THE ETHNOBOTANY OF CHAYA (*CNIDOSCOLUS ACONITIFOLIUS* SSP. *ACONITIFOLIUS* BRECKON): A NUTRITIOUS MAYA VEGETABLE[1]

JEFFREY ROSS-IBARRA AND ALVARO MOLINA-CRUZ

Ross-Ibarra, Jeffrey *(Department of Genetics, University of Georgia, Athens, GA 30602) and* **Alvaro Molina-Cruz** *(Departamento de Bioquímica, Instituto de Investigaciones, Universidad del Valle de Guatemala, Apartado Postal 82, Guatemala City 01901, Guatemala).* THE ETHNOBOTANY OF CHAYA (*CNIDOSCOLUS ACONITIFOLIUS* SSP. *ACONITIFOLIUS* BRECKON): A NUTRITIOUS MAYA VEGETABLE. *Economic Botany 56(4):350–365, 2002.* *Chaya (*Cnidoscolus aconitifolius *ssp.* aconitifolius *Breckon) is a domesticated leafy green vegetable of the Maya region of Guatemala, Belize, southeast Mexico and the Yucatán Peninsula, and parts of Honduras. Though relatively unknown outside of this area, evidence suggests that chaya was of significant importance to ancient peoples of the Yucatán Peninsula and perhaps elsewhere within the Maya region. Here we review what little research has been done on this impressive plant, as well as recount our own ethnobotanical investigation into its use as a food plant and medicine, and discuss its botany, nomenclature, and agricultural use. Due to its ease of cultivation, potential productivity, and above all its substantial nutritional value, we propose chaya as a potential crop for areas outside Mesoamerica.*

LA ETNOBOTANICA DE CHAYA (*CNIDOSCOLUS ACONITIFOLIUS* SSP. *ACONITIFOLIUS* BRECKON): UNA VERDURA NUTRITIVA MAYA. *La chaya (*Cnidoscolus aconitifolius *ssp.* aconitifolius *Breckon) es una verdura domesticada de la región Maya de Guatemala, Belice, el Sureste de México y la península de Yucatán, y partes de Honduras. Aunque es poco conocida afuera de esta región, la evidencia sugiere que la chaya era una planta importante para los antiguos Mayas de la península de Yucatán, y tal vez en otras partes de la región Maya. A continuación presentamos la poca investigación realizada sobre esta sorprendente planta, a la vez presentamos resultados de nuestra investigación etnobotánica acerca de su uso como verdura y medicina, y discutimos su botánica, nomenclatura, y su agricultura. Dada la facilidad de cultivarla, su productividad potencial, y sobre todo su alto valor nutritivo, proponemos la chaya como cultivo potencial para regiones afuera de Mesoamérica.*

Key Words: Chaya; *Cnidoscolus aconitifolius*; Mesoamerica; Maya.

Mesoamerica, as one of the world's major centers of origin and domestication of plants, has contributed several important crops to modern agriculture, including corn, beans, squash, cotton, tomatoes, cacao, avocados, and agave (McClung de Tapia 1992). In addition to these well-known crops, Mesoamerican peoples cultivated and domesticated many other useful plants that remain relatively unknown outside of this region. One of these is the nutritious leafy vegetable called chaya (*Cnidoscolus aconitifolius* ssp. *aconitifolius* Breckon). A crop domesticated in pre-Columbian times, chaya continues to be used today as food, medicine, a living fence-post, and an ornamental plant by at least 10 Maya groups, as well as many other Mexican and Mesoamerican peoples. Although the nutritive and agronomic potential of this shrub has been recognized before (Martin and Ruberté 1978; NAS 1975), there has been little research and promotion of its use. Here we report on the botany, history, and mode of use of chaya in Mesoamerica, as well as other evidence that helps to understand the importance of this plant in its region of origin, and perhaps its future in other regions as well.

METHODS

Botanical collections of both cultivated and wild chaya were made during the summer of

[1] Received 24 October 2000; accepted 15 June 2002.

1999 in Guatemala (Escuintla, Alta and Baja Verapaz and Petén), the Yucatán Peninsula, Chiapas, Tabasco, and Veracruz. Specimens have been deposited in the herbarium at the University of California Riverside (UCR), to be later distributed to the herbaria at CICY (*Centro de Investigaciones Científicas de Yucatán*), UADY (Universidad Autónoma de Yucatán), FCME (Herbario de la Facultad de Ciencias de la Universidad Nacional Autónoma de México) and UVG (Universidad del Valle de Guatemala). The vast majority of cultivated material was collected from home gardens, with a few specimens collected from *milpas* (swidden corn fields), secondary vegetation, or small experimental plantations. Ethnobotanical interviews with local people, predominantly—though not exclusively—middle-aged to elderly housewives, were conducted along with the botanical collections. Formal surveys were conducted in the town of Bacalar in southern Quintana Roo and at several sites in Guatemala. All interviews and surveys were conducted in Spanish, though local help in translation from Maya was occasionally necessary. Stem cuttings were collected and grown in greenhouses at UCR and UVG.

Botany

Chaya and its relatives are a group of arborescent shrubs of section *Calyptosolen* of the genus *Cnidoscolus,* closely related to the more well-known genus *Manihot* (Fig. 1). Both belong to the tribe Manihoteae of the subfamily Crotonoideae of Euphorbiaceae (Webster 1975). Though previously grouped with, or even considered synonymous to, *Jatropha* by many authors, *Cnidoscolus* is readily separated from both *Manihot* and *Jatropha* by its urticating epidermal hairs, distinctive petiolar or foliar glands, and a single white floral envelope (McVaugh 1944). A later study of petiolar vascular anatomy and pollen morphology strongly confirms this separation (Miller and Webster 1962).

Although other species in the genus will be mentioned, the body of this article deals with those taxa collectively known as chayas, including *C. chaya* Lundell, *C. chayamansa* McVaugh, *C. tenuilobus* Lundell, *Jatropha aconitifolia* Mill., *J. palmata* Willd., *J. papaya* Medic., *J. urens* 'inermis' Calvino, and others, all currently subsumed under the taxon *Cnidoscolus aconitifolius* (Mill.) I.M. Johnst. ssp. *aconitifolius* (Breckon 1975). These plants are evergreen or drought-deciduous shrubs up to six meters in height with alternate, palmately lobed leaves, milky sap, and small, white flowers on dichotomously branched cymes. Leaves are large and chartacious or sometimes succulent, up to 32 cm long and 30 cm wide, on petioles up to 28 cm in length. Despite recent work claiming the contrary (Carbajal, Parra-Tabla, and Rico-Gray 1998), the species is monoecious, with separate male and female flowers each exhibiting defunct reproductive organs of the opposite sex. Though flowering is most common in the summer months, flowering and fruiting individuals can be found year-round.

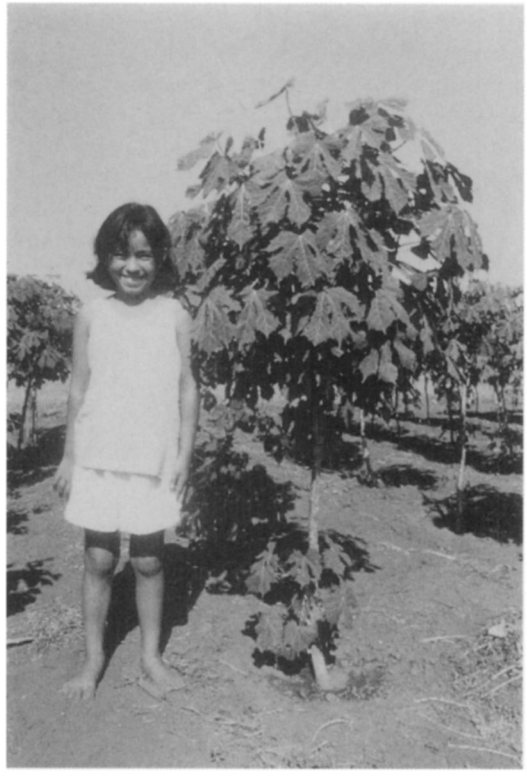

Fig. 1. Young chaya cultivar 'Estrella' at 20 masl in Southern Guatemala.

