AGRITROPICA
Journal of Agricultural Sciences

Content available at:
https://ejournal.unib.ac.id/index.php/jagritropica/index
ISSN (PRINT) 2621-217X ISSN (ONLINE) 2621-699X

Wild World of Wild Food Plants in Cambodia: The Utilization, Challenges, and Opportunities to Scaling up the Use of Wild Food Plants

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ABSTRACT: Underexploited wild food plant (WFP) species have a high potential to contribute to nutritional and/or medicinal health, generate income and sustain the environment. The objective of this study was to identify market-available WFP species and characterize their beneficial use and economic values in northwestern Cambodia. Two hundred seventy-five (275) retailers in Battambang and Siem Reap were interviewed to collect data on wild food plant species availability and their values. Thirty-four (34) plant species were identified as WFP species, including annual and perennial herbs, perennial shrubs, vines, and trees. Leave, shoots, stems, rhizomes, corms, flowers, and fruits were the parts of the plant used for cooked dishes. Most of the parts used (92.4%) were collected from the wild, while 7.6% were reported as cultivated. The plant species are high in vitamin A, C, a good source of minerals, and can be used as traditional medicine. To enhance health and alleviate the 'hidden hunger' of micronutrient malnutrition, Cambodia should promote the production and dietary incorporation of wild food plants rich in minerals and vitamins.

Keywords: Perennial vegetables, neglected and underutilized plant species (NUS), nutrition.

Reference to this paper should be made as follows:
Seav, S., Lo, S., Ry, S., Ngang, C., Pok, P., Pekarcik, C. G., Huot, S., Ader, D., Bates, R., and Srean, P. 2021. Wild world of wild food plants in Cambodia: the utilization, challenges, and opportunities to scaling up the use of wild food plants. *Agritropica: Journal of Agricultural Science.* 4 (2): 102-113. Doi: https://doi.org/10.31186/Jagritropica.4.2.102-113

INTRODUCTION

To meet the expected rise in global food demand we need robust and resilient agriculture systems. This means increased reliance on strategies such as the use of diverse and regionally adapted species for food production. About 150 crop species out of 30,000 edible plant species are produced at a global scale, and only 103 crop species provide 90% of the world's plant food supply (Prescott-Allen and Prescott-Allen 1990). Agricultural biodiversity (agrobiodiversity) is a key for food and nutrition security; however, due to loss of agrobiodiversity in farming systems, and modern food is preferred by young generations and those who live in urban areas while wild food plants (WFP), or neglected and underutilized plant species, are largely ignored (Tshin 2016). Perennial crops have been proposed as a multifunctional approach to address environmental and other challenges in agriculture due to their many benefits (Pimentel et al. 2012; Toensmeier et al. 2020). In Cambodia, diversifying smallholder farms via the use of nutritious and climate-hardy underutilized plant species is at the core of this effort, particularly during food gaps of drought and flood periods. Underexploited WFP species have a high potential to contribute to nutritional and/or medicinal health, generate income, and sustain the environment. There is limited study on characterization of how these diverse species integrate (both individually and as wild gardens) with local food systems in specific geographic regions (Eissler et al. 2020). Thorng et al. (2015) have described 32 WFP species in northeastern Cambodia, including 17 species of wild edible fruits, 8 species of wild vegetables, and 7 species of root and tuber plants. These species are traditionally an important supplement to household diet and serve as a source of vitamins and minerals. Consumption of locally available fruits, vegetables, roots, and tubers can improve nutrition and complement current strategies to combat malnutrition (Kahane et al. 2013). The use of WFP can be an effective tool for diversifying smallholder food systems resulting in improved nutrition and cash income generation. The objective of the study was to identify market-available WFP species and to characterize their beneficial use and economic values in northwestern Cambodia.

MATERIALS AND METHODS

A field survey was conducted in the northwest region of Cambodia between 24th and 31st July 2020. Two hundred seventy-five (275) retailers from seven markets in Battambang and seven markets in Siem Reap provinces were selected and interviewed to collect data on wild food plant species availability and their values in the markets (Table 1).

Table 1. Study areas of the fourteen markets in Battambang and Siem Reap provinces.

No.	Target areas	Market names	No. of respondents
1	Battambang	Boeung Chhouk Martket	14
2		Central Market	19
3		Phu Poy Martket	24
4		Anlong Vil Martket	19
5		La Ey Baitang Martket	16
6		Thmey Market	23
7		Ek Phnom Martket	20
8	Siem Reap	Leu Martket	35
9		Krom Martket	34
10		Samaki Martket	16
11		Chas Martket	11
12		Derm Krolanh Martket	24
13		Nhae Martket	13
14		Phum Pheak Martket	7
	Total		**275**

A survey tool was designed to investigate WFP species selling at the markets and their value in northwest Cambodian following a structured interview design. The questionnaires were created with an online software developed by the Harvard Humanitarian Initiative to serve as a "suite of tools for field data collection" (KoBoToolbox 2020). Parts used of the WFPs observed were identified for their botanical taxonomic species, totally, thirty-four species; and then categorized into herb, shrub, vine, and tree by annual or perennial crop.

