Ethnobotany of *Dioscorea* L. (Dioscoreaceae), a Major Food Plant of the Sakai Tribe at Banthad Range, Peninsular Thailand

Katesarin Maneenoon, Puangpen Sirirugsa and Kitichate Sridith

Research

Abstract

Dioscorea is the main source of carbohydrate for the Sakai tribe at Banthad Range, Peninsular Thailand. Nine subgroups of Sakai wander in this area where fifteen species of the genus have been found. Thirteen of the species are consumed by the Sakai. The remaining two species are inedible. This study investigates the Sakai population pyramid, the Sakai living areas, the species diversity and ethnobotany of *Dioscorea* as well as the nutritional compositions of selected *Dioscorea* species.

Introduction

The genus *Dioscorea* L., a monocotyledon, belongs to the family Dioscoreaceae. It comprises 350-400 species (Caddick *et al*. 2002), and is distributed throughout the tropics and subtropic regions especially in West Africa, parts of Central America and the Caribbean, the Pacific Islands and Southeast Asia.

The genus *Dioscorea* has been the main food source for tribal people particularly in many parts of West Africa since prehistoric times because its tubers are rich in essential dietary nutrients. (Coursey 1967, Hladik & Dounias 1993). It is the main food source for the Mbuti pygmies of Eastern Zaire (Hart & Hart 1986, Milton 1985), the Batek of Peninsular Malaysia (Endicott & Bellwood 1991), the Baka pygmies in the forests of Southern Cameroon (Dounias 2001, Sato 2001), and people at Kuk Swamp of Papua New Guinea (Fullagar *et al*. 2006).

In some forest areas of Southern Thailand specifically Trang, Phatthalung, Satun, Songkla, Yala and Narathiwat provinces which are situated in the tropical rain forest zone of Southeast Asia, a tribe known as the Sakai (Orang Asli) can be found. The Sakai have inhabited these parts for more than ten thousand years. They are an indigenous minority people of the Malay Peninsula who have been classified as part of the Negrito group (Duangchan 1980). In Thailand, the current Sakai population is around 500 and they live in small groups. At least nine groups from this tribe can be found in the Banthad Range, an area which covers parts of Trang, Phatthalung and Satun provinces (Maneenoon 2001).

The Sakai people depend on plant products in the forest for their main essentials in life. Examples include food, medicines and shelters. The traditional knowledge of using plants for their continuing survival has been passed down from generation to generation.

Nowadays, forests in Peninsular Thailand are being destroyed and this affects the availability of plant products that are necessary for Sakai's way of life. This means that the food and other supplies from plants, which are necessary for their daily needs are in short supply. In addition, Sakai people are being dominated by non-indigenous people around their habitats. Consequently, the ethnobotany and culture of the Sakai, specifically the use of *Dioscorea* as a staple food, the nutritional composition of *Dioscorea* tubers is changing and perhaps lost be-

Correspondence

Katesarin Maneenoon, Department of Biology, Prince of Songkla University, Songkla 90112, Thailand
katesarin.m@psu.ac.th
Puangpen Sirirugsa, Department of Biology, Prince of Songkla University, Songkla 90112, Thailand
Puangpen.s@psu.ac.th
Kitichate Sridith, Department of Biology, Prince of Songkla University, Songkla 90112, Thailand
Kitichate.s@psu.ac.th

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fore publicly available, This present study documents the ethnobotanical knowledge of the Sakai and evaluates the nutritional values of different *Dioscorea* species.

Materials and Methods

Study sites

The living areas of the Sakai tribe at Banthad Range were surveyed and marked by a Global Positioning System (GPS) unit. Scattered groups of Sakai people in the study areas were observed as they searched and utilized food plants from the forest. All surveys were conducted between January 2005 and April 2007. The population of each group was counted. Gender and age statistics were also gathered for each group. A population pyramid for all the Sakai living in Banthad Range was created.

Plant specimen studies

Specimens of *Dioscorea* species in the living areas of the Sakai tribe were collected in triplicates whenever possible for identification and analysis. Herbarium specimens were prepared following the method of Bridson & Forman (1992). The voucher specimens were deposited at the herbarium of Prince of Songkla University (PSU), Princess Maha Chakri Sirindhorn Natural History Museum, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, Thailand and The Forest Herbarium (BKF), Department of National Park, Wildlife and Plant Conservation, Ministry of Natural Resource, Bangkok, Thailand. Flowers were preserved in 70% ethanol. Field data on plant habits and localities were recorded. Notes on plant morphological characters such as the twinning of stems, tubers, leaves, flowers and fruits were collected to aid in the plant identification process. Underground parts were also collected for nutritional analysis and identification.

Ethnobotanical investigations

The way of life of the Sakai tribe was investigated through interviews and by observing all members of each group in the study sites as they conducted their daily activities. Ethnobotanical and other relevant information pertaining to *Dioscorea* were investigated by interviewing all members including teenagers. (Ages of informants were estimated by the researchers). The questions asked were about the plants used by the Sakai tribe. Specific information about Sakai names of the plants, utilized plant parts, cooking and harvesting methods were collected. The interviews were conducted individually as a way to ensure that data supplied by each informant was reliable.

