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著者	YAMAMOTO Sota
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YAMAMOTO Sota

Research Center for the Pacific Islands, Kagoshima University

Abstract

The local nomenclature and usage of *Capsicum* in Weno, Romanum, and Piis islands, Chuuk Atoll, Federated States of Micronesia (FSM), were surveyed to investigate the relationship between people and *Capsicum* with a focus on dispersal routes, ethnobotany, and food security. Two species of *Capsicum*, *C. annuum* and *C. frutescens*, are cultivated in Chuuk Atoll, but *C. frutescens*, especially the green type, is a common seasoning in the daily diet of locals and has become an important and indispensable condiment. *Capsicum* peppers are called “*mwik (mwiik)*” in Chuuk Atoll, which is of unknown origin. People used *C. frutescens* in various ways: as a condiment (fresh fruits and fruits soaked in the water of mature coconuts), vegetable (leaves), and medicine (fruits and/or seed for treating toothaches, fruits for eliminating the stomach parasite known as “*nikanipwun*”, roots for an ointment to treat skin wounds, fruits for treating sick domestic fowl, and fruits for boosting energy of gamecocks after fighting). However, with modernization, residents of Chuuk Atoll have been eating fewer *C. frutescens* leaves in recent years. The FSM has faced serious public health problems due to a new diet and other lifestyle changes especially from the 1980s, and the government, non-governmental organizations, and many researchers have attempted to promote a return to local foods because of their higher carotenoid and vitamin contents compared to modern foods. On small islands and atolls, imported foods and medicines may not arrive for more than a month if a typhoon or an oil crisis occurs. Therefore, for food security, it is imperative to re-discover plants already naturalized on each island. From this perspective, an important candidate plant is *C. frutescens*, which can serve not only as a spice but also as a vegetable rich in carotenoids and vitamins. *Capsicum frutescens* has long been naturalized in these regions; therefore, it does not need to be cultivated and its fruits and leaves can be harvested throughout the year. To improve public health on Pacific islands, there should be renewed focus on plants that are already naturalized on each island.

Keywords: dispersal routes, ethnobotany, leaves as vegetable, local food, medicinal use, naturalized plants

Introduction

Capsicum peppers, consisting of approximately 25 species belonging to the Solanaceae family, are native to both tropical and temperate regions of the Americas (ESHBAUGH 1993). *Capsicum frutescens* is a semi-domesticated species characterized by

seed dormancy, small fruit size, deciduous fruit, and the inhibition of flowering under prolonged illumination (YAMAMOTO and NAWATA 2006, 2009b, YAMAMOTO *et al.* 2007, 2008). It is widely distributed throughout the tropical and subtropical regions of the world.

Capsicum was introduced to Europe from the New World in 1493 by Columbus (BOSWELL 1949). After spreading through European countries in the early sixteenth century, *Capsicum* was introduced to Asia in the late sixteenth century (ANDREWS 1995, KUMAZAWA *et al.* 1954, STURTEVANT 1885) and into Oceania during the early European era (WHISTLER 1992a). However, its detailed dispersal routes remain unknown. Many varieties of *Capsicum annuum* have been produced and distributed around the world, making it difficult to reconstruct its dispersal routes, whereas numerous local varieties of *C. frutescens* still exist in Asia and Oceania. YAMAMOTO and NAWATA (2004, 2005, 2009a) and YAMAMOTO *et al.* (2011) studied the distribution and dispersal routes of *C. frutescens* in Southeast and East Asia and found that accessions from the Ryukyu Islands in Japan have a rare isozyme pattern, known as shikimate dehydrogenase phenotype B (ShDH-B), and that this phenotype is distributed throughout Taiwan, the Batanes Islands in the Philippines, Indonesia, Vanuatu, and Ecuador, but not in continental Southeast Asia. The authors postulated that this phenotype was introduced to the Philippines from the Americas via Oceania by the Manila galleons (Spanish trading ships) in the mid-sixteenth century through to the early nineteenth century, and thereafter dispersed into insular regions of Southeast and East Asia. To further elucidate the dispersal and distribution of *C. frutescens*, it is necessary to survey the distribution of the ShDH-B phenotype in Oceania. However, very few accessions of *Capsicum* have been collected from Oceania partly due to its geography, which makes it difficult to access.

