GRAIN MORPHOLOGY AND MINERAL ELEMENTS CONTENT IN RICE LANDRACES

Theera Thummawongsa[1,*], Kanya Manok[1], Kanyarat Chaekkrathok[1], and Saijai Posoongnoen[2]

[1]Department of Biology, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima, 30000, Thailand

[2]Department of Chemistry, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima, 30000, Thailand

Contact: Thummavongsa25@hotmail.com*

ABSTRACT

Rice landraces consisting of many good characteristic cultivars are important resource for utilization and conservation. The purposes of this research were to study the grain morphological character and mineral elements content of rice landraces using standard evaluation system for rice and atomic absorption spectroscopy (AAS), respectively. Grain morphological analysis revealed that rice landraces have variation of grain characters among cultivars. The variation of grain length, grain width and grain weight raged from 7.02 to 8.80 mm, 2.17 to 2.59 mm and 2.52 to 3.64 mm, respectively. Most of all cultivars showed extra-long and long slender grain including Hom nual, Loi Sai Bua, Hommali Dang, Leuang Tahang, Marum, Yod Bao, Leuang Thong and Kong Sai. Seed coat color showed white, purple and red colors. Most of the cultivars showed straw color of lemma and palea. Mineral elements analysis revealed that average P content was highest (179.96 mg/kg) followed by Ca (70.41 mg/kg), Fe (60.68 mg/kg), Zn (16.93 mg/kg) and Cu (9.44 mg/kg). The minerals content has variation among different rice cultivars which were highest with ratio of the maximum/minimum content of 6.68 fold (3.03-20.23 mg/kg) for Cu. The smallest variation was the content of Zn with 1.69 fold (12.73-21.49 mg/kg). The variation of Ca, P and Fe were 2.25 fold (44.31-99.4 mg/kg), 1.46 fold (144.78-212.00 mg/kg) and 3.40 fold (30.73-104.58 mg/kg), respectively. We suggested that the elements were highly affected by the genotype and environment. Loi Sai Bua contains highest phosphorus (212.0 mg/kg). While Yod Bao showed highest calcium (99.64 mg/kg) and iron (104.58 mg/kg). The highest copper and zinc were found in Leuang Tahang (20.2 mg/kg) and Neow Dam (21.5 mg/kg), respectively. Grain morphological characters and mineral elements content indicated that rice landraces are good resource which could be applied for breeding, quality improvement and geographical indication (GI) of rice.

INTRODUCTION

Rice (*Oryzasativa* L.) is a major staple and most considerable food by over one-half of the world's population (Bhattacharjee, et al. 2002). Rice composed of important nutritional value such as carbohydrate, protein, vitamins and minerals with many benefits for health and also contain various bioactive compounds consisting of total phenolic, flavonoid and antioxidant capacity (Chotimarkorn, et al. 2008; Sompong, et al. 2011). Humans required at least 49 nutrients for growth which are generally supplied by rice (Welch and Graham, 2004). Mineral elements are essential nutrients which play roles to metabolism and may lead to diseases and several dysfunctions on human (Garcia-Oliverira, et al, 2009). Rice is important source of mineral elements because rice is stable food that provides caloric energy and minerals at the same time (Zhang, et al., 2014). Huang, et al. (2016) reported that genotypic variance mainly affected to Ca, Na, K contents. Therefore, high minerals of rice genotype are important to discover for humans.

Local rice cultivars consist of many cultivars such as wide consumed white rice, color rice including brown rice, red rice and black rice. The glutinous black local Thai rice bran revealed high content cyaniding-3-gluco side, ferulic acid and caffeic acids and wound healing effect and antioxidant properties (Phetpornpaisan, et al. 2014). The wide variation of grain morphological characters of traditional rice revealed wide genetic variation for utilization in rice grain quality

improvement (Sinha, et al., 2015). In different countries, among the rice cultivars represent wide genetic diversity (Satoh, et al., 1990a, b). The grain shape correlated to rice cooking quality (Webb, et al., 1985). Therefore, grain morphological characteristics are important for breeding and quality improvement of rice.

Hence, the grain morphological characters and mineral elements content of rice landraces in Thailand were studied. This research could be applied for rice breeding and high rice quality production which are important for health and marketing.

MATERIALS AND METHODS

1. Sample preparation

The 10 local rice cultivars were collected form Nakhon Ratchasima province, Thailand. Rice samples were prepared by removing husk which was called brown rice. Then, brown rice was stored at 4°C for further analysis.

2. Study of grain morphology

The specimens were planted twice for the morphological description using modified method of standard evaluation system for rice (International Rice Research Institute: IRRI, 2002).