Nutritional analyses

To compare nutritional compositions between staple and substitute species, four common staple species, *Dioscorea calcicola* Prain & Burkill, *D. glabra* Roxb., *D. wallichii* Hook. f., and *D. stemonoides* Prain & Burkill were selected to compare against the substitute species, *D. daunea* Prain & Burkill, which was the only species that could be found. Tubers of these species were prepared for nutritional analysis. The tubers were peeled, cut into small pieces and stored in a refrigerator until ready to be analyzed. Protein content, crude fat, moisture, ash and crude fiber were determined in accordance with the standard method of the AOAC as developed by Agro-Industry Development Center for Export (ADCET, Agro-Industry Faculty, PSU). The calorific values were obtained by the summation of the mean values of protein, fat and carbohydrate which were multiplied by their respective factors of 4, 9 and 4 (Bhandari *et al*. 2003). All results for proximate composition were recorded on the basis of edible portion as g/100 g fresh weight.

Results and Discussion

Sakai population and their living areas

There are 139 members of the Sakai tribe living in the Banthad Range. Based on living area and behavior, these Sakai can be classified into two main groups. Group 1 or the “semi-nomadic” group, consists of those who settle into permanent living areas and collect natural products from nearby areas for subsistence. This group can be further sub-divided into four subgroups (Figure 1). Group 2 or the “nomadic” group consists of those who wander throughout the forest collecting natural products for their subsistence and have no permanent living areas. This group can be further sub-divided into five subgroups (Figure 1).

According to the population pyramid of the Sakai (Figure 2), the majority of the Sakai is either children or adult. There are very few old Sakai in the population. Males outnumber females.

The living style of the nomadic group is simple as they normally live in traditionally small shelters or in front of caves. Their shelters are made from the leaves of *Calamus castaneus* Griff, *Licuala distans* Ridl. or *Zingiber spectabile* Griff. Most of their daily living needs are acquired from the forest. Their main food source is *Dioscorea* tubers. They usually wander throughout the forest without maintaining any permanent home shelter. Upon harvesting all the forest products they need in one area, they move on to another area where they continue their nomadic lifestyle. The living style of the semi-nomadic group is different from the nomadic group in that the former sets up in permanent living areas and build small huts. Some of their daily needs for subsistence are imported from outside the forest. However, they still hunt and harvest the forest products.

