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MORPHOLOGY AND ANATOMY OF INDIGENOUS RICE LANDRACES IN KHON KAEN, THAILAND

SUMMARY

This study comprised collecting and determining the morphology and anatomy of leaf blade and leaf sheath of indigenous rice landraces in Khon Kaen, Thailand. A total of twenty-seven indigenous rice landraces were discovered, while, only 12- plant and grain samples were collected: Khao Plong Aew, Khao Jao Leuang, Khao San Pla Tong, Khao Gam Poon, Khao E-Leuang Noi, Khao Niaw dang, Khao Lao Taek, Khao E-Tom Kao, Khao Kam Pai, Khao Kao Gon, Khao Nang Nuan and Khao Mun Ped. Gross morphology was investigated and descriptions made. The anatomical characteristics of leaf blade and leaf sheath were studied using peeling and paraffin methods. The results demonstrated that the morphological and anatomical characters of 12 indigenous rice landraces are similar with a slight difference in some characters. Morphology differed in the color of collar, auricle and ligule as well as the shape and color of brown rice. The main distinguishing morphological characteristics for identifying indigenous rice landraces are grain features. For the anatomy of leaf blade and leaf sheath, the results revealed that there were only differences in the presence of prickles and the shape of anticlinal wall of epidermal cell on the lower surface of leaf sheath. Even though, the anatomical characters of leaf blade and leaf sheath were not appropriated to identify the indigenous rice landraces in Khon Kaen. However, Khao Jao Leuang was distinguished from other indigenous rice landraces by the absence of prickles on both leaf blade surfaces. Moreover, Khao Jao Leuang is the only landrace in which the shape of the anticlinal wall of the epidermal cell on lower surface of leaf sheath, is undulate, others are sinuate.

Keywords: indigenous rice, anatomy, morphology, leaf, grain

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INTRODUCTION

At the present, Thailand is developing in industry and the adoption of modern technology. However, rice cultivation remains Thailand 's principal industry and priority crop; maximizing yields relies on farmers' knowledge and understanding of ecology and environment, on societal and cultural factors, and the ability to adapt agricultural technology to increase rice production (Polthanee, 2010). Nowadays, modern technology has enabled changes in rice cultivation, while economic and environmental factors often necessary novel approaches. New rice cultivars are able to grow more abundantly, offering high tillering and yield, and good grain quality. Thus, rice breeding programs require the collection and survey of rice germplasm as a genetic resource. In the past, human collected grains and carried them as a food during migration. This resulted in the transfer of rice grains from one locality to another. The presence of particular rice landraces in different regions leads to the rice diversity in each locality. As a result, the name of rice landraces posses distinctive traits or a point of origin, becoming indigenous rice.

Thailand is an important source of rice germplasm; indigenous rices are genetic diverse. These Thai indigenous rice germplasms are useful for future rice breeding programs. Department of Agriculture collected over 2000 samples of rice germplasm from various provinces across Thailand for conservation, consisting of indigenous rice, good rice cultivars, foreign rice and wild type rice. Since 1937, the indigenous rice germplasms were collected in Thailand and between 1946-1950, there was the first phase for rice collection and selection from Thai farmers in term of rice government. In 1982, Rice Research Institute established a gene bank in Thailand as a center for Thai rice germplasm collection, which was supported by the Japanese government. Unfortunately, many indigenous rice landraces have been degraded, and Thai farmers also prefer to cultivate high yield rice cultivar. This has led to the rapid disappearance of Thai indigenous rice. Consequently, nowadays, rice germplasm collection aims to conserve rice grains as a rice genetic resource with potential utilization in various fields including rice selection and breeding for industrial processing. This allows the development of Thai indigenous rice landrace to increase their diversity and unique characteristics in terms of value, taste and health benefits.

Between 1995-1999, the Rice Department found and collected 5,928-Thai indigenous rice landraces (Wuttiyano, 2000) and in the Northeast area, 1,564-Thai indigenous rice landraces were found (Jaidee and Thongpitak, 1988). At the present, there were a number of Thai indigenous rice landraces because of the development of a rice breeding program and a growing rice trade leading to export of Thai indigenous rice landraces (Alternative agriculture network in the Northeast, 2003). In 2000, the collection of Thai indigenous rice across 76 provinces of Thailand, there was 101-Thai indigenous rice landraces in Khon Kaen province (Plant varieties protection office, 2000). Additionally, 15-Thai indigenous rice landraces in Khon Kaen were collected by the Center for Promoting Rice Production (Kaewkaenkoon *et al.*, 2017). In other provinces of

