Volume 1: Final Report

Phase III Data Recovery Investigations at Three Prehistoric Archaeological Sites (CE-11, CE-32, and CE-33)

Municipality of Ceiba, Naval Activity Puerto Rico

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11 ASSESSING ETHNOBOTANICAL DYNAMICS AT CE-11 AND CE-33 THROUGH ANALYSIS OF STARCH GRAINS, PLANT PROCESSING, AND COOKING ARTIFACTS

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This chapter discusses the results derived from the analysis of eight starch residue samples obtained from one coral tool, two stone tools, and five ceramic sherds from the two hilltop habitation sites of CE-11 and CE-33. The time frame pertinent to this starch-grain study can be bracketed by radiocarbon dates between approximately AD 1000 and 1450. This small sample produced both firm and provisional identifications of 10 different plant species and provides a glimpse of the botanical cultures at these two communities.

Using a microbotanical/microarchaeological approach, this study constructs direct associations between artifacts and human actions and thus has the potential to provide information on site function and other social dynamics. At the very least, the new information gained from this work reveals internal ethnobotanical dynamics at each site (e.g., subsistence, plant procurement, plant processing), which can be incorporated into our understanding of prehistoric plant use for eastern Puerto Rico and for the cultural periods represented by both sites.

Discussion begins by introducing starch-grain analysis in archaeology and establishing the general contexts for the artifacts selected for the study. The methodological framework for the work is outlined and followed by the results obtained from each selected artifact with a discussion of particular plant/artifact correlations. Some recovered starch grains have clear indications of anthropogenic modification (e.g., processing by grinding and cooking), which can include ritual use. An important archaeological discovery from CE-11 is the tentative identification of the hallucinogen cohoba (*Anadenanthera peregrina*). Some aspects related to the meaning of this plant for the people who processed its seeds are discussed and interpreted.

BACKGROUND

A starch grain, one of the various microscopic residues of roots, tubers, and seeds of food plants, can provide archaeobotanical identification of economic plants used in ancient human subsistence. Starch is the predominant polysaccharide that serves as food reserves for plants. Its morphology, size, chemical composition, and basic structure are characteristic for each species (Bello and Paredes 1999; Czaja 1978; Gott et al. 2006; Reichert 1913; Trease and Evans 1986). As other studies have shown, starch residues can be preserved for a long time in the imperfect, irregular surfaces (e.g., pores, fissures, cracks) of lithic, coral, and ceramic tools related to the processing of plants (Haslam 2004; Loy et al. 1992; Pagán Jiménez 2007; Pearsall et al. 2004;

Piperno and Holst 1998; Rodríguez Suárez and Pagán Jiménez 2008). If starch grains can be extracted from a tool and correlated to the starch of a known plant, then a direct link can be established between the implement and the plant or plants that it processed. Of all the microbotanical remains that have been studied, such as pollen grains and phytoliths, starch grains appear to be the only ones that can be directly correlated with human plant processing and use (Holst et al. 2007; Pagán Jiménez 2009; Pagán Jiménez et al. 2005; Pearsall et al. 2004; Perry 2004). Starch residues are not free in the natural environment, as has been wrongly suggested (see Newsom 2008); therefore, the pedological and taphonomical processes ascribed to other plant structures such as pollen and phytoliths (e.g., "pollen rain" and phytolith formation and natural dispersion) simply do not apply to starch grains in any circumstance (see Beck and Torrence 2006; Pagán Jiménez 2007).

For more than 25 years, the paleoethnobotanical studies developed in the Caribbean region have revealed valuable information regarding the introduction of continental plants (mainly trees and shrubs, and to a lesser extent tubers and seed/grain plants) and the intrinsic importance of plants for human historical development. However, the emphasis that is still predominant in tropical paleoethnobotany research, including the Antilles, is the study of macrobotanical remains, which provides important but limited perspectives on ancient human plant use (Piperno and Pearsall 1998) due to the fragile preservation of such remains. Because of this, those high-yield economic plants that have been thought of as essential for the prehistoric inhabitants of the West Indies have been almost imperceptible in the archaeobotanical (macrobotanical) record (see Newsom and Wing 2004). Recently, the study of archaeological starch grains in the West Indies has revealed early introductions of major exotic plants to the islands (e.g., maize [*Zea mays*], manioc [*Manihot esculenta*], sweet potato [*Ipomoea batatas*], arrowroot [*Maranta arundinacea*]), in addition to the continuous exploitation of resources that are strictly local (e.g., marunguey [*Zamia* sp.]). Puerto Rico is the only island of all the West Indies where systematic starch-grain studies have been undertaken, and this methodology has been central to understanding a wide-ranging number of archaeological and paleoethnobotanical research problems not only for Puerto Rico but for all the West Indies (see Berman and Pearsall 2008; Pagán Jiménez 2007, 2009; Pagán Jiménez et al. 2005) and beyond (Keegan 1987).

ARTIFACT CONTEXTS

CE-11 is a habitation site that contains large amounts of pottery (primarily Esperanza and Santa Elena) as well as shell tools, animal bone, and lithics deposited within dense shell middens (see Chapter 7). Artifacts incorporated into this study (Sample-1 through Sample-5) were recovered from four different excavation units (Table 11.1): EU 11, EU 13, EU 15, and EU 16. EU 11 was located on the southern half of the midden and contained late Cuevas and Santa Elena pottery. This is the earliest context from which microbotanical results were obtained. Level 2 of EU 11 produced two artifacts, a greenstone mano fragment (Sample-2) and a griddle fragment (Sample-3), that underwent starch-grain analysis. EU 13 was located in the northwest corner of the site in an area that produced abundant Esperanza and Santa Elena pottery but no earlier styles of pottery. A coral milling base fragment (Sample-1) was recovered in Level 1 of EU 13 in an area that contain almost no shell midden refuse. EU 15 and EU 16 are in the northern portion of the midden. EU 15 contained the same ceramic types as EU 13, while EU 16 had a mix of Cuevas

Table 11.1. Artifacts selected for analysis by provenience, type, and point samples at CE-11 and CE-33.

Sample Number FS No. Radiocarbon Dates (if available)	Site, Unit No., Level Cultural Association	Artifact Type Raw Material	Use Wear Sections (No. of Sample Points)	Lab. Number sample weight sample volume
Sample-1 **(FS 290)** **AD 1100-1120** **(cal. 2-σ)**	CE-11, EU 13, Level 1 (Santa Elena/Esperanza)	small milling base coral	used section: concave/cracked and porous (1)	10-01 0.045g 0.05ml
Sample-2 **(FS 277)** **AD 1030-1220** **(cal. 2-σ)**	CE-11, EU 11, Level 2 (Late Cuevas/Santa Elena)	mano fragment with a pecked end cf. tuff (greenstone)	used section (1)	10-02 0.217g 0.04ml
Sample-3 **(FS 277)**	CE-11, EU 11, Level 2 (Late Cuevas/Santa Elena)	griddle fragment clay	used section (1)	10-03 0.333g 0.5ml
Sample-4 **(FS 300)** **AD 1150-1270** **(cal. 2-σ)**	CE-11, EU 15, Level 2 (Santa Elena/Esperanza)	pottery fragment with charred interior crust clay	charred crust taken inside the body fragment (1)	10-04 0.107g 0.35ml
Sample-5 **(FS 327)** **AD 1160-1270** **(cal. 2-σ)**	CE-11, EU 16, Level 4 (Cuevas/Esperanza)	pottery fragment with charred interior crust clay	charred crust taken inside the base fragment (1)	10-05 0.150g 0.35ml
Sample-6 **(FS 190)** **AD 1410-1470** **(cal. 2-σ)**	CE-33, EU 20, Level 2 (Esperanza)	griddle fragment clay	used section (1)	10-06 0.024g 0.04ml
Sample-7 **(FS 51)**	CE-33, EU 5, Level 1, Feature 1 (Esperanza)	multi-faceted mano cf. tuff (greenstone)	used/pecked sections (1)	10-07 0.005g 0.01ml
Sample-8 **(FS 67)**	CE-33, EU 3, Feature 4 (Esperanza)	griddle fragment with rim section clay	used section (1)	10-08 0.053g 0.07ml

and Esperanza sherds. This unit contains mixed deposits because of its location at the exposed northern edge of the midden away from the protection of the large boulders in this area. Two ceramic vessel fragments with charred interior crusts were recovered in Level 2 of EU 15 (Sample-4) and Level 4 of EU 16 (Sample-5). Two radiocarbon dates obtained for the site come precisely from these two sherds, and both dates fall within the transitional Santa Elena to Esperanza time periods. The date range of the starch grain sampled proveniences for CE-11 is approximately AD 1150 and 1270. Additional samples from EU 13 and EU 11 also were dated, with the material from EU 11 having a slightly earlier beginning date (AD 1030) than all the other sampled units (a full discussion of radiocarbon dating from CE-11 is provided in Chapter 12).

CE-33 is also a habitation site located on a hillside terrace overlooking Puerto Medio Mundo (see Chapter 6). Excavations recovered primarily Esperanza-style ceramics and a sample of a remnant shell midden. Artifact Sample-6 through Sample-8, which consist of two griddle fragments and one multifaceted greenstone mano, came from three different excavation units: EU 3, EU 5, and EU 20 (see Table 11.1). All three units abutted a cut slope created when the midden was mechanically stripped sometime in the past, with EU 5 and EU 20 in shell midden deposits (Locus 1) and EU 3 in the tool production and use activity area (Locus 2). All these

proveniences contained Esperanza-style pottery, and one was radiocarbon dated (FS 190, EU 20; containing Sample-6) to AD 1410–1470 (cal. 2-σ).

MATERIALS AND METHODS

The eight artifacts used in this study were not washed after excavation in order to retain sediments or residues on their used surfaces. All potentially worked lithics were sent to the lithic laboratory of Dr. Reniel Rodríguez Ramos in Puerto Rico, where the grinding tools most conducive to this study were selected and sent to the paleoethnobotanical laboratory of the author. The Principal Investigator for the project chose griddles, vessel sherds, and the coral tool for possible inclusion in the study and sent these artifacts to the paleoethnobotanical laboratory, where the author selected the eight artifacts to sample.

For each artifact, the work surface for the sample extraction procedure was thoroughly cleaned with a new, moist rag and placed over a sterile paper. Sediment residues (dry method) and charred crust samples were extracted from various pinpoint locations on each artifact using a sterilized dental pick (see Pearsall et al. 2004; Perry 2004). The reason for multiple-point sampling was to ensure that microbotanical signatures were recovered from different facets or aspects of the same artifact. Finally, the extracted sediment was placed in a sterile microcentrifuge tube of 1.5 ml, which was then placed inside an appropriately labeled sterile plastic zip-top bag.

For all the samples, the following protocol was applied (modified from Atchison and Fullagar 1998; Barton et al. 1998; Pearsall et al. 2004). Samples (≥0.005 g each) were processed for the separation of starch grains with a solution of cesium chloride (CsCl) with a specific gravity of 1.79g/cm^{-3}. The objective was to separate the starch grains through flotation and to isolate them from other particles, as the starches are known to have an average specific gravity of 1.5g/cm^{-3} (Banks and Greenwood 1975). The separation was conducted by a centrifuge running at 2,500 rpm for 12 minutes during the first phase. The supernatant, where the starch grains would be contained, was then decanted and poured into a new sterile centrifuge plastic tube. The next step was to add distilled water to the sample and agitate the mixture for 10 seconds. With repeated washes this process reduced the specific gravity of the mixture through the dilution of salt crystals. This last step was repeated two more times, adding less water in each successive step and running each sample through the centrifuge at 3,200 rpm for 15 minutes. A droplet taken from the remaining residue was then placed on a sterile slide. Half a drop of liquid glycerol was added and stirred in order to increase the viscosity of the medium and enhance the birefringence of the starch grains.

Taxonomic Ascription of the Recovered Starch Grains

At present, the author has assembled a reference collection of starch grains obtained from modern economic plants (Table 11.2). It includes 55 specimens that have been formally described, along with 30 others informally described, together representing 68 genera and 61 species that encompass wild, domesticated, and cultivated species from the Antilles, continental tropical America, and parts of the Old World (Pagán Jiménez 2007). Through comparison, the detailed description of the morphological traits of the modern starch allows identification of taxa

Table 11.2. Sample of plants and their modern starch grains from the Pagán Jiménez reference collection.