To understand the connection to diet, nutritional data on energy, protein, vitamin A, vitamin C, iron, and zinc of the thirty-four species were derived from published data. Three out of the thirty-four species such as *Amomum kravanh, Feroniella lucida,* and *Garcinia oliveri* were unavailable data. Fruits of *Feroniella lucida*, stems of *Amomum kravanh*, and leaves of *Garcinia oliveri* were sampled for protein, vitamin A, vitamin C, and moisture content analysis at the Science, Technology, and Innovation National Laboratory in Phnom Penh, Cambodia. Standard methods were applied for the chemical component analysis, AOAC 960.52, ISO 1871 for protein, AOAC 935.29, 925.40 for moisture (AOAC, 1995), and Titration method (Ullah, 2012) for vitamin C.

The data collected were described and the frequency of plant species was plotted, to illustrate their patterns. All the plots were performed using 'ggplot2' package in R statistical software of version 3.6.3 (R Core Team 2020).

RESULTS AND DISCUSSION

Thirty-four (34) plant species were observed at the 275 retailers, selling in the fourteen markets in Battambang and Siem Reap, Cambodia (Table 2). These species were identified as wild food plants (WFP), including annual and perennial herbs, perennial shrubs, vines, and trees. Parts of these plants such as leaves, shoots, stems, rhizomes, corms, flowers, and fruits were used in cooked dishes. The parts used of WFP for selling at the markets were mainly collected from the wild (92.4%); only 7.6% were reported as cultivated (2.7% in Battambang and 4.9% in Siem Reap). Thirty-one out of the thirty-four plant species were perennial crops, most of them were terrestrial plants and only five species were aquatic plants.

Table 2. Wild food plant species observed at the markets in northwest Cambodia.

No.	WFP Category	Scientific name	Common name	Parts used
1	Annual herb	*Amaranthus palmeri*	Carelessweed	Leaves
2		*Cleome gynandra*	Shona cabbage	Leaves
3		*Psophocarpus tetragonolobus*	Winged bean	Fruits
4	Perennial herb (Aquatic plants)	*Limnophila aromatica*	Finger grass	Leaves
5		*Marsilea quadrifolia*	Four-leaf clove	Leaves
6		*Nelumbo nucifera*	Lotus	Shoots
7		*Neptunia oleracea*	Water mimosa	Leaves
8		*Nymphaea caerulea*	Water lily	Stems
9	Perennial herb	*Alpinia galanga*	Galanga	Rhizomes
10		*Amomum kravanh*	Cardamom	Stems
11		*Colocasia esculenta*	Taro	Corms
12		*Curcuma longa*	Turmeric	Rhizomes
13		*Ipomoea aquatica*	Morning glory	Shoots
14		*Musa sapientum*	Banana	Fruits
15		*Oenanthe javanica*	Java water dropwort	Leaves
16		*Zingiber officinale*	Ginger	Rhizomes
17	Perennial shrub	*Cnidoscolus aconitifolius*	Chaya	Leaves
18		*Ocimum tenuiflorum*	Holy basil	Leaves
19		*Sauropus androgynus*	Katuk	Leaves
20		*Acacia pennata*	Climbing wattle	Leaves
21	Perennial vine	*Aganonerion polymorphum*	River leaf	Leaves
22		*Basella alba*	Malabar spinach	Stems/Leaves
23		*Coccinia grandis*	Ivy gourd	Leaves
24		*Telosma cordata*	Chinese violet	Flowers
25	Perennial tree	*Azadirachta indica*	Neem	Flowers

26	*Feroniella lucida*	Krasang	Leaves
27	*Garcinia oliveri*	Tromoung	Leaves
28	*Garcinia schomburgkiana*	Madan	Fruits
29	*Leucaena leucocephala*	White leadtree	Leaves
30	*Morinda citrifolia*	Noni	Leaves
31	*Moringa oleifera*	Moringa	Leaves
32	*Phyllostachys edulis*	Bamboo	Shoots
33	*Sesbania grandiflora*	Vegetable hummingbird	Leaves/Flowers
34	*Tamarindus indica*	Tamarind	Leaves

The parts used of the WFP were observed included leaves, fruits, young shoots, stems, rhizomes, corms, and flowers. Among these parts used, leaves were frequently found for the most plants; except for perennial herbs, where rhizome represented about the half (Fig. 1).

