The potentials and prospects of tidal swamp local brown rice as a nutrition source of iron and zinc and the parent of rice breeding

I Khairullah and M Sarwani

1 Indonesia Swampland Agricultural Research Institute (ISARI), Jl. Kebun Karet, Loktabat Utara, Tlp/Fax 05114772534 Banjarbaru 70712 South Kalimantan
2 Indonesia Center for Agricultural Land Resources Research and Development (ICALRD), Jl. Tentara Pelajar No. 12 Bogor 16114

Email: izhar.balittra@gmail.com

Abstract. Brown-rice originating from local tidal swamp rice is identified as having high iron (Fe) and zinc (Zn) content. This paper aims to elaborate the potentials and prospects of Fe and Zn content of brown rice in tidal swamp local rice, especially from South Kalimantan. This research was carried out at tidal swampland of Belandean Experimental Station, Barito Kuala District South Kalimantan. A total of 71 local varieties of tidal swamp rice originating from the tidal swampland were planted in a 2 m x 5 m plot. The planting system was followed by the South Kalimantan farmers’ traditional system with three times transplanting. The harvested rice was threshed and then milled which was still aleuron. The analysis of Fe and Zn of the brown rice was carried out in the laboratory of The Center for Soil and Agroclimate Research (at present ICALRD) Bogor. The results of the analysis of Fe and Zn levels of rice showed that levels of Fe and Zn of brown rice varied greatly. Fe levels ranged from 11-83 ppm, where Fe levels of local varieties were higher than high yielding varieties. Likewise, levels of Zn with a wide enough interval, which ranged from 20-108 ppm Zn. Among 71 brown rice local varieties, Siam Panangah showed high levels of Fe and Zn, which were 54 ppm Fe and 108 ppm Zn. The brown rice can be used as a source of nutrition Fe and Zn and as the parents in rice breeding with high Fe and Zn content.

1. Introduction
Nutrient deficiency of iron and zinc in Indonesia is still high and is one of the problems that occur in children. The percentage of iron (Fe) nutrient deficiency was 50% and zinc (Zn) deficiency was 17% [1]. Iron (Fe) and zinc (Zn) nutrition is a micronutrient that functions in the development of the brain, especially in functioning of neurotransmitter that plays an important role in increasing intelligence especially for children [2]. One source of nutrition for Fe and Zn was the consumption of rice from local varieties of tidal swamp rice. Brown rice from several local varieties of tidal swamp rice showed that Fe and Zn levels were high.

Local varieties of tidal swamp rice are still dominating paddy fields in tidal swamplands, especially in South Kalimantan. Tidal wetlands in South Kalimantan are around 191,740 ha of the total land area, about 146,612 ha had been cultivated, while the remainder was not planted or cultivated. The utilization of
146,612 ha of land is for paddy fields which are more dominated by local varieties [3]. In 2001, around 92% of the land was grown by rice, with local rice varieties dominating, which was around 96%, the rest were planted by high yielding varieties twice a year. The average productivity of rice (local and high yielding varieties) was 3.08 in 2000 t/ha [4]. The large percentage of local rice varieties planted in the tidal swamplands area might be due to high adaptability, as well as ease of cultivation in the field. According to Wiggin [5], local varieties had several advantages from the interests of farmers, which were easily obtained in almost all places, only require very minimum maintenance, and tall plant height so that farmers did not need to bend in harvesting by using ani-ani tool, a kind of harvested tool using hand.

Tidal wetland is one part of swampland that had specific hydrological and soil properties. Based on hydrologic nature or type of overflow, it is divided into types A, B, C, and D, while based on the type of soil, it is categorized into potential soils, acid sulfate, saline, and peat land. Type A land is the land that is always waterlogged and daily tidal drainage; Type B land is only affected by large tides, but drained daily; type C land has never been fulfilled even though tides is large, permanent drainage, tides affect it indirectly, ground water near surface soils <50 cm; type D land has never been flooded with the tide, and groundwater > 50 cm from ground surface, and drainage was limited [6].