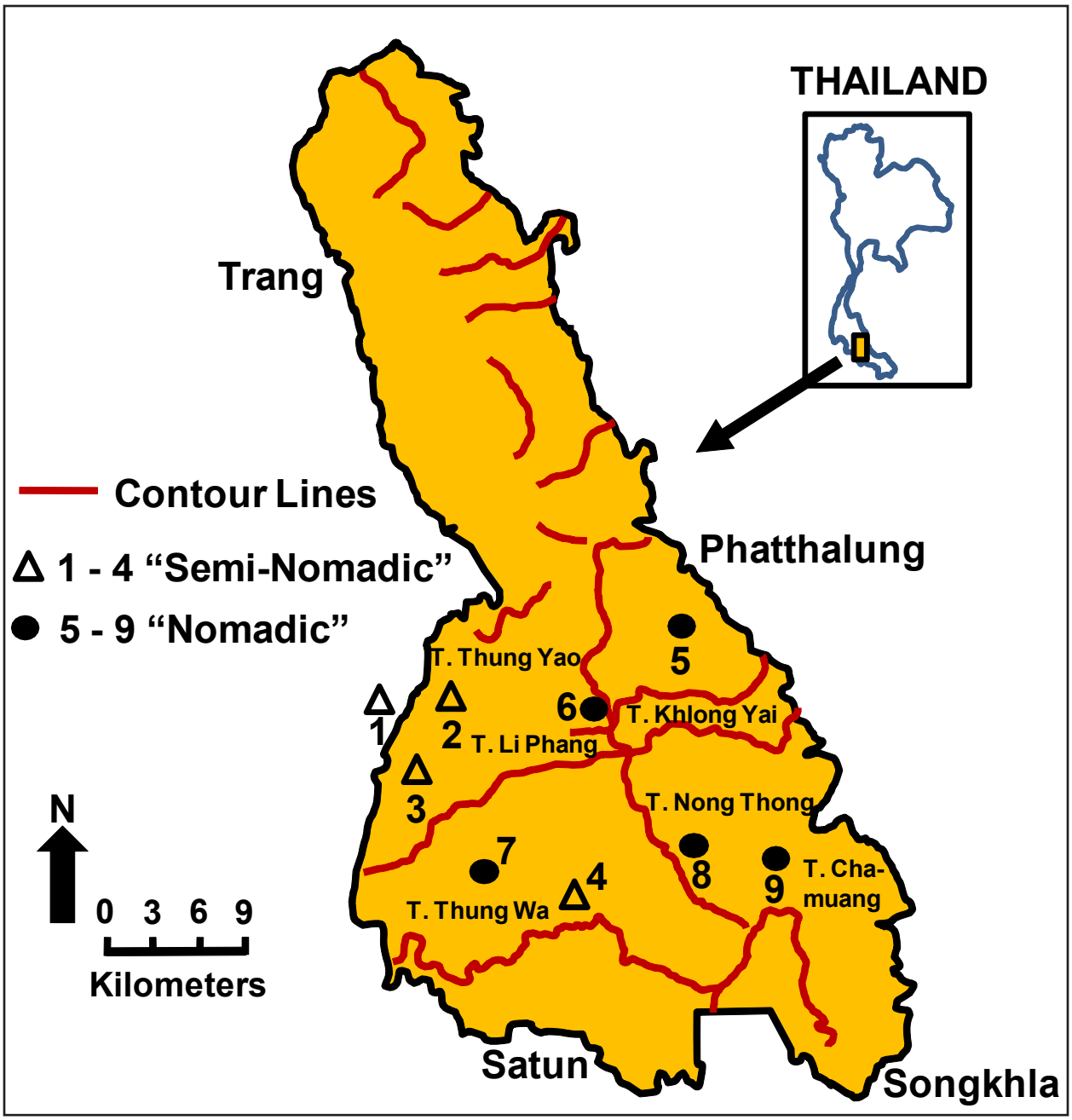

Figure 1. The living areas of the Sakai tribe at Banthad Range, Peninsular Thailand.

Species of Dioscorea at Banthad range

Fifteen species of *Dioscorea* were found at the Banthad Range. Thirteen species are edible but only eight of these which are *D. calcicola*, *D. filiformis* Griseb., *D. glabra*, *D. orbiculata* Hook. f., *D. pentaphylla* L., *D. pyrifolia* Kunth, *D. stemonoides* and *D. wallichii* serve as main sources of carbohydrate for the Sakai. The remaining five edible species, *D. daunea*, *D. membranacea* Pierre ex Prain & Burkill, *D.* cf. *piscatorum* Prain & Burkill, *D. prazeri* Prain & Burkill and an unidentified *Dioscorea* species are substituted species during famine. All the substitute species are bitter and have an unpleasant taste. The two inedible species are *D. bulbifera* L. and *D. laurifolia* Wall. *Dioscorea bulbifera* is inedible because it is bitter and has a coarse fiber and hard texture while *D. laurifolia* is so toxic that it is impossible to detoxify.

The flowers and fruits of *Dioscorea* are rarely seen because most of them are hidden in the canopy of high

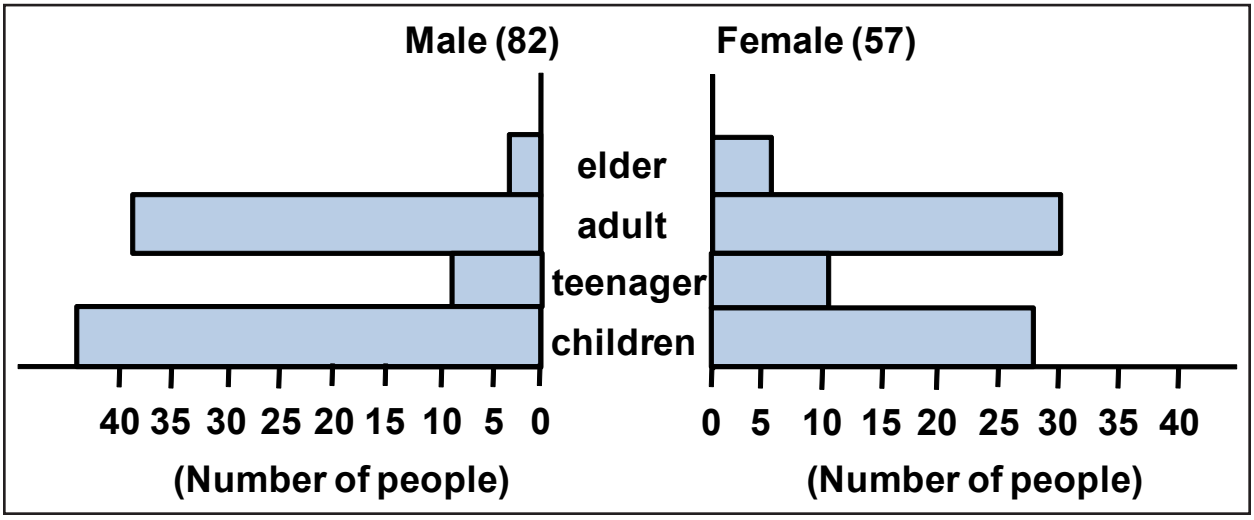

Figure 2. Population pyramid of Sakai people at Banthad Range, Peninsular Thailand.

trees. This makes identification to the species level difficult. The list of *Dioscorea* species with their respective Sakai names, and whether they are edible or not are provided in Table 1.

