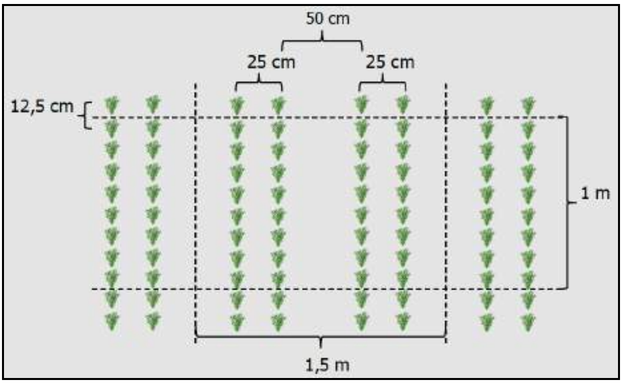

Figure 1. Planting distance of the *Jarwo* 2:1 system with plant spacing.

This *jajar legowo super* or *jarwo super* is an integrated cultivation technology based on the previous *legowo* row planting method. The implementation of this system is the use of 1) qualified seeds of newly improved varieties with high yield potential, 2) biodecomposers during soil processing, 3) biological fertilizers as seed treatment and balanced fertilization, 4) integrated pest control organisms techniques, and 5) agricultural machine tools for planting and harvesting (IAARD 2016). The main component for jarwo super applied in tidal swamplands in South Kalimantan is presented in Table 1.

The meaning of *jarwo super* could be explained as a technology of rice cultivation based on "jajar legowo" 2: 1. An important part of the *super legowo* series is the use of:

Table 1. The main component of technology package "Jajar Legowo Super" in tidal swamp areas, South Kalimantan.

Technology package "Jarwo Super"	Information
Land preparation	No tillage or minimum tillage
Newly improved varieties released by IAARD	Inpari 32, Inpara 2 dan Inpara 8
Planting method	*Jajar legowo* 2:1
Biodecomposer application (kg/ha)	M-Dec = 2–4
Biofertilizer (kg/ha)	Biotara = 50 Agrimeth = 0,5 Bioprotector
Nursery bed	Tray or paddy field
Inorganic fertilization (kg/ha)	Urea = 250 NPK = 200 SP36 = 100 KCl = 90 Dolomite = 1600
Integrated pest and disease control	Implementation of balanced pest and disease control or biopestisida
Harvest	Use of combine harvester machine
Water Management	One way

Source: Yuliani (2018).

1. Newly improved varieties with high yield potential.
2. Microbes to accelerate the decomposition of organic matter (Biodecomposer), microbes for biological fertilizer, and seed treatment.
3. Balanced fertilization based on the Swamp Soil Test Kit.
4. Control of pests, biological pesticides and inorganic pesticides based on threshold control.
5. Use of agricultural equipment and machinery, such as transplanters: planting equipment, and combine harvester; harvest tools.

Jarwo super rice cultivation carried out on tidal land includes:

1. One-way water management modified by pumping. Water management is done by installing culverts and block doors at several points in the planting field. The installation of culverts and sluice gates is aimed at managing water entering and leaving the rice field. A water pump is carried out to allow the water enter from secondary channels into tertiary and from tertiary channels to rice field plots.
2. Land preparation is to clean the land from grass and shrubs. Herbicide is commonly applied after the field is cleaned with a plow (long machete). Surrounding the land plot is a drainage channel/worm channel, which functions to store water, or release water as appropriate.
3. Land management.
   a. Processing I is carried out with a hand tractor (rotary), to avoid oxidized pyrite.
   b. Next step, the application of agricultural lime (dolomite) 1 ton/ha if the soil pH is 4.0–5.5, and 2 ton/ha if the pH <4.0,

leave it for 2–3 days, aimed at increasing nutrient availability and reducing soil acidity.

4. Biodecomposer application in the form of Biotara (25 kg/ha) or M-Dec (2 kg/ha) if necessary and subsequently soil is processed with rotary. Aims of it are to accelerate the process of decay and overhaul of organic matter, left 5–7 days in moist soil conditions but not flooded. Biodecomposers accelerate composting of straw/organic material, facilitating to increase the availability of NPK nutrients in the soil to make efficient fertilization.

5. Improved/superior varieties planted are varieties well known to be adaptive in swamps, namely Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 8, Inpara 9. It is important to use labeled/certified seeds.

6. Nursery:

   a. If not using *dapog*, land for the nursery is prepared in advance with an area of 4–8 m2/1 kg of seed. The nursery must be spatial enough to facilitate the roots to penetrate the soil to support plant growth. Mixed nursery land is a soil-manure-ash husk. Once seedlings are transplanted and, the land is applied with 2 kg of compound fertilizer for 1 ha seedlings.

   b. The application of Agrimeth biofertilizers in seeds aims to increase plant growth and productivity. It uses the seeds after soaking 24 hours, drained, then sprinkled with Agrimeth evenly, then incubated for 24 hours. Agrimeth dose of 500 gr/ha is equivalent to 500 gr/30 kg of seeds. Mixing them with Agrimeth is done in a shady place to avoid over sunlight to allow microbes alive. The remaining agrimeth is sown/sprinkled in the seedbed.

c. After being cultivated, the seeds are sown in the prepared land. To avoid eating poultry, the seeds are covered with coconut leaves or another light stover. If there is no rain, the seedlings must be watered every evening.

d. Planting. Seedlings with 15–21 days after germination are transplanted, by 2: 1 *legowo* row, spacing of 20cm x 10cm x 40cm or 25cm x 12.5cm x 50cm, and 2–3 clumps per planting hole. Application of the 2: 1 *legowo jajar* system is to get the border effect of edge plants, allowing all plants to get optimal solar radiation and to optimize plant populations.

7. Maintenance, including:

a. Fertilization. Inorganic fertilization should be done 3 times.

Fertilization I: 7 days after planting: dose per hectare about 200 kg NPK + 50 kg urea

Fertilization II: 30 days after planting; 200 kg of NPK + 100 kg of urea

Fertilization III; 45 days after planting; 100 kg of NPK

b. Weeding. To control weeds 2 times, with post-emergent herbicides (4 weeks after planting) and traditional means (8 weeks after planting).

c. Pest control. The main disease pests are stem borer, rat, leaf blast and neck blast.

8. Pest and desease control

a. Overcoming rat pests. It is done since the beginning/before planting including mass *gropyok*, habitat sanitation, feeding, installation of Trap Barrier System and LTBS (Linear Trap Barrier System)

b. Planting refugia. This is to reduce the use of pesticides. Refugia plants are natural enemy decoy plants, and can suppress pests.

c. Installation of light traps to determine the type and range of pest populations and estimate the strategy of how to control them.

d. Pumping is routinely carried out to meet the water needs by rice plants, especially during the vegetative phase and early flowering phase. The water that is channeled into the paddy fields (*kemalir* channel) is water that has been neutralized using dolomite in tertiary channels.

9. Harvest. Use a combine harvester (if land conditions allow) for labor efficiency, cost and time.

According to Yuliani (2018) report, the *legowo jajar* system was proven to increase rice productivity in tidal land in South Kalimantan, especially in the village of Sampurna, Jejangkit District, Barito Kuala. Components of crop yield and production are presented in Table 2.

The highest 1000 grains weight is found in Inpara 2. The highest yield of unhusked rice was Inpara 2 with 5.63 ton/ha, followed by Inpari 32 and Inpara 8 having 5.35 ton/ha and 4.66 ton/ha, respectively. While local varieties only produce 3.31 ton/ha, indicating the difference of yield between local and

Table 2. The yield and yield components of different rice varieties in tidal swamp areas, South Kalimantan.

Varieties	Panicle length	The amount of grain per panicle (grains)	Percentage of grain content (%)	1000 weights (g)	Production (ton/ha)
Inpari 32	22.08	94	65	18.49	5.352
Inpara 2	25.45	96	63	21.99	5.630
Inpara 8	22.74	92.8	62	20.21	4.667
Siam (lokal)	100	96	70	16.00	3.31

improved varieties reaches >30%. According to Haryati and Liferdi (2017) report using *jajar legowo super* technology package in irrigaed land, Inpari 30 produced 172.97 gr of grain per panicle and yield around 7.60 ton/ha.

CONCLUSIONS

The *jajar legowo super* technology package using the 2:1 legowo planting method is one component of technology for rice. This technology in tidal swamplands is very feasible to be developed in local communities as one of the breakthroughs in increasing rice production in achieving sustainable food self-sufficiency. The increase in rice production uses a *super legowo* technology package reaching >30%.

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SOIL CHEMICAL PROPERTIES IN ACID SULFATE LAND WITH INTERCROPPING SYSTEM OF RICE AND CITRUS

Nurmili Yuliani and Khairatun Napisah

INTRODUCTION

Development of agriculture needed for food supply is still challenged in line with the increased population. Rice being the main food in Indonesia, is planted widely in the various type of lands with various pH, including acid sulfate land. Acid sulfate land is defined as one type of land that can be found in swamp environments and is classified as problematic land due to an unfavorable internal nature of soil with a low fertility rate. A common problem in acid sulfate land is high soil acidity, low available P, and high P fixation by Al and Fe, causing the reduced yield of crops (Tambunan et al. 2013). The utilization of potential acid sulfate land so far is not optimal yet for rice cultivation.

In the inundated state, pyrite is harmless when oxidized. The longer the land experiences drought, the concentrations of formed sulfuric acid and ferrous sulfate are more increasing (Yuliana 2010). Paddy rice field is the most widely grown commodity in acid sulfate tidal land, but the rice production is less optimal in comparison to lowland and upland for rice.

The use of rice and citrus intercropping patterns is expected to increase the utilization and productivity of acid sulfate land since the improved soil physical and chemical properties, and increase farmers' income. Intercropping, defined as planting two or more types of plants in a plot of land at the same time, is commonly practiced in a specific area in Indonesia. This intercropping system pattern can put into practice of the top (raise beds) for citrus plants and the bottom (sunken beds) for rice plants. Citrus used for this intercropping is a local fruit plant called as Siamese orange. Siamese orange is one of the citruses that has a vital role for farmers in South Kalimantan, because of its high production, favored by consumers and having a favorable economic value. (Andrew and Kassam 1979 *in* Bunada et al. 2016). This paper aims to describes the soil chemical properties in acid sulphate land which is introduced with paddy and citrus Intercropping system.

POTENCY AND CHARACTERISTICS OF ACID SULFATE TIDAL LAND

Tidal land has the potency to be developed as agricultural land by eliminating the various existing constraints. Based on the typology, swampland consists of tidal swampland of ± 8.92 million ha and *lebak* swampland of ± 25.21 million ha (Table 1). From the total area of swamps, around 19.19 million ha or 56.04% is a potential land to be used for agriculture, such as wetland rice, horticultural crops, as well as annual crops. The remaining parts, approximately 14.93 million ha, are not suitable for the cultivation of agricultural plants (ICALRRD 2015). Thus other

Table 1. Area of Tidal Swamp and Lebak Swamps in Indonesia.

Island	Tidal swampland		*Lebak Bog* (Fresh water swampland)		Total (ha)
	Mineral (ha)	Peat (ha)	Mineral (ha)	Peat (ha)	
Sumatera	2,501,888	517,466	3,988,301	5,919,180	12,926,835
Java	94,756	-	-	-	94,756
Kalimantan	2,01,410	685,028	2,944,085	4,092,977	10,023,500
Sulawesi	318,030	-	706,220	23,844	1,048,094
Maluku	74,395	-	88,159	-	162,554
Papua	2,262,402	163,974	3,916,123	3,526,947	9,869,446
Indonesia	7,552,881	1,366,468	11,642,888	13,562,948	34,125,185

Source: ICALRRD (2015).

efforts must be taken into account to minimize their disadvantages.

Acid sulfate tidal land, a sub-optimal land, needs special handling to support plant growth as a consequence of the soil problems such as the presence of pyrite minerals (FeS_2), low soil pH, sulfuric horizons, iron (Fe) toxicity, and less nutrient. The high iron causes soil pH to drop to ≤ 3.5 (Muhrizal et al. 2006; Natural Resources Conservation Service 2010). Sulfide minerals such as pyrite and sulfur elements resulting from the sulfur sediment reduction process are elements forming acid sulfate soils that are oxidized in the unfavorable condition due to drainage (Janjirawutikul et al. 2011). Pyrite (FeS_2) mostly existed in acid sulfate soils are stable in reductive conditions; in contrast, the pyrite will be oxidized when drained, facilitating the formation of H_2SO_4 compounds that can increase soil acidity (Susilawati and Fahmi 2013).

According to chemical properties, acid sulfate soil is considered to have low fertility. High soil acidity triggers the dissolution of toxic substances, and particular macro and micronutrient deficiencies (Susilawati et al. 2016). Some of the problems encountered in acid sulfate soils in terms of soil fertility resulting in low rice productivity, namely: (1) low soil pH (pH <4) due to sulfuric acid, (2) high toxicities of Al, Fe and Mn due to low soil pH, (3) low level of available P because of its chelation with toxic elements such as $FePO_4^{2-}$ and $AlPO_4^{2-}$ and (4) waterlogs that cannot be controlled due to tidal water excess (Purnomo et al. 2005). Water management is an essential factor in the thriving agriculture on acid sulfate land. Water management can also reduce soil acidity, prevent soil acidification due to pyrite layer oxidation, prevent salinity hazards, flood hazards, and wash off toxic elements that have accumulated in the plant root zone (Suryadi et al. 2010).

In actual acid sulfate fields, the irrigation system must be laid down and not polled so iron and pyrite do not poison the plant. The arrangement of water in farmers' land is made with a one-way flow system and a two-way flow system. For potential acid sulfate land, soil management and the making of ridges should be done carefully and gradually. The soil for mounds is taken from the upper layer could avoid pyrite oxidation (Suriadikarta 2005). As a good example, the application of micro water management in acid sulfate land in Karang Agung Ulu with various land management systems can improve both land quality and crop yields (Djayusman et al. (1995) in Suriadikarta (2005).

RICE (*Oryza sativa*)–CITRUS (*Citrus nobilis*) INTERCROPPING SYSTEM

Rice productivity in acid sulfate fields from various studies is still low at approximately 4.2–6.3 ton/ha. Local varieties are very predominantly cultivated in such land, such as Unus Siam, Karang Dukuh, and Pandak. Notably, rice production in South Kalimantan over the past 9 years has continued to increase, along

Table 2. Harvested area, productivity, and rice production in South Kalimantan Province in 2008–2017.

Years	Area of harvest (ha)	Productivity (ton/ha)	Production (ton)
2008	507,319	3.852	1,954,284
2009	490,069	3.993	1,956,993
2010	471,166	3.91	1,842,089
2011	489,134	4.167	2,038,309
2012	496,082	4.205	2,086,221
2013	479,721	4.234	2,031,029
2014	487,899	4.205	2,094,591
2015	455,205	7.364	2,140,275
2016	547,449	7.839	2,313,573
2017	569,993	7.529	2,452,366
Mean	499,404	5.130	2,090,973

Source: BPS South Kalimantan (2018).

with an increase in harvested area and productivity, as shown in Table 2.

To increase rice productivity in acid sulfate land required innovative technologies, such as crop-intercropping between rice and citrus. Rice is planted in the lower ground (*tabukan*) adjacent to orange plants in intercropping. Intercropping system is the planting of more than one kind of early maturing plant in a row of regular planting (Francis 1986 *in* Turmudi 2002). According to Vandermeer (1989), intercropping systems will be able to increase the productivity of agricultural land by combining the plant species in mutually beneficial interactions. The intercropping technology is to use the land around lowland rice for citrus plants, especially conjoined oranges (Widiyanti and Sugihardjo 2002). With this technology, farmers will be able to reduce the high risk of crop failure since farmers still get income from other commodities.

The supporting land arrangement by elevating part of the land is not reachable by tidal overflows and inundation. The cube or dome support has a width or centerline of about 2–3 m, and height adjusts to the local water level. In this system, rice is planted in the paddy field, and annual crops such as oranges are planted in support (Simatupang et al. 2014). Citrus plants in South Kalimantan are the first commodity of superior fruit then followed by rambutan, pineapple, durian, and banana. Citrus farming in South Kalimantan is spread across the Regency with the development of production centers, especially in the Hulu Sungai Tengah, Tapin, Banjar, and Barito Kuala districts. In Barito Kuala Regency and parts of Banjar District, oranges are planted in tidal land (AIAT South Kalimantan, 2001). Citrus is cultivated in swamps, where its planting is increasing along with the opening of agricultural land, which includes tidal swampland, *lebak* land, dryland, and rainfed land in South Kalimantan.

It appears that the production of citrus plants in South Kalimantan amounted to 1,238,449 quintals (BPS South Kalimantan, 2018). Citrus production centers are in Barito Kuala Regency, which has a swampy area of 915,426 quintals (Table 3).

Table 3. The number of plants and citrus production in South Kalimantan.

Regency/city	Number of citrus plants	Production(ton)
Tanahlaut	5,970	450.5
Kotabaru	11,333	469.2
Banjar	199,315	4380
Barito Kula	1,094,987	91,542.6
Tapin	160,856	14,280.8
Hulu Sungai Selatan	10,304	448.8
Hulu Sungai Tengah	148,558	11,119.6
Hulu Sungai Utara	1,457	58.2
Tabalong	31	4.8
Tanah Bumbu	1,901	348.3
Balangan	3,281	314.8
Banjarmasin	3,355	193.9
Banjarbaru	3,400	233.4
Total	1,644,748	123,844.9

Source: Bureau of Statistics of South Kalimantan province (2018).

Citrus plants, as well as other plants, will grow well and produce high yield when rowing environment, including fertile soil, enough water, sufficient intensity of sunlight, and proper treatment and management are optimized (Balittra 2011).

Cultivation systems with intercropping can increase soil fertility through improved soil biological and chemical properties (Sainju et al. 2008 *in* Bunada et al. 2016). The soil pH value of conjoined citrus plants planted by intercropping with vegetable crops was higher at 6.72–6.85 than with monoculture patterns of citrus tangerines (6.38). The level of organic C-soil is also relatively higher in the intercropping of citrus, which is 2.85–3.54% compared to the monoculture cropping pattern, which is 2.32% (Bunada et al. 2016).

To grow oranges in tidal acid sulfate, is commonly conducted by generating *baluran* or soil beds. *Baluran* is made by leveling land to 0.5 m hight, width 3 m and length according to the size of the plot of land. On the *baluran*, in the middle part, is made a mound (support) in size of 50 cm x 50 cm x 50 cm, where oranges are planted (AIAT South Kalimantan 2001). Rice intercropping with citrus in tidal land is feasible to be developed with an interest rate of 12%, 15%, and 40%, a B/C value >1. Therefore, the development of an intercropping rice system with oranges will provide excellent benefits for the local community or farmers (Rina et al. 2006 *in* Nazemi et al. 2012).

PROPERTIES OF SOIL CHEMISTRY WITH INTERCROPPING SYSTEM

Soil fertility has focused on provisioning mineral nutrients for plant growth. One way to assess nutrient status in determining soil fertility is by soil analysis, which has a good concept of plants' response to fertilization if the nutrient levels are insufficient for their optimal growth.

As a part of the soil element, sulfidic (pyrite) content is a characteristic of acid sulfate soil. Acid sulfate soil is Typic Sulfaquent subgroup and having a soil pH value of 3.92 (very acidic) with C-organic soil content of 8.889% (very high), total N content of the soil of 0.429% (moderate), and Fe content of 103.706 ppm (very high) (Soil Survey Staff, 2010) (Table 4).

Chemical properties will change according to the time being. The change in chemical properties is related to the dry and wet dynamics of the soil, which causes the reduction and oxidation processes in soil. Disturbance in acid sulfate soils with support will spur oxidation, which result in increased soil acidity and

Table 4. Properties of Soil on Rice Field–Citrus in Barambai District.

Chemical soil characteristics	Value	Criteria*
pH H_2O	3.92	Slightly acid
P Tsd (ppmP)	38.204	
C-Org (%)	8.889	Very high
N (%)	0.429	moderate
Kdd (cmol(+)/kg)	0.231	Low
Nadd (cmol (+)/kg)	0.177	Low
Ca-dd (cmol(+)/kg)	1.658	Slightly low
Mgdd (cmol(+)/kg)	0.810	Low
KTK	55.25	Slightly high
Fe (ppm)	103.706	Slightly high
Kej.Basa (%)	5.205	Low
P potensial (mg/100g)	33.817	
K Potensial (mg/100g)	10.783	
C/N Ratio	20.72	High
Tekstur (%)		Clay
Sand	5.77	
Silt	14.27	
Clay	79.96	

*Balai Penelitian Tanah 2012.
Source: Data not yet publish.

increased toxic ions such as Al, Fe, and so on (Balitbangtan, 2014). Thus, a well-managed technology like the intercropping of rice and orange plants could be one of the solutions to maximize the productivity of the acid sulfate land.

CONCLUSIONS

Acid sulfate land with rice (*Oryza sativa*) and citrus (*Citrus nobilis*) intercropping system has a very low nutrient content. A well managed on soil and water, fertilization, and cropping patterns, allows land to have an optimal productivity. Intercropping is one of the management of agricultural land by combining intensification and diversification of crops. Intercropping models carried out by farmers usually plant more than one crop, such as rice with citrus to get more profitable than the monoculture system. The use of acid sulfate land with intercropping to allow food shortages due to crop harvest failure can be prevented. The intercropping system of rice with citrus is beneficial to increase farmers' income and food diversification.

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EFFECTIVITY OF BIO AMELIORANT TO INCREASE RICE PRODUCTIVITY IN SWAMPLANDS

Mukhlis and Izhar Khairullah

INTRODUCTION

There is 14.18 million ha out of 34.12 million ha swamplands in Indonesia that is suitable for rice cultivation (ICALRRD 2015). However, the role of swampland on national food security is still limited. The contribution of swampland on food security, especially rice, is about 600–700 thousand tons or 1.0–1.5% of total domestic production. There are some opportunities to increase rice production through productivity, plant index increase, and extensification of planting area.

The development of swampland for food especially rice is strategic and vital because some reasone as folllows (1) rice production has to overcome the increase of food need and people population; (2) the potency of swampland is high, but its contribution on food security and farmer welfare is still low; (3) the productivity and plant intensity are still low but could be increased; (4) swampland management to be productive for agriculture can increase farmer income and reduce poverty. Based on land typology, swampland can be classified into acid sulfate soil, peat soil, and saline soil, however, swampland is still less productive. The average rice production is still low (3–4 ton/ha/season) with one crop per year in some areas. The low productivity of swampland is attributable by mostly low fertility and flooding because of the condition of the infrastructure. Therefore, an innovative approach is needed to improve soil quality, allowing to increase rice production. Amelioration and fertilization as the main factor in improving soil conditions and productivity of swampland should be addressed. This paper dicussed the use of bio-ameliorant and bio-fertilizer to enhance the quality of soil and increase rice productivity of swampland.

CHARACTERISTICS OF SWAMPLAND

Swampland is saturated or waterlogged land for a long period or all the year and has mud in the part of soil surface. Swampland is distributed in low land areas between coastal and swale or lagoon or sea. In natural conditions, before opened for agriculture, swampland is covered with mangrove, weeds, or forest vegetation. Swampland in Indonesia mainly exist in Sumatera, Kalimantan, Papua, and Sulawesi. Swampland occupies 34.12 million ha consisting of the tidal swamp (8.92 million ha) and back swamp (25.21 million ha) (ICALRRD 2015).

Swampland is classified into acid sulfate soil, peat soil, and saline soil. A pyrite (FeS_2) layer in the soil surface is one of the main characteristics of these soil types. When pyrite is exposed to air, sulfides are oxidized to Fe(III) sulfates, and sulfuric acid is generated. This process results in soil acidification, rendering these soils marginally suitable for agriculture: low pH levels and the presence of elements such as aluminum, iron, and manganese, which can become highly toxic to crops and result in declining crop yields. The most significant constraints in using swampland are the (1) acidity, including the combined effects of pH, Al toxicity, and P deficiency, and (2) Fe stress which is due to Fe toxicity and lack of other divalent cations, such as Ca) (Moore et al. 1990).

USE OF BIOCHAR AS BIO AMELIORANT

Biochar (biological charcoal) is defined as a product of biomass combustion under conditions of limited oxygen supply. In contrast to other biomass or compost, biochar is stable for hundreds and thousands of years when mixed into the soil, and thus its carbon is removed from the carbon cycle (Lehmann 2007; Renner 2007).

The use of biochar for improving soil physical properties and soil fertility has been investigated in mineral soils of Indonesia (Dariah and Nurida 2012; Sutomo and Nurida 2012; Suwarji et al. 2012, Widowati et al. 2012). Biochar could restore the health of contaminated soil and water (Hamzah et al. 2012; Nurida et al. 2012). Santi et al. (2012) have shown that biochar is a better carrier of consortium bacteria than peat and compost. Biochar provides a unique opportunity to improve soil fertility and nutrient-use efficiency using locally available and renewable materials sustainably.

Application of biochar in peat soil can be increased through adding other organic matter in high nutrients, in order to be used not only as ameliorant but also as fertilizer for the plant. Biochar made from coconut shell has a water retention capacity of 25.30%, N-total of 1.92%, P-total of 0.07%, K-total of 0.08%, C-organic of 25.60%, bulk density of 0.68%, and porosity of 63.30%. In comparison, rice husk biochar has pH of 6.7 and N-total of 0.68% (ISARI 2012). The nutrient content of biochar is affected by the kind of materials and the process of making, especially temperature and time (Lehmann and Joseph 2009).

Research result conducted in peat soil of South Kalimantan showed that biochar combined with chicken manure (F2), as many as 7.5 ton/ha, could increase rice growth and yield compared to control (without biochar) and the combination of chicken manure + *purun tikus* weed (F3) treatments (Table 1). Based on soil analysis, the F2 treatment could have the most available K compared with the F3 and control treatments. F2 also had the highest pH (Table 2).

In acid sulfate soil, biochar of 5 ton/ha + chicken manure of 0.5 ton/ha (Biodetox 4) does not only increase soil pH and the

Table 1. Effects of ameliorants on the growth and yield of rice in peat soil, Landasan Ulin, South Kalimantan, in 2012 dry season*.

Treatment	Plant height (cm)	Tillers (no.)	Dry weight (g/plant)	100-grain weight (g)	Yield (ton/ha)
F1	87.55 a	15.43 a	28.87 a	2.55	3.58
F2	84.98 a	13.32 ab	25.02 ab	2.80	3.42
F3	84.45 a	12.22 ab	20.53 b	2.67	3.17
Control	74.23 b	8.66 b	12.23 c	2.80	3.00

[a]F1 = 2.5 ton/ha chicken manure + 2.5 ton/ha *purun tikus* weed + 2.5 ton/ha agricultural weeds; F2 = 1.25 ton/ha chicken manure + 6.25 ton/ha biochar; F3 = 0.7 ton/ha chicken manure + 6.8 ton/ha *purun tikus.*
* ISARI (2012).

Table 2. Effects of addition of ameliorants on peat soil characters at the Landasan Ulin, South Kalimantan, in 2012 dry season*.

Treatment	pH H_2O	N total (%)	K-dd (cmol(+)/kg)	P-Bray 1 (ppm P_2O_5)	Fe (ppm)
F1	3.55	1.82	3.84	51.69	165
F2	3.58	1.78	2.27	23.93	61
F3	3.50	1.82	1.26	101.95	67
Control	3.33	1.68	0.65	11.43	342

[a]F1 = 2.5 ton/ha chicken manure + 2.5 ton/ha *purun tikus* weed + 2.5 ton/ha agricultural weeds; F2 = 1.25 ton/ha chicken manure + 6.25 ton/ha biochar; F3 = 0.7 ton/ha chicken manure + 6.8 ton/ha *purun tikus.*
*(ISARI 2012).

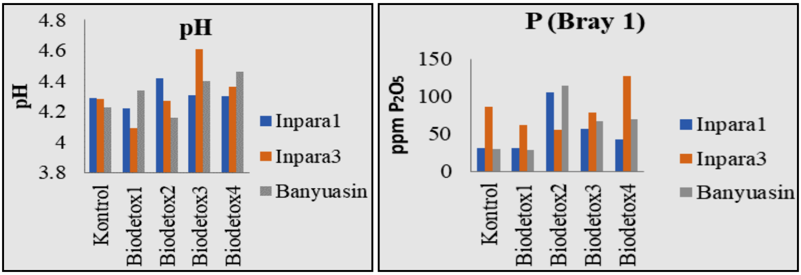

Figure 1. Effects of ameliorant Biodetox on soil pH and P of some rice varieties in acid sulfate soil. Remarks : Biodetox 1 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.1 ton/ha dolomite + 0.1 ton/ha chicken manure); Biodetox 2 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 3 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 4 (5 ton/ha biochar + 0.5 ton/ha chicken manure).

available P (Figure 1) but also decrease soluble Fe and iron toxicity symptom of rice plant (Figure 2). For all rice varieties, the application of Biodetox 4 increased the amount of available P in the soil. The highest increase was shown by Inpara 3, which is moderately iron toxicity-tolerant. Inpara 1 has iron toxicity tolerance, while Inpara 3 has moderate tolerance for iron toxicity and submergence. Banyuasin is also moderate tolerance to iron toxicity. Application of Biodetox 4 decreased the amount of soil Fe, especially in Banyuasin. Iron toxicity symptoms observed on the leaves decreased in all Biodetox treatments. However, Biodetox 4 containing biochar showed the least iron toxicity symptoms. According to Masulili et al. (2010), the application of biochar on acid sulfate soil could decrease exchangeable Al and Fe and increase soil porosity, pH, CEC, P, and exchangeable Ca, and K.

Rice growth (plant height, the number of tillers, and dry weight of plant) increased with the application of Biodetox. Biodetox 4 increased plant height, especially those of Inpara 3 and Banyuasin (Table 3). Biodetox 1 and 3 increased the number

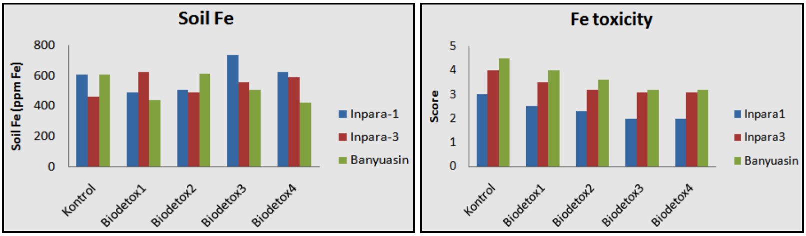

Figure 2. Effects of ameliorant Biodetox on soil Fe and iron toxicity symptoms of some rice varieties in acid sulfate soil. Remarks: See Figure 1 for treatment description.

Table 3. Effect of ameliorants on plant height of 90 days after planting of some rice varieties grown in acid sulfate soil*.

Main plot	Subplot					Average
	Control	Biodetox 1	Biodetox 2	Biodetox 3	Biodetox 4	
Inpara 1	74.4	68.5	76.0	81.4	72.7	74.6
Inpara 3	74.0	76.8	79.5	79.3	81.7	78.3
Banyuasin	74.3	73.5	81.0	79.1	74.8	70.5
Average	74.2	72.9	78.8	79.9	76.4	

Remarks : Biodetox 1 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.1 ton/ha dolomite + 0.1 ton/ha chicken manure); Biodetox 2 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 3 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 4 (5 ton/ha biochar + 0.5 ton/ha chicken manure).
*ISARI (2012).

of productive tillers in all varieties; Biodetox 4 increased it only in Banyuasin (Table 4). The positive response of Banyuasin may be due to its moderate tolerance for iron toxicity. The total dry weight of plants in Biodetox-treated soil was higher than that in untreated soil (control) (Table 5). On average, Biodetox 4 application could increase rice yield, although it was lower than that obtained from Biodetox 2 and 3 treatments (Table 6). The improved soil nutrient status through the application of biochar and other ameliorants increased the rice yield in acid sulfate soil (Masulili et al. 2010).