Potential land is the land that includes potential acid sulfate, pyrite content of 2% at a depth <50 cm from the soil surface. The acidic sulfate soil has a pyrite layer > 2% at a depth <50 cm, which is divided into potential acid sulfate soil if the pyrite layer has not been oxidized, and actual acid sulfate soil if pyrite has been oxidized to a soil pH <3.5. Peatland was a land that is formed by organic matter with organic carbon content of 12-18% if the matter is saturated with water, and 10% if it has never been saturated [7]. Thus, the diversity of tidal swamplands could be seen, and it potentially allows for a diversity of food crops, especially local rice that could grow adaptively on the land.

Its hydrological nature was influenced by tidal diurnal and flooded over 3 months, while the characteristics of soil was the presence of pyrite minerals as a form of acid sulfate soils and the peat as the basic ingredients of peat soil. Under natural conditions, tidal swamplands were one of the ecosystems that had a high level of biological diversity including a variety of plants, fish, and livestock that were typical of swamplands [8].

The development of agriculture in tidal swamplands faces some problems including water management, soil fertility, and soil acidity [9]. Besides, the high level of Fe, Al, Mn, P deficiency, low base cations, and high salinity also encounter [10,11]. Land problems that are often encountered in tidal swamplands were the presence of pyrite layers (FeS₂). It was under conditions of inundation the soil pH increase that caused an increase in Ferro concentration to reach thousands of mg L⁻¹ in the soil solution [12,13].

Tidal swampland has a diversity of plants that has superior properties, such as tidal swamp local rice that is able to adapt to inundation conditions, low pH, and high levels of soil Fe. This local rice is also tolerant of Fe toxicity [14,15]. Local varieties of tidal swamp rice are widely grown in tidal swamp rice fields, including in South Kalimantan. Various local varieties on the tidal swampland of South Kalimantan are found under various local names. Naming could be based on plant-specific characteristics such as grain size, grain color, number of grains in panicles, and so on. Khairullah [16] compiled it with several names groups such as Siam, Bayar, Pandak, and Lemo.

Adaptive rice varieties in tidal swamplands, especially for acid sulfate soil, has the potential to contain high levels of Fe and Zn because the growth environment is rich in Fe and Zn soil. Conversely, varieties that are not adaptive would languish their growth and might even die, partly because the plant is Fe toxicity. In general, local varieties of tidal swamp rice has been adaptive to grow environmental conditions so that they could contain high Fe and Zn in their brown rice [17].

This paper aims to elaborate the potentials and prospects of Fe and Zn levels of brown rice in tidal swamp local rice, especially those from South Kalimantan tidal swamplands.
1.1. Potential of local rice varieties

Local varieties of tidal swamp rice still dominate rice fields on tidal swampland. For example, in South Kalimantan, tidal swampland is around 172,117 ha, and 84.3% or 145,168 ha have been developed. About 92.5% of the land is planted with rice, where once a year local rice varieties are dominating about 96.24%, the rest are planted with high yielding varieties (HYV’s) twice a year. Average rice productivity (local and HYV’s) in 2000 was 3.08 t/ha [4]. The large percentage of local rice varieties planted might be due to good adaptability, in addition to the ease of cultivation at the farmer field. According to Wiggin [5], local varieties has several advantages seen from the farmers’ interests which are easily obtained in almost all places, only require minimum maintenance, and height plant so that farmers do not need to bend in harvesting with ani-ani tool.

Local rice varieties on tidal swampland, for example in South Kalimantan, are inseparable from early history of land clearing by the people. The utilization of tidal swampland for agriculture, especially lowland rice by local farmers began spontaneously since hundreds of years ago. Reclamation and opening of tidal swampland began first in the area around Banjarmasin conducted by Banjarese farmers from Hulu Sungai Selatan since 1920 along with the opening of the road. Until 1965, about 65,000 ha of tidal swampland in South and Central Kalimantan had been reclaimed into paddy fields [18].