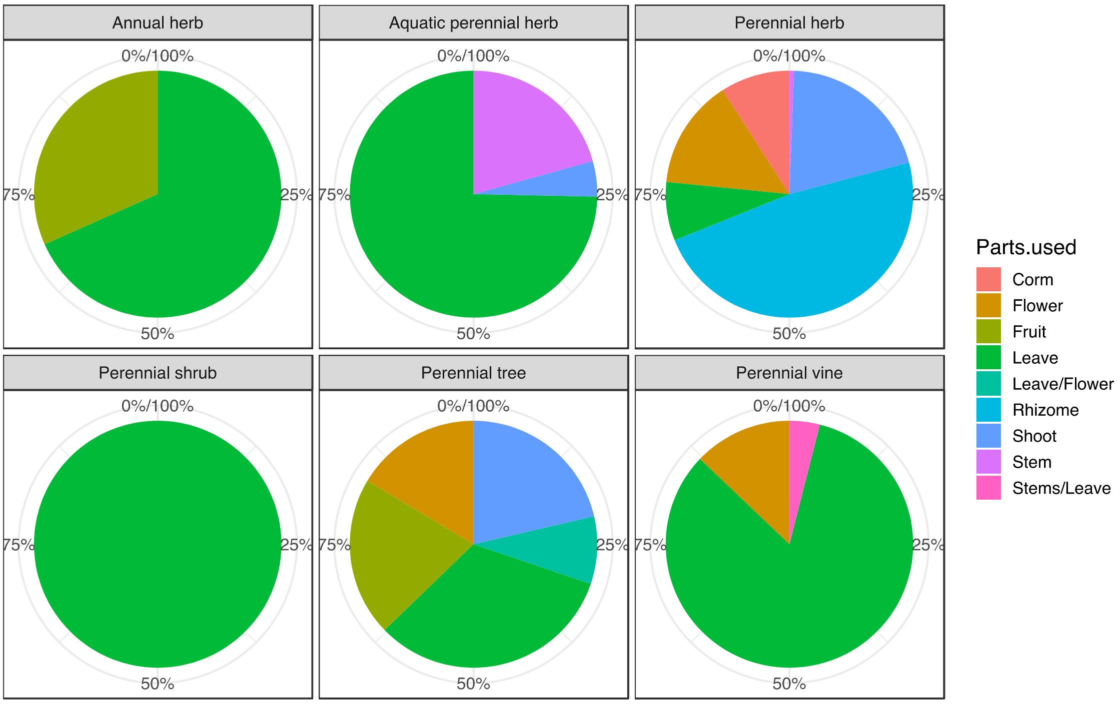

Fig. 1. Plant form and parts used for wild food plant species selling at the 275 stores of the markets in the northwest Cambodia.

The WFP species availability is presented in Fig. 2, showing from low to high frequencies observed in Battambang and Siem Reap. Interestingly, some species including Tromoung, Java waterdropwart, Kantuk, Carelessweed and Finger grass were more frequently observed in Siem Reap than in Battambang, whereas Sesbania, Tamarind, Ivy gourd, Bamboo shoots and Climbing Wattle were more frequently observed in Battambang than in Siem Reap.