Tuber characters

Based on the direction of that tubers grow into the soil, the *Dioscorea* tubers may exhibit any of the following three growth types: "orthotropic" (vertical direction), "plagiotropic" (horizontal direction) or "ground level" (place on ground or shallowly buried). The general characters of *Dioscorea* tubers are provided in Table 2. The representative species of "orthotropic" and "ground level" growth types are shown in Figure 3. All eight of the staple species are orthotropic. As for the substitute species, *D. daunea* is "orthotropic", the unidentified *Dioscorea* species is "plagiotropic", and the other remaining three species are "ground level". The two inedible species, *D. bulbifera* and *D. laurifolia* have "ground level" or "shallowly buried" growth type. This characteristic of *Dioscorea* tubers is quite useful for identification but it is rarely used by taxonomists because it can be rather difficult to collect the tubers.

Table 1. List of *Dioscorea* species at Banthad range. The vouchers were deposited at the herbarium of Prince of Songkla University (PSU) and The Forest Herbarium (BKF) of Department of National Park, Thailand.

Scientific Name		Sakai Name	Voucher Number
Staple species	*Dioscorea calcicola*	**Bayae**	Maneenoon 923, 926, 939
	Dioscorea glabra	**Luntak**	Maneenoon 909, 910, 915, 931, 945, 946
	Dioscorea filiformis	**Balun**	Maneenoon 907, 913, 916, 918, 924, 934
	Dioscorea pyrifolia	**Hngo**	Maneenoon 949, 950, 951
	Dioscorea orbiculata	**Takob**	Maneenoon 902, 908, 914, 919, 940, 941
	Dioscorea pentaphylla	**Ser**	Maneenoon 952
	Dioscorea stemonoides	**Kungkwad**	Maneenoon 904, 906, 927, 928, 943, 944
	Dioscorea wallichii	**Yarex**	Maneenoon 912, 938
Substitute species	*Dioscorea daunea*	**Suna**	Maneenoon 901, 905, 917, 920, 929, 937
	Dioscorea membranacea	**Chatong**	Maneenoon 953
	Dioscorea cf. *piscatorum*	**Kiyak**	Maneenoon 911, 932, 933
	Dioscorea prazeri	**Sehod**	Maneenoon 935, 936
	Dioscorea sp.	**Kammarak**	Maneenoon 921, 922, 925, 947
Inedible species	*Dioscorea bulbifera*	**Kapuang**	Maneenoon 903, 942, 948
	Dioscorea laurifolia	**Clangporn**	Maneenoon 930

Table 2. Tuber characters of *Dioscorea*.

Scientific Name		Sakai Name	Tuber Characters
Orthotropic growth	*Dioscorea calcicola*	**Bayae**	cluster, clavate or cylindrical, inside white, little mucilaginous, outside brown
	Dioscorea daunea	**Suna**	single or cluster, cylindrical, inside greenish white, outside pale brown , mucilaginous
	Dioscorea filiformis	**Balun**	single, cylindrical, inside white, outside brown
	Dioscorea glabra	**Luntak**	cluster, cylindrical, long columnar, inside fresh white, outside pale yellow or pale brown
	Dioscorea orbiculata	**Takob**	cluster, branched, inside white, outside brown or gray
	Dioscorea pentaphylla	**Ser**	single, clavate or pyriform, inside pale yellow, outside dark brown, covered with robust roots
	Dioscorea pyrifolia	**Hngo**	single, cylindrical, inside fresh yellow, mucilaginous, outside pale yellow or pale brown
	Dioscorea stemonoides	**Kungkwad**	cluster, cylindrical, inside pale purple, outside yellow-brown, mucilaginous
	Dioscorea wallichii	**Yarex**	cluster, long columnar, inside white, outside yellowish brown
Plagiotropic growth	*Dioscorea* sp.	**Kammarak**	cluster, long and slender, inside pale red, outside dark brown or gray
Ground level or shallowly buried	*Dioscorea bulbifera*	**Kapuang**	single or cluster, globose or irregular, inside pale or bright, yellow, outside dark brown covered with robust roots
	Dioscorea laurifolia	**Clangporn**	cluster, long and flat, inside pale red, outside rough, dark brown or black
	Dioscorea membranacea	**Chatong**	cluster, branched, irregular, inside pale yellow, outside rough, brown, covered with robust roots
	Dioscorea prazeri	**Sehod**	cluster, branched, inside pale yellow, outside rough, brown or gray
	Dioscorea cf. *piscatorum*	**Kiyak**	digitate, irregular, inside pale red, outside dark brown

Usages of Dioscorea

Food

The present study found that 13 species of *Dioscorea* are eaten by the Sakai people at Banthad Range (Table 1). The number of edible species are more than those eaten by the "Batak" in Malaysia (Endicott & Bellwood 1991). All edible species, with the exception of the highly toxic *D. daunea*, can be cooked by simply roasting or burning. The detoxifying process for *D. daunea* (Figure 4) is rather complicated and will be described later. However some wild *Dioscorea* tubers such as *D. hispida Dennst.*, *D*. cf. *piscatorum* and *D. prainiana* R. Knuth can be eaten after prolonged boiling and others can only be eaten after an all-night boiling along with wood ashes to mitigate their acridity. Many species hold enough tannin to make them too unsavory for consumption (Burkill 1951). One species found in the study area, *D. bulbifera*, is high in toxicity and is not eaten by the Sakai. However, there are other local people in Thailand and some other countries who know how to eat this particular species safely.

