THE IRON CONTENT OF TRADITIONAL AND PURPLE THAI RICE VARIETIES UNDER ACID-SOIL CONDITION

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Abstract- This study investigated the iron content and the yield of traditional and purple rice varieties under the acid-soil condition. The samples included three improved (Riceberry, Jao Hom Nin and Sinlek) and one native (Mali Daeng) varieties containing high iron content. The experiment was conducted in farmers' fields in Theppharat Subdistrict, Ban Pho District, Chachoengsao Province, Thailand, having the soil pH of 4-5. The iron content in the unmilled grains was 2.196, 1.469, 3.817 and 1.524 mg/100 g grains for Riceberry, Jao Hom Nin, Sinlek and Mali Daeng, respectively. The iron content in the polished grains was 4.407, 0.936, 1.216 and 10.631 mg/100 g grains, respectively. Sinlek had the highest unmilled-grain iron content among the four varieties, while Mali Daeng had the highest polished-grain iron content. Cluster analysis divided the iron content of the four rice varieties into three groups each for both unmilled and milled grains. Sinlek and Mali Daeng were among the high-iron-content varieties for unmilled and polished rice, respectively. Riceberry constituted the medium-iron-content group, while Jao Hom Nin was among those having the lowest iron content. The result showed that the four rice varieties could produce reasonable yield in acid soil and that Mali Daeng showed a potential as a nutritional, alternative food with high iron content.

Index Terms- iron content, purple rice, traditional rice, acid soil

I. INTRODUCTION

Iron deficiency is a critical problem that leads to anemia in 30% of the world population. This important public health problem directly affects the living quality of the population. Anemia caused by iron deficiency can hamper growth and intellectual development. Children with iron deficiency may have reduced learning ability and lowered immunity. Also, it may lead to premature delivery in pregnant women, underweight infants with retarded learning ability. Among working adults, iron deficiency may result in reduced work efficiency, fatigue and lethargy. This problem could easily lead to economic and public health loss especially in developing countries such as Thailand. In Thailand, iron deficiency is mostly caused by insufficient iron intake form food. This is a common problem in developing countries that consume rice or other cereals as their stable food [1]. More than half of the world population make rice and cereals their stable food due to their high energy output and their lower prices. Nonetheless, rice contains only small amounts of vitamins and essential minerals, and has a lower amount of iron in its grains than corn and wheat [2]. Rice only contains 0.63 – 2.44 mg iron for each 100 g grains. Attempts have been made to breed new rice varieties with higher grain iron contents such as IR68144 developed by International Rice Research Institute [3]-[4] having unmilled-grain iron content 1.8 – 2.2 mg/100 g. In Thailand, Khao Dawk Mali 105 (Thai Jasmine rice) and Jao Hom Nin were used as parental lines to develop improved rice varieties having the grain iron content 1.6 – 2.1 mg/100 g with good agronomic characters and cooking quality [5]. Analyses were carried out on native varieties from India and China to identify high iron-content variety including Jalmagna, Zuchem and Xua Bue for use as the genetic resources in breeding programs [2]. In Thailand, Sirithunya and colleagues [6] reported an analysis of unmilled-grain iron content of several native varieties to be ranging from 0.430 – 2.667 mg/100 g. Varieties with high iron content included Hom Mali Tung Ruang Tong and Nam Sa Gui 19 having 2.667 and 2.550 mg iron in 100 g grains. Also, CMU122, CMU123 and CMU124, native varieties obtained from Lee Sor mountain tribe residing in Northern Thailand, contained 1.6 -2.2 mg/100 g grain iron content [7]. Thus, it appeared that native Thai rice varieties showed great variations with some having rather high iron and protein content in their grains [6].