Table 4. Effect of ameliorants on number of productive tillers at 90 days after planting of some rice varieties grown in acid sulfate soil*.

Main plot	Subplot					Average
	Control	Biodetox 1	Biodetox 2	Biodetox 3	Biodetox 4	
Inpara 1	9.53	9.27	8.27	10.87	8.53	9.29
Inpara 3	8.27	8.60	7.33	9.07	7.87	8.23
Banyuasin	8.00	9.87	11.30	9.60	9.60	9.67
Average	8.60	9.24	8.97	9.84	8.67	

Remarks : Biodetox 1 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.1 ton/ha dolomite + 0.1 ton/ha chicken manure); Biodetox 2 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 3 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 4 (5 ton/ha biochar + 0.5 ton/ha chicken manure).
*ISARI (2012).

Table 5. Effect of ameliorants on plant dry weight at 90 days after planting of some rice varieties grown in acid sulfate soil*.

Main plot	Subplot					Average
	Control	Biodetox 1	Biodetox 2	Biodetox 3	Biodetox 4	
Inpara 1	81.7	95.0	68.3	116.7	78.3	88.0
Inpara 3	78.3	80.0	66.7	76.7	73.3	75.0
Banyuasin	66.7	71.7	90.0	78.3	71.7	75.7
Average	75.6	82.2	75.0	90.6	74.4	

Remarks : Biodetox 1 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.1 ton/ha dolomite + 0.1 ton/ha chicken manure); Biodetox 2 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 3 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 4 (5 ton/ha biochar + 0.5 ton/ha chicken manure).
*ISARI (2012).

Table 6. Effect of ameliorants on rice yield of some rice varieties grown in acid sulfate soil*.

Main plot	Subplot					Average
	Control	Biodetox 1	Biodetox 2	Biodetox 3	Biodetox 4	
Inpara 1	4.73	4.00	5.27	5.90	4.57	4.89
Inpara 3	4.33	5.20	5.57	6.07	6.57	5.55
Banyuasin	4.77	4.80	5.63	5.70	4.73	5.13
Average	4.63	4.67	5.49	5.89	5.29	

Remarks : Biodetox 1 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.1 ton/ha dolomite + 0.1 ton/ha chicken manure); Biodetox 2 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 3 (5 ton/ha rice straw + 5 ton/ha *purun tikus* weed + 0.2 ton/ha dolomite + 0.2 ton/ha chicken manure); Biodetox 4 (5 ton/ha biochar + 0.5 ton/ha chicken manure).
*ISARI (2012).

USE OF "BIOSURE" AND "BIOTARA" AS BIOFERTILIZER

Biofertilizer "Biosure" can be used to reduce acidity and increase soil productivity. The Biosure contains sulfate-reducing bacteria that have an essential role in the reduction process of acid sulfate soil. The Biosure minimizes the use of lime up to 80% and increases rice yield by up to 20%. Figure 4 shows the increase of pH and rice yield because of the Biosure application.

Biofertilizer adaptive to acid soils in swampland is an alternative way to increase soil fertility, plant productivity, fertilization efficiency, and reduce environmental risk. Biofertilizer "Biotara" has been known to be adaptive in swampland and enhance soil productivity. The Biotara contains a mixture of microbes, such as decomposer (*Trichoderma sp*), P-solubilizing bacteria (*Bacillus sp*), and N-fixing bacteria (*Azospirillium sp*). This biofertilizer could increase the efficiency of an anorganic fertilization up to 30%, and rice yields up to 20%.

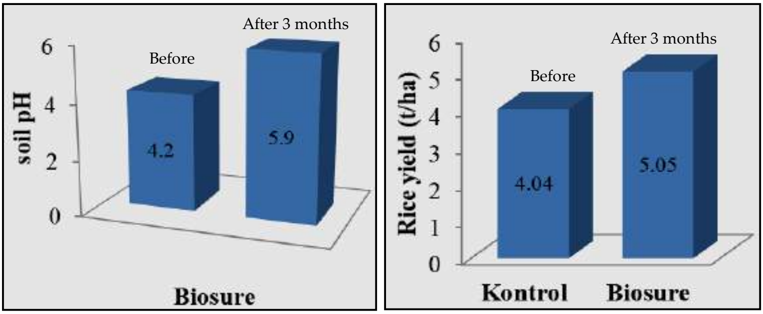

Figure 4. Effect of Biosure on soil pH and rice yield.

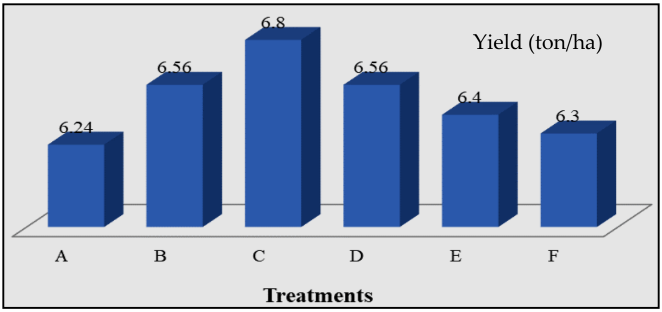

Figure 5. Effect of Biotara on rice yield in acid sulfate soil in Kutai Kertanegara, East Kalimantan in 2012 dry season. Remarks : A = 400 kg NPK Pelangi/ha + 25 kg Biotara/ha; B = 400 kg NPK Pelangi/ha + 100 kg urea/ha;C = 300 kg NPK Pelangi/ha + 25 kg Biotara/ha; D = 300 kg NPK Pelangi/ha + 100 kg urea/ha; E = 100 kg Urea + 100 kg SP36 + 50 kg KCl/ha + 25 kg Biotara/ha; F = 100 kg urea + 100 kg SP36 + 50 kg KCl/ha.

Figure 5 shows the effect of biofertilizer "Biotara" on rice yield in acid sulfate soil.

CONCLUSIONS

The high potency of swampland is not in parallele with its contribution to food security. There are some opportunities to increase rice production, *i.e.*, plant index increase, areal extensification, and productivity. Innovation technologies of swampland management could raise its productivity. Several fertilizer products were formulated to support the improvement of swampland productivity, i.e., bioameliorant (biochar) and biofertilizer (Biotara, Biosure). Biochar combined with chicken manure could improve some properties of peat and acid sulfate soils. In peat soil, the application of biochar (6.25 ton/ha) and chicken manure (1.25 ton/ha) increased soil pH and available soil K. In acid sulfate soil, biochar (5 ton/ha) + chicken manure (0.5 ton/ha) increased soil pH and available soil P, and also decreased soluble Fe and iron toxicity of the rice plant. Improvement of soil properties increased rice growth and yield. Biofertilizer "Biosure" can be used to reduce acidity and enhance soil productivity. The Biosure minimizes the use of lime up to 80% and increases rice yield by up to 20%. Meanwhile, "Biotara" could increase the efficiency of inorganic fertilization by up to 30%, and rice yields up to 10%. Overall, the application of the bioameliorant technology could enchance the growth and yield of rice.

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CHAPTER 3.
MANAGEMENT AND UTILIZATION OF RICE GENETIC RESOURCES

Rice cultivation is well-suited in the Asian regions that has a warm climate, low labor costs, and high amounts of rainfall as this staple crop is labor-intensive and requires ample supplies of water. Rice production has increased prominently in this region, but it exists mainly in irrigated areas. Due to the high rate of population growth and the negative effect of climate change, rice area extensification should shift to marginal land, including swampland area. Therefore, new technology for the new ecosystem should be prepared for rice improvement.

There are a lot of breeding targets for rice improvement to solve the constrain of increased production under the climate change condition pressure, such as resistance to biotic and abiotic stresses. Blast and bacterial leaf blight (BLB) are highly destructive in lowland rice in temperate and subtropical Asia, and upland rice in tropical Asia, Latin America, and Africa. Breeding for submergence tolerance and enhanced yield in flash-flood areas has been going to be an important target since flooding forces seriously constrain on rice production. The environment changes rapidly especially drought become the major obstacle to rice production in these countries. In Vietnam, Indonesia, Myanmar, and Cambodia had been faced severe drought in some areas including paddy field to date due to unpredicted climate changes. Moreover, over 50% of the rice area in this region is rainfed which can limit total rice yield. However, most of the improved rice varieties grown in drought-prone areas were originally bred for the irrigated system.

Rice fields clearly are major sources of global atmospheric greenhouse gases, including methane (CH4) and nitrous oxide (N2O). The total CH4 and N2O emissions from paddy fields mainly depend on several microbial-mediated processes in soils, e.g. CH4 production, CH4 oxidation, nitrification, and denitrification, and on numerous pathways of gas transport, e.g. plant-mediated transport (through the aerenchyma), molecular diffusion, and ebullition. Flooding are ideal conditions for the continuous decomposition of organic materials in the swampland. CH4 is produced in anaerobic zones by methanogens, 60–90% of which is subsequently oxidized by methanotrophs in the rhizosphere and converted into CO2. Rice plants play an active role as a medium for transporting methane from the rice fields into the atmosphere.

Certain genes and proteins associated with environmental stress tolerance need to be well elucidated to solve the corresponding problems appeared in South East Asia regions where unpredictable climate is challenged. Therefore, different disciplines to better understand rice plant responses to water deficits and link this understanding with the breeding of improved cultivars related to drought-resistance/tolerance traits are important to be elucidated, especially its physiological and molecular basis. Recent genetic techniques and genomics tools coupled with advances in breeding techniques and precise phenotyping probably reveal candidate genes and metabolic pathways underlying on the trait targets such as drought tolerance or for reducing the global atmospheric greenhouse gases.

To find potential genetic materials harboring desired genes corresponding to important traits, the genetic diversity is the principle on breeding scenario. Based on these genetic group characterizations could show the adaptations mode of the genetic resources to specific climates, according to the agro-ecological conditions where they were cultivated. Indonesia has diverse on local rice/landraces. The importance of the diversity of local germplasm including local varieties of the plant is being recognized nowadays as a valuable genetic resource for future crop improvement and its contribution to food security. Landraces/local rice varieties in every country are potential genetic materials that should be improved their genetic by a breeding approach in parallel with preservation activity. Research on genetic diversity based on molecular markers is needed to facilitate the efficient use of the local rice genetic resources.

The swampland area is now very important for supporting rice production. Fe toxicity, the most constrain in swampy area are put in highly effort. Besides, salinity problem which has also affected around 13.2 million ha of potential areas for rice growth in Indonesian wetland, is expected to expand along with rising sea levels due to global warming. Utilization of local rice varieties adaptive to Fe toxicity and salinity is an alternative for food security in coastal areas especially tidal swampland. Importantly, diverse local rice varieties are predominant in tidal swampland because of its adaptation to the waterlogged condition and its rice texture.

This chapter is intended to discuss the studies on genetic diversity analysis and breeding program of rice for adaptation to swamp land ecosystem, and practical use both of local and modern varieties in production of rice in swamp area; the development of rice cultivation in tidal swamps; as well as the genetic diversity of rice in this area. Importantly, the development of new varieties in swamps adaptive to environmental stresses in parallel with local people preferences is described.

CO-DEVELOPMENT IN RICE BREEDING TECHNOLOGY FOR BIOTIC AND ABIOTIC STRESS TOLERANCE IN INDONESIA AND MALAYSIA

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INTRODUCTION

Rice is one of the main crops for human consumption and is produced in 95 countries across the world (Maclean et al. 2002). The world's five largest rice producers, and rice consumers, are China, India, Indonesia, Bangladesh, and Vietnam (Khazanah 2019). Rice also is the staple food in many countries, accounting for more than 40% of global food production. People in the majority of countries in Asia depend on rice as their primary source of nutrition, as well as for income and employment (Maclean et al. 2002; Makino 2011).

The rice production system in Southeast Asia has, over recent years, become increasingly challenge by climate change impacting the environmental stresses and diseases/pest incidence, agricultural land conversion, and the shift in consumer's preference on food quality. Several programs addressing in management, breeding, and evaluation of rice germplasm lines have been evolved to pioneer the increased rice production (Redfern et al. 2013) and improved its quality. Accumulation of knowledge and advanced technology involving rice genetic resources and breeding technology have been acquired in the quest for rice production, particularly in the Asia region. Landraces/local rice varieties in every country are potential genetic materials that should be improved by the breeding approach in parallel with preservation activity.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), a legally binding international framework for the conservation and sustainable use of plant genetic resources for food and agriculture (PGRFA), emphasizes the fair and equitable sharing of the benefits derived from the utilization of PGRFA through the multilateral system. As a priority, such benefits flow to farmers in developing countries, including Southeast Asian, who conserve and sustainably utilize PGRFA. The Treaty's Governing Body has called for Contracting Parties and other relevant stakeholders to explore innovative ways to realize effective technology transfer is required to enhance the capacity to use PGRFA through plant breeding (The International Treaty 2009).

Rice production is an integral part of the national economy of Indonesia and Malaysia. Indonesia is the third-largest producer of rice in the world. While in Malaysia, rice is a crucial part of everyday Malaysian diet (https://en.wikipedia.org). Similarly to Indonesia and Malaysia, the increasing population is calling for more research and technological advancement to raise rice production for consumption within the nation (Selamat et al. 2009).

The objective of this article is to describe the co-development technology in rice breeding research for improving the biotic and abiotic resistance in Indonesia and Malaysia. This objective of this was related to the one of activities output on research collaboration under FAO-BSF project W3B-PR-08-Indonesia entitled 'Co-Development and Transfer of Rice Technologies'.

RICE AND FOOD SECURITY IN ASIA

Rice is one of the leading crops in the world. More than 90% of rice is produced and consumed in Asia. In terms of food consumption, which distinguishes Asia from the rest of the world is its high dependency on rice. It is the primary staple for the majority of the population, including the region's 560 million poor. Other areas rely more heavily on other cereals.

In many countries, rice is deeply patterned in their rich culture and tradition. Rice (*Oryza sativa*) was domesticated from the wild grass *Oryza rufipogon* roughly 10,000–14,000 years ago. Two main subspecies of rice such as indica that prevalent in tropical regions and japonica in the subtropical and temperate regions of East Asia, are believed to be derived from single domestication events in the Pearl River valley region of China, possibly in the middle Yangtze and upper Huai rivers, 8,200–13,500 years ago (Huang et al. 2012). Another cultivated species, *O. glaberrima*, was domesticated much later in West Africa (Sweeney and McCouch 2007). Rice and farming implements dating back at least 8,000 years have been found. Cultivation spread down these rivers over the following 2,000 years (GRiSP 2013).

The introduction of rice high-yielding varieties in the late 1960s, which marked the beginning of the Green Revolution, has more than tripled Asian rice production in the past four-plus decades, from 200 million ton (paddy equivalent) in the early 1960s to more than 600 million ton in 2010. This has been possible with the introduction of modern varieties in tandem with assured irrigation, subsidized inputs (such as fertilizer, fuel, and pesticide), and guaranteed prices. During this period, more than 1,000 modern varieties were released to farmers in Asian countries, with farmer adoption on a range 40% (Pandey et al. 2012; Ghimere et al. 2015) to about 68% (Chogyel and Bajgai 2015).

The success of the Green Revolution in the 1960s witnessed a steady rise in Asia's per capita rice consumption from 85 kg in the early 1960s to nearly 100 kilograms by 2010; on the other hand, global per capita consumption rose from 50 to 65 kg during the same period. Rice production and consumption are among the highest in Asian populations. Rice provides up to 50% of the dietary caloric supply and a substantial part of the protein intake for about 520 million people living in poverty in Asia (Muthayya et al. 2007). Rice consumption per capita, calorie intake also increased by more than 40% from 1,891 in 1960 to 2,706 in 2009.

RICE PRODUCTION CONSTRAINT

The anticipated changes of the global climate in the form of rising temperatures, the increasing amount of carbon dioxide in the atmosphere, higher frequency of extreme weather events (e.g., floods and droughts), and higher incidence of pests and diseases are likely to make things more complicated for rice production. A large part of rice production is already lost to various abiotic stresses (flood, drought, and salinity) and biotic stresses (pests and diseases).

A significant problem in Asia is the yield decline noticeable in irrigated due to various factors of environmental changes. Pests (including insect-pests and diseases), one of the factors that evolved under the influence of host genes, are changing the rice-environment. Thus, scientists are in a continuous war with ever-changing races, pathotypes, and biotypes of rice pests. New and more potent genes, being added continuously using conventional or biotechnological tools.

INDONESIA

The Indonesian archipelago covers about 2,000 km from north to south and 5,000 km from east to west. There are more than 13,000 islands, including five of the world's largest: Sumatra, Kalimantan (the Indonesian part of Borneo), Irian Jaya (Western New Guinea), Sulawesi (Celebes), and Java. Most of Indonesia has a moist tropical climate, with abundant rain and high temperatures. Annual rainfall ranges from 1,000 to more than 5,000 mm, with more than 90% of the country receiving an average rainfall of more than 1,500 mm. December through March are the months with the highest rainfall (IRRI's Rice Almanac 2013).

Indonesia is particularly vulnerable to the vagaries of the El Niño Southern Oscillation (ENSO). In years when surface-water temperatures rise substantially in the western Pacific Ocean, signaling an El Niño event, rice production suffers a severe shortfall, with most of the effects coming from a reduction in rice area planted (as opposed to lower yields). The decrease in the rice planting area occurs even in the irrigated rice areas due to less rainfall leads to reduce the availability of irrigation water. In upland rice areas, erosion is a crucial problem because, on steep slopes, the fields are neither bonded nor terraced. The scarcity of rainfall can cause serious sedimentation problems in lowland irrigation systems. Alley cropping, as well as terracing, has been introduced in some areas to reduce these problems. Upland soils are also more weathered and leached, leading to issues of aluminum toxicity and phosphorus deficiency that combine to lower yields. Soil acidity is severe in tidal swamps because of acid sulfate soils. These are accompanied by iron toxicity, as well as some deficiencies of phosphorus and micronutrients.

The other constraints in increasing rice production are:

- Rive fields are reduced due to land conversion to nonagricultural use (such as commercial, industrial, urban), estimated at 100,000 ha per year.
- Higher global population increase in pressure on every available hectare of rice-growing areas and decreasing average farm size due to traditional inheritance practices.
- Low budget for irrigation infrastructure development and repair, both centrally and provincially.
- Inadequate capital for poor farmers.
- Slower in generating rice varieties and slow uptake of rice high-yielding varieties.
- An inadequate number of highly qualified and educated crop extension officers due to lack of performance incentives.

Yield growth slowed by about 0.5% per year between 1990 and 2010, and this is causing great concern. Likewise, growth in rice area weakened from 2% per year in 1960–1998 to less than a 0.1% increase per year in 1999–2010. Both stagnating growth trends threaten the capability of local producers to supply enough rice to domestic markets in the coming years (IRRI's Rice Almanac 2013).

MALAYSIA

Malaysia, particularly Peninsular Malaysia, paddy is cultivated as a rainfed or irrigated lowland crop. Rice is currently constrained to eight major granary areas in Peninsular Malaysia.

It is mainly grown in states such as Kedah, Perak, and Kelantan, together control more than half of Malaysia's harvested area (FAO 2002). Dryland cultivation occurs mostly in Sabah and Sarawak, in the islands of Borneo. In comparison to other countries in Asia, Malaysia produces only a small amount of rice. Out of 656.4 million tons of rice produced in Asia, only 2.7 million tons is from the peninsula and the Borneo islands, approximately 0.4% of Asia's rice production, as reported by the FAO in 2011. The actual average local rice yield was 30–50% lower than achievable potential in 2007, based on the report of Malaysian Agricultural Research and Development Institute/ MARDI (Omar 2008), and local verification trials are located in granary areas. Due to the inability to currently meet its goal of being 100% self-sufficient in rice, Malaysia still has to import rice from major suppliers fromThailand and Vietnam. The current average yield has been reported as 4.5–5 ton/ha, due mostly to farmers applying more than the recommended rate of 170 kg N/ha (Nori et al. 2008). FAO reported paddy yields slightly lower, between 3.36 and 3.97 ton/ha between 2006 and 2012, in comparison with an average for Southeast Asia over the same period of 3.90–4.23 ton/ha, indicating that Malaysian yields are slightly lower than regional rice yields (http://www.faostat.org).

RICE BREEDING PROGRAM FOR BIOTIC AND ABIOTIC STRESS RESISTANCE

Rice breeding will play a vital role in this coordinated effort for increased food production. Given the context of current yield trends, predicted population growth and pressure on the environment, and traits relating to yield stability and sustainability should be a significant focus of plant breeding efforts. These traits include durable disease resistance, abiotic stress tolerance, nutrient, and water-use efficiency (Trethowan et al. 2005).

BIOTIC STRESS

Rice plants have been under cultivation for thousands of years in 115 countries; therefore, it hosted several plant pests. In the temperate zone, there have been identified about 54 important plant pests and approximately 500 in the tropic. Of the major diseases, 45 are fungi, ten bacteria, 15 viruses, and 75 are insect-pests and nematodes. Realizing the economic losses caused by them, efforts have been directed to understand the genetic basis of resistance and susceptibility.

The studies led to understand the host-plant interaction in rice that has given rising specialized breeding programs for resistance to diseases and insect pests. Ten bacterial diseases have been identified in rice. The major ones causing economic losses in any rice-growing country are bacterial blight, bacterial leaf streak, and bacterial sheath rot. Fungi cause many of the serious rice diseases. Some of the plant diseases, such as rice blast, sheath blight, brown spot, narrow brown leaf spot, sheath rot, and leaf scald are of economic significance in many rice-growing countries of the world. Twelve virus diseases of rice have been identified. Still, the important ones are tungro, grassy stunt, ragged stunt, orange leaf (in Asia), hoja blanca (America), and stripe and dwarf virus (in temperate Asia). Brown planthoppers, stem borers, and gall midges are among the major insect-pests in rice production.

BLAST DISEASE

Blast is highly destructive in lowland rice in temperate and subtropical Asia, and upland rice in tropical Asia, Latin America, and Africa. Blast disease is found in approximately 85 countries throughout the world. Its first known occurrence was as early as 1637 in China, where it caused fever disease.

Blast is considered a major disease of rice because of its wide distribution and extent of destruction under favorable conditions. Although rice blast is capable of causing very severe losses of up to 100%, little information exists on the scale and intensity of actual damages in farmers' fields. Losses of 5–10%, 8%, and 14% were recorded in India (1960–1961), Korea (the mid-1970s), and in China (1980–1981), respectively. In the Philippines, yield losses ranging 50–85% were reported.

BACTERIAL LEAF BLIGHT (BLB) DISEASE

Bacterial blight (BLB) is one of the most destructive rice diseases in Asia and has historically been associated with major epidemics. It occurs in China, Korea, India, Indonesia, the Philippines, Sri Lanka, Myanmar, Laos, Taiwan, Thailand, and Vietnam. The disease also occurs in Northern Australia and Africa.

In the late1970s, epidemics due to BLB were reported in India. The advent of rice varieties bearing genes with resistance to the disease has changed the perception about the disease. They include incorporation of host-plant resistance genes in rice varieties, their adoption and deployment in the world’s main rice-producing environments which is probably one of the most significant shreds of evidence of the role of plant pathology in agricultural development.

BLB nevertheless remains an important concern, and many countries will not endorse the release of new rice varieties unless they carry resistance to the disease. Whenever susceptible rice varieties are grown in environments that favor BLB, very high yield losses, as much as over 70%, may be caused by BLB. It is particularly severe in hybrid rice, and therefore, active breeding in national and commercial breeding programs have developed and released some hybrids that have resistance to the disease.

ABIOTIC STRESS

Flooding imposes severe selection pressure on plants, principally because excess water in the plant surroundings can deprive them of specific basic needs, notably of oxygen and of carbon dioxide and light for photosynthesis (Sakagami 2012). A few tolerant and improved agronomic rice lines for submerging conditions have been generated. The recent discovery of the *Submergence 1 (SUB1)* QTL that confers tolerance of complete submergence opens new hope further improved the rice varieties by transferring tolerance genes into semi-dwarf breeding lines using marker-assisted selection (Gonzaga et al. 2016).

Several new varieties have been released in South and Southeast Asia, with the higher yield of more than 1 ton/ha over the original rice varieties lacking the SUB1 QTL. Some breeding progress has been made for deep-water areas, and a few new lines with reasonable yield and grain quality have been released. Recently, three significant QTLs genes were identified for elongation ability, and two related genes were cloned, which will speed up the incorporation of tolerance into modern popular varieties through MABC. Progress has also been made in breeding varieties that can tolerate flooding during germination and early seedling growth. This trait is important for using direct seeding in rain-fed areas and also for weed control in irrigated areas, where shallow flooding after direct seeding could effectively suppress most rice weeds (www.knowledgebank.irri.org).

CO-DEVELOPMENT AND TRANFSER OF RICE TECHNOLOGY

Co-development of rice technology is a multi-country project which consists of the Indonesian Agency for Agriculture Research and Development (IAARD), Indonesia and other research organization in Southeast Asia countries including the Malaysian Agriculture Research and Development Institute (MARDI), Malaysia. The objective of this research activity depends on the significance of breeding programs targeted in Indonesia and Malaysia. Indonesia initiates on blast resistance for the breeding target, while Malaysia offers on BLB resistance and submergence as the breeding target, the activities on co-development of rice breeding consisted of activities such as development of the segregation population from selected parents, phenotypic evaluation for the target traits, genotypic analysis using molecular markers, and linkage analysis for segregate selection.

INDONESIA: BLAST RESISTANCE BREEDING PARENTS SELECTION

Anak Daro is the high yielding and popular local lowland rice variety originating from Solok, West Sumatra. Anak Daro has been continuously cultivated in the field in this area because of its profitable for farmers in Sumatera (Atman et al. 2011).

Donor parents using blast monogenic lines

Blast monogenic lines (MLs) like IRBL were developed as a set differential rice variety for identifying the specificity gene to gene reaction between race pathogen and resistance gene in the host plant (Tsunematsu et al. 2000). Blast MLs used in this activity have the genetic background of the japonica, susceptible variety, from China, Lijian-xintuan-heigu (LTH).

The MLs including IRBL-Kp, IRBL-ta2Re, IRBL- iF5 dan IRBL-aA possess blsat resistance up to the current season in Indonesian differential isolates. This indicated that these MLs were potential genetic materials for blast resistance varietal improvement in the breeding program.

The IRBLi-F5 has blast resistance gene, *Pii* from the donor plant, Fujisaka5 variety; IRBL-ta2Re has Pita2 gene from Reiho variety as the donor plant; IRBLkp-K60 has Pikp gene from the donor plant K60 variety, and IRBLa-A has Pia blast resistance gene coming from Aichiasahi variety as a donor plant (Yasuda et al. 2004). The genetic mapping of the fourth blast resistance gene(s), as shown in Figure 1.

Indonesia used IRBLaa and IRBLta carrying *Pia* and *Pita* gene, respectively, to improve a local variety originated West Sumatera, named Anak Daro. The F_2 populations derived from crosses were evaluated at blast endemic field area at Temanggung, Central Java. The diagrammatic cross scheme of these activities was shown in Figure 2.

Field evaluation of blast resistance

Description of local variety Anak Doro (SK No.73/Kpts/SR.120/2/2007) examined days of harvest of 135–145 days, and the yield potential reaches 6.40 ton/ha milled dry grains

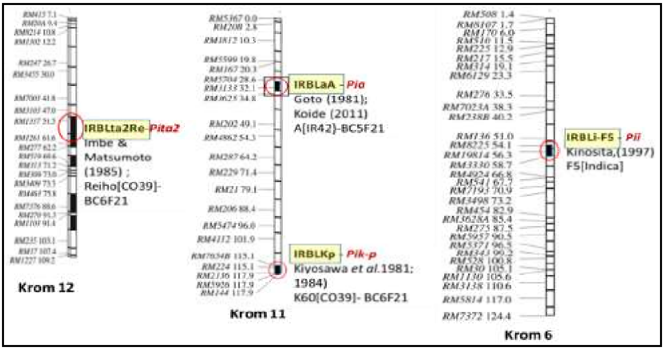

Figure 1. Genetic map of blast resistance gene(s) on MLs: *Pii* gene on chromosome 6, *Pia* and *Pik-p* on chromosome 11 and 12, respectively.

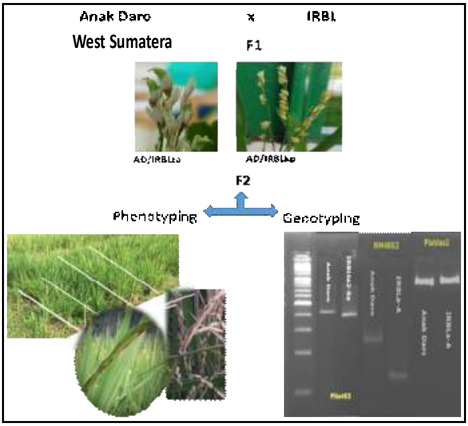

Figure 2. Developing of F_2 population derived from Anak Daro originating from West Sumatera) and IRBL (ta and aa) continued with blast endemic field phenotyping and genotyping selection, started by molecular parental survey.

with the average of production reach 5.65 ton/ha milled dry grains. The characteristic of this local rice is the height ranging of 105–121 cm, number of productive tillers of 20–27, number of seed per panicle of 165–225 dan thousand-grain weight of 22,.3 gram. Anak Daro is resistant to tungro virus t but susceptible to blast disease.

The population from cross between Anak Daro and the monogenic lines (IRBLta and IRBLa) produced the introgressed lines resistant to blast disease. One of the segregate populations from these progenies derived from the cross of Anak Daro and IRBLa is shown in Figure 3.

A total of 33 F_2 lines have positive introgression which has resistance to natural blast isolates in an endemic location in Central Java. These lines could be the candidate selected lines to be further use for the next crossing to re-current parent, Anak Daro for backcrossing, or selfing multiplication for developing inbred lines (Figure 3).

Genotypic performance based on specific molecular markers

DNA markers tightly-linked to target loci as a substitute for or to assist phenotypic screening. By determining the allele of a DNA marker, plants that possess particular genes or quantitative trait loci (QTL) may be identified based on their genotype rather than their phenotype (Jonah et al. 2011).

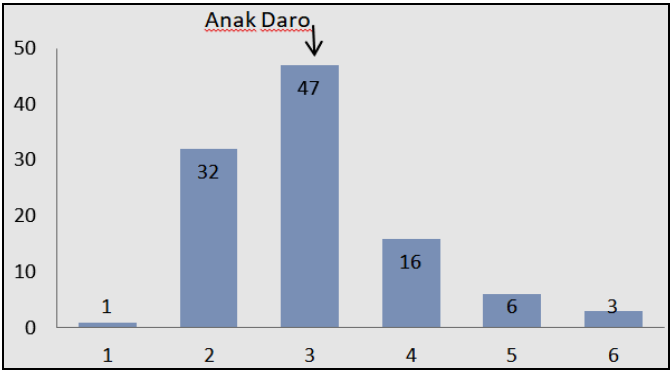

Figure 3. The F_2 population (Anak Daro/IRBLaa) segregation of blast resistance performance based on phenotypic data on blast endemic field test in Temanggung, Central Java.