3. Minerals content analysis

Sample preparation and minerals content analysis were analyzed according to previous reports (AOAC, 2000). Rice power was placed into a crucible and dry-ashed by oven at 550 °C until the sample turned into white residue. Then, it was dissolved with 70% v/v HNO_3 and was placed on an electro thermal plate to reduce the volume. The sample was filtered and then was adjusted the volume with 70% v/v HNO3. The sample solutions were subjected to analyze for Ca, Zn, Cu and Fe using Atomic Absorption Spectrophotometer and P using UV-visible spectrophotometer.

RESULTS AND DISCUSSIONS

1. Grain morphological characters of rice landraces

The grain morphology of 10 rice landraces was summarized in Table 2. The variation of grain length raged from 7.02 to 8.80 mm, grain width from 2.17 to 2.59 mm. The variation of grain weight varied from 2.52 to 3.64. The extra-long types of brown rice length were found in 7 cultivars followed by long types (4 cultivars). The medium and short types were not present. For length-width ratio, most of the cultivars possessed slender grain types, whereas, only 2 cultivars represent as medium types. The bold and round types were not found. Seed coat color consisted of white, purple and red colors. Most of the cultivars showed straw color of lemma and palea. The purple color represented in Neow Dam and Kam. Seed coat color showed wide diversity among all of grain morphological characters. For grain length and width, the long grain had less width. Siddiqui, et al. (2007) reported that more width (3.0 mm or more) was shorter in length for Pakistan rice cultivars suggesting very large of shape variation. The grain length and width have correlation with 100 grain weight according to traditional rice in West Bengal, India (Sinha et al., 2015). The highest market value was characters of long slender grain (Sinha, et al., 2015) which were Hom nual, Hommali Dang.

Table 1 Grain morphological characteristics of rice landraces

Local name	Morphology							100 grains weight (g)
	Brown rice Length (Len)		Brown rice width (mm)	Brown rice shape (BrS)		Seed coat color (SCC)	Lemma and Palea Color (LmPC)	
	Length (mm)	type		length-width ratio (mm)	type			
Hom nual	7.38	2	2.37	3.11	1	1	0	2.77
Loi Sai Bua	8.80	1	2.21	3.98	1	1	0	3.34
Neow Dam	7.02	2	2.50	2.80	2	7	8	2.81
Hommali Dang	7.35	2	2.17	3.38	1	5	0	2.52
Leuang Tahang	8.17	1	2.32	3.45	1	1	0	3.24
Kam	6.66	2	2.59	2.57	2	7	8	3.29
Marum	7.91	1	2.46	3.31	1	1	0	3.26
Yad Bao	8.09	1	2.50	3.23	1	1	0	3.13
Leuang Thong	8.04	1	2.25	3.56	1	1	0	3.55
Kong Sai	8.21	1	2.24	3.65	1	1	0	3.64

Len: 1.extra-long (>7.50 mm.) 2.Long (6.61-7.50 mm.) 3.Medium (5.51-6.60 mm.) 4.Short (<5.51 mm.)
BrS: 1.Slender (>3.0) 2.Medium (2.1-3.0) 3.Bold (1.1-2.0) 4.Round (< 1.1)
SCC: 1.white, 2.light brown, 3.speckled brown, 4.brown, 5.red, 6.variable purple, 7.purple
LmPC: 0.straw, 1.gold and gold furrows on straw background, 2.brown spots on straw, 3.brown furrows on straw, 4.Brown, 5.Reddish to light purple, 6.purple spots on straw, 7.purple furrows on straw, 8.Purple

2. Minerals content and variation of cultivars in rice landraces

The minerals content in rice landraces was shown in Table 1 and Figure 1. Average P content was highest (179.96 mg/kg) followed by Ca (70.41 mg/kg), Fe (60.68 mg/kg), Zn (16.93 mg/kg) and Cu (9.44 mg/kg). Among the local rice, Loi Sai Bua contains highest phosphorus (212.0 mg/kg). While Yad Bao showed highest of Ca (99.64 mg/kg). Leuang Tahang and Neow Dam showed highest Cu (20.2 mg/kg) and Zn (21.5 mg/kg), respectively. Highest of Fe content (104.58 mg/kg) was found in Yod bao. The values of Fe, Zn and Cu are higher than previous report (Huang, et al., 2016). Huang et al., 2016 reported that twenty brown rice accessions of China in 2012 consisted of Ca (73.5-185.1 mg/kg), Fe (4.01-15.81 mg/kg), Zn (17.98-38.52 mg/kg) and Cu (1.20-2.84 mg/kg). The local rice had higher Ca content (44.31-99.4 mg/kg) than the earlier report which contains Ca content ranging from 15 to 28 ug/g (Renuka, et al., 2016).