Even within this subspecies, however, extensive morphological and phenological variation exists. The taxon includes a diverse array of plants, spanning the range from wild to completely domesticated. Based on our observations and collections, we have identified four cultivated varieties of chaya, the taxonomy of which will be dealt with in a later paper; for current purposes, gross morphological differences are

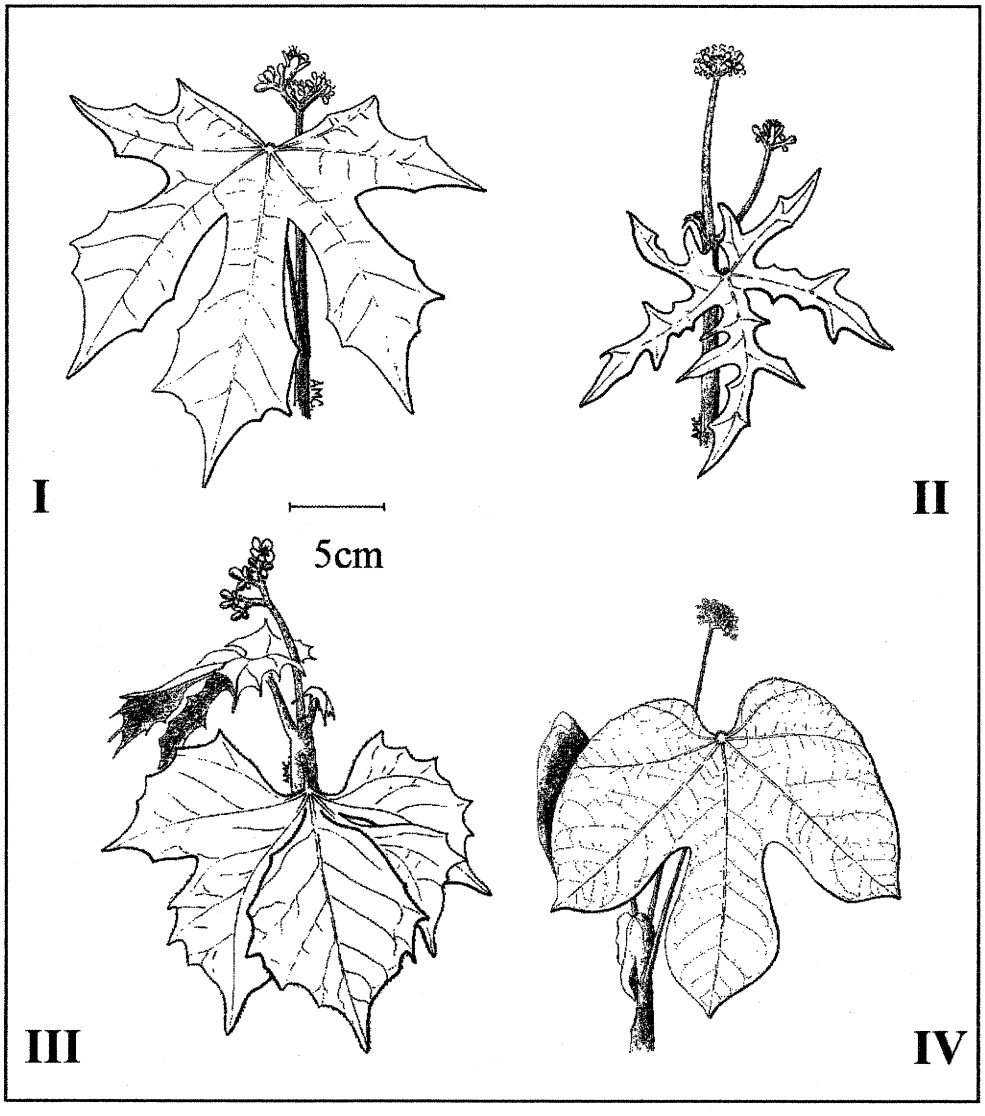

Fig. 2. The four cultivated varieties of chaya: I. 'Estrella' II. 'Picuda' III. 'Chayamansa' IV. 'Redonda.'

sufficient to distinguish the varieties. These four varieties are shown in Fig. 2. Although it is on occasion difficult to identify juvenile or incomplete specimens, the four varieties are readily separable and fairly consistent. Varieties 'Estrella' and 'Picuda' fall well within the variation seen in strictly wild material, though both are in fact cultivated. 'Chayamansa' exactly fits the description of McVaugh's species of that name (McVaugh 1944), whereas 'Redonda', as far as we are aware, is an almost unrecognized form of the taxon, having been described only briefly as two separate varieties (*chaya dormilona* and *chaya golondrina*) by Salazar Goroztieta (1991).

Variety 'Estrella' exhibits a leaf morphology common in wild material—five spreading, non-overlapping dentate lobes. The cultivated material differs from the wild only in the apparent paucity of stinging hairs. 'Picuda', also of wild leaf morphology and lacking in stinging hairs, differs from 'Estrella' in having five to nine lobes that are much narrower, and strongly dentate to pinnatafid. Though mature fruit is unknown in variety 'Estrella', at least some plants

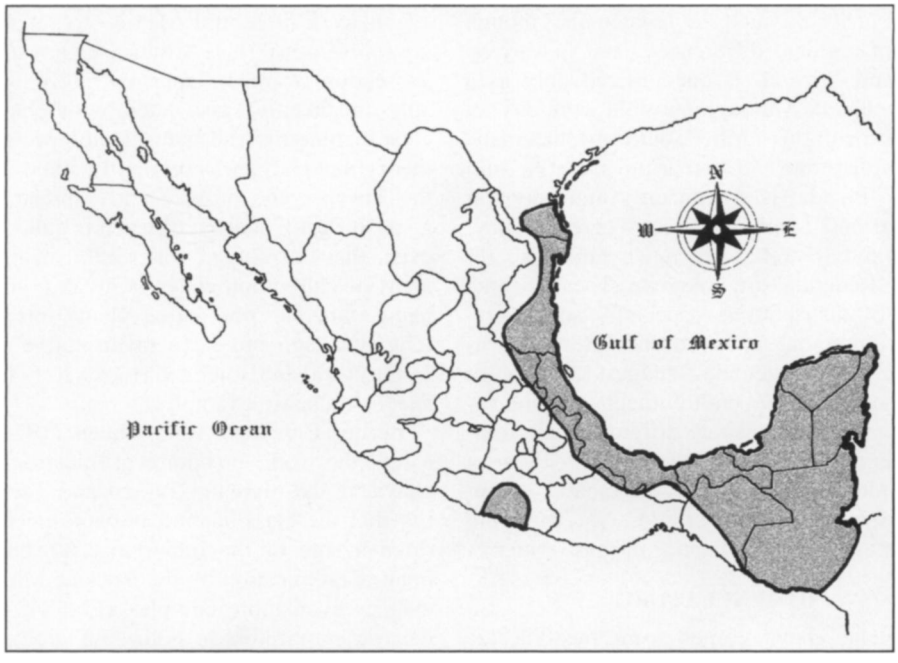

Fig. 3. Distribution of *C. aconitifolius* ssp. *aconitifolius*, modified following Breckon (1975).

of 'Picuda' readily produce mature fruit and seed.

'Chayamansa' is the most clearly domesticated of the varieties. Commonly of five lobes, the strongly obovate and usually overlapping nature of the central three lobes is a trait never seen in wild material. Leaves do exhibit stinging hairs, although reduced in size and found only along the petiole and bottom margin of the lamina. Mature fruit is rare and never produces viable seed, and the thick, succulent stems are easily differentiated from wild taxa. Anthers produce at most a few, usually deformed, pollen grains, and completely empty anther sacks are common (Ross-Ibarra, unpub. data). Variety 'Redonda' is almost certainly domesticated as well. Mature leaves are almost exclusively three-lobed, with entire to slightly dentate margins and apparently completely lacking in stinging hairs. Juvenile leaves are often entire, lacking any distinct lobes. Although mature plants flower and actively produce pollen, preliminary tests show that less than 1% of this pollen is viable (Ross-Ibarra, unpubl. data) and mature fruit and seed is extremely rare.

Distribution

Subspecies *Cnidoscolus aconitifolius aconitifolius* is of extensive distribution, growing wild from southern Texas south along the Gulf Coast, through Yucatán and Chiapas, and through Central America to as far south as Colombia, with a disjunct population in the Mexican state of Guerrero (Fig. 3). Although populations south of Guatemala are considered to be recently introduced (Breckon 1975), there is some question as to their origin. Throughout its "native" range chaya is cultivated, often only as an ornamental or living fence-post. Cultivated material, however, has spread in recent times to Cuba, Florida, and the Mexican states of Mexico, Morelos, and Puebla. Even more recently, chaya has spread to Maya families in urban and suburban areas throughout Mexico and the Southwest United States. In 1977 chaya was introduced to Ghana from an agricultural research station in Puerto Rico (Newton 1984), and in 1979 brought to Brunei (Peregrine 1983) as a potential agricultural crop.

The four varieties of chaya do not share similar patterns of distribution. In Yucatán 'Chayamansa' is by far the most common variety; both 'Estrella' and 'Redonda' are rare, and 'Picuda' is unknown in the region. In most of Chiapas varieties 'Chayamansa' and 'Redonda' are the most common, whereas in Veracruz all of the varieties except 'Picuda' can be found. All four

varieties are cultivated in Guatemala, though significant regional differences exist in varietal choice, and 'Picuda' is encountered only as a rare ornamental. Although our field work did not include expeditions farther south of Guatemala, both the literature and herbarium material suggest that 'Picuda' is significantly more popular in Central and South America, whereas 'Chayamansa' and 'Estrella' are much rarer, and records of 'Redonda' are unknown. These distinct patterns of distribution—especially across significant altitudinal and terrain differences as those found in Guatemala—suggest selection or adaptation to different environments, and the varieties seem to demonstrate differential environmental preferences. Unfortunately, without a better understanding of the origin and subsequent dispersal of the varieties, we can only speculate as to the significance of these patterns.

