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Diversity, utilization and cultural significance of purple rice in northeastern Thailand

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Abstract Fifteen cultivars of purple rice, including eleven of glutinous rice and four of non-glutinous rice, were studied for diversity, culture, and utilization in Northeastern Thailand. The morphological study found a difference in terms of color of leaf blade, leaf sheath, ligule, leaf collar, auricle, and husk and grain width and length. 28 morphological characteristics were used for the purple rice classification using UPGMA method and Principal Coordinate Analysis by NTSYS program. The results of the analysis showed the genetic similarity at 0.54-0.87 which could be divided into 3 groups. The purple rice is a source of household income of the farmers. A certain amount of the rice is spared and exchanged for ritual purposes. The purple rice is believed to be sacred among the Northeastern farmers. They hold high regard of it as a queen of rice due to it can be grown only during the annual planting season. The farmers believe that the purple rice protects other rice varieties from diseases and insect pests; acts as an insect repellant, and induces the white rice growth. In terms of utilization, the purple rice can be consumed either as a staple diet or as a healthy drink. Moreover, the purple rice can be used as a kind of herbs for its medicinal property. The result demonstrated that diversity of the purple rice has both cultural and ecological significances. In addition, it can be shown as sa geographic indicator. Thus, it is recommended that further studies concerning promotion and conservation of local wisdom relating to the purple rice diversity, utilization and significance should be encouraged by both government and private sectors.

Keywords: morphological characteristics, glutinous rice, non-glutinous rice, local wisdom

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Introduction

Purple Rice or black rice is a range of rice types of the *Oryza sativa* L. Purple rice is one among of more than 40,000 varieties of rice (Barrell, 2017) and some of which are glutinous rice. Purple rice is grown mainly in Asia including India, China, Sri Lanka, Indonesia, Philippines, Laos, and Thailand (Yawen *et al.*, 2003). Thai people name it "Khao Kam" or "Khao Dam" since "Khao" means rice and "Kam" and "Dam" mean purple and black respectively. They are called by these names because of their nature of the grain or husk with purple or black color. Purple rice is widely grown in the northern and northeastern region of Thailand, in which glutinous rice or sticky rice is a staple food for local people. Most of Thai purple rice can be grown during the season only thanks to its photoperiod sensitivity. Moreover, Thai people believe purple rice to be the queen of rice, which in line with the ancient Chinese belief that revered purple, or black rice. Only the emperors had a privilege in consuming it. Therefore, the rice was named "forbidden rice" among ancient Chinese (Barrell, 2017). Several studies show that the purple rice is utilized as food, material for a healthy drink, desserts, functional food, natural colorants, traditional medicine, rituals plant, agriculture and animal feed (Abdel-Aal *et al*., 2006, Chunta, *et al*., 2014, Pratiwi and Purwestri, 2017).

Purple rice comprises a variety of bioactive compounds, particularly anthocyanin that is a major antioxidant compound with biological activities including free radicals, cancer protection, hyperglycemia, hyperlipidemia etc. (Abdel-Aal *et al.*, 2006, Pedro *et al.*, 2016). In addition, Chen *et al.* (2016) founded the purple rice anthocyanin extractant can reduce myocardial tissue damage and loss of heart function in rats. For livestock, Jaturasitha *et al.* (2016) founded the good effects of feeding purple rice on bioactivity for the quality of pork and pork product. Purple rice presented higher total phenolics, flavonoids, and antioxidation than white rice (Pedro *et al.*, 2016).

Purple rice is diverse and each locality has different names. Particularly, when classified according to the color on the husk, grain, stem, and leaf. Several studies showed the purple rice has a wide range of total anthocyanins and varied in nutritional concentration (Rerkasem, *et al.*, 2015, Xiongsiyee, *et al.*, 2018). Although some data of purple rice previously had been reported, there has been no scientific data published in purple rice harvested on northeastern Thailand. Therefore, the objective of this study was to investigate the diversity of native purple rice in the northeastern region of Thailand. Morphological characteristics were studied to identify and analyzed using the NYSYS pc software. Results were discussed related to local wisdom, conservation, utilization, and cultural significance.