Taxa	Range of Measures in µm	Mean in µm (Standard Deviation)	No. of Measures Considered
Domesticates			
1. Maize (*Zea mays*): Races			
a. Pollo	2-28	13 (±3.9)	116
b. Early Caribbean	3-20	13 (±3.6)	101
c. Negrito de Colombia	5-20	12.3 (±3.3)	107
d. Cateto cristalino	3-18	10.3 (±3.1)	107
e. Chandelle	2-20	12.3 (±3.2)	89
f. Tuśon	1-18	12 (±3.2)	109
2. Bean (*Phaseolus vulgaris*)	10-40	20 (±6.1)	111
3. Poroto (*Phaseolus lunatus*)	8-48	30	(Reichert 1913)
4. Manioc or yuca (*Manihot esculenta*)	5-20	13.5 (±3.7)	86
Cultivars			
5. White cocoyam or yautía blanca (*Xanthosoma sagittifolium*)	3-14	8 (±2.11)	115
6. Purple cocoyam or yautía lila (*Xanthosoma violaceum*)	5-15	10 (±2.8)	107
7. Maranta, yuquilla or pitisilén (*Maranta arundinacea*)	10-50 (Piperno and Holst 1998)	?	?
8. Lerén (*Calathea allouia*)	8-40	28 (±8.6)	126
9. Gruya or Achira (*Canna indica*)	15-88	40 (±13.04)	126
10. Achiote or Annatto (*Bixa orellana*)	4-40	14.3 (±6.2)	110
Wild			
11. Cohoba/Yopo (*Anadenanthera peregrina*)	4-38	22 (±5.7)	111
12. Jack bean (*Canavalia rosea*)	10-53	28 (±8)	109
13. Habichuela parada (*Macroptilium lathyroides*)	3-28	17.5 (±3.9)	122
14. Maraca (*Canna sylvestris*)	13-110	53 (± 17.61)	126
15. Calathea (*Calathea veitchiana*)	9-38	20 (±6.2)	126
16. Zebra (*Calathea zebrina*)	11-46	28 (±7.4)	112
17. Marunguey (*Zamia portoricensis*)	5-50	20 (±9.9)	108
18. Marunguey (*Zamia amblyphyllidia*)	1-83	18 (±13.5)	103
19. "Guáyiga" or Marunguey (*Zamia pumila*)	6-95	30 (±16)	110

of archaeological starches, as long as these grains exhibit sufficient diagnostic traits. If the taxonomic identification is deemed less secure, the category "cf." (in reference to the closest tentative classification) is used. A reliable or secure identification will not be established if archaeological starch grains exhibit traits that are not documented in our reference collection or in the published literature (Pearsall et al. 2004; Perry 2004; Piperno and Dillehay 2008; Piperno and Holst 1998; Reichert 1913; Ugent et al. 1986).

Identifications of archaeological starch grains in this study were conducted with an Olympus BH-2 microscope (with polarizing capacity) employing a 10X eyepiece with reticule and a 40X objective. A principal, but not exclusive, diagnostic element used to discern starch grains from other residues is the presence of the extinction (Maltese) cross observable under polarized light. The slides with the archaeological samples were comprehensively examined and their X/Y coordinates were annotated to facilitate their location in later inspections. After the analysis, the slides were stored in standard horizontal cardboard slide-holders and are presently preserved at the laboratory of Pagán Jiménez in Puerto Rico.

RESULTS

The results for the two sites are presented separately and include the proposed taxonomic ascription of the recovered starch grains for each artifact. Table 11.3 details the starch grains identified from the five artifacts sampled from CE-11.

Table 11.3. Starch grains identified on five artifacts from CE-11.

Taxa	**Sample-1** coral milling base	**Sample-2** mano with a pecked end	**Sample-3** griddle	**Sample-4** pot fragment with charred residues	**Sample-5** pot fragment with charred residues	**Starch Count**	**Ubiquity**[1] (%)
Tuberous roots, trunks, corms and rhizomes							
cf. *Zamia pumila*					1	1	20%
cf. *Zamia* sp.			1			1	20%
Zamia sp.		14				14	20%
Xanthosoma sagittifolium			3			3	20%
cf. *Xanthosoma sagittifolium*		2				2	20%
Calathea sp.				2		2	20%
Manihot esculenta					1	1	20%
Canna sp.		1				1	20%
Seeds							
Zea mays					3	3	20%
cf. *Zea mays*				1		1	20%
Leguminosae: cf. *Anadenanthera peregrina*	64 (cluster) + 5 isolated					69	20%
cf. *Phaseolus vulgaris*			1 (apparently gelatinized)			1	20%
Not Identified		2 (gelatinized)	5 (gelatinized)		1 (gelatinized)	8 (gelatinized)	----------
Starch Count	69	19	10	3	6	107	----------
Species Richness [2]	**1**	**3**	**3**	**2**	**3**		

[1] Ubiquity refers to the occurrence of the identified taxa between the sample spectra.
[2] Species richness combines both approximate ("cf.") and secure identifications.

Identified Starches from CE-11

Artifact Sample-1

This fragment of a small milling base made of elkhorn coral (*Acropora palmata*) has an obvious use wear pattern and a marked concavity on one of its surfaces (Figure 11.1). Although such concavities can be natural in this species of coral, this specimen is heavily modified along its borders, and individual polyps within the concavity have been ground smooth. Because of its small size, 5.5 x 5.4 cm (reconstructed at 9 cm across), it is likely that this tool was not used to produce plant derivatives (e.g., flour, vegetable pastes) in large quantities. Figure 11.2 is a

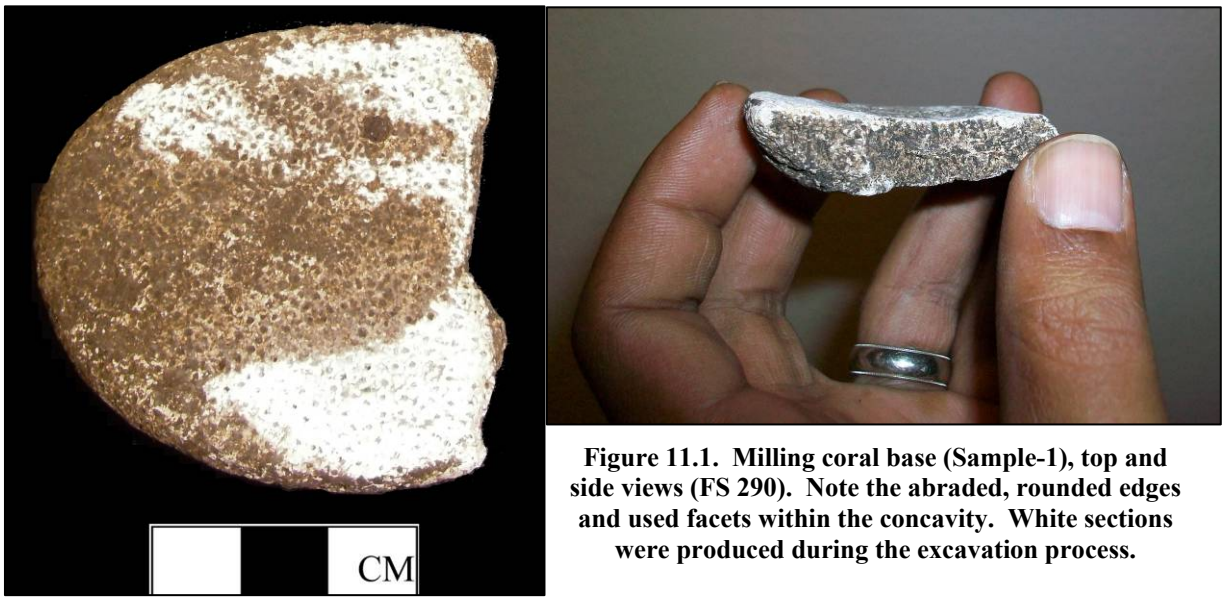


Figure 11.1. Milling coral base (Sample-1), top and side views (FS 290). Note the abraded, rounded edges and used facets within the concavity. White sections were produced during the excavation process.

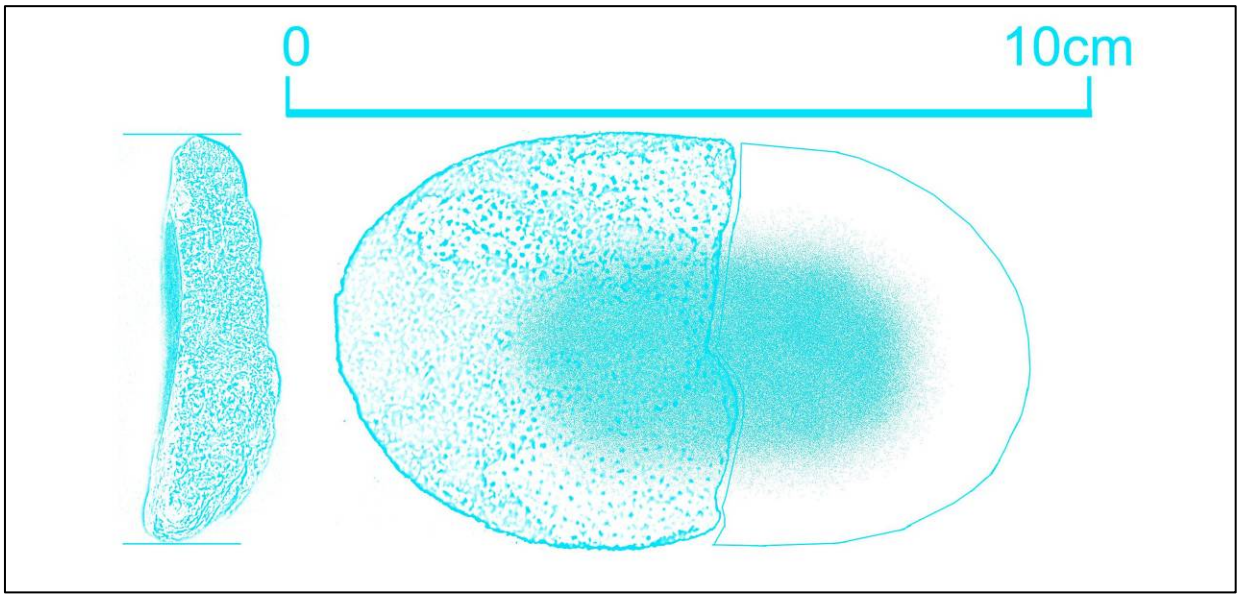


Figure 11.2. Hypothetical form of the complete coral milling base in top and side views (FS 290; Sample-1). Drawings by J. Pagán Jiménez.

rendering of the imagined complete artifact. It is possible that the tool has been used to process plant materials used as condiments (seasoning items), or to produce important plant derivatives used for medical, ritual, or magical-religious purposes, such as the preparation of hallucinogenic powders. Another possibility for such a small grinding surface is the processing of minerals, although there are no visible signs, such as pigmentation, on the used surface. Having no doubt that the coral artifact was a tool used to macerate, grind, or manipulate different materials on its surface, we extracted sediment samples from an artificial pore and from some polyps within the used surface.

Sixty-nine starch grains, all from a legume, were recovered (see Starch Appendix Figure 11-A at the conclusion of this chapter); 64 granules were documented in a cluster, and the remaining five occurred individually. The predominant shape of the granules was oval or oval-to-spherical; however, elliptical and some truncated shapes also were documented. The size of these granules ranged between 2 and 41µm. In the conglomerated and better represented granules within the cluster, the common size was 14µm, while the less common but better distinguished starches ranged in size from 27 to 34µm. Only four starches, each larger than 30µm, showed either of the typical lamellae variants of Leguminosae (symmetric and asymmetric circles).

The hilum was observed only in a few cases, mainly in those truncated or spherical bodies of less than 10µm. The position of the hilum could be determined mainly by the presence of the extinction (Maltese) cross. Birefringence of the starch grains was varied, with some reflecting high birefringence while others, mainly those bigger than 20µm, showed limited birefringence and almost imperceptible extinction crosses. Three of the four starch grains documented outside of the cluster showed surface fissures, which are consistent with the striations and cracks produced by grinding and processing seeds (Henry et al. 2009). Observed within the cluster was one broken starch grain and other granules with subtle extinction crosses; such alterations to the granule's structure may also have been the result of grinding. Transversal fissures are commonly associated with Leguminosae starch grains, and where fissures were documented, they were commonly transversal. Other fissures observed were the "T" type, the radial (asymmetrical) type, and the cross type, as well as abundant and thin striations that ran between the center and the edges of the starch grains. All these are likely related to anthropogenic disturbance processes (e.g., grinding).

In general terms, all the starch grains documented within the cluster are similar to those previously described for some legumes (Babot et al. 2007; Piperno and Dillehay 2008; Reichert 1913; see also Pagán Jiménez 2007). The granules found individually all share similar characteristics and also share characteristics with some of the granules observed in the cluster. All the granules on this object appear to be from the same legume species. These recovered starch grains definitely do not match domesticated legumes such as *Phaseolus* (common bean), due to differences in many important features including lamellae, size, fissure, striations, and conspicuous shapes (see Piperno and Dillehay 2008). The average starch grain size for our archaeological sample is 14µm, with shapes that fluctuate between spherical and oval. Some starch grains within the sample with better visibility were larger, between 27 and 34µm. The average size for modern domesticated *Phaseolus vulgaris* and *P. lunatus* is 20 and 30µm, respectively (see Table 11.2). The standard deviation for *P. vulgaris* is ±6.1; hence, the average size range for this species oscillates between 13.9 and 26.1µm (the standard deviation for

P. lunatus is likely similar). The combination of the smaller starch grains recovered from the cluster (14µm) and the recurrence of spherical-to-oval granules with a size range between 25 to 35µm are all characteristics widely consistent with those starch grains stored in the seeds of a wild species that is of enormous magical-religious importance to the prehistoric Antilles and large areas of the pre- and post-Columbian South American continent: cohoba (*Anadenanthera peregrina*) (Figure 11.3).

Figure 11.3. Cohoba (*Anadenanthera peregrina*) seeds dried naturally (above) and mature pods from an adult tree located at the University of Puerto Rico, Río Piedras (left). Photos by J. Pagán Jiménez.