It is clear that certain rice varieties do have high iron content. Nonetheless, not all of that grain iron may be available for uptake by human body. Rice grains contained oxalic acid as well as phytate that can reduce bioavailability of iron. As a result, consumption of high iron content rice still cannot fulfil the recommended daily iron intake. As a way to alleviate the problem, rice breeders have tried to genetically increase the accumulation of iron in the grains to the level of 2.7 – 3.0 mg/100 g for both white and black rice [5]. Another approach is to make the best use of soil iron, especially in the area with low soil pH. At low pH, iron takes the form of water soluble FeSO4 which poses toxicity toward many plant species. In rice paddy, acid soils causes the paddy water to become acidic resulting in the reduction of Fe^{3+} to Fe^{2+}, especially in the presence of sulfate. Accumulated Fe^{2+} could reach 5,000 mg/kg in soils and 500 – 2,000 mg/kg in plant tissues [8].

Native varieties of Thai rice exhibit a wide range of genetic variation and are often able to adapt to changing environment such as drought, flood and certain biotic stresses. Many varieties can withstand low soil pH; thus, their roots are not affected by iron and aluminum toxicity of acid soils. Therefore, growing these varieties in acid soils with high iron concentration may present another way to increase iron accumulation in rice grains.

This report aimed at determining the grain iron content in three improved varieties as well as in a native variety of Thai rice cultivated in acid soils with high iron concentrations in order to increase iron accumulation in their grains. The varieties were among those with high grain iron content. If these varieties could be cultivated in high-iron soils (> 300 mg/kg) and could accumulate iron to a high level in their tissues, the resulting grain iron content would increase. Therefore, this report attempted to explore the utilization of areas with acid soils as areas for cultivating high iron content rice. The success of the study could lead to value addition for native rice varieties and might serve as an option to help solve iron deficiency problem among Thai population.

II. MATERIALS AND METHODS

A. Rice Varieties and Cultivation

Seeds of Oryza sativa rice varieties Riceberry, Jao Hom Nin and Sinlek were received from Rice Gene Discovery Laboratory, Kasetsart University. Seeds of Mali Daeng were obtained from the collections of four local sages who preserved this traditional variety in the local area of Theppharat Subdistrict, Ban Pho District, Chachoengsao Province, Thailand.

The four varieties were cultivated in the farmers' fields in Theppharat Subdistrict by using the randomized complete block design with four replicates. The fields were fertilized with liquid bio-extract (egg-hormonal formula), produced by Theppharat Subdistrict Agricultural Technology Transfer Center, and chemical fertilizers. Grain yields and physical appearances were recorded according to Thailand's Rice Department's standard.

B. Iron content analyses

Soil chemical properties and the iron content of rice grains were assayed according to the AOAC method. Rice varieties were categorized according to their iron content using cluster analysis with unweighted pair-group average algorithm of PAST v.2.0 [9].

III. RESULTS

C. Soil chemical compositions

Paddy soils were collected for chemical analysis before and after planting. Soil organic matters were unchanged and in the medium range (2.11 – 2.13 %). The averaged soil total nitrogen was 0.28 – 0.24%; averaged total phosphorous, measured as P2O5, was 0.12 – 0.18 %; averaged total potassium (K2O) was 0.28 – 0.30 %. The soil pH was between 4 and 5. Soil aluminum, iron and zinc were averaged to be 4.89 – 4.88, 2.52 – 2.48, 0.003172 – 0.002810 %, respectively (Table I).

Table I: Soil chemical composition

Soil composition	Amount before planting (g/100 g)	Amount after planting (g/ 100g)
organic matters	2.11	2.13
total nitrogen	0.28	0.24
total phosphorous (P_2O_5)	0.12	0.18
total potassium (K_2O)	0.28	0.30
aluminum (Al)	4.86	4.88
iron (Fe)	2.52	2.48
zinc (Zn)	0.003172	0.002810

D. Iron content in unmilled and polished rice grains

Iron content in the unmilled grains of Riceberry, Jao Hom Nin, Sinlek and Mali Daeng was 2.196, 1.469, 3.817 and 1.524 mg/100 g, respectively. In the polished grains, the iron content was 4.407, 0.936, 1.216 and 10.631 mg/100 g, respectively. Therefore, rice variety with the highest iron content in the unmilled grains was Sinlek, and rice variety with the highest iron content in the polished grains was Mali Daeng in this study (Table II).