The Federated States of Micronesia (FSM) consists of four states (Yap, Chuuk, Pohnpei, and Kosrae, from west to east) composed of approximately 600 small islands, which amounts to only approximately 700 km². However, the FSM is spread over more than 2,600,000 km² of the Pacific Ocean and spans approximately 2,500 km from east to west. The FSM is considered to be one of the best regions for studying the hypothetical dispersal routes of *C. frutescens*, from the Americas via Oceania to Asia, because it lies along one of the routes used by the Manila galleons and spans many degrees of longitude between Southeast Asia and the Americas. However, there is very little information on *Capsicum* in the FSM, except for that published in a recent study conducted in Pohnpei State (YAMAMOTO 2011).

In the 1950s, people in the FSM still ate a "traditional" diet (MURAI 1954), but this began to be replaced by a modern diet rich in rice, flour, sugar, fatty foods, and other imported, processed foods after the United States Department of Agriculture started its supplementary feeding program in the 1960s (ENGLBERGER *et al.* 2003). This phenomenon accelerated after a Compact of Free Association was signed between FSM and the United States in 1986 (HEZEL 2004). Since then, FSM has faced serious public health problems due to this new diet and other lifestyle changes, and the government, non-governmental organizations (NGOs), and many researchers have attempted to promote a return to local foods because of their higher carotenoid and vitamin contents compared to modern foods (*e.g.*, ENGLBERGER *et al.* 2008, 2009). Even

though *Capsicum* did not originate in the FSM, it has been cultivated and consumed there for about 400 years and thus it is reasonable to consider it a traditional local food. Although the fruits and especially leaves of *Capsicum* are rich in carotenoids and vitamins (RESOURCES COUNCIL OF THE SCIENCE and TECHNOLOGY AGENCY 2001), the importance of this plant as a nutritious local food in this region has been largely overlooked.

In the present study, the local nomenclature, usage, and distribution of *Capsicum* in Chuuk Atoll were surveyed to investigate the relationship between people and *Capsicum* with a focus on dispersal routes, ethnobotany, and food security.

Study Site and Data Collection

Fieldwork was conducted over a month-long period in July and August 2011 on the islands of Weno, Romanum, and Piis in Chuuk Atoll, Chuuk State, FSM. The work consisted of interviewing locals and documenting local knowledge, use, and dispersal of *Capsicum* species. Figure 1 shows the study sites. A total of 76 people (34 males and 42 females, including 38 from Weno, 19 from Romanum, and 19 from Piis) were interviewed regarding the local nomenclature and use of the genus *Capsicum*. These interviews sought to capture taste perception of pungent *Capsicum*; knowledge of weed forms of *C. frutescens* and bird behavior toward fruits of *Capsicum*; usage as a condiment, vegetable, and/or medicine; and popular beliefs, agricultural rituals, and taboos related to this genus. The interviewees were aged 20 to 75 years old, with a median age of 46. Chuukese words are given following GOODENOUGH and SUGITA (1990).

Results and Discussion

Local nomenclature for *Capsicum* and perception of pungent *Capsicum* in Chuuk Atoll

Two species of *Capsicum* are cultivated in Chuuk Atoll: *C. annuum* (two pungent types, one with a long fruit and another with a round fruit; Fig. 1A) and *C. frutescens* (several pungent types of various sizes with a green or greenish-yellow color when immature; Fig. 1B). People on Weno Island who cultivate the *C. annuum* cultivars reported that they bought seeds or seedlings at an agricultural institute. Sweet peppers (paprika) and dried fruits of *C. annuum*, some of which were confirmed to be imported from the United States, are also sold in small stores, but this species seems to be rarely cultivated on the three islands studied. In contrast, *C. frutescens*, especially the green type, is a common seasoning in the daily diet of locals and has become an important and indispensable condiment in Chuuk Atoll.