Modern Cohoba. Starch grains from the mature (but not dried) seeds of modern cohoba are mostly spherical-to-oval in shape and range in size from 4 to 38µm. The average size of the granules is 22µm, with a standard deviation of 5.7, and the hilum is visible only in a few occasions, primarily in the smallest starch grains (34.9% of the modern sample). The position of the hilum is predominantly centric (55%), both in cases where it was directly discernable and in cases where the extinction cross was used to establish its position. Less than 10% of these starches (primarily the larger ones) show any type of lamellae (mainly concentric rings and symmetric circles). Margins are characterized by an undulating line around the bodies in more than half of the modern samples. Also, the fissures documented in these modern starches show some diversity, but the variability is restricted to the oval shapes. The radial (or asymmetrical) fissure is the most common of all those documented and occurs primarily in two of the oval shape variants. This type of fissure, which can be a set of deep lines or thin striations projecting from the center to the edge of the granules, seems to be diagnostic of *A. peregrina*, when compared to other Leguminosae. The second most common fissure registered in the oval granules is the transversal, also a regular element registered in other legumes. Finally, the third

important fissure variant is the "Y" type, which also occurs in other oval shapes of modern starches of cohoba.

There is a frequent shape in the modern starches of cohoba that is imperceptible or nonexistent in all the other legume starches studied until now, and that is the transovate-obtuse shape (see Starch Appendix Figure 11-A: image j compared with image c). Starches with this particular shape in the modern sample range in size from 13 to 19μm and typically show "T" and expanded "m" fissure types. However, outside the group of modern starch grains analyzed for this morphometric characterization, it was possible to associate this same shape with larger dimensions (between 22 and 27μm), as well as with radial fissures or thin striations that extend from the center to the margin of the starches. Interestingly, the oval-kidney-shaped starch that is ubiquitous and diagnostic in many of the cultivated or domestic legumes is totally absent in the modern starches studied from *A. peregrina* and in the archaeological sample described above.

Based on these characteristics, we tentatively ascribe all the starch grains recovered in Sample-1 to cohoba or *Anadenanthera peregrina*, knowing that the granules generally coincide with those produced by a legume but do not match with any of the known domestic or wild species used for food. Matches between the retrieved ancient starches and those described for modern cohoba are quite clear.

Other plant microstructures also were recovered within the Sample-1 artifact, although for now they are not identifiable. Three vessel element fragments with bordered pits and one of the scalariform type are xylem structures, which are commonly found in plant tubers and rhizomes (thick, horizontal, underground stems) of economic species such as *Calathea*, arrowroot, *Smilax*, manioc, and *Zamia*, but they also occur in seeds such as cohoba.

Artifact Sample-2

This metavolcanic mano (pestle) fragment contains clear signs of non-natural pecking in one of its ends (Figure 11.4). The raw material was tentatively identified as tuff (greenstone). Sediment recovered from the pecked end of the tool yielded a total of 19 starch grains (see Table 11.3; Starch Appendix Figure 11-B) mostly of the genus *Zamia* (locally called marunguey, in Florida called coonti). Other starches include a possible identification of yautía blanca/white cocoyam (*Xanthosoma sagittifolium*) and an example of the genus *Canna* (locally called gruya or achira).

Figure 11.4. Mano (pestle) fragment with a pecked extremity (at left) (FS 277; Sample-2). Material is likely tuff (greenstone).

Marunguey (*Zamia* sp.) is a cycad root, the edible portion of which is its subterranean stem, which can grow to 25 cm in diameter. It is pounded and ground into flour, and contains toxins that must be eliminated before consumption. Starch grains ascribed to the genus *Zamia* were recovered in a cluster and share characteristics with

documented modern specimens of the species *Z. pumila*, *Z. amblyphyllidia*, and *Z. portoricensis*. *Z. pumila* starches were identified in another sample from CE-11 (see Sample-5 discussion below), which advocates for this cluster being *Zamia pumila*. The general size range of the recovered starch grains oscillates from 9 to 41µm; however, the most common size range is between 30 and 41µm (comparable with modern *Z. pumila*; see Table 11.2). Shapes include oval, spherical, truncated, and transovate, and one of the starches has a linear fissure common to the genus *Zamia*. Although absent in the archaeological specimens described above, radial or asymmetric fissures and prominent lamellae are diagnostic for this genus; their absence here is likely a result of processing or cooking the plant.

Two starch grains tentatively ascribed to white cocoyam (*Xanthosoma sagittifolium*) match all the characteristics previously described for modern examples of this species (Pagán Jiménez 2007), including its size (13 and 18µm), the characteristics and location of the hilum (open hilum in one case and centric- and eccentric-position hilums, respectively), the registered shape (triangular with convex sides), and generally well-defined and discernible features.

The genus *Canna* was identified from a diagnostic granule 83µm long (Starch Appendix Figure 11-B, image c) with an elliptic shape, concentric lamellae, and open hilum in eccentric position. It was not possible to ascribe this sample to a particular species because the granule shows considerable damage on its surface (large cracks and striations) that could alter morphological features necessary for a more refined identification. The fissures and observed striations are the result of food preparation that included pounding of the plant rhizomes. Finally, two unidentified starch grains show evidence of gelatinization (Starch Appendix Figure 11-B, image d and image e), which is a chemical/molecular change in the granules likely produced by the process of cooking the starch in a liquid base. The presence of these granules in a milling/pounding mano reveals that starches were processed with this tool after they had already been intentionally heated or cooked.

In the sediment analyzed from artifact Sample-2, other plant microstructures were recovered that could not be identified, including three vessel elements with bordered pits that match with those found in rhizomes or tubers of cocoyam, manioc, *Calathea*, and arrowroot, among other vascular plants of economic importance.

Artifact Sample-3

This clay griddle fragment displays clear features (color and consistency) related to its use over fire (Figure 11.5). A total of 10 grains from three plant species were recovered from this object (Starch Appendix Figure 11-C), six of which are gelatinized, indicating exposure to heat. Of these six modified starches, one could be tentatively ascribed to common bean (*Phaseolus vulgaris*), while the remaining five could not be identified. An additional four starches were not gelatinized and could be positively identified as white

Figure 11.5. Clay griddle fragment showing used face (FS 277, Sample-3).

cocoyam and marunguey. The three cocoyam granules showed tenuous extinction crosses indicating some degree of damage caused by high temperatures or pounding. The size range of these starches oscillates from 11 to 15µm, two of them have spherical and truncated shapes, and the open hilum appears to be centric in all the three cases. These documented features, in addition to the presence of a raphide whose shape and dimension is very common in cocoyam corms, help confirm the proposed identification.

The remaining starch grain has sufficient morphological traits to ascribe it tentatively to the genus *Zamia* (possibly *pumila* as in the case of Sample-2). This grain has a pentagonal shape with convex facets and measures 26µm; a linear fissure is barely perceptible at the center of the body. An open hilum also was registered at the center of the grain only (coinciding with the fissure), and a pattern of thin striations runs from the center to the edges. These striations were likely formed by the action of pounding. All the starch grains recovered from this griddle were affected in one way or another by processes that are strictly cultural (heating or pounding).

Other plant microstructures noted on this artifact included two fragments of xylem cells that were vessel elements with bordered pits and scalariform types that occur in tubers such as sweet potato (*Ipomoea batatas*), *Calathea allouia*, *Canna* sp., *Smilax dominguensis*, and marunguey, among others.

Artifact Sample-4

Figure 11.6. Ceramic vessel fragment with charred residue on interior surface (FS 300, Sample-4).

One ceramic vessel fragment recovered from EU 15 retained a thick, charred residue on its interior surface, which was subjected to both radiocarbon dating and paleoethnobotanical analysis (Figure 11.6). Three starch grains were recovered, two of them ascribed to the genus *Calathea* (in the same family as arrowroot) and the other tentatively identified as maize (*Zea mays*). Starches identified as *Calathea* measure 90 and 30µm, respectively, and their shapes (triangular and oval), lamellae, open hilum and location within the body, and linear fissure recorded in one of the granules are all diagnostic features of this genus (Starch Appendix Figure 11-D, image b and image c). Although comparisons with sampled modern *Calathea* species in our reference collection do not reveal sizes greater than 40-45µm (see Table 11.2), starch dimensions as long as 80µm have been reported in rare cases for *Calathea zebrina* (locally called zebra) and *Calathea allouia* (locally called lerén). Either of these species are possible matches for the two archaeological starch grains, but they could also belong to another species not yet included in our comparative collection.

The starch grain tentatively identified as maize has morphological and dimensional features found regularly in modern starches of this species, specifically in those flint varieties with hard

endosperm such as some popcorns (Starch Appendix Figure 11-D, image d). In fact, the size of this grain (30 x 23µm) is larger than all the varieties in our modern comparative collection except for *Pollo*, which is a primitive popcorn from Colombia and Venezuela (Holst et al. 2007; Pagán Jiménez 2007:250).

Artifact Sample-5

A second ceramic vessel fragment with charred residue on its interior surface was recovered from EU 16 (Figure 11.7). Six starch grains were recovered from this sherd, five of which could be identified to three different species—marunguey (cf. *Zamia pumila*), manioc (*Manihot esculenta*), and maize (Starch Appendix Figure 11-E). One granule could not be identified due to gelatinization (compare Starch Appendix Figure 11-E, image g).

Figure 11.7. Interior base of a ceramic vessel with charred residues (FS 327, Sample-5).

The starch grain tentatively identified as *Zamia pumila* has features consistent with the genus *Zamia* such as shape, size, fissure, and lamellae patterns, while its size (79µm) is within the range produced by *Z. pumila* (Starch Appendix Figure 11-E, image b). It was not possible to establish a secure identification because of the large cracks and asymmetrical striations observed in the grain (a result of pounding). The birefringence evident in this starch grain when observing its extinction cross suggests that it may not have been affected by high temperatures. However, other researchers have noted these features in modern starches subjected to various cooking and heating experiments (e.g., Boyd et al. 2006; Henry et al. 2009; Messner and Schindler 2010).

The three starch grains securely identified as maize have sizes ranging from 13 to 24µm and shapes that are all diagnostic to the species (e.g., pentagonal enlarged, spherical, quadrangular-irregularly enlarged). Taken together with the fissures and position of the hilum, there is no doubt of its origin (Starch Appendix Figure 11-E, images c, d, and e).

A starch grain securely identified as manioc has four features (shape, point of inflection, fissure, and size) that are diagnostic of this species (Starch Appendix Figure 11-E, image f). Its size of 20 x 19µm, truncated shape, and stellate fissure are diagnostic and secure the confidence of this identification (see Perry 2002; Piperno and Holst 1998).

One remaining starch grain recovered from this sherd could not be identified due to its state of gelatinization (Starch Appendix Figure 11-E, image g). Although the starch had a more or less defined shape, when seen in dark field and cross-polarization, the extinction cross is lacking and its margins are significantly roughened. Because gelatinization can cause drastic changes in the overall size and shape of starches, this condition makes it impossible to identify such grains, at least until a comprehensive comparative collection of modern starches subjected to different cooking experiments (e.g., boiling, roasting, baking, and pounding/grinding before and after the cooking process) has been compiled.

Identified Starches from CE-33

Three artifacts were analyzed from CE-33; two were griddle fragments and one was a lithic mano with various use wear facets. Table 11.4 details the findings that include the identification of five different plant species.

Table 11.4. Starch grains identified on three artifacts from CE-33.

Taxa	Sample-6 clay griddle fragment	Sample-7 mano with used facets	Sample-8 griddle rim	Starch Count	Ubiquity(%)[1]
Tuberous Roots, Trunks, Corms and Rhizomes					
Zamia pumila	1			1	33.3%
cf. *Zamia* sp.	1		1	2	66.6%
Maranta cf. *arundinacea*	3 and ~20 (cluster in cellulosic tissue)			3 and ~20 (cluster in cellulosic tissue)	33.3%
Seeds					
Zea mays	1	2		3	66.6%
Leguminosae-Fabaceae			1	1	33.3%
cf. *Bixa orellana*	1			1	33.3%
Not Identified			3 (gelatinized)	3 (gelatinized)	----------
Starch Count	~27	2	5	11 + ~20 (cluster) + 3 (gelatinized)	----------
Species Richness [2]	**4**	**1**	**2**		

[1] Ubiquity refers to the occurrence of an identified taxa between the sample spectra.
[2] Species richness combines both approximate ("cf.") and secure identifications.

Artifact Sample-6

The clay griddle chosen for inclusion in this study showed clear patterns of having been subjected to heat (Figure 11.8). Analysis recovered 27 starch grains (Starch Appendix Figure 11-F), of which approximately 20 were found inside a package of cellulosic tissue. Four different plant species were identified from this griddle—marunguey, maize, arrowroot, and possibly the red dye annatto.

Figure 11.8. Clay griddle fragment showing used face (FS 190, Sample-6).

The two starches identified as marunguey (*Zamia* sp. and *Z. pumila*) have dimensions of 30 and 41µm, respectively, and their oval and pentagonal shapes with convex margins are consistent with both *Z. amlyphyllidia* and *Z. pumila*. The group of morphometric features documented in the pentagonal grain allows its confident identification as a starch from *Z. pumila*, thus allowing us to infer that the other (oval) starch grain comes from the same plant. Other features observed on

these two starches are the presence of the hilum in one case and lamellae (symmetric circles) in the other. Also, several fissure types were noted in one granule (when rotated) and included a "Y" type, an asymmetric or radial type, and a linear type in the area of the hilum.