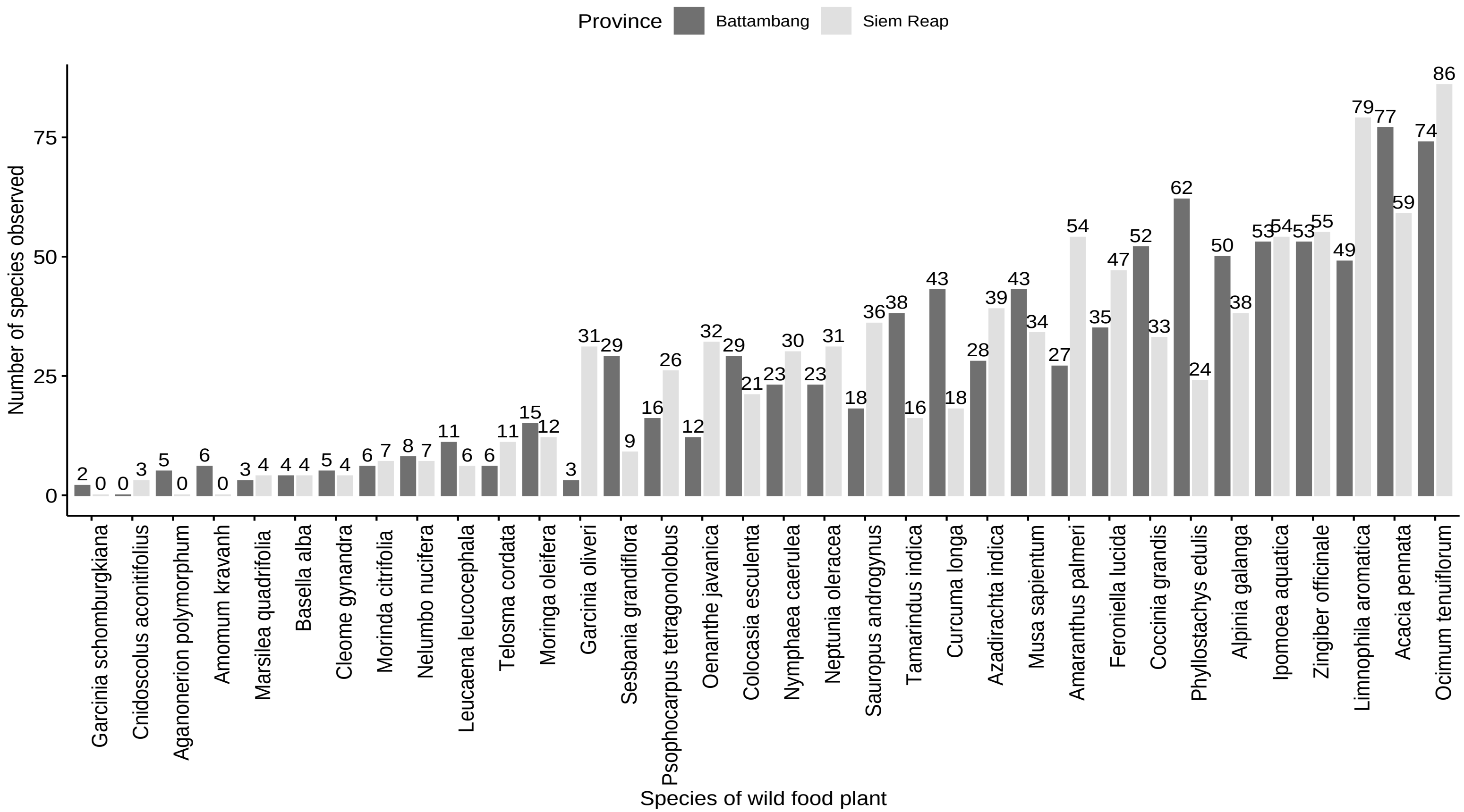

Fig. 2. Wild food plant species observed at 275 vegetable stores of the markets in northwest Cambodia.

As for the economic value of the WFP species, results show that their values were negatively correlated with their availabilities, indicating that higher values were given to those that were less available in the market (Fig. 3). Parts used of the WFP species were more available in the rainy season, compared to the dry season (Fig. 4). Sixteen out of the thirty-four plant species were considered rare plant species throughout the year.