The opened paddy field was originally called Bayar rice, because the rice planted was Bayar variety. Furthermore, segregation of local Bayar varieties is to bring up the names of new local varieties, namely Bayar Putih, Bayar Kuning, and Bayar Melintang. The naming of Bayar Putih and Bayar Kuning is related to color of light yellow (white) and yellow straw. The description of Bayar varieties included 9-10 months, nurseries 4-5 months, including photoperiod sensitive varieties, sensitive to water systems, easy to fall down or lodged, and can not stand drought, and plant height 160-170 cm, yield 65-70%, productivity 2.5-3.0 t/ha.

The segregation of local Siam varieties initially gave names of Siam Halus (small), Siam Manangah (medium), and Siam Ganal (bold). This naming is associated with the grain form of the variety. Siam Halus is the most popular because it is considered more delicious, and its price is more expensive. From Siam Halus then it is known as Siam Karangdukuh, which is a Siam variety that shows its superiority in the Karangdukuh area village. The popularity of Siam Karangdukuh lasted long enough and spread widely in the farmer paddy field. The next, come to a new variety called Siam Unus, which is thought to be a segregation of Siam Karangdukuh.

Unus Kuning, Siam Unus variety then becomes very popular in South Kalimantan replacing Siam Karangdukuh, because of its small, slender in grain form, translucency in the hulled rice, the very white color of boiled rice with good eating quality, as well as its expensive price. The segregation of Siam Unus variety gives rise to Siam Unus Halus, Siam, and Siam Unus Putih varieties. All of which refer to the nature of the shape and color of the grain. Siam Unus Halus variety is furthermore popular among farmers and consumers particularly in South Kalimantan [19].

2. Materials and methods

The research was conducted in acid sulfate tidal swampland in Belandean Experimental Station, ISARI in WS 2001 to DS 2002. A total of 71 local varieties and five high yielding varieties were planted in a 2 x 5 m² plot. The local varieties came from the tidal swampland of South Kalimantan. The planting was carried out based on the local farmers' planting, namely with the seedling system up to three times. The seedlings (Banjar language - teradak) was carried out in October; first transplanting was called menampak) in November; transplanting II (melacak) in January; and transplanting III (planting) in April. Planting this way was done because the local rice varieties were classified as photo period varieties. The land management and preparation were done by using a tajak tool. Weeds were cut down, allowed to mine on the water then spun and spread back to the land when it had undergone a perfect decomposed. The
fertilization only used urea at a rate of 100 kg/ha given one week after planting. The planting was maintained by weeding and preventing pest attacks.

The rice harvested for each variety then threshed and dried, and a manual milled to get brown rice. The brown rice sample was taken as much as 100 g to be analyzed Fe and Zn contents. Analysis of Fe and Zn contents of brown rice was carried out at the Indonesian Center for Soils and Agricimate Research laboratory (at present the Indonesian Center for Agricultural Land Resources Research and Development – ICALRD, Bogor. The data analysis used frequency distribution method to determine groups based on a range of Fe and Zn contents.

3. Results and discussions

The frequency distribution Fe and Zn content of 71 local brown rice varieties showed in Figure 1 dan Figure 2. The frequency distribution of brown rice Fe content (%) consisted of seven groups, namely group 1 (11-21 ppm), group 2 (11-21 ppm), group 3 (33-43 ppm), group 4 (44-54 ppm), group 5 (55-65 ppm), group 6 (66-76 ppm), and group 7 (77-87 ppm). Group 1, 2, 3, 4, 5, 6, and 7 consisted of 41%, 38%, 13%, 4%, 0%, 3%, and 1% of 71 local varieties, respectively (figure 1). Meanwhile the frequency distribution of brown rice Zn content (%) consisted of seven groups too, namely group 1 (20-32 ppm), group 2 (33-45 ppm), group 3 (46-58 ppm), group 4 (59-71 ppm), 5 (72-84 ppm), group 6 (85-97 ppm), and group 7 (98-110 ppm). Group 1, 2, 3, 4, 5, 6, and 7 consisted of 51%, 40%, 4%, 1%, 3%, 6%, and 4% of 71 local varieties, respectively (figure 2).

