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**ORIGINAL ARTICLE**

# Traditional knowledge of wild and semi-wild edible plants used in Bali (Indonesia) to maintain biological and cultural diversity

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**Abstract**
We report the first ethnobotanical study of wild and semi-wild food plants used by the inhabitants of the villages of Bali. Considering the urgent need to avoid the loss of this traditional knowledge, 50 informants from 13 "*Bali Aga*" villages across four districts were selected for our field investigation. Ethnobotanical data were collected through different interview methods (direct observation, semi-structured interviews, key informant interviews, individual discussions, focus-group discussions, and questionnaires). The 86 recorded species belonging to 41 families and 68 genera, including angiosperms (82) and pteridophytes (4), are categorized as wild (33) and semi-wild (53), of which 63.64% are native to Malesian, Indian, and Indochinese. Wild and semi-wild edible plants play an important role in providing the Balinese with various essential nutrients. Fourteen species (16.28%) are also used medicinally. In recent years, with the growth of the tourist industry, the wild habitats of edible plants have been severely impacted. Traditional knowledge related to wild and semi-wild edible plants is also endangered. Therefore, the management of these resources and the preservation of biodiversity along with indigenous knowledge are of primary importance.

**Keywords:** *Bali, ethnobotany, food plants, wild and semi-wild edible plants, food security*

## Introduction

Wild and semi-wild edible plants (grown or produced with no formal cultivation or human intervention) provide vegetables, fruits, staple food, and spices for indigenous people and are the main source of food in rural areas. In addition, such plants have an important role in the development of new crops through domestication, giving rise to cultivated food plants, reducing dependency on imported foods, and strengthening local food security (Jha et al. 1996; Termote et al. 2011; Uprety et al. 2012; Ranfa et al. 2013).

The consumption of wild and semi-wild edible plants has been "a way of life" for many rural populations throughout the world (Shrestha and Dhillion 2006; Ghorbani et al. 2012; Ju et al. 2013). Nevertheless, the use of wild and semi-wild edible plants is an ancient tradition that has been increasingly neglected (Cruz et al. 2013). Due to socio-economic changes, indigenous knowledge of plant uses has been eroded by globalization and modern lifestyles (Termote et al. 2011; Ju et al. 2013; Meitei and Prasad 2013). At the same time, the loss of indigenous knowledge has been discovered to be one of the major threats to the sustainability of biological diversity (Keller et al. 2005; Ju et al. 2013). Thus, documentation and evaluation of wild and semi-wild edible plants and related indigenous knowledge, carried out through ethnobotanical studies, are urgently needed to preserve biological and cultural diversity (Guarrera et al. 2005; Shrestha and Dhillion 2006; Tardío et al. 2006; Heywood 2011; Lulekal et al. 2011; Guarrera and Savo 2013; Ju et al. 2013; Luczaj et al. 2013).

Few studies have analyzed the ethnobotanical heritage of tropical areas, and the only documentation that exists of this kind regarding Bali is a study of medicinal plants (Leurs 2010). The richness and complexity of the chosen area's culture and wildlife make it an interesting subject (Agung 2005), along with the fact that its ancient culture is being rapidly

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lost to tourism and modernization. Therefore, considering the urgency of avoiding the loss of such traditional ethnobotanical knowledge (TEK), with its potential for sustainable development, we aim to analyze botanical data and the applicative potential of wild and semi-wild edible plants.

## Materials and methods

### *Study area*

Within Bali Island, we selected 13 Bali *Aga* villages, inhabited by families who had lived in Bali for many generations, and are therefore representative of the TEK present on the island. Ethnic group of 13 Bali *Aga* villages belongs to Bali *Aga* people (Astuti et al. 2000). These villages have populations which vary between 2000 and 5000 and are the oldest, best known, and most representative of the west and east of the island. Geographically, these villages belong to the districts of Buleleng (1365.88 $km^2$), Bangli (520.81 $km^2$), Tabanan (839.33 $km^2$), and Karangasem (839.54 $km^2$) (Badan Pusat Statistik 2013) (Figure S1).