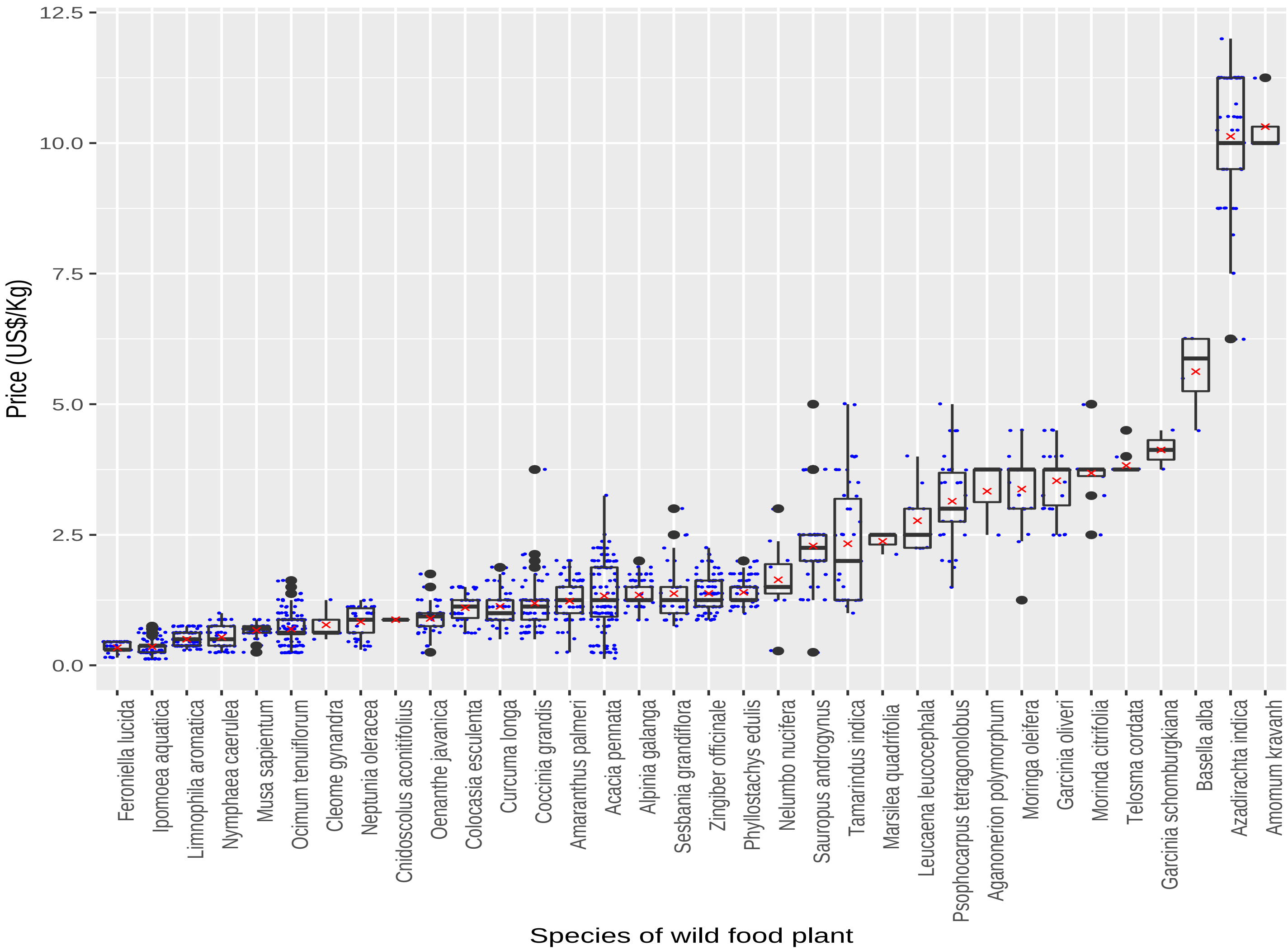

Fig. 3. Boxplot of the price of wild food plants selling at the markets in northwest Cambodia. The blue dots indicated the frequency of each wild food plant species and the red crosses in the boxplots indicated mean values of the price per kg of each species.

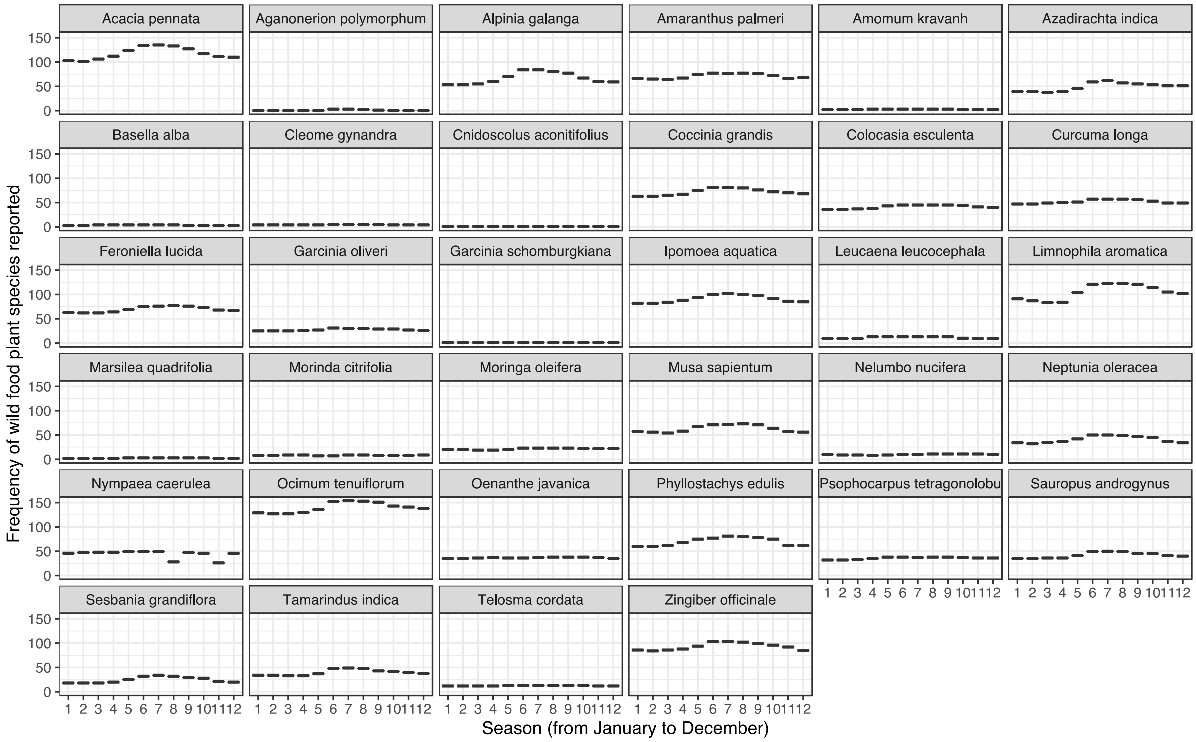

Fig. 4. Seasonal wild food plants are available at the markets in northwest Cambodia. Note: the axis label with 1 to 12 indicates month: January to December.