![Graph](image)

**Figure 1.** Distribution of Fe content of brown rice of local tidal swamp rice varieties.
Figure 2. Distribution of Zn content of brown rice of local tidal swamp rice varieties.

The results of Fe and Zn contents analysis on 71 local varieties of rice showed that Fe and Zn content varied greatly (figures 3 and 4). Fe content of 71 brown rice of local varieties of tidal swamp rice ranged from 11-83 ppm, where the lowest levels were indicated by Kutut variety (11 ppm Fe), and the highest was shown by Siam Pandak variety (83 ppm Fe). The highest frequency was in range 11 - 21 ppm Fe followed by 22 - 32 ppm Fe with a frequency 40.8% and 38.0% respectively. This means that around 75% of local varieties tested for Fe content of brown rice were in the range 11 - 32 ppm Fe.

Figure 3. Fe content (ppm) of brown rice local tidal swamp varieties.
The Fe and Zn content variation for HYV’s (Margasari, Martapura, Mendawak, Kapuas, Banyuasin, IR66) or promising lines (GH 47, GH 137, GH 173) were not as wide as local varieties. The HYV’s (Margasari 43 ppm dan Banyuasin 44 ppm Fe) showed Fe higher than Martapura, Mendawak, Kapuas, and IR66 varieties. The promising lines that had higher Fe content showed by GH 47 (70 ppm Fe) than GH 137 (32 ppm Fe) and GH 173 (32 ppm Fe). The lowest Fe content showed by Kapuas variety (20 ppm Fe). Meanwhile, the highest Zn content was Martapura variety 65 ppm Zn and the lowest Zn content was Mendawak variety 32 ppm Zn. For promising lines, the highest Zn content was GH 137 (63 ppm Zn) and the lowest was GH 173 (28 ppm Zn) (figure 5).

Fe and Zn (ppm) content of brown rice of HYv’s and promising lines

Figure 4. Zn content (ppm) of brown rice tidal swamp varieties.

Fe and Zn content (ppm) of brown rice of HYv’s and promising lines

Figure 5. Fe and Zn (ppm) content of brown rice HYV’s and promising lines planted same with local varieties.
The results of Yustisia [20] showed that levels of Fe and Zn of brown rice were varied from 5 HYV’s (Ciherang, Widas, IR64, Cisokan, and Cimelati) planted in inceptisol soil (10.84 - 19.80 ppm Fe and 19.64 - 24.55 ppm Zn). The highest Fe content was indicated by Widas variety and the lowest was Cisokan. The highest Zn level was shown by Ciherang variety and the lowest was by Cimelati. The results of other studies of Fe and Zn levels of red rice and white rice using the co-AANI method showed that Fe levels were higher than Zn levels. Fe content of white rice was 46.53 ± 1.51 µg/g and red rice 61.07 ± 3.43 µg/g Fe. While Zn contents of white rice were 44.75 ± 0.53 µg/g and brown rice 19.27 ± 1.79 µg/g Zn [21]. While Indrasari [22] showed that the mean content of Fe and Zn in HYV’s were 11.7 ppm Fe and 23.9 ppm Zn. Of the 71 brown rice local varieties of tidal swamp rice from South Kalimantan that was analyzed by its content of Fe and Zn, only Siam Panangah showed high levels of Fe and Zn, i.e. 54 ppm Fe and 108 ppm Zn.

3.1. Prospects of local varieties rice development

From the results it can be seen that there are several local varieties of tidal swamp rice from South Kalimantan which have higher Fe and Zn levels than the broken rice of other varieties. It is suspected that the high level of Fe content in rice had to do with the soil where the rice was planted. The location of this test was in acid sulphate soil containing high levels of Fe. The results of Dianawati [23] research showed that iron content in rice correlates with iron content in soil where rice is planted and has no correlation with iron content in water used to irrigate the rice.

If the brown rice was milled to milled rice it will reduce the content of Fe and Zn about 67% Fe and 13.2% Zn, respectively [24]. When referring to nutritional adequacy rate for Fe of 13 mg and Zn of 15 mg/capita/day [25], some local varieties that containing high Fe and Zn in groups 44-54 ppm, 66-76 ppm, and 77-87 ppm Fe in Figure 1 and group 59-71 ppm, 72-84 ppm, 85-97 ppm, and 98-110 ppm Zn in Figure 2 fulfill the mineral or nutrient adequacy of Fe and Zn.