Capsicum peppers are called “*mwik (mwiik)*” in Chuuk Atoll. Other regional names include “*t’eebil*” in Yap State (JENSEN 1977) and “*meringel*” in Palau (JOSEPHS 1990), both located to the west of Chuuk State, and all of these names are of unknown origin. YAMAMOTO (2011) reported that local names for *Capsicum* in Pohnpei State, located to the east of Chuuk State, include “*sele*” and “*jeli*”, possibly derived from “*chile*” in Spanish or English. Local names such as “*pwepuh*” in Kosrae State (LEE 1976) and “*peybah*” or “*pepah*” in Marshall (ABO *et al.* 1976), both to the east of Pohnpei State, seem to be related to “*pepper*” in English or other languages. Further linguistic studies in Micronesia may serve to elucidate the dispersal routes of *Capsicum*.

Among the 76 interviewees, 30 recognized only one kind of pungent *Capsicum* (Table

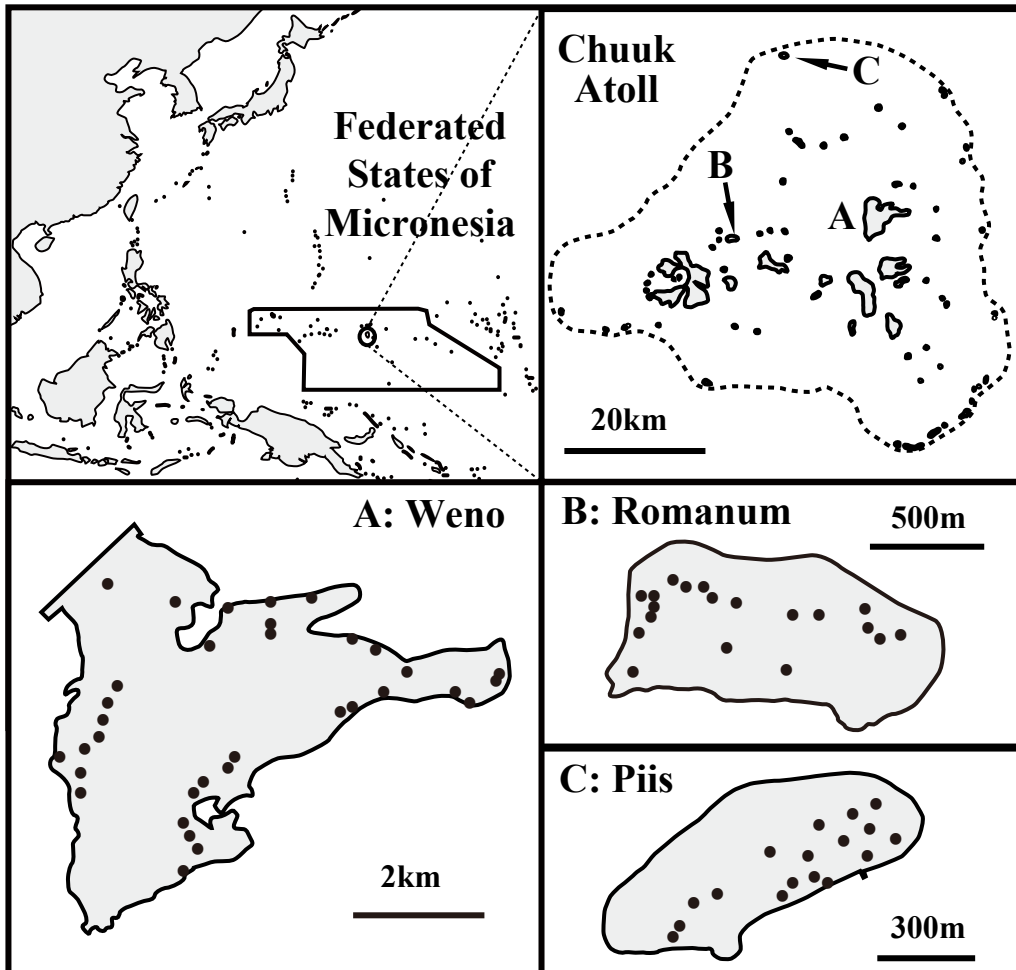


Fig. 1 Study sites (●) on Weno (A), Romanum (B), and Piis (C) islands, Chuuk Atoll, Chuuk State, Federated States of Micronesia.