Materials and methods

Sample collection

Purple rice seed samples were collected from different area in northeastern Thailand. For the purpose of this study, each collected seed sample was measured morphological cahracteristics and analysis. Fifteen cultivars of purple rice were planted in Walai Rukhavej Botanical Research Institute, Mahasarakrm University. A total of 28 morphological characteristics were measured for each rice cultivar including type, plant height, culm number, culm angle, leaf blade pubescence, basal leaf sheath color, ligule color, ligule shape, ligule length, auricle color, collar color, culm internode color, flag leaf angle, panicle length, awn color, awn presence, apiculus color, lemma and palea color, paddy length, paddy width, paddy ratio, brown rice length, brown rice width, brown rice shape (length/width ratio), seed coat color, 100-grain weight, 100-grain weight paddy and ecological rice. An assessment was carried out adapted from the standard evaluation system for rice (IRRI, 1996).

Statistical analysis

To generate a binary matrix for morphological data, the presence or absence of a character class for the 61 morphometric with 28 morphological characteristics of each of the 15 cultivars purple rice used in the analyses was marked as 1 or 0, respectively. The initial data were converted to rectangular matrix and standardized using STAND module. The distance matrix were use to in dendrogram following unweight pair group method with arithmetic average (UPGMA). Mantel's test (1967) was calculated to examine how glowing the cluster analysis fits the distance matrix using COPH and MxComp modules. The standardized matrix was also converted to a product-moment correlation matrix and then a Principal Coordinate Analysis (PCoA) was performed using DCenter, Eigen algorithms and Graphics (Mod3D) as described. All the analyses were performed using NTsys-pc version 2.1 (Rohlf, 2002).

Utilization and cultural data collection

The case study allowed to combine different data collection strategies: observation and interview. Informal interviews, in-depth interviews, and focus group discussions were utilized. The qualitative approach was implemented in order to acquire an in-depth understanding of the farmer communities, socio-

economic characteristics, traditional knowledge, utilization, conservation and culture significance of purple rice under the circumstance of changing of society, culture and economic context of the community.

Results

Analysis of morphological characteristic

Thirty-seven samples of purple rice were collected from eight provinces of northeastern Thailand, however, they are known by 15 different names. Fifteen varieties of purple rice were investigated (Table 1.). The morphological analysis using NTSYS pc program version 2.1 and grouped by UPGMA method. The results found in dendrogram shown a high goodness of fit in Mantel's test ($r = 0.854$; approximate Mantel t-test: $t = 4.895$; probability random $z <$ observed Z: $P = 1.000$). The similarity coefficient was related one way with ranged from 0.54 - 0.87. The purple rice varieties morphologically divided into 2 group as follows: Group 1 including R02 and R70. Group 2 comprised of R03 R81, R23, R43, R22, R30, R84, R66, R82, R05, R35, R25, and R21 respectively (Figure 1).

Table 1. List of code, Thai purple rice name, province and their location used in the morphology analysis

Code/ Thai purple rice name	Location	
	Province	Latitude/Longitude
R02 Kam Bueak Khao	Sakon Nakorn	17.078113N, 103.785531E
R03 Kam Bueak Dam	Sakon Nakorn	17.078113N, 103.785531E
R05 Maled Fai	Maha Sarakham	16.155893N, 103.027626E
R21 Mali Dam	Maha Sarakham	16.155893N, 103.027626E
R22 Kam Bai Khiao	Kalasin	15.829639N, 103548975E
R23 Kam Ka Dam	Khon Kaen	16.756799N, 104.058549E
R25 Kam Rai	Maha Sarakham	16.155893N, 103.027626E
R30 Kam Dok	Maha Sarakham	16.155893N, 103.027626E
R35 Hom Nin	Roi Et	16.012729N, 104.011790E
R43 Kam Tin Muang	Roi Et	16.012729N, 104.011790E
R66 Kam Bueak Dam	Sakon Nakorn	17.078113N, 103.785531E
R70 Mali Nin	Surin	14.640787N, 103.414198E
R81 Niao Dam	Surin	14.640787N, 103.414198E
R82 Kam Bi	Maha Sarakham	15.899411N,103.043006E
R84 Kam Dong	Maha Sarakham	15.899411N,103.043006E