Thirty-four botanical taxonomic species of the market-available WFP species observed are annual and perennial herbs, perennial shrubs, vines, and trees. Of these, some species are geographic region dependent. Plant leaf was the most preferred part used in cooked dishes, followed by shoot, stem, rhizome, corm, flower, and fruit. Their availability indicates the economic value, the rarer WFP parts have higher economic values in the market. This study found that of the WFP species which are wildly grown, 19 out of 34 WFP species are rare species and unvaried with seasonal changes in available amounts selling at the market. Those with less availability had a higher price per unit. The WFP species collected from the wild, are considered neglected and underutilized plant species (NUS) and are typically referred to as 'non-timber forest products (NTFP) that have adapted to particular, often local environments.

Nutritional value

The nutritional values of the selected WFP were present in Table 3, to understand the connection to diet. The nutritional data analyzed for *Amomum kravanh, Feroniella lucida,* and *Garcinia oliveri* were combined with the available published data. For example, leaves and young shoots of the WFP are usually boiled or used to prepare soups. These plants are high in beta-carotene (vitamin A), vitamin C and a good source of minerals (iron and zinc), e.g., *Amaranthus palmeri, Basella alba, Cleome gynandra, Psophocarpus tetragonolobus, Sauropus androgynus,* and *Senegalia pennata*. Some plants contain essential amino acids, which enhance the efficient digestion, absorption, and use of nutrients from food and other herbs, which can be potential nutritional-medicinal-economic contributions of WFP. The WFP can also be used to enhance health and alleviate the 'hidden hunger' of micronutrient malnutrition by promoting

Table 3: Nutrition values of the wild food plant (WFP) species per 100 g edible portion.