1), which was a cultivar of *C. frutescens* with small green fruits (Fig. 2B-1). The other 46 interviewees recognized more than two types of pungent *Capsicum* with the highest number being five types, although they did not have any specific names for each type. Many people thought that the *C. frutescens* cultivar with small green fruits was native to their region and that the other *Capsicum* peppers were introduced from the outside after World War II, although YAMAMOTO (2011) revealed that at least two kinds of *C. frutescens*, including that with greenish-yellow fruits, were found in Oceania before 1945 during a specimen survey at the Bishop Museum, Hawai'i. These results may imply that people in Chuuk Atoll are more attached to the small fruits of *C. frutescens* in their local culture.

The 46 people who recognized more than two types of pungent *Capsicum* were asked to comment on each pepper's spiciness and smell, and which pepper they preferred. Table 1 presents the results. Forty-three people considered *C. frutescens* to



Fig. 2 Use of *Capsicum* peppers on Weno, Romanum, and Piis islands, Chuuk Atoll.

A long fruit (A-1) and a round fruit (A-2) cultivar of *C. annuum*. A green immature fruit color type (B-1) and a greenish-yellow type (B-2) of *C. frutescens*. A weed plant of *C. frutescens* found growing in an abandoned car (C-1) and seedlings of *C. frutescens* in a small cup (C-2). "Setifat" on Weno and "unuken" on Romanum (water, salt, and fruits of *C. frutescens*) (D-1), raw fish mixed with a sauce made of *C. frutescens*, soy sauce, and lime juice (D-2), and using the peppers as a stimulant (D-3: *C. frutescens* and salt; D-4: *C. frutescens*, salt, and lime juice). Water of mature coconuts placed in the sun for fermentation (E-1) and *C. frutescens* fruits soaked in such water, occasionally with garlic, also placed in the sun (E-2 and E-3).

Table 1 Perception of pungent *Capsicum* on Weno, Romanum, and Piis islands, Chuuk Atoll.

How many kinds of pungent <i>Capsicum</i> do you know?		Questions for 46 interviewees who knew several kinds of pungent <i>Capsicum</i>											
		Which fruits are hotter?				Which fruits smell better?				Which fruits do you prefer to eat?			
1 * ¹	2 more	Total	C. f. * ²	C. a. * ²	S * ²	C. f.	C. a.	S	C. f.	C. a.	S		
Weno	12	11	15	38	23 [GR:23, GY:0]* ³	2	1	18 [GR:17, GY:1]	5	3	18 [GR:18, GY:0]	2	6
Romanum	13	5	1	19	6 [GR: 6, GY:0]	0	0	2 [GR: 2, GY:0]	2	2	4 [GR: 4, GY:0]	0	2
Piis	5	5	9	19	14 [GR:14, GY:0]	0	0	11 [GR:11, GY:0]	2	1	6 [GR: 6, GY:0]	5	3
Total	30	21	25	76	43 [GR:43, GY:0]	2	1	31 [GR:30, GY:1]	9	6	28 [GR:28, GY:0]	7	11

*¹: people know only *C. frutescens* (small fruits of which immature fruit color was green).

*²: C.f.: *C. frutescens*, C.a.: *C. annum*, and S: Same.

[] *³: GR: small fruits of which immature fruit color was green, GY: fruits of which immature fruit color was greenish yellow.

Table 2 Perception of weedy forms of *C. frutescens* and bird behavior toward fruits on Weno, Romanum, and Piis islands, Chuuk Atoll.

Do you know weedy forms of <i>C. frutescens</i> ?		Do you know birds eat its fruits?		Do you have its plants in your home garden?		How did you get the plants? * ¹	
Yes	No	Yes	No	Yes	No	Seeds or plants from villagers	Weedy forms * ²
Weno	35	3	7	24	14	9	15
Romanum	19	0	1	15	4	1	14
Piis	15	4	2	7	12	4	3
Total	69	7	10	46	30	14	32

*¹: questions for 46 people who had *C. frutescens* plants in their home garden.