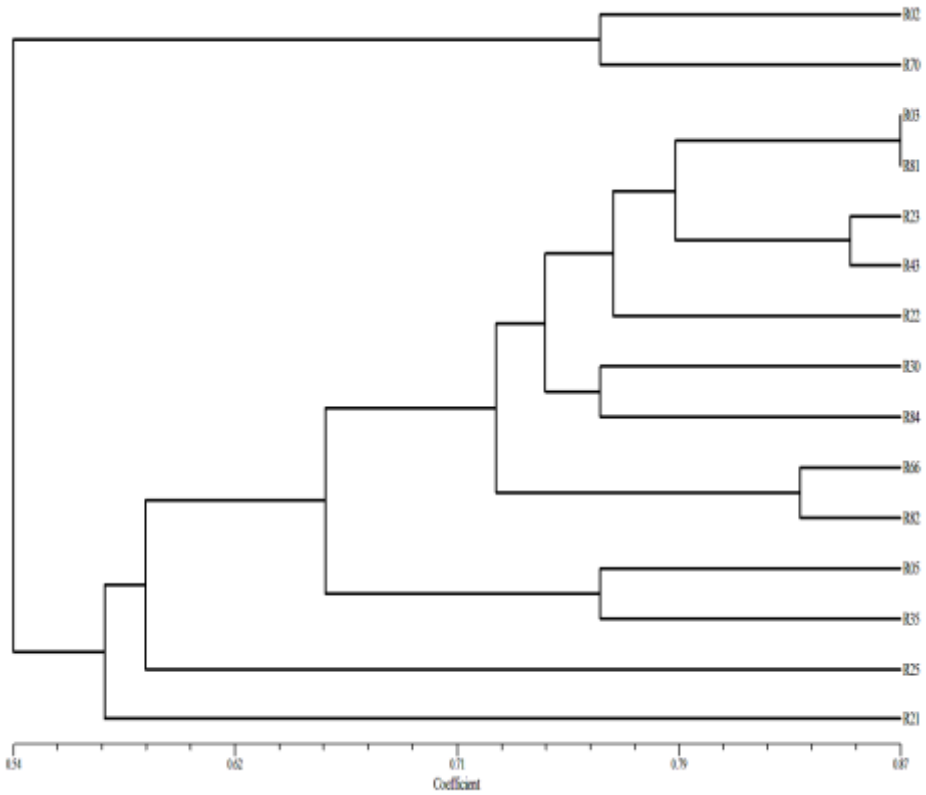

Figure 1. Dendrogram of 15 purple rice derived by UPGMA from the distant matrix of 28 morphological characteristics

Principal Coordinate Analysis (PCoA) was carried out to determine the characteristic variation and component among the 15 cultivars purple rice. The results showed that the first eigenvector (PC1) of Mod3D PCoA based on morphological data accounted for 21.84 % of the total variation observed in the whole data set. The second eigenvector (PC2) accounted for 14.37 % and the third eigenvector was 12.01 % of the morphological variation. The 15 cultivars purple rice were classified into three groups as follows: Group 1 had the highest membership group of 13 cultivar purple rice namely R03, R05, R21, R23, R23, R25, R30, R35, R43, R66, R81, R82, and R84 respectively. Group 2 was R02 and Group 3 was R70 as shown in Figure 2.

The utilization of purple rice in communities Northeastern or Isan region is as Table 3.

Table 3. Utilzation of purple rice in Northeastern, Thailand

Categories	Local wisdom/utilization
Food and drink	-consume as a staple food (Figure 3.2)
	-mixed with white rice for steaming
	-use as an ingredient for isan or northeastern localfood
	-make desserts such as Sung kaya, Khao lam dum, Kanom Salee (Figure 3.3) and Kanom Nangled
	-make healthy drinks such as Satoe or wine rice
Folk medicine	- promote health for postpartum and the elderly an old man
	-cure illnesses
Tradition and culture	-plant to protect white rice from diseases and insects pests
	-use as a ritual artifact such as funeral and propitiate the spirits
	- prohibited for postpartum and animal after giving birth
Miscellanous	-economic purpose
	-exchange in farming network

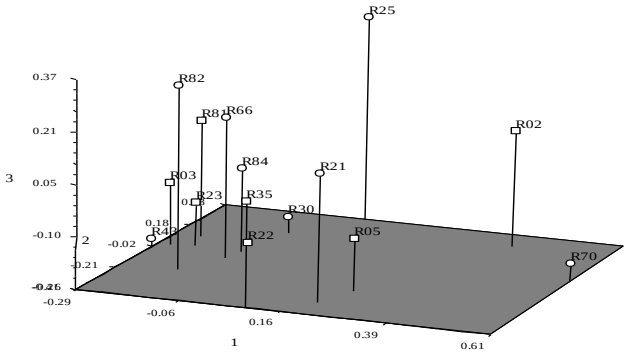

Figure 2. Principal coordinate analysis of 15 purple rice based on morphological data

Figure 3. 3.1 purple rice planted in a long row between white rice, 3.2 Steamed purple rice, 3.3 Dessert of the Phu Tai tribe in the tradition called "Khanum Salee"