Scientific name	Local name	Edible part	Moisture (%)	Energy (KJ)	Protein (g)	Vit. A (µg)	Vit. C (mg)	Iron (mg)	Zinc (mg)	Ref.*
Amaranthus palmeri	Phaty	Leaves	91.7	96.0	2.5	292.0	43.3	2.3	0.9	[1]
Aganonerion polymorphum	Voi-thneoung	Leaves	85.3	122.0	3.5	n.a	26.0	n.a	n.a	[2]
Alpinia galanga	Ramdeng	Rhizomes	85.9	213.5	1.0	n.a	n.a	2.1	n.a	[1]
		Leaves	n.a	n.a	0.5	n.a	n.a	n.a	n.a	
Amomum kravanh	Kravanh	Stems	89.5	n.a	1.5	n.a	80.0	n.a	n.a	[#]
Azadirachta indica	Sdao	Flower	9.3	n.a	17.3	1,255	n.a	n.a	n.a	[3]
Basella alba	Chunlung	Leaves	90.4	117.0	3.4	2,213	79.8	10.9	0.5	[4]
Cleome gynandra	Mormeanh	Leaves	85.0	180.0	4.8	2,603	64.0	2.6	0.76	[4]
Cnidoscolus aconitifolius	Chaya	Leaves (boiled)	n.a	15,400.0	17.2	n.a	n.a	39.4	36.3	[5]
Coccinia grandis	Sloekbaas	Leaves	n.a	n.a	14.6	70,000	25.6	2.2	n.a	[6]
Colocasia esculenta	Trav	Corms	66.8	1,231.0	1.96	3.0	5.0	0.68	3.2	[1]
		Leaves	85.0	210.0	5.0	57.0	90.0	0.62	0.7	
		Leaf stalk	93.0	101.0	0.5	180.0	13.0	0.9	n.a	
		Leaf (cooked)	92.2	92.2	2.7	424.0	35.5	1.2	0.2	
Curcuma longa	Romiat	Rhizome	11.4	1,481.1	7.8	0.0	25.9	41.4	4.4	[2]
Feroniella lucida	Crasang	Fruit	67.6	n.a	2.0	n.a	220.0	n.a	n.a	[#]
Garcinia oliveri	Tromoung	Leaves	82.4	n.a	1.6	n.a	210.0	n.a	n.a	[#]
Garcinia schomburgkiana	Sandan	Fruits	n.a	n.a	0.3	129.3	5.0	n.a	n.a	[7]
		Leaves (young)	n.a	n.a	7.3	67.5	16.0	n.a	n.a	
Ipomoea aquatica	Trakuon	Leaf	90.3	126.0	3.9	315.0	60.0	4.5	n.a	[1]
		Leaf (boiled)	92.9	84.0	2.1	n.a	16.0	1.3	0.2	
Leucaena leucocephala	Kathomthet	Leaves	79.5	284.0	8.4	n.a	n.a	9.2	n.a	[2]
Limnophila aromatica	Ma-om	Leaves	94.9	1,037.6	10.0	n.a	n.a	n.a	n.a	[2]
Marsilea quadrifolia	Juntolphnom	Leaves	84.2	105.0	4.6	n.a	76.0	n.a	n.a	[2]
Morinda citrifolia	Nhoi	Fruit	86.1	160.0	0.8	n.a	56.0	1.1	n.a	[2]
Moringa oleifera	Marom	Leaves	76.4	302.0	5.0	197.0	165.0	3.6	n.a	[1]
		Flower	84.2	205.0	3.3	n.a	n.a	5.2	n.a	
		Leaf (boiled)	87.0	189.0	4.7	40.0	31.0	2.0	0.2	
		Pod (raw)	88.2	155.0	2.1	4.0	141.0	0.4	0.5	
		Seed	6.5	n.a	46.6	n.a	n.a	n.a	n.a	
Musa sapientum	Chek	Fruit	73.0	n.a	1.2	2.9	17.9	2.3	2.1	[4]
Nelumbo nucifera	Chhouk	Seed	38.8	545.0	8.8	2.0	3.0	8.0	0.2	[2]
		Root (boiled)	81.4	267.0	1.6	0.0	27.4	0.9	0.3	
		Seed (dry)	12.7	1,440.0	16.3	3.0	0.0	5.6	1.1	
		Seed (green)	80.8	312.0	74.0	4.1	0.0	1.0	0.3	
Neptunia oleracea	Kanhchhet	Leaves	88.0	142.0	5.2	114.0	n.a	3.0	n.a	[1]
Nymphaea caerulea	Bralet	Root	89.0	332.0	4.6	n.a	n.a	n.a	n.a	[2]
Ocimum tenuiflorum	Marahprov	Leaves	n.a	125.5	n.a	n.a	25.0	n.a	15.1	[8]
Oenanthe javanica	Phlovkangkeb	Leaves	90.6	117.0	1.8	40.0	6.0	3.0	0.5	[2]
Phyllostachys edulis	Tompang	Shoots (raw)	91.0	113.0	2.6	2.0	4.0	0.5	1.1	[2]
		Shoot (boiled)	n.a	n.a	1.5	n.a	n.a	0.2	n.a	
Psophocarpus tetragonolobus	Porpeay	Seed	8.5	1,764.0	41.9	0.0	n.a	15	4.5	[1]
		Pod (fresh)	92.0	105.0	2.1	n.a	n.a	n.a	n.a	
		Leaf	95.0	197.0	5.0	809.0	30.0	6.2	1.3	
		Seed (young)	87.0	205.0	7.0	13.0	18.3	1.5	0.4	
		Root	57.4	619.0	11.6	0.0	0.0	2.0	1.4	
Sauropus androgynus	Ngob	Leaves	81.0	244.0	4.8	133.0	85.0	2.7	n.q	[2]
Senegalia pennata	Sa-om	Leaves	82.4	239.0	10.5	108.0	58.0	2.5	0.5	[2]
Sesbania grandiflora	Angkeadei	Flowers	89.0	92.0	1.8	0.0	59.0	0.6	n.a	[1]
		Seed	10.4	n.a	68.2	n.a	n.a	n.a	n.a	
Tamarindus indica	Ampel	Fruit	38.7	995.0	2.3	20	60	1.1	0.7	[1]
		Flower	80.0	314.0	2.5	n.a	n.a	1.4	n.a	
		Leaf	78.0	305.0	3.1	n.a	n.a	2.0	n.a	
Telosma cordata	Pkalayheang	Leaves/flower	80.5	272.0	5.0	n.a	n.a	1.0	n.a	[2]
Zingiber officinale	Knhei	Rhizomes	87.4	192.0	1.6	n.a	n.a	1.3	n.a	[2]

*References: the data on nutritional values adapted from [1]: Rotary (2015), [2]: FPI (2021), [3]: Narsing Rao et al. (2014), [4]: FBN (2018), [5]: Aye (2012), [6]: Khatun et al. (2012), [7]: Poomipamorn & Kumkong (1997), [8]: Pattanayak (2010); and [#] this study.

the production and dietary incorporation of wild food plants rich in minerals and vitamins.