Bali has a complex orography, with Mount Agung in the Karangasem District reaching an altitude of 3142 m, giving rise to a variety of bioclimatic conditions. In general, the island has a sub-humid tropical climate, with yearly average temperatures of 31°C, with wide variations according to altitude. Rainfall also varies between districts and seasons. Buleleng District has the lowest annual rainfall, 1182 mm, and the highest annual rainfall of 3696 mm is in Tabanan District. The rainy season occurs between November and April, with the dry season between May and October (Badan Pusat Statistik 2013).

In addition to cultural values and traditions, Bali has a rich biological diversity. The flora of Bali is characterized by 1595 species of Spermatophyta, 173 species of Pteridophyta, and 169 species of Bryophyta (Girmansyah et al. 2013).

### *Field survey and data collection*

Field studies were carried out from May to July 2013. Interviews were conducted in both Balinese language and Indonesian language, and we provided vernacular names of the plants according to the information obtained from the local inhabitants. The 50 interviewed informants (three to four per village) were made up of 45 males and 5 females, with ages between 14 and 78 years. Ethnobotanical data was collected using different interview methods (direct observation, semi-structured interviews, key informant interviews, individual discussions, focus-group discussions, and questionnaires) (Alexiades & Sheldon 1996; Ju et al. 2013).

Specimens were identified by the authors and other taxonomists and deposited in the Herbarium of the Hortus Botanicus Baliense, Bali Botanical Garden. The scientific nomenclature used in this paper was derived from pre-existing databases (The Plantlist 2014), and chorological information was also obtained and applied to the present study (Blume 1828; Zollinger & Moritzi 1845; Nakai 1933; Kunkel 1984; Heyne 1987; Dransfield & Manokaran 1994; Faridah & van der Maesen 1997; Kepler 1999; Kelvin et al. 2001; Chen et al. 2002; Grubben & Denton 2004).

A checklist of different wild and semi-wild edible plant-use categories (fruits, vegetables, staple foods, spices, and edible seeds) was developed and used to determine which species were used and for what purposes (Uprety et al. 2012). Wild refers to the plants that are growing or produced without cultivation or the care of human, and semi-wild refers to partially wild (Menendez-Baceta et al. 2012). Semi-wild plants mostly include native species growing in their natural habitat, but sometimes managed (e.g., *Arenga pinnata* and *Colocasia esculenta*), as well as introduced species that have been naturalized (e.g., *Psidium guajava*) (Astuti et al. 2000).

Data were grouped into the following categories of edible plants based on folk perceptions: “vegetables”, plants whose leaves, fruits, or seeds were consumed; “edible fruits”, plants whose fruits were consumed when ripe; “staple foods”, plants whose tuberous roots were consumed to provide a large proportion of energy requirements; “spices”, plants whose fruits, barks, leaves, and tuberous roots were used for flavoring; “edible seeds”, plants whose seeds were consumed; “additional use(s)”, general medicinal use.

Nutritional properties and bioactive compounds for each plant were verified in scientific literature, considering reviews on plants for human consumption (e.g., Kunkel 1984), pharmacological studies (e.g., Pongprayoon et al. 1991; Haruenkit et al. 2007; Gunjan et al. 2011; Saxena et al. 2013), and toxicity studies (e.g., Kunkel 1984; Matheson & Robins 1992).

## Results and discussion

### *Wild and semi-wild edible plant diversity*

The 86 species recorded include Angiosperms (82), and Pteridophytes (4) (Table SI), categorized as wild (33) and semi-wild (53), of which 37.01% are native to Malesian, 18.18% native to Indian, 8.44% native to Indochinese, 3.90% native to the Caribbean, and 3.25% native to Madagascan (Figure S2). Details of usage and chorological type are given in Table SII. Food-related gymnosperms were not found in this study.

Ethnobotanical food plants belong to 41 families and 68 genera, most species are Fabaceae (6), Rosaceae (6), Euphorbiaceae (5), Arecaceae (5), Myrtaceae (5), Moraceae (4), and Araceae (4). The genera represented by the highest number of species are *Rubus* (6), followed by *Syzygium* (4) and *Dioscorea* (3). The dominant life forms are trees (39%), followed by climbers (21%), perennial herbs (20%), shrubs (19%), and woody climbers (1%).