NOMENCLATURE

The name chaya comes from the Yucatec Maya word *chay,* the generic and most commonly used name for the plant. A comprehensive list of all the names used for chaya and its relatives is found in Table 1. Many of the names, especially in Spanish, are due to the urticating hairs of the plant (hence *ortiga, pica, mala mujer,* tread-softly, spurge nettle, and others). Others refer to chaya's association with other leafy green vegetables (hence tree spinach, and various *col,* or cabbage, references).

Our ethnobotanical field work has reinforced a dichotomy already apparent in the literature available: names found for chaya in Yucatán compared to names encountered in other areas. Among the Yucatec Maya, names of unquestionably native origin exist for the plant (*chay, tsah, tzin-tzin-chay, x'etel,* etc.), whereas in all other areas chaya is referred to by Spanish or English names, or by names in the native language but of obvious Spanish origin. In Chiapas, where the highland Tzeltal and Tzotzil have names both for wild and cultivated chaya (*sla ek* and *kulis ek,* respectively), it has been shown that the name for the cultivated material is undoubtedly derived from the Spanish *coles* (Berlin, Breedlove, and Raven 1974); the etymology of the wild material is uncertain (though a native name for wild material is unsurprising, considering Chiapas is well within the species' native range). The only other indigenous name for chaya is *tzitzicastle,* a common name of Nahuatl origin used in central Mexico to refer to *Cnidoscolus urens* (L.) Arthur (section *Jussieuia,* subsection *Urentes*), and only rarely (and probably mistakenly) associated with chaya. This clear dichotomy lends considerable weight to the theory that chaya was originally domesticated in the Yucatán and only recently spread to other areas in Post-Conquest times. It is quite possible, even, that this spread was recent; in these new areas of cultivation chaya is given a non-native name, whereas non-native plants introduced a long time ago often are given native names—*Delonyx regia* (Bojer ex Hook) Raf. (*mascabche*) is a classic example.

Berlin, Breedlove, and Raven (1974) delineated the folk taxonomical classification of chaya by the highland Tzotzil and Tzeltal, noting that the classification is over-differentiated, often a sign of the importance attributed to a plant. Classification by the Yucatec Maya, however, is even more complex (Fig. 4). The folk generic *chay* refers to both cultivated and wild material of *C. aconitifolius*; *C. Souzae* McVaugh, although recognized as a relative (hence the intermediate level, unnamed taxon) is referred to alternatively by either of the folk generics *tsah* or *x'etel.* Whereas *tsah* appears to be an unanalyzable primary lexeme, *x'etel* means "little rooster eyes"—due to the plant's small, white flowers—according to one knowledgeable informant. The folk generic *chay,* then, is differentiated further in the separation of wild and cultivated material. Cultivated material, regardless of variety, all belongs to the folk specific *chay* (the name is thus polysemous). Wild *C. aconitifolius* is known almost invariably by the name *tzin-tzin chay,* though it is unknown what meaning, if any, is attributed to the secondary lexeme *tzin-tzin.*

Though the folk specific *chay* is further divided into varietal names, these names are neither consistent nor widespread; in many areas local peoples are only aware of a single type of cultivated chaya. When further differentiation is recognized, most commonly it is between *chaya pica,* or chaya with spines, and *chaya mansa,* or spineless chaya. Often this differentiation is seen not between two different cultivated varieties (of the four recognized here), but within a single variety. Surprisingly, when this difference is recognized, *chaya* pica is unanimously thought to be better tasting than its unarmed counterpart. Although some of the literature refers to multi-

ple local varieties known by various names (*keken-chay* or pig chaya, *y'ax chay, joom chay,* etc.), we encountered none of these names in our field work, suggesting that they are either highly localized or that knowledge of the intricate differentiation of varieties has been lost as chaya has become less culturally important in modern times. Considering the geographical separation of the varieties, it is equally possible, however, that more than one of the varieties of chaya was not available in any given location until recently, which would explain the predominance of Spanish names at the varietal level.

Food Use

The use of chaya leaves as human food in Mesoamerica goes back without doubt to pre-Columbian times. Fray Diego de Landa left a brief but informative description of chaya in his 16th century work, *Relación de las Cosas de Yucatán* (Tozzer 1978:196). "They have a little tree," he wrote, "with soft branches and which holds a great deal of milk, the leaves of which are eaten cooked and are like cabbages to eat, and good with much fat bacon. The Indians plant it at once wherever they are going to stay and during the whole year it has leaves to gather." Another Spanish chronicle of the time (Coe 1994) mentioned chaya as an important food in the diet of Maya lords. Chaya is also cited twice as human food in the Maya text of the *Book of Chilam Balam of Chumayel* (Roys 1967). These historical references document what was probably an extensive use of chaya at the time of the European conquest, and suggest the antiquity of chaya as a Maya domesticate. The continuity of its use is evidenced in several historical documents (Marcus 1982; Pérez 1870), and in the first part of the 20th century the consumption of chaya was still quite common in the Yucatán peninsula. Benedict and Steggerda (1937) reported chaya as the only edible green in a list of the 60 most common foods of the Maya daily diet.

Chaya leaves and young shoots are still eaten today throughout Mesoamerica. Fresh chaya leaves are often sold in food markets in the Yucatán, and their consumption, though variable, is as frequent as several times per week in some families. As a food, Chaya is most popular in the small villages of the state of Yucatán, but is still common throughout the Maya region. In Guatemala, chaya is eaten about once a week in El Petén and in the southeast whereas in other regions of the country consumption is on the order of once a month or less (pers. obs.). Consumption of chaya is also not uncommon in Belize and western Honduras.

Though the diversity of uses of chaya as a food is unknown in pre-Hispanic times, modern usage of chaya is rather diverse. Although the larger mature leaves are preferred for use as wraps, generally the young, tender leaves and apical shoots are eaten. Often chaya leaves are eaten after boiling them in water with salt, with or without the apical shoots and sometimes with petioles. Cooking time is usually 10–20 minutes. Occasionally the broth is consumed in addition to the greens. Likewise, chaya greens are frequently combined with other vegetables and/or meat in soups and stews. Boiled chaya greens, covered with ground roasted *pepita* seeds (*Cucurbita* sp.), cooked tomato and chile (*Capsicum* sp.) are eaten as a sort of burrito in a corn tortilla. The most famous chaya dish is probably *Dzotobilchay,* consisting of diced chaya leaves mixed with *nixtamalized* corn dough, covered with sauce or vegetables and diced eggs, then wrapped in banana leaves or other chaya leaves, and cooked to make a tamale. Other popular Yucatec dishes include *Pibxcatic,* or stuffed chiles served over chaya leaves (de Caraza Campos and Luna Parra 1994), and *Brazos de la Reina,* made by rolling chaya leaves in corn dough, which is then steamed and served with tomato and squash seeds. Some people fry previously boiled chaya leaves and mix them with eggs, onions, and tomatoes, or cook the leaves on a hot clay pan (*comal*) and add them to salads. Most people consume cooked chaya leaves, and the leaves are only rarely eaten raw as fresh greens. A popular drink in the Yucatán peninsula is made by blending raw chaya leaves in sugar water with lemons, pineapple, and other fruits and sold to tourists as *chayagra,* along with claims of heightened virility. Altogether, we have amassed some 70 recipes for chaya from the literature alone, including four dishes with indigenous Yucatec names.