*²: including transplantation from weedy forms in home garden or village.

be hotter, and all of these people reported that the small, green fruit type (GR) was hotter than the greenish-yellow type (GY). Of the remaining three respondents, two said that *C. annuum* was hotter, and one reported that *C. frutescens* and *C. annuum* were equally hot. Many people remarked that smaller fruits were much hotter. Regarding smell, 31 people thought *C. frutescens* smelled better (GR: 30, GY: 1), nine thought that *C. annuum* smelled better, and six thought there was no difference between the two species. As for preference, 28 people preferred to eat *C. frutescens* (GR: 28, GY: 0), seven preferred *C. annuum*, and 11 had no preference. Those who preferred spicy flavors tended to prefer *C. frutescens*, whereas others tended to prefer *C. annuum* or GY type *C. frutescens*.

Weed forms of *C. frutescens* and bird behavior toward fruits

Weed forms of *C. frutescens* were found along forest edges and the roadside in Chuuk Atoll (Fig. 2C-1). More than 85 % of interviewees had seen weed forms of *C. frutescens* (Table 2) and knew of or had seen birds eating fruits of *C. frutescens*. These birds included a species known as “*anga*” on Weno and Romanum or “*mwii*” on Piis (*Aplonis opaca* subspp.), as well as the “*chuko*” (common domestic fowl) on three islands and “*nikeitopar*” (*Myzomela cardinalis* subspp.) on Weno (the scientific names of these birds are taken from ENGBRING *et al.* (1990); Table 3). A common domestic fowl and birds belonging to the genus *Zosterops* are known to disseminate seeds of *C. frutescens* in Pohnpei State (YAMAMOTO 2011), Japan (YAMAMOTO 2010a), Taiwan (YAMAMOTO 2009), the Batanes Islands, the Philippines (YAMAMOTO 2010b), and Cambodia (YAMAMOTO and MATSUMOTO 2008).

Table 3 Local names for birds that eat fruits of *C. frutescens* on Weno, Romanum, and Piis islands, Chuuk Atoll

	Local name	People answered
Weno	<i>anga</i> (: <i>Aplonis opaca</i> subspp.) *	23
	<i>chuko</i> (: common domestic fowl)	17
	<i>nikeitopar</i> (: <i>Myzomela cardinalis</i> subspp.) *	4
Romanum	<i>anga</i> (: <i>Aplonis opaca</i> subspp.) *	18
	<i>chuko</i> (: common domestic fowl)	8
Piis	<i>mwii</i> (: <i>Aplonis opaca</i> subspp.) *	17
	<i>chuko</i> (: common domestic fowl)	5

* referred to Engbring *et al.* (1990).

Use of *C. frutescens* on Weno, Romanum, and Piis islands, Chuuk Atoll

Fresh or dried fruits

Locals who preferred spicy flavors reported eating fresh *C. frutescens* fruits raw, adding them to soups and canned meats or fish, and using them to make a dipping sauce (a mix of fruits, salt, soy sauce, and lime juice, occasionally with garlic, onion, and/or black pepper) for fish (Fig. 2D). Some people put only the fruits of *Capsicum* into un-boiled water with salt (a dish called “*setifat*” on Weno or “*unuken*” on Romanum) and used it as a soup and/or dipping sauce (Fig. 2D-1). Several females noted eating the peppers raw with salt and/or lime juice as a stimulant (Fig. 2D-3,4). People throughout Chuuk Atoll appeared to use dried fruits only rarely, similar to people in Pohnpei State (YAMAMOTO 2011) and the Batanes Islands (YAMAMOTO 2010b). This is likely because the relatively warm temperatures and generally plentiful rainfall throughout the year in Chuuk Atoll enable people to collect fresh *C. frutescens* fruits year-round.