The most frequently used parts are fruits, leaves, tuberous roots, seeds, and young leaves (Figure S3). Most plants are collected throughout the year. Most uses are specific to a particular plant part (such as fruit, leaf, tuberous root, seed, and young leaf), although in a few cases a single plant part has multiple uses, e.g., the bark of *Cinnamomum burmanni* is used as a spice or as an ingredient in herbal drinks.

More than one plant part is used for about 28% of the species. For example, young fruits and seeds of *Artocarpus heterophyllus* (breadfruit) are used as a vegetable, while leaves are used in a herbal drink. The inner stems of *Arenga pinnata* are used as a staple food, while the roots are used in a herbal drink, and its fruit is eaten fresh.

The fruit and leaves of *Moringa oleifera*, *Averrhoa bilimbi*, *Averrhoa carambola*, and *Cucurbita moschata* are used as vegetables. The young leaves of *Zingiber purpureum* are used as a vegetable and the tuberous roots as a condiment. The fruits of *Tamarindus indica* and *Solanum nigrum* are eaten fresh, and the leaves are consumed as a vegetable. Overall, fruit (35%) and vegetable (34%) are the categories that have most uses, followed by the categories of additional use (13%) and staple food (9%) (Figure S4). Fruits are often eaten fresh, green leafy vegetative parts (e.g., leaves, young leaves, tip leaves, and stems) are usually boiled, cooked, or added to soups, and less commonly are used fresh in salads. All these parts are used as ingredients for *Lawar* (mixed vegetables), which is very popular among the Balinese.

Edible wild and semi-wild plants play an important role in providing the inhabitants of Bali with various essential nutrients, such as vitamins and minerals needed to maintain health and improve immunity to diseases (Ju et al. 2013). For example, a well-known traditional Balinese dish is a *jukut undis* soup with red rice, which is the seeds of *Cajanus cajan*, reported to have low cholesterol, high dietary fiber, protein, carbohydrate, minerals, and thiamine (USDA 2014).

### *Multiple uses of wild, semi-wild and cultivated edible plants*

In addition to edible use, 16.28% of plants recorded (14 species) have additional uses (Table SII). Such species are common in rural areas and important to local communities. They not only balance the nutritional value of starchy diets (compensating for the lack of some vitamins, proteins and minerals), but may also provide pharmacologically active compounds. These multiple uses prove the importance of these plants for subsistence and as a part of the local cultural heritage (Shrestha and Dhillion 2006; Ju et al. 2013).

Fourteen species are used as medicines to treat urolithiasis, heartburn, removal of waste products from the blood, body odor, skin allergies, fluor albus, sprue, rheumatism, headache, hypertension, sore throat, cough, diarrhea, fever, and to stimulate the appetite. For example, the decoction of leaves of *Cinnamomum burmanni* is used to treat heartburn, fever, cough, sore throat, hypertension, and to stimulate the appetite.

Wild and semi-wild edible plants can provide resources for future development of new health foods. As living standards rise, there is an increasing global demand for healthy and safe food (Zou et al. 2010). Compared to cultivated vegetables, wild and semi-wild food plants require less maintenance, are not affected by pesticide pollution, and are a rich source of micronutrients (Ju et al. 2013).

Six species have cultural significance in a religious rite named *banten*, during which specific plants are used as ornamentation. These are *Colocasia esculenta*, *Arenga pinnata*, *Borassus flabelifer*, *Dioscorea hispida*, *Aleurites moluccana*, and *Pangium edule*. This rite plays an important role in the daily life of the people of Bali, and it is said that the *banten* is not only able to purify the soul, but it is also believed that it protects and preserves food supplies. The Balinese use the *Banten* rite to pray for happiness, prosperity, a good harvest, and good fortune.