Thailand, the indigenous rice landraces were Hom Udom, San Patong, Nang Nguan, and Keetom in Keang subdistrict, Mahasarakham province. However, in earlier study, 20-indigenous rice landraces had been discovered from Mahasarakham (Kijtewachakul et al., 2008). The field survey in Thale Noi Basin, Phatthalung province by Panomjan and Amornviriyachai (2011) exhibited 7-indigenous rice landraces, namely; Dawk Pa-Yawm (uplandrice), Sang Yod, Leb Nok, Khem Tong, Niaw Dam (glutinous rice), Chiang Phatthalung and Hawm Jan. And 17-indigenous rice landraces were found in Emad Esai, Banrai district, Uthaithani province (Khunhan, 2018).

In addition, morphological characters are used as a basic information for classifying rice varieties and rice landraces. Anatomical details can also be utilized to supply additional information for rice classification. However, this is dependent on plant species (Taia, 2005). Further, the morphological and anatomical characteristics can be used to classify plants at different levels, for example, some characteristics may be classified at species level, whilst some may be classified at infraspecific level. The database of Thai indigenous rice, was informed by the study of rice diversity in different areas of Thailand (Promsomboon and Promsomboon, 2016) and reports comparing the different Thai indigenous rice landraces from some areas of Thailand by using morphology and anatomy. Such Thummavongsa et al. (2012) showed the different morphology and anatomy of different rice grain cultivated in Northeast Thailand. Boonrueng and Jampeetong (2016) studied the morphology of grain and the anatomy of leaf blade and leaf sheath in rice landrace *Bue Po Lo*, an upland indigenous rice landrace. In addition, indigenous rice landraces in Southern Thailand, such as Sang Yod, Chaw Jam Pah, Niaw Look Pueng, Niaw Dawk Yong, and Khao Nang exhibited various seed coat color including straw and brown which could classify them as different indigenous rice landraces (Panomjan and Tongkiaw, 2011). Besides seed coat color, the shape and color of brown rice were also classified for the different indigenous rice landraces (Panomjan and Amornviriyachai, 2011; Panomjan and Tongkiaw, 2011). In analyzing the function of anatomy characteristics of leaf blade and leaf sheath were useful for identifying indigenous rice landraces. These characters might relevant to plant adaptation, such as the leaf blade occurring papillae in upper and/or lower epidermis was a plant against pathogen invasion by modification of cell wall to form a physical barrier (Underwood, 2012). Moreover, unicellular hair appearing on leaf sheath was found to be a simple structure which usually does not have glands. It plays a role in resisting extreme environmental conditions such as drought, high salt, UV, pathogen and insects (Han et al., 2022). Thus, these anatomical characteristics of leaf blade and leaf sheath were useful for identifying indigenous rice landraces.

As mentioned above, the database of indigenous rice collection is informed by old data and the survey area only covers some parts of Khon Kaen province. Also, the morphological and anatomical database of Khon Kaen indigenous rice landrace is limited. This resulted in lack an updated database and germplasms bank for Khon Kaen indigenous rice landraces, which would better enable classifying,

conservation and breeding programs. Thus, this study aimed to contribute a collection and a database of Khon Kaen indigenous rice diversity for conservation by collecting and determining the morphological and anatomical characteristics of indigenous rice in Khon Kaen province. In addition, the obtained data was used for classifying and also selecting high potential Khon Kaen indigenous rice landraces for a rice breeding program.

MATERIAL AND METHODS

Survey and sample collection

Indigenous rice samples were surveyed and collected in Khon Kaen province. Rice samples were obtained from the farmer and took them for studying morphological and anatomical characteristics; a reference specimen (voucher specimen) was kept in Khon Kaen University Herbarium. For the anatomical characteristics study, rice samples were preserved with 70% ethanol.

Morphological study of Indigenous rice landraces

The morphological characteristics of Indigenous rice samples were described, such as leaf size, leaf blade color, leaf sheath color, grain size and grain color. The description of general morphology was compared among diverse different indigenous rice landraces.