The majority of people interviewed in Guatemala claim to eat chaya primarily for its pleasant flavor; fewer mentioned its nutritive value. In contrast, the nutritional value of chaya leaves is highly regarded in Yucatán—primarily for its protein—and is sometimes seen as a suitable replacement for meat. Several informants ex-

TABLE 1. VERNACULAR NAMES OF *CNIDOSCOLUS ACONITIFOLIUS*.[1]

Name	Taxa Used	Locale
Chame	CNAC	Panama (Burger and Huft 1995)
Chatate	CNAC	Guatemala (Molina-Cruz, Curley, and Bressani 1997)
Chay	CNAC	Guatemala, Mexico
Chaya, chaya común	CNAC	Guatemala, Mexico
Chaya brava	CNAC	Mexico (Martin and Ruberté 1978; Pérez Toro 1948)
Chaya cimarona	CNAC	Mexico (Miranda 1952)
Chaya col, chaykol, col chaya	CNAC	Belize (Mallory 1991), Guatemala, Mexico (Barrera Marin, Barrera Vásquez, and López Franco 1976; Diaz-Bolio and León de Gutiérrez 1974; Pulido Salas and Serralta Peraza 1993; Sánchez-Jiménez and Estrada-Lugo 1989)
Chaya del monte	CNAC	Guatemala, Mexico (García, Sierra, and Balam 1996, Pérez 1870)
Chaya mansa	CNAC	Mexico
Chaya pica, pica, picar	CNAC	Estado de Yucatán (Banco Nacional de Crédito Rural 1988; Mendieta and del Amo R. 1981)
Chayo	CNAC	Guatemala (Coe 1994; Standley and Steyermark 1949)
Chicasquil	CNAC	Middle America (Morton 1981), Costa Rica (Burger and Huft 1995)
Chichicaste, tzitzicastli	CNUR, CNTU	Guatemala (Orellana 1987; Standley and Steyermark 1949) Mexico (Rzedowski and Equihua 1987; Sánchez-Jiménez and Estrada-Lugo 1989)
Chorera	CNAC	Panama (Burger and Huft 1995)
Copapayo	CNAC	Guatemala (de Pöll 1983; Standley and Steyermark 1949)
Hierba santa	CNAC	Costa Rica (Burger and Huft 1995)
Jom chaay	CNAC	Mexico/Maya (Teran, Rasmussen, and May Cauich 1998)
K'an chaay, chaya amarilla	CNAC	Mexico/Maya (Teran, Rasmussen, and May Cauich 1998)
Keken-chay, chaykeken, k'ek'ek'enchay	CNAC	Mexico (Díaz-Bolio and León de Gutiérrez 1974; Martin and Ruberté 1978; Sánchez-Jiménez and Estrada-Lugo 1989) Belize (Mallory 1991)
Kikil-chay, kiki-chay	CNAC	Mexico (Díaz-Bolio and León de Gutiérrez 1974; Sánchez-Jiménez and Estrada-Lugo 1989) Belize (Mallory 1991)
Kulis ek	CNAC	Chiapas (Berlin, Breedlove, and Raven 1974)
Mala mujer	CNAC, CNTU, CNSP, CNUR	Mexico
Ortiga, ortiguilla	Cn.sp.	Mexico (Martínez Alfaro 1984; Rzedowski and Equihua 1987; Schoenhals 1988) Costa Rica, Panama (Burger and Huft 1995)
Pingamoaz, pringamosca	CNAC	Panama (Burger and Huft 1995)
Quelite	JAAC	Estado de Yucatán (Mendieta and del Amo R. 1981)
Salik la, sla ek	CNAC, CNMU, CNTU	Chiapas (Berlin, Breedlove and Raven 1974; Breedlove and Laughlin 1933a,b)
Spurge nettle	CNAC, Cn.sp.	Mexico (Schoenhals 1988)
Tread softly, drug tread softly	CNAC, Cn.sp.	Guatemala (Orellana 1987), Mexico (Ingram 1957; Schoenhals 1988)
Tree spinach	CNAC	Central America (Kuti and Torres 1996; Rehm 1994), Belize (Mallory 1991)
Ts'its'ik-chay	CNAC	Yucatan (Souza-Novelo 1945)
Tza, tsats, tsah, xtsah, xtzah, tsaj, tsajim	CNAC	Mexico (del Amo R. 1979; Emes Boronda et al. 1994; Mendieta and del Amo R. 1981; Roys 1976; Salazar-Goroztieta 1991; Souza Novelo 1945; Standley 1920)

TABLE 1. CONTINUED.

Name	Taxa Used	Locale
Tzintzinchay, tzintzin-chay, chinchin-chay, ch'inch'inchay, ts'imtys'imchay, chim-chimchay	CNAC	Mexico (del Amo R. 1979; Díaz-Bolio and León de Gutiérrez 1974; Marcus 1982; Martin and Ruberté 1987; Roys 1976; Standley 1920)
X'etel, e'tel	CNAC, CNSO	Yucatan (Ortega et al. 1993)
X'chay, xchay	CNAC	Mexico (Argueta Villamar 1994; Barrera Marín, Barrera Vásquez, and López Franco 1976; García, Sierra, and Balam 1996; Sánchez-Jiménez and Estrada-Lugo 1989)
Xts'ats, tsats	JAAC	Estado de Yucatán (del Amo R. 1981; Mendieta and del Amo R. 1979; Standley 1920)
Ya'ax chaay, chaya verde	CNAC	Mexico (Teran, Rasmussen, and May Cauich 1998)

[a] Similar names are placed together. Some of the names are also used for the related species indicated as: CNTU = *C. tubulosis*, CNMU = *C. multilobus*, JAAC = *Jatropha aconitifolia*, CNSO = *C. souzae*, CNSP = *C. spinosus*, Cn. sp. = unidentified *Cnidoscolus* species.

plained that in the past, when meat was scarce or expensive, chaya was much more popular. But as the price of meat has dropped in modern times, chaya has decreased in popularity. Adding to this, chaya suffers from being seen by many of the younger generations as a food of the poor, a stigma which by no means augments its popularity. We also received reports of people eating wild chaya leaves—boiled to remove the spines and toxins—in times of extreme scarcity. The use of wild chaya as a famine food is confirmed by in the 16th century Maya text of Chilam Balam of Chumayel (Roys 1967) and in 16th century Spanish chronicles (Marcus 1982).

The continued presence of chaya in the Mesoamerican diet is probably due to its nutritional content. Many chemical analyses have shown

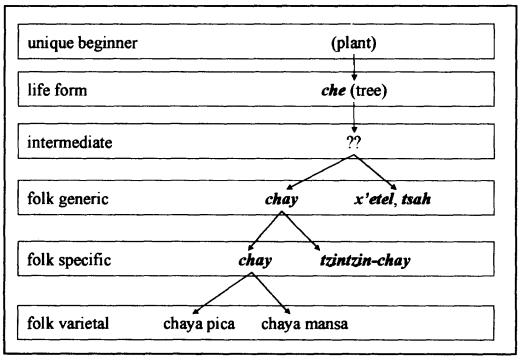

Fig. 4. Folk taxonomic structure of the Yucatec nomenclature for chaya.

that chaya leaves have a high content of vitamin C, β-carotene, and protein (Table 2), and are rich in calcium, phosphorus, iron, thiamin, riboflavin, and niacin (Ranhotra et al. 1998). In their 1952 study comparing the nutritional value of the 137 most common food plants of Yucatán, Cravioto et al. ranked chaya first overall in β-carotene content, second in vitamin C, fifth in calcium, fifth in riboflavin, sixth in iron, and thirteenth in protein. They note that chaya leaves may contain up to 10 times the vitamin C per mass of an orange. In fact, properly cooked, a mere 25 g of chaya greens with their cooking broth can provide the vitamin C daily requirement of an adult (Molina-Cruz et al. 2000). In addition, chaya leaf protein seems to be of relatively good quality, as has been shown by studies in chickens (Donkoh, Kese, and Atuahene 1990; Donkoh et al. 1999) and rats (Pérez-Gil et al. 1988), as well as a study of its amino acid composition (Kuti and Kuti 1999). Leaf protein extracts have been successfully extracted from chaya leaves (Nagy et al. 1978; Rivas-Burgos 1985). It is worth noting, too, that fresh chaya leaves contain significantly less moisture than other greens like spinach or lettuce, and therefore contribute more dry matter per unit fresh weight. Indeed, the inclusion of chaya—especially rich in vitamin C and β-carotene—would have been beneficial in the Mesoamerican diet, where staples of corn and beans are lacking in these nutrients. And although all four varieties of chaya are of high

TABLE 2.—COMPOSITION OF FRESH CHAYA LEAVES PER 100 G.

	Guatemala[1]	Mexico[2]	USA[3]
		g	
Moisture	72.1–83.0	80.00	—
Protein	4.17–6.82	7.20	5.8–8.2
Fat	1.72–2.87	0.09	0.4
Crude fiber	2.47–3.84	2.20	1.9–2.1
Total carbohydrates	8–13	6.70	5.9–6.4
Ash	2.5–2.8	—	2.1–2.3
		mg	
Calcium	141–497	324.00	199–221
Phosphorus	69–98	76.00	—
Iron	2.4–4.7	5.60	8.9–11.4
Retinol equivalents	—	946.00	—
β-carotene	10–18	—	—
Thiamin	0.2[4]	0.24	0.15–0.18
Riboflavin	0.4[4]	0.35	0.12–0.17
Niacin	1.6[4]	1.60	—
Ascorbic acid	287–318	235.00	165–172
HCN	27–42	—	—
		kcal	
Energy	675–105	57	—

[1] Ranges from 4 different cultivated chaya varieties analyzed at least in duplicates (Molina-Cruz et al. 2000).
[2] Muñoz de Chávez et al. 1996.
[3] Ranges from 2 different chaya cultivars (Kuti and Kuti 1999).
[4] INCAP-ICNND 1961.

nutritional value, differences in nutritional content do exist among the cultivars (Molina-Cruz et al. 2000).