Discussion

The surveyed of native rice germplasm in northeastern Thailand has shown particularly high diversity among purple rice. Thirty-seven purple rice samples were collected but under only fifteen different names. Hence, fifteen varieties of purple rice were investigated. Those purple rice varieties were encoded, namely R02 (Kam Bueak Khao),R03(Kam Bueak Dam), R05 (Maled Fai), R21 (Mali Dam), R22 (Kam Bai Khiao), R23 (Kam Ka Dam), R25 (Kam Rai), R30 (Kam Dok), R35 (Hom Nin), R43 (Kam Tin Muang), R66 (Kam Bueak Dam), R70 (Mali Nin), R81 (Niao Dam), R82 (Kam Bi) and R84 (Kam Dong) were originated and found that R03 and R66 share related named in Kam Bueak Dam., and they originated from a different province. However, the differences in morphological characteristics R03 and R66 were not related such as 100-grain weight paddy, lemma and palea color, and seed coat color were clearly differentiated. It was also found that R03 had a darker shade and a higher seed weight than R66.

Numerical taxonomy using thorough morphological character was used in classify several plants as well as rice varieties. In this study, both the UPGMA dendrogram and PCoAsupport group was divided into 2 groups and 3 group respectively. UPGMA dendrogram showed that the big group was 13 cultivars of purple rice. The remaining groups were R02 and R70. Meanwhile, the PCoA was divided into 3 group with the highest member of 12 cultivars purple rice, and 2 group with 1 member R02 and R70. Therefore, these two methods give a consistent result in the classification of purple rice varieties. The big groups are clearly that cultivar of purple rice or black rice characterized by purple color of basal leaf sheath, ligule, auricle, culm internode, and apiculus. In addition, most of the lemma and palea color had clear purple furrows on straw. In contrast, R02 and R70 showed characteristics of white rice. For example, straw lemma

and palea color, green basal leaf sheath, green basal blade, white ligule and auricle, green culm internode, straw awn, and apiculus color. There was also a difference between R02 and R70 which classified by rice type. R02 as glutinous rice and R70 as non-glutinous rice. The morphological characterization of each character can be used as a morphological mark in a selection of rice varieties after mating. Grouping can be used as a basis for selecting breeders and planning for breeding, reduce repetition of rice varieties, and managing rice genetic continuity. Whereas, Bajracharya *et al*. (2006) showed the result of the low morphological variability of rice landrace diversity in Nepal. They found that 10 different rice names were not associated with diversity using SSR loci tested, indicate that the genomic loci conversing the qualitative differences contributing to variation are in a limited part of the genome. Only two morphological characteristics of panicle and grain were an unreliable indicator of genetic identity.

Utilization, conservation, and culture: The role of indigenous knowledge

Purple rice is believed to be sacred among northeastern farmers. They hold high regard of it as the queen of rice due to the fact that it can be grown during the annual planting season only. The farmers believe that purple rice protects rice varieties from diseases and insects pests; acts as an insect repellant, and induces white rice growth. In some communities, the farmer would plant purple rice in the middle of the field, half of a plot, or in a long row (Figure 3.1) and on the edge of the rice field.

"Khao Kam" is a name that the farmers in northeastern Thailand are called the purple or black rice. That rice are mostly glutinous rice, such as Kam Bueak Khao, Kam Bueak Dam, Kam Bai Khiao, Kam Ka Dam, Kam Rai, Kam Dok and Kam Tin Muang. While non-glutinous rice is rarely called up as Kam, but called as Maled Fai, Mali Dam, Mali Nin and Hom Nin.

The conservation of rice varieties in the northeastern community is divided into 3 levels, consisting of the first conservation of rice varieties on an individual and family level. The conservation of family level is the most vital due to the fact that purple rice is being popular among certain groups of people not for all isan people in general. Those who prefer consuming purple rice will use it in making some dessert dished for the traditional ceremony. This study also found that the existence of the cultivar of the old generation is preserved on the belief that purple rice is a rice that will help take care of all the rice planted in the field. It is believed to have disease-preventing quality. In terms of nutrients. It is found in different number competing to white rice. Each household keeps the rice annually cultivated as an heirloom. However, the

storage of cultivated rice volume is not much, approximately20-30 kg per household per year.

The second level was conservation at the community level. A conservation is raised by the nature of the farmer communities that is farming for sustenance rather than farming for commerce. The number of households that preserve rice varieties and willing to exchange it among neighboring families and neighbors. Thirdly, the conservation in the form of an alternative farming network with the exchanged of rice varieties at different levels. Native rice varieties including white rice and purple rice are preserved and exchanged among members of such networks.