Anatomical study of Indigenous rice landraces

The comparative leaf and leaf sheath anatomy of Indigenous rice samples were studied. Leaf and leaf sheath samples were preserved with 70% ethanol at least 24 h and then epidermal features were studied using the leaf epidermal peeling technique, and the transverse section was studied using the paraffin method. Leaf and leaf sheath epidermal peeling was stained with 1% safranin in 70% ethanol, washed with tap water and then, permanent slides were made by the dehydration with ethanol, soaked in 70%, 95%, 100%, 100% ethanol:xylene (ratio 1:1) and xylene for 5 min, respectively. After that, the slides were mounted with DPEx. A transverse section of the leaf was prepared by paraffin methods according to Johansen (1940). All anatomical characters of leaf epidermis and leaf cross section of 12 indigenous rice landraces were recorded under a light compound microscope.

RESULTS AND DISCUSSION

Indigenous rice diversity in Khon Kaen province

Base on the survey and collection of indigenous rice in 16 districts of Khon Kaen province, Thailand, 27-landraces were found as show in Table 1 and Figure 1. Only plant and grain samples of 12-landraces were collected as show in Table 1 and Figure 1, namely, Khao Plong Aew, Khao Jao Leuang, Khao San Pla Tong, Khao Gam Poon, Khao E-Leuang Noi, Khao Niaw dang, Khao Lao Taek, Khao E-Tom Kao, Khao Kam Pai, Khao Kao Gon, Khao Nang Nuan and Khao Mun Ped. The results indicated a slight decline in the diversity of indigenous rice varieties from Year 2017, when 15 landraces were reported by Center for Promoting Rice Production, Khon Kaen (Kaewkaenkoon *et al.*, 2017). Furthermore, the diversity sharply decreased compared to Year 2000, when 101 landraces were reported by the Plant varieties protection office (2000). The reduction in the numbers of Khon Kaen indigenous rice landraces may be caused by the undesirable texture (such as

hard grain) of some cultivars or some landraces, leading to rejection by consumers. Nowadays, Khon Kaen farmers tend to cultivate commercial varieties such as KDML105 and RD6, which are famous by customers and hold strong market demand, command high cost, and also offer good quality, with a good texture and taste. Thus, slight reduction in Khon Kaen indigenous rice landraces found by this study suggested a need to conserve Khon Kaen indigenous rice landraces in order to maintain a store of rice germplasms and evolution knowledges for the future.

Table 1. Indigenous rice landraces in 16 districts of Khon Kaen province

No.	Indigenous rice landraces	Location
1	Khao Plong Aew*	Ban Phai district; Ubolratana district
2	Khao Jao Leuang*	Phon district
3	Khao San Pla Tong*	Waeng Yai district; Ubolratana district
4	Khao Gam Poon*	Non Sila district; Phra Yuen district; Nong Na Kham district
5	Khao E-Leuang Noi*	Non Sila district
6	Khao Niaw dang*	Non Sila district; Ban Haet district
7	Khao Lao Taek*	Manchakhiri district
8	Khao E-Tom Kao*	Non Sila district
9	Khao Kam Pai*	Waeng Yai district; Chum Phae district; Phu Pha Man district
10	Khao Kao Gon *	Chum Phae district; Phu Pha Man district
11	Khao Nang Nuan*	Non Sila district
12	Khao Mun Ped*	Khao Suan Kwang district
13	Khao Keetom Yai	Mueang Khonkaen district
14	Khao Keetom Klang	Mueang Khonkaen district
15	Khao E-Kao Yai	Waeng Yai district
16	Khao Jaw Loy	Waeng Noi district; Sam Sung district
17	Khao Kao Bai Rong	Phon district
18	Khao Jaw Dang	Non Sila district
20	KhaoE-Dang Pla Look Krok	Chum Phae district
21	Khao Ta Dee	Chum Phae district
22	Khao Lung Ma	Sam Sung district
23	Khao E-Tum	Ban Phai district
24	Khao Kam	Phra Yuen district
25	Khao Niaw Dum	Phon district
26	Khao Niaw E-Tia	Phu Wiang district
27	Khao Kao Lum	Phu Pha Man district

* indicates the landraces that plant and grain samples can be obtained for this study.

In addition, our findings showed that 27-indigenous rice landraces were found in Khon Kaen province. While, in other province of the Northeastern region such as in Keang subdistrict, Mahasarakham Province, Kijtewachakul et al. (2008) found 20-indigenous rice landraces in the past. However, many landraces were still cultivated in the Northeastern region, namely Hom Udom, San Patong, Nang Nguan, and Keetom. Two indigenous rice landraces, namely Nang Nguan, and

Keetom, were similarly found in Non Sila district and Mueang Khon Kaen district, Khon Kaen province, respectively.