Three individual starches have all the diagnostic traits of arrowroot (*Maranta* cf. *arundinacea*) (Starch Appendix Figure 11-F, images b, c, and d). It should be noted that the only element that does not allow us to propose a final identification of these starches is their size. Piperno and Holst (1998) established a general size range for the starches of this species between 10 and 50µm. Reichert (1913:224) estimated an average range of 40 to 50µm, while commenting that another author documented sizes up to 60 and 70µm. The three granules from Sample-6 measure 38µm, 54µm, and 71µm long (this last example is a compound starch). In the author's comparative collection of modern starches, arrowroot occasionally reached lengths of 70µm in both the original (green) variety and in the variegated cultivar; however, these were uncommon and far from the average and standard deviation of the mean, which was between 30 and 40µm. At least 20 more unidentifiable starch grains clustered together in cellulosic tissue. Even though this agglomeration concealed specific features, it was possible to measure and observe the extinction crosses of some of the granules. The size range of the starches within the cluster oscillates between 8 and 47µm, with the most common size being larger than 30µm. Considering that the features documented within the cluster match nicely with the starches produced by modern arrowroot (especially the particular shapes, sizes, and eccentric extinction crosses), they are likely one and the same.

Maize was identified from a single starch grain with all the diagnostic attributes previously described for this species (pentagonal-obtuse enlarged shape, 19 x 15µm) and especially those starches deposited in seeds of hard endosperm (flint) landraces (Cortella and Pochettino 1994; Holst et al. 2007; Pagán Jiménez 2007; Pearsall et al. 2004).

The final possibly compound starch was tentatively ascribed to *Bixa orellana* (achiote or annatto), which can be used as a red colorant or as a cooking spice. This granule displayed a combination of features (shape, size, and lamellae; see Starch Appendix Figure 11-F, image f) that resemble modern annatto starch grains. Transversal fissures are common in the oval starches of annatto (Starch Appendix Figure 11-F, image i) as well as other legumes (Leguminosae). Although the starch recovered from this griddle does not have fissures of any kind, it displays a sort of roughness on its surface that has only been seen, to date, on annatto starches (when compared to legume starches). The recovered grain size (33 x 24µm) is within the size range seen in the modern reference collection (see Table 11.2), but larger than the average size (14.3µm with a standard deviation of 6.2µm). Several modern annatto grains from the reference collection measure over 30µm (two are 30µm, one is 49µm, and two are 34µm; see Starch Appendix Figure 11-F, image i).

Artifact Sample-7

This complete metavolcanic mano (cf. tuff [greenstone]) contains various facets that show use wear patterns related to the pounding or grinding of vegetables and perhaps other materials (Figure 11.9). Testing yielded two starch grains, both identified as maize. This small number of recovered starches may be due to the low volume of sediment that could be extracted from the

used facets. These minor facets contain few imperfections (cracks, fissures, etc.), which may indicate that this tool was used minimally before being discarded in this midden.

Figure 11.9. Stone mano with multiple use wear facets (on face, left end, and top). Recovered in shell midden from CE-33 (FS 51, Sample-7).

The recovered maize starches are both 28µm long and triangular in shape (Starch Appendix Figure 11-G). In both cases it was possible to document an open, central-position hilum associated with smooth linear cracks (likely produced from grinding). A radiant double border was particularly notable in both cases. These starches are typical of maize races with hard endosperm, particularly the popcorn varieties (such as *Pollo*).

Other unidentified plant residues were recovered in the analyzed sample. Of the 11 xylem cell fragments observed, 10 were vessel element fragments with bordered pits and the other was a scalariform type, which occurs in various tubers, rhizomes, and seeds.

Artifact Sample-8

This griddle fragment displays post-production oxidation evident in the orange coloration on both surfaces, showing its use over fire (Figure 11.10). The rounded and upwardly curved and thickened rim on this artifact has been observed in several griddles studied at other archaeological sites of Puerto Rico (see AR-39 at Río Tanamá; SEARCH 2008). The variations seen in the griddle rim shapes may relate to different uses for the griddles. For example, thickened lips create a raised edge to the griddle that would contain foods with a higher liquid content (see Deboer 1975).

Figure 11.10. Clay griddle rim (FS 67, Sample-8).

Five starch grains were recovered from the extracted sample; two were tentatively identified as *Zamia* sp. and a legume, and the other three were gelatinized (Starch Appendix Figure 11-H). All five starches show different levels of alteration due to pounding, grinding, or boiling.

The marunguey (*Zamia* sp.) identification was based on shape (pentagonal), size (38 x 34µm), and fissures (asymmetric or radial); however, the identification is tentative due to the fractures and morphological alterations produced by pounding (Starch Appendix Figure 11-H, image a).

These documented qualities are consistent with those starches of the genus *Zamia* and more specifically with the *pumila* species, and taking into account the results of some experimental studies on starch grain alteration that included processing and cooking (Henry et al. 2009; Messner and Schindler 2010), it is feasible that this starch grain retains features that mirror its original characteristics.

The other starch grain tentatively identified was a legume (Fabaceae), possibly of the genus *Phaseolus* or *Canavalia* (Starch Appendix Figure 11-H, image b). Due to its morphological alterations, it is not possible to propose a more precise identification of this grain. However, some cracks and the apparent particle inlays (perhaps starch fragments) observed have been associated with the toasting process of certain legume starches by other researchers (Henry et al. 2009). Three other starches could not be identified because of their remarkable state of alteration (Starch Appendix Figure 11-H, images c and d); it appears that these grains are surrounded by fragments of other starches or the same starch in a melted state.

DISCUSSION

Important food plants of the prehistoric Antillean people including manioc, maize, beans, cocoyam, arrowroot, and marunguey have been identified in this study. For the first time in American pan-tropical archaeology, the processing and/or handling of seed powders from cohoba (*Anadenanthera peregrina*) have been tentatively identified. Previously, the only identification of this plant has been microscopic (Pochettino et al. 1999) and chemical (Torres Constantino et al. 1991) signatures noted on preserved snuff found in the southern Neotropics.

The results obtained in this study provide information regarding the following research topics in Caribbean archaeology: (1) procurement and production of domestic and wild plants as well as cultivars, (2) food, medicinal, and/or ritual use of plants, (3) determination of artifact functions, and (4) the reconstruction of daily activities directly related to the procurement of wild plants, the production of domestic and crop plants, and the processing and consumption of starch-rich plants.

A discussion of the identified individual plants follows in order of the plant's commonness and assumed importance in the subsistence practices of the people of CE-11 and CE-33. Table 11.5 combines the results of the starch-grain identifications by species from both sites and shows the varying ubiquity of the recovered plants. An extended discussion is provided for cohoba because of the unique relationship that existed between this hallucinogenic plant and Taíno religious practices and rituals supporting this culture's complex sociopolitical interaction sphere.

Plant Biographies: Procurement, Production, Processing, and Consumption

The plants identified in this study are mainly tubers, although edible seeds provide a significant portion of the subsistence items. Other plants, especially those valued for their fruits and vegetables (e.g., sapote [*Pouteria* sp.], soursop [*Annona* sp.], avocado [*Persea* sp.], squash [*Cucurbita* sp.], and other similar plants) cannot be documented by their microbotanical remains in the manner studied here. Similarly, industrial species used for fuel or in construction due to properties of the wood, fibers, and other derivatives (e.g., guayacán [*Guaiacum* sp.],

Table 11.5. Distribution of taxa within the group of samples analyzed from CE-11 and CE-33.

Taxa (Family or Genus)	CE-11					CE-33			Ubiquity[1] % for Both Sites
	Sample-1 coral milling base	**Sample-2** mano fragment, lithic	**Sample-3** clay griddle fragment	**Sample-4** pot fragment with charred residues	**Sample-5** pot fragment with charred residues	**Sample-6** clay griddle fragment	**Sample-7** mano, lithic	**Sample-8** griddle rim	
Tuberous Roots, Subterranean Stems, Corms and Rhizomes									
Zamia (marunguey)		X	X		X	X		X	62.5%
Xanthosoma (yautía/cocoplum)		X	X						25%
Maranta (arrowroot)						X			12.5%
Calathea (arrowroot family)				X					12.5%
Manihot (manioc/yuca)					X				12.5%
Canna (gruya or achira)		X							12.5%
Seeds									
Zea (maize)				X	X	X	X		50%
Leguminosae-*Anadenanthera* (cohoba)	X								12.5%
Leguminosae-Fabaceae (bean)								X	12.5%
Phaseolus (domesticated bean)			X						12.5%
Bixa (annatto)						X			12.5%
Not Identified		2 (gelatinized)	5 (gelatinized)		1 (gelatinized)			3 (gelatinized)	----------
Species Richness[2]	1	3	3	2	3	4	1	2	

[1] Ubiquity refers to the occurrence of an identified taxa between the sample spectrum.
[2] Species richness combines both approximate ("cf.") and secure identifications.

cotton/algodón [*Gossypium* sp.]) fall outside the restrictions of this discipline (cotton can potentially be identified through macroremains, phytoliths, or pollen). Even so, there is no doubt that the plant resources identified in this study and outlined below were the most relevant economic plants for the groups studied from these sites.

Marunguey

Marunguey (*Zamia* sp. and *Zamia pumila*) was the most commonly identified plant across the sampled artifacts, occurring in three of the five artifacts from CE-11 (Sample-2, Sample-3, and Sample-5) and two of the three artifacts from CE-33 (Sample-6 and Sample-8). Every clay griddle sampled contained remnants of this plant; it also was found in the charred residue on the inside of one clay pot and on a stone mano.

Figure 11.11. Marunguey (*Zamia amblyphyllidia*) plant (top) and its tuberous (subterranean) stem, which is very similar to *Z. pumila*. Photos by J. Pagán Jiménez.

This perennial belongs to the Zamiaceae family (order Cycadales) and grows wild and is native to Puerto Rico (Figure 11.11). Its natural distribution range is associated mainly with the limestone (karstic) and serpentinite regions of the island. Two of the three Puerto Rican species of marunguey (*Z. pumila* and *Z. amblyphyllidia*) grow in moist to dry forests and tend to form conglomerated populations as a result of their reproduction system (propagation by shoots or seeds). A third species (*Z. portoricensis*) does not form dense population clusters and is currently only found in southwestern Puerto Rico, a semi-arid region of the island characterized by karstic and serpentinite geology. It is possible to imagine that in the past at least two of the Puerto Rican marunguey species would have been relatively abundant and vigorous in the wild (as the author has currently observed at El Polvorín, Manatí, Puerto Rico).

At present, natural populations of marunguey are unknown for eastern Puerto Rico, with the nearest documented populations in the south-central portion of the island (e.g., Salinas-Guayama, Santa Isabel-Juana Díaz-Villalba). Several discrete limestone lenses in the south and west portions of Vieques, in the Loíza region in northern Puerto Rico, and in the region south of Naguabo (about 30 km west of NAPR) could have supported natural populations of this plant in

the past (see the 'Kll' variable in Briggs and Akers 1965). If these plants never occurred naturally in eastern Puerto Rico, it is possible that its derivatives (e.g., flour) could have been integrated into regional trade networks (for examples of perishable trade items, see Langebaek 1992; Lathrap 1973; Rodríguez Ramos and Pagán Jiménez 2006, 2007). Alternately, it is likely that this plant was transplanted and maintained in agricultural plots or house gardens along with other cultivated species.

Marunguey is a wild, high-yield food source of not only carbohydrates but also protein. However, powerful neurotoxins (cycasin) are found in all parts of this plant that require complex processing. After the underground, tuberous stems are grated, the pulp is submitted to various processes to remove the toxins. At least two different techniques for eradicating the toxic substance have been documented (Sturtevant 1969; Veloz Maggiolo 1992:137): one of these is biological (the action of enzymes and larvae), and the other involves multiple washes and squeezing of the pulp. The resulting flour is then made into bread called bollos (buns) (Figure 11.12). Las Casas (1909) described the use of this plant on the island of Hispaniola in the 16th century and referenced the consumption of bollos cooked in pots (cazuelas) with larvae:

> "Hácese el pan [de guáyiga o marunguey] de esta manera, conviene a saber, que en unas piedras ásperas como rallo, las rallan como quien rallase un nabo o una zanahoria en un rallo de los de Castilla, y sale luego una masa blanca y hacen della unos globos o bollos redondos, tan grandes como una bola, las cuales ponen al sol, y luego pónense de color de unos salvados o afrechos; están al sol uno y dos y tres días y al cabo dellos se hinchen de gusanos [larvas] como si fuese carne podrida, y quedan eso mismo tan negros poco menos que una tizne, como un negro algo deslavado que tira a pardillo; después que ya están en esta disposición, negros y hirviendo de gusanos tan gordos como piñones, hacen una tortilla dellos, que ya es masa cuanto a la blancura y ser correosa como la de nuestro trigo, y en una cazuela de barro que tienen ya sobre unas piedras, y fuego debajo, caliente, ponen sus tortillas, y desde un rato que están cociendo de un lado las vuelven del otro, donde bullendo con el calor los gusanos se fríen y mueren, y así quedan allí fritos."