For the selection of the segregate (Anak Daro/IRBL) population, genotyping analysis was developed by using the specific primers *Pita403* (F: CAATGCCGAGTGTGCAAAGG R: TCAGGTTGAAGATGCATAGC) and *Piablas2* F: TAAAAATGAGGTTGGGAGTC- R: GTTCTTAGCAATGATGTCCTC) to detect the genotype segregation (Fukuta et al. (2009). Genotyping the segregate population derived from crossing between Anak Daro (AD) and IRBLa (I-a) and IRBLta (I-ta) has been done to identify the introgressed lines which have 'AD' and 'I-a' or 'I-ta' genotype performance on F_2 population. One of the genotype performances using *Piablas 2* marker is presented in Figure 4.

Figure 4 showed that the genotype identification could select the lines harboring the IRBLa allele. This selection approach could combine by using the *background* marker to speed up the selection of the re-current genome profile. This approach had advantage of selection process in early generations because plants with undesirable gene combinations can be eliminated.

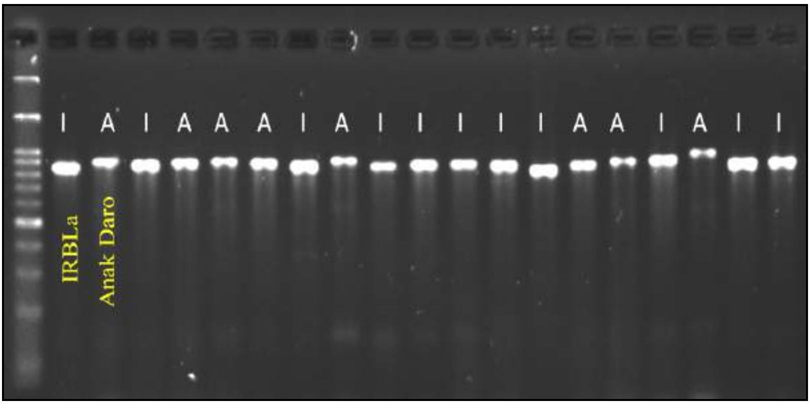

Figure 4. Genotype performance of F_2 population from crossing between Anak Daro as female parents and IRBLa as male/donor parents, using *Piablas2* marker. I: IRBLa allele type; A: Anak Daro allele type.

Linkage analysis for segregate target selection

Collard and Mackill (2008) reported the fundamental advantages of molecular marker application for selection (called marker assisted selection/MAS) compared to conventional phenotypic selection due its strength such as (i) simpler compared to phenotypic breeding, and (ii) selection may be carried out at breeding stage and single plants may be selected with high reliability. In this technique, linkage analysis required specific DNA markers and essential agronomic traits such as resistance to blast disease.

A rapid growth in genomics research has broadened minds to develop the genotype profile and the linkage analysis by using various kinds of genetic software. The data could be generated from functional genomics studies have led to the identification of many candidate genes for numerous traits. SNPs within candidate genes could be extremely useful for association mapping an, ultimately, MAS (Rafalski 2002; Flint-Garcia et al. 2003; Gupta et al. 2005; Breseghello and Sorrells 2006). This approach also circumvents the requirement for constructing linkage maps and performing QTL analysis for new genotypes that have not been previously mapped, although genotyping and phenotyping of segregating populations (e.g., BC_1, BC_2, F_2 or F_3) is recommended for marker validation (Breseghello and Sorrells 2006).

MALAYSIA: BLB RESISTANCE BREEDING

Malaysia used *Xa7* gene carried by IRBB7 to improve MR263. Six F_4 lines from the cross were selected during off season of 2018 based on good phenotypic score after inoculation with

Table 1. Selected lines of IRBB7xMR263 in off season of 2018

Crosses	Generation
IRBB7/MR263-166	F4
IRBB7/MR263-173	F4
IRBB7/MR263-173	F4
IRBB7/MR263-178	F4
IRBB7/MR263-178	F4
IRBB7/MR263-178	F4

Xanthomonas oryzae at 50–60 DAT and positive *Xa7* gene identification via genotyping (Table 1).

MALAYSIA: SUBMERGENCE TOLERANCE BREEDING

Improvement of the varieties for abiotic stress tolerance was carried out by Malaysia. The development of a local variety called MR 253 tolerant to the submerged condition was carried out by the introgression *sub-1* gene from Swarna variety. The generation of BC_3F_2 is being evaluated on the main season of 2018/2019.

CONCLUSIONS

The co-development on breeding technology in Indonesia and Malaysia have been developed on the target of molecular assisted rice breeding (MAB) purposes. To accomplish the target of MAS and to date, the impact on variety development is imperative that there should be greater integration with breeding programs and that current barriers are well understood, and appropriate solutions developed. The exploitation of the advantages of MAS relative to conventional breeding could have a significant impact on crop improvement.

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CHARACTERIZATION AND POTENTIAL DEVELOPMENT OF SIAM EPANG LOCAL RICE VARIETY IN CENTRAL KALIMANTAN

Susilawati

INTRODUCTION

East Kotawaringin is one of the regencies in Central Kalimantan that rich in a diverse range of plant genetic resources, including local rice varieties. One of the popular local rice varieties in its origin area and other areas in Central Kalimantan is *Siam Epang*. *Siam Epang* has been registered at the Center for Plant Variety and Agricultural Licensing, Ministry of Agriculture, since 2011, with the registration number of 28/PVL/2011. In 2018, *Siam Epang* variety was released as a superior rice variety according to the Ministry of Agriculture with Decree number 2047/HK.540/C/11/2018 as local tidal swamp rice. Also, *Siam Epang* was registered internationally with the DOI register of 10.18730/J7ZF5. Since *Siam Epang* variety is also known as upland rice, then also it is potentially adapted to a rain-fed land ecosystem (Kemtan 2011, 2018).

Siam Epang originated from sub-district of Teluk Sampit in East Kotawaringin. Nearly 95% of the agricultural land in this sub-district is planted with *Siam Epang* variety, with a total planting area currently reaching 11,000 ha. This variety is resistant to several pests and diseases, easy to maintain and well adapt to extreme environments such as low acidity (pH), resistance to high rainfall, and efficiently use inorganic fertilizers (Rasijo 2018). *Siam Epang* cultivation is cultivated as modern rice varieties, i.e. by sowing and transplanting or direct seeding. Inorganic fertilizer is applied equally to modern rice cultivation, 100 kg urea/ha, 75 kg SP36, and 50 kg KCl per ha, eventhough local rice is generally less responsive to fertilization (Susilawati et al. 2012, 2015).

In its native area, the *Siam Epang* local rice variety is planted in the rainy season, October to March, or the at same period to the time planting season of modern rice in other areas in Central Kalimantan. While, in some areas, local rice varieties are generally planted in the dry season, April to September. There is tremendous support of the local government incentives to develop *Siam Epang*. The support includes the registration of and the releasing of *Siam Epang* variety, the policy to purchase of *Siam Epang* rice for government employees, and the establishment of local government funds for increase Siam Empang production. As consequence, the farming fields and rice production of *Siam Epang* continue to increase every year.

This paper discusses the efforts to protect local genetic resources and policies on developing local rice varieties of *Siam Epang*. The steps taken in the context of germplasm conservation and its development in sub-optimal land are also outlined based on a review of the results of studies, literature review, and field experiences.

CHARACTERIZATION OF *SIAM EPANG* LOCAL RICE VARIETY

At present, the number of local rice varieties in Indonesia is decreasing. Only in certain regions, local farmers still planted the rice varieties, including in Central Kalimantan (Silitonga 2004). Genetic erosion of local rice varieties will be increased if existing local rice varieties have not been conserved (Hawkes 2000; Hairmansis et al. 2005; Sitaresmi et al. 2013). The *Siam Epang* local rice variety, which has been cultivated in East Kotawaringin Regency, is one of the local rice varieties which still exist. *Siam Epang* rice variety has various advantages, such as able to adapt in sub-optimal lands, suitable for planting in the tidal area and also can grow in the soil with minimal water like on rainfed land (Susilawati et al. 2015). Rice varieties with a high tolerance to water stress will be quickly selected by farmers, while the yield potential is relatively low. Adaptation of rice varieties is a major factor in tidal land, so that the superior variety can be adopted by farmers (Rina and Koesrini 2016). In addition to good adaptability in the tidal swampland, *Siam Epang* variety has a high potential yield, good consumer preferences, and market demand. Those advantages influenced the sustainability of the rice variety in swamps (Roel et al. 2007). Some characters of *Siam Epang* are shown in (Table 1 and Table 2).

In the development of local rice, it is explained that local rice varieties that have not undergone purification are not uniform in appearance, because the population is heterozygous. Such local rice varieties have genetic characteristics with several different attributes, suggesting that their agronomic appearance is not uniform like superior varieties (Sitaresmi et al. 2013). The *Siam Epang* is a rice plant that is classified into sativa species. Domestication of *Oryza sativa* species has formed a population of rice genotypes that are very diverse and differ from one

Table 1. The character of *Siam Epang* local rice variety from East Kotawaringin regency.

Character		Value
Plant height (cm)	:	110–130
Number of the tiller (tiller)	:	30–50
Number of filled grains per panicle (btr)	:	229
Number of empty grains per panicle (btr)	:	30
Age of harvest (days)	:	135–140
Weight of 1000 grains (g)	:	17
Production (ton/ha)	:	6,0
Resistance to plant harmful organism:	:	
WBC Biotype 1	:	Moderate susceptible
WBC Biotype 2	:	Moderate susceptible
WBC Biotype 3	:	A little susceptible
HDB Strain III	:	A little susceptible
HDB Strain IV	:	Susceptible
HDB Strain VIII	:	Susceptible
Blas Race 033	:	Susceptible
Blas Race 073	:	Susceptible
Blas Race 133	:	Susceptible
Blas Race 173	:	Moderate tolerant
Blight disease/Tungro	:	Tolerant
Tolerant of Fe	:	Susceptible
Tolerant of Al	:	Susceptible

production center to another (Nafisah et al. 2007). In cultivation crops systems intensively, the use of less pure varieties is not recommended, because their crop management complicates. Therefore, it is necessary to strive for the process of pure lines selection to extract components of the formation of local varieties with mature age uniformity.

Further, the ability to form puppies, the amount of grain per panicle, and the high fertility of panicles, can be improved. The selection of a number of these characters in the components forming local varieties with pure genotype/line of microbe for selection techniques is expected to enhance the appearance of the

Table 2. Characters of grain and quality of rice of *Siam Epang*.

Quality Variable		Value
Rice moisture content (%)	:	11.40
Broken skin yield (%)	:	75.87
Milled rice yield (%)	:	62.01
Rice head (%)	:	68.00
Broken rice (%)	:	36.56
Chalky grain (%)	:	0.008
Broken skin grains (%)	:	1.46
Grain length (mm)	:	5.45
Grain width (mm)	:	2.22
P/L ratio	:	2.45
Amylose content (%)	:	23.25
Gel consistency	:	Medium
Rice texture	:	Crumb
Protein content (%)	:	7.10

resulting lines. The best genotype is expected to have better productivity compared to the local varieties of origin.

POTENTIAL AND SUPPORT FOR DEVELOPMENT OF *SIAM EPANG*

Siam Epang local rice variety is a specific swamp rice variety. The plant has been cultivated in Subdistrict Teluk Sampit, Cental Kalimantan, such as Parebok, Besawang, Regei Lestari, Kuin Permai, Lampuyang, and Ujung Pandaran villages. The cultivation of the variety covered 95% of the potential land area in the district around 11,000 ha. Besides having high adaptability, the *Siam Epang* variety is also adaptive in the land with extreme conditions, both high acidity or low soil and water pH (Shimono et al. 2007). Other factors that also determine community preferences for rice varieties in swamps are high yield potential, market demand, plant age, plant height, and pest and disease resistance (Tahir et al. 2002; Rina and Koesrini 2014). *Siam Epang* rice variety produces around 30–50 productive tillers and panicles. One panicle contains ±437 seeds, thus *Siam Epang* productivity reaches 7 ton/ha. This high yielding potential is the main focus in the selection of rice varieties by farmers. The rice variety is very beneficial for increasing rice production in the tidal swamp of Central Kalimantan because local tidal rice, only produces 1.0–1.2 ton/ha on new open land and 2.0–2.8 ton/ha on existing land (Susilawati et al. 2014).

On the other hand, the program of achieving self-sufficiency in food by increasing production and increasing the area of rice planting, encouraged the use of superior and high-quality and certified varieties (Ruskandar et al. 2008). The program is in contrast to promote the cultivation of local rice varieties, such as *Siam Epang*. Therefore, some improvements in yield productivity are needed for this local rice variety to meet internal and external needs. *Siam Empang* is registered in the Center for Plant Variety Protection and Agricultural Licensing in 2011 with a certificate of registration number 28/PVL/2011. Following the registration, the local government supports through the Agriculture Office of East Kotawaringin Regency to expand planting areas of *Siam Epang*. Total areas of *Siam Epang* in 2011 was around 13,000 ha and increased to approximately 25,000 ha in 2016 (Dinas Pertanian Kabupaten Kotawaringin Timur 2018) (Figure 1).

With the rapid development of planting area and high market demand for rice *Siam Epang*, since 2013, the East Kotawaringin Regency Government through the Department of Agriculture has re-registered the purification and release of *Siam Epang* varieties. The objectives are: 1) to obtain legality that the local rice varieties of Siam Epang deserve to be regionally superior varieties suitable for site-specific; 2) to get legality for the effort to produce certified seeds from *Siam Epang* varieties; 3) to obtain equal rights in the

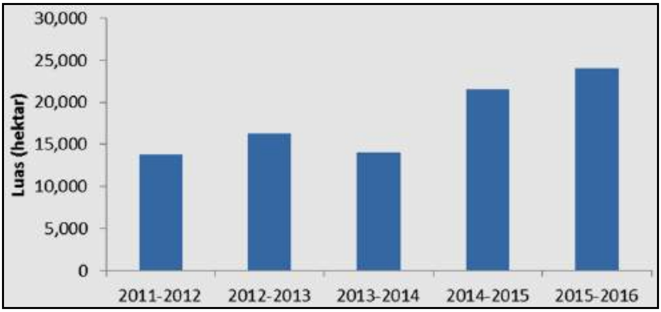

Figure 1. The planting area of local rice variety of *Siam Epang* in Kotawaringin Timur, Central Kalimantan in 2011–2016.

use of quality seeds from local rice varieties of *Siam Epang* as well as superior rice varieties released by the government, and 4) to increase the benefits and economic value of local variety seeds for the community and local government (Dinas Pertanian Kabupaten Kotawaringin Timur 2018). Therefore, in 2018, the *Siam Epang* variety was released as a superior rice variety according to the Ministry of Agriculture with Decree Number 2047/HK.540/C/11/2018. In the same year, the Central Kalimantan Assessment Institute for Agriculture Technology carried out international registration through Digital Object Identifier with DOI register number: 10.18730/J7ZF5 (Susilawati and Sabran 2019).

Another support from the local government to promote the use of *Siam Epang* is the existence of a policy from the local government to allow the State Civil Apparatus (civil servants) to buy *Siam Epang* rice, which is a minimal package at 5 kg. In the case of seed and rice production through the Agriculture Office of East Kotawaringin district, a package of rice has been made, which is then carried out by the Geographical Indications, which are registered with the Ministry of Law and Human Rights (Figure 2). Collaborative efforts are made with the Production Seed Central of Central Kalimantan Province, to obtain

Figure 2. The commercial package of *Siam Epang* rice (left) and delivery of *Siam Epang* rice package for a public servant in Kotawaringin Timur (right).

BS/Breeder Seed/Yellow Label seeds), i.e., seeds produced by and under the supervision of the relevant Plant Breeders or their Institutions. This seed is the source of propagation of Basic Seeds. Basic Seed/BD (FS/Foundation Seed/white Label), i.e., the first offspring of the *Penjenis Seed*. The BS seeds are produced under intensive guidance and close supervision, in order to get the purity of varieties to be maintained by the Agency/Agency appointed by the Directorate General of Food Crops. The Seed Supervision and Certification Agency certify the BS seed produced. Then, Staple Seed (SS/Stock Seed/Purple Label) is produced from the BS seeds and certified by the Supervisory Office and Seed Certification. Seed dispersal (ES/Extension Seed/Blue Label) is a descendant of the main seed produced and maintained in such a way that the identity and level of purity of the variety can also be maintained and meet the quality standards. Therefoe the seeds must be certified as scattered seed by the Seed Supervision and Certification Center (Mulsanti and Wahyuni 2010; Mulsanti et al. 2014).

CONCLUSIONS

Siam Epang, originated from Kotawaringin Timur district, is tolerant in sub-optimal land and has a high potential yield of 6.0–7.0 ton/ha and is equivalent to superior rice productivity, indicating its potential to increased productivity in suppor of food self-sufficiency. The agronomic characters of *Siam Epang* include plant height ranging of 110–130 cm, the number of productive tillers of 30–50 tillers, and the number of grains per panicle of 292–450 seeds, tolerant of Al toxicity, moderately tolerant of Fe toxicity, and resistant to brown planthopper biotypes 2 and 3.

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ADAPTABILITY OF INPARA RICE VARIETIES IN TIDAL SWAMPLAND SOUTH KALIMANTAN

Koesrini, Wahida Annisa Yusuf, and Yanti Rina Darsani

INTRODUCTION

Tidal swampland is the land that naturally frequent flooding in the year. Tidal swampland is marginal land with considerable potentials for rice farming. The total area of tidal swampland in Indonesia is about 20.1 million hectares. Approximately 9.5 million hectares of tidal swampland have potential to agriculture, but only 2.27 million hectares have been reclaimed (Nursyamsi and Noor 2014). The contribution of rice production from tidal swampland is still low, estimated at 600–700 thousand ton/year or about 1.5% from the national rice production of 62.56 million tons (ICALRRD 2011).

Local rice variety is an adaptive indigenous plant and widely planted by farmers in tidal swampland. Nearly 90% of rice fields in the tidal swampland are planted with local rice variety. This local rice variety is preferred to be grown because of its adaptation to waterlogged conditions and its rice texture. However, the local rice has late maturity (8–10 months) with low productivity (2.0–2.5 ton/ha) (Koesrini et al. 2014). Low rice productivity in tidal swampland is due to biophysical conditions and socio-economic constraints. The main constrain in the tidal swampland are nutrient and water management which need specific effort, as well as the use of less adaptive rice varieties.

The main constraints of tidal swampland were high soil acidity, nutrient deficiency, iron toxicity, and water stress, that can limit rice development. Iron toxicity can reduce rice yield ranging 30–60% (Majerus et al. 2007), particularly some less tolerant varieties can effect yield loss higher (75%) in comparison to that on tolerant varieties (30%) (Virmani 1977). Koesrini et al. (2014) reported that high soil acidity and iron toxicity harmed plant growth and yield. The average yield of such rice varieties was only 3–4 ton/ha, lower than their yield potential, which reaches 5.0–7.6 ton/ha (ICRR 2018). Introducing an adaptable rice variety can expectedely increase yield in tidal swampland.

Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture has released adaptive rice varieties for tidal swampland, called Inpara (inbred swamp rice). Ten Inpara varieties have been released, namely, Inpara 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 (ICRR 2018), and each variety has specific characteristics both in terms of morphology and its adaptability. This review paper aims to discuss the performance and adaptation of Inpara rice variety in tidal swampland.

TIDAL SWAMPLAND CONSTRAINTS FOR RICE CULTIVATION

Local rice and high yielding variety suitable for tidal swampland have been developed and its economic value expectedly can increase the farmer's income. The main problems in tidal swampland are biophysical conditions, biological, and socio-economic constraints. For this reason, through a specific program namely "Save swampy land farmers' welfare program" (named SERASI), the government provided support to improve the facilities and infrastructure. It is well known that tidal swampland has very high soil and water acidity, macro (P, K) and micro (Zn, Cu, Bo) nutrients deficiency, high iron (Fe), sulfate (SO_4) and hydrogen sulfide (H_2S) content which are toxic to plants (Alihamsyah and Noor 2003). The high soil acidity and Fe toxicity in the tidal swampland could be minimized by liming. The main biological obstacles that attack rice crops are pests, disease, and weeds. Integrated pest management can control pests and diseases through environmental sanitation, proper cultivation management, synchronous planting time, using resistant varieties, and proper pesticides application. The main pests that attack rice plantations are commonly rats, white rice stem borer, leaf folding pests, brown planthopper, and green leafhopper, while the major diseases in this rice plant are blast and virus tungro disease (Thamrin et al. 2014). Pest and disease attack depends on weather conditions, especially rainfall, environmental sanitation, and cultivation management by farmers. Weed have been managed by manual control/hand weeding or with herbicides to avoid competing nutrients with rice.

Socio-economic constraints on tidal swamplands are related to labor, limited capital, and supporting facilities/infrastructure. The common cultivated land area of farmers is less approximately 1.93 ha/household (Rina and Koesrini 2018), and limited labor to help land owner, and limited farmers’ capital. Moreover, farmers' organizations are not able to engage all supporting parties to work optimally. This condition mainly causes many lands fallow and becomes forest again because of the natural succession process (Noorginayuwati and Rina 2003). Another social problem is low technology adoption, and farmers, in general, will adopt a new technology that has a real impact on increasing rice productivity.

CHARACTERISTICS OF INPARA VARIETIES

Inpara or inbred swamp rice are varieties that are developed for tidal swamplans. Inpara varieties that have been released until 2018, namely Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 5, Inpara 6, Inpara 7, Inpara 8, Inpara 9, and Inpara 10 (ICRR 2018). Inpara 1, 2, 3, 6, 7, 8, 9, and 10 varieties are developed from lines developed from crossing or rice varieties with superior characteristics, while Inpara 4 and 5 varieties are introduced from IRRI that have excellent adaptability in swamplands. Descriptions of Inpara varieties are listed in Appendix Table 1.

PERFORMANCE OF INPARA VARIETIES

All Inpara varieties have the upright plant shape like other superior/improved varieties. Its plant height is less than 110 cm which is classified as semi-dwarf based on description criteria from IRRI (2014). The number of productive tillers is between 12–18 tillers/clumps. Inpara varieties 4, 6, 8, 9, and 10 are relatively

Table 1. Soil properties in actual acid sulfate soil and potential acid soil.

Soil properties	Tidal swampland		
	Actual type C overflow **	Potential type B overflow ***	Potential type C overflow ****
pH H_2O	3.99	4.62	5.3
Organic-C (%)	3.71	5.73	4,31
Total-N (%)	0.38	0.46	0.31
P-Bray 1 (ppm P)	13.76	10.83	38.94
Exchangeable Ca*	0.36	1.49	2.19
Exchangeable Mg*	0.89	1.22	12.30
Exchangeable K*	0.25	0.15	0.44
Exchangeable Na*	0.41	0.39	-
KTK*	51.8	53.40	-
Fe^{2+} (ppm)	181.89	439.56	149.89

Note: *($Cmol^{(+)}/kg$) **Koesrini et al (2018); ***Koesrini et al (2017); ****Alwi et al (2018).

resistant to lodging, while other Inpara varieties are grouped as moderate. Some varieties performances in the generative phase was demonstrated by the simultaneous formation of panicles and seed filling (Figure 1). The upright figures of some Inpara varieties are mostly contributed by the flag leaves which are in the upright position, thus covering the panicles formed. All Inpara varieties have resistance to Fe toxicity, except for Inpara 4 and 5 varieties, but the two are resistant to waterlogging (Suprihatno et al. 2010).

Potential yields of Inpara varieties are, on average above 5 ton/ha so that they are prospectively developed in their areas adaptive to their growth. Days to maturity of Inpara varieties are commonly shorter than that of local rice variety, i.e., 6–9 months. There are five criteria for rice age, namely late maturity (>165 days), medium maturity (125–164 days), early maturity (105–124 days), very early maturity (90–104 days), and ultra-early maturity (<90 days). Based on these criteria, Inpara 5, 6, 7, 8, and 9 are classified as early maturing varieties, while Inpara 1, 2, 3, 4, and 10 are classified as medium maturing varieties (Figure 2).

Figure 1. Performance of Inpara varieties in generative phase grown in swampland (Source: Koesrini 2016).

PERFORMANCE OF GRAIN/RICE AND RICE TEXTURE

There are two types of rice grain to group rice varieties, i.e., a medium grain (Inpara 1, 2, 4, 6, 8), and slim grain (Inpara 3, 5, 7, 9, and 10). Farmers or local consumers generally prefer a slim-grain shape and "pera"/less fluffy rice texture. Ningsih and Khairatun (2013) also reported that farmers in the tidal swampland majority preferred varieties with slim grain and "pera"/less fluffy rice texture. Rice texture is determined by amylose content which can be categoried in several groups. Rice with 0–10% amylose (very low amylose), 10–20% (low amylose), 20–25% (medium amylose), and >25% (high amylose) represented the stickiness level from high to low, respectively (Juliano 1993 *in* Suprihatno et al. 2010). Based on these criteria, the taste of Inpara 1, 3, 4, 5, 8 and 9 rice is classified as less fluffy, Inpara 2, 6 and 10 are medium; whereas Inpara 7 is classified fluffier (Figure 3).

ADAPTATION OF INPARA VARIETIES IN TIDAL SWAMPLAND

Inpara varieties have a good adaptation in swamplands, but not all Inpara varieties are recommended to be planted in the swampland. Adaptation assay in tidal swamplands in particular, potential acid sulfates and actual acid sulfates, indicate that the adaptability and performance of Inpara varieties depends on soil

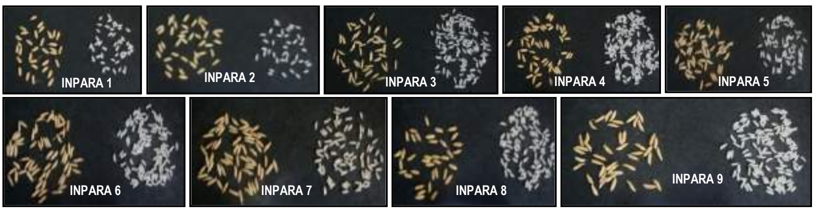

Figure 3. Performance of Inpara varieties of grain and rice. (Source: Koesrini 2016).

fertility. The biophysical condition of real acid sulfate land is generally lower than that of potential acid sulfate land (Table 1).

The actual acid sulfate field mainly has a overflow type C overflow, where the effects of tides do not reach the land. The main water source is rainwater. Inpara's productivity variety is only 1.93 ton/ha milled dry grain (DMG) (Koesrini et al. 2018). In general, biophysical conditions of potential acid sulfate sites are better than actual acid sulfate fields. The case of study in Mandastana-Barito Kuala Regency typology of potential acid sulfate land with type B showed that the area is only affected by huge tides. Inpara's productivity varieties are higher (around 3.21 ton/ha DMG) than those in acid sulfate fields in Barambai, which only produce 1.95 ton/ha DMG (Koesrini et al. 2018). However, in potential acidic land with a overflow type C, such as in Paloh-Sambas Regency, the Inpara's productivity reaches 3.84 ton/ha DMG (Alwi et al. 2018) as presented in Table 2. Soil fertility influences the plant adaptation and grain yield in tidal swamplands.

Table 1. Soil properties in actual acid sulfate soil and potential acid soil.

Soil properties	Tidal swampland		
	Actual type C overflow**	Potential type B overflow***	Potential type C overflow****
pH H_2O	3.99	4.62	5.3
Organic-C (%)	3.71	5.73	4,31
Total-N (%)	0.38	0.46	0.31
P-Bray 1 (ppm P)	13.76	10.83	38.94
Exchangeable Ca*	0.36	1.49	2.19
Exchangeable Mg*	0.89	1.22	12.30
Exchangeable K*	0.25	0.15	0.44
Exchangeable Na*	0.41	0.39	-
KTK*	51.8	53.40	-
Fe^{2+} (ppm)	181.89	439.56	149.89

Note: *(Cmol$^{(+)}$/kg) **Koesrini et al (2018); ***Koesrini et al (2017); ****Alwi et al (2018).

Table 2. Average yield of Inpara varieties in actual and potential tidal swampland located in South Kalimantan and West Kalimantan.

Varieties	Tidal swampland			Mean yield (ton/ha)
	Actual overflow type C*	Potential overflow type B**	Potential overflow type C***	
Inpara 1	2.53	2.54	5.39	3.49
Inpara 2	2.12	2.73	4.00	2.95
Inpara 3	1.43	3.70	3.31	2.81
Inpara 4	2.82	4.30	3.47	3.53
Inpara 5	1.26	2.34	-	1.80
Inpara 6	2.18	3.83	3.79	3.27
Inpara 7	2.15	2.40	-	2.28
Inpara 8	1.33	3.60	3.84	2.92
Inpara 9	1.52	3.48	3.09	2.70
Mean yield (ton/ha)	1.93	3.21	3.84	2.99

Source: *Koesrini et al (2018); **Koesrini et al (2017); ***Alwi et al (2018).

Adaptation and performance of Inpara varieties are strongly influenced by land typology and soil fertility. The results of adaptation assay in 3 locations of tidal swamps are listed in Table 2. Among the Inpara varieties tested, only Inpara 5 produced <2 ton/ha, the other Inpara varieties produced >2 ton/ha. Inpara 5 variety is not recommended to be grown in tidal swampland, because of its sensitive to iron toxicity. Inpara 1 and Inpara 4 varieties produced >3 ton/ha, but the two rice varieties are not suggested for further cultivation in the tidal swampland due to their late maturity. Inpara varieties that have been further cultivated and adopted by farmers are Inpara 2 and Inpara 3 in tidal swampland of South Kalimantan.

CONCLUSIONS

The capability of Inpara rice varieties in tidal swampland varied according to their genetic backround. Most of Inpara varieties are adaptable in the swampland agroecosystem, except Inpara 5 because of its susceptibility to iron toxicity. Inpara 2 and Inpara 3 are preferreable by farmers in tidal swampland of South Kalimantan. Further studies are needed to improve the productivity of Inpara varieties in the tidal swampland.

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Appendix Table 1. Descriptions of rice Inpara varieties

Characteristics	Varieties									
	Inpara 1	Inpara 2	Inpara 3	Inpara 4	Inpara 5	Inpara 6	Inpara 7	Inpara 8	Inpara 9	Inpara 10
Origin of selection	Batang Ombilin/IR9884-54-3	Pucuk/ Cisanggarung/Sita	IR69256/IR43524-55-1-3-2	Introduksi dari IRRI	Introduksi dari IRRI	IR64/IRBB21/ IR51672	Bio 12/beras merah	B10597F-KN-18/B10600F-KN-7	Mesir/IR60080-23	B13100-2-MR-3-KY-3
Plant age (days)	131	128	127	135	115	117	114	115	114	126
Plant shape	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright
Plant height (cm)	111	103	108	94	92	99	88	107	107	101
Productive tillers	18	16	17	18	18	13	12	-	-	
Lodging	Medium	Medium	Medium	Resistant	Medium	Resistant	Medium-Resistant	Resistant	Resistant	Resistant
Loss	Medium		Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Grain shape	Medium	Medium	Slim	Medium	Slim	Medium	Slim	Medium	Slim	Slim
Rice texture	Less fluffy	Medium	Less fluffy	Less fluffy	Less fluffy	Medium	Fluffier	Less fluffy	Less fluffy	Medium
Amilosa content (%)	27,9	22,1	28,6	29	25,2	24,0	20,0	28,5	25,2	24,9
Glycemic index	-	-	59,2	50,9	59	-	-	-	-	-
Weight 1000 grains (g)	23,3	25,6	25,7	19,5	25	26	24	27,2	25,2	26,3
Mean yield (ton/ha)	5,0	5,1	4,6	4,7	4,5	4,7	4,5	4,7	4,2	5,0
Potential yield (ton/ha)	6,47	6,08	5,6	7,6	7,2	6,0	5,1	6,0	5,6	6,8
Resistance to abiotic stress	Fe and Al toxicity tolerant	Fe and Al toxicity tolerant	Fe and Al toxicity tolerant, and 6 days immertion tolerant during the vegetative phase	14 days immertion tolerant during the vegetative phase	14 days immertion tolerant during the vegetative phase	Fe toxicity tolerant	Moderate Fe and Al toxicity tolerant	Fe toxicity tolerant	Fe toxicity tolerant	Fe toxicity tolerant
Recommended planting	Tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland, freshwater swamp, and irigation	Tidal swampland, freshwater swamp and rice fields prone to flooding	Tidal swampland, freshwater swamp and rice fields prone to flooding	Potential tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland, freshwater swamp	Tidal swampland, freshwater swamp
Plant breeder	Bambang Kustianto et al.	Bambang Kustianto et al.	Hamdan Pane et al.	D.J. Mackill et al.	D.J. Mackill et al.	A.Hairmansis et al.	Suwarno et al.	Suwarno et al.	Suwarno et al.	Indrastuti et al.
Released year	2008	2008	2008	2008	2010	2010	2012	2014	2014	2018

Sumber: Suprihatno et al. (2010) and Info ICRR (2014).