The minerals content has variation among different rice cultivars. The mineral contents varied among 10 genotypes which were highest with ratio of the maximum/minimum content of 6.68 fold (3.03-20.23 mg/kg) for Cu. The smallest variation was the content of Zn with 1.69 fold (12.73-21.49 mg/kg). The variation of Ca, P and Fe were 2.25 fold (44.31-99.4 mg/kg), 1.46 fold (144.78-212.00 mg/kg) and 3.40 fold (30.73-104.58 mg/kg), respectively. We suggested that the elements were highly affected by the genotype and environment. Content of Ca, Na and K have been reported that were mainly affected by genotype and Fe, Zn and Cu were mainly affected by environment (Huang, et al., 2016). The different genetic resources might be affected to differences of mineral content among genotype (Jiang, et al., 2007). Suggesting, the high mineral content has opportunities to select from genotypic variation (Gregorio, 2002; Huang, et al., 2016). The different minerals content in plants may also depend on variation in many factors such as climate (Du, et al., 2013) processes of mineral transport pathway (Clemens, 2001; Ghandilyan, et al., 2009).

Table 2 The minerals content of rice landraces

Code	Local name	Ca (mg/kg)	P (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
NRRU 03	Hom nual	68.36±0.652	155.14±2.019	43.41 ±0.098	5.33 ±0.016	12.73 ±0.051
NRRU 17	Loi Sa iBua	74.44±0.205	212.00±0.337	30.73±0.395	3.03±0.053	14.86±0.048
NRRU 30	Neow Dam	82.12±0.127	173.02±0.528	74.48±0.487	12.58±0.038	21.49±0.100
NRRU 37	Hommali Dang	70.41±0.340	196.39±1.783	59.35±0.203	5.82±0.020	15.67±0.086
NRRU 57	Leuang Tahang	68.30±0.295	169.35±0.657	87.32±0.368	20.23±0.111	17.09±0.116
NRRU 75	Kam	68.68±0.764	188.33±0.755	60.85±0.463	3.26±0.013	19.97±0.095
NRRU 78	Marum	44.31±0.336	201.22±1.589	55.15±0.136	18.16±0.083	18.82±0.180
NRRU 80	Yad Bao	99.64±0.508	144.78±0.445	104.58±0.966	7.46±0.048	19.13±0.016
NRRU 83	Leuang Thong	66.67±0.610	164.95±0.868a	50.69±0.079	5.39±0.027	15.25±0.070
NRRU 90	Kong Sai	61.15±0.397	194.44±1.436	40.25±0.152	13.14±0.155	14.26±0.097

Data were showed as mean value ± standard deviation.

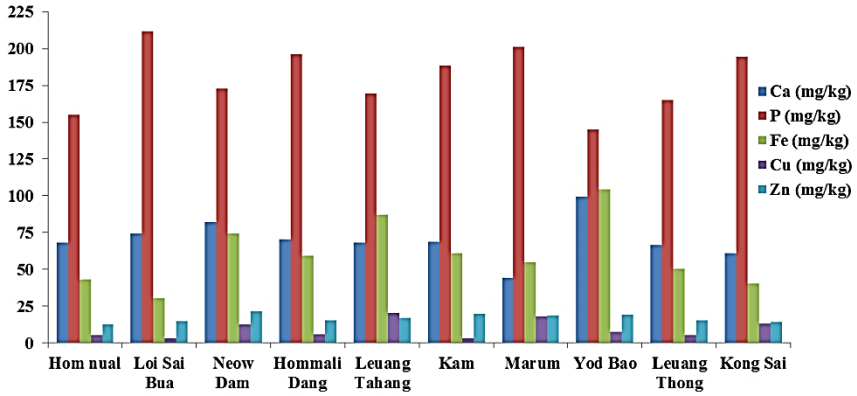

Figure 1 Minerals content (mg/kg) in rice landraces

CONCLUSION

Morphological characteristics of local rice revealed wide genetic diversity including length, width, length-width ratio, seed coat color and hull color. For minerals content, the P, Ca, Fe, Zn and Cu were found ranging from 144.78-212.00 mg/kg, 44.31-99.4 mg/kg, 30.73-104.58 mg/kg, 12.73-21.49 mg/kg and 3.03-20.23, respectively. Grain morphological characters and mineral elements content indicated that rice landraces are good resource for utilization and conservation. This research provides new information of local rice which could be useful for rice quality improvement, rice breeding and geographical indication (GI).

ACKNOWLEDGEMENTS

This research was supported by Office of the Higher Education Commission, HERP-NRU, Research and Development Instiute of Nakhon Ratchasima Rajabhat Universit grant. We would also like to thank Nakhon Ratchasima Rajabhat University including Biology program, Chemistry program and Research institute for their supports.