In the other regions of Thailand, a field survey of indigenous rice landraces in the Southern region in Thale Noi Basin, Phatthalung province found seven indigenous rice landraces, including Dawk Pa-Yawm (uplandrice), Sang Yod, Leb Nok, Khem Tong, Niaw Dam (glutinous rice), Chiang Phatthalung and Hawm Jan (Panomjan and Amornviriyachai, 2011). While, in the Central region, in the community of Emad Esai, Banrai district, Uthaitani province, approximately 17-indigenous rice landraces were found (Khunhan, 2018). In ASEAN country such as Lao PDR, there was 49-rice varieties from 6 villages, 3 districts of Luang Prabang province (Xiongsiyee *et al.*, 2018). Overall, these findings suggested that the indigenous rice diversity from the same region or different regions may be similarly name of some indigenous rice landraces.

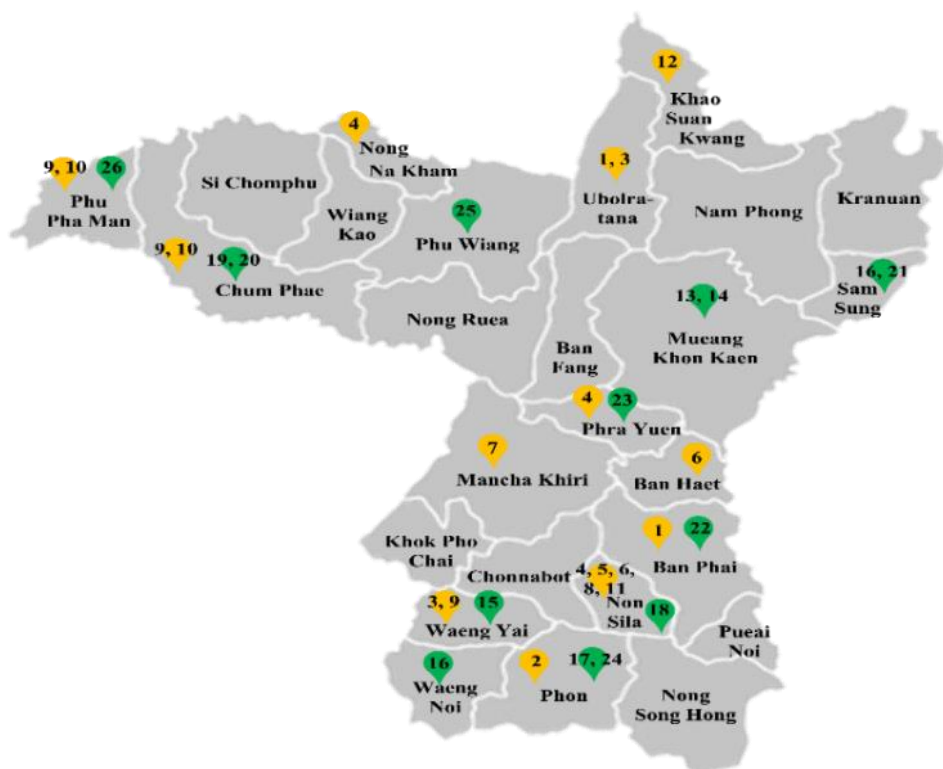


Figure 1. 27-indigenous rice landraces are found in 16 districts of Khon Kaen province, Thailand. The number represents indigenous rice name, including 1) Khao Plong Aew, 2) Khao Jao Leuang, 3) Khao San Pla Tong, 4) Khao Gam Poon, 5) Khao E-Leuang Noi, 6) Khao Niaw dang, 7) Khao Lao Taek, 8) Khao E-Tom Kao, 9) Khao Kam Pai, 10) Khao Kao Gon, 11) Khao Nang Nuan, 12) Khao Mun Ped, 13) Khao Kee Tum Yai, 14) Khao Kee Tum Klang, 15) Khao E-Kao Yai, 16) Khao Jaw Loy, 17) Khao Kao Bai Rong, 18) Khao Jaw Dang, 19) Khao E-Dang Pla Look Krok, 20) Khao Ta Dee, 21) Khao Lung Ma, 22) Khao E-Tum, 23) Khao Kam, 24) Khao Niaw Dum, 25) Khao Niaw E-Tia and 26) Khao Kao Lum. The yellow pin indicates the present plant and grain samples collecting for this study and the green pin indicates plants reported in the past.