Other purposes

Dioscorea laurifolia, *D. membranacea*, *D*. cf. *piscatorum* and the unidentified *Dioscorea* species from the Banthad Range are also used as medicines. The mucilage from the tubers of *D. laurifolia* and the unidentified *Dioscorea* species are used to treat warts. The boiled tubers of *D. membranacea* are used to treat asthma and fever. The mucilage from the tubers of *D*. cf. *piscatorum* is used by the Sakai people to poison fish. *Dioscorea* cf. *piscatorum* contains saponin which is used by the native people of Malaysia as a piscicide and as an alternative to *Derris* sp.

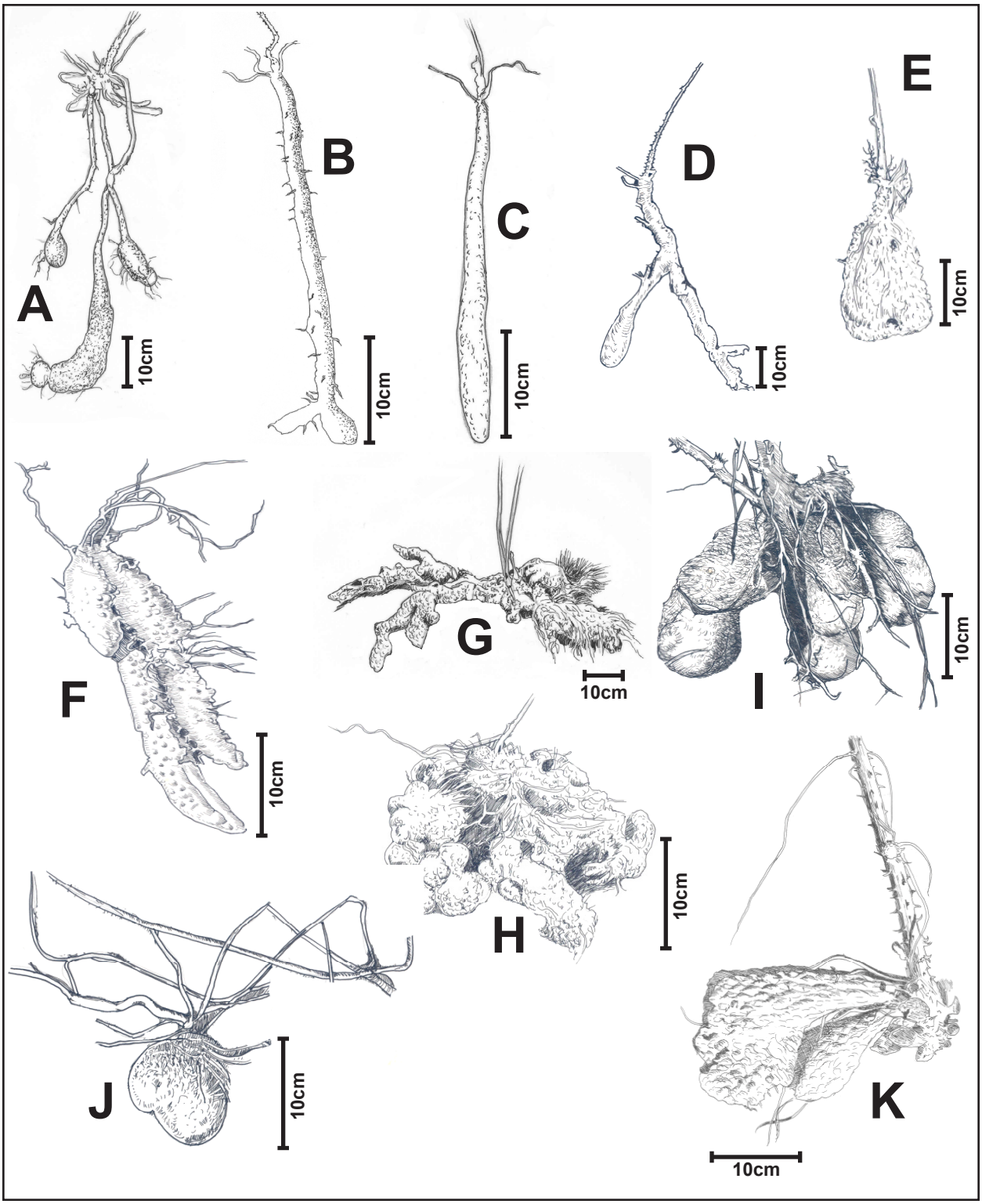

Figure 3. Tubers of some species of *Dioscorea* (scale = 10cm). A - F (Orthotropic growth): 3A. *D. stemonoides*, 3B. *D. glabra*, 3C. *D. pyrifolia*, 3D. *D. calcicola*, 3E. *D. pentaphylla*, 3F. *D. daunaea*. G - K (Ground level): 3G. *D. membranacea*, 3H. *D. prazeri*, 3I. *D.* cf. *piscatorum*, 3J. *D. bulbifera*, 3K. *D. laurifolia*.