Processed or preserved fruits

People in Chuuk Atoll soak *Capsicum* fruits, especially those of *C. frutescens*, in the water of mature coconuts (*Cocos nucifera*). These are placed in the sun for several days, and allowed to ferment and then sour (Fig. 2E), creating a spicy-sour condiment called “*manakini*”, which is then added to fresh fish, soup, and other dishes. People in Pohnpei State (YAMAMOTO 2011) and Fiji (unpublished data) do this, suggesting that this technique may be common throughout Oceania. People also soak fruits into lime juice, but they thought it would be a recent technique in Chuuk Atoll, as same as in Pohnpei State (YAMAMOTO 2011). On the Batanes Islands, “*bagun*” is made by soaking *C. frutescens* peppers in “*silam*” (a sour vinegar made from sugarcane; YAMAMOTO and NAWATA 2009a), while in Cambodia one of the most important elements of soaking fruits in liquid seems to be the sour taste (YAMAMOTO *et al.* 2011). As noted by YAMAMOTO (2010b), it is unknown whether people in Southeast and East Asia developed this spicy-sour flavor themselves or had widely adopted it after its introduction from Europe. The same phenomenon was observed in Chuuk Atoll.

Use of leaves of C. frutescens

The leaves of *Capsicum*, especially *C. frutescens*, are used in soups and in mixes of vegetables in Chuuk Atoll; in contrast, no one interviewed reported eating the roots as a spice or vegetable. On Romanum and Piis islands, 15 of 19 people indicated that they still use *Capsicum* leaves for food (although this was not observed during the study period). On Weno, 19 of 38 people reported that they had not recently eaten the leaves (Table 4). The frequency of using leaves did not differ among the three islands (Table 4). YAMAMOTO (2011) reported that, in Pohnpei State, the frequency of using the leaves is much higher in remote atolls, such as Mokil and Pingelap, than on the main island, Pohnpei Island. It is known that the lifestyle on Pohnpei Island was more modernized than that on Mokil and Pingelap atolls (KAWAI *et al.* 2010), which seems to have affected the use of *C. frutescens* leaves. In Chuuk Atoll, Weno is the main island and is also more modernized, which may explain the decreased usage of leaves on that island. YAMAMOTO (2009) reported that indigenous peoples of Taiwan used to add

Table 4 Use of leaves of *C. frutescens* on Weno, Romanum, and Piis islands, Chuuk Atoll.

	Use of leaves of <i>C. frutescens</i> as vegetable			Frequency of use of leaves of <i>C. frutescens</i> per ^{* 2}				
	Yes	No	Total	Week		Month		Year
				Several times	One time	Several times	One time	Several times
Weno	19 [SO:18, FR:4]	19	38	0	7	5	4	3
Romanum	15 [SO:15, FR:0]	4	19	0	1	2	4	8
Piis	15 [SO:13, FR:2]	4	19	0	4	1	7	4
Total	49 [SO:46, FR:6]	27	76	0	12	8	15	15

[] ^{* 1}: they used leaves for SO: soup and FR: fried vegetables. Results from multiple answer.

^{* 2}: questions for 49 people who eat leaves of *C. frutescens*.

C. frutescens leaves to gruel made of foxtail millet (*Setaria italica*) or maize (*Zea mays*), or to soup as a vegetable, but that today they seem to rarely use the leaves because they can buy other vegetables at markets. These results suggest that the leaves of *C. frutescens* may be used less in modern society.

Medicinal uses of *Capsicum*

When asked about medicinal uses of *Capsicum*, three people answered that the peppers are used to treat toothaches. In other regions of Oceania, the fruits, seeds, and leaves are used to treat various ailments: fruits for painful joints in Pohnpei State (YAMAMOTO 2011); fruits for back pain (UHE 1974) and leaves and/or fruits for other pains (WHISTLER 1996) in Samoa; seeds for aching muscles and body pains in Hawai'i (WHISTLER 1992a); fruits for sore throats in the Cook Islands (HOLDSWORTH 1990); fresh leaves for aching muscles and rheumatism in Vanuatu (BRADACS 2008); red pepper juice as an analgesic for body pains and aches on the Admiralty Islands (HOLDSWORTH and WAMOI 1982); and fruits for aches and pains, especially chest pains, on New Britain Island (HOLDSWORTH 1992). Modern medical researchers have found that capsaicin, the pungent ingredient in hot peppers, has a long-lasting suppressive effect on sensory neuron activity, and this compound is used to relieve pain caused by arthritis and pruritus in modern medicines (CRAFT and PORRECA 1992).