The nutritional potential of chaya is modified by its preparation. Cooking chaya leaves leaches vitamin C from the leaves, transferring it to the cooking water; drying the leaves also significantly decreases their vitamin C content (Molina-Cruz, Solórzano, and Bressani 1997). Though other nutrients have not been studied in such detail, β-carotene does seem to be conserved during cooking (Molina-Cruz, Curley, and Bressani 1997). Uncooked chaya leaves contain cyanogenic glycosides that produce hydrogen cyanide (HCN) upon tissue damage. Cyanide levels readily decrease during cooking to below the allowable levels established for dry beans, peas, and nuts (0.025 mg HCN/g; ATSDR 1989), and there is no residual HCN left in the cooking water (Molina-Cruz, Solórzano, and Bressani 1997). The required cooking time to lower HCN to safe levels by boiling is around 15 minutes (Molina-Cruz, Solórzano, and Bressani 1997); this corresponds well to traditional cooking times. Drying the leaves significantly reduces the HCN content; but blending is sufficient only if the blended leaves are allowed to sit for several hours. A significant difference in the HCN content exists among the different cultivated chaya varieties (Molina-Cruz et al. 2000) suggesting that there might have been selection to decrease this toxicant. Goiter and konzo are frequently cited effects of the long-term consumption of cassava, which is thought to contain the same cyanogenic glycoside (linamarin) as chaya (Seigler 1994). To the best of our knowledge, however, there have been no reports of acute or chronic effects due to the consumption of fresh or cooked chaya leaves.

AGRICULTURE

The cultivated varieties of chaya are reproduced almost exclusively by stem cuttings. 'Picuda' is occasionally reproduced by seed, but the other three varieties are only propagated vegetatively. Many informants claim that it is better to let the cuttings dry for some time—advice in the literature and from informants varies from one day to two weeks—before planting them, because under humid conditions

the stems rot easily. It is also advised that the stems be broken, rather than cut with a machete, as this seems to decrease the incidence of infection.

The chaya plant itself seems to adapt equally well to humid or dry areas. We have successfully cultivated chaya in low light conditions with permanently inundated soil, as well as non-irrigated desert conditions in practically full sun. Although the plant survives in these extreme conditions, obviously more favorable conditions are necessary to maintain plentiful leaf production. But the fact that chaya grows well in the thin, dry limestone soil of the Yucatán Peninsula suggests that chaya could be used in other areas of the world with poor soil. Indeed, it is likely that the higher frequency of chaya in the northern Yucatán Peninsula compared to the more fertile southern areas of Mesoamerica may be due to the lack of other edible greens that can tolerate such poor soil.

Most often chaya is found planted in home gardens or as part of a hedge, rather than grown in agricultural fields. The exception to this rule is the occasional *milpa* or experimental station, where one or more shrubs are cultivated in a more or less agricultural setting. The only evidence of chaya planted on agricultural basis in ancient times is some tentatively identified root material from raised fields in Pulltrouser Swamp in Belize (Miksicek 1983). Plants are grown primarily for human consumption or medicinal use, though it is not infrequent to find chaya greens being used as a feed for animals—mainly for pigs, chicken, iguanas, ducks, and goats, and occasionally for cattle.

A widespread belief in Mesoamerica is that one has to ask a chaya plant for permission before harvesting leaves to avoid being stung by its spines. It is also believed by some that the plant, and thus its spines, wakes up in the early morning with the arrival of the sun, and that to harvest leaves safely, they should be cut in the early morning or late evening. We have found that wearing gloves or even thin plastic bags is also effective for preventing being stung during harvest, and that these are useful even with glabrous plants, because long-term contact with the white sap can cause skin irritation.

The chaya plant can grow into a five to six meter shrub, but its weak branches are easily broken by the wind. It is therefore recommended to cut the plant to maintain a height of less that two meters. This is common practice in home gardens, and is probably the reason that the maximum height of cultivated chaya is often cited as 1.5–2 m. Despite the need to keep the plants relatively small, chaya actively produces large amounts of leaf material. According to Sandoval, Cetina, and Herrera (1991a,b), 'Chayamansa' has produced as much as 5.7 t/ha per year of leaf dry weight (including petiole) in the Yucatán Peninsula, and in Guatemala 12 t/ha per year (Cifuentes, Molina-Cruz, and Arias 2000) has been achieved with 'Estrella' at twice the plant density (8889 plants/ha in fertile soil at 20 masl). This production compares favorably to that of other leafy vegetables. The optimum harvest period seems to be between two to three months (Cifuentes, Molina-Cruz, and Arias 2000; Sandoval, Cetina, and Herrera 1991a,b), though in home gardens, of course, leaves are harvested as needed.

Though occasional predation by herbivorous insects is apparent, no significant pests or diseases have been reported for chaya. In Yucatán, 23 of 33 collections of chaya were found infected with the cassava common mosaic virus, but the effect of this pathogen on chaya is minimal, because viral symptoms were not obvious in most of the plants collected (Elliot and Zettler 1987). The virus is presumably transmitted mechanically through infected knives or machetes during cutting of stems (Lozano et al. 1981).

Medicine

Although chaya's main use, at least in its original area of domestication, was as a valued food source, chaya was and continues to be an important medicinal plant. Much of the recent spread of chaya into new areas likely can be attributed to its medicinal value.

Unfortunately, the historical evidence for the medicinal use of chaya is somewhat limited. The two best sources available are Roys's famous work, *The Ethnobotany of the Maya* (1976), in which he compiled recipes and references from a variety of rare or unique manuscripts, and *Recetarios de Indios en Lengua Maya* by Juan Pio Pérez (1870), a compilation of Maya herbals published some years after the author's death. Although Pérez did not cite his sources, the earliest of the manuscripts used by Roys was probably early 18th century, but due to their informal nature it is difficult to know (Roys 1976). Although references exist from the 18th century

onward, we can only suppose that chaya was a valuable medicinal plant even before the Spanish Conquest. None of the Spanish texts from that time mention any use of chaya medicinally. Likewise, there is no historical evidence of the medicinal use of chaya outside of the Yucatán peninsula.

Entering the 20th century, however, we find numerous works citing chaya as a medicinal plant, not only in Yucatán but throughout its distribution. Table 3 lists the most commonly cited medicinal uses of chaya and its wild relatives. A wide variety of claims have been made as to the medical efficacy of chaya as a treatment for numerous ailments, ranging from the ability to strengthen fingernails and darken graying hair (Díaz-Bolio and León de Gutiérrez 1974), to its use as a cure for alcoholism (Argueta Villamar 1994), insomnia (Sánchez-Jiménez and Estrada-Lugo 1989), venereal disease (Mendieta and del Amo R. 1981), gout (Orellana 1987), scorpion stings (Salazar Goroztieta 1991), and as an improvement of brain function and memory (Jensen 1997). A wild relative of chaya, *Cnidoscolus multilobus* (Pax) I.M. Johnst., is even attributed with anticonceptive properties (Espinosa Salas 1985) and the power to cure fright or witchcraft (Martínez Alfaro 1984). Most of these claims are made only by a single author, and it is thus difficult to determine their validity as a commonly considered use of chaya.

Medicinally, chaya leaves are prepared and used often in a manner similar to when normally eaten. It is quite commonly advised to prepare the leaves simply by boiling, and the method of administration is usually cited as "oral." Apart from merely eating cooked leaves, infusions or teas are occasionally made from the leaves (Mellen 1974; Pulido Salas and Serralta Peraza 1993; Sánchez Jiménez and Estrada-Lugo 1989), and to treat diabetes and kidney problems the ground or blended leaves are often made into a shake, many times with other vegetables such as *calabaza* (*Cucurbita* sp.) or *nopal* (*Opuntia* sp.) (Salazar Goroztieta pers. obs. 1991). There are notable exceptions to these standard recipes, however. Sometimes the roots of wild or cultivated chaya are to be crushed and poulticed (Roys 1976) or taken orally (pers. obs.) to treat kidney disorders and back pain. And though a few authors insist on orally administering treatment for inflammation or hemorrhoids (Díaz-Bolio and León de Gutiérrez 1974; Sánchez Jiménez and Estrada-Lugo 1989), poultices are the most commonly prescribed remedy (Roys 1976). In the case of gum disease and skin disorders, the sap of the plant is sometimes applied directly to the affected part (Salazar Goroztieta pers. obs. 1991), though other authors prescribe the use of the leaves locally (del Amo R. 1979; Mendieta and del Amo R. 1981; Roys 1976). Simply eating the leaves is claimed to improve vision (Díaz-Bolio and León de Gutiérrez 1974; Jenson 1997), but Anderson (unpubl. data) notes that the water in which the leaves were boiled is used directly as an eyewash to treat vision disorders or discomfort. Roys (1976:17) recommended the administration of "grated *Jatropha aconitifolia* Mill. (*Chaya*) with horse-dung and honey and *Capsicum annum* L." to new mothers in the case of a retarded afterbirth, adding that the concoction "be drunk warm." As a cure for jaundice Roys (1976:127) suggested to "seek the leaf grated *Jatropha aconitifolia* Mill. (*Chaya*), squeeze the liquor out of this boiled *chaya* and put it out in the dew at the doorway of the house until dawn . . . then you add white sugar to it and give it to drink as a remedy." Another use of chaya is to treat muscle disorders, fatigue, and even rheumatism or arthritis, for which it is often prescribed to rub or beat the affected part with the stems or leaves of the plant; the painful stinging caused by the trichomes or spines supposedly revives disabled muscles or joints (pers. obs.). This use is probably the most common when considering the genus as a whole, for at least three other species are used in a similar manner—*C. multilobus, C. Souzae,* and *C. urens* (pers. obs.).