### *"Most preferred" species and their commercial potential*

Aside from having importance as a food source, the species recorded provide the inhabitants of rural areas with the possibility of limited cash opportunities that supplement their household income (Meng et al. 2006; Ju et al. 2013). *Colocasia esculenta*, *Artocarpus heterophyllus*, *Piper betle*, and *Zingiber purpureum* are the most frequently mentioned vegetable. In Bali, the leaves of these four species are eaten as a vegetable. They are added to soups, stir-fried, or eaten together with other vegetables. Several studies have focused on a nutritional analysis of these plants and found that they contained carbohydrates, protein, vitamin C, vitamin A, dietary fiber, low fatty acids, and mineral elements in quantities comparable with some common vegetables (Pradhan et al. 2013; USDA 2014). Although local people do not use it as a medicine, *Artocarpus heterophyllus* is recorded as an ingredient in

herbal drinks since ancient times. For instance, their leaves are used to treat diarrhea, and young fruits and seeds also have commercial value and prices at the traditional market varied from 7000 IDR (Indonesian rupiah) to 10,000 IDR (ca. 1 USD = 12,000 IDR) per kilogram (fresh weight) from April to December.

Other preferred plants (mentioned by more than 50% of respondents) include *Arenga pinnata*, *Dioscorea hispida*, *Cajanus cajan*, *Cinnamomum burmanni*, *Moringa oleifera*, *Psidium guajava*, and *Diplazium esculentum*. All these plants are collected mainly in forest areas by local people and sold at traditional markets, providing local people on low incomes with a chance to increase their income.

Another renowned edible fruit, known as *gunggung*, includes six species: *Rubus alpestris*, *R. calycinus*, *R. chrysophyllus*, *R. fraxinifolius*, *R. lineatus*, and *R. rosaefolius*. Its fruit is collected mostly between November and April. When young they are sour but rich in vitamin C and minerals and low in fat (USDA 2014). One local industry already exploits the fruit of *Rubus rosaefolius* commercially.

In the present study, we found that taste and availability are the principal criteria for all types of edible plants, in agreement with other surveys (Dansi et al. 2008). However, taste itself is not enough to build a reliable list of priorities for future conservation, domestication, and exploitation. Furthermore, detailed nutritional analyses and phytochemical studies should be carried out to comprehensively evaluate food and nutraceutical values of the "most preferred" plants, and provide scientific and critical information (Ju et al. 2013).

It is generally believed that local people are more likely to support and participate in conservation initiatives if they benefit directly from such efforts (Acharya & Acharya 2010; Ju et al. 2013). If managed sustainably, these plants can be a good source of income for rural communities. Some species are becoming rare on the island of Bali, although there were rich resources 20 years ago (Astuti et al. 2000; Leurs 2010). Land use changes were observed and identified as causes of decline for *Amorphophallus campanulatus*, *Arenga pinnata*, *Borassus flabellifer*, *Antidesma bunius*, *Sandoricum koetjape*, *Artocarpus elasticus*, *Syzygium polycephalum*, *Averrhoa bilimbi*, and *Paederia scandens*. Because few people in this area are aware of sustainable land use management, conservation of these plants should be undertaken both *in situ* and *ex situ*.

### *Interesting species to study from a nutritional and/or pharmacobotanical point of view*

Of the botanical species listed in Table SII, 10 species (indicated with an *) are not reported in Kunkel's checklist on edible plants of the world (Kunkel 1984), and these species should be the subject of further in-depth investigations. Moreover, a certain number of plants have not been thoroughly studied for their nutritive value or from a pharmacobotanical point of view. Among these, we can cite *Dendrocnide stimulans*, *Diplazium repandum*, *Elsholtzia elata*, *Heliconia wagneriana*, *Musa brachycarpa*, *Nicolaia speciosa, Pneumatopteris callosa*, *Rubus lineatus*, *Schleichera oleosa*, and *Syzygium polycephalum*. For other species, we have little information, e.g., *Amomum maximum*, *Cicca acida*, *Cinnamomum burmanni*, *Citrus amblycarpa*, *Euchrestia horsfieldii*, *Flacourtia inermis*, *Pangium edule*, *Rubus alpestris*, *R. calycinus*, *R. fraxinifolius*, *R. rosaefolius*, *Syzigium polyanthum*, and *Trevesia sundaica*.

Some fruits are very interesting in that they contain powerful antioxidant compounds, e.g., xanthones in *Garcinia dulcis* and *G. parvifolia* (Haruenkit et al. 2007). Other plants have additional properties, e.g., antidiabetic in *Cajanus cajan* (Gunjan et al. 2011), anti-inflammatory in *Ipomea pes-caprae* (Pongprayoon et al. 1991), and anti-mutagen in *Syzygium cumini* (Saxena et al. 2013).