Table II: Iron content in unmilled and polished rice grains

Rice variety	Iron content in unmilled grains (mg/100 g)	Iron content in polished grains (mg/100 g)
Riceberry	2.196	4.407
Jao Hom Nin	1.469	0.936
Sinlek	3.817	1.216
Mali Daeng	1.524	10.631

E. Grain yield

Cultivation of high-iron content rice varieties under using a liquid bio-extract as nutritional supplements led the varieties to achieve their standard grain yields even under acid soil conditions. The resulting yield was 750, 720, 876 and 643 kg/rai, respectively. The variety with highest yield was Sinlek while that with lowest yield was Mali Daeng (Table III).

Table III: Plant characteristics and grains yield under acid soil conditions

Rice variety	Maturity (days)	Height (cm)	Averaged yield (kg/rai)	Seed dimension (L x W x H) (mm)
Riceberry	130	110	750	11.0 x 7.5 x 7.0
Jao Hom Nin	100	75	720	6.5 x 7.0 x 7.0
Sinlek	120	110	876	11.0 x 7.6 x 7.0
Mali Daeng	125	130	643	7.5 x 2.1 x 1.7

F. Cluster analysis using the iron content

Cluster analysis was used to group the four varieties of rice according to their grain iron content. Three categories emerged: high, medium and low iron content. The variety with high unmilled grain iron content was Sinlek (3.717 – 4.008 mg/100 g); the variety with medium unmilled grain iron content was Riceberry (2.106 – 2.305 mg/100 g); the varieties with low unmilled grain iron content included Jao Hom Nin and Mali Daeng (1.207 – 1.607 mg/100 g) (Fig. 1).

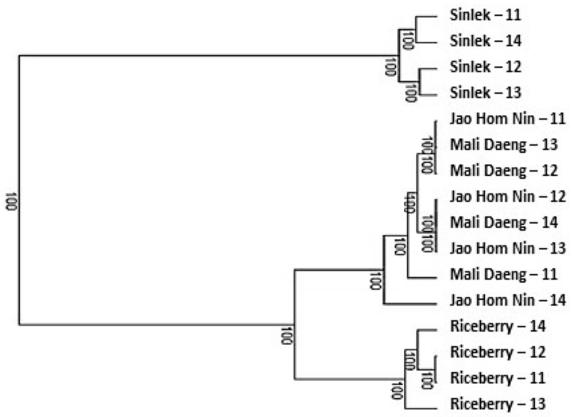

Fig. 1. Clustering of rice varieties according to their unmilled grain iron content.

When polished grain iron content was used in cluster analysis, the four varieties of rice also fell into three categories: high, medium and low iron content. The variety with high polished grain iron content was Mali Daeng (10.407 – 10.413 mg/100 g); the variety with medium polished grain iron content was Riceberry (4.410 – 4.505 mg/100 g); the varieties with low polished grain iron content included Jao Hom Nin and Sinlek (1.007 – 1.219 mg/100 g) (Fig. 2).

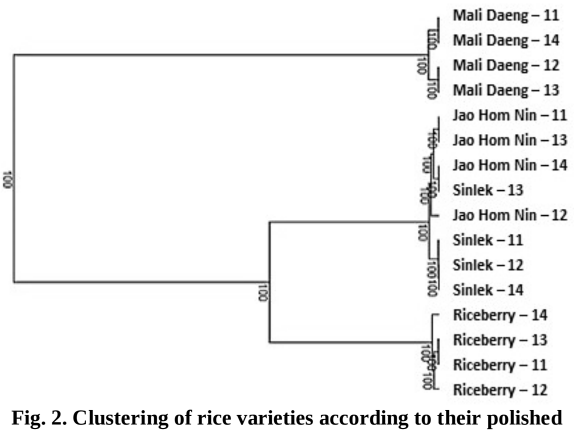

Fig. 2. Clustering of rice varieties according to their polished grain iron content.