> "The bread [of guáyiga or marunguey] is made thus, convenient to know, that on rough stones such as rallo [possibly pumice], you grate them as you would grate a turnip or a carrot on a grater from Castille [Spain]. This results in a white dough that is then formed into globes or round buns, as big as a 'bola' [possibly a reference to the balls used in the game bola], which are put out in sunlight until they attain the color of bran; if left out in sunlight one and two and three days at which time they will be swollen with maggots (larvae) as if it were rotten meat, and turn as black as soot, or a washed out black more brownish; once they reach this condition, black and boiling with maggots as fat as pine nuts, shape them into flat cakes, that are like dough already as to the whiteness and toughness, like our wheat, and in a hot clay pot that is already on rocks with fire beneath it, you place the cakes to cook on one side and then the other, where simmering with the heat, the maggots fry and die, and thus are cooked."

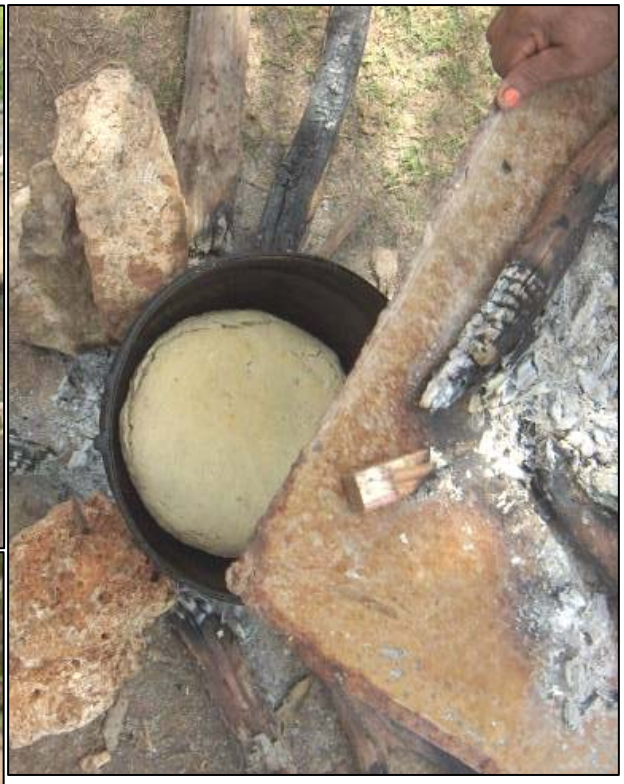


Figure 11.12. Processing and baking marunguey (guáyiga).
(Left top: grating the peeled tuberous stems with a homemade metal grater.
Above: baking the marunguey bread in a metal bowl by applying heat to the top and the bottom.
Left bottom: Doña María Villa with the final product, called "arepa de guáyiga."
Photos taken at El Cabo, Altagracia, Dominican Republic, courtesy of Dr. José R. Oliver.

Abbad y Lasierra (1957:252) documented a processing technique for Puerto Rico in the 18th century, noting maceration once the larvae have disappeared, in order to make the bollos:

> "... de su raíz, que es como una batata, hacen pan en esta forma: rallan las raíces [el tronco tuberoso] hasta que quedan bien desechas; luego las amontonan hasta que se pudren, crían gusanos y se secan; entonces parecen un montón de barro de color rojo oscuro; estando seco lo muelen hasta reducirlo á polvo, del cual hacen bollos con que socorren la falta de maíz, plátanos o yuca en tiempo de los huracanes (...) Este socorro les es muy perjudicial... que los años en que usan esta especie de pan mueren muchos de este accidente..."

> "…of the root, which is like a sweet potato, [they] make bread in this way: they grate the roots [the tuber stem or trunk] until they are well shredded, then they pile them up until they rot, breed maggots, and dry up; then it looks like a bunch of dark red mud, being dried, they grind it to powder, which is made into buns that is relied upon for lack of corn, plantains or yucca in the time of hurricanes (...) This relief is very damaging to them... the years when this kind of bread is used many are killed by this accident [note: the "accident" refers to possible poisoning from the marunguey].

At CE-11, marunguey starch grains were recovered in a stone mano with a pecked facet, in a griddle fragment, and in the charred crust within a ceramic pot. This suggests the maceration of the tuberous stem, followed by two cooking techniques: baking of bollos in pots and on griddles. Bollos made from marunguey have been documented from starch-grain studies at several late Saladoid (Cuevas) archaeological localities (e.g., Río Tanamá 2, Arecibo [ca. AD 400–750]; Kings Helmet/Punta Guayanés, Yabucoa [ca. AD 650–780]; Punta Candelero, Humacao [ca. AD 850]), identified on griddles, cooking pot fragments, and lithic microflakes used as grater-board teeth. Marunguey continued to be a staple food through the late Ostionoid, as confirmed by its identification on two griddle fragments from CE-33 in addition to two later-period sites on Cuba (Macambo II [ca. AD 1200–1600]; Laguna de Limones [ca. AD 1150–1490]).

Recent studies continue to document the economic and dietary importance of marunguey (including its related protein component provided by the insect larvae) to the prehistoric inhabitants of the Greater Antilles (e.g., Pagán Jiménez 2007, 2009; Pagán Jiménez and Oliver 2008; Rodríguez Suárez and Pagán Jiménez 2006, 2008), securing its place among the more widely known dietary staples of this region (e.g., legumes, maize, and probably cassava).

Maize (Maíz)

After marunguey, the second most common plant in this study is maize, found in two artifacts from CE-11 (Sample-4 and Sample-5, both clay pots) and two artifacts from CE-33 (Sample-6 and Sample-7, one griddle and one stone mano). These findings show both grinding and pounding of the seeds from this plant and the cooking of the processed maize both on griddles and in ceramic bowls.

Maize is a domesticated plant species that depends exclusively on humans for its reproduction and dispersal (Figure 11.13). The current research shows that maize was originally domesticated in the deciduous tropical forests of the Balsas River basin in Mexico at approximately 8500 BC (Piperno et al. 2009; Staller et al. 2006) by the selection and manipulation of its wild relative teosintle (*Zea mays* subsp. *parviglumis*). The oldest direct evidence for this comes from starch

grains ascribed to fully domesticated maize dating to ca. 7000 BC in the Balsas River basin (Piperno et al. 2009). Once the initial domestication began, maize was dispersed by humans in a relatively short span of time to other regions of the Americas (Staller et al. 2006), including Panama by ca. 5500 BC and Colombia and Ecuador by ca. 4500 BC (Dickau et al. 2007; Piperno and Pearsall 1998; Piperno et al. 2009). Maize entered the Antilles with the "Archaic" or Pre-Arawak peoples by at least ca. 3000 BC and has been documented for all the subsequent cultural periods in this region (Pagán Jiménez 2009).

As maize depends on humans for its reproduction, propagation seeds must have been stored for this purpose and were likely maintained with special care (e.g., stored inside vessels and possibly kept inside structures). Although it is generally accepted that maize requires exceptional soils and climatic conditions for its successful production, it can be grown in rocky soils and specifically in silty clays, silty sands, and slightly plastic clay soils. Large and continuous tracts of land are not required to produce significant quantities of maize, although open or cleared spaces are key to successful cultivation. Multiple small plots may have been common on the periphery of settlements, in addition to planting in the fertile alluvial river valleys. Water is a delicate aspect of maize production, because the excess or lack of it easily destroys the plants. Such an agricultural pursuit would have required consistent oversight of the cultivated plots, especially when we consider that CE-11 and CE-33 are both located in an ecotonal area between the subtropical moist and dry forests of Puerto Rico (López Marrero and Villanueva 2006).

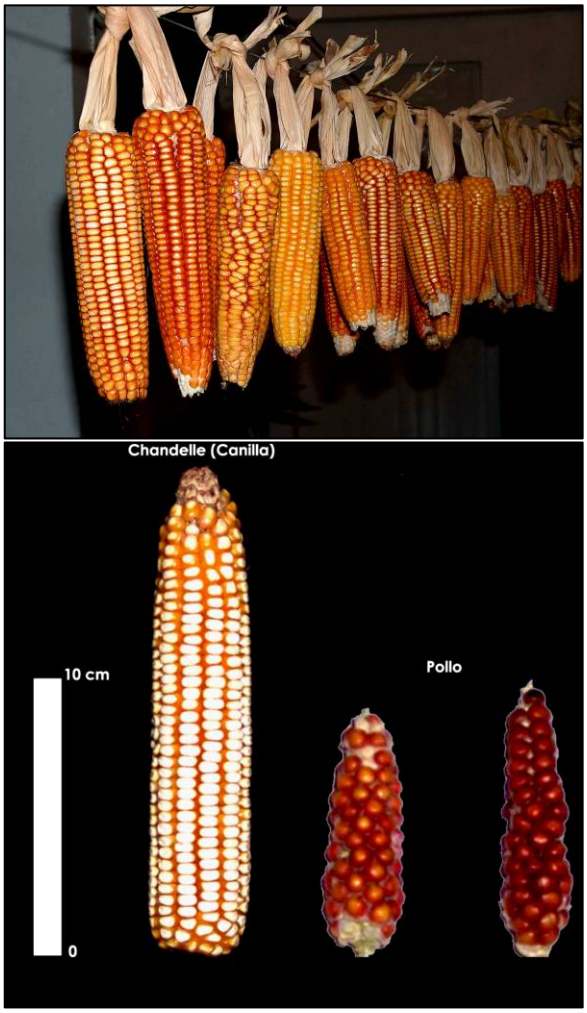


Figure 11.13. Indigenous races of maize. Top: ears of the Early Caribbean race grown by Santos Pagán, which its pre-colonial origin as a variety of maize has been traced exclusively to the Antilles; Bottom: maize kernels of the Chandelle (left) and Pollo (right) races that has a wider distribution in northern South America and the Antilles (Venezuela and Colombia for the Pollo race and the Venezuela, Colombia and the Antilles in the case of the Chandelle race). Photos by J. Pagán Jiménez.

The maize starch grains recovered in this study suggest multiple processing and cooking methods (Figure 11.14). The stone mano from CE-33 attests to the grinding of raw maize seeds. This conclusion is based on the fissures documented in the starches, which could only be produced by grinding the seeds when they were still hard. Ground maize flour could have been formed into a paste and baked on griddles as suggested by the starch findings in Sample-6 at CE-33. Because multiple plant varieties are often identified on a single griddle, it is likely that

recipes combined different foods. For instance, corn tortillas or bread may have been combined with other food ingredients (plant, animal, or condiments) during the cooking process. In addition, gas chromatography studies have identified fatty acids from palm fruits and fish on griddles (Rodríguez Suárez and Pagán Jiménez 2008). An annatto starch grain, probably used as colorant or flavoring, was documented on the same griddle as the maize in CE-33.

The finding of maize in charred crusts on two ceramic vessel fragments at CE-11 suggests a second cooking method. Both charred crusts produced multiple species: Sample-4 contained *Calathea* and maize; Sample-5 contained manioc, marunguey, and maize. It is possible that mixed vegetable pastes were being cooked in a water-based environment (i.e., boiled) in these pots. During the course of water evaporation, the plant paste forms a gelatinous mass that is susceptible to charring; one gelatinized grain was recovered in Sample-5. An alternative to cooking the paste directly in boiling water is to wrap the paste in leaves and steam them like tamales (Rodríguez Ramos 2005b).

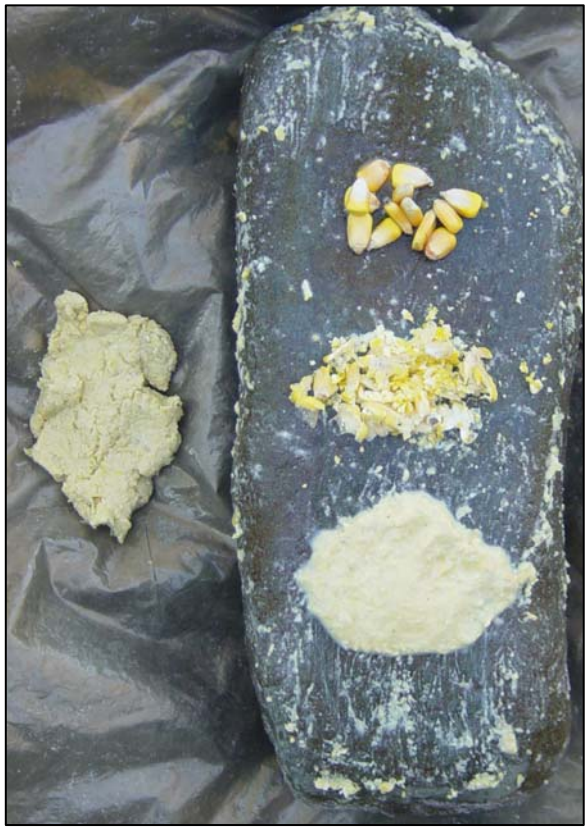


Figure 11.14. Grinding of maize with an edge-ground cobble and a milling stone base to produce flour and paste. Photo courtesy of Dr. Reniel Rodríguez Ramos.