THE IMPORTANCE OF DIVERSE LOCAL RICE VARIETIES FROM BALI ISLAND FOR CROP IMPROVEMENT

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I Gusti Komang Dana Arsana, and Puji Lestari

INTRODUCTION

Rice (*Oryza sativa* L.) is the main staple food which becomes an essential for more than half of the world's population and influences the economic growth of several countries (IRRI 2006). It is also the most important food crop in the world and popularly called 'global grain' due to its ability to adapt to a wide range of environmental conditions (Skaria, Sen and Muneer 2011). Approximately 90% of the world's rice is cultivated in the Asia region, and most of it is consumed daily (Seck et al. 2012). In Southeast Asia, rice also plays anessential role in the agrarian system and livelihoods of a majority of farmers which are being a leading user of land and water resources, and used heavily in local cultures and traditions (Choices et al. 2014).

Local or landrace variety is defined as a traditional variety that has historical origin, distinctive identity and lacks formal crop improvement as well as often being genetically diverse, adapte to local environmental conditions and associated with conventional farming systems (Villa et al. 2006; Berg 2015). Landraces have played a fundamental role in the history of crops worldwide, in crop improvement and agricultural production, and they have been existed since the origins of agriculture itself. For centuries, landraces crops were the main focus for agricultural production (Harlan 1975a). Landrace comprising a domesticated and locally adapted or traditional variety (Villa et al. 2006) has been developed over time, through adaptation to its natural and cultural environment of agriculture, and due to isolation from other populations (Sponenberg 2000).

Crop improvement often utilizes landrace diversity in the development of new variety, particularly when developing new rice variety for marginal environments. Local genetic resources diversity is attributable in the development of new superior rice variety, particularly for high adaption in marginal environments (Frankel and Soule' 1981). Harlan (1975) reports that local rice varieties are balanced populations in the environment and genetically dynamic. Local rice varieties might have probably unique genetic characteristics that are potential to be developed for early maturity, adaptive to marginal soil conditions, resistance to pests and diseases, and tolerant to abiotic stresses (Das et al. 2013; Sitaresmi et al. 2013). Local varieties with superior characteristics need to be preserved as assets of national genetic resources and utilized in breeding programs.

Indonesia is prosperous with rice germplasm, which benefits as genetic resources, consisting of local varieties and wild species (Sitaresmi et al. 2013). The country has a long history of rice production across a broad range of rice-growing environments (Van der Kroef 1952), resulting in a diverse array of local rice varieties. Indonesian archipelago was an integral part of the Asia continent, which is considered as the center of origin of rice. Vavilov (1926) postulated that India is the center of origin of rice, and Indonesia could be considered as the secondary center of origin of rice. Thelocal rice has been planted and preserved by indigenous farmers in Indonesia including Bali island for many generations on specific agroecology to the commercial variety developed during the green revolution. Indigenous farmers had selected seeds from the population, based on good adaptation and good grain quality for the next growing season. Therefore, most of the local varieties have a good grain quality, and their taste quality met the local consumers' preference (Sitaresmi et al. 2013).

Many studies have known identified local rice varieties in Indonesia that are resistant/tolerant to biotic and abiotic stresses (Abdullah 2006) and have been used in the breeding program. However, the number of germplasm used as parental lines is still quite low. Research on genetic diversity, gene analyses, gene mapping, and gene inheritance is needed to facilitate the efficient use of genetic resources. Use of local varieties as parental hybridization is recommended, to get superior specific genotype on the new rice varieties, therefore, the released varieties of rice should have a broad genetic variability (Putu and Aryana 2009). Rice breeding using local varieties as donors with its specific superior characters could targeted to increase rice varieties in specific locallity (Sitaresmi et al. 2013).

This review discussed the potential of the local rice varietiesfrom Bali island for rice crop improvement programs in Indonesia. An effort was made to address the diversity of local rice varieties, mainly from Bali island, on specific traits or characteristics that can be utilized through plant breeding programs for genetic improvement. It is necessary to exploit the genetic diversity of local rice varieties from Bali to achieve sustainable production in the future.

GENETIC DIVERSITY OF LOCAL RICE VARIETIES FROM BALI

Bali is one of the leading rice-producing areas in Indonesia. Bali, along with Java provinces, contributes to 22% of the total rice production in Indonesia (Naylor et al. 2007). Bali island is bestowed with lush green fields and around 150 rivers and streams with facilitating the irrigation of rice fields. Rice and Bali have been going hand in hand over a thousand years, making it a staple food in Bali as well as a symbol of life and culture of Balinese people. Rice production has remained very dynamic in Bali since the 11th century, making Indonesia the highest rice yielding country (Secrets 2018).

Breeding success in crops is strongly related to the genetic variation of the available genetic materials. Therefore, an understanding of genetic diversity is a prerequisite for crop genetic improvement (Xiao et al. 2012). The genetic variability found within local varieties affords the possibility of genetic flexibility. Local varieties have the potential to adapt to local field conditions, changing environments, and climate changes (Frankel and Bennett 1970; McCouch 2004). Moreover, the genetic diversity of local varieties is the most immediately useful and economically valuable component of rice biodiversity (Wood and Lenné 1997). A better understanding of the structure, apportionment, and dynamics of local genetic resources, diversity in rice varieties is required (Fukuoka et al. 2006). Bali island is also known to have highly diverse rice germplasm, thus the local rice varieties belonging to the region are expected to have high genetic variability for many biotic and abiotic stresses.

In 2013, Assessment Institute for Agricultural Technology (AITA) of Bali started to inventory and characterized local rice germplasm that spread across Bali island. Until 2019, as many as 20 local rice accessions from Bali have been explored and characterized (Table 1). The morpho-agronomical characters of rice varieties has been well known based on recommended descriptors (IRRI 1996). These characters included the leaf pubescence, flag leaf position, collar color, leaf auricle color, leaf node color, leaf sheath color, leaf midrib color, leaf ligule color, leaf length, leaf width, culm color, culm strength, panicle type, panicle length, sterile lemma, lemma and palea color, sterile lemma color, the awn color, pericarp color, anther and stigma color, group variety, days to flowering, days to maturity/harvest, number of tillers, plant height, habitus, and yield loss. Evaluation of specific characteristics such as amylose content, resistance to biotic stresses, and tolerance to abiotic stresses, however were limited.

Table 1. Local rice varieties from Bali island*.

Variety	District	Rice color
Injin Pupuan	Tabanan	White
Kerotok Pupuan	Tabanan	White
Ketan Tahun Pupuan	Tabanan	White
Mansur Pupuan	Tabanan	White
Taun Barak Pupuan	Tabanan	Red
Taun Putih Pupuan	Tabanan	White
Ijo Gading	Tabanan	White
Cicih Suar	Tabanan	White
Cicih Merah	Tabanan	Red
Merah Cendana	Tabanan	Red
Injin Sambangan	Buleleng	Black
Taun Putih Sambangan	Buleleng	White
Beras Merah Munduk	Buleleng	Red
Cicih Gundil	Buleleng	White
Gondrong Sudaji	Buleleng	White
Ketan Gundil Sudaji	Buleleng	White
Gogo Susut	Bangli	White
Ingse Barak	Karangasem	White
Ingse Putih	Karangasem	White
Ingse Merah Selat	Karangasem	Red

*www.bali.litbang.pertanian.go.id.

The diversity of local rice varieties also can be seen from various seed pericarp color, which are not only white but also red and black (Table 1). The differences in colors in the rice are due to the different deposition of anthocyanin pigment in the rice coat (Chaudary 2003). Black and red rice are becoming popular not only for the development of functional foods, but also due to the genetic variability of cultivars which causes diverse pigmentation, nutrition value, and phytochemical properties (Pratiwi and Purwestri 2017). White rice is the most consumed rice, but pigmented rice such as Cicih Merah, Merah Cendana, Ingse Merah Selat, and Injin Sambangan are considered as functional rice useful for the health in term of taste, nutrient and anthocyanin content. Cicih Merah, the sweet and creamy aroma local rice, had high amylose content with soft texture of cooked rice in cold conditions (Indrasari et al. 2019).

Several studies have assessed genetic diversity and variations among local rice varieties from Bali based on morpho-agronomic characters. Pharmawati and Wrasiati (2018) have characterized Mansur and Putih Cempaka varieties based on morphological characters of the seedling. Budiwati (2016) also has conducted on the characterization and genetic diversity analysis of local rice varieties from Bali. The study used seven local rice varieties (Merah Cendana, Injin, Putih Cempaka, Ketan Beton, Ketan Tahun, Jaka Selem, and Mansur) collected from Wongaya Gede village in Tabanan district, Bali. Agro-morphological traits such as culms, leaves, inflorescent, pollen, grain, and endosperm characters were assessed their diversity. Cluster analysis according to those traits was used to identify the degree of similarity and relationships among seven local rice varieties studied. According to Aliyu and Fawole (2000), cluster analysis has the singular efficacy and ability to identify crop accessions with the highest similarity using the dendrogram. The unweighted pair group method and arithmetic (UPGMA) dendrogram broadly clustered the seven local varieties into two main clusters at 62.16% of similarity, which implied a high level of morphological diversity. The first cluster consists of Indica rice (Mansur and Ketan Tahun), and the second cluster consistsof Javanica rice (Merah Cendana, Injin, Putih Cempaka, Ketan Tahun, and Jaka Selem).

SPECIFIC CHARACTERIZATION RELATED TO THE BREEDING TARGETS

Integration of morphology, physiology, and molecular characters is the main goal for characterization, as this would lead to an improved selection of where particular types of environments are present (McLaren and Wade 2000). Morphological characterization would generate valuable information that is beneficial as the basis for selecting individuals in the populations as well as parents in breeding programs or for separate scientific investigations, including specific gene discovery (Engels and Mba 2014).

Since the physiological understanding of patterns of genotype adaptation is needed for the identification of superior traits conferring adaptability to particular conditions, the representative reference lines could provide a first step in the characterization (McLaren and Wade 2000). The agro-climatic classification for rice and rice-based cropping systems has been widely adopted, based on the length of the rice-growing season, months in which surface flooding and disease incidence can be maintained (Oldeman and Frere 1982).

Compared to other regions of rice cultivation, Bali is characterized by a short rainy season. For example, a typical rainy season in North Sumatra starts in early September and lasts until early June. However, the rainy season in Bali begins in late November and ends in late April. Thus, Bali is more likely to face water shortages, which is unfortunate because it is an essential region for rice production in Indonesia. It is said that the northern and eastern parts of Bali are particularly susceptible to drought stress (Takama et al. 2014).

Drought stress causes significant physiological and biochemical changes (Lawlor and Cornic 2002). If the plant get drought, stomata will close, which is mediated by abscisic acid (ABA), consequently, the yield will be decreased. The response of local rice from Bali to drought conditions has been carried out by some studies. Breeding program using local varieties to explore their specific characters, such as Kencana Bali that is susceptible to bacterial leaf blight (BLB) and used as a parental line in the breeding of Inpago 12 Agritan as new variety released in 2017 (Hermanasari et al. 2017). The local rice varieties as parental lines for the breeding programs is recommended to obtain new superior rice varieties with a broad genetic variability important for crop improvement.

Pharmawati and Wrasiati (2018) have studied morpho-physiological and genetic responses of Bali local rice cultivars of Mansur and Putih Cempaka to drought stress at the seedling stage. Mansur, an indica rice, while Putih Cempaka being as javanica (Budiwati 2016) could be a good combination to improve their genetic. Mansur and Putih Cempaka are known to have higher root to shoot ratio of fresh weight as compared to IR64 both at PEG20% and PEG 30% (Table 2). IR64 has the lowest root to shoot ratio, almost 1/3 of that in Putih Cempaka, and is drought-sensitive cultivar (Prakash et al. 2016). The high root to shoot ratio is beneficial to increase water uptake, as a result, root characters become essential for selection. A good structure of root is indicated by the thickness and depth of the root which

Table 2. Fresh weight root to shoot ratio after three days treatment with PEG.

Treatment	Length (cm)			Average
	Mansur	Putih Cempaka	IR64	
Control	0.438±0.017[a]	0.407±0.030[a]	0.254±0.042[c]	0.366[A]
PEG 20%	0.487±0.018[a]	0.563±0.058[ab]	0.316±0.020[c]	0.455[B]
PEG 30%	0.816±0.082[b]	0.977±0.125[b]	0.382±0.087[ac]	0.725[C]
Average	0.580[A]	0.649[B]	0.317[C]	

Means with the same letters are not significantly different.

commonly present in plant tolerant to drought stress (Baloch et al. 2012).

The assessment of local rice has to be based on allelic variation at one or more loci. It will link to characterization activity to find the unique combinations of alleles that result in unique or distinct phenotypes. The *DREB* and *SOD* gene, for example, are discovered gene correlated to drought stress response in rice.The expression of the *SOD* gene increased under PEG stressed in Mansur and Putih Cempaka, in contrast, in IR64, *SOD* was not expressed both in untreated/control and PEG-treated seedling (Figure. 1). There was an increase in gene expression of *DREB1* as a response to drought stress. However, in IR64 the *DREB1* expression only increased at 20% PEG but decreased at 30% PEG, indicating low oxidative defense at a high concentration of PEG. The decreased expression may be related to the characteristics of IR64 as drought susceptible cultivar. The high *DREB1* expression shows better tolerance to drought in several crop species, including rice. As demonstrated by previous study, over-expression of *DREB1F* in a transgenic plant improves tolerance to drought stress induced by PEG 6000 (Wang et al. 2008).

Morpho-physiological characters, as well as genetic responses of local rice cultivar Mansur and Putih Cempaka from Bali, provide information for the future breeding program to develop

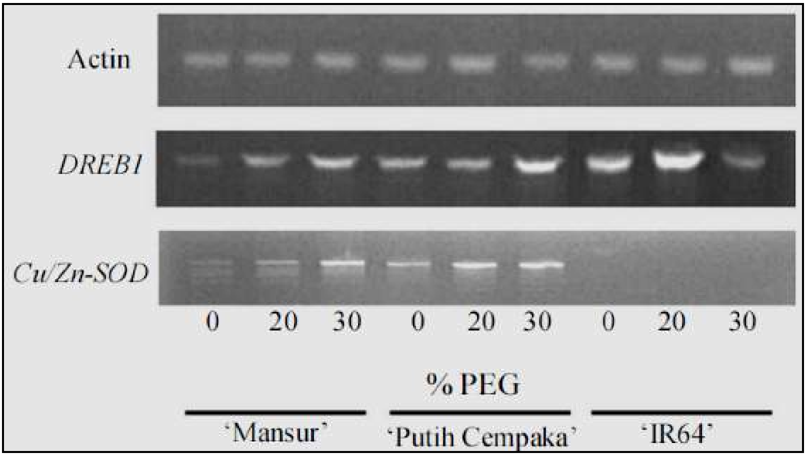

Figure 1. Expression of Cu/Zn-SOD and DREB1 in Mansur, Putih Cempaka, and IR64 after PEG treatment. Actin was used as a transcriptional control gene.

cultivar tolerant to water deficit. The discovery of abiotic stress at tolerant alleles in local rice clearly shows the importance of conserving and exploring landrace germplasm as a means to identify genomic-based to find beneficial alleles for enhancing adaptation and productivity in stress-prone environments (Dwivedi et al. 2016).

Strategies to maintain the diversity found in rice of local varieties from Bali must be implemented. The first strategy is measuring diversity to establish core collections where genetic diversity is maximized with minimum repetition and in intermediate generations of a breeding program to conserve genetic variability for selection in later generations. The second is addressing the allelic variation for key traits in the breeding program where the importance of keeping diversity has been well established. Allele mining for traits and alleles of interest will be highly valuable for enriching the genetic diversity within the breeding program. Studies on genetic diversity assessment of local rice varieties from Bali based on the molecular markers still had been very limited. Thus, it should be done for efficient and effective use of the local rice genetic resources for breeding programs.

CONCLUSIONS

Local rice varieties from Bali had been known to be planted by farmers for many generations on specific agroecology, therefore presumably it possesses particular traits for adaptation on a specific location. The local rice variety have better adaptation than modern varieties for changing climate conditions and to stress environments due to their population genetic structure, buffering capacity, and a combination of morpho-physiological traits conferring adaptability to stressful environments. The use of local rice varieties as parental lines for the breeding program is recommended to obtain new superior varieties with a broad genetic variability for their genetic improvement. Several local rice varieties from Bali had been reported to be used in the breeding program and diversity studies based on the morphological and physiological characters, but limited study on molecular analysis. Assessment of Bali local rice varieties based on molecular marker is needed to facilitate the efficient use of the local rice varieties. Phenotypic and genotypic information and related aspect to Bali local rice varieties can be used as important baseline information for selecting prospective parents in a plant breeding program. Diversity information of Bali local varieties also must be implemented to maintain their diversity and minimize the genetic erosion of for future agriculture.

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CHARACTERIZATION OF LOCAL VARIETIES OF TIDAL SWAMP RICE FOR FE TOXICITY TOLERANCE AND THE FE CONTENT OF ITS BROWN RICE

Izhar Khairullah, Nurita, and Syaiful Asikin

INTRODUCTION

Tidal swampland in Indonesia is estimated around 20.1 million ha, which spread mostly on four large islands, namely Kalimantan, Sumatra, Irian Jaya (Papua), and Sulawesi (Nugroho et al. 1992). Various studies show that with proper swampland management and technological innovation, tidal swampland can be developed into productive swampland for agriculture, especially rice (Jumberi and Alihamsyah 2005).

Tidal swampland can be divided into four land typologies, i.e., potential, acid sulfate, saline, and peat soils. A number of problems occurs mainly in acid sulfate soils (high Fe and Al, low pH), saline soils (salinity), and peat soils (deficient Cu and Zn elements) (Subagyo 2009). Tidal swampland are grouped into overflow types A, B, C, and D. Type A is defined as land overflowed by high and small tide both in wet and dry seasons. Type B is an area overflowed by only high tide in wet season. Type C is not overflowed by both tides, but has a water depth

<50 cm. Type D is land like type C, but has water level depth >50 cm (Widjaja Adhi (1992).

Local rice varieties for tidal swampland still dominate rice fields in the area. Local varieties have several advantages from the point of views of farmers, easily obtained almost everywhere, require minimal maintenance, and farmers do not need to bend in harvesting with manual means (Wiggin, 1976). Farmers have long planted various local varieties in tidal swampland in South Kalimantan. Siam, Bayar, Pandak, and Lemo varieties groups are a well-known group of local rice varieties. Bayar variety group has been cultivated by tidal farmers since 1920, while Lemo was around 1956 (Idak 1982). Siam group is currently most often found with a variety of names depending on grain shape, taste, name of the farmer, or its special characteristics received by local farmers (Khairullah et al. 1998). This article discusses about the characterization of local varieties suitable for tidal swamp land for Fe toxicity tolerance and also its Fe content in the brown rice.

FE TOXICITY TOLERANCE

In tidal swampland of South Kalimantan, there was Datu variety conserved *in situ*, with strong and large culms with plant heights >2 meters, long panicles and bold grain. This rice variety is found in the mature phase in submerged conditions with saline soils around 30–40 cm. Another rice variety having strength is Pudak which is identified as aromatic rice (Khairullah et al. 2003). Local rice varieties characterized in the rice field visually did not sensitive to Fe toxicity, because the plants are in the late developmental stage approximately 4 month old-seedling which are not suitable for Fe test. Another reason, the Fe toxicity is reduced since it has begun to be dissolved in the rice farming fields.

Khairullah et al. (2005) reported that local varieties probably have a certain mechanism like avoiding the harmful effects of Fe^{2+}. Characterization and screening of tolerance to Fe toxicity of 130 local varieties from tidal swampland in Kalimantan and Sumatera showed variations in Fe toxicity symptom. The results reveal soil Fe content of 156 ppm Fe; whereas Fe content in groundwater is at first high (0, 44 me/L) then decreases with time (week 13^{td} = 0.06 me/L). Fe content of groundwater is consecutive. Moreover, at week 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. 13, and 14 showed 0.44; 1.71; 0.13; 0.01; 0,008; 0.079; 0,006; 0.56; 0.34; 0.08; 0.06; and 0.47 me/L Fe respectively (Khairullah et al. 2006).

A number of local rice varieties have been evaluated their tolerance to Fe (iron) toxicity in tidal swampland South Kalimantan. The seedlings of rice were tested according to different week old-seedling. Fe toxicity symptoms scoring (IRRI 1996) indicated that there was considerable variation between seedlings age. One week old-seedling showed higher resistance compared to 2 and 3 week old-seedlings. There were 35 local varieties tolerant to Fe toxicity at 1 week old-seedling, 29 tolerant varieties at 2 week old-seedlings and 20 varieties tolerant to Fe toxicity at 3 week old-seedling (Table 1). Observations per week during four weeks showed that the response of local rice varieties seedlings was not consistent with Fe toxicity. Several local varieties are capable of recovering from the Fe toxicity at an older developmental stage. Notable, some varieties revealed their high tolerance to Fe toxicity (Khairullah et al. 2006).

Table 1. List of local varieties tolerant to Fe toxicity planted in acid sulfate soils in di KP Belandean, in 2003 dry season.

No. ACC	Local varieties	Seedling age		
		1 week	2 week	3 week
4	Siam halus	*		
5	Siam perak	*	*	*
6	Siam brandal	*	*	
7	Siam perak halus	*	*	
8	Siam karang dukuh kuning	*		
42	Pandak	*		
44	Siam pontianak tinggi	*		
46	Kutut	*		
47	Siam unus kuning	*		
48	Siam gumpal	*		
49	Siam PX	*	*	
50	Siam arjuna		*	
51	Siam karta	*	*	
52	Siam randah putih	*	*	*
53	Pal enam	*	*	*
54	Pal sebelas	*	*	*
55	Lakatan	*	*	*
56	Raden rata	*	*	*
57	Kawi	*	*	*
58	Siam puntal	*	*	*
59	Siam randah kuning	*	*	*
60	Pirak	*	*	*
61	Pandak kembang	*	*	*
62	Palon	*	*	*
63	Siam rata	*	*	*
64	Bayar palas	*	*	*
65	Unus organik	*	*	*
66	Siam pontianak halus	*	*	*
67	Siam pangling	*	*	
68	Siam tanggung	*		
69	Unus gampa	*		*
70	Adil kuning	*		
71	Siam iantik	*	*	*
72	Selumbung	*	*	*
73	Bonai	*	*	*
74	Putih rampak	*	*	
75	Petek	*	*	

(*) score: denoting tolerance from first week to three week (low to high).

AGRONOMIC TRAITS AND MORPHOLOGICAL CHARACTERS

Plant height of local rice varieties commonly are between 105–180 cm and tiller numbers are 10–24 tillers. Panicle in general is well exerted, and panicle thresh ability is moderate (6–25%). The leaf characters demonstrate leaf angle which is erect to horizontal, flag leaf angle that is moderately erect to horizontal, and no flag leaf angle upright unlike in the improved rice varieties. Likewise, the culm angle was moderately erect to horizontal. Tall and strong culm rice is commonly suitable for tidal swampland, which is high overflowed. Whereas a well-exerted panicle will be easy for farmers to harvest using traditional mean of '*ani-ani*.' A horizontal leaf angle might suppress weed's growth. Characteristics of several local rice varieties in tidal swampland in South Kalimantan are summarized as follows (Khairullah et al. 2004):

Leaf angle	:	intermediate to horizontal
Flag leaf angle	:	erect to intermediate
Leaf length	:	33–46 cm
Flag leaf length	:	24–36 cm
Leaf width	:	0.8–1.2 cm
Flag leaf width	:	0.8–1.2 cm
Culm angle	:	erect to intermediate
Tiller number	:	7–19 tillers
Productive tiller number	:	7–17 tillers
Ligule shape	:	cleft
Ligule length	:	0.5–2.3 cm
Grain	:	no awned, sleder
Panicle	:	well exerted, compact, axis droopy
Brown rice	:	small and slender and translucent
Plant height	:	80–125 cm

Most of the varieties characterized were relatively tolerant to lodgings, such as Bayar Palas, Pandak Putih, Siam Unus, and Lemo Putih. The tolerance to lodging is attributable by factor of strong culms which is important to support plant growth in flooding/overflowing. The basal culm diameter of local varieties was 4.9–8.9 mm and vigor seedlings are normal to weak (3–4 leafy seedlings). Tilling ability is high to very high (20 to 25 tillers), but the percentage of productive tiller is low, suggesting the weakness of local rice varieties. Agronomic traits of local rice varieties grown in tidal swampland in South Kalimantan is presented in Table 2.

The culm of the tidal swampland local rice varieties originating from South Kalimantan is stable even in lodged conditions, especially before harvest, where land is still submerged, with hard wind. Lodging of 0 to 40% depends on land conditions and is also supported by the plant height (120 to 130 cm). Culms of plants majority are long, broad, and not compact with long internodes. The tall plant is still preferable by farmers because harvest become easy using a traditional harvester of 'ani-ani' (Wiggin 1976).

Table 2. Some agronomic traits of local rice varieties in tidal swampland in South Kalimantan.

Traits	Siam Unus	Pandak	Bayar Palas	Lemo Kwatik	Lakatan Gadur
Tiller number	20	18	15	14	15
Plant height (cm)	142	121	140	182	149
Duration (days)	291	305	305	272	295
Leaf length (cm)	58	44	46	44	47
Leaf width (mm)	12	12	12	11	13
Culm length(cm)	118	95	116	154	121
Culm diameter (cm)	6.9	6.7	7.3	6.8	7.9
Grain length (mm)	7.7	8.2	8.8	8.5	8.8
Grain width (mm)	1.7	1.7	1.8	1.9	1.8
Lodging (%)	5	0	0	10	25

Source: Khairullah et.al. 2006.

Although the rice panicles are well exerted and allow birds attack, but it is easily harvested. The grains on the panicle are easy to thresh, collected and thrashed with sickles. Harvesting can be done at 9–10 months after seeding. Practically, cultivation of late maturing rice variety is not efficient and not profitable, but such varieties in tidal swampland is still beneficial in order to be able to transplant twice to allow seedlings become large and strong. The leaves are generally long, wide, and dropped, probably due to less sunlight distribution to basal plant and less optimal photosynthesis. Such leaf characters can suppress the weeds growth at the basal but with flag leaf which is not erect will increase bird attacks. Basal sheath leaves are spaced between the sheets, indicating its potential to reduce the sheath blight incidence (Prayudi 2000).

PLANT RESISTANCE

The resistance of the tidal swampland local rice varieties varied. Few of them are resistant to pests and diseases that could have a genetic resource for the improvement of rice varieties in the tidal swampland (Table 3).

FE CONTENT OF BROWN RICE

Local brown rice shape is generally slender to moderate, translucent, and a little chalkiness on the endosperm. These shapes and conditions are preferred by farmers whose rice are sold with higher prices, and their appearance is more attractive. However, the disadvantage of local varieties of rice of easily being broken because of the grain length and low yield of brown rice of about 40–50%, makes them less attractive. Analysis on 71 local rice varieties showed that the Fe content considerably varied (Table 4). Fe content of 71 brown rice varieties ranged from 11 (Kutut variety) to 83 ppm (Siam Pandak). Local varieties in the

Table 3. Resistance to pest and disease of several local rice varieties of tidal swampland.

Local varieties	Resistance to pest and disease
Siam Arjan	Resistant to leaf blast ras-002, brown spot
Palui	Resistant to brown planthopper biotype 1, moderately resistant brown spot
Lakatan Jambu	Moderately resistant to brown spot
Siam Pontianak	Resistant to leaf blast race 002
Badagai	Resistant to brown planthopper biotype-1, moderately resistant leaf blast race-002
Latur	Resistant to brown planthopper biotype-1, moderately resistant leaf blast race-002
Siam Unus	moderately resistant to leaf blast race-002
Isip	Resistant to brown planthopper biotype 1
Siam Pandak	Resistant to brown spot
Sabat Jalan	Resistant to leaf blast race-002
Siam Cinta	Resistant to leaf blast race-002
Sanggul	Resistant to leaf blast race-002
Siam Bamban	Resistant to leaf blast race-002
Sasak Jalan	Moderately resistant to leaf blast race-002
Siam Sanah	Moderately resistant to leaf blast race-002

Source: ISARI (2001).

range of 11–21 ppm Fe were found in the highest frequency followed by the rice group having 22–32 ppm Fe, with the rates of 40.8% and 38.0%, respectively. Around 75% of the local varieties contained Fe in the range of 11–32 ppm (Khairullah 2016).

Fe content affecting broken rice pericarp varied on 5 improved rice varieties (Ciherang, Widas, IR64, Cisokan, and Cimelati) which are grown in Inseptisol soil (10.84–19.80 ppm Fe). The highest Fe content was indicated by Widas and the lowest one was possessed by Cisokan (Yustisia et al. 2012). Indrasari et al. (2002) reported that average Fe level in improved rice was around 11.7 ppm Fe. The information on the Fe content of local rice varieties is beneficial to provide potential genetic material to assist breeding.

Table 4. Fe content of brown rice of 71 local rice varieties suitable on tidal swampland in South Kalimantan.

Group	Fe (ppm)	Frequency (%)	Local varieties
1	11–21	40.8	Kutut, Siam unus kuning, Siam randah putih, Siam randah kuning, Palon, Siam babirik, Siam gumpal, Raden rata, Kawi, Siam puntal, Pandak kembang, Siam klubut, Pal 6, Siam rata, Siam suruk, Siam lantik putih, Siam lantik merah, Pandak, Lakatan hirang, Siam teladan, Lakatan, Siam randah, Siam PX, Adil kuning, Siam brandal, Siam perak halus, Lemo kwatik, Siam putih, Siam tanggung.
2	22–32	38.0	Siam unus, Siam kretek, Siam karangdukuh kuning, Lakatan putih, Siam pals, Bayar pahit, Bayar papuyu, Siam perak, Siam birik, Lakatan pacar, Siam arjuna, Siam halus, Lakatan gadur, Pirak, Siam pontianak tinggi, Siam karta, Jurut, Siam pontianak halus, Siam puntal, Siam sabar, Siam pangling, Lakatan Siam, Siam perak ganal, Siam ubi, Lemo putih, Siam adus, Siam sebelas.
3	33–43	12.7	Unus organik, Siam karangdukuh, Pal sebelas, Unus gampa, Pandak manggar, Siam unus putih, Siam ganal, Pandak arjuna, Pandak kembang.
4	44–54	4.2	Pandak putih, Siam lantik, Siam panangah
5	55–65	0	-
6	66–76	2.8	Bayar palas, Siam wol
7	77–87	1.4	Siam Pandak

Source: Khairullah, 2016.