IV. DISCUSSION

In this report, four varieties of rice: Riceberry, Jao Hom Nin, Sinlek and Mali Daeng, were cultivated on paddy soils having the pH 4 – 5 using chemical fertilizers and a supplemental bio-extract formulated with hormones and eggs. Soil organic matters and major elemental contents were in the medium levels, while minor elements, namely aluminum, and iron, were present at high levels. Upon cultivation in the acid soils, the varieties produced medium amounts of grain yields. Analysis showed that the resulting grains still contained a high level of iron content. For example, Jao Hom Nin, whose grain iron content on normal soils reportedly ranged from 1.3 – 1.7 mg/100 g with the grain yield of 400 – 700 kg/rai. On acid soils in this report, its grain iron content was averaged to be 1.469 mg/100 g. Our findings confirmed the results report by Vanavichitr et al. [5], which showed an increase in Jao Hom Nin's grain iron content from 1.3 to 1.6 mg/100 g when cultivated on soils having a high iron content. Grain iron content of Riceberry ranged from 1.3 – 1.8 mg/100 g in normal soils, but in acid soils, the iron content increased to 4.407 and 2.196 mg/100 g in unmilled and polished grains, respectively, in this report. For Sinlek, the iron content increased from 1.5 -2.1 mg/100 g unmilled grain iron content when cultivated on normal soils to 3.817 mg/100 g unmilled-grain iron content and 1.216 mg/100 g polished-grain iron content when cultivated on acid soils. In Mali Daeng, which is a native rice variety, had a higher polished-grain iron content than the three improved varieties, in agreement with other reports of iron content of some other native varieties including Hom Mali Tung Ruang Tong and Nam Sa-gui 19 which contained 2.667 and 2.550 mg/100 g iron in their grains. The reason was that native varieties exhibited variation in their grain protein and iron content [6]; some with higher and some with lower protein and iron contents. When total grain yields were considered, the four varieties being studied exhibited the yields appropriate to the varietal potential. The use of the supplementary bio-extract formulated with hormones and eggs together with the use of chemical fertilizers helped to reduce the toxicity of iron and aluminum that dissolved out under acidic conditions causing the depletion of available phosphorous, potassium and magnesium. Soils with high iron content could limit the root growth, and the deposited iron(II) oxide on the root surface would reduce the efficiency of its nutrient absorption. The supplementary bio-extract helped to increase the soil organic matter, which absorbed cations well, thus reducing the fixation of phosphorous in soils with high iron and aluminum content. Soil organic matters led to the formation of insoluble iron and aluminum complexes, causing the release of soil phosphorous for plant use, leading to an increase in yields [10]. Riceberry and Mali Daeng had 4.407 and 10.631 mg iron content in 100 g of polished grains, respectively. This constituted 1/3 and 2/3 of the recommended daily iron intake of 15 mg. However, not all of the grain iron might be available for body absorption due to the presence of polyphenol and phytic acid in the grains, which could inhibit the iron absorption. Polyphenol and phytic acid are abundant in rice brans; therefore, polished grains tended not to inhibit iron absorption as much as unmilled grains [5].

CONCLUSION

Cultivation of improved rice varieties with high iron content, namely Riceberry, Jao Hom Nin and Sinlek, and cultivation of the native variety Mali Daeng in acidic soil, pH 4 – 5, could increase the amount of grain iron content. In this study, the varieties exhibited the highest and the second highest polished-grain iron content was Mali Daeng and Riceberry, while Sinlek and Riceberry exhibited the highest and the second highest unmilled-grain iron content. The use of supplementary bio-extracts together with chemical fertilizers might have reduced the toxicity of iron and aluminum that leached out from acidic soils. As a results, plant roots could absorb more nutrients from soil and the plants themselves could produce a yield appropriate to their respective varieties.