Morphology of Indigenous rice landraces in Khon Kaen province

The leaf morphology of 12 indigenous rice landraces are shown in Table 2 and Figure 2. Plant height was determined in all rice and the highest and the lowest of plant height was found in Khao Plong Aew (120-170 cm) and Khao E-Leuang Noi (80-105 cm), respectively. The color of leaf blade, leaf sheath and node were green in all landraces. However, different colors of collar, auricle and ligule were found. The collar color in Khon Kaen indigenous rice varied between white, yellow, light green, green, and purple. The auricle color in Khon Kaen indigenous rice varied in white, yellow, light green, purple and brown. In addition, the ligule color in Khon Kaen indigenous rice varied between white and purple. Some indigenous rice landraces such as Khao E-Tom Kao, Khao Kam Pai and Khao Kao Gon was not determined because their leaf organs such as collar, auricle and ligule were damaged or incomplete.

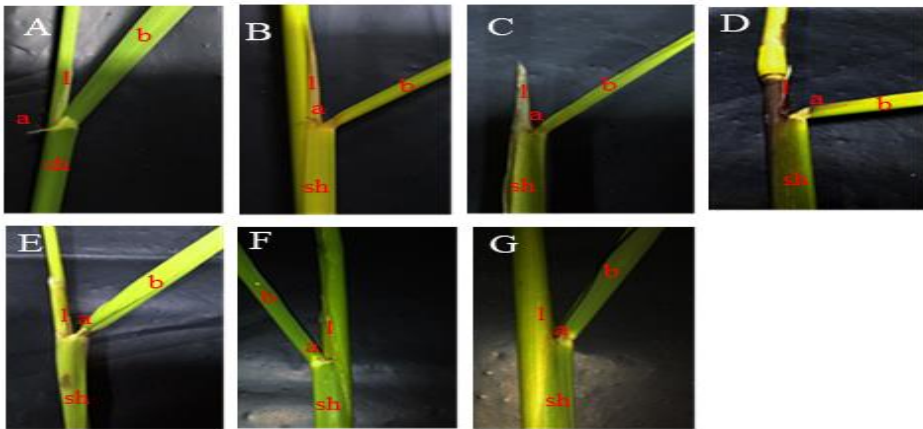


Figure 2. Leaf morphological characters (blade; b, auricle; a, ligule; l and sheath; sh) of some indigenous rice landraces in Khon Kaen province such as Khao Plong Aew (A), Khao Jao Leuang (B), Khao San Pla Tong (C), Khao Kam Poon (D), Khao E-Leuang Noi (E), Khao Lao Taek (F) and Khao Mun Ped (G).

The grain morphology of 12 indigenous rice landraces are shown in Table 3 and Figure 3. The size of grain and brown rice was similar in all rice landraces. However, the color of seed coat of grain and shape and color of brown rice showed variation in all rice landraces. The color of seed coat of grain in Khon Kaen indigenous rice varied between yellow, purple and brown. This result was quite similar to indigenous rice landraces identified in the Southern Thailand, such as Sang Yod, Chaw Jam Pah, Niaw Look Pueng, Niaw Dawk Yong, and Khao Nang, their seed coat color was straw and brown. However, only purple color was unrepresented in rice from the Southern Thailand (Panomjan and Tongkiaw, 2011). The shape of brown rice varied between long round, long narrow, long flat, short round and short flat. Moreover, the color of brown rice in Khon Kaen indigenous rice varied between white, white with yellow and yellow with green. Meanwhile, the shape of brown rice in the Southern Thailand differed in being slender (Sang Yod, Chaw JamPah, and Niaw Dawk

Yongvarieties) and medium (Niaw Look Pueng, and Khao Nang), while the brown rice color was distinguished by a red color compared to Khon Kaen indigenous rice (Panomjan and Tongkiaw, 2011).

Thus, our studies suggested that leaf and grain morphology such as colors of collar, auricle, ligule, seed coat of grain and brown rice and also shape of brown rice in Khon Kaen indigenous rice showed distinctive characteristic in each landrace. The results revealed that the morphological and anatomical characters of 12 indigenous rice landraces were similar with a slight difference in some characteristics. The different morphology was color of collar, auricle and ligule as well as shape and color of brown rice. The most distinguished morphological characteristics to identify indigenous rice landraces was grains feature. This study accorded to Panomjan and Amornviriyachai (2011) showed the highly distinctive grain morphology to identify indigenous rice landraces was seed coat color and shape and color of brown rice.