The species Aganonerion polymorphum contains antioxidant compounds and antioxidant activity, i.e., anti-tussive, expectorant, and use for muscle pain (Somdee et al. 2016). Fruits of Amomum kravanh are used as traditional Chinese medicine for digestive disorders and stomach diseases (Yu et al. 1981), and the fruits enrich phytochemical constituents (Zhang et al. 2020), which activate and exert beneficial effects on health or in amelioration of diseases. The species Garcinia oliveri contains phenolic compounds, which are known to be antioxidants (Ha et al. 2011). Roots of Feroniella lucida contain alkaloids, natural bioactive compounds for human health (Sripisut et al. 2011).

Agrobiodiversity and plant propagation

Strategic interventions can be made to make WFP more commercially competitive by developing improved modern varieties, as well as integration with other components of home/community food production for improved household nutrition and income. Producing alternative food and forage crops will not only enhance agrobiodiversity but will improve their resiliency in adapting to extreme climate conditions and minimize problems of pests, biotic, and abiotic stress (Kahane et al. 2012). Neglected and underutilized plant species like the WFP species discussed have been considered as an important role to play in moving from mono-cropping to agrobiodiversity to improve the yields of staple crops (Padulosi et al. 2013). Integration with other components of home/community food can be an option for the rural landless who often do not have access to additional land for expansion but can maximize existing land or space to accommodate perennial WFP (Eissler et al. 2021). To promote WFP production, WFP germplasm evaluated as having high market value needs to be established, and their planting materials should be produced for greater access and availability of important underutilized indigenous perennial vegetable species. Table 4 described the growth rate and propagation materials of the 34 WFP species.

Table 4: Growth rate and propagation of the 34 wild food plant species. Note: the growth rate is evaluated by the authors.

Category	Scientific name	Local name	Growth rate	Propagation
Annual herb	*Amaranthus palmeri*	Phaty	VF	Seed
	Cleome gynandra	Mormanh	VF	Seed
	Psophocarpus tetragonolobus	Porpeay	F	Seed
Perennial herb (Aquatic plants)	*Limnophila chinensis*	Ma-om	VF	Cutting
	Marsilea quadrifolia	Juntolphnom	VF	Root
	Nelumbo nucifera	Chhouk	F	Seed, Root
	Neptunia oleracea	Kanhchhet	VF	Cutting
	Nymphaea caerulea	Bralet	VF	Root
Perennial herb	*Alpinia galanga*	Ramdeng	M	Rhizome
	Amomum kravanh	Krvanh	VS	Seed, root
	Colocasia esculenta	Trav	F	Root
	Curcuma longa	Romiat	M	Rhizome
	Ipomoea aquatica	Trakuon	F	Seed, cutting
	Musa sapientum	Chek	S	Sucker
	Oenanthe javanica	Phlovkangkeb	VF	Stem cutting
	Zingiber officinale	Knhei	M	Rhizome
Perennial shrub	*Cnidoscolus aconitifolius*	Chaya	F	Cutting
	Ocimum tenuiflorum	Marahprov	F	Seed

	Sauropus androgynus	Ngob	F	Seed, cutting
	Senegalia pennata	Sa-om	F	Air layering
Perennial vine	*Aganonerion polymorphum*	Voi-thneoung	S	Cutting
	Basella alba	Chunlung	VF	Cutting
	Coccinia grandis	Sloekbaas	VF	Seed
	Telosma cordata	Pkalayheang	S	Cutting
Perennial tree	*Azadirachta indica*	Sdao	VS	Seed
	Feroniella lucida	Krasang	VS	Seed
	Garcinia oliveri	Tromoung	VS	Seed, air layering
	Garcinia schomburgkiana	Sandan	VS	Seed, air layering
	Leucaena leucocephala	Kathomthet	F	Seed
	Morinda citrifolia	Nhoi	S	Seed, air layering
	Moringa oleifera	Marom	M	Seed, air layering
	Phyllostachys edulis	Tompang	M	Cutting
	Sesbania grandiflora	Angkeadei	F	Seed
	Tamarindus indica	Ampel	S	Seed

CONCLUSION

Overall, results indicate that WFP is a beneficial tool to improve Cambodian biodiversity and livelihoods along with both health and economic indicators. The wide-ranging availability and sale of WFP by those in the marketplace indicate that Cambodians are aware of and make use of a wide variety of neglected and underutilized plants species. However, the percentage of these plants that are intentionally cultivated remains low. As such, there is potential to scale up the production and cultivation of these plants to further enhance livelihoods and agrobiodiversity. Further research is needed to assess the best methods of scaling up WFP and disseminating knowledge on their nutritional and economic benefits.

ACKNOWLEDGEMENTS

This research was supported by the Sub-project on 'Innovative Farming Systems for Improved Nutrient and Income in NW Cambodia' – IFINI (ref. HEIP–UBB–SGA#01) of the 'Higher Education Improvement Project' – HEIP.

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