White Cocoyam (Yautía Blanca)

Yautía starches were documented only in CE-11, found in a stone mano (Sample-2) and in a griddle fragment (Sample-3). Yautía is a plant native to northern South America that produces corms (the swollen base of an underground stem) with high nutritional value (Figure 11.15). But, because yautía has abundant raphides (calcium oxalate crystals) in its corms, which can cause suffocation in humans, pretreatment is required in the form of pounding and cooking. At least three species of yautía have been identified previously at Puerto Rican sites, found on coral milling bases, stone manos and mortars, and griddles (Pagán Jiménez 2007; Pagán Jiménez et al. 2005; Rodríguez Suárez and Pagán Jiménez 2008).

Cocoyam/yautía starches recovered in the stone mano (Sample-2) from CE-11 show that this plant was ground. Although yautía-specific starches from the mano did not show any signs of alteration by heat (gelatinization), there were unidentified gelatinized grains on this stone artifact. It is possible that the corms were boiled first and then pounded (possibly to treat the raphides). In addition, the presence of yautía starches in the griddle fragment (Sample-3) shows clearly that these corms were cooked in the form of cakes or pastes, or as an auxiliary ingredient in other recipes. Marunguey starch grains were recovered on the two artifacts that contained yautía, suggesting that they may have been processed and/or cooked together.

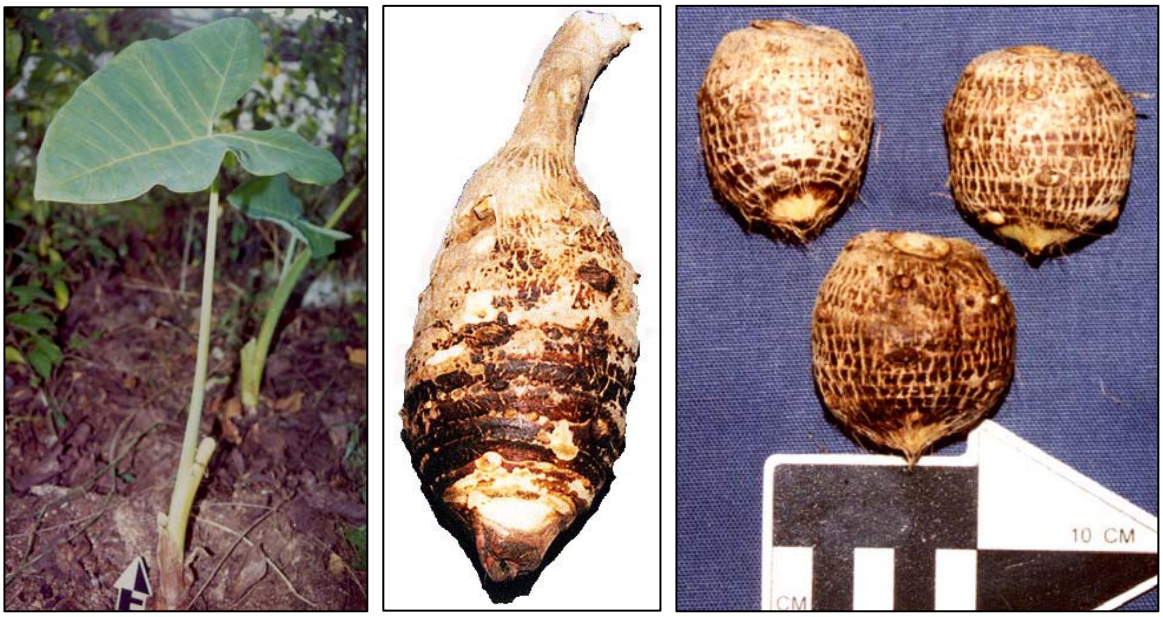


Figure 11.15. Plant (left) and different corms of white cocoyam (yautía blanca). Photos by J. Pagán Jiménez.

Yautía can be produced both in fully cleared fields and in plots partially covered with vegetation (trees and bushes), where it develops with little care. Although this crop has been phenotypically modified by humans due to selection pressures, it has retained the ability to reproduce itself and thrive outside of cultivation.

Manioc (Yuca)

A single grain securely identified as manioc starch was recovered in the charred crust within a ceramic pot (Sample-5) from CE-11, found in association with maize and marunguey. Manioc was not identified on any of the griddles or on either of the stone manos in this sample, and was not found on any tested artifact from CE-33. Manioc is a perennial shrub that reproduces mainly through the planting of its stems, and there are more than 100 related species distributed from southern Arizona to Argentina. Most species are native to arid or seasonally dry regions such as the tropical deciduous forests (Piperno and Pearsall 1998). Two areas have been identified as main centers of domestication: the Guianas and central Brazil. Cultivated manioc displays great variability (Figure 11.16), which seems to be the result of natural and anthropogenic hybridization between this species and other wild relatives. Manioc may be produced in almost any soil type, and with very little work it will produce high yields. Cultivation requires open, cleared plots for its successful production, although it can also be grown in home gardens with a slight cover of dispersed trees and shrubs. Manioc is generally regarded as the most efficient energy source among all the lowland tubers and roots (Piperno and Pearsall 1998).

The introduction of manioc to Puerto Rico dates to the so-called "Archaic" era, based on starch grains recovered on grinding stone artifacts dated to ca. 1290–890 BC (Pagán Jiménez et al. 2005). Although considered a staple of the diet in this region through all cultural periods, the presence of manioc is extremely minimal in artifacts studied to date. Ancient manioc starches have only been documented in eight (4.9%) of approximately 164 tools sampled so far from Antillean sites (Pagán Jiménez 2009). All these identifications correspond with artifacts used for pounding or grinding (manos and mortars of stone or coral) and come from "Archaic," La Hueca, Ostiones, and Esperanza cultural tradition sites (Pagán Jiménez 2007, 2009; Pagán Jiménez et al. 2005; Pagán Jiménez and Oliver 2008; Rodríguez Suárez and Pagán Jiménez 2008). None of the griddles analyzed so far (seven in previous studies and three in the present study) have documented manioc starches, even though such artifacts have been attributed to the cooking of manioc bread (cassava). A limited number of stone grater teeth, traditionally associated with manioc processing, have also been studied, and no manioc starch has been found (Pagán Jiménez 2006). Interestingly, the species that are found in these "manioc-processing artifacts" are consistently maize, bean, arrowroot, cocoyam, and marunguey, among others (Pagán Jiménez 2009; see also Berman and Pearsall 2008; Perry 2004).

Figure 11.16. Manioc plot in Suriname (northern South America). Photo adapted from http://www.mongabay.com

Among the cultivated varieties of manioc, the bitter species has been historically more esteemed, at least in lowland South America, even though it contains extremely powerful toxic substances (*Cyanogenic glycoside*) that must be removed prior to consumption. Manioc tubers must be peeled, grated, washed, and squeezed in preparation for cooking (Figure 11.17). The finding of manioc on manos from previous studies shows that the manioc starch was ground into flour or paste, but the manner in which it was cooked is not clear. Perhaps the manioc was cooked and/or consumed in ways that are virtually unknown to the West Indies but resemble other ways of processing that are known from outside the islands. For example, some common recipes in Brazil are farinha and tapioca, both made with the manioc starch previously extracted by traditional means (grated, washed, and squeezed). These recipes involve the use of pots to heat the food paste, which usually consists of several mixed ingredients and condiments. Traditionally, farinha and tapioca were side dishes that were combined with other food products (León 1987:305; Montaldo 1977:211).

The recovery of manioc in CE-11 within a ceramic pot is the first identification so far for the West Indies of this starch in any sort of cooking vessel. This is evidence that the cooking process is not destroying the manioc grains, or making them unidentifiable in the sampled artifacts.

Figure 11.17. Canela people of central Brazil peeling and grating the tuberous roots of manioc. Photo adapted from the Smithsonian Institution http://www.anthropology.si.edu/canela/about.com

Other Identified Plants: Legumes, Arrowroot, Calathea, Canna, and Annatto

Starches of seeds and rhizomes of other important economic plants were processed and/or cooked in these sites, although they appear to be secondary in importance to the species discussed above; they include wild/domestic Fabaceae (bean), arrowroot, calathea (lerén), and canna (achira or gruya). All of these plants have consistently been identified in previous starch-grain studies, recovered on a wide range of artifacts and spanning many cultural periods in Puerto Rico (Pagán Jiménez 2009). In contrast, annatto (*Bixa orellana*) has only been recovered previously in a single grinding tool in a north-central Puerto Rican site dating to the Ostiones (Pure) time period (Pagán Jiménez and Oliver 2008). Its recovery on a griddle from CE-33 is a unique find.

Fabaceae (Legumes). In the world of economic plants, legumes are a substantial source of vegetable protein widely used in the Neotropics. Wild plants of the genus *Canavalia* (jack beans) and others from the genus *Phaseolus* (bean, both wild and domestic) have been consistently identified in previous starch-grain studies of the Antilles (Pagán Jiménez 2009) and beyond (see Piperno and Dillehay 2008). In this sense, the intentional introduction of *Phaseolus* and *Canavalia* plants into the Antilles very likely occurred by at least 3000 BC, based on data from the site of Maruca located in the arid south coastal region of Puerto Rico (Pagán Jiménez et al. 2005; Rodríguez López 2004). Wild bean species can be used as a food after processing the seeds through various grinding and cooking techniques. Processing is necessary due to the presence of cyanogenetic compounds (e.g., saponins, soyasaponin, phasin [a toxalbumin]) in some wild bean seed coats and endosperm, which are poisonous and can cause damage to the human central nervous system (Ayet et al. 1996).

Wild species of the *Phaseolus* genera (with about 275 species and/or accepted varieties), as well as other legumes of economic importance (e.g., *Canavalia* sp.), are mostly perennials that are easily reproduced without human intervention, accepting of many soil types, and tolerant of salinity, low fertilization, and water scarcity. However, the species most commonly related to prehistoric human subsistence in the American hemisphere, *Phaseolus vulgaris* and *Phaseolus lunatus*, are annuals that require cultivation in partially or fully cleared plots and can grow in

friable clay soils. Domestication of *P. vulgaris* and *P. lunatus* occurred simultaneously in Central America and South America (Piperno and Pearsall 1998). In cultivation areas located on the periphery of sites, domesticated beans would have been planted in open plots (possibly together with maize), while wild beans could have been tended in either open or partially cleared plots.

Two bean starch grains were identified in this study: one wild legume (Fabaceae) was recovered from a griddle in CE-33, and one gelatinized bean starch was recovered also from a griddle in CE-11. Because of its gelatinized condition, this starch grain could only be tentatively identified as domesticated bean (cf. *Phaseolus vulgaris*). This possible domesticated bean was recovered in association with marunguey and cocoyam. In CE-33, the wild bean was recovered in association with marunguey. It is possible that multiple vegetables were combined into mixed pastes prior to cooking, but it is also possible that as the griddles were used over and over again, starches of various species were deposited over time within the cracks on its working surface. Compared to other archaeological sites studied in this region where legumes have been commonly identified on griddles in association with marunguey, maize, arrowroot, and sometimes sweet potato, the presence of legume starches in this study is surprisingly minimal (see Pagán Jiménez 2008a, 2008b; Rodríguez Suárez and Pagán Jiménez 2008).

Marantaceae (Arrowroot Family). Arrowroot (*Maranta* cf. *arundinacea*) was recovered from CE-33 and calathea (*Calathea* sp.) was recovered from CE-11. Arrowroot (Figure 11.18) is a perennial plant that originated in the northern lowlands forests of South America (Montaldo

Figure 11.18. Arrowroot (*Maranta arundinacea*) and its edible rhizomes (right). Photos by J. Pagán Jiménez.

1977; Piperno and Pearsall 1998). It has a high nutritional value and, unlike many of the other foods identified in this study, is easily digested. Arrowroot has been used to treat people with stomach problems (especially diarrhea) and in some cases used as a food specifically for infants because of its easy digestion (DeFilipps et al. 2004). Arrowroot has medicinal properties as well, and is used in the treatment of wounds or irritated skin (DeFilipps et al. 2004). Sturtevant (1969) suggested that this plant was used by the Caribbean indigenous people as an antidote for poisoned arrows.

Calathea is quite similar in its characteristics to arrowroot. Although it was not possible to assign specific taxa to the documented calathea starch, any of the approximately 250 species of this genus have rhizomes or tubers that are edible or contain important healing components (DeFilipps et al. 2004; see also Piperno and Pearsall 1998). Both arrowroot and calathea thrive in partially cleared plots or even under light canopies within silty sand or sandy loam soils. The cultivation of arrowroot and/or calathea may have occurred in a small house garden on the periphery of the site that would have also contained useful medicinal plants and herbs, or both plants could have been maintained at the edges of nearby forested areas.

Calathea was recovered along with maize in the charred crust within a ceramic pot, while the arrowroot was recovered along with maize, marunguey, and annatto in a griddle. This suggests that both these species were processed and cooked and used as food (probably combined with other ingredients) rather than used solely for medicinal purposes.

Cannaceae (Canna Family). Canna (locally called Achira or gruya) was identified on a pecked lithic mano from CE-11. Canna is an herbaceous perennial that does not require human intervention for its reproduction, although it can be propagated by seeds or by planting the rhizomes (Figure 11.19). It grows in various climates and elevations and can tolerate full sun or partially covered settings (León 1987; Piperno and Pearsall 1998). Its economic importance is based on the easy management and minimal care that this plant requires, but also on the high content of starches in their rhizomes, which can be eaten boiled or roasted. Like arrowroot,

Figure 11.19. Achira or gruya (*Canna indica*) and its edible rhizomes (right). Photos by J. Pagán Jiménez.

canna starches are used in the preparation of food for infants and sick people due to its easy digestion.