To our knowledge the only study of the frequency of the different medicinal uses of chaya was that done by Salazar Goroztieta (1991) in her thesis on chaya in the state of Morelos. Though a recent introduction to the state—none of her informants had owned a chaya plant for more than eight years—and thus probably not representative of its medicinal use as a whole, she found that, of 85 informants interviewed, 60 used chaya for kidney ailments, 21 for diabetes, 10 for ulcers, blood pressure, and scorpion bites, and only four used chaya for other medicinal purposes (Salazar Goroztieta 1991). Our own field work, though not quantitative in nature, agrees at least with the first two uses in her list. In the Yucatán Peninsula, treatment of kidney disorders, and specifically kidney stones, is

TABLE 3. COMMONLY CITED MEDICINAL USES OF CHAYA.[1,2]

Medicinal Use	Reference
Back pain, kidney pain, kidney stones	Díaz-Bolio and León de Gutiérrez 1974; Pulido Salas and Serralta Peraza 1993; Sánchez-Jiménez and Estrada-Lugo 1989; Zavala Ramos 1990
Biliousness, jaundice	del Amo R. 1979; Díaz-Bolio and León de Gutiérrez 1974; Mendieta and del Amo R. 1981; Roys 1976
Blood purifier, circulation, heart disease, cholesterol	Argueta Villamar 1994; Díaz-Bolio and León de Gutiérrez 1974; Jensen 1997; Orellana 1987; Salazar Goroztieta 1991; Sánchez-Jiménez and Estrada-Lugo 1989
Boils, warts, pimples or other skin conditions	Anderson (unpubl. data); Argueta Villamar 1994; Breedlove and Laughlin 1993a,b; Díaz-Bolio and León de Gutiérrez 1974; Salazar Goroztieta 1991; Sánchez-Jiménez and Estrada-Lugo 1989
Labor, retention of afterbirth	del Amo R. 1979; Roys 1976
Diabetes	Espinosa Salas 1985; García, Sierra, and Balam 1996; Kuti and Torres 1996; Pulido Salas and Serralta Peraza 1993; Salazar Goroztieta 1991
Digestion stimulant, laxative	Argueta Villamar 1994; Calvino 1919; Díaz-Bolio and León de Gutiérrez 1974; Morton 1981; Orellana 1987; Sánchez-Jiménez and Estrada-Lugo 1989
Eye problems, vision enhancement	Anderson (unpubl. data); Díaz-Bolio and León de Gutiérrez 1974; Jensen 1997; Salazar Goroztieta 1991
Gum disease, toothache	del Amo R. 1979; Mendieta and del Amo R. 1981; Roys 1976
Inflammation, hemorrhoids, piles, ulcers	Díaz-Bolio and León de Gutiérrez 1974; Morton 1981; Orellana 1987; Pulido Salas and Serralta Peraza 1993; Roys 1976; Salazar Goroztieta 1991; Sánchez-Jiménez and Estrada-Lugo 1989
Muscular disorders, rheumatism, arthritis	Arugeta Villamar 1994; Díaz-Bolio and León de Gutiérrez 1974; Orellana 1987; Salazar Goroztieta 1991; Sánchez-Jiménez and Estrada-Lugo 1989
Purgative, weight loss, diet	Jensen 1997; Osado 18th century
Stimulus for mother's milk	Argueta Villamar 1994; Osado 18th century; Teran, Rasmussen and May Cauich 1998
Urinary troubles, diuretic	Díaz-Bolio and León de Gutiérrez 1974; García, Sierra, and Balam 1996; Morton 1981; Osado 18th century; Pulido Salas and Serralta Peraza 1993; Salazar Goroztieta 1991

[1] Uses have been grouped into rough categories which do not necessarily reflect the original authors' classification.
[2] Uses are included for *C. chayamansa, Jatropha aconitifolia,* and *C. aconitifolius.*

overwhelmingly the most commonly cited medicinal use of chaya, and in most cases the only medicinal use of the wild species (in which case the root, instead of the leaves, was always used). All of the common uses cited above were mentioned in varying degrees by informants, as were most of the unusual ones, though the latter were expectedly more rare. The only two uses given by informants that were not cited in the literature were the application of chaya to treat cancer and HIV. These responses were, however, rare. In the Gulf Coast, where there is a history of medicinal use of *C. multilobus* and *C. aconitifolius* for gum disease (del Amo R. 1979; Espinosa Salas 1985), this use was more common for the cultivated chaya as well. Of the interviews conducted in Guatemala, only four informants were aware of any medicinal properties of chaya, and each of these gave a different use. Not surprisingly, medicinal knowledge seemed to be heavily correlated with an informant's experience and frequency of use of chaya. The majority of younger informants, whose use of or exposure to chaya was limited at best, knew few medicinal uses or were not even aware of its use as a medicinal plant; this held true for most informants who had recently acquired their plants as well.

Not uncommonly, chaya can be found sold as a medicinal plant in local markets. Normally,

when sold as such, the material is dried, somewhat shredded, and occasionally includes inflorescences and fruit. The chaya collected in markets as distant as Xalapa in northern Veracruz is undoubtedly *C. aconitifolius,* but occasionally other material is sold under the name chaya. In one market we purchased a bag of dried *Jatropha gossypiifolia* L. sold as chaya. Material purchased as chaya, along with an explanation of several of chaya's more well known medicinal qualities, in the city of Morelia in Michoacan was actually a mixture of three different genera: *Tagetes* (Asteraceae), *Hibiscus* (Malvaceae), and *Eryngium* (Apiaceae). In addition to pure plant material, chaya is occasionally sold in nutrition and health food stores as part of various herbal remedies. In such stores, one can even purchase capsules of "purified" chaya extract—evidence enough that the medicinal use of chaya continues to be popular even today.

The most important factor contributing to chaya's medicinal efficacy is undoubtedly its impressive nutritional value (Díaz-Bolio and León de Gutiérrez 1974). Most of its medicinal properties have never been experimentally tested, and it is unknown what the actual efficacy of chaya is in curing many ailments. The only published study on its antidiabetic properties indeed found a significant drop in blood sugar levels in diabetic rabbits fed increasingly higher quantities of chaya (Kuti and Torres 1996). In a recent study of the use of chaya leaf meal as a potential feed source for broiler chicks, Donkoh et al. (1999) provided some powerful evidence of the positive health benefits of chaya: chicks fed diets high in chaya leaf meal, though significantly lower in overall mass, experienced a significant increase in absolute heart mass, liver mass, red blood cell count, and a significant reduction in mortality. Though this cannot be directly extended to medicinal effects in humans, it certainly merits further investigation. These two studies, unfortunately, are the only of their kind with respect to chaya, though a few other species of *Cnidoscolus* have been evaluated for potentially bioactive compounds to no avail (Delgado et al. 1994; Macrae, Hudson, and Towers 1988), and the clinical effects of contact urticaria caused by species of *Cnidoscolus* and *Urtica* (Urticaceae) have been described in detail (Lampe and McCann 1985). Finally, with respect to the use of chaya sap for skin disorders, chaya is known to contain proteolytic enzymes (Iturbe-Chiñas and López-Mungia Canales 1986) that could have an effect on those ailments.

Conclusion

Chaya is a plant of ancient origin, with a long history of human use, propagation, and domestication. It is currently a widespread cultivar of increasing popularity, and both historic and ethnographic evidence suggest that it has been a plant of some importance as food and medicine. Based on linguistic evidence, local knowledge of medicinal information, what little historical evidence is available, and the degree to which chaya has been incorporated into the culture, it seems clear that chaya was domesticated in the Yucatán Peninsula, later spread to other areas within the Maya region, and has only recently been noticed by modern breeders and agronomists.

Chaya's potential as a crop plant is immense, either as a supplement to poor diets or as a crop on a larger industrial agricultural scale. Its use as an inexpensive source of protein for animals has been considered by several researchers (Donkoh et al. 1999; Newton 1984), its use in the herbal and nutritional industry is already growing, and several attempts have been made to improve it as an agricultural crop (Cifuentes, Molina-Cruz, and Arias 2000; Newton 1984; Peregrine 1983; Sandoval, Cetina, and Herrera 1991a,b). Its high nutritive value, ease of propagation, productivity, tolerance of poor growth conditions, and resistance to pests and disease all make chaya a valuable potential crop that could benefit peoples of many different regions.