Some have claimed that eating *Capsicum* fruits eliminates the stomach parasite known as "*nikanipwun*", as previously reported for Pohnpei (YAMAMOTO 2011). *Capsicum* fruits are also used to treat stomach problems in Samoa (UHE 1974), Taiwan, the Batanes Islands (YAMAMOTO and NAWATA 2009a), and Cambodia (YAMAMOTO *et al.* 2011).

Four people said that eating fruits or leaves is good for eyesight, as in Pohnpei State (YAMAMOTO 2011). One person reported learning this information at a local workshop. People in seventeenth-century Spain reportedly ate two roasted *Capsicum* peppers after every meal to improve poor eyesight (NAJ 1992). However, indigenous peoples in Taiwan and the Batanes Islands claim that consumption of too many

Capsicum fruits, apart from *C. frutescens*, could cause poor eyesight, which may be related to a concept in Han Chinese traditional medicine (YAMAMOTO and NAWATA 2009a).

The leaves of *Capsicum* are often applied to boils or wounds in Tonga (WHISTER 1992b), Samoa (UHE 1974, COX 1993), the Cook Islands, Tahiti (WHISTER 1992a), and Fiji (unpublished data). Although this remedy was not observed in Chuuk Atoll in the present study, the locals did report drying the roots of *Capsicum* and mixing them with coconut oil to prepare an ointment for treating skin wounds. There is little information on the medicinal use of *Capsicum* roots, but people in Cambodia and Taiwan use them as medicine (YAMAMOTO and MATSUMOTO 2008, YAMAMOTO 2009).

Other uses of Capsicum

People in Chuuk Atoll also give *Capsicum* fruits to gamecocks after fighting to boost their energy. A man in Weno also mentioned that a gamecock will perform well if juice from the *Capsicum* pepper is placed on its spur. The use of *Capsicum* on gamecocks has also been confirmed in Pohnpei State (YAMAMOTO 2011), the Batanes Islands (YAMAMOTO 2010b), and Cambodia (YAMAMOTO and MATSUMOTO 2008). Some interviewees reported that the fruits are also used to treat sick domestic fowl. Similar practices have been reported in Pohnpei State, Taiwan, the Batanes Islands, and Japan (YAMAMOTO and NAWATA 2009a, YAMAMOTO 2010b, YAMAMOTO 2011).

Capsicum peppers have been found to play a role in popular beliefs, agricultural rituals, and taboos in many areas of Southeast and East Asia (YAMAMOTO 2009, 2010a, YAMAMOTO and MATSUMOTO 2008), and they are also used to produce rice malt and in rituals related to rice malt production (YAMAMOTO and MATSUMOTO 2008, YOSHIDA 1993). However, in the present survey, there was no evidence of any of these uses in Chuuk Atoll.

Conclusion

Capsicum frutescens remains a very important spice, vegetable, medicine, and cultural resource in Chuuk Atoll. However, the present study suggests that its use as a medicine is more limited in Chuuk Atoll than on other small and remote Pacific islands, such as Pohnpei (YAMAMOTO 2011) and the Batanes Islands (YAMAMOTO 2010). Moreover, people in Chuuk Atoll have been eating less *C. frutescens* leaves in recent years. In the FSM, the government and NGOs have encouraged people to cultivate vegetables such as squash, cucumber, lettuce, tomato, and eggplant to improve public health, but the outlook for this project is bleak, partly due to local inexperience in cultivating such crops. On small islands and atolls, imported foods and medicines may not arrive for more than a month if a typhoon or an oil crisis occurs. Therefore, for food security, it is imperative to re-discover plants already naturalized on each island. From this perspective, an important candidate plant is *C. frutescens*, which can serve not only as a spice but also as a vegetable rich in carotenoids and vitamins. *Capsicum frutescens* has long been naturalized in these regions; therefore, it does not need to be cultivated and its fruits and leaves can be harvested throughout the year. To improve public health on Pacific islands, there should be renewed focus on plants that are already naturalized on each island.

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