REFERENCES

Bhattacharjee, P., Singhal, R. S., and Kulkarni, P. R., Basmati rice: A review, *Int J Food Sci Technol*,vol. 37, pp.1-12, 2002.

Chotimarkorn, C., Benjakul, S., and Silalai, N., Antioxidant components and properties of five long-grained rice bran extracts from commercial available cultivars in Thailand, *Food Chem*, vol. 111, pp. 636-641, 2008.

Clements, S., Molecular mechanisms of plant metal tolerance and homeostasis, *Planta*, vol. 212, pp. 475-486, 2001.

Du, J., Zeng, D., Wang, B., Qian, Q., Zheng, S., and Ling, H. Q., Environmental effects on mineral accumulation in rice grains and identification of ecological specific QTLs, *Environ Geochem Hlth*, vol. 35, pp. 161-170, 2013.

Garcia-Oliveira, A. L., Tan, L., Fu, Y., and Sun, C., Genetic identification of quantitative trait loci for contents of mineral nutrients in rice grain, *J Integr Plant Biol*, vol. 51, pp. 84-92, 2009.

Ghandilyan, A., Ilk, N., Hanhart, C., Mbengue, M., Barboza, L., Schat, H., et al., A strong effect of growth medium and organ type on the identification of QTLs for phytate and mineral concentrations in three *Arabidopsis thaliana* RIL populations.*J Exp Bot*, vol. 60, pp. 1409-1425, 2009.

Gregorio, G. B., Progress in breeding for trace minerals in staple crops, *Nutrition*, vol. 132, pp. 500S-502S, 2002.

Jiang, S. L, Wu, J. G., Feng, Y., Yang, X. E., and Shi, C. H., Correlation analysis of mineral element contents and quality traits in milled rice (*Oryza sativa* L.), *J Agric Food Chem*, vol. 55, pp. 9608-9613, 2007.

Phetpornpaisan, P., Tippayawat, P., Jay, M., and Sutthanut, K., A local Thai cultivar glutinous black rice bran: A source of functional compounds in immunomodulation, cell viability and collagen synthesis and matrix metalloproteinase-2 and -9 inhibition, *J Funct Foods*, vol. 7, pp. 650-661, 2014.

Renuka, N., Mathure, S. V., Zanan, R. L., Thengane, R. J., and Nadaf, A. B., Determination of some minerals and β-carotene contents in aromatic indica rice (*Oryza sativa* L.) germplasm, *Food Chem*, vol. 191, 2-6. , 2016.

Satoh, H., Ching, H. M., Ilai, D., and Katayama, T. C., On distribution and grain morphology of cultivated rice collected in Tanzania, 1988. Research center for the South Pacific, Kagoshima University, *Occas pap*, no. 18, pp. 114-126, 1990b.

Satoh, H., Ching, H. M., Ilai, D., and Katayama, T. C., On distribution and grain morphology of cultivated rice collected in Madagascar, 1988. Research center for the South Pacific, Kagoshima University, *Occas pap*, no. 18, pp. 63-72, 1990a.

Sompong, S., Siebenhandl-Ehn, S., Linsberger–Martina, E., and Berghofera, E., Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka, *Food Chem*, vol. 124, pp. 132-140, 2011.

Webb, B.D., Bollich, C. N., Carnahan, H. L., Kuenzl, K. A., and MscKenzie, K. S., Utilization and characteristics and qualities of United States rice, In Rice grain quality and marketing, IRRI., pp. 25-35, 1985.

Welch, R. M., and Graham, R. D., Breeding for micronutrients in staple food crops from a human nutrition perspective. *J Exp Bot*, vol. 55, pp. 353-364, 2004.

Zhang, M., Pinson, S. R. M., Tarpley, L., Huang, X. Y., Lahner, B., Yakubova, E., et al., Mapping and validation of quantitative trait loci associated with concentration of 16 elements in unmilled rice grain, *Genetics*, vol. 127, 137-165, 2014.

TheeraThummawongsa received the B.S., Applied Biology (2008), M.S. (2011) degree in Biology from Khon Kaen University. He is a lecturer, Department of biology, Nakhon Ratchasima Rajabhat University. His current interests are plant morphology and local rice.

Saijai Posoongnoen received the B.S., Chemistry (2008), M.S., Biochemistry (2011), and Ph. D. (2015) degree in Biochemistry from Khon Kaen University. She is a lecturer, Department of chemistry, Nakhon Ratchasima Rajabhat University. Her current interests are local rice, enzyme, gene cloning and expression.

Kanya Manok is a student in department of biology, Nakhon Ratchasima Rajabhat University. Her current interests are local rice.

Kanyarat Chaekkrathok is a student in department of biology, Nakhon Ratchasima Rajabhat University. His current interests are local rice.