Acknowledgments

JRI would like to acknowledge financial support for travel from both the Bedding Plants Foundation International and University of California MEXUS. Gracious advice, and help with revisions of the manuscript was provided by Eugene Anderson, Norman C. Ellstrand, and Arturo Gómez Pompa of the University of California Riverside. Reserva Ecológica El Edén and the Jardín Botánico Alfredo Barrera-Marín assisted with transportation and field work in Yucatán, as well as with maintenance of living collections.

AMC acknowledges partial support from the Programa de Investigaciones de la Cultura Maya de la Universidad del Valle de Guatemala and FONACYT, Guatemala (Projects No. 69-98 and 45-99). Important insights and advice were given by Ricardo Bressani and Rolando Cifuentes at UVG and Cesar Azurdia at USAC. Carlos Arias, Ursula Fisher, ICTA, Elfriede Pöll and Lida. Ana Lucía MacVean at the Herbarium UVG and Jardín Botánico at El Colegio de la Frontera Sur in San Cristóbal, Chiapas, helped with collections and identification. Finca el Capullo, Masagua, collaborated to maintain a living chaya collection.

Literature Cited

Argueta Villamar, A. 1994. Atlas de las plantas de la medicina tradicional Mexicana I. 1. ed. Biblioteca

de la medicina tradicional mexicana. Instituto Nacional Indigenista, México, D.F., México.

ATSDR. 1989. Cyanide, ATSDR public Health Statement. Report to Agency for Toxic Substances and Disease Registry, Department of Health and Human Services, Washington, D.C.

Banco Nacional de Crédito Rural. 1988. Comida familiar en el estado de Yucatán. Banco Nacional de Crédito Rural, México, D.F., México.

Barrera Marín, A., A. Barrera Vásquez, and R. M. López Franco. 1976. Nomenclatura etnobotánica maya: una interpretación taxonómica. Instituto Nacional de Antropología e Historia SEP Centro Regional del Sureste, México, D.F., México.

Benedict, F. G., and M. Steggerda. 1937. The Food of the Present-Day Maya Indians of Yucatan. Contributions to American Archaeology 3(18):157–187.

Berlin, B., D. E. Breedlove, and P. H. Raven. 1974. Principles of Tzeltal plant classification; an introduction to the botanical ethnography of a Mayan-speaking people of highland Chiapas. Academic Press, New York.

Breckon, G. J. 1975. *Cnidoscolus,* section Calyptosolen (Euphorbiaceae) in Mexico and Central America. Ph.D. thesis, University of California Davis.

Breedlove, D. E., and R. M. Laughlin. 1993a. The flowering of man: a Tzotzil botany of Zinacantán vol.1. Smithsonian contributions to anthropology no. 35. Smithsonian Institution Press, Washington, D.C.

———, **and** ———. 1993b. The flowering of man: a Tzotzil botany of Zinacantán vol.2. Smithsonian contributions to anthropology no. 35. Smithsonian Institution Press, Washington, D.C.

Burger, W., and M. Huft. 1995. Flora Coastaricensis. Feldiana Botany (New Series 36):6–17.

Calvino, M. 1919. La Mejor Verdura del Trópico. Revista de Agricultura, Comercio, y Trabajo 2(8): 364–365.

Carbajal, M., V. Parra-Tabla, and V. Rico-Gray. 1998. Effect of herbivory on sexual expression and reproductive success in the gynomonoic *Cnidoscolus aconitifolius* (Mill.) I. M. Johnston (Euphorbiaceae). Biotrópica 30(2 Suppl.):25.

Cifuentes, R., A. Molina-Cruz, and C. Arias. 2000. La chaya (*Cnidoscolus aconitifolius*): Efecto de la densidad de siembra, nivel de nitrógeno y defoliación en la producción de biomasa y la composición de las hojas. Paper presented at the XLVI Reunión Anual del PCCMCA, San Juan, Puerto Rico.

Coe, S. D. 1994. America's First Cuisines. University of Texas Press, Austin.

Cravioto, R., G. Massieu H., J. Guzman García, and J. Calvo de la Torre. 1952. Valor nutritivo de plantas alimenticias de Yucatán. Boletin de la Oficina Sanitaria Panamericana 32:328–339.

de Caraza Campos, L. B., and G. Luna Parra. 1994. Comida Yucateca. Guía gastronómica México desconocido. Editorial Jilguero, México, D.F., México.

de Pöll, E. 1983. Plantas Silvestres Comestibles de Guatemala. Facultad de Ciencias Químicas y Farmacia USAC, Revista científica. 1(1):6–17.

del Amo R., S. 1979. Plantas Medicinales del estado de Veracruz. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, México.

Delgado, G., J. Hernández, M. Y. Ríos, and M. I. Aguilar. 1994. Pentacyclic Triterpenes From *Cnidoscolus multilobus.* Planta Medica 60(4):389–390.

Díaz-Bolio, J., and L. León de Gutiérrez. 1974. La chaya, planta maravillosa: alimenticia y medicinal: crónica etnobotánica. Etnobotánica Maya. Mérida, México.

Donkoh, A., A. G. Kese, and C. C. Atuahene. 1990. Chemical composition of chaya leaf meal (*Cnidoscolus aconitifolius* (Mill) Johnston) and availability of its amino acids to chicks. Animal Feed Science and Technology 30(1–2):155–162.

———, **C. C. Atuahene, B. Poku-Prempeh, and I. G. Twum.** 1999. The nutritive value of chaya leaf meal (*Cnidoscolus aconitifolius* (Mill.) Johnston): Studies with broiler chickens. Animal Feed Science and Technology 77(1–2):163–172.

Elliott, M. S., and F. W. Zettler. 1987. Cassava common mosaic virus infections of chaya (*Cnidoscolus aconitifolius*) in Yucatan, Mexico. Plant Disease 71(4):353–356.

Emes Boronda, M., et al. 1994. Flora medicinal indígena de México: treinta y cinco monografías del Atlas de las plantas de la medicina tradicional mexicana. 1. ed. Biblioteca de la medicina tradicional mexicana. Instituto Nacional Indigenista, México, D.F., México.

Espinosa Salas, A. J. 1985. Plantas Medicinales de la Huasteca Hidalguense. Tesis licenciatura, Universidad Autónoma de México (UNAM), México, D.F., México.

García, H., A. Sierra, and G. Balam. 1996. Medicina maya tradicional: confrontación con el sistema conceptual chino. Educación Cultura y Ecología, México, D.F., México.

INCAP-ICNND. 1961. Tabla de Composición de Alimentos para uso en América Latina. Instituto de Nutrición de Centro América y Panamá, Guatemala, Guatemala.

Ingram, J. 1957. Notes on the Cultivated Euphorbiacea. Baileya 5:107–117.

Iturbe-Chiñas, F. A., and A. López-Munguia Canales. 1986. Proteolytic Enzymes from *Cnidoscolus chayamansa* "chaya". Journal of Food Science 51(1):243–244.

Jensen, S. A. 1997. Chaya, the Mayan miracle plant. Mexico Connect. http://www.mexconnect.com/mex_/travel/sjensen/sajchaya.html

Kuti, J. O., and E. S. Torres. 1996. Potential Nutri-

tional and Health Benefits of Tree Spinach. Pages 516–520 *in* J. Janick, ed., Progress in new crops. ASHS Press, Alexandria.

———, **and H. O. Kuti.** 1999. Proximate composition and mineral content of two edible species of *Cnidoscolus* (tree spinach). Plant Foods for Human Nutrition (Dordrecht) 53(4):275–283.

Lampe, K. F., and M. A. McCann. 1985. AMA handbook of poisonous and injurious plants. American Medical Association, distributed by Chicago Review Press, Chicago.

Lozano, J. C., A. Belotti, J. A. Reyes, R. Howler, D. Lethner, and J Doll. 1981. Problemas en el Cultivo de la Yuca. Centro Internacional de Agricultura Tropical, Cali, Colombia.

Macrae, W. M., J. B. Hudson, and G. H. N. Towers. 1988. Studies on the pharmacological activity of Amazonian Euphorbiaceae. Journal of Ethnopharmacology 22:143–172.

Mallory, J. 1991. Common medicinal ethnobotany of the major ethnic groups in the Toledo District of Belize, Central America. Masters thesis, California State University Fullerton, Fullerton.

Marcus, J. 1982. The plant world of the sixteenth- and seventeenth-century lowland Maya. Pages 239–273 *in* K. V. Flannery, ed., Maya subsistence: studies in memory of Dennis E. Puleston. Academic Press, New York.

Martin, F. W., and R. M. Ruberté. 1978. Vegetables for the hot, humid tropics. Dept. of Agriculture Science and Education Administration Office of the Regional Administrator for Federal Research, New Orleans.

Martínez Alfaro, M. A. 1984. Medicinal plants used in a Totonac community of the Sierra Norte de Puebla: Tuzamapan de Galeana, Puebla, Mexico. Journal of Ethnopharmacology 11:203–211.