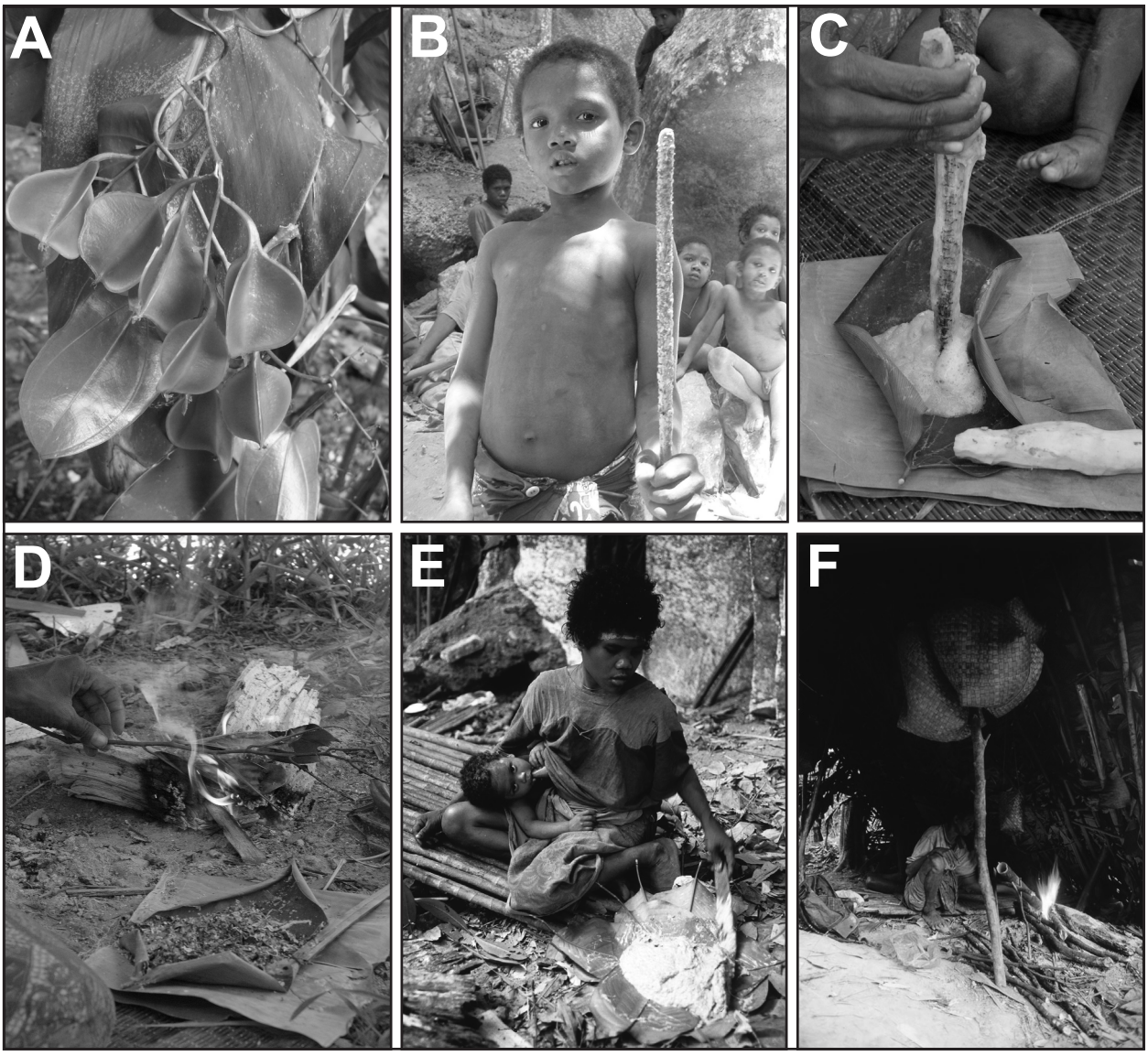

Figure 4. The process of reducing the toxicity of *D. daunea*. 4A. Part of stem and fruits. 4B. Grinding tool. 4C. Tuber being grounded. 4D. *Diospyros* leaves, burning for ash. 4E. The mixture of *Dioscorea* powder and *Diospyros* ash. 4F. Roasting bamboo filled with the *Dioscorea* mixture.