The information on Fe and Zn content from local varieties of brown rice is very useful for practical purposes: (1) as a consumption material, especially for the mineral or nutrient intake needs of Fe and Zn; in addition (2) it is also useful for rice plant breeders for improving high yielding varieties with high Fe and Zn content in rice, which will help reduce iron and zinc intake from other food sources.

4. Conclusions

Local varieties of tidal swamp rice have great prospects for development because some of them have high Fe and Zn content in brown rice. The results of the analysis of Fe and Zn content of brown rice of 71 local tidal swamp rice varieties of South Kalimantan showed that content of Fe and Zn of brown rice varied greatly. The Fe content ranged from 11-83 ppm, where Fe content of local varieties were higher than high yielding varieties. Zn content was also with a ranged wide enough, which ranged 20 - 108 ppm Zn. Siam Panangah variety showed high content of Fe and Zn, which had 54 ppm Fe and 108 ppm Zn, respectively. The high Fe and Zn content can be used as parents in crossing to get high yielding varieties of rice with high Fe and Zn content. Moreover, it can also be used as direct consumption material to meet the intake of Fe and Zn minerals. The varieties tested were relatively tolerant to be planted in acid sulfate tidal swampland with high soil Fe content.

References

[1] Hidayati L, Hadi H and Kumara A 2010 Kekurangan energi dan zat gizi merupakan faktor risiko kejadian stunted pada anak usia 1-3 tahun yang tinggal di wilayah kumuh perkotaan Surakarta J. Kesehatan 4 89-104