CONCLUSIONS

Local rice varieties of tidal swampland are potential genetic resources for Fe toxicity tolerance. Some varieties out of 130 local rice varieties of tidal swampland in Kalimantan and Sumatera were identified to be tolerant to Fe toxicity. There were found 35, 29, and 20 local varieties were tolerant to Fe toxicity at one week, two week and three week old-seedlings, respectively. Fe content of 71 brown rice ranged from 11 ppm to 83 ppm, of which the highest Fe content shown by Siam Pandak variety (83 ppm Fe), followed by Bayar Palas and Siam Wol which have range of 66–76 ppm Fe. Taken together, these potential genetic materials could be used as parental lines in the future breeding program related to tolerance to Fe toxicity in tidal swampland.

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POTENCY, CHARACTERISTIC, AND AGRONOMIC PERFORMANCE IN RICE VARIETIES ON FRESHWATER SWAMPLAND

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INTRODUCTION

Fresh water swampland is a land that is overflowed by water at a minimum of 50 cm depth for at least three months. Since it is located in a basin with poor drainage, this land will be flooded during rainy season and experience drought in dry season.

The total area of freshwater swampland in Indonesia is estimated approximately 13.28 million ha, consisting of 4.17 million ha of shallow freshwater swampland, 6.08 million ha of medium freshwater swampland, and 3.04 million ha of deep freshwater swampland (Nugroho et al. 1992). About 1.55 million ha of freshwater swampland has been reclaimed to develop paddy fields and settlements, where local people reclaimed 1.10 million ha (71%), and the government of Indonesia recovered 29%. This indicates that Indonesia still has a considerable area of freshwater swampland (11.73 million ha), which can be developed as prospective agricultural production areas.

Freshwater swampland can be used to overcome land depreciation and the effects of drought in some land typologies during climate anomalies such as El Nino. Farmers have utilized some freshwater swamplands for food crops, horticulture, fisheries, and livestock, but their utilization and productivity were still below their potential. The variation in hydrology requires specific land preparation and cropping patterns under the typology of the land to provide benefits for farmers.

The use of high-yielding varieties and planting systems of *Jajar Legowo* (*Jarwo*) are a cheap technological innovation that can be easily implemented by farmers (Suparwoto and Waluyo 2013). *Jarwo* is an engineering technique for rice planting by adjusting the spacing between hills and between rows, resulting in compaction of rice hills in rows and widening the distance between rows. The distance between the rows is expected to facilitate maintenance, such as weeding, fertilizing, and controlling pests and diseases. In addition, high-yielding variety is one component of technology that plays a role in increasing production and yield quality. This article aims to discuss the potency, characteristic, and agronomic performance in rice varieties on freshwater swampland which is important in Indonesia.

POTENCY DAN CHEMICAL CHARACTERISTICS OF FRESHWATER SWAMPLAND

The potential of swampy land is primarily determined by the materials deposited from the upstream area, while the water is relatively lacking in soil materials because the water only comes from rainfall. In general, the fertility level of freshwater swampland is much better than that of tidal swampland since its soil is composed of river alluvium material, which does not contain sulfidic/pyrite material. The transition zone between freshwater swampland and tidal swampland, especially in the lower layer at a depth of more than one meter, contains a layer of sulfidic material from marine deposits. The intensity and duration of overflowing determine the potential and typology of the freshwater swampland. In rainy season, all fields are flooded and gradually subside in dry season (Noorginayuwati and Rina 2006).

Shallow freshwater swamplands are typically overflowed by water with less than 50 cm depth for three months. This type of swampland can be utilized as a rice field in dry and rainy seasons. In season, it is called the eastern rice field and is planted with early-maturing rice. The upper part of the land can be planted with secondary and horticultural crops using a raised bed system. Medium freshwater swampland is overflowed by water with less than 50 cm depth for 3–6 months. In contrast, it may be flooded to a depth of more than 100 cm in rainy season, which is called the western rice field. Deepwater rice (*padi surung*) can be cultivated such as Alabio, Tapus, Nagara and Hiyang varieties at the end of dry season, and harvested during rainy season even during a overflowing depth of 100–150 cm. Deep freshwater swampland is overflowed by water with more than 50 cm depth for more than six months, reaching the peak in dry season. In relevant to previous study that cultivation of rice depends on the water level, and this swampland is usually used as a water conservation area (Rina et al. 2008).

SOIL CHEMICAL PROPERTIES

The chemical properties and soil fertility in shallow freshwater swampland are generally better than those in medium and deep freshwater swampland. The texture of freshwater swampland commonly is characterized by high clay and silt, and low sand fraction. The soil texture of shallow freshwater swampland highly varied (from fine to medium), but sometimes it can be relatively coarse. Medium freshwater swampland has a fine texture, while deep freshwater swampland is classified as very fine with very high clay content (55–80%). The content of organic matter (%C) in soils of the medium and deep freshwater swamplands is relatively higher than that in shallow freshwater swampland. Whereas the content of P_2O_5 and K_2O are almost similar among those three typologies. The number of exchangeable bases, as indicated by the percentage of base saturation (% BS) in shallow freshwater swampland, tends to be more productive than the other typologies (Subagyo 2006). The chemical properties of soil in freshwater swampland is presented in Table 1.

The type of soil determines the its chemical properties of freshwater swampland. Mineral soil with river sediment has a clay texture and pH of 4.5 to 6.5. Soil fertility of freshwater swampland is classified as moderate due to the amount of nutrient from the upstream area that enters through water runoff.

Tabel 1. Soil chemical properties of freshwater swampland.

Soil properties	Shallow	Medium	Deep
Texture	heavy clay, clay, silty clay, loam, silty loam, and sandy loam	heavy clay, clay, silty clay, and silty clay loam	heavy clay and silty clay loam
Soil-pH in the field	5.5–7.0	5.0–7.0	5.5–6.5
Soil-pH at laboratory	4.0–5.5	3.5–4.5	3.5–4.5
C-organic (%)	0.1–12.0	0.5–17.2	1.2–18.9
P-Bray (ppm)	2–23	2–27	3–15
K-exchangeable (mg/100 g)	5–40	5–60	5–25
CEC (%)	0.6–21	1–20	4–18
BS (%)	10–100	3–80	6–75

Note: CEC = cation exchange capacity, BS = base saturation.
Source: Subagyo (2006).

Freshwater swampland is suitable for agriculture eventhough possessing unpredictable water flooding fluctuation (Arifin et al. 2005).

AGRONOMIC PERFORMANCE OF RICE VARIETIES

Freshwater swampland is heterogeneous and need appropriate technologies to improved gradually it in order to increase its capacity. Land preparation is one of the technology components that can be applied in freshwater swampland. The unpredictable water flooding fluctuations underline the importance of water management in agricultural cultivation on freshwater swampland.

Technological innovations with cheap and easy implementation by farmers including the use of high-yielding varieties (Suparwoto and Waluyo 2013), plays a role in increasing the rice production and yield quality. Some factors influence the selection process of rice varieties in swampland, such as yield potential, tolerance to abiotic stresses (adaptability), market demand, preferences, age and height of plants, and resistance to pests and diseases (Izhar 2016). A rice variety with high yield potential may not be able to express its full potential because of the low adaptation in freshwater swampland. Conversely, rice varieties with low yield potential, mostly local rice varieties are often more adaptable to such land (Izhar and Nurita 2017).

The selection of rice varieties planted in swampland is strongly influenced by flooding conditions, as shown in Table 2. In shallow freshwater swamplands in dry season under normal conditions, the choice of rice varieties is diverse but becomes limited during a long drought (El Nino). In rainy season, since overflow in shallow freshwater swamplands is less than 50 cm, the choice of varieties is almost the same as that in dry season.

Tabel 2. Several potential rice varieties for freshwater swampland.

Shallow freshwater swampland			Medium freshwater swampland		Deep freshwater swampland
DS (normal)	DS (El Nino)	RS	DS	RS	
Inpara 1-9 Ciherang Mekongga Inpari-9 Inpari-19 Inpari-27	Early-maturing varieties	Inpara 1-9 Ciherang Mekongga Inpari-11 Inpari-22 Inpari-20	Inpara 1-9 Ciherang Mekongga Inpari-13 Inpari-18 Inpari-19 Sidenuk	Inpara 3 Inpara 4 Inpara 5 Inpari 29 Inpari 30	Tapus Alabio Nagara

Note: DS = dry season, RS = rainy season.
Source: Jamil et al. (2015) and Izhar (2016).

Sufficient water during dry season in medium freshwater swamplands also allows the selection of a wider choice of rice varieties developed for swamplands and normal irrigated lands. Unlike in rainy season especially La Nina, the selection of varieties becomes more limited. Submergence-resistant varieties such as Inpara-3 (6 days submergence-resistant), Inpara-4, Inpara-5 and Inpari 29 (14 days submergence-resistant), and Inpari-30 (resistant to 15 days submergence) as an alternative variety. Almost all high-yielding varieties and local varieties of rice cannot be planted in deep freshwater swampland. However, when ISARI was named LP3 Banjarmasin, deep swamplands were planted with Tapus, Alabio, and Nagara varieties which are easily harvested. These three varieties are able to elongate and form node buds even though they are planted in the land with depth of overflow of 150 cm and rising by 1–3.5 cm per day. Notably, the deep freshwater swampland is very fertile and suitable for rice cultivation.

Inpara variety shows good vegetative and generative performances in the shallow freshwater swampland at Experimental Station of Banjarbaru. The highest yield Inpara 2 was 5.05 ton/ha (Table 3). In dry season, the vegetative and generative growth are classified as good to medium, with the highest yield obtained from Inpara 6 (2.73 ton/ha) (Table 3).

Tabel 3. Scores of vegetative and generative growth, and yield of rice varieties in shallow freshwater swampland, in Experimental Station of Banjarbaru, rainy season and dry season of 2015.

Rice variety	Vegetative score		Generative score		Rice yield (ton/ha)	
	RS	DS	RS	DS	RS	DS
Inpara 2	3	3	3	5	5,05	1,95
Inpara 3	3	3	3	5	3,56	1,95
Inpara 4	3	3	3	5	2,69	-
Inpara 6	3	3	3	5	2,67	2,73
Inpara 7	3	3	3	5	1,38	2,15

Note: 3 = good, 5 = moderate, DS = dry season, RS = rainy season.

However, drought and bird attacks caused the differences in yield between in dry and rainy seasons (Norginayuwati and Nurzakiah 2015).

Previous study revealed that the yields of Inpara varieties in the swampland were prospective for further program, i.e., 5.6 ton/ha, 4.4 ton/ha, 4.3 ton/ha, and 3.74 ton/ha for Inpara 2, Inpara 3, Inpara 6, and Inpari 17, respectively. Whereas the *surung* rice harvested at the beginning of rainy season yielded 5.60 ton/ha for the Inpari 20 in a medium freshwater swampland at Alabio polder in Tambalang Kecil Village, Sungai Pandan District, Hulu Sungai Utara Regency, South Kalimantan (Figure 1). In both growing seasons with the same cultivation technology package, which was no soil tillage, the *Jajar Legowo* (*Jarwo*) planting system 2:1 and Decision Support System (DSS) for fertilizing (150 kg/ha of urea and 250 kg/ha of NPK Mutiara) demonstrated being as powerful means for swampland rice (Norginayuwati and Nurzakiah 2015).

Good performance and yields of several rice varieties (Table 4) have been revealed by assessing them in a medium freshwater swampland at Hamayung polder in Hamayung village, Daha Utara district, Hulu Sungai Selatan Regency, South Kalimantan in

2017 dry season. The minimum soil tillage, 15 ton/ha of in situ weed (*Pistia stratiotes*), 25 kg/ha "biotara" bio-fertilizer, spacing based on *jarwo* 2: 1 and DSS fertilization system (200 kg urea/ha, 150 kg SP-36/ha, and 100 kg KCl/ha) were applied as the cultivation technology package in this assessment (Saleh et al. 2017).

Growth performance during the vegetative phase can be classified as moderate to good score, while the generative growth phase had a good score. Plant height at the vegetative stage for all rice varieties are not significantly different from control of Ciherang (84.81 cm). The tallest plant was found in Inpara 9 (103.17 cm), and the shortest was Inpari 20 (74.25 cm). At the generative stage, two varieties are taller than the control, namely Inpara 8 and Inpara 9, with a height of 138.93cm and 146.33cm, respectively. According to IRRI (1996), the criteria for plant height are short, medium, and tall with a height of <110 cm, 110–130 cm, and >130 cm, respectively. Based on these criteria, the Inpari 20 was classified as short, Inpara 8, and Inpara 9 were considered tall, and the other rice varieties were grouped as moderate.

The number of tillers at the vegetative phase ranged 20.17–26.83; the tiller number of Ciherang as the check variety was 21.50. The number of tillers of all rice varieties were not significantly different from Ciherang. IRRI (1996) classified the number of productive tillers into very low, low, medium, high, and very high, which correspond to values of <5, 5–9, 10–19, 20–25, and >25, respectively. As observed, varieties with medium productive tillers were Inpara 6, Inpara 8, Inpara 9, Inpari 30, and Ciherang. High scores were recorded for Inpara 7, Inpari 17, and Mekonggga, while those classified as very high were Inpari 9, and Inpari 20.

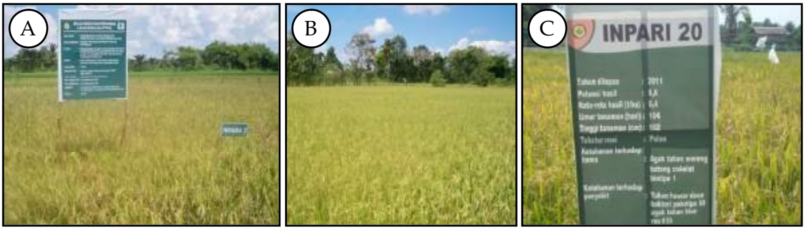

Figure 1. The performance of *rintak* rice at the pre-harvest season (A and B) and *surung* rice (C) in medium freshwater swampland at Alabio polder in Tambalang Kecil village.

Tabel 4. Growth scores, plant height, and the number of tillers in the vegetative phase, productive tillers, and yields of 10 rice varieties in medium freshwater swampland at Hamayung polder in Hamayung village in 2017 dry season.

Rice variety	Growth score		Plant height (cm)		Number of tillers	Producti ve tiller	Yield (ton/ha)
	Veg.	Gen.	Veg.	Gen.			
Inpara 6	5	3	81.50	125.67	22.67	16.53	5.96
Inpara 7	3	3	79.78	123.60	24.61	22.87	6.34
Inpara 8	3	3	94.03	138.93*	20.17	17.60	6.37
Inpara 9	3	3	103.17*	146.33*	25.44	16.20	3.07*
Inpari 9	5	3	79.94	121.13	25.72	26.87*	3.69*
Inpari 17	3	3	90.78	112.53	25.78	22.00	5.63
Inpari 20	3	3	74.25*	99.80	25.17	27.43*	4.99
Inpari 30	3	3	82.44	122.00	20.61	17.40	4.70
Mekongga	3	3	80.39	118.13	26.83	24.13	5.73
Ciherang (comparative varieties)	3	3	84.81	114.90	21.50	18.87	6.42

Note: *= significantly different from the check variety, veg = vegetative, gen = generative.

The yield of 10 varieties ranged from 3.07 to 6.42 ton/ha. Seven varieties were found to have similar yield with the check variety Ciherang (6.42 ton/ha), namely Inpara 6 (5.96 ton/ha), Inpara 7 (6.34 ton/ha), Inpara 8 (6.37 ton/ha), Inpara 17 (5.63 ton/ha), Inpari 20 (4.99 ton/ha), Inpari 30 (4.70 ton/ha) and Mekongga (5.73 ton/ha). While Inpara 9 (3.07 ton/ha) and Inpari 9 (3.69 ton/ha) produced lower yields than Ciherang. The performance of 10 rice varieties grown in medium freshwater swampland is presented in Figure 2.

At the same location, planting season, and applying the cultivation technology package used by Saleh et al. (2017), the yield of Inpara 2 was 7.6–8.1 ton/ha. This yield was 60–70% higher than that of local farmers (4.5–5.0 ton/ha) (Hairani et al. 2017). This variety performance in such swampland can be seen in Figure 3.

Another adaptation test of swamp rice varieties/cultivars was conducted in a shallow freshwater swampland at Alabio polder in Hambuku Raya village, Sungai Pandan district, Hulu Sungai Utara Regency, South Kalimantan in 2018/2019 rainy season. Ten varieties/cultivars (Inpara 3, Inpara 8, Tapus, Inpari 42, Inpari 22,

Figure 2. Performance of 10 rice varieties in medium freshwater swampland at Hamayung polder, Hamayung village, in 2017 dry season.

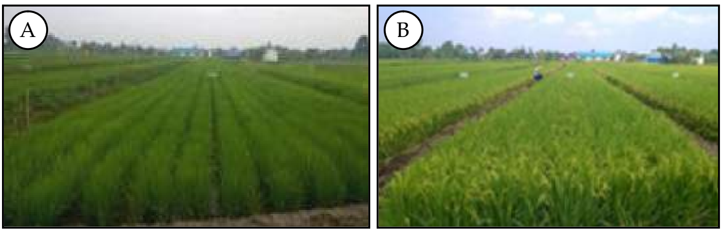

Figure 3. Performance of Inpara 2 rice variety in the vegetative stage (A) and generative stage (B) in medium freshwater swampland at Hamayung polder in Hamayung village in 2017 dry season.

Inpari 30, UDHL 9, UDHL 12, and Ciherang RBN) show consistently healthy growth with green color and good vegetative vigor, indicating their good adaptation to the soil pH (pH 4.9). No symptoms of chlorosis are seen in all varieties/cultivars. Plant height at 45 days after planting (DAP) varied from 84.0 to 99.1 cm, with the number of tillers ranged 18.6–28.7 (Table 5 and Figure 4) (Sosiawan 2019).

All varieties/cultivars also showed good performance during the generative phase (66 DAP), and the number of tillers and panicles were quite normal (Figure 5), suggesting their high adaptability to the environment. As demonstrated by the varied grain yield among the varieties/cultivars. The highest yield is produced by Inpara 8 (6.3 ton/ha) and the lowest one is yielded y UDHL 12 (3.0 ton/ha).

Tabel 5. Plant height, number of tillers, number of panicles, and yield of 10 varieties/cultivars in freshwater swampland at Alabio polder, in Hambuku Raya village in rainy season of 2018/2019.

Rice variety	Plant height (cm) phase vegetative	Number of tillers	Plant height (cm) phase generative	Number of panicles	Yield (ton/ha)
Inpara 3	99.1	22.8	132.5	14.6	4.8
Inpara 8	88.7	23.1	140.2	16.5	6.3
Tapus	86.4	24.4	119.3	19.5	4.9
Inpari 42	87.6	23.2	109.3	15.2	5.3
Inpari 22	87.9	25.1	107.7	11.2	5.6
Inpari 30	84.0	24.9	115.0	13.3	5.8
Inpari 43	91.6	28.7	90.2	13.7	3.8
UDHL 9	98.9	26.8	118.5	14.7	4.7
UDHL 12	97.1	18.6	118.0	16.0	3.0
Ciherang RBN	88.9	24.8	125.2	13.5	3.5

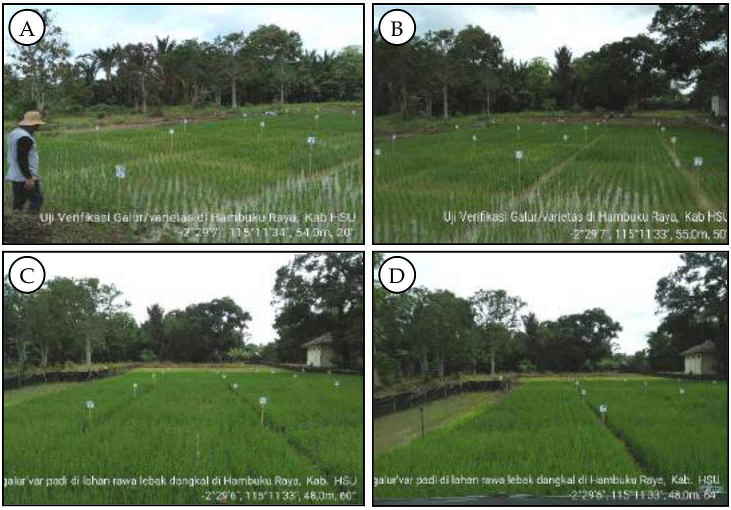

Figure 4. Performance of 10 rice varieties/cultivars at 16 DAP (a and b) and 32 DAP (c and d) in shallow freshwater swampland at Alabio polder in Hambuku village in 2018/2019 dry season.

Figure 5. Performance of 10 rice varieties and cultivars in 66 DAP (a), 81 DAP (b), and 85 DAP (c and d) in shallow freshwater swampland in Alabio polder at Hambuku village in 2018/2019 dry season.

CONCLUSIONS

Shallow and medium freshwater swampland has the potential to be used as paddy fields. As a result of this swampland characters, deep freshwater swampland is more suitable for freshwater aquaculture during dry season. Rice cultivation in freshwater swampland has long been practiced by farmers and generally uses high-yielding local varieties that were developed a long time ago, such as Ciherang, Cisokan and Mekongga varieties. Ten varieties/cultivars (Inpara 3, Inpara 8, Tapus, Inpari 42, Inpari 22, Inpari 30, UDHL 9, UDHL 12, and Ciherang RBN) were tested in a freshwater swampland and showed good performance and promising yield. Their good adaptability in freshwater swampland provides an alternative new high-yielding rice varieties for farmers, implying as an essential step in increasing production.

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RESPONSES OF RICE VARIETIES TO GREENHOUSE GAS EMISSIONS ON TIDAL SWAMPLANDS

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INTRODUCTION

The utilization of tidal swampland is one of the choices to achieve sustainable food security to compensate for the high rate of land conversion, land degradation, and climate change in the rice producing areas, especially in Java, Sumatra, and Sulawesi. Tidal swampland is a marginal land with many problems related to high soil acidity, low phosphorus content, and the presence of toxic elements. Thus, rice production in swampland is usually low. The utilization of tidal swampland requires specific local wisdom and environmentally friendly technology to increase rice production and farmer's income.

Rice cultivation in tidal swampland mainly in dry seasons can cause soil to be anaerobic, which facilitate methane formation due to increased activity of methanogenic bacteria in reductive soil conditions with a potential redox value of <-250 mV. The roles of rice in the dynamics of methane are (1) methanogen substrate sources, (2) transpose methane through the air cavity of aerenchyma tissue, and (3) potentially oxidizing methane in the rhizosphere microenvironment. The main strategies in reducing the capacity of the methane production rate and methane emissions from paddy fields are to choose the right varieties and cultivation techniques.

Greenhouse gas emissions from the agricultural sector mainly come from lowland rice cultivation. Methane is one of the greenhouse gases released from the interface of the paddy field through diffusion and ebullition, the amount of which depends on the soil type, soil moisture condition, physical and chemical soil properties, soil temperature and management factors including the rice variety used (Wassmann et al. 2000). The global agricultural sector contributes more than 11% of the total greenhouse gas emissions of 3.3 gigatons of CO_2 equivalent, and in the atmospheric CO_2 concentrations increase each year by 5% due to combustion and land-use change. This paper aims to discuss the disparity in greenhouse gas emission from different rice varieties in tidal swampland.

GLOBAL CLIMATE CHANGE AND RICE FARMING

Climate change is a major environmental problem caused mainly by increased emissions of anthropogenic greenhouse gases (GHGs) (Myhre et al. 2013). Agriculture contributes about 20% of the present atmospheric GHG concentration (Hutsch 2001). Methane (CH_4) and nitrous oxide (N_2O) are the two most important GHGs from agriculture. The soil contribution reached 20% of total CO_2 emissions to the atmosphere through soil respiration. The global warming potential of CH_4 and N_2O are 25 and 298 times greater than the mass equivalent of CO_2 in the atmosphere (IPCC 2007). CO_2 is used by plants in the process of photosynthesis, while CH_4 from the soil will be released into the atmosphere. Methane contributes to 14% of global GHG emissions. Increased rice production may lead to higher emissions of CH_4 (Anastasi et al. 1992) and may require higher nitrogenous fertilizers to paddy fields, which can lead to increased emissions of N_2O to the atmosphere (Gagnon et al. 2011). Paddy fields whose water is drained becomes CH_4 sinks due to the high rate of CH_4 diffusion into the soil and CH_4 oxidation by methanotrophic microbes. In the rainfed lowland system, aerobic-anaerobic soil conditions occur and affect the dynamics of CO_2 and CH_4 gas in the soil. GHG emissions release from paddy soils is influenced by the physiological and morphological characteristics of rice plants and the availability of carbon in the soil derived from soil organics.

CH_4 is well known as an important greenhouse gas and a critical factor in tropospheric and stratospheric chemistry. While wetland rice fields are an essential source of CH_4, accounting for approximately 20% of the global anthropogenic methane emission. CH_4 could be produced by strictly anaerobic bacteria commonly living in anoxic soils such as wetland rice fields. CH_4 emission from a rice field is the net effect of CH_4 production (methanogenesis) and CH_4 oxidation (methanotroph). Notably, monooxygenase enzyme for the oxidation of CH_4 to CH_3OH, requires molecular oxygen (King 1992).

Methane formed in the rice plant rhizosphere will be partially oxidized by methanotrophic microbes that are also present in plant roots. CH_4 is emitted to the atmosphere by rice plants via several ways like ebullition and diffusion processes (Wassmann et al. 2000). Organic matter and soil enhancers play a role in increasing grain yield and methane emissions in rice cultivation in paddy fields. Organic matters stimulate methane production through a series of processes that end with the formation of CO_2 and CH_4. CO_2 emissions released from paddy fields are influenced by the respiration of rice and the oxidation process of organic matter in the rhizosphere. Rice plants can absorb oxygen from the atmosphere to the roots through the aerenchyma network. The pattern of CO2 emissions existed at the beginning of high growth and then decreased until the final period of rice growth in line with the pattern of CO_2 flux.

The type of rice variety is one of the factors very influential to the release of CH_4 emissions (Su et al. 2015). In rice fields, oxic-anoxic interfaces are found at the floodwater-soil interface and in the rice rhizosphere. Rice plants rely on aerobic respiration for growth and transport atmospheric O_2 to their roots to survive in the anaerobic environment. Rice varieties affect CH_4 emissions through the provision of exudates and decay of root tissues and plant leaves that fall to the ground, and the diversity of CH_4 transport capacity varies between rice varieties. Oxidation at the rice rhizosphere is caused partly by enzymatic oxidation but mostly by radial O_2 loss through the root wall (Ando et al. 1983). Methanotroph can be an essential sink for CH_4 produced in anaerobic soils (King 1992). CH_4 oxidation was often estimated as CH_4 production minus CH_4 emission (Sass et al. 1990; Denier van der Gon and Neue 1995b).

China is a major rice-producing country, accounting for 18.7% of the total area of rice paddy fields (3.06×10^7 ha) and 28.6% of rice production (2.06×108Mg) globally (FAOSTAT 2013). While rice paddies contribute 9% of the total agricultural GHG emissions (1.59×109t CO_2 equivalent) from China (Tan 2011). Understanding the dominant processes of CH_4 and N_2O exchange and their main controlling factors is vital for developing appropriate strategies to mitigate GHG emissions.

DYNAMICS OF METHANE EMISSION ON RICE VARIETIES

Irrigated rice cultivation is a primary anthropogenic source of CH_4 emission. Methane gas emissions involve production, oxidation, and transportation systems (Mer and Roger 2001; Mingxing and Jing 2002) in the irrigated rice field, following three pathways, viz., molecular diffusion, ebullition and plant-mediated transport (Wassmann et al. 1996; Khosa et al. 2010). Rice plants have a significant role in the release of CH_4 gas in paddy fields. Inundated conditions create an anaerobic atmosphere that can trigger the rapid activity of methanogenic bacteria to produce CH_4 gas. Methane emissions from rice fields in 2010 were 493–723 Mt CO_2 per year or 11% of global CH_4 emissions (IPCC 2014). Rice plants regulate methane budget from the functions of three factors (Zheng et al. 2014), including a source of the methanogenic substrate (Wang et al. 1999; Kerdchoechuen 2005), active methane gas exchange through aerenchyma (well developed intercellular air spaces) between the atmosphere and anaerobic soil (Fu et al. 2007), and active CH_4-oxidizing site in the rice rhizosphere by supporting O_2 counter transport through the aerenchyma system (Gutierrez et al. 2014).

The appropriate varieties can reduce methane emissions. The ability of rice plants to emit methane varies, depending on the physiological and morphological characteristics of a rice variety. The age and root activity of different rice varieties are also closely related to the volume of methane emissions. Rice varieties produce different methane emissions depending on the number of leaves, the number of tillers, leaf area index, and root dry weight. They are positively correlated to CH_4 flux (Baruah et al. 2010; Su et al. 2015). The lowest methane emissions in tidal swamps were released from Inpara 3 at 37.8 kg/ha/season and the highest was released from Inpara 6 at 47.3 kg/ha/season in a tidal swampland. Inpara 3 has a better root oxidizing capacity that can allow methanotrophic bacteria biologically to oxidize the oxygen concentration around the roots increases and methane (Annisa et al. 2017). The diversity of rice varieties at different growth phases caused differences in GHG emissions released from the soil-atmosphere system (Zheng et al. 2014). Rina et al. (2017) reported that the Mekongga and Inpari 13 cumulatively produced a low average CH_4 flux (<250 mg/m^2/season) while Inpari 31 and Inpari 32 varieties produced the highest average CH_4 flux (>300 mg/m^2/season). Methane emissions are positively correlated to the number of tillers and biomass and negatively related to the emission index, root biomass, and panicle (Qin et al. 2015). Variations in plant structure, size, number of tillers, metabolism, the potential for CH_4 gas transport, and root exudate also affect emissions. As reported by Rafiqul Islam et al. (2019), the growth duration of different rice genotypes had a positive correlation with root biomass. Methane emission among the rice genotypes varied and was correlated with stages of growth and organ formation (Table 1). In early-maturing rice genotypes, the peak emission was observed at 67 days after transplanting (DAT) while in late maturiting genotypes this was observed at 84 DAT (Miyata et al. 2000; Inubushi et al. 2003; Suryavanshi et al. 2012; Alberto et al. 2014; Bhattacharyya et al. 2014). Methanogenesis, microbial decomposition of rhizosphere deposition, root exudates, and other carbon inputs affect amounts of methane gas emitted (Tokida et al. 2010; Meijide et al. 2011). Notably, rice genotypes have effects on methane emission, which should be taken into account while increasing the rice grain yield.

The emission index is a comparison between the amount of grain produced and GHG released through rice plants. The emissions index is calculated according to the formula used by Sass et al. (1990), which is the yield in a unit of grain weight

Table 1. Correlation matrix of rice growth parameters and methane emission.