This report showed that the native variety, Mali Daeng, carries a potential to be used as iron supplements for those who exhibited iron deficiency. Each 100 g of its polished grains could supplement 2/3 of the body daily iron requirement. Therefore, cultivation of rice on acid soils is a way to help increase the grain iron content on top of the genetic potential of certain rice varieties. Although the native varieties such as Mali Daeng might be highly nutritious and resistant to environmental harshness such as acid soils, they still carried a disadvantage in their low yield comparing with the improved varieties. Future work on the yield improvement of nutritious native varieties will be highly beneficial to both Thai farmers and consumers.

ACKNOWLEDGMENT

We thanked the Higher Education Research Promotion and National Research University Project, Office of the Higher Education Commission, Thailand, for funding, and Theppharat Subdistrict Agrucultural Technology Transfer Center, Banpho District, Chachoengsao Province, Thailand, for providing a learning and knowledge preservation center in the community and Rajabhat Rajanagarindra University Thailand for publication financial support.

REFERENCES

[1] S. Taprab, S. Palawisut, S. Nakprach, R. Panpitpat, A. Kotchasatit, S. Sriwisut, W. Hormsombut, A. Suwanwong, P. Vajanapoom, and L. Chusiri. “Environmental factors affecting iron content of rice grain,” Proceedings of Rice and Temperate Cereal Crops Annual Conference, pp. 168-180, 2006.

[2] P. Jaksomsak, S. Jamjod, and B. Rerkasem, “Genetic control of iron content in rice grains,” J. Agric. (Thailand), vol. 22(1), pp. 1-5, February 2006.

[3] G. B. Gregorio, D. Senadhira, H. Htut, and R. D. Graham, “Breeding for trace mineral density in rice,” Food Nutr. Bull., vol. 21, pp. 382-386, 2000.

[4] S. Pintasen, C. Prom, S. Jamjod, N. Yimyam, B. Rerkasem, “Variation of grain iron content in a local upland rice germplasm from the village of Huai Tee Cha in northern Thailand,” Euphytica, vol. 158, pp. 27–34, 2007.

[5] A. Vanavichit, et al., “Biotechnology for the Development of Value-added and High Quality Rice Varieties,” Research Report, National Research Council of Thailand, 2005.

[6] P. Sirithunya, O. Watanesk, Y. Khaosumain, and T. Toojinda, “Diversity of iron content in traditional rice varieties,” Proceedings of Rice and Temperate Cereal Crops Annual Conference, p. 35, March 2003.

[7] C. Prom-u-thai, and B Rerkasem, “Grain iron concentration in Thai rice germplasm,” Develop. Plant Soil Sci., vol. 92, pp. 350-351, 2001.

[8] M. Becker, and F. Asch, “Iron toxicity in rice - conditions and management concepts,” J. Plant Nutri. Soil Sci., vol. 168, pp. 558-573, 2005.

[9] O. Hammer, “Ecological cluster analysis with Past,” Natural History Museum, University of Oslo, http://nhm2.uio.no/norlex/past/ClusterPast.pdf pp. 1-5, June 2011.

[10] P. Ariyatanakatawong, and P. Saranrom, “Development of rice quality in acid soil using bio-extracts and technology transfer,” Research Report, Office of the Higher Education Commission, 2012.

[11] J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility,” IEEE Trans. Electron Devices, vol. ED-11, pp. 34-39, Jan. 1959.

[12] C. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, “Rotation, scale, and translation resilient public watermarking for images,” IEEE Trans. Image Process., vol. 10, no. 5, pp. 767-782, May 2001.

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