McClung de Tapia, E. 1992. Origins of agriculture in Mesoamerica and Central America. Pages 143–171 *in* C. W. Cowan and P. J. Watson, eds., Origins of Agriculture: an International Perspective. Smithsonian Institution Press, Washington, D.C.

McVaugh, R. 1944. The Genus *Cnidoscolus*: Generic Limits and Intrageneric Groups. Bulletin of the Torrey Botanical Club 71(5):457–474.

Mellen, G. A. 1974. El uso de las plantas medicinales en Guatemala. Guatemala Indígena 9(1/2):99–179.

Mendieta, R. M., and S. del Amo R. 1981. Plantas medicinales del Estado de Yucatán. 1a ed. Instituto Nacional de Investigaciones sobre Recursos Bióticos; Cía. Editorial Continental distributor, Xalapa, México.

Miksicek, C. H. 1983. Macrofloral Remains of the Pulltrouser Area: Settlements and Fields. Pages 95–104 *in* B. L. Turner and P. D. Harrison, eds., Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize. University of Texas Press, Austin.

Miller, K. I., and G. L. Webster. 1962. Systematic Position of *Cnidoscolus* and *Jatropha.* Brittonia 14: 174–180.

Miranda, F. 1952. La vegetación de Chiapas. Sección Autográfica, Departamento de Prensa y Turismo, Tuxtla Gutiérrez, México.

Molina-Cruz, A., L. M. Curley, and R. Bressani. 1997. Redescubriendo el valor nutritivo de las hojas de chaya (*Cnidoscolus aconitifolius*; Euphorbiaceae). Ciencia en Acción, Universidad del Valle de Guatemala (3):1–4.

———, **M. Solórzano, and R. Bressani.** 1997. Hojas de chaya (*Cnidoscolus aconitifolius*): II. Efecto de cocción y almacenamiento en la vitamina C y los glucósidos cianogénicos. Paper presented at the II Simposio Latino Americano de Ciencia de Alimentos-Progreso y acción para el año 2000, Campiñas, Brasil.

———, **R. Cifuentes, C. Arias, and R. Bressani.** 2000. La chaya (*Cnidoscolus aconitifolius*): variedades, composición y distribución en Guatemala. Paper presented at the XLVI Reunión Anual del PCCMCA, San Juan, Puerto Rico.

Morton, J. F. 1981. Atlas of medicinal plants of Middle America: Bahamas to Yucatan. Charles C. Thomas, Springfield.

Muñoz de Chávez, M. A. Chávez, J. A. Roldán, J. A. Ledesma, E. Mendoza, F. Pérez-Gil, S. L. Hernández, and A. G. Chaparro. 1996. Tablas de Valor Nutritivo de los Alimentos de Mayor Consumo en México. Editorial Pax México, México, D.F., México.

Nagy, S., L. Telek, N. T. Hall, and R. E. Berry. 1978. Potential food uses for protein from tropical and subtropical plant leaves. J. Agric. Food Chem. 26(5):1016–1028.

NAS. 1975. Chaya. Pages 45–48 *in* Underexploited tropical plants with promising economic value. National Academy of Sciences, Washington, D.C.

Newton, L. E. 1984. Chaya, a protein rich vegetable. Report to the University of Science and Technology, Kumasi, Ghana.

Orellana, S. L. 1987. Indian medicine in highland Guatemala: the pre-Hispanic and colonial periods. University of New Mexico Press, Albuquerque.

Ortega, L. M., S. Avendaño, A. Gómez-Pompa, and E. U. Ek. 1993. Los solares de Chunchucmil, Yucatán, México. Biótica, Nueva Época 1:37–51.

Osado, R. [18th century.] El Libro del Judío ó Medicina Doméstico: descripción d elos nombres de las yerbas de Yucatán y las enfermedades a que se aplican. Mérida, México.

Peregrine, W. T. H. 1983. Chaya (*Cnidoscolus aconitifolius*)—a potential new vegetable crop for Brunei. Tropical Pest Management 29(1):39–41.

Pérez, J. P. 1870. Recetarios de Indios en lengua maya: índices de plantas medicinales y de enfermedades; con estractos de los recetarios, notas y

añadiduras por C. Hermann Berendt. Serie de Fuentes Para el Estudio de la Cultura Maya. Universidad Nacional Autónoma de México, México, D.F., México.

Pérez-Gil, R. F., M. L. Arellano, R. H. Bourges, M. M. García, and C. D. Grande. 1988. Alimentos tradicionales y no tradicionales: V. Aspectos del valor nutritivo de la hoja de chaya (*Cnidoscolus chayamansa*) para la alimentación humana y animal. Revista de Tecnología de Alimentos 23:5–10.

Pérez Toro, A. 1948. La chaya en Yucatán. Tierra 3(7):566.

Pulido Salas, M. T., and L. Serralta Peraza. 1993. Lista Anotada de las Plantas Medicinales de Uso Actual en el Estado de Quintana Roo, México. Centro de Investigaciones Quintana Roo, Chetumal, México.

Ranhotra, G. S., J. A. Gelrothm, S. D. Leinen, M. A. Viñas, and K. J. Lorenz. 1998. Nutritional profile of some edible plants from Mexico. Journal of Food Composition and Analysis 11:298–304.

Rehm, S. ed. 1994. Multilingual dictionary of agronomic plants. Kluwer Academic Publishers, Boston.

Rivas-Burgos, J. I. 1985. Obtención de un concentrado proteico de hojas de chaya (*Cnidoscolus chayamansa*). Tesis de maestría, Instituto Politécnico Nacional, México, D.F., México.

Roys, R. L. 1967. The book of Chilam Balam of Chumayel. 2 ed. University of Oklahoma Press, Norman.

———. 1976. The Ethno-botany of the Maya. ISHI reprints on Latin America and the Caribbean. Institute for the Study of Human Issues, Philadelphia.

Rzedowski, J., and M. Equihua. 1987. Atlas cultural de México: Flora. Secretaría de Educación Pública, México, D.F., México.

Salazar Goroztieta, L. P. 1991. Estudio Etnobotánico de la Chaya *Cnidoscolus chayamansa* McVaugh, en 17 Municipios del estado de Morelos. Tesis de licenciatura, Universidad Autónoma del Estado de Morelos, Cuernavaca, México.

Sánchez-Jiménez, M. L., and E. Estrada-Lugo. 1989. Distribución de 10 plantas medicinales mexicanas: su medio ecológico y cultural (Zapote blanco, Guarumbo, Chaya mansa, Mala mujer, Guácima, Muicle, Berro, Zarzaparrilla, Tronadora y Chichicastle). Page 307 *in* E. Estrada Lugo, ed., Plantas Medicinales de México. Universidad Autónoma Chapingo, Departamento de Fitotecnia, Programa Universitario de Plantas Medicinales, Chapingo, México.

Sandoval, C., R. Cetina, and F. Herrera. 1991a. Avances en la agronomía de *Cnidoscolus chayamansa.* I. Comparación de dos intervalos de tiempo para la cosecha de hoja. Pages 58–60 *in* Informe anual de la facultad de medicina veterinaria y zootecnia, 1990. Ediciones de la Universidad Autónoma de Yucatán, Mérida, México.

———, ———, **and** ———. 1991b. Avances en la agronomía de *Cnidoscolus chayamansa.* II. Producción de materia seca cosechando rama tierna mas hoja a dos intervalos de corte. Pages 61–63 *in* Informe anual de la facultad de medicina veterinaria y zootecnia, 1990. Ediciones de la Universidad Autónoma de Yucatán, Mérida, México.

Schoenhals, L. C. 1988. A Spanish English Glossary of Mexican Flora and Fauna. Instituto Lingüístico de Verano, México, D.F., México.

Seigler, D. S. 1994. Phytochemistry and the Systematics of the Euphorbiaceae. Annals of the Missouri Botanical Garden 81(2):380–401.

Souza-Novelo, N. 1945. Apuntes relativos a la flora de Yucatán (1942). Instituto Técnico Agrícola Henequénero, Mérida, México.

Standley, P. C. 1920. Trees and Shrubs of Mexico. Contributions from the Untied States National Herbarium v. 23. Government Printing Office, Washington, D.C.

———, **and J. A. Steyenmark.** 1949. Flora of Guatemala. Fieldiana: Botany 24(6).

Teran, S., C. Rasmussen, and O. May Cauich. 1998. Las Plantas de la Milpa Entre los Mayas: Etnobotánica de las plantas cultivadas por los campesinos mayas en las milpas del noroeste de Yucatán. Fundación Tun Ben Kin, Yucatán, México.

Tozzer, A.M. 1978. Landa's Relación de las Cosas de Yucatán. Kraus Reprint Co., Millwood.

Webster, G. L. 1975. Conspectus of a New Classification of the Euphorbiaceae. Taxon 24(5/6):593–601.

Zavala Ramos, F. T. 1990. Plantas medicinales de la región de los Chenes: español-maya. Instituto Nacional Indigenista, Centro Coordinador Indigenista Maya, Hopelchen, Campeche, México.