Parameters	Filled grain	Grain yield	Straw yield	Biomass yield	Root biomass	Growth duration	Methane emission
Filled grain	1						
Grain yield	0.8169	1					
Straw yield	0.8542	0.9903	1				
Biomass yield	0.8325	0.9985	0.9963	1			
Root biomass	0.3789	0.6994	0.6644	0.6854	1		
Growth duration	0.2835	0.6168	0.5965	0.6089	0.9615	1	
Methane emission	0.2261	0.5831	0.5474	0.5688	0.9774**	0.9845**	1

** means significant at $p<0.01$ level of significance.
Source: Rafiqul et al. (2019).

divided by the rate of GHG emissions. A higher emission index means the variety has low emission but a high grain yield. As an example, Annisa et al. (2017) reported Inpari 13 has an emission index of 0.007, which is lower than Inpara 3 with an emission index of 0.013. If the variety with the lower emission index has a higher yield, meaning that the increased yield is accompanied by even higher emission, which reduces the emission index. Mulyadi et al. (2014) demonstrated that the emission index of Inpari 6 is lower than Inpari 1 and Ciherang varieties. Inpari 1 variety produced the highest emission index along with higher grain yield than Ciherang, indicating that the raised yield in Inpari 1 is not in parallel with the increasing emission. Therefore, Inpari 1 can be considered as a substitute for rice variety with high GHG emissions currently cultivated by farmers.

CONCLUSIONS

Inpari 1 rice variety produces less GHG emissions in tidal swamplandion South Kalimantan. Development of rice varieties that are not only high-yielding but also have low methane emissions are neccessary and should be highly prioritized. The number of tillers is an essential factor in developing low-emission rice varieties, of which a large number of productive tillers tend to produce lower CH_4 emissions. Further studies need to be investigated in different types of tidal swampland across Indonesia to generate superior and/or improved rice varieties having low methane emission.

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CHARACTERISTICS OF LOCAL RICE GENETIC RESOURCES IN TIDAL SWAMPLAND AND ITS CONTRIBUTION TO RICE PRODUCTION IN SOUTH KALIMANTAN

Aidi Noor, Agus Hasbianto, Puspita Harum Maharani, and Aulia Dina Pramesti

INTRODUCTION

As a strategic commodity, rice production needs to be increased along with the population growth. In Indonesia, lowlands are some of the most suitable land for rice production, including in South Kalimantan, where rice is planted in various agroecosystems such as irrigated lowland, rain-fed land, freshwater swampland, and tidal swampland. Tidal swamplands with the potential for rice production cover an area of 188,908 ha or 34.2% of the total area of paddy fields in South Kalimantan (BPS Kalsel 2016). The largest tidal swampland area in South Kalimantan is located in Barito Kuala Regency, which has 101,228 ha of harvested area for rice in 2018 (BPS Kalsel 2018). However, rice productivity in this regency is only 3.85 ton/ha, which is lower than the average of lowland rice productivity in South Kalimantan at 4.50 ton/ha (BPS Kalsel 2018).

Local variety still dominates in rice cultivation in South Kalimantan tidal swamplands, while superior rice varieties are estimated to be planted in only around 10% of the area. The domination of local rice in tidal swampland is because of their high adaptability to such soil, which has several biophysical constraints such as soil acidity, the toxicity of some substances like Fe, and low nutrient content (Sarwani et al. 1994). Local rice germplasm in South Kalimantan tidal swampland is highy diverse, generally adaptive, and grows well under stress conditions even though it has low yield potential.

Local rice varieties in tidal swampland are essential genetic resources to be conserved for their extinction. In addition to the adaptability to the unfavorable environment, the texture and taste of local rice are preferred by the Banjar community in South Kalimantan. Therefore, local rice has a high selling value compared to improved varieties. Although currently, their genetic diversity appears to be unharmed; in reality, many existing rice genetic resources are not maintained properly (Rao and Riley 2004). To protect and conserve these local rice varieties, some efforts involving many related parties are needed.

The importance of local rice varieties are their valuable genetic resources that may have useful genetic traits attributable for improving rice varieties (Nafisah et al. 2006). The more diverse the genetic resources, the higher the opportunity to pool the desired traits into newly improved rice varieties (Sumarno 2007). Various local rice varieties adaptable to tidal swamplands can be used as sources of genes donors to improve rice varieties suitable for the environmental conditions in tidal swampland and meeting the preferences of farmers or communities in South Kalimantan. This paper dicusses characteristics of local rice genetic resources in tidal swampland and its contribution on rice production in South Kalimantan with relevant aspects.

POTENCY AND CONSTRAINTS OF TIDAL SWAMPLAND IN RICE PRODUCTION

Lowland rice cultivation is carried out in irrigated lowlands, rainfed lands, freshwater swamplands, and tidal swamplands. The composition of paddy fields in South Kalimantan in those agroecosystems was as follows: irrigated lowland 55,166 ha, rainfed land 172,074 ha, tidal swampland 188,908 ha, and freshwater swampland 135,604 ha (Figure 1). Therefore, tidal swampland is the most extensively used land type for paddy fields in South Kalimantan. Despite of its potential for rice production, such land also has some constraints for rice farming.

Indonesia has 33.4 million ha of swampland, comprising 20.1 million ha of tidal swampland and 13.3 million ha of freshwater swampland. This type of land can be a good option for agricultural development to overcome the loss of productive and fertile soil in Java Island due to land conversion. Among the 20.1 million ha tidal swamplands in Indonesia, around 9.53 million ha has the potential to be used as agricultural land (Alihamsyah

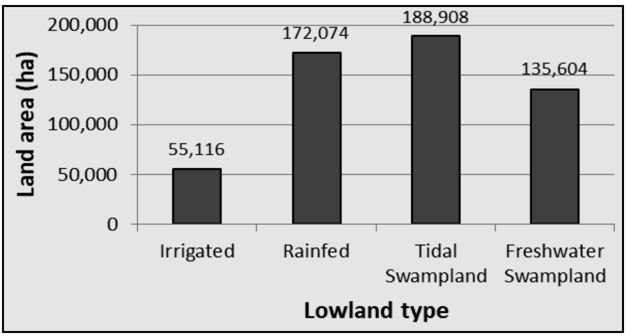

Figure 1. Lowland types in South Kalimantan (BPS Kalsel 2016).

2004). Based on their typology, the 20.1 million ha of tidal swamplands consist of 10.9 million ha of peatland, acid sulfate land (6.7 million ha), potential land (2.1 million ha) and saline land (0.4 million ha) (Widjaja Adhi 1986; Alihamsyah 2004). Acid sulfate land is a land type that presents more severe problems due to its pyrite layer. When oxidized, this layer causes a very acidic soil pH, which releases high concentrations of toxic elements such as Al, Fe, and H_2S while simultaneously has low nutrient content and availability (Sarwani et al. 1994).

The largest tidal swampland area in South Kalimantan can be found in three regencies namely Barito Kuala (113,998 ha), Banjar (35,135 ha), and Tanah Laut 15,628 ha (Table 1). The area of tidal swamplands in South Kalimantan is covering 188,908 ha (34.2%) of the total lowlands (551,702 ha), while the rest (65.8%) are non-tidal swamplands which include irrigated, rainfed and freshwater swamplands.

Table 1. The area of tidal swamplands in each regency in South Kalimantan.

Regency	Tidal Swamplands (Ha)	Non Tidal Swamplands (Ha)	Total (Ha)
Tanah Laut	15,628	60,070	75,698
Kotabaru	4,210	27,765	31,975
Banjar	35,135	34,333	69,468
Barito Kuala	113,998	0	113,998
Tapin	17,265	48,702	65,967
Hulu Sungai Selatan	-	45,694	45,694
Hulu Sungai Tengah	-	38,470	38,470
Hulu Sungai Utara	-	36,051	36,051
Tabalong	-	15,511	15,511
Tanah Bumbu	307	17,451	17,758
Balangan	-	34,273	34,273
Banjarmasin	1,988	0	1,988
Banjarbaru	377	4,474	4,851
Total (Ha)	188,908	362,794	551,702

Sources: BPS Kalsel (2016).

The low productivity of rice in tidal swamplands is caused by some factors such as high Fe content, soil acidity, low soil nutrient levels, and constant flooding during the whole planting season (Sahrawat 2004). Some improved rice varieties showed susceptible responses to the environmental stresses and compelled many farmers; therefore, farmers prefer local rice varieties, which are high tolerant to the environment of the tidal swamplands. According to previous studies (Suhartini 2004; Suhartini and Makarim 2009), the use of susceptible rice genotypes can result in iron toxicity and, in some instances, can even lead to crop production failure. Ningsih et al. (2014) reported that the use of varieties adaptive and tolerant to iron toxicity could increase the productivity. The adaptive varieties of Inpara 1, Inpara 2, Inpara 3, and Inpara 4, produce 4.13–5.55 ton/ha of grain yield compared to less adaptive varieties such as Ciherang (1.59 ton/ha).

One of the limiting factors for rice cultivation in lowlands is iron (Fe) toxicity, which has been reported to occur extensively in several Asian countries such as China, India, Indonesia, Thailand, Malaysia, and the Philippines (Asch et al. 2005). In rice plants, severe iron toxicity results in inferior plant and tiller growth, allowing the very low yield (Audebert and Sahrawat 2000).

Iron toxicity in rice is caused by high levels of Fe in soil or soil solution which affect diversely to plants . Majerus et al. (2007) and Mehraban et al. (2008) showed that Fe nutrient solution at 250–500 ppm, pH 4.5–6.0, significantly increased Fe levels in plant tissues and produced symptoms of Fe toxicity in sensitive/susceptible plants. Based on the report of Noor et al. (2012), the high Fe in the soil solution ($\geq$ 200 ppm) signs of Fe toxicity symptom which were appeared in IR 64 and Margasari rice varieties. Moreover, Fe toxicity in dry season is lower than that in rainy season as observed in the tidal swampland of Barito Kuala Regency (Noor et al. 2015).

Another point of view stated that Fe toxicity commonly occurs due to the absorption of the element Fe^{2+} that exceeds 300 ppm (Peng and Yamauchi 1995), which results in the disruption of some metabolic processes that can cause damages to plants (Bode et al. 1995). Plants affected by Fe toxicity have reduced tiller formation, which produces low rice yield. A study done in Blandean acid sulfate tidal swampland in Barito Kuala Regency revealed that rice genotypes had different responses to Fe toxicity, of which the rice yields ranged from 2.24 to 5.9 ton/ha and the scores of Fe toxicity ranged from 1.3 to 6.3 (Noor et al. 2007).

LOCAL RICE CHARACTERISTICS IN TIDAL SWAMPLAND

Local rice in tidal swamplands comprises diverse accessions/varieties with different names, although they may have different characteristics.The diversity of local rice varieties/accessions could be identified and characterized accurately. According to Marum (2006), germplasm preservation can be done by exploration, conservation, characterization, evaluation, as well as documentation. Exploration activities are the search for and the collection of various types of germplasm to secure them from extinction. The collected germplasms are observed, and their characters are recorded, and information from the surrounding community needs to be explored as the essential properties of the germplasms. Germplasm conservation is the maintenance and management stage for all the collections to keep them viable. Genes currently not yet useful may, in the future, be needed, and the accessions carrying those genes can be used as parental lines in the development of new high yielding varieties (Tickoo et al. 1987). Utilization of useful genes from local rice for plant breeding is expected to produce rice with features similar to local rice but have higher productivity and earlier maturity. The specific characters of a local variety are advantage to be used to assist breeding scheme (Liu et al. 2007). The completed phenotypic and genetic characters of germplasm will add value in the diversity as well as uniqueness of local rice for improving rice varieties (Neeraja et al. 2005).

The local varieties of Siam Mutiara from Barito Kuala and Siam Saba from Banjar suitable in the tidal swamplands in South Kalimantan have been released as a superior national variety. Siam Mayang, Siam Unus, and Karang Dukuh (from Barito Kuala) are known to have late maturity with a range of 240–260 days to harvest. The plants are erect to intermediate, while plant height range 139–160 cm. Their productive tiller numbers are 14–19 tillers, with grain colour of clear yellow, pale yellow, or brownish yellow, slender (slim) grains and the number of grains per panicle range from 214 to 233 (Table 2).

The local rice varieties adaptive in tidal swampland have their phenotypes. The plants are either resistant or moderately resistant to lodging, moderate grain loss, hard rice ("pera") texture, amylose content >28%. The grains are small with the weight of 1000 seeds ranging from 15.15–18.25 g and yield potential is around 4.2–5.8 ton/ha (Table 2). Five rice varieties have been assayed their phenotypic characters in the tidal swampland in South Kalimantan. The general characters of the five varieties were late maturity (>8 months of days to harvest), small grain size with a slender shape, and the hard rice texture.

Local rice varieties generally have an average number of tillers, which was very few to moderate, plant height is tall and easily lodged. Some of the local rice is sensitive to daylength

Table 2. Characteristics of some local rice from tidal swamplands in South Kalimantan.

Characteristic	Local varieties				
	Siam mutiara[1)]	Siam Saba[1)]	Siam Mayang[2)]	Siam Unus[2)]	Karang Dukuh[2)]
Origin (Regency)	Barito Kuala	Banjar	Barito Kuala	Barito Kuala	Barito Kuala
Harvest age (day)	255	240	240–245	245–250	255–260
Plant shape	Erect	Erect	Moderate	Erect	Erect
Plant height (cm)	159.6–160.0	149.8–150.9	160–168	148–154	139–149
Tiller number	17–19	18–19	14–16	16–19	15–19
Grain Colour	Light yellow	Brownish yellow	Light yellow	Pale yellow	Pale yellow
Grain Shape	Slim	Slim-small	Slim	Slim	Slim
Filled grain/panicle (%)	97.8	96.3	91.7	92.4	94.5
Grain number/panicle	215	233	225	214	227
Grain Loss	Moderate	Moderate	Moderate	Moderate	Moderate
Lodging	Moderate	Less	Less	Moderate	Moderate
Rice Texture	Less fluffy (hard)	Less fluffy (hard)	Less fluffy (hard)	Less fluffy (hard)	Les fluffy (hard)
Rice Taste	Good	Good	Good	Good	Good
Weight of 1000 grains(g)	17.7	17.87	15.15–15.73	17.9–18.25	16.23–71.33
Amylose content (%)	28.28	29.75%	-	-	-
Protein content (%)	8.12	7.36	-	-	-
Carbohydrate content (%)	48.88	81.69	-	-	-
Yield potency (ton/ha)	4.80–5.67	4.5–5.5	4.2–5.0	4.6–5.2	4.8–5.6

Sources: 1) Kemtan (2008), 2) Noor et al. (2018).

(photoperiodic). The character of the daylength sensitivity is essential when introducing a new variety from other regions or selecting a suitable rice variety for an area to get new rice varieties that are not affected by day length (Sutoyo 2011).

Forty rice accessions/varieties from the tidal swamplands of South Kalimantan differ based on their plant height, age, panicle, shape, size, and color of the grain. Five selected accessions (Siam Harli, Siam Unus, Siam Kuatek, Siam 11, and Siam Gumpal) had 2.1–6.1 ton/ha grain yield, small grains, the weight of 1000 seeds ranging from 16.76–20.67 g (Wahdah et al. 2012).

Local rice yields in tidal swamplands are generally low, ranging between 2–2.5 ton/ha (Sutami and Sulaiman 2000). Still, local rice varieties have several advantages such as being adaptive to tidal swampland environment, and their planting can be delayed according to water conditions, climate conditions, or labor availability. They can also recover if attacked by rats because they have a long vegetative phase. Also, local rice generally has a stable yield, requires low input, and has small and slim grains that are favored by farmers and consumers (Sulaiman and Imberan 1996, Sulaiman 1997). On the other hand, according to Koesrini et al. (2014), local rice also has several weaknesses, such as low yield (2.0–2.5 ton/ha), long age (8–10 months), and relatively susceptible to pests and plant diseases.

A study of farmers' preferences among superior rice varieties in tidal swamplands showed that Banjar ethnic farmers preferred the Margasari rice variety due to its plant type, grain shape, rice quality, color, texture, and taste of rice (Darsani and Koesrini 2018). Margasari variety is the result of a cross between a Siam local variety of tidal swampland origin and superior varieties that have similar grain shape to local varieties (Siam types).

RICE PRODUCTION IN TIDAL SWAMPLAND IN SOUTH KALIMANTAN

Local rice varieties still dominate tidal swampland cultivation in South Kalimantan. Most farmers in tidal swamplands grow local rice varieties once a year. However, 10% of farmers plant improved variety, then followed with local rice. The reason farmers grow local rice is because of the ease of cultivation (as they do not require high inputs), higher selling price in markert and more preferable by local consumers (Wahdah and Langai 2010).

The harvested area of lowland rice in South Kalimantan in 2017 was 506,823 ha, average productivity was 4.5 ton/ha, and the total grain yield was 2,258,261 tons. Barito Kuala Regency where the largest tidal swampland existing, has a rice cultivation area of 101,228.3 ha, and its productivity was 3.85 ton/ha (Table 3). The estimated rice cultivation areas in tidal swamplands were around 166,324 ha (BPS Kalsel 2016). By the calculation of the proportion of local rice planted in tidal swamplands which is about 90%,

Table 3. Harvested area, production, and productivity of tidal swampland rice in South Kalimantan in 2017.

Regency	Harvest area (ha)	Production (ton)	Productivity (ton/ha)
Tanah Laut	52,837.7	200,498.0	3.79
Kotabaru	14,058.5	62,181.0	4.42
Banjar	56,190.3	218,855.0	3.89
Barito Kuala	101,228.3	389,757.0	3.85
Tapin	77,612.1	356,186.0	4.59
Hulu Sungai Selatan	46,024.4	231,431.0	5.03
Hulu Sungai Tengah	55,258.9	305,653.0	5.53
Hulu Sungai Utara	23,292.8	131,787.0	5.66
Tabalong	19,895.3	105,174.0	5.29
Tanah Bumbu	21,188.6	104,524.0	4.93
Balangan	35,602.6	138,485.0	3.89
Banjarmasin	1,787.6	7,034.0	3.93
Banjarbaru	1,845.9	6,696.0	3.63
Total	506,823.0	2,258,261.0	4.50

Sources: BPS Kal-Sel (2018).

thus the total cultivation area of local rice is approximately 150,000 ha. If the average productivity of local rice is 3.0 ton/ha, in theory, local rice in tidal swamplands should produce 450,000 tons of grain annually, thus contributing to rice production in South Kalimantan by around 19.9%.

CONCLUSIONS

Local rice varieties widely planted by farmers in South Kalimantan are Siam Mutiara, Siam Saba, Siam Unus, Siam Mayang, and Karang Dukuh. Siam Mutiara and Siam Saba have been released as national varieties. The swampland local rice has the characteristics of days to harvest of 240–260 days, plant height of 139–160 cm, productive tillers of 14–19, number of grains/panicles of 214–233 seeds, slim/slim long grain, the weight of 1000 seeds at 15.15–18.25 g, hard rice texture, amylose content >28%, and potential yield of 4.2–5.8 ton/ha. Local varieties are preferable by farmers because of their taste and favored by consumers in South Kalimantan. The selling price of local rice variety is Rp. 12,000–15,000/kg. An estimation of acreage of local varieties cultivation in the tidal swamplands is 150,000 ha with average productivity of 3.0 ton/ha. Therefore, the local varieties annually produce 450,000 tons or around 19.9% of national needs. These local varieties are beneficial for further development for their optimal rice production in this region and need further assessment for the sustainable utilization.

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ADVANCES OF IMPROVEMENT OF DROUGHT TOLERANCE IN RICE IN SOUTHEAST ASIA

Puji Lestari, Mastur, Karden Mulya, and Haryono

INTRODUCTION

Rice (*Oryza sativa* L.) is predominantly produced and consumed in Southeast Asia. Rice production, however, has always been affected by environmental changes, and farmers have looked for ways to manage them (Redfern et al. 2012). Adaptation to climate change in rice production systems is complex and must be taken into account for a range of environmental factors. There are thresholds for some climate variables which can reduce rice yields (Zhai and Zhuang 2009). A previous study reported that climate change would reduce rice yield from 1.29 to 23.05% during the winter season for both scenarios and all periods, while yield increase by 2.07 to 6.66% is expected in the summer season in 2020 and 2050, relative to baseline yield (Deb et al. 2014). Rice production systems in Southeast Asia in recent years have become more severely threatened by the effects of climate change. Moreover, several countries in this region have begun to experience a gradual stagnation in production levels due to abiotic stress (Redfern et al. 2012).

Drought, which is defined as water stress mostly because of lack of rain, is the most serious constraint to rice production in unfavorable rice-growing areas, including Southeast Asian countries. Drought is one of the most widespread and damaging of all environmental stresses, affecting 23 million hectares of rainfed rice in South and Southeast Asia. At present, there are no economically viable means of increasing rice yield under drought stress. The development of new rice varieties tolerant to drought could be a promising approach to meet the increasing demand for food. Unfortunately, most of the popular rice varieties used by farmers are susceptible to this drought stress (Manickavelu et al. 2006; Farooq et al. 2013).

An understanding of the physiological mechanisms and genetic controls of traits that contribute to resistance at different developmental stages is essential (Manickavelu et al. 2006). The mechanism of drought tolerance is complicated due to variations in plant phenology. Moreover, drought traits are controlled by quantitative trait loci (QTL). Many QTLs related to drought tolerance in rice have been identified (Lang et al. 2013; Oladosu et al. 2019). IRRI scientists involved in the 3000 rice genomes project have identified QTLs that give rice drought tolerance to improve rice grain yield. Notably, drought tolerance has been put into popular high-yielding rice varieties, including IR64, Swarna, and Vandna (Mansueto et al. 2017).

To develop new varieties, molecular breeders of rice should understand the fundamentals of molecular pathways involved in complex agronomic traits to increase the yield. At present, the use of cost-effective DNA markers derived from the fine-mapped position of the genes for important agronomic traits will provide opportunities for breeders to develop high-yielding, drought-resistant, and better quality rice varieties (Shabir et al. 2017). Several studies have been reported on the drought response of rice plants in South East Asia (Bernier et al. 2008; Kamoshita et al. 2008). This article describes rice production in South East Asia and the drought constraint, which affect yield, general issues of crop breeding for drought, and how the biotechnological approach can be an alternative to solve this issue in rice.

DROUGHT IN SOUTH EAST ASIA AFFECTS RICE PRODUCTION

Southeast Asian region (including Indonesia, Malaysia, and the Philippines) has a more complicated climate due to its position on the boundaries of significant air flows, and because of the fragmented and insular nature of the land areas with the presence of many highlands. Climate can affect agriculture production in a variety of ways. Temperature, radiation, rainfall, soil moisture, and carbon dioxide (CO_2) concentration are all important variables to determine agricultural productivity. Changes in temperature regimes greatly influence not only the growth duration but also the growth pattern and the productivity of rice crops (Redfern et al. 2012). The critical temperatures for the development of rice plants at different growth phases varies, and a decrease of 10% in rice yield has been found to be associated with every 1 °C increase in temperature in Indonesia (ADB 2009), while the rice yield of dry-season rice crops in the Philippines decreased by as much as 15% for each 1 °C increase in the mean temperature of a growing season. Heat and other aggravating climate change effects may cause a decline in the world rice production (Furuya and Koyama 2005), and have already been proven to have adverse effects on agricultural production.

Even though in recent times, rice production has significantly increased in South East Asia, but it occurred mostly in irrigated areas. The progress has been much slower in countries where the proportion of irrigated rice is small, i.e., Thailand, Laos, and Cambodia. One of the significant constraints for rice production in South East Asia is drought. In Cambodia, late-maturing varieties have been replaced by faster-maturing varieties with high yield to increase the chance of escaping from severe droughts that commonly set in dry seasons since rice crops in Cambodia are mostly grown under rainfed conditions without irrigation. Rice yield in this country is low compared to most neighboring countries. The harsh environment also exists in North-East Thailand, where the largest area of rice is grown under rainfed lowland conditions, and crops often encounter frequent severe drought problems. Similar problems also occur in Northern Thailand, Laos, and Cambodia, but to a lesser extent. Low rainfall is the primary reason for the frequent drought problem; in some areas of North-East Thailand mean annual rainfall is less than 1000 mm. Thai breeders have realized the variation in drought development across the toposequence positions, and are using this variation in their breeding program (Jongdee et al. 2006; Fukai 2007).

In Lao PDR, rice self-sufficiency was achieved recently for the whole country. However, Northern Laos is mountainous, and crop production is limited. The availability of irrigation water has allowed for rice cropping in the dry season and hence double cropping of rice. In Vietnam, the progress in agricultural production is very rapid in recent years, and rice is exported in a large quantity. In the Mekong River Delta, which is the central rice-growing region in Vietnam, post-harvest losses from harvesting to the storage of rice range from 7 to 26%. A further decrease of 3.8% in rice production occurred in Southeast Asia because of water deficit and increased temperatures, despite CO_2 fertilization (Murdiyarso 2000). By 2100, Indonesia, The

Philippines, Thailand, and Viet Nam are projected to experience a potential fall of about 50% in rice yield, assuming no adaptation and no technical improvement are implemented. The rice yield decline would range from 34% in Indonesia to 75% in the Philippines (ADB 2009). Besides, economic losses arising from drought affect rice production in rainfed areas. A better understanding and application of technologies is needed as the strategies to minimize the effect of drought.

CROP IMPROVEMENT FOR DROUGHT

Increased productivity is one of the main goals of the rice breeding program. However, the other purposes can vary according to its importance from region to region and country to country. Advanced strategies will have an impact on the increase of the genetic potential for grain yield of rice varieties in the crop improvement. The main breeding methods used to improve rice are pedigree selection, development of hybrids, and population improvement. Biotechnological tools can be used to enhance the breeding capacity; however, there is a struggle on how to integrate them into the breeding programs and how to balance the allocation of resources between conventional and modern tools (Khan et al. 2015). Conventional breeding is often based on empirical selection for yield (Atlin and Lafitte 2002). However, understanding the physiological and molecular basis may complement conventional breeding programs and hasten rice yield improvement (Cattivelli et al. 2008).

Genetic improvement for drought tolerance has been addressed using integrated approaches between conventional selection for yield and secondary traits and biotechnology (Farooq et al. 2009). These traits include deeper and thicker roots, root pulling resistance (Pantuwan et al. 2002), and higher root penetration (Clark et al. 2000). To locate important gene sequences and introgressing QTL to develop drought-tolerant genotypes are strongly affected by yield-determining physiological processes (Sahebi et al. 2018). A diagram of the development of new varieties or genetic materials tolerant to drought (Farooq et al. 2013) is presented in Figure 1.

Drought stress reduces rice growth and development, which affect flowering and grain filling. These adverse effects depend on the timing, duration, severity, and intensity of the stress level. The drought resistance mechanism is complex, involving physiological and biochemical processes at cell, tissue, organ, and whole-plant levels, depending on the stage of plant development. For drought tolerance, therefore, the primary focus should be to improve crop yield by increasing carbon gain during the crop cycle under drought. Consequently, target genes that increase water-use efficiency without yield penalties should be understood (Condon et al. 2004; Farooq et al. 2013). Genetic variations in germplasm expectedly influence the response of rice to drought stress.

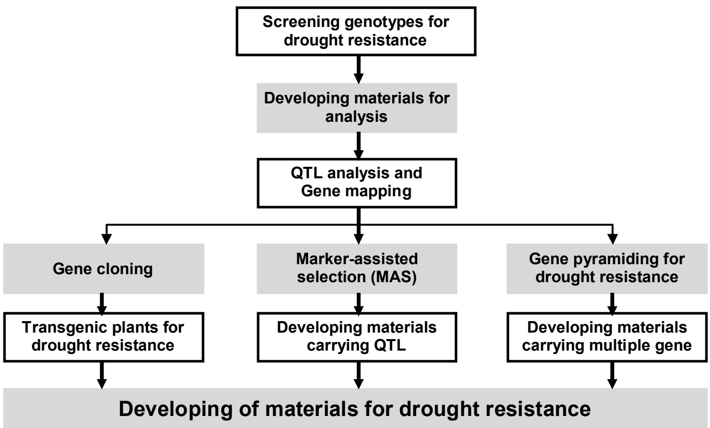

Figure 1. Development of new varieties tolerant to drought stress.

Little progress has been made in characterizing the genetic determinants of drought resistance because of its different transcription factors that control a complex phenomenon comprising physio-biochemical processes in rice. Specific genes and proteins associated with drought tolerance are expressed in rice. *WRKY* genes play positive or negative regulatory roles in plant responses to different abiotic stress, including drought. Some genes for aquaporins or putative aquaporins, such as rice *rTip1,* are upregulated under drought stress. Rice zinc-finger protein mutation induces improved drought and salt tolerance (DST mutant) by reducing stomatal density and increasing stomatal closure. However, DST non-mutants act negatively on stomata closure by modifying H_2O_2 homeostasis (Oladosu et al. 2019). It is noted that genetic engineering techniques could also be useful for developing rice with drought tolerance. Moreover, the rice genetic map is well covered by SSR markers (McCouch et al. 2003), and rice researchers worldwide have developed diverse mapping populations and related databases. Overall, molecular breeding approaches can be used to exploit QTLs for rice crop improvement; thus, candidate genes are the primary targets for genetic engineering and the production of transgenic lines (Varshney et al. 2011; Sahebi et al. 2018).

A CASE STUDY: GENETIC DIVERSITY OF RICE FROM ASEAN ASSESSED BY SSR MARKER

The availability of complete rice genome sequence and recent improvements in rice genomics research have made it possible to detect and map a large number of genes accurately by using linkage to DNA markers. Linkage mapping is a practical approach to identify genetic markers that are co-segregating with the target traits within the family. The ideas of gene diversity, quantitative trait locus (QTLs) mapping, and marker-assisted selection (MAS) is evolving into more efficient concepts of linkage disequilibrium (LD), which is also called association mapping and genomic selection (GS) (Shabir et al. 2017).

To improve a better adaptation of rice plants to climate change and drought stress, as well as enhance food security in South East Asian countries, so local rice and improved varieties have been shared among four countries. A new gene pool consisting of 106 local and improved varieties from Lao PDR (22 rice varieties), the Philippines (22 rice varieties), Indonesia (25 rice varieties), and Malaysia (25 varieties), have been established and characterized using molecular markers. This new gene pool of local varieties, along with their genotypic and phenotypic character data could be useful to strengthen the conservation and sustain the use of rice genetic resources.

The genetic diversity among rice germplasm in the new gene pool of 95 shared local varieties has been analysed using 14 simple sequence repeat (SSR) markers corresponding to QTL for drought tolerance. A total of 124 alleles were amplified with an average of 8.86 alleles per locus and Polymorphic Information Content (PIC) value of 0.70, indicating highly informative SSR markers. The high average of PIC represented the high genetic diversity of these rice varieties (0.73). Heterozygous alleles were identified in these rice germplasms with the average of major allele frequency of 0.37.