Figure 3. Grain morphological characters of indigenous rice such as Khao Plong Aew (A), Khao Jao Leuang (B), Khao San Pla Tong (C), Khao Gam Poon (D), Khao E-Leuang Noi (E), Khao Niaw dang (F), Khao Lao Taek (G), Khao E-Tom Kao (H), Khao Kam Pai (I), Khao Kao Gon (J), Khao Nang Nuan (K) and Khao Mun Ped (L).

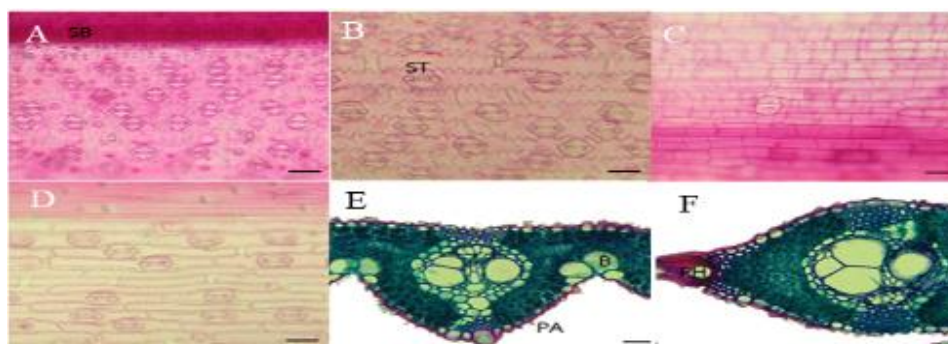


Figure 4. Leaf anatomical characters of Khao Jao Leuang: upper epidermis (A), lower epidermis (B), upper epidermis of leaf sheath (C), lower epidermis of leaf sheath (D), x-section of leaf blade (E) and x-section of leaf margin (F) (B = bulliform cell, FG = fibrous group, PH = prickle hair, PA = Papillae, SB = silica bead and ST = stomata), Scale bar = 20 μ m.

Table 2. Leaf morphological characters of 12 indigenous rice landraces in Khon Kaen province, Thailand.

No.	Indigenous rice landraces	Height (cm)	Leaf blade		Leaf sheath color	Collar color	Node color	Auricle color	Ligule	
			Width × Length (cm)	Color					Length (cm)	Color
1	Khao Plong Aew	120 - 170	1.00 × 25 - 55	green	green	light green - white	green	light green - white	1.5 - 1.7	white
2	Khao Jao Leuang	100 - 145	1.00 × 20 - 40	green	green	light green	green	light green - white	0.5 - 1.5	white
3	Khao San Pla Tong	115 - 140	1.00 × 20 - 50	green	green	light green - yellow	green	Brown-white	1.2 - 2.0	white
4	Khao Gam Poon	85 - 100	1.00 × 15 - 40	green	green	purple	green	purple	1.0 - 1.5	purple
5	Khao E-Leuang Noi	80 - 105	1.00 × 25 - 40	green	green	light green	green	yellow	0.5 - 1.5	white
6	Khao Niauw dang	82 - 120	1.00 × 30 - 55	green	green	light green	green	white	1.0 - 3.0	white
7	Khao Lao Taek	100 - 130	1.00 × 25 - 55	green	green	light green - white	green	white	0.5 - 2.5	white
8	Khao E-Tom Kao	95 - 125	1.00 × 35 - 48	ND	ND	ND	ND	ND	1.5 - 3.0	ND
9	Khao Kam Pai	135 - 140	1.00 × 35 - 52	ND	ND	ND	ND	ND	2.0 - 2.5	ND
10	Khao Kao Gon	125 - 135	1.00 × 25 - 45	ND	ND	ND	ND	ND	1.0 - 2.0	ND
11	Khao Nang Nuan	85 - 105	1.00 × 30 - 48	green	green	green	green	purple	0.5 - 2.0	purple
12	Khao Mun Ped	105 - 185	1.00 × 30 - 50	green	green	green-white	green	white	1.5 - 2.0	white

Noted: ND = not determine

Table 3. Grain morphological characters of 12-indigenous rice landraces in Khon Kaen province, Thailand.