At CE-11, the raw rhizomes of this plant were processed by pounding with a mano. This genus has been identified previously in grinding/pounding tools from Puerto Rican sites of various time periods (Puerto Ferro—Archaic; Punta Candelero—early Ostionoid; Vega de Nelo Vargas—late Ostionoid) (Pagán Jiménez 2009). In all cases, canna was recovered in association with other food items (maize, beans, marunguey, manioc, and sweet potato). In CE-11, canna was found in association with marunguey and cocoyam; this along with the presence of gelatinized starches (cooked) in the stone tool points to the use of canna in the preparation of mixed culinary recipes.

Annatto/Achiote. *Bixa orellana* (annatto or achiote) starches were recovered on a griddle fragment from CE-33, found in association with maize, arrowroot, and marunguey. The annatto plant is a perennial shrub that produces ovoid fruits containing seeds of economic interest (Figure 11.20). It can be grown in almost all types of terrain in the lowland and middle tropics, and is often grown in home gardens in association with other fruit trees. It can be propagated through the seeds or by planting stem segments, requiring little care in its cultivation in both partially cleared (e.g., home gardens) and open plots.

Figure 11.20. Annatto shrub with its flowering fruits (left) and mature seeds (right). Photo on left by J. Pagán Jiménez. Photo on right adapted from Forest and Kim Starr's web page http://www.hear.org/starr/

The most common use of annatto among the indigenous people of the West Indies was as an insect repellent, with an extract from the ground seeds applied to the skin that concurrently functioned as a sunblock (Las Casas 1909). Las Casas also reported the application of annatto coloring to the skin for ritual activities and in preparation for battle against enemy groups. Ground annatto seeds are currently used in Colombia as a colorant and flavoring ingredient in food preparations (Fonnegra and Jiménez 2007) and as a healing remedy for numerous conditions (e.g., inflammation, burns, diarrhea, gastritis), in which it is made into a poultice. Because of the many documented uses of annatto, it is informative that this starch was recovered

in a cooking utensil in CE-33, found along with the greatest diversity of food plants identified in this study. In this context, annatto was being used as colorant and condiment for other food items (Figure 11.21). This is the first identification of annatto in such a context for the West Indies. In fact, the only other condiment or flavoring item identified to date in this region is the recovery of chili pepper starches (*Capsicum* sp.) at the Three Dog site (Bahamas) and at En Bas Saline (Haiti) (see Berman and Pearsall 2008; Las Casas 1909; Newsom and Wing 2004:155). Annatto seeds and a single starch grain of this plant have been recovered in Ostiones contexts from the Finca Valencia site and Cueva de los Muertos (both in Puerto Rico); in the latter case the identification of annatto starch from a spherical mano was tentative and related to a funerary ritual context.

Figure 11.21. Commercially available achiote (annatto) seasoning. Reproduced from Bayless (2005:36).

Plant of the Deities, Plant for the Humans: Cohoba (*Anadenanthera peregrina*)

The raw, mature seeds of cohoba were tentatively identified in a small milling base made of elkhorn coral (*Acropora palmata*) in CE-11. The following discussion seeks to understand how this species came to be present on this coral grinding tool and how this hallucinogenic substance may have been utilized within the site of CE-11.

Cohoba (cojóbana in some parts of Puerto Rico) is an exotic tree species of South American origin that was introduced to the Antilles at an unknown date during the prehistoric era. There are two recognized species of the genus *Anadenanthera* in the Americas (*A. peregrina* and *A. colubrina*) that have been historically used by indigenous peoples in ritual ceremonies and magical-religious activities due to the chemical components or tryptamines (alkaloids)[1] contained in its seeds, leaves, and bark. The current natural distribution of these species is restricted to South America, generally north of the Tropic of Capricorn. As an exotic plant, the *Anadenanthera peregrina* species is known today in some of the Lesser Antilles, in Puerto Rico, and Hispaniola. Interestingly, it has never been introduced in Cuba or Jamaica. In Puerto Rico, discrete populations of cohoba trees are currently known for the lowland semi-arid south of the island—from Salinas to Cabo Rojo—but also for middle elevation landscapes where rainfall is relatively abundant (e.g., moist subtropical forests in Carolina and Utuado). Generally, cohoba trees grow in partially cleared, low- to mid-elevation forests and are commonly associated with transitional zones between the cerrado (savannah) and the semi-deciduous forests of central South America (Brido da Costa et al. 2003; Malhado and Petrere 2004).

[1] The hallucinogenic tryptamines of the cohoba are dymethyltryptamine (or DMT), 5-hydroxydimethyltryptamine (or bufotenine) and 5-methoxydimethyltryptamine (5-MeO-DMT).

According to Torres Constantino (1998), smoking pipes associated with the use of cohoba (called cebil by the Inca) are found in northwestern Argentina, with the oldest archaeological examples dating to ca. 2100–1200 BC (at the sites of Inca Cueva and Huachichocana) (Figure 11.22, right). There are also several archaeological contexts in Peruvian sites with abundant paraphernalia and botanical remains (seeds and preserved snuff identified as *Anadenanthera peregrina*) directly associated with the inhalation of cohoba that date to ca. 1000–800 BC (e.g., Chavín de Huántar, Huaca Prieta, Asia, Solcor 3) (Figure 11.22, left). It has been proposed that cohoba was so important for prehistoric indigenous people of the Andean Highlands and Pacific coast regions, where the plant does not grow, that people there acquired it through trade with people of the lowlands (Schultes 1998; Schultes and Hofmann 2000). Schultes and Hofmann (2000) suggest that cohoba, and the ritual associated with the cohoba snuff, originated in the Orinoco region of Venezuela. The wide distribution of this plant, including its presence in the Antilles, is a direct consequence of the human dispersion of the species.

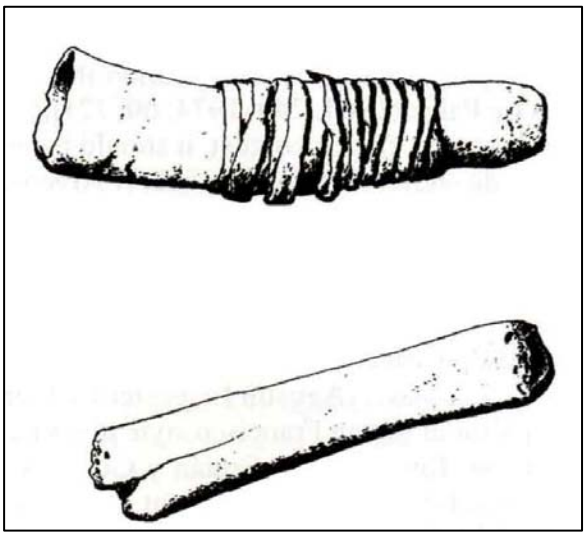


Figure 11.22. Illustration of tubular smoking pipes made of bone recovered at site of Inca Cueva in northern Argentina (above) and a snuff kit used with *Anadenanthera peregrina* recovered at the site of Solcor 3 (Tomb 107) in San Pedro de Atacama, Chile (left). Snuff kits typically consist of a container, spoon, tablet, and inhaling tube. Reproduced from Torres Constantino (1998:52, 56).

In the prehistoric Americas, hallucinogenic substances were considered intermediaries between the human and supernatural realms and, as such, participated in the interpretation and creation of cultural elements (Torres Constantino 1998). The European chroniclers Fray Ramón Pané (1999, 2004), Cristobal Colón (F. Colón 1892) and Bartolomé de Las Casas (1909), among others, documented the use of cohoba in rituals across Hispaniola. Those chroniclers made detailed descriptions on the social contexts (e.g., divine communication, divination, healing rituals) in which the hallucinogenic snuff was used (see Oliver 2009; Oliver et al. 2008; Román Castañer 2007; Sánchez 2005) (Figure 11.23 and Figure 11.24).

Figure 11.23. Pictograph of prehistoric origin (Cueva de Borbón, Dominican Republic) showing people seated on duhos and/or their own heels and snuffing unknown powders (presumably cohoba) with inhaling tubes. Photo courtesy of Santiago Silva and Reynaldo Pérez, http://www.ajuaresprehispanicos.blogspot.com

Figure 11.24. Ceramic vessel representing a behique (medicine man) or a cacique (with highly decorated personal adornments) seated on a duho, with his head lowered and his arms on his knees, probably just after the inhalation of a hallucinogenic snuff (cohoba) as described by Pané (2004:33, 1999:26, see quotation at left). Photo courtesy of Jordi Mas Lloveras and the Fundación García Arévalo.

> "…La cual cohoba es para hacerle oración, y para complacerlo, y para preguntar y saber del dicho cemí las cosas malas y buenas, y también para pedirle riquezas (…) y el señor de ellos es el primero que comienza a hacer la cohoba y toca un instrumento; y mientras hace la cohoba, ninguno de los que están en su compañía habla hasta que el señor ha concluido. Después que ha terminado su oración, está un rato con la cabeza baja y los brazos sobre las rodillas; luego alza la cabeza, mirando al cielo, y habla (…) y él narra la visión que ha tenido."
>
> Fray Ramón Pané, 2004:33

> "… That cohoba is used to pray to it and to please it and to ask and find out from the aforesaid zemi god and bad things and also to ask it for riches (...) and their cacique is the first one to begin to prepare cohoba, and he plays an instrument; and while he is making the cohoba none of those who are in his company speaks until the cacique has finished. After he has finished his prayer, he stays awhile with his head lowered and his arms on his knees; then he lifts his head, looking toward the heavens, and he speaks (…) and he relates the vision he has had."
>
> Friar Ramón Pané 1999:26

In the West Indies, the oldest archaeological evidence associated with the use of hallucinogenic snuffs (presumably cohoba) comes from Huecoid and Saladoid sites in Puerto Rico and some of the Lesser Antilles. The use of hallucinogenic substance in the Antilles dates from at least 500 BC through European contact (see Fitzpatrick et al. 2009).

The use of cohoba has been commonly ascribed to the inhalation of hallucinogenic powders through the nose with two types of instruments: inhaling bowls/vessels and inhaling tubes. Inhaling bowls of ceramic or wood are small, globular or spherical containers with flattened

bases and two spouts on one side. In the case of the Huecoid and Saladoid materials, the vessels are finely decorated with geometric incisions and/or applications of white or red paint (Figure 11.25). Inhaling tubes were typically made with large bird bones (which are hollow), some of which were polished and decorated. The apparatus could be simple or sophisticated with the tubes occasionally embedded into a central piece made of ceramic, wood, shell, or bone. The resulting compound Y-shaped artifact could be quite complex (Figure 11.26, left).

Figure 11.25. Turtle effigy snuffing bowl from La Hueca culture (ca. 160 BC–AD 520); snuff tubes at right. Orifice is 5 cm in diameter. Photo courtesy of the Centro de Investigaciones Arqueológicas (UPR, Río Piedras).

Other artifacts traditionally ascribed to the cohoba ritual include impressive vomiting sticks made of manatee bone, wood, or shell (Figure 11.26, right); small globular vessels to hold the snuff made from ceramic, wood, bone, or shell; small wood platters with detailed decorations (Figure 11.26, center); and elaborate "canopied" wooden idol tables (Conrad et al. 2001; see also Rouse 1992:Figure 30). Additionally, special artifacts have been identified that relate to the

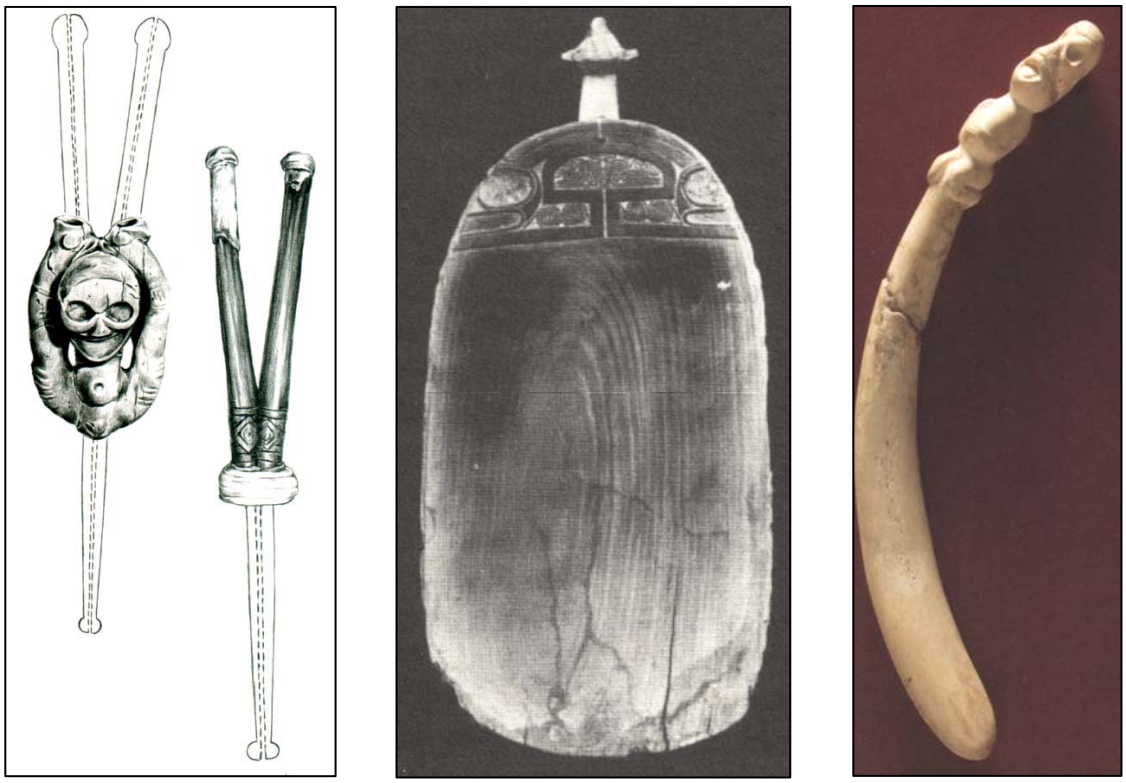


**Figure 11.26. Cohoba-related artifacts from the Antilles.
Left: reconstruction of Y-shaped inhalers. The example on the left is a finely elaborated sculpture of manatee bone with holes to accept the inhaling tubes. Drawing by H. da Silva (in Oliver et al. 2008).
Center: wood platter presumably used to contain the cohoba snuff. Photo after Arrom (1989).
Right: vomiting stick made of manatee bone.
Photo courtesy of Jesús E. Marrero (in Méndez Bonilla 2005).**

processing and preparation of the cohoba and include small to medium-size stone mortars and manos that are finely decorated and sometimes carved as effigies (Cassá 1995:117).