The local varieties are group into two main clusters, reflecting a correlation between their genetic background and the country origin (Fig. 2). Relatively comparable genetic diversity indices were observed among rice germplasm originated from each country, at approximately 1.6. Pairwise population matrix of Nei genetic distance revealed that the closest distance was identified between local varieties from Malaysia and Indonesia, suggesting the high probability of shared genetic and geographical origin,

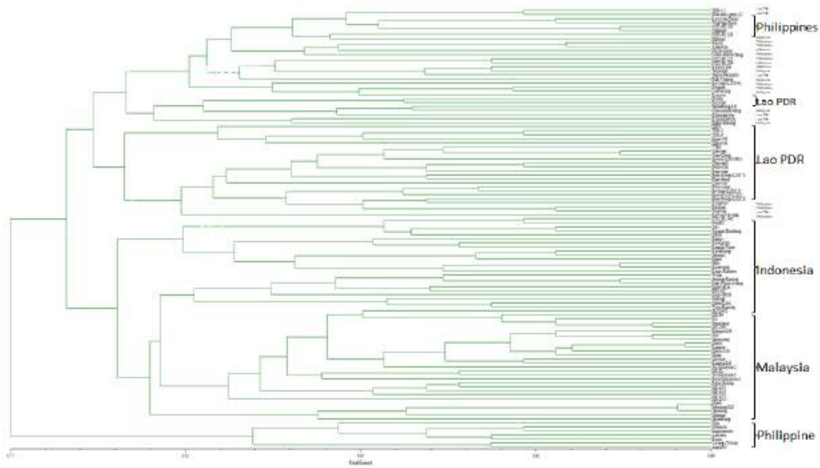

Figure 2. Dendrogram of 95 local rice varieties originating from Indonesia, Philippine, Lao PDR, and the Philippines based on polymorphism of SSR markers corresponding to QTL for drought tolerance and upland rice.

and the furthest was between those originated from Malaysia and the Philippine. Local varieties from Indonesia seem to have similar genetic distances with those from Laos and The Philippines. Drought response assessment of these accessions is necessary to support this molecular identification. The broadening of the genetic bases of local varieties from these four countries is vital for future parental lines selection in breeding for improved varieties with tolerance to drought.

FUTURE PERSPECTIVE

Screening and evaluation of drought tolerance in rice still used conventional methods, which is inadequate, laborious, and inefficient in comparison to more advanced techniques. The SSR markers used in genetic diversity analysis were chosen according to the high genotypic variation of QTL related to drought tolerance in upland rice. Thus, for their potential use, further validation on broader germplasm with varied tolerance level is needed. The characters observed in the assays should be comprehensive to cover root plasticity and architecture, and related morpho-agronomical characteristics. Moreover, the information on the genome sequences of these varieties that were analyzed using these SSRs in this study could be useful to find significant structural variations or alleles governing drought tolerance that are specific for these variety set.

To enrich and broaden genetic materials for drought-tolerant donors, shared rice germplasm from South East Asian countries under co-development and technologies transfers schemes are needed. Integrated approaches are essential to elucidate complex quantitative traits of yield stability under drought stress in rice plants. Major QTLs that are proven to be associated with drought tolerance in rice should be tested as the genetic donors in the breeding. Many major genes controlling drought tolerance, which have been transferred to develop new rice plants using genetic engineering, should be evaluated in the field. A better understanding on rice plant responses to water deficits is important, followed by linking it to breeding, along with drought-tolerance traits that may be divided into primary, secondary, integrative, and phenological. Taken together, to solve the drought problem, the advanced genomics combined with other new technologies in quantitative genetics, functional genomics, and bioinformatics along with an eco-physiological understanding of the interactions between rice plants and the environment is needed, to achieve a better crop improvement program.

CONCLUSIONS

Rice production has increased prominently in South East Asia countries, but it exists mainly in irrigated areas. Recently, drought becomes the major obstacle in rice production in the region. Vietnam, Indonesia, Myanmar and Cambodia had been faced severe drought in some areas due to unpredicted climate changes. Furthermore, over 50% of the rice area in this region in is rainfed which can limit total rice yield. However, most of the improved rice varieties grown in drought prone areas were originally bred for irrigated system. Drought may affect rice development at morpho-agronomical, physiological, and molecular levels. Certain genes and proteins associated with drought tolerance are expressed in rice and change their expression under water stress. Therefore, breeding programs for the improvement of drought-tolerant rice varieties must be based on an understanding of the response of rice to drought which is assessed from a physiological and genetic perspective., especially its physiological and molecular basis. Recent genetic techniques and genomics tools coupled with advances in breeding techniques and precise phenotyping probably reveal candidate genes underlying drought tolerance in rice plant. A genetic diversity study using SSR markers on shared rice varieties among Indonesia, Malaysia, Lao PDR and the Philippine suggested their potential as drought-tolerant donors which are important for breeding program.

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DIVERSITY OF RICE GENETIC RESOURCES ON SALINE SOILS IN KEPULAUAN MERANTI, RIAU PROVINCE

Parlin H. Sinaga, Usman, Hery Widyanto, and Masganti

INTRODUCTION

Salinity has affected around 13.2 million ha of potential areas for rice growth in Indonesian swamps (Ponnamperuma et al. 1980; Suprianto et al. 2010) which is increasing along with rising sea levels due to global warming. The distribution of saline land is generally in coastal areas, irrigated land, excess fertilizer land, and land naturally high in salt. The expansion of saline land in Riau Province is a formidable challenge for food crop agriculture. Agricultural areas in coastal are generally overflowing with seawater at certain times which can limit plants cultivation since high salinity.

Saline land is characterised by high pH <8.5, and are dominated by salts of Na, Ca and Mg in the form of chloride or sulfate, low availability of N, P, Mn, Cu, Zn, and Fe in the soil, high osmotic pressure, weak movement of water and air, and low activity of soil microbial. Salinity causes morphological, physiological, biochemical, and anatomic changes (Tester and Davenport, 2003). Salinity is an abiotic-stress that can affect crop productivity and quality, root, stem, and leaf area growth. The growth of leaf area is reduced due to metabolic imbalance caused by NaCl ion poisoning, osmotic stress, and nutrient deficiency (Sembiring and Gani 2007).

Agricultural areas that have gained a direct influence of rising sea levels in Riau Province include Kepulauan Meranti, Siak, Indragiri Hilir, Bengkalis, and Pelalawan. A thousand hectares of rice fields are threatened to turn into unproductive land. Rice yields fell due to salt. Therefore, farmers choose to plant rice in rainy season when salt concentrations are low in the fields.

In high salt concentration, limited varieties of food crops can survive in saline soil. Only a few newly improved rice varieties can survive, but the preferences of local farmers hinder their development. Therefore, farmers prefer local rice varieties adaptable to salinity and good taste. For decades, farmers in Kepulauan Meranti Regency planted many local rice varieties, mostly late maturing rice varieties, and less fluffy or hard texture ("pera"). Introduction of newly improved rice varieties in the future could impact to the extinction of local varieties. The local rice need to be preserved because of their valuable as source of genes for tolerance to salinity, resistance to pathogens, and specific tastes. This study aimed to explain the genetic diversity and yield potential of local salt-tolerant rice based on field assay in Meranti Regency.

DIVERSITY ANALYSIS

Field evaluation of 105 local rice genotypes was conducted in 2016–2017 in the saline rice fields in Kepulauan Meranti Regency. The research was designed based on a Randomized Complete Block Design (RCBD). The characters observed were plant height, number of productive tillers, number of seeds per panicle, grain weight per clump, days to flowering, days to harvest, harvest index, number of short seeds, number of empty seeds, total seeds, the weight of 1000 grains, culm thickness, and yield.

Cultivation techniques consisted of: (1) organic fertilizer 2 ton/ha and dolomite 1 ton/ha; (2) 25 days old-seedlings; (3) plants in the nursery are fertilized with urea 50 kg/ha, TSP 50 kg/ha, KCl 25 kg/ha (urea ½ dose, TSP, and KCl applied at one day before sowing, and ½ dose urea applied at 13–14 day old seedlings, nursery area 5% of planted area, (4) spacing of 30 x 30 cm, (5) 1 seedling per hole, (6) urea based fertilizer 100 kg/ha, TSP 150 kg/ha, KCl 50 kg/ha, added with Furadan 16 kg/ha at three days after planting, (7) urea supplementation fertilizer 100 kg/ha and KCl 50 kg/ha given at 35 days after transplanting, (8) weeding using herbicides, (9) integrated pest control method; (10) harvest at 95% panicles turn yellow. The water salinity was determined in dry season and rainy season.

Data were processed using analysis of variance (Table 1). Based on the mean square value of Anova, genetic and phenotype differences were calculated for the coefficient of gene variability (CGV) and the Coefficient of Phenotype Variability (CPV).

Table 1. Expectations of mean square based on randomized complete block designs.

Sources	Db	MS	EMS
Replication	r-1	MSR	
Genotype	g-1	MSG	$\sigma^2_e + r\sigma^2_g$
Error	(r-1)(g-1)	MSE	σ^2_e
Total	rg-1		

where:

σ^2_e = MS error/r

σ^2_g = (MS genotype–MS error)/r

$\sigma^2_f = \sigma^2_g + \sigma^2_e$

The coefficient of phenotype variability (CPV) and the coefficient of genetic variability (CGV) are calculated according to Kearsey and Pooni (1996) with the formula:

$$CPV = \frac{\sqrt{\sigma_f^2}}{\bar{X}} \text{ x } 100\% \quad CGV = \frac{\sqrt{\sigma_g^2}}{\bar{X}} \text{ x } 100\%$$

where:

σ_f^2 = phenotype variance

σ_g^2 = genetic variance

$\bar{X}$ = average of each character

Criteria for breadth of diversity are low (0% ≤ 25%), rather low (25% ≤ 50%), high enough (50% ≤ 75%), and high (75% ≤ 100%). This value is repeated using the highest value of coefficient variability of all observed characters as a value of 100%. Heritability in a broad sense (h^2) is calculated based on the separation of component variance according to Acquaah (2012).

$$h^2 = \frac{\sigma_g^2}{\sigma_g^2 + \sigma_e^2}$$

where: σ_g^2 = genetic variance

σ_e^2 = environment variance

Criteria for estimating heritability in a broad sense are high (h^2 >0.50), moderate ($0.20 \leq h^2 \leq 0.50$), low (h^2 <0.20) (Stansfield 1991).

SOIL AND AGRO-MORPHOLOGICAL PROPERTIES

As a result of a new open field near coast, seawater intrusion occurs through waterways during large tides. Soil type is alluvial with dusty clay texture (60–75% clay and 24–39% dust). In the long dry season, grains of salt can be found on the surface of the soil. Farmers grow rice only once a year with dominant local varieties. Soil analysis reveals that the main limiting factor for plant growth at this location is salinity. In dry season, no newly improved rice varieties are able to adapt well. Most of them die only a few weeks after transplanting, or those that survive till generative phase with empty panicles (Sinaga et al. 2017). Most of local varieties adapt to both dry and rainy seasons. Saline soil properties in Kepulauan Meranti Regency for growing rice is presented in Table 2.

The high value of soil cation exchange capacity (CEC), base saturation, organic matter content, and P-available, indicates that the fertility of the soil at the study site is relatively high. Therefore, stresses faced by plants are most likely due to high salinity or sulfate nutrient not nutrient deficiency.

The level of salinity at the study site is very high. Salinity observed using a salinity refractometer in surface water and subsurface water show significant differences (Table 3). Rice field water consisted of three depths, namely: +15 cm, -15 cm, and -30 cm from the ground surface. Water samples with a height of +15 cm from the ground surface are taken from inundated paddy fields, while water samples of -15 cm depth and -30 cm are taken from holes made according to treatment. Table 3 presents salinity measured in the rainy season, with the height of standing water in the rice fields starting from 10 cm. The salinity of water at ground level is 6‰ and as a comparison, the salinity seawater around the planting area is 25‰.

Table 2. Saline soil properties to grow various saline rice cultivars in Segomeng 1 and Segomeng 2, Kepulauan Meranti Regency.

Variable	Type of soils			
	Segomeng 1	Criteria	Segomeng 2	Criteria
pH (1.5)				
- H_2O	5.2	Acid	5.5	Acid
DHL (dS/m)	3.920	High	5.600	Very high
Salinity (mg/L)	1,962.0	High	2,800.0	Very high
C-Organic (%)	4.49	High	6.01	Very high
N Kjeldahl (%)	0.28	Moderate	0.32	Moderate
C/N	16	High	19	High
HCl 25%				
- P_2O_5 (mg/100 g)	45	High	37	Moderate
- K_2O (mg/100 g)	143	Very high	154	Very high
P_2O_5-Bray 1 (ppm)	26.9	Very high	19.0	Very high
K_2O-Morgan (ppm)	1,177		1,534	
CEC ($cmol_c$/kg)	31.22	High	34.76	High
Exchange base cation ($cmol_c$/kg)				
- K	2.34	Very high	3.05	Very high
- Ca	6.39	Moderate	10.42	High
- Mg	3.44	High	23.20	Very high
- Na	31.69	Very high	39.89	Very high
Base saturation (%)	>100	Very high	>100	Very high
Exchangeable acidity KCl 1 N				
- H^+ ($cmol_c$/kg)	0.14		0.14	
- Al^{3+} ($cmol_c$/kg)	0.05		0.02	
Extract Morgan Wolf				
- Fe (ppm)	53	Very high	62	Very high
- SO4 (ppm)	9,230	Very high	14556	Very high
HCl 25%				
- Ca (mg/100 g)	48	Very low	168	Moderate
- Mg (mg/100 g)	302	Very high	300	Very high
Total (HNO3)				
- Al (%)	6.25		5.80	
- Fe (%)	2.72		2.76	
- S (%)	0.32		1.14	
- Pyrit (%)	0.59		2.14	

Source: Sinaga et al. (2017).

Table 3. Salinity levels based on water levels in paddy fields for saline-tolerant rice is cultivated in December 2017.

Water level (cm)	Salinity (‰)
+15	6
-15	6
-30	12

Twenty two local rice varieties (population) cultivated by farmers in Kepualauan Meranti are Padi Kijang, Padi Putih, Padi Kecik, Sendani, Sendani Anak Dara, Siam Malaysia, Padi Kalus Kubu, Ketek, Pulut, Pulut Belanda, Pulut Herang, Anak Dara, Padi Burung, Korea, Padi Telor, Padi Induk, Malaysia Wangi, Serayu, Serai Wangi, Siam Bengkalis, and Sendaur Anak Dara, as well as an unidentified one (NN). Within each population, other variants can be distinguished from the original population, thus the number of genotypes becomes 105 (Table 4). The selection of each genotype of the population is useful to purify the variety and find high yielding genotypes in dry season in salty soil.

GENETIC AND PHENOTYPIC VARIANCE

The rice varieties adaptable in saline soil has the highest coefficient of genetic variance (CGV) 34.34% and is expressed as 100%, and the highest coefficient of phenotype variance (CPV) 39.97% as 100% (Table 5). Thus, the criteria for the breadth of diversity based on CGV are low (0%–8.6%), rather low (8.7%–17.3%), high enough (17.4%–26.0%), and high (>26%). Indicators of phenotype diversity based on CPV are low (0%–10%), rather low (11%–20%), high enough (21%–30%), and high (>30%). Characters with low and rather low in the coefficient of genetic variance values are classified as characters with narrow genetic diversity, in contrast to those with high enough and high criteria which will be grouped as broad genetic diversity.

Table 4. Diversity of agronomical characters of 105 rice genotypes in saline soil observed in rainy season (SI), Kepulauan Meranti, 2017.

No Genotype	Name	Plant height (cm)	No of productive tiller	Days to flowering (day)	Days to harvest (day)	Straw weight (g)	Panicle weight (g)	Harvest index	No. of pithy seeds	No. of empty seeds	Total seeds	Weight of 1000 seeds (g)	Culm thickness (cm)	Weight of seeds per clump (g)	Yield (ton/ha)
1	Padi Kijang	173.7	21.3	116.7	143.3	108.6	79.4	0.42	195.3	26.0	221.3	24.7	0.9	98.7	4.1
2	Padi Kijang A	187.0	20.3	120.0	151.7	95.9	61.8	0.39	153.7	27.3	181.0	26.1	0.7	76.8	6.0
3	Padi Kijang B	201.0	22.3	115.7	148.0	99.7	70.7	0.41	176.7	17.0	193.7	24.4	0.8	87.8	5.6
4	Padi Kijang C	197.0	23.7	126.7	160.0	95.6	67.7	0.42	180.7	9.7	190.3	20.8	0.7	84.2	4.9
5	Padi Kijang D	182.7	22.7	125.3	158.3	81.4	43.1	0.33	99.3	28.3	127.7	23.6	0.7	53.6	2.8
6	Padi Kijang 1	200.0	28.3	143.0	180.0	118.6	79.7	0.39	136.0	13.7	149.7	27.1	0.7	99.1	5.1
7	Padi Kijang 2	184.7	22.0	120.7	151.7	91.2	60.5	0.39	138.3	19.0	157.3	25.3	0.7	75.2	4.7
8	Padi Kijang 3	175.0	15.7	124.7	158.0	80.0	23.5	0.23	88.7	33.3	122.0	21.5	0.7	29.2	2.3
9	Padi Kijang 5	205.0	22.0	124.7	158.3	77.6	39.3	0.31	85.7	25.3	111.0	24.4	0.7	48.9	2.2
10	Padi Kijang 7	191.3	26.3	122.0	154.3	94.5	55.7	0.37	97.7	21.0	118.7	28.1	0.6	69.2	4.2
11	Padi Putih A	171.7	35.3	130.0	163.3	98.4	48.9	0.33	76.3	23.7	100.0	23.0	0.5	60.8	3.8
12	Padi Putih B	192.7	17.0	121.3	155.0	90.7	25.4	0.22	78.0	17.3	95.3	24.5	0.6	31.5	2.4
13	Padi Putih C	204.0	14.3	111.0	145.0	76.1	43.1	0.36	178.7	29.7	208.3	21.7	0.6	53.5	4.2
14	Padi Putih D	201.0	16.7	103.7	145.0	43.3	26.4	0.38	106.7	16.0	122.7	19.3	0.4	32.8	2.5
15	Padi putih E	188.7	17.3	114.0	147.0	100.5	66.0	0.40	219.0	11.3	230.3	22.5	0.5	82.0	5.4
16	Padi Putih F	146.3	14.0	110.0	145.0	60.8	58.1	0.49	193.7	14.3	208.0	27.6	1.0	72.2	5.6
17	Padi Putih 1	218.3	11.3	108.3	144.0	68.1	45.3	0.39	212.0	19.3	231.3	22.6	0.7	56.3	2.8
18	Padi Putih 2	172.3	17.0	94.7	138.3	83.6	59.5	0.43	201.3	17.3	218.7	22.7	0.6	73.9	4.6
19	Padi Putih 3	125.7	15.0	100.0	140.0	115.8	67.5	0.37	253.0	31.0	284.0	23.2	0.6	83.9	3.7
20	Padi Putih 5	173.0	15.7	106.0	143.0	82.9	44.2	0.34	176.0	38.3	214.3	20.4	0.8	55.0	4.3
21	Padi Putih 6	204.3	13.0	107.0	145.0	67.9	47.5	0.41	242.3	22.3	264.7	19.5	0.8	59.1	4.6
22	Padi Putih 7	188.3	21.0	106.0	143.0	90.0	64.7	0.41	178.7	18.7	197.3	22.5	0.8	80.4	4.3
23	Padi Putih 8	192.7	20.0	90.7	145.0	61.5	77.3	0.56	180.0	19.7	199.7	28.5	1.0	96.0	7.5
24	Padi Putih 9	111.7	10.0	98.7	130.0	75.4	40.1	0.35	221.0	15.7	236.7	23.1	0.8	49.8	3.9
25	Padi Putih 10	183.3	16.0	107.3	143.3	68.2	50.1	0.43	186.7	18.0	204.7	22.1	0.8	62.3	4.8
26	Padi Putih 11	190.3	19.7	94.7	140.3	108.1	63.9	0.37	163.3	32.3	195.7	25.5	0.8	79.5	5.5
27	Padi Putih 12	176.0	19.3	98.0	131.0	77.3	47.9	0.36	138.0	27.7	165.7	22.8	0.8	59.6	3.7
28	Padi Putih 13	151.7	12.0	115.0	148.7	52.8	34.6	0.40	137.0	34.0	171.0	27.0	0.8	42.9	3.3
29	Padi Putih 14	216.7	13.7	122.0	159.0	87.2	37.0	0.29	137.0	30.7	167.7	25.2	0.7	45.9	3.6
30	Padi Putih 15	197.7	14.3	124.3	160.0	79.5	49.0	0.38	152.7	21.3	174.0	28.5	1.0	60.9	4.7
31	Padi Putih 16	224.0	11.7	116.3	155.0	60.7	43.3	0.41	174.7	16.0	190.7	26.7	0.7	53.8	4.2

Table 4. continue.

No Genotype	Name	Plant height (cm)	No of productive tiller	Days to flowering (day)	Days to harvest (day)	Straw weight (g)	Panicle weight (g)	Harvest index	No. of pithy seeds	No. of empty seeds	Total seeds	Weight of 1000 seeds (g)	Culm thickness (cm)	Weight of seeds per clump (g)	Yield (ton/ha)
32	Padi Kecik	190.0	16.0	112.0	151.0	92.7	46.0	0.33	137.0	25.3	162.3	27.6	0.7	57.2	4.4
33	Padi kecik 1	186.0	24.7	123.0	140.0	107.5	74.4	0.42	153.3	25.7	179.0	26.0	0.8	92.5	5.5
34	Padi Kecik 4	171.0	21.3	109.3	145.0	108.9	73.2	0.40	206.7	17.0	223.7	24.4	0.8	91.0	7.1
35	Padi Kecik 5	172.7	14.0	110.0	148.0	86.1	50.8	0.36	179.0	21.3	200.3	26.2	0.7	63.2	4.0
36	Padi Kecik 6	155.0	11.3	114.3	155.0	65.4	35.4	0.36	176.7	9.7	186.3	22.7	0.7	44.1	3.4
37	Padi Kecik 7	186.0	13.3	101.3	145.0	33.0	31.2	0.49	126.7	16.7	143.3	23.2	0.9	38.8	3.0
38	Padi Kecik 8	134.3	12.7	103.3	142.7	47.2	44.0	0.48	173.7	15.7	189.3	27.2	1.0	54.7	4.2
39	Padi kecik 9	194.3	11.3	98.3	134.7	71.7	38.0	0.34	176.0	10.7	186.7	24.9	0.8	47.2	3.7
40	Padi kecik 10	180.7	15.7	114.0	146.3	84.5	58.5	0.41	195.0	31.3	226.3	25.4	0.8	72.7	5.6
41	Padi kecik 11	200.3	11.7	121.3	156.3	88.7	43.9	0.33	198.7	17.3	216.0	24.5	0.8	54.5	4.2
42	Padi Kecik 12	115.3	13.0	116.7	148.3	152.8	40.7	0.21	200.0	48.7	248.7	21.3	0.7	50.6	3.9
43	Padi Kecik 13	198.3	15.7	115.7	141.3	77.2	52.1	0.40	174.7	36.0	210.7	24.7	0.7	64.8	5.0
44	Padi Kecik 14	160.3	22.3	114.0	145.0	113.4	45.7	0.29	112.3	24.0	136.3	23.5	0.7	56.8	4.4
45	Padi Kecik 15	196.3	21.3	116.3	147.3	67.6	43.2	0.39	118.0	40.0	158.0	21.6	0.9	53.7	4.2
46	Padi Kecik 16	199.0	21.7	120.0	153.3	104.3	43.0	0.29	125.7	20.3	146.0	20.4	0.7	53.4	4.2
47	Padi Kecik 17	206.3	14.7	107.7	143.0	74.2	43.9	0.36	187.9	18.3	206.2	20.0	0.8	54.6	4.2
48	Padi Kecik 18	189.0	13.7	115.0	145.0	82.4	19.2	0.19	81.7	58.3	140.1	21.6	0.7	23.8	1.8
49	Padi kecik 19	175.0	20.3	119.3	148.0	79.8	74.4	0.48	173.0	20.0	193.0	27.3	1.0	92.5	7.2
50	Sendani 1	188.0	15.0	102.7	140.0	87.9	54.3	0.38	216.9	11.0	227.9	20.9	0.8	67.5	5.2
51	Sendani 2	192.3	15.3	119.7	151.3	91.1	48.7	0.35	165.0	28.3	193.3	24.7	0.8	60.5	4.7
52	Sendani 3	172.0	19.0	111.3	150.0	103.1	59.3	0.36	173.3	21.0	194.3	23.4	0.7	73.7	5.7
53	Sendani 4	190.7	11.0	109.0	145.0	45.2	48.5	0.52	222.0	17.0	239.0	25.4	1.0	60.3	4.7
54	Sendani anak dara	176.0	18.7	100.0	140.0	85.3	45.6	0.35	127.6	19.0	146.6	25.9	0.8	56.7	4.4
55	Siam Malaysia	188.3	18.0	94.0	140.0	54.1	43.5	0.45	149.5	15.7	165.2	20.6	0.8	54.1	4.2
56	Padi Kalus Kubu	145.0	17.0	100.0	145.0	100.5	45.5	0.31	149.3	25.0	174.3	23.5	0.8	56.6	4.4
57	Ketek 2	174.0	14.3	170.0	206.7	68.1	45.5	0.40	192.8	36.7	229.4	21.8	0.9	56.5	4.4
58	Ketek 3	185.0	14.3	109.0	145.0	66.9	54.7	0.45	231.0	20.7	251.7	21.7	0.8	67.9	5.3
59	Ketek 4	170.3	10.7	106.7	145.0	79.0	30.0	0.27	162.8	23.0	185.8	23.2	0.8	37.3	2.9
60	Ketek Tinggi	197.7	12.3	150.0	185.0	90.3	55.7	0.38	212.0	12.3	224.3	26.5	0.8	69.2	5.4
61	Pulut 1	164.0	15.0	101.7	137.0	90.8	58.8	0.39	174.3	20.7	195.0	28.5	0.8	73.1	5.7
62	Pulut Belanda	170.3	13.3	140.0	177.3	96.4	51.8	0.35	182.0	22.3	204.3	28.2	0.9	64.4	5.0

Table 4. continue.

No Genotype	Name	Plant height (cm)	No of productive tiller	Days to flowering (day)	Days to harvest (day)	Straw weight (g)	Panicle weight (g)	Harvest index	No. of pithy seeds	No. of empty seeds	Total seeds	Weight of 1000 seeds (g)	Culm thickness (cm)	Weight of seeds per clump (g)	Yield (ton/ha)
63	Pulut 2	179.3	14.7	135.0	170.0	90.6	41.0	0.32	143.3	12.7	156.0	25.8	0.8	51.0	4.0
64	Pulut Herang	190.3	17.0	110.0	150.0	82.7	52.5	0.38	171.7	15.0	186.7	23.5	0.8	65.3	5.1
65	Anak Dara	134.7	17.7	90.0	120.0	46.7	50.4	0.52	162.7	22.3	185.0	23.0	0.7	62.7	4.9
66	Padi Burung	193.7	17.3	115.0	145.0	89.1	51.4	0.37	193.7	31.3	225.0	19.6	0.9	63.9	5.0
67	Korea	171.0	13.7	109.0	148.3	72.1	40.7	0.36	178.7	39.0	217.7	22.7	0.9	50.6	3.9
68	Korea 1	168.0	16.7	100.0	135.0	49.8	50.0	0.50	158.0	17.0	175.0	24.3	1.0	62.1	4.8
69	Padi Telor (coklat)	185.3	12.3	115.3	146.7	61.9	50.5	0.45	201.3	39.0	240.3	26.1	0.9	62.8	4.9
70	Padi Telor	216.7	16.0	173.3	208.3	84.3	78.7	0.48	245.0	17.0	262.0	26.4	1.0	97.8	5.8
71	Padi Induk	189.0	19.3	165.0	201.0	98.5	61.5	0.38	174.3	25.7	200.0	23.6	0.7	76.4	5.9
72	Malaysia Wangi	188.7	16.0	101.0	140.0	77.6	48.8	0.39	178.7	37.7	216.3	22.2	0.6	60.7	4.7
73	Malaysia wangi 1	176.3	16.7	110.0	140.0	63.9	38.8	0.38	125.0	33.0	158.0	24.0	0.7	48.2	3.7
74	Serayu 1	181.0	18.3	115.0	150.0	88.5	50.2	0.36	174.7	14.0	188.7	23.7	0.7	62.4	4.9
75	Serayu 2	190.3	15.0	99.7	136.7	38.0	33.2	0.47	116.0	19.3	135.3	24.5	0.9	41.2	3.2
76	Serai wangi	176.7	21.3	109.7	143.0	130.4	58.4	0.31	155.7	30.0	185.7	23.2	0.6	72.5	5.6
77	Siam Bengkalis	172.7	20.3	98.0	141.7	57.6	74.0	0.55	176.3	16.3	192.7	27.0	1.0	92.0	6.2
78	Siam Bengkalis Merah	185.7	20.3	103.3	138.7	51.9	50.4	0.49	139.3	21.3	160.7	23.8	1.0	62.7	4.9
79	Siam bengkalis 1	178.7	13.7	100.0	132.0	69.7	36.6	0.34	137.3	51.7	189.0	24.9	0.7	45.5	3.5
80	Pulut belanda 1	201.7	12.7	140.0	177.0	59.7	40.2	0.38	165.3	22.0	187.3	24.0	0.8	49.9	3.9
81	Pulut belanda 2	191.0	18.3	135.0	170.0	81.4	51.1	0.38	153.7	25.3	179.0	23.0	0.8	63.5	4.5
82	Pulut belanda 3	169.3	15.0	150.0	186.7	74.2	44.9	0.38	152.7	29.3	182.0	24.6	0.8	55.8	4.3
83	Padi kecik 2	194.3	17.7	114.0	150.0	92.8	54.9	0.38	179.0	37.0	216.0	22.5	0.8	68.3	5.3
84	Siam bengkalis 2	180.3	14.0	98.3	136.7	44.3	28.0	0.40	115.7	32.0	147.7	22.9	0.8	34.9	2.7
85	Siam Bengkalis 3	190.3	21.0	100.0	143.3	69.5	38.2	0.35	217.7	17.7	235.3	25.6	0.9	47.5	3.7
86	Siam Bengkalis 4	199.0	15.0	106.0	147.3	77.8	23.6	0.24	92.7	34.0	126.7	22.6	0.7	29.4	2.3
87	Sendani	181.0	14.7	100.0	130.7	83.9	53.4	0.38	181.7	19.0	200.7	25.5	0.7	66.4	5.2
88	NN	165.7	15.7	91.7	121.7	81.2	49.9	0.39	160.0	20.3	180.3	28.2	0.8	62.0	4.8
89	Padi kijang bulu	199.0	14.7	120.0	150.0	73.6	49.8	0.40	175.7	34.7	210.3	24.9	0.7	61.9	4.8
90	Padi Kijang 8	185.3	21.3	115.0	150.0	94.4	57.0	0.38	156.0	24.3	180.3	25.0	0.8	70.8	5.5
91	Sendaur Anak Dara 1	217.7	21.7	109.7	140.0	102.2	84.7	0.42	219.7	45.7	265.3	24.0	0.8	105.3	3.6
92	Sendaur Anak Dara 2	166.3	21.0	106.7	141.7	89.1	56.6	0.38	133.0	44.0	177.0	26.2	0.9	70.4	5.5
93	Sendaur Anak Dara 3	171.7	22.7	100.0	133.3	79.2	58.5	0.40	125.3	56.0	181.3	27.1	0.8	72.7	2.6

Table 4. continue.