[2] Almatrsier S  2010 Prinsip Dasar Ilmu Gizi (Jakarta: PT Gramedia Pustaka Utama)
[3] Dinas Pertanian TPH Kalsel 2006 *Laporan Tahunan 2006* (Dinas Pertanian Tanaman Pangan dan Hortikultura Provinsi Kalimantan Selatan Banjarbaru)
[4] Zauhari R M 2001 *Pengembangan Lahan Basah di Dalam Otonomi Daerah* (Makalah pada Lustrum ke-8 Fakultas Pertanian Universitas Lambung Mangkurat Banjarbaru)
[5] Wiggin G 1976 *Buginese Agriculture in the Tidal Swamps of South Sumatera* (Lembaga Pusat Penelitian Pertanian Bogor)
[6] Kselik R A L 1990 *Workshop on Acid Sulphate Soils in the Humid Tropics* (Bogor: AARD-LAWOO)
[7] Widjaja-Adhi I P G 1986 Pengelolaan lahan rawa pasang surut dan lebak *J. Litbang Pertanian* 5 (1)
[8] Silvius M J, Steerman A P J M, Berczy E T, Djuhara E and Taufik A W 1987 *The Indonesian Wetland Inventory. A Preliminary Compilation of Existing Information on Wetlands of Indonesia* (Bogor: PHPA AWB/Interwader Edwin)
[9] Maas A, Afandie R and Suryanto 1992 *Potensi dan Kendala Reklamasi Lahan Pasang Surut* (Makalah pada Pertemuan Nasional Pengembangan Pertanian Lahan Pasang Surut Cisarua 3-4 Maret 1992)
[10] Ikehashi H and Ponnampuruma F N 1978 *Varieties Tolerance of Rice for Adverse Soils* (Los Banos: Soil and Rice International Rice Research Institute
[11] Ponnampuruma F N 1977 *Physico-Chemical Properties of Submerged Soil in Relation to Fertility* (IRRI Research Paper Series No. 5 Int. Rice Res. Ins. Los Banos The Philippines)
[12] Widjaja-Adhi I P G, Suriadipta D A, Sutriadi M T, Subiksa I G M and Suastika I W 2000 *Pengelolaan Pemanfaatan dan Pengembangan Lahan Rawa 127-64* In Adimihardja A, Amien L I, Agus F ja Jaenudin D *Sumberdaya Lahan Indonesia dan Pengololaannya* (Pusat Penelitian Tanah dan Agroklimat Bogor)
[13] Jumberi A and Alihamsyah T 2005 *Pengembangan Lahan Rawa Berbasis Inovasi Teknologi* In Arriza et al 2005 *Proc. Inovasi Teknologi Pengelolaan Sumberdaya Lahan Rawa dan Pengendalian Pencemaran Lingkungan* (Banjarbaru: Puslitbang Tanah dan Agroklimat) pp 11-42
[14] Khairullah I, Humairie R, Imberan M, Subowo S and Sulaiman S 2003 *Varietas Lokal Padi Pasang Surut Kalimantan Selatan: Karakterisasi dan Pemanfaatannya* In Kasno A et al *Proc. Perpimpinan Ilmu Pemuliaan Indonesia (PERIPI)* (Balai penelitian Kacang-Kacangan dan Umbi-Umbian Malang)
[15] Khairullah I and M Saleh 2014 *Sumberdaya lokal tanaman pangan lahan rawa Biodiversiti Rawa: Eksporasi Penelitian dan Pelestariannya* Penyunting : Mukhlis et al Badan Penelitian dan Pengembangan Pertanian IAARD Press Jakarta 366 hal
[16] Khairullah I, Imberan M and Sulaiman S 1997 *Keragaan Agromorfologi Lima Varietas Padi Lokal yang Populer di Lahan Pasang Surut Kalimantan Selatan* In Maamun M Y, Arriza I, Simatupang R S, Noor M, Sumanungkalit D and Rayitno B M *Proc. Pembangunan Pertanian Berkelanjutan Menyongsong Era Globalisasi* (Banjarmasin 13-14 Maret 1997)
[17] Khairullah I, Mawardi and Sarwani M 2006 *Karakteristik dan Pengelolaan Lahan Rawa: 7 Sumberdaya Hayati Pertanian Lahan Rawa* (Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian) pp 203-28
[18] Idak H 1982 *Perkembangan dan Sejarah Persawahan di Kalimantan Selatan* (Banjarmasin: Pemda Tk. I Kalimantan Selatan) p 40
[19] Khairullah I 2007 *Pros. Pertanian Lahan Rawa “Revitalisasi Kawasan PLG dan Lahan Rawa Lainnya untuk Membangun Lombung Pangan Nasional”* (Kuala Kapuas: Badan Penelitian dan Pengembangan Pertanian) pp 339-48 ISBN 978-979-8253-63-8
[20] Yustisia, Tohari, Shiddieq D and Subowo G 2012 Pengkayaan besi (Fe) dan seng (Zn) dalam beras dan karakter penentu varietas padi sawah efisien pada tanah vertisol dan inseptisol Agrotrop. 2(1) 67-75

[21] Mulyaningsih T R 2009 Kandungan unsur Fe dan Zn dalam bahan pangan produk pertanian, peternakan, dan perikanan dengan metode ko-AANI J. Sains dan Tekno. Nuklir Indonesia 10 71-80

[22] Indrasari S D, Hanarida I and Daradjat A A 2002 Indonesian Final Report Year I Breeding for Iron Dense Rice: A Low Cost Sustainable Approach to Reduce Anemia (Asia International Food Policy Research Institute (IFPRI) & Indonesian Center Food Crop Research and Development (ICFCR))

[23] Dianawati N and Sugiarso R D 2015 Penentuan kadar besi selama fase pematangan padi menggunakan spektrofotometer UV-Vis J. Sains dan Seni 4 2337

[24] Indrasari S D, Wibowo P and Daradjat A A 2008 Proc. Sem. Nas. BB Padi pp 1457-72

[25] Muhilal, Sadono A, Krisdinarumurtin, Husaini, Sugih R and Khumaidi M 1989 Angka Kecukupan Gizi Rata-rata yang Dianjurkan (AKG) (Widyakarya Pangan dan Gizi Lembaga Ilmu Pengetahuan Indonesia)