In term of utilization of the purple rice in the Northeastern Thailand or Isan communities are revealed as firstly, food and healthy drink. Most people in the northeastern region rely on sticky rice or glutinous rice as their staple food. However, only white rice is consumed in daily life. In some communities, purple rice is mixed with white rice for steaming especially in traditional communities, such as Kaleng tribe in Kudbak district, Sakon nakon province. Even in the northeastern region, daily consumption of rice is varied by areas: such as Sakon Nakhon, Kalasin, Roi Et, Maha Sarakham, Khon Kaen and Ubon Ratchathani, sticky rice is the staple food but in the area; such as Nakhon Ratchasima and Surin province, the resident consumes non-glutinous rice as the main food.

Purple rice can also be used in making various kinds of dessert. This is similar to Indian tradition in which it is used to make desserts, and is considered a feature of community feasts (Barrell, 2017). Desserts made with purple rice are with a long history as in the concept of the cycle of the year or known as lunar festival and fourteen laws. Isan folk food is unique in preparing method, flavor, and manner of consumption. For example, the use of roasted rice as an ingredient in adding a savory flavor to the curry, so that it tastes better. Rice is also used as food preserves. Northeastern people will add rice into a container of their fermented food such fish, pork, and beef. To consume rice in form of healthy drink such as wine rice and Satoe is also well accepted. Satoe or glutinous rice wine is considered as one of local wisdom. It is prepared with steamed rice and then fermented with yeast, then put in the fermenting jars, leaving it for weeks, and then the drink is ready for special occasion or ceremony.

Secondly, the process of rice production from the beginning to harvesting and utilization are all related to tradition. The rice itself is used as a symbol or ritual artifact, featuring in most of the Isan rituals. Rice is a part of the sacred offering in the traditional rituals practice in each stage of one's life. For instance, in the goddess of rice offering ritual, farmers will put rice crackers on

banana leaves along with other food to signify prosperity and abundance. Besides, rice crackers are also used in a funeral procession. A headman will throw the rice while leading the funeral procession. It symbolized purifying the path for the dead to the cemetery.

Thirdly, the use of rice is "Herbs and healing". Farmers sometimes take rice as a remedy. For example, they use rice to promote good health for women after childbirth or postpartum. These women are considered a patient who lost blood and water from giving birth with is resulted in being weak and imbalance body elements. Nevertheless, people in the past are also prohibited women after birth from consuming purple rice. They believed it might cause lethargic and leading to death. Even cattle such as newborn cows or buffaloes were not allowed to eat purple rice for the same reason. Purple rice is forbidden for sick people because it is believed to be “wrong” and it might cause further illness. Purple rice is used for the health benefits as in form of rice cup. By putting rice in a cup of water and steam cook it, and then bring it to the sick to eat; the illness will be cured faster. Fourth, the use of "exchange" for this aspect, purple rice varieties are mainly exchanged among farmer to cultivate in their own field, exclusively, the alternative farming network in the northeastern. The purple rice becomes rare and difficult to cultivate. Finally, to use to "increase the economic income of the household". From the increasing trend of healthy consumption, purple rice gains more attention from consumers. The demand for the product is increased and the price of rice is improved. Many communities began adding more space to grow purple rice. In addition, the healthy rice trend causes some agricultural groups to produce colorful rice to increase the rice value-added. The variety of healthy rice, such as Mali Dang, Mali Dam, and Mali Duang Derm, So malee and Hom Nin have become popular among the consumers in the Central region and capital city. Consequently, the varieties of native rice have been grown for commercial purposes. While as, Bajracharya *et al.* (2006) discussed the ecological rice growing has been characterized by local farmers in Nepal, according to the water source. Differently named landraces appear to be adapted to a specific ecosystem, but farmers also select which landraces to grow for socio-economic reasons.

This result indicated that traditional knowledge of purple rice in northeastern Thailand could play an important role in the formation and implementation of conservation strategies. Such knowledge reflects a lifetime’s experience of the relationship between human culture and its environment. In preserving purple rice genetic resource, the benefits derived from their sustainable management could also be conducted among farmers living inclusively in the communities, expanding to the neighborhood, or coving all farming network. In addition, purple rice has a wide range of total anthocyanins

depending upon cultivar and their environmental effect. It is suggested that the next research should include all of anthocyanin and nutrient for development of purple rice food processing. Thus, it is recommended that further studies concerning the promotion as well as conservation of local wisdom relating to purple rice diversity, utilization and significance should be encouraged by both government and private sectors.

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