### *Potentially toxic species*

Caution should be taken regarding the consumption of some species containing toxic compounds, e.g., *Gynura* spp. (*Asteraceae*, group *Senecioneae*) for the presence of toxic pyrrolizidine alkaloids (Matheson & Robins 1992), *Solanum nigrum* which contains toxic alkaloids, like solanin, *Euphorbiaceae* for caustic latex, and some ferns (*Blechnum orientale* and *Diplazium* spp.) which contain anti-vitamins. According to Kunkel (1984) some plant parts should be ingested in small amounts (e.g., the tuberous roots of *Coleus parviflorus*, and the nuts of *Aleurites moluccana*, perhaps better roasted). Other warnings regard the tuberous roots of *Dioscorea hispida*, which are toxic unless soaked in saltwater. *Pangium edule* is considered a poisonous species, although its seeds are said to be eaten after prolonged soaking or being buried for a long period (Kunkel 1984).

### *Wild and semi-wild relatives of crop plants for genetic improvement and crop production*

It has been estimated that, globally, there are around 216,000 wild relatives of crop species and among these only 1200 are primary and secondary relatives, although these estimates rely largely on European and Mediterranean flora, and many other parts of the world have yet to be explored (Maxted and Kell 2009; Uprety et al. 2012). Wild and semi-wild crop relatives, which are species that are closely related to crops and include crop progenitors, may provide genes with a higher resistance to adverse circum-

stances which could prove particularly important in response to global climate change (Hajjar and Hodgkin 2007; Maxted and Kell 2009; Uprety et al. 2012; Ju et al. 2013). They are also of great significance in maintaining the productivity and stability of traditional agro-ecosystems (Harlan 1965; Meilleur and Hodgkin 2004; Ju et al. 2013). Their conservation will ensure that genetic resources are preserved so as to enhance food security (Pandey et al. 2008; Ford-Lloyd et al. 2011; Uprety et al. 2012; Ju et al. 2013). Biodiversity and indigenous knowledge inventories are the starting point for both *in situ* and *ex situ* conservation campaigns which can provide critical baseline data for the assessment and monitoring of biodiversity (Blasi et al. 2005; Heywood et al. 2007; Ju et al. 2013).

Some species recorded in this study can be identified as wild and semi-wild relatives of vegetable crops (e.g., *Blechnum*, *Coccinia*, *Diplazium*, *Gynura*, *Ipomoea*, *Momordica*, *Piper*, and *Sauropus*), fruit crops (e.g., *Acanthus*, *Antidesma*, *Areca*, *Borassus*, *Elaeocarpus*, *Flacourtia*, *Rubus*, *Schleichera*, and *Syzygium*), and spice and staple food crops (e.g., *Alocasia*, *Amomum*, *Arenga*, *Cinnamomum*, *Coleus*, *Colocasia*, *Dioscorea*, and *Nicolaia*). Due to their advantageous traits, such as high adaptability and longevity, resistance to disease, and tolerance to drought and flood, they can constitute a genetic resource for improved cultivation techniques.

## Conclusion

This first study of the ethnobotany of wild and semi-wild food plants shows that, as well as planting a variety of plants, the inhabitants of Bali also gather wild and semi-wild edible plants as food. The most frequently used were fruits, followed by leafy vegetables, and tuberous roots. These edible plants provide food and nutrition, such as essential amino acids, vitamins, and minerals, for local communities to stay healthy and boost immunity against disease and infection. If managed properly, they can be valuable sources of income for local people because of their popularity and tradability at traditional markets.

In addition to food value, more than 16% of the plants were recorded as having medicinal uses which are an important part of Bali's indigenous culture, and some plants can provide useful genes for crop improvement that could have significant consequences for global food security. However, along with economic development, multi-value resources are threatened by human activities, and the associated local knowledge erodes quickly. Therefore, the management of these resources and the preservation of biodiversity as well as of indigenous knowledge are of the utmost importance.

## Supplementary material

Supplementary material for this article is available online.

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## Notes

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