(Burkill 1951). *Dioscorea prazeri* is used as a soap and shampoo to kill lice in India. However, the Sakai people neither use *D. prazeri* as soap nor shampoo.

The detoxification of Dioscorea daunea

The tubers of *D. daunea* are peeled and grounded into a sticky powder by using a special tool made from a *Salacca* stem (Figures 4A, 4B & 4C). The powder is mixed with the ash of a *Diospyros* leaf (Figures 4D & 4E), and the mixture is wrapped in a leaf of either *Musa acuminata* Colla, *Donax grandis* (Miq.) Ridl. or *Z. spectabile* or put into a tube of bamboo and roasted (Figure 4F).

Nutritional compositions

The nutritional composition of five species, *D. calcicola*, *D. glabra*, *D. stemonoides*, *D. wallichii* and *D. daunea* are shown in Table 3. *Dioscorea calcicola*, *D. glabra*, *D. stemonoides* and *D. wallichii* are the main sources of food for the Sakai people and are commonly found in the forest, whereas *D. daunea* is a substitute species which is only eaten during famine since it is highly toxic. The result of this study was compared with those of Bhandari *et al*. (2003) who studied the nutritional composition of *Dioscorea* tubers eaten by tribal people in Nepal, and the report of Rajyalakshmi & Geervai (1994) who studied the

Table 3. Proximate composition of *Dioscorea* tubers (g per100 g fresh weight).

Scientific name		Protein	Carbohydrate	Fat	Moisture	Ash	Fiber	Energy (kcal)
Present study	*Dioscorea calcicola*	2.65	34.35	0	61.79	0.83	0.38	148.00
	Dioscorea daunea	2.32	30.93	0	65.09	1.02	0.64	133.00
	Dioscorea wallichii	2.83	29.41	0.02	66.52	0.79	0.43	129.14
	Dioscorea stemonoides	0.94	21.98	0.066	75.57	0.73	0.72	92.22
	Dioscorea glabra	1.60	29.65	0.22	66.62	0.79	1.12	126.98
Bhandari *et al*. (2003)	*Dioscorea bulbifera*	3.10	25.90	0.30	69.50	1.20	1.10	118.70
	Dioscorea deltoidea	1.60	17.40	0.20	80.20	0.60	1.50	77.80
	Dioscorea versicolor	1.70	17.50	0.20	80.10	0.50	1.10	78.60
	Dioscorea triphylla	2.30	20.00	0.20	76.90	0.60	0.60	91.00
Rajyalakshmi & Geervai (1994)	*Dioscorea oppositifolia*	1.80	21.00	1.10	73.00	-	0.90	100.00
	Dioscorea bulbifera	3.40	27.00	1.10	67.00	-	0.50	132.00
	Dioscorea pentaphylla	2.80	15.00	0.67	79.00	-	2.00	72.00
	Dioscorea hispida	5.20	15.00	4.30	74.00	-	0.80	134.00

nutritive value of food eaten by southern Indian tribes. In addition, this study compares the nutritional values of *Dioscorea* with those of *Colocasia esculenta* (L). Schott and *Solanum tuberosum* L. *Colocasia esculenta* is a native plant of Thailand used by local people as a supplemental food while *S. tuberosum* is the main source of carbohydrate for western people. The results are shown in Table 3.

Based on fresh weight, the ranges of percentages of protein, carbohydrate, fat, crude fiber, moisture and ash in the study samples were 0.94 – 2.83, 21.98 – 34.35, 0 – 0.22, 0.38 – 1.12, 61.79 – 75.57, and 0.73 – 1.02 respectively. The protein content of food source in this study was lower than the protein content of *D. hispida* and *D. bulbifera* in the study of Rajyalakshmi & Geervai (1994) and *D. bulbifera* in the study of Bhandari *et al.* (2003). Even though both species contain alkaloids and are very poisonous, they are used as supplemental food by Thai people. It is surprising that these two species are not eaten by the Sakai even though these plants are also found in their living areas. They may not known how to reduce the toxicity. The carbohydrate content of food sources in this study was much higher than those found by Bhandari *et al.* (2003) and Rajyalakshmi & Geervai (1994) except in the case of *D. bulbifera*. The fat content was much lower than those found by Rajyalakshmi & Geervai (1994) except for *D. hispida* which has a very high fat content. Most fiber content values in this study were lower than those found by Bhandari *et al.* (2003) and Rajyalakshmi & Geervai (1994). The *Dioscorea* tubers with the highest fiber content belonged to *D. pentaphylla* which is eaten by the Sakai but rarely found in the Banthad Range. Similarly, most moisture values in this study were lower than those found in previous studies. The highest moisture content was found in *D. deltoidea* Wall. (Bhandari *et al.* 2003). Most ash content values in this study were higher than those found by Bhandari *et al.* (2003) with the exception of *D. bulbifera*. The energy values of all *Dioscorea* species in this study were more than 100 kcal with the exception of *D. stemonoides,* and the highest energy value was found in *D. calcicola*.