No Genotype	Name	Plant height (cm)	No of productive tiller	Days to flowering (day)	Days to harvest (day)	Straw weight (g)	Panicle weight (g)	Harvest index	No. of pithy seeds	No. of empty seeds	Total seeds	Weight of 1000 seeds (g)	Culm thickness (cm)	Weight of seeds per clump (g)	Yield (ton/ha)
94	Sendaur Anak Dara 4	185.0	20.3	104.3	138.0	83.8	40.4	0.32	119.7	23.7	143.3	21.6	0.8	50.2	3.9
95	Sendaur Anak Dara 5	173.7	19.3	109.0	145.0	84.0	48.0	0.37	134.7	27.3	162.0	24.3	0.8	59.7	4.6
96	Padi Putih Sei Cina 1	161.3	19.0	108.0	145.0	92.5	81.0	0.46	212.3	23.3	235.7	21.3	0.7	100.7	4.1
97	Padi Putih Sei Cina 2	170.7	22.7	125.0	159.0	109.3	74.8	0.42	181.7	25.7	207.3	26.2	0.7	92.9	4.4
98	Padi Putih Sei Cina 3	137.0	14.0	110.7	145.0	85.7	44.5	0.36	180.1	16.7	196.8	22.9	0.7	55.3	4.3
99	Padi burung 1	133.3	14.3	102.0	140.0	93.2	55.8	0.38	208.3	32.7	241.0	24.3	0.8	69.4	5.4
100	Padi burung 2	159.3	21.3	110.0	144.0	98.3	49.7	0.33	160.0	34.3	194.3	18.8	0.6	61.8	4.8
101	NN1	186.3	13.7	108.0	145.0	63.0	56.4	0.47	194.3	25.3	219.7	27.2	0.7	70.2	5.5
102	NN2	146.7	18.0	105.0	140.0	80.7	52.2	0.40	148.0	24.3	172.3	25.4	0.7	64.8	5.0
103	NN3	167.7	18.3	110.0	145.7	63.7	50.1	0.44	140.0	20.0	160.0	25.2	0.9	62.2	4.8
104	NN4	160.7	15.0	108.0	145.0	86.2	64.7	0.42	210.0	46.0	256.0	26.1	0.7	80.4	4.1
105	NN5	115.3	20.0	113.3	140.0	70.8	45.7	0.39	178.0	23.0	201.0	22.4	0.9	56.8	4.4

Table 5. The genetic and phenotypic variance of rice plant characteristics as an indicator of diversity of the population in saline land to be used to count broads heritability.

Variable	V_G	V_P	h^2_{bs} (%)
Plant height (cm)	399.0031	483.3676	82.55
No. of productive tillers	8.8701	17.4119	50.94
Days to flowering (days)	233.005	234.2505	99.47
Days to harvest (days)	219.6004	220.8869	99.42
Straw weight (g)	478.9064	798.3435	59.99
Panicle weight/clump (g)	215.3411	373.2394	57.70
Harvest index	0.0039	0.0044	87.48
Number of pithy seeds	1,355.0457	1,463.5873	92.58
Number of empty seeds	73.9876	100.2773	73.78
Total seeds	1,315.0075	1,425.6274	92.24
1000 seeds weight (g)	4.9552	5.1985	95.32
Culm thickness (mm)	0.0104	0.0131	79.34
Yield (ton/ha)	1.4975	2.2459	66.68

Characters with narrow genetic diversity are found in plant height, a number of productive tillers, days to flowering, days to harvest, harvest index, the weight of 1000 seeds, and culm thickness. The narrow variations of character between cultivars will cause selection based on these characters to be less effective, and genetic gain will be low. The characteristics of 105 rice genotypes in saline land had a narrow to broad diversity is presented in Table 6.

Plant height is an important indicator of salt tolerance. Although the genetic variability of rice plants height in this study is relatively narrow, almost all cultivars have a height that exceed the newly improved varieties. This is in good agreement with previous study (Chang et al. 2019), that salinity only affects plant height in salt-sensitive cultivars.

A broad genetic variability was found in the straw weight, panicle weight, number of pithed seeds, total number of seeds per panicle, and yield. All of these characters are directly related

Table 6. Mean values of observed variables, coefficient of genetic variance, and coefficient of phenotype variance, as an indicator of broad or narrow diversity of the 105 rice genotypes population in saline land.

Variable	Mean ± STD	Range	CGV	Criteria	CPV	Criteria
Plant height (cm)	179.42±25.49	101–236	11.13	RL	12.25	RL
No. of productive tillers	17.19 ± 6.78	5–50	17.32	RL	24.27	HE
Days to flowering (days)	113.46 ± 15.34	90–175	13.45	RL	13.49	RL
Days to harvest (days)	148.84 ± 14.91	120–210	9.96	RL	9.99	L
Straw weight (g)	81.50 ± 28.41	21.35–184.87	18.80	HE	24.27	HE
Panicle weight/clump (g)	50.90 ± 20.36	14.28–140.7	20.18	HE	26.57	HE
Harvest index	0.40 ± 0.07	0.16–0.65	15.61	RL	16.58	RL
Number of pithy seeds	165.14 ± 41.00	65–297	22.29	HE	23.17	HE
Number of empty seeds	25.05 ± 12.38	7–80	34.34	H	39.97	H
Total seeds	190.19 ± 40.53	87–321	19.07	HE	19.85	RL
1000 seeds weight (g)	24.12 ± 2.39	18.3–29.4	9.23	RL	9.45	L
Culm thickness (mm)	0.78 ± 0.14	0.4–1.1	13.14	RL	14.75	RL
Yield (ton/ha)	4.50 ± 1.46	0.97–8.62	19.04	HE	23.32	HE

Note: CGV = coefficient of genetic variance, CPV = coefficient of phenotype variance. CGV criteria: low (0%–8.6%), rather low (8.7%–17.3%), high enough (17.4%–26.0%), and high (>26%). CPV criteria: low (0%–10%), rather low (11%–20%), high enough (21%–30%), and high (>30%). RL = rather low, L = low, HE = high enough, H = high.

to grain productivity and production, therefore, selection of these characters will produce genotypes with high yield potential. This results are relavent to the report of Jalata et al. (2011), the selection will be useful in populations that have broad genetic diversity.

All of the observed characters have a high heritability (h^2 >0.5), which ranged from 0 to 1. Heritability value is closer to 1, meaning that the character is more influenced by genetic factors. In comparison, the value of heritability is closer to 0, indicating that environmental factors influence the character. Genetic factors can be inherited, in contrast to environmental factors. The yield component that has the highest heritability is the number of pithy seeds/panicles. These characters have a high enough CGV or broad genetic variability (Table 6). Extensive genetic variability indicates that in the observed population, there are genotypes that produce very small to huge amounts of pithed seeds. This could also mean that in the 105 genotypes observed, there were genotypes that were not genuinely tolerant of salinity but only escaped in rainy season or tolerated only at low salinity levels. The emptiness of seeds in rice plants in coastal areas is not only caused by genetic factors, but also by environmental factors such as salt content in the air. Therefore, local farmers avoid the rice flowering period to coincide with the northern wind season, which carries salt. Genotypes with a high number of pithy seeds and low-empty seeds are as an indicator of their resistance to the salty condition. Other yield components, namely the weight of 1000 seeds and number of productive tillers, have a narrow genetic variability but high heritability. This also suggests that genetic factors strongly change the phenotype.

Plants height in rice have been used by local farmers as indicators of large panicles, avoiding plants from flooding during rainy season or during high tide, and can be harvested in an upright position. The short plants are not preferred because they are prone to drowning during floods and have difficulty to be harvested manually. Local farmers generally harvest rice using a traditional tool (*anai-anai*) and choose ripening panicles one by one. Therefore, they do not like short clumps although lots of tillers. Farmers like rather tall plants and large panicles to allow easy and rapid harvest. Traditional farming is practiced by farmers to adapt to the physical environment. Rice fields in the coastal areas are generally very soft peat and alluvial soils with deep solum, and bumpy surface of rice fields, which could be constrain when harvest using heavy mechinary.

The culm thickness and the long vegetative period give the plant a chance to build a strong and less succulent culm. Although the genetic diversity of culm thicknesses is relatively narrow, many genotypes have a thick culm wall >9 mm. Culm thickness has economic potential for local farmers who only plant rice once a year. According to Sinaga et al. (2014), thick culms can produce good ratoon so farmers can do the second harvest in 2

Table 7. Diversity of yield and yield components of 10 the best selected genotypes in dry season.

Genotypes	No. of productive tillers	Panicle length (cm)	No. of pithy seeds	No. of empty seeds	Weight of 1000 seeds (g)	Yield (ton/ha)
Padi Putih 15	13	26.7	172.7	43.8	25.4	4.1
Padi Kecik 7	14	29.6	152.1	72.4	25.0	3.5
Padi Kecik 8	14	29.6	137.7	73.5	22.6	3.9
Padi Kecik 19	18	25.5	171.9	72.3	20.3	6.5
Sendani 4	15	27.5	133.7	65.2	20.1	4.2
Siam Malaysia	17	27.0	158.9	77.6	20.5	4.8
Padi Telor	17	28.4	127.8	26.5	22.4	5.3
Serayu 2	13	25.4	139.3	54.0	22.4	3.4
Siam Bengkalis	18	30.8	233.4	53.5	21.5	6.0
Siam Bengkalis 4	15	26.6	123.4	47.8	27.3	3.9

months from the first harvest. Ratoons are the shoots growing from leftover rice stalks and develop into plants that produce seeds.

The different yield potential between genotypes, accounting 0.97–8.62 ton/ha is good for high-yielding genotype selection. Five genotypes resulted in an average yield of ≥6 ton/ha dry milled grain (dmg), including G2 of the Padi Kijang population, G23 from the Padi Putih population, G34, and G49 from the Padi Kecik population, and G77 Siam Bengkalis.

HIGH YIELD GENOTYPE SELECTION IN THE DRY SEASON

A total of 31 genotypes with yield ≥5 per ha dmg and 7 other genotypes as control were replanted in dry season to determine their resistance to higher salt concentrations and yield potency. The seven control genotypes such as Padi Putih 15 (G30), Kecik 7 (G37), Kecik 8 (G38), Sendani 4 (G53), Siam Malaysia (G55), Serayu 2 (G75), Siam Bengkalis 4 (G86), have a vigorous appearance with large culms and allegedly as a native population. The results showed a very strong depression in most high-yielding genotypes. Symptoms of stress until the death of plants a few days after transplanting have happened to most high-yielding genotypes. Of the 31 genotypes, only 3 genotypes were consistently good in performance, namely Padi Kecik 19 (G49), Padi Telor (G70), and Siam Bengkalis (G77). Meanwhile control genotype is relatively stable with a non-drastic decrease in yields.

The number of less survival genotypes in dry season showed that the tolerance for salt has exceeded the tolerance threshold. Within 2 weeks after transplanting, the plant has experienced severe stress until death. Boudsocq and Lauriere (2005), state that plants will dehydrate due to high soil salinity and drought. This condition causes plants to experience hyperosmotic pressure which is characterized by reduced turgor pressure and loss of water from the tissues. Anthraper and DuBois (2003) report that excessive Na^+ can increase the rate of membrane leakage. Salt suppresses plant growth through poisoning due to excess salt, decreased water absorption, decreased absorption of important nutrients, for example K^+ (FAO 2005).

Soil salinity can inhibit seed germination, irregular growth in agricultural crops, decrease in the number of leaves, growth in plant height and cell length growth ratio (Waskom 2003), reduced stomata opening because intercellular CO_2 concentrations increase and salt accumulation in mesophils tissues interfere with photosynthesis (Robinson 1999 in Da Silva et al. 2008). Salinity causes a drastic decrease in the concentration of Fe ions in leaves and roots in wheat plants. The decrease was due to the reduced absorption of Fe in high salinity conditions (Yousfi et al. 2007).

Adaptation of plants to high salt concentrations can occur with morphological modification. Leaf size becomes small as a way to maintain turgor, while root lignification is needed for osmose adjustment which is very important for maintaining turgor. Rapid plant growth is also a mechanism for thinning salt (Salisbury and Ross 1995). Supplementary application of calcium-rich fertilizers in saline prone soils can be an effective approach to acclimatize salt stress and cultivate rice successfully (Roy et al. 2019).

CONCLUSIONS

The diversity of rice genetic resources on saline soils in the Kepulauan Meranti, Riau Province is broad, especially for the characters of straw weight, panicle weight, number of pithed seeds, total number of seeds per panicle, and yield. Selection based on these characters will be effective. Genotype tolerance to salinity varies and there are genotypes well adapted in rainy season with rather low salt concentration and in dry season when salt concentration is very high, namely: Padi Kecik 19 (G49), Padi Telor (G70), Siam Bengkalis (G77), Padi Putih 15 (G30), Kecik 7 (G37), Kecik 8 (G38), Sendani 4 (G53), Siam Malaysia (G55), Serayu 2 (G75), and Siam Bengkalis 4 (G86). There are 3 genotypes were consistently good in performance and high yield, namely Padi Kecik 19 (G49) 6.5 ton/ha dmg, Padi Telor (G70) 5.3 ton/ha dmg, and Siam Bengkalis (G77) 6.0 ton/ha dmg. These genotypes can be used as a source of genes to develop newly varieties with high productivity and salt-resistant.

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THE CHARACTERIZATION OF LOCAL RICE VARIETIES FROM EAST AND NORTH BARITO DISTRICTS IN CENTRAL KALIMANTAN

Twenty Liana and Susilawati

INTRODUCTION

Rice is one of the most important crops and consumed by half of the world's population in almost all countries across the globe (Masoumiasl et al. 2013; Ehiakpor et al. 2017). Before the Green Revolution technology, farmers in each region planted local rice, which is adapted to specific agroecosystems. These local varieties have been cultivated for centuries in generations. In its journey, these local varieties have adapted to the conditions of agroecosystems with different biotic and abiotic stresses in the local area. Agroecosystem considered as suboptimal conditions involving drought, acid soils, flooded land, and iron poisoning, etc. will allow local varieties to be tolerant to the suboptimal conditions. For every season, the farmers have chosen high quality of rice varieties with good taste to meet 'consumer's preferences (Sitaresmi et al. 2013). The highly diverse local rice in Central Kalimantan is a valuable source as a potential asset to be utilized and preserved.

The Local Governments of North and East Barito Districts can also propose for promoting the local rice to be registered and released as superior varieties legally. In 2019, the local Government of East Barito had developed local rice as superior regional products, which has high economic value, and it was able to increase 'people's income. The release of this variety has been carried out by the government.

Data and information on local rice involving morphological characteristics, epidermal appearance, productivity, resilience pests and diseases, 'consumer's preference, and the nutritional content are then required (Limbongan and Jufry 2015). However, a less precise and incomplete description can cause uncertainty in the existence of a variety. Individual testing of rice was done to characterize 14 local rice cultivar originating from East and North Barito (10 local rice from East Barito and four local rice from North Barito), the varieties tested revealed distinctive agronomic characteristics. The objective of this paper was to provide information on the diversity of local rice, including their essential characteristics, which could be useful as a basis for further research on rice crop improvement, selection, conservation, and management of germplasm in general.

THE CULTIVATION PRACTICE OF LOCAL RICE IN CENTRAL KALIMANTAN

Local rice varieties in Central Kalimantan mainly found at two agroecosystems, i.e., dry rice farming and wetlands or swamps areas. The rice varieties are mostly indigenous, while few rice varieties were introduced from other regions across Indonesia. Four local rice varieties were chosen for characterization from North Barito, including Longkong, Raden Pahit, Talun Serai, and Talun Wangi Mampuak (Figure 1). While, rice varieties originating from North Barito usually are grown in dry field cultivation, having 5–6 months to harvest, and using traditional practices for agriculture. Local rice from Nort Barito was cultivated in dryland annually, especially after land clearing of primary forest. Pest and disease management have been applied, as demonstrated by local people. These activities are usually started by land clearing in July or August to minimize pests threats. Ten local rice from East Barito (Figure 2) that have been collected are Siam Kupang, Siam Serai, Palui, Palui Gunung, and Bayar Pahit. They are grown in wetlands, while for drylands, there are several local rice such as Taring Palanuk, Dite Item, Lungkung, Tampeko, and Dite.

Figure 1. The performance of stem, panicle and grain of local rice varieties explored from North Barito District, i.e., A) Longkong, B) Raden Pahit, C) Talun Serai and D) Talun Wangi Mampuak.


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Figure 2. The performance of stem, panicle and grain of local rice variteis explored from East Barito District. A) Siam Kupang, B) Siam Serai, C) Palui, D) Palui Gunung, E) Bayar Pahit, F) Taring Palanuk, G) Dite Intem, H) Lungkung, I) Tampeko and J) Dite.

Similarly to the local rice from North Barito, local rice from East Barito also have 5–6 months to harvest, but the cultivars in wetland have implemented modern cultivation practices. In East Barito, local rice varieties have been cultivated in an integrated manner with the recent rice varieties. As a result, both the local rice and current varieties are commonly grown in wetland or swamps areas.

According to Freeman (1970) *cit.* Hendra et al. (2009), in a particular area of Kalimantan, called as Iban area, each rice variety has a local name, and the farmers become familiar with the distinctive characters or origin from which the name is derived. Various names and sub names are mostly referred to as the name of the local source.

THE MORPHOLOGICAL CHARACTERS OF SEVERAL LOCAL RICE VARIETIES FROM EAST AND NORTH BARITO

Fourteen local rice varieties have been characterized in drylands and wetlands or swamps areas. The types of the growing stem; anthocyanin on the auricle, collar, coleoptile, ligula, node, and internode; colors of the branch, leaf, palea, lemma, caryopsis, pericarp; fragrance; ligula shape; attitudes of the flag leaf and branch panicle; panicle secondary branching and exsertion; unhulled grain; and abiotic tolerance are unique and critical characters of local rice varieties from the East and North Barito Districts. Some quantitative morphological characteristics have been observed, including plant height, culm length, culm thickness, pannicle number per plant, leaf length, leaf width, panicle length, and 1000 grain weight.

The qualitative and quantitative morphological characters were distinguished among local rice varieties (Tables 1, 2). Local rice varieties from both dryland and wetland regions show unique characters on their morphological, grain yield, and fragrance. For example, Talun Serai, Talun Wangi Mampuak, Taring Palanuk, and Tampeko rice varieties have good milling quality and adaptability to abiotic stress. According to Mathure et al. (2011), aromatic rice is considered a unique group of rice because of the best quality. In Central Kalimantan, fragrant rice with smell pandanus is preferred by the local community because the cooked rice is more flavorful compared to nonaromatic rice. The aromatic character of rice is controlled by additive, dominant genes, including tolerance to the low-temperature stress, plant height, flag leaf length, days to harvest, panicle length, feather length, and percentage of rice grain (Shimono et al. 2007). Also, each rice variety has similarities and differences due to their uniqueness (Irawan (2008). The existence of similarities and differences are often used to determine the relationship of genetic kinship between rice varieties. Cluster analysis of phenotypic and genotypic characters is able to differentiate rice varieties and to expand the genetic background to produce heterotic and superior rice varieties (Cooper et al. 2001; Irawan et al. 2008). Several qualitative agro-morphological characters could be contributed to the selection process in the hybridization program for recognizing new variety and intellectual property rights, such as agro-morphological characters *of Balam rice in Bangladesh* (Ahmed et al. 2016).

Appendix Table 1. Descriptions of rice Inpara varieties

Characteristics	Varieties									
	Inpara 1	Inpara 2	Inpara 3	Inpara 4	Inpara 5	Inpara 6	Inpara 7	Inpara 8	Inpara 9	Inpara 10
Origin of selection	Batang Ombilin/IR9884-54-3	Pucuk/ Cisanggarung/Sita	IR69256/IR43524-55-1-3-2	Introduksi dari IRRI	Introduksi dari IRRI	IR64/IRBB21/ IR51672	Bio 12/beras merah	B10597F-KN-18/B10600F-KN-7	Mesir/IR60080-23	B13100-2-MR-3-KY-3
Plant age (days)	131	128	127	135	115	117	114	115	114	126
Plant shape	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright	Upright
Plant height (cm)	111	103	108	94	92	99	88	107	107	101
Productive tillers	18	16	17	18	18	13	12	-	-	
Lodging	Medium	Medium	Medium	Resistant	Medium	Resistant	Medium-Resistant	Resistant	Resistant	Resistant
Loss	Medium		Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Grain shape	Medium	Medium	Slim	Medium	Slim	Medium	Slim	Medium	Slim	Slim
Rice texture	Less fluffy	Medium	Less fluffy	Less fluffy	Less fluffy	Medium	Fluffier	Less fluffy	Less fluffy	Medium
Amilosa content (%)	27,9	22,1	28,6	29	25,2	24,0	20,0	28,5	25,2	24,9
Glycemic index	-	-	59,2	50,9	59	-	-	-	-	-
Weight 1000 grains (g)	23,3	25,6	25,7	19,5	25	26	24	27,2	25,2	26,3
Mean yield (ton/ha)	5,0	5,1	4,6	4,7	4,5	4,7	4,5	4,7	4,2	5,0
Potential yield (ton/ha)	6,47	6,08	5,6	7,6	7,2	6,0	5,1	6,0	5,6	6,8
Resistance to abiotic stress	Fe and Al toxicity tolerant	Fe and Al toxicity tolerant	Fe and Al toxicity tolerant, and 6 days immertion tolerant during the vegetative phase	14 days immertion tolerant during the vegetative phase	14 days immertion tolerant during the vegetative phase	Fe toxicity tolerant	Moderate Fe and Al toxicity tolerant	Fe toxicity tolerant	Fe toxicity tolerant	Fe toxicity tolerant
Recommended planting	Tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland, freshwater swamp, and irigation	Tidal swampland, freshwater swamp and rice fields prone to flooding	Tidal swampland, freshwater swamp and rice fields prone to flooding	Potential tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland and freshwater swamp	Tidal swampland, freshwater swamp	Tidal swampland, freshwater swamp
Plant breeder	Bambang Kustianto et al.	Bambang Kustianto et al.	Hamdan Pane et al.	D.J. Mackill et al.	D.J. Mackill et al.	A.Hairmansis et al.	Suwarno et al.	Suwarno et al.	Suwarno et al.	Indrastuti et al.
Released year	2008	2008	2008	2008	2010	2010	2012	2014	2014	2018

Sumber: Suprihatno et al. (2010) and Info ICRR (2014).

Besides, the local rice varieties generally are well grown in dryland and wetland were observed their quantitative characters in relevant to rice production character, including plant height, panicle number per plant, leaf length, leaf width, panicle number, and weight of 1000 grain. Varieties with the highest plant height (>150 cm) were Talun Serai, Dite Item, Tampeko, Dite, Bayar Pahit, Palui, and Siam Serai. Some local varieties possessed large panicle numbers such as Palui Gunung, Raden Pahit, Siam Kupang, and Palui, Talun Wangi Mampuak, Siam Serai, and Talun Serai. In contrast, Dite Item, Tampeko, Dite, and Palui have the most significant leaf length and width. The most excellent panicle length (>30 cm) was found on Dite Item, Dite, Siam Kupang, Bayar Pahit, Palui, and Siam Serai. Some varieties of Taring Palanuk, Dite Item, Lungkung, Tampeko Dite, and Siam Serai have a greater 1000 grain weight. This information is useful and complements the previous report that rice yield component is one of the morphological characters closely related to plant productivity (Makarim and Suhartatik 2009). Although local rice varieties commonly produce less yield, however, the indigenous varieties usually exhibit higher resistance to a pest, more adaptive to marginal land in regional areas, and better-eating quality than introducing and improved rice varieties (Hendra et al. 2009).

Based on the diversity of quantitative morphological character (Table 3), a value of variants coefficient from low to slightly low was identified. The character with narrow diversity does not have wide variations in traits, which affect to less effective selection due to low genetic gain. More quantitative characters should be considerable to increase the diversity.

Table 2. The local rice characters commonly cultivated in wetlands of East Barito District.

Character	Varieties				
	Siam Kupang	Bayar Pahit	Palui Gunung	Palui	Siam Serai
Quantitative Character					
Fragrance rice	-	-	-	-	-
Rice milling	Difficult	Difficult	Prone	-	-
Abiotic Superiority	Drought tolerance	-	Drought tolerance	Drought tolerance	-
Quantitative Character					
Plant height	± 141 cm	± 175 cm	± 146 cm	± 170 cm	± 155 cm
Pannicle number per plant	± 21 pannicle	± 9 pannicle	± 27 pannicle	± 21 pannicle	± 13 pannicle
Leaf length	± 56 cm	± 56 cm	± 52 cm	± 66 cm	± 56 cm
Leaf width	± 1,8 cm	± 1,0 cm	± 1,8 cm	± 1,3 cm	± 1,4 cm
Panicle length	± 34 cm	± 32 cm	± 24 cm	± 32 cm	± 34 cm
Weight of 1,000 grain	± 90 g	± 80 g	± 90 g	± 70 g	± 120 g

Note : Siam Serai, Siam Serai, Bayar Pahit, Palui Gunung dan Palui taken from East Barito.

Table 3. The value of genetic variation coefficient (C.G.V.), phenotype variation coefficient (CPV) in local rice quantitative character.

Observation character	Mean	C.G.V.	Criteia	CPV	Criteria
Plant height	153.00	4.20	Low	8.96	Low
Panicle number per plant	13.21	25.97	Rather low	31.86	Rather low
Leaf length	58.29	6.81	Low	10.51	Low
Leaf width	1.66	9.47	Low	27.27	Rather low
Panicle length	28.43	11.29	Low	7.80	Low
Weight of 1,000 grain	86.83	30.20	Rather low	33.60	Rather low

CONCLUSIONS

Several local rice varieties originating from the East and North Barito districts have unique qualitative and quantitative morphological characters. These local varieties are valuable genetic resources for crossing parents as gene donors in breeding programs. Some local rice varieties have superior qualitative morphological characteristics related to production (fragrance rice) such as Talun Serai, Talun Wangi Mampuak, Taring Palanuk, and Tampeko. In contrast, for the quantitative characters that related to production (weight 1000 grain), the best local rice varieties include Dite Item, Dite, Taring Palanuk, Lungkung, and Tampeko.

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EPILOGUE
APPLICATION OF TECHNOLOGIES FOR SUSTAINABLE RICE PRODUCTION

Puji Lestari, Karden Mulya, and Dwinita Wikan Utami

The adoption of improved varieties brought dramatic increase in rice production in ASEAN countries, however, the increment cannot cope with the increase in demand for quantity and quality/consumer's preferences. There are various obstacles in achieving higher production of rice, involving genetic background of existing varieties, environmental constrains due to climate change, nutrient stresses, and archipelagic nature of some countries such as Indonesia and the Philippine. On the other hand, consumer demand for certain rice quality is getting stronger. The movement of people to the city to get access to business space also encourages growing demand for rice supplies according to what they have been consuming. This condition is a challenge in disseminating new varieties of rice which are only oriented to high productivity. In addition, farmers who have been tied to a pattern of work find it difficult to adjust to new rice varieties into their ordinary business. This is especially farmer who have worked not only on rice cultivation, but also have other businesses such as services in urban areas.

To improve technology for both crop improvement strategies and the effective and efficient system, scientists and breeders at IRRI and other relevant rice research centres have proposed strategies that could increase rate of genetic gains in grain yield and other traits, and improve the effectiveness and efficiency of breeding operations, including rapid advance generation,earlier multi-location trials, increased selection pressure for yield, intensify the use of molecular breeding, and use of a variety product profile. Furthermore, breeding operations should be streamlined to make breeding like a “factory line”. To enhance the efficiency of both pre breeding and breeding phases on rice, advances in biotechnology offer new opportunities. Relevant to this breeding program, anther culture has become an important technique for plant breeders to shorten the breeding cycle for the development of rice varieties. and has produced several rice varieties. Molecular markers lead to explore potential gene/traits of genetic resources and become important tool for introgressing genes from one varietal background to another and pyramiding genes. Map-based cloning has made it possible to isolate useful genes governing important agronomic traits and the incorporation of these genes into elite rice cultivars through transformation resulting in broadening of the gene pool of rice and have enhanced the efficiency of introgression of useful genes from wild species across cross ability barriers. Moreover, sequencing the rice genome have added new dimensions for research in functional genomics to precisely reveal the function of rice genes. Identification of genes and their manipulation present another major breakthrough in rice genetics and breeding.

To strengthen and sustain the national food security, operational policies on rice research depend on the consideration of their specific national condition. Malaysia successfully transformed their rice industry system from manual transplanting to direct-seeding and from manual harvesting to mechanical harvesting. Malaysian researches on rice mainly have developed rice varieties suitable for double cropping with high yield, and those having resistance/tolerance against biotic and abiotic stresses. Currently, Lao government policy is to promote green agriculture, therefore to support the policy, development of multi tolerant rice varieties to abiotic stress (drought and flood) and biotic stress (pests and diseases) is the priority of the Lao rice breeding program. While, Philippine established Farmer-Scientist Partnership for Agricultural Development in 1986. The rice breeding and agricultural innovations in the country are led by farmers while decision-making structures are based on a bottom up approach. To increase an efficient and effective breeding achievement, the Philippine government has developed collaborative researches with International Rice Research Institute (IRRI). Indonesia focused in the rice researches on development of (1) rice varieties with high yielding potential, yield stability, superior cooking and eating quality and early maturity, and rice varieties with increasing added value specified for the optimal agroecosystem, and (2) improved varieties with higher productivity, and with tolerance to environmental stresses by combining multiple gene resistance gene to harsh environment such as drought, salinity, flood, and metal toxicity, dealing with the suboptimal agro-ecosystem.

Sustainability of rice production could be achieved by maximizing both optimal and suboptimal agroecosystem. Utilization of suboptimal land and available technology could be an alternative to solve this problem. Limited fertile land due to land conversion, encourages the use of marginal land for the expansion of rice cultivation land. Indonesia chose the expansion of rice cultivation land into swamps with consideration of the availability and history of the use of swamps by communities in certain areas for the cultivation of agricultural crops. These natural features of the swampland influenced rice yield.

Technologies on water management, application of fertilizer and soil ameliorant, and crop spacing setting are being developed to improve rice productivity in swampland area on the basis of local genetic resources.

Local rice genetic resources have long been interacted with local community and swamps in rice cultivation encouraged the development of local varieties adapted naturally to swamps and community culture. Interestingly. the genetic diversity formed by the selection of farmers is still cultivated until now and has unique characteristics. Some local rice varieties are widely cultivated by local farmers based on their adaptability to local environment, suitable with local consumer preference, and high price in market. Others local varieties also still exist in farmers due to their adaptability on specific stresses, such as adaptation to high salinity of the soil. Therefore, those local varieties are not only potential as a source of specific traits on improvement of modern varieties, but also could be directly developed by local farmer.

The utilization of rice genetic resources for several purposes is not only in national level in each country but also in global scope. Therefore, the exchange of genetic material needs to be accompanied by an adequate exchange of information. The exchange of relevant scientific information of plant genetic resources under the Treaty is regulated in article 17 of the agreement and implemented by the Global Information System of the International Treaty (GLIS). The GLIS provides a standardized automated one-stop shop for plant genetic resources for food and agriculture (PGRFA) information around the world. It facilitates easy access to information on seeds and other crop material for research, training and plant breeding. Recently, in parallel with the genomic breeding technology progression, the accessions of rice have registered in the digital object identifier (DOI) system and exposed in multi lateral system. Notably, the progressive technologies supported by government policy in research and development is important to support breeders, researchers, and farmers on utilization of rice genetic resources.

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STRATEGIES AND TECHNOLOGIES FOR THE UTILIZATION AND IMPROVEMENT OF RICE

Technological progress to support rice sustainable use and breeding in genomics and relevant fields, has opened up new areas to accelerate the productivity improvement in various agroecosystems. Creative solutions from multiple areas not only addressing in the plant but also water and soil properties, can be explored to balance the need for increased production and coping the current climate. An effort of securing our future food supply needs the involvement of strategies and technologies for the utilization of rice genetic resources. As in any complex systems, a single component may not drastically change the dynamics of food production. However, a synergistic interaction between multiple factors can move the system to a positive direction. An initiative platform of the co-development of rice technologies are well synergized with various aspects for rice production resources and technologies, such as local genetic resources, traditional knowledge, and modern innovation in genetics and agriculture.

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