No.	Indigenous rice landraces	Grain			Brown rice			100-grain weight (g)
		Width × Length (cm)	Awn	Seed coat color	Width × Length (cm)	Shape	Color	
1	Khao Plong Aew	0.30 × 1.00	present	yellow	0.20 × 0.70	long round	white	2.67
2	Khao Jao Leuang	0.30 × 1.00	present	yellow	0.20 × 0.60	short round	white	2.52
3	Khao San Pla Tong	0.30 × 0.80	present	yellow	0.20 × 0.70	long round	white	2.61
4	Khao Gam Poon	0.30 × 1.00	present	purple	0.30 × 0.60	short flat	purple	1.27
5	Khao E-Leuang Noi	0.25 × 1.00	present	yellow	0.20 × 0.70	long narrow	yellow with green	1.34
6	Khao Niaw dang	0.25 × 1.00	present	brown	0.20 × 0.70	long round	yellow with green	1.61
7	Khao Lao Taek	0.30 × 1.00	present	yellow	0.20 × 0.70	long round	white with yellow	3.67
8	Khao E-Tom Kao	0.30 × 0.90	present	yellow	0.20 × 0.70	long flat	white	3.09
9	Khao Kam Pai	0.30 × 1.00	present	yellow	0.30 × 0.70	long flat	white	3.23
10	Khao Kao Gon	0.30 × 0.90	present	yellow	0.30 × 0.70	long flat	white	3.31
11	Khao Nang Nuan	0.30 × 0.80	present	yellow	0.20 × 0.60	short round	white	2.36
12	Khao Mun Ped	0.30 × 1.00	present	yellow	0.20 × 0.70	long round	white with yellow	7.14

Table 4. Leaf blade anatomical characters of 12-Indigenous rice landraces in Khon Kaen province, Thailand.

No.	Indigenous rice landraces	Epidermal cell				Stomata type		Trichrome type		Vascular tissue type
		Shape		Anticlinal wall of epidermis		Upper	Lower	Upper	Lower	
		Upper	Lower	Upper	Lower					
1	Khao Plong Aew	rectangular	rectangular	sinuous	sinuous	P	P	PA	PH, PA	CB
2	Khao Jao Leuang	rectangular	rectangular	sinuous	sinuous	P	P	PA	PA	CB
3	Khao San Pla Tong	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
4	Khao Gam Poon	rectangular	rectangular	sinuous	sinuous	P	P	PA	PH, PA	CB
5	Khao E-Leuang Noi	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
6	Khao Niaw dang	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
7	Khao Lao Taek	rectangular	rectangular	sinuous	sinuous	P	P	PA	PH, PA	CB
8	Khao E-Tom Kao	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
9	Khao Kam Pai	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
10	Khao Kao Gon	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
11	Khao Nang Nuan	rectangular	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB
12	Khao Mun Ped	rectangle	rectangular	sinuous	sinuous	P	P	PH, PA	PH, PA	CB

Noted: P = paracytic stomata, PA = papillae, PH = prickly hair and CB = collateral bundle.

Table 5. Leaf sheath anatomical characters of 12-Indigenous rice landraces in Khon Kaen province, Thailand.

No.	Indigenous rice landraces	Epidermal cell				Stomata type		Trichrome type		Vascular tissue type
		Shape		Anticlinal wall of epidermis		Upper	Lower	Upper	Lower	
		Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
1	Khao Plong Aew	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB
2	Khao Jao Leuang	rectangular	rectangular	straight	undulate	P	P	-	-	CB
3	Khao San Pla Tong	rectangular	rectangular	straight	sinuous	P	P	-	-	CB
4	Khao Gam Poon	rectangular	rectangular	straight	sinuous	P	P	-	-	CB
5	Khao E-Leuang Noi	rectangular	rectangular	straight	sinuous	P	P	-	-	CB
6	Khao Niaw dang	rectangular	rectangular	straight	sinuous	P	P	-	-	CB
7	Khao Lao Taek	rectangular	rectangular	straight	sinuous	P	P	-	-	CB
8	Khao E-Tom Kao	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB
9	Khao Kam Pai	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB
10	Khao Kao Gon	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB
11	Khao Nang Nuan	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB
12	Khao Mun Ped	rectangular	rectangular	straight	sinuous	P	P	-	UN	CB

Noted: P =paracytic stomata, UN= unicellular hair, CB = collateral bundle and - = absent

Anatomical characteristics of Indigenous rice landraces in Khon Kaen province

The anatomy of leaf blade and leaf sheath of 12 indigenous rice landraces is shown in Table 4 and 5, respectively. Most of the leaf blade anatomical characters in all Khon Kaen indigenous rice landraces were the same as follows (Table 4):

Upper and lower epidermis were: 1) rectangular epidermal cells, 2) shape of anticlinal wall of epidermal cell was deep sinus, 3) elongated- and shorted-epidermal cells arranged alternately along leaf blade, 4) epidermal cells were oval-shape with smooth cell wall, 5) paracytic stomata, 6) silica beads present, 7) some trichomes were papillae type and 8) most trichomes were prickly hair. *Mesophyll* were: 1) mesophyll cells were oval-shape chlorenchyma with rough cell wall that could not classify as palisade and spongy mesophyll and 2) bulliform cells arranged alternately with vascular tissue.