It was noted that *Dioscorea* species provide higher protein, carbohydrate and energy than *C. esculenta* (Huang *et al*. 2007) and *S. tuberosum* (Juliano 1993). Its tubers also have a higher protein content than *Manihot esculenta* Crantz (Schoeninger *et al*. 2001) and they have a better amino acid balance than other cereals and tubers. In addition, the fiber content of *Dioscorea* tubers is higher than *M. esculenta*, *Zea mays* L., *Oryza sativa* L. and *Triticum aestivum* L. (Treche 1996). Some mineral contents, such as calcium and iron in *Dioscorea* tubers are higher than that of *O. sativa* (Treche 1996). However, the results of the nutritional composition between toxic and non-toxic species of *Dioscorea* tubers showed no difference.

Harvesting technique of the Sakai people

Sakai people use a special wooden digging tool, similar to an “auger” (Figure 5), for harvesting orthotropic elongate tubers. The excavation is made by digging around the plant using this tool, making a hole as deep as the tuber before the tuber is removed without damaging the plant. The remaining parts of the plant continue their growth after the tuber is removed. This excavating method was also used by the Baka pygmies in southern Cameroon. After the Baka people have collected the tubers, the pit is backfilled with an enriched organic matter which is a mixture of earth and humus so that renewed tubers are encouraged

to grow. This method is called “paracultivation” and has a positive effect on the *Dioscorea* population without affecting tuber production (Dounias 2001). In contrast, Endicott & Bellwood (1991) who studied Batak foragers in Peninsular Malaysia concluded that some species, such as *D. orbiculata*, are totally killed after harvesting.

Conclusions

Fifteen species of *Dioscorea* were found in the living areas of the Sakai tribe at Banthad Range in Peninsular Thailand. Only eight species are consumed as main food sources by the Sakai people. This study shows that the major food plants of the Sakai are rather limited. The *Dioscorea* habitats are constantly being disturbed by illegal para-rubber plantations and loggers. This has a detrimental effect on the environment in their living area, and makes the availability of their main food source highly unstable. This may be a key factor that leads the Sakai people to change their way of life. Observations confirm that nowadays some Sakai people have interacted with outsiders. The biology and ethnobotany of *Dioscorea* as it relates to the Sakai people have been documented. The information about the various usages of the *Dioscorea* species as well as the sustainable use of this particular group of plants will be useful for future research on pharmaceutical plants, and the selection and propagation of some species of *Dioscorea* as crop plants.

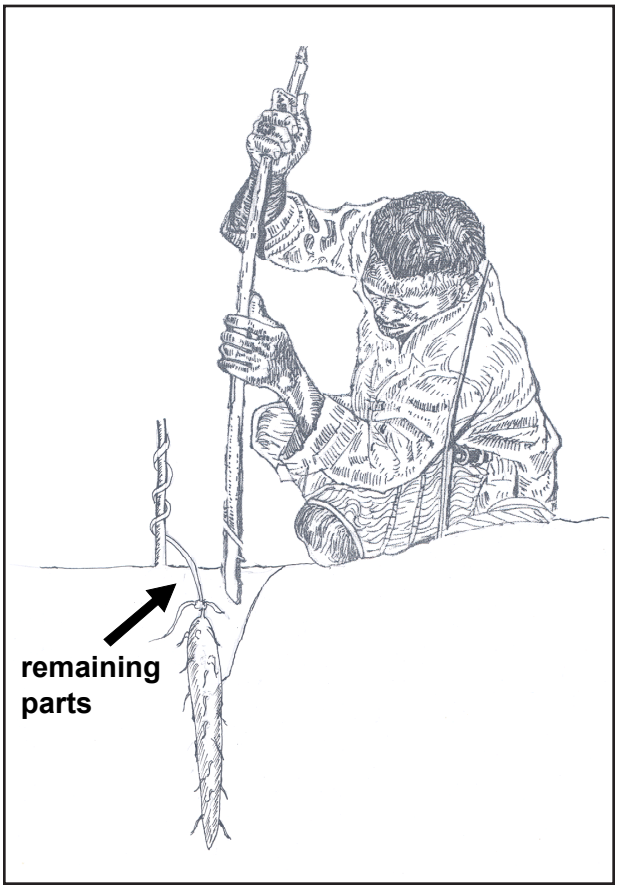

Figure 5. Harvesting *Dioscorea.* This drawing shows the digging tool and excavation of the tuber.

More information on the nutritional values of the plants the Sakai use is needed. Research on chemical compositions and pharmaceutical values of these plants must be conducted to further show the wisdom of the Sakai tribe to the world. This interesting and conservative tribe has great wisdom about living in harmony with the natural forest. They have caused so little impact on the environment around them. *Dioscorea* is a good example of the Sakai’s sustainable use of the natural products. Therefore, a good management of the protected areas where the Sakai is living is needed so that they can maintain their way of living as they have been doing for years.

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