Vascular tissues were: 1) three sizes of vascular bundle were large, medium, and small, 2) collateral bundle arranged as the same radius with xylem, 3) bundle sheath cells were parenchyma cell type, 4) fibrous tissue placed on upper and lower of or only upper of vascular bundle and 5) parenchyma tissue arranged along with epidermis.

However, leaf blade of one indigenous rice landrace, Khao Jao Leuang, was different from others by absence prickly hair in both upper and lower epidermis. Meanwhile, papillae only occurred in both upper and lower epidermis (Table 4 and Fig. 4F). This suggested that Khao Jao Leuang was found in Phon district where the climate was relatively low rainfall and drought condition compared to other districts. That resulted in Khao Jao Leuang was sensitive to environmental stress such as drought and also pathogen. Thus, it may modify the cell wall to be physical barrier, as papillae, against pathogen invasion (Underwood, 2012).

The anatomy of leaf sheath in all Khon Kaen indigenous rice landraces was described as follows: 1) epidermal cell in upper epidermis was rectangular, 2) shape of anticlinal wall of upper epidermal cell was straight, 3) epidermal cell in lower epidermis was rectangular, 4) shape of anticlinal wall of lower epidermal cell was deep sinus excluding Khao Jao Leuang that was undulate (Table 5), 5) paracytic stomata in both upper and lower epidermis and 6) trichome absent in upper epidermis but unicellular hair occurred in lower epidermis in Khao Plong Aew, Khao E-Tom Kao, Khao Kam Pai, Khao Kao Gon, Khao Nang Nuan and Khao Mun Ped (Table 5). This unicellular hair has a simple structure and usually does not have glands. It can play an important role to resist drought and high salt and to prevent UV and biological invasion (Han et al., 2022). Because these indigenous rice landraces were found in various climate condition, such as high rainfall (Khao Plong Aew, Khao Kam Pai, Khao Kao Gon), low rain fall (Khao E-Tom Kao, Khao Nang Nuan and Khao Mun Ped), high salt (Khao E-Tom Kao and Khao Nang Nuan). However, the anatomical characteristics of leaf blade and leaf sheath cannot be used for identifying indigenous rice landraces.

CONCLUSIONS

In summary, we found 27-landraces, while, only 12-plant and -grain samples were collected in Khon Kaen province, namely; Khao Plong Aew, Khao Jao Leuang, Khao San Pla Tong, Khao Gam Poon, Khao E-Leuang Noi, Khao Niaw dang, Khao Lao Taek, Khao E-Tom Kao, Khao Kam Pai, Khao Kao Gon, Khao Nang Nuan and Khao Mun Ped. The morphological characteristics of the vegetative organs such as color of leaf blade, leaf sheath, auricle and ligule and of the reproductive organs such as shape and color of brown rice can be used to identify indigenous rice landraces. Particularly, the shape and color of brown rice were the most effective diagnostic characteristics of indigenous rice landraces. The anatomical characters of leaf blade and leaf sheath such as upper and lower epidermis, mesophyll cells and vascular tissue were similar in all 12 indigenous rice landraces. Thus, the anatomical characteristics were not appropriated to identify the indigenous rice landraces. However, Khao Jao Leuang was distinguished from other indigenous rice landraces by the absence of prickles on both leaf blade surfaces. Moreover, Khao Jao Leuang was the only landrace in which the shape of anticlinal wall of epidermal cell on lower surface of leaf sheath was undulate while the other were sinuate. Consequently, the database of 12-Khon Kaen indigenous rice landraces such as the collection sites, and the characteristics of leaf and grain morphology and anatomy will benefit the conservation indigenous rice seeds, providing a rice genetic resource, and evolution knowledges. Classifying rice landraces enables the selection of high potential indigenous rice landraces for rice breeding program.

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