Although ethnohistorical references to the use of cohoba exist, only vague descriptions were made concerning the formulation of the hallucinogenic powder. In the following discussion, ethnohistorical descriptions are provided from the Antilles on the ways of processing the cohoba seeds into the hallucinogenic snuff. This information is compared with some ethnohistoric and ethnographic data from other regions where cohoba has been historically used in multiple ways—as a stimulant, in rituals, as medicine, and in magical-religious contexts. For additional information regarding the "ritual de la cohoba" in the Antilles from an ethnohistoric and anthropological perspective, see Cassá (1995), Lovén (1935), Ortíz (1987), and Safford (1916).

Regarding the processing of cohoba and the resulting hallucinogenic powder, the only allusion that Las Casas made (1909: ch. CLXVI) is to leaves that "had made certain powders of certain very dry and well ground herbs, with a color like ground cinnamon or *alheña*; thus, they were of a leonada color." López de Gómara (1999) also referred to a powder that, "when they need to make divinations on what they are asked, then they eat an herb that they call cohoba, ground or in the process of grinding, or they take the smoke by their noses." Other important chroniclers such as Fray Ramón Pané, Fernando Colón (son of Cristobal Colón), Gonzalo Fernández de Oviedo, and Diego Álvarez Chanca made mention of the consumption, physiological effects, and ritual or ceremonial use of a plant that the indigenous people called cohoba. To the best of our understanding, none of these chroniclers ever explained the true source of the hallucinogenic powder or the way in which this snuff was made. This situation led important researchers such as Sven Lovén (1935) and Fernando Ortíz (1987) to postulate that tobacco (*Nicotiana tabacum*) was the only correct identity for the cohoba (see Boomert 2001 for a discussion of this issue).

Oliver (2008) has proposed that in the Antilles the hallucinogenic substance used in the cohoba ceremony came from the seeds of *A. peregrina*. He describes the process of preparing the seeds (Oliver 2008:175): the seeds are "slightly roasted to remove moisture and later they are crushed with a mortar pestle to obtain a fine powder of a color of the cinnamon." He continues, "[to] it is added an alkaline substance (lime) to accelerate its absorption through the mucous membrane . . . the resulting mixture is then placed on a plate and, after that, inhaled." Lime can be extracted from the bark of certain trees or, more frequently, from heated and crushed sea shells. Another source of lime is heated and crushed coral. Senior (2003) proposes that the cohoba seeds should be first dried and then crushed and mixed with lime. It should be noted that these interpretations are not based on the 15th- and 16th-century texts, but on ethnobotanical data from various South American indigenous people.

In the early decades of the 19th century, the German geographer Alexander von Humboldt recorded the processing of cohoba seeds among the Ottomacs of the Orinoco region in Venezuela (Humboldt and Bonpland 1881). He described that after the seeds were harvested, water was added to encourage the fermentation process until the seeds turned black; the seeds were then ground to a powder, and a final addition of manioc flour and lime (from crushed shells) was made. In 1851 a British botanist (Spruce, cited in Schultes 1998) recorded among the Guahibo people of the Orinoco that the cohoba seeds were toasted, pulverized, sifted, and then mixed in equal parts with the alkaline ashes of certain barks or leaves. The modern Piaroa

people of southern Venezuela grind the raw cohoba seeds with mortars and wooden manos, adding alkaline ashes of a tree bark and then exposing the resulting paste to indirect heat (Rodd 2002) until dehydration occurs. Schultes and Hofmann (2000) note that some indigenous people use the cohoba snuff without any addition of alkaline substance.

Macrobotanical remains (charred wood) of the genus *Anadenanthera* have been identified in the ceremonial archaeological site of Tibes in southern Puerto Rico (ca. AD 500–900) (Newsom 2010; Newsom and Wing 2004). This finding establishes the presence of the genus *Anadenanthera* in the prehistoric Antilles at least by the Saladoid/Ostionoid transitional period. This is important because most of the arguments in favor of tobacco as the true identity of cohoba (e.g., Ortíz 1987) are based mainly on the absence of clear evidence for *Anadenanthera peregrina* in the Antillean prehistoric era, as well as chronicler accounts that mention the use of leaves or herbs (not seeds) in the preparation of the hallucinogenic snuff (specifically Las Casas and López de Gómara). Furthermore, during the second decade of the 20th century, Safford (1916) demonstrated the great differences in the effects caused by snuffs made from tobacco and those made from the ground seeds of *Anadenanthera*. Cohoba seed snuff was the only one that caused the effects described by the chroniclers in the Antilles, namely, violent sneezing, perspiration, salivation, loss of balance, physical heaviness, bloodshot and watery eyes, headaches, and significant mucus production. Such descriptive images have been identified on sculptures from the Antilles (see Rodd 2002) (Figure 11.27).

Figure 11.27. Wood sculpture (cemí) directly associated with the cohoba ritual. The upper table was used, according to Las Casas (1909), for placing the cohoba snuff prior to the inhalation. Note the depiction of weeping eyes as described by Rodd (2002). From Carpenters Mountain (Jamaica), currently at the British Museum, 39 cm (tall) by 17 cm (wide). Reproduced from Oliver et al. 2008.

From a paleoethnobotanical point of view, starches that correspond well to those produced by cohoba seeds were identified in this study. In contrast to suggestions that the seeds were toasted prior to their grinding (Oliver 2008; Senior 2003), our archaeological starches were not subjected to direct heat or accelerated dehydration produced by parching or toasting. Various experiments performed by the author indicates that the grinding of cohoba seeds in the coral milling base from CE-11 was done without previously subjecting them to parching or toasting.

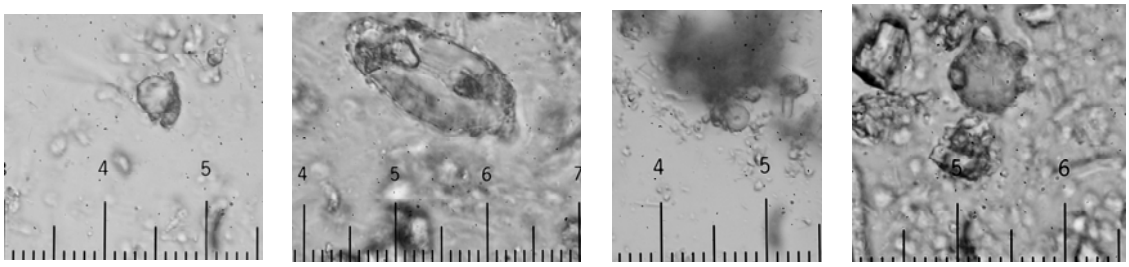
An Experiment with Modern Cohoba

In order to create comparative starch grain samples of modified cohoba seeds, the following process was undertaken. The author took mature cohoba seeds and submitted them to dehydration in two ways: (1) by slow, natural drying (in an indoor environment) and (2) by

parching. In the first case, the seeds were set aside for three days to allow partial dehydration, and then were macerated together with the seed coat using a mortar and pestle to create a paste. In the second case, the seeds were placed on a metal griddle for 40 seconds until they became partially toasted. The seed coats were withdrawn and the seeds were ground with a mortar.

To produce the cohoba snuff, a mixture was created of equal parts parched cohoba seeds and heated and ground marine shells, which was added to 1.5 ml of distilled water and gently mixed. The resulting color of the paste was a clear gray to light brown. After being placed into an open container, the paste was left to dry naturally (in the shade) for four days, then subsequently ground to a powder. The sample of naturally dehydrated seeds was similarly treated and upon grinding produced a fine, whitish powder with light green tonalities.

General observations were documented with an optical polarizing microscope (Figure 11.28) and clearly show an extremely high degree of alteration and destruction to the starches in the snuff that was subjected to heat. Very few starches retained their morphology, and of these, none retained their extinction crosses. Some starches gelatinized and multiplied in size (see image b), and most of them were dramatically affected, making their identification nearly impossible (compare with unmodified *Anadenanthera* starches in Starch Appendix Figure 11-A, j to m). Other features observed in the starches affected by heat was the formation of vacuoles (see image c) and the prominence of multiple radial striations perpendicular to the edge of the starch (see image d). Among the preserved diagnostic remains of cohoba within the seed after parching, we could document fragments of the microscopic structure of the seed coat, which is a microbotanic element with unique features that would serve to identify cohoba at the species level in future studies (see Pochettino et al. 1999).



a b c d

Figure 11.28. Modified and/or damaged starch grains from modern *Anadenanthera peregrina* (cohoba) seeds after parching (toasting). All the starches lost their extinction crosses, some of them (b) quadrupled their size due to the gelatinization process, and others (c) revealed a small circumscribed central depression (vacuole).
Scale for all microphotographs: space between major units (numbers) = 37.5µm.

As described earlier, all the starch grains recovered in the small coral milling base from CE-11 were tentatively identified as those produced in cohoba (*A. peregrina*) seeds. The coral milling base could not have been used to produce large quantities of food. In contrast to all the other artifacts analyzed for this project, which contained multiple foods species, only one species was found on this coral tool. This in itself suggests that the coral milling base had a defined (restricted) use, and the fact that it is an alkaline substance (coral) may also contribute to its

specific function (at least symbolically). No sign of seed toasting was evident in the making of this cohoba snuff. Considering the contextual association of the coral milling base (within a domestic household) as well as the expectations for highly elaborate decorations of those artifacts traditionally related to the cohoba ritual, it is feasible to suggest that the seeds of this plant were used here in two possible scenarios: (1) as a medicinal component (e.g, for the diagnosis of diseases, for healing) or (2) as an everyday stimulant, as has been described ethnographically (Schultes 1998:5).

In the first scenario, it has been documented that cohoba snuff was used by healers (behiques) to diagnose disease, using the hallucination effect of the drug as a vehicle to confer with the supernatural entities about the condition of the sick (Cassá 1995; Las Casas 1909; Pochettino et al. 1999; Schultes and Hofmann 2000). In the second scenario, cohoba could be used on a daily basis as a stimulant, outside of ritual or religious activities, and even as an ingredient in the preparation of some food recipes (e.g., cassava) (Schultes and Hofmann 2000). Considering the small size of the artifact used to prepare the cohoba and its restricted use (processing one species only), it seems more feasible that the function of this cohoba snuff was medicinal. Because of this specialized use, the ritual (religious sphere) or ceremonial (initiations, celebrations, consultation) uses of cohoba at CE-11 cannot be completely disregarded, even though the overall artifact assemblage did not contain sumptuary, high-status, or obviously ritualistic artifacts. It should be remembered that excavations recovered only a sample of the total spectrum of artifacts that must have existed in the locality. Moreover, it is likely that religious artifacts did not get discarded in the refuse midden where all of the excavations took place for this study.

Beyond utilitarian items, the site did contain several large stone beads, multiple pieces of red ocher, some finely decorated pottery, and one greenstone "palette" (Figure 11.29). The greenstone artifact is a lamina of a river cobble that measures 5 x 5.5 cm (incomplete) and is approximately 1 cm thick; it is completely flat on two sides and has unifacial flaking along its edges. The very fine-grained greenstone provides a smooth, flat surface that could have been used to prepare small amounts of medicines, mix pigments from red ocher or annatto, or act as a tablet from which to inhale cohoba. Although small, this artifact is the exact size as the coral milling base that produced the possible cohoba starch grains.

Figure 11.29. Lamina of a greenstone cobble that may have functioned as a palette for preparing medicines, pigments, or, perhaps, cohoba.

Plant Procurement Strategies

CE-11 and CE-33 are surrounded by a variety of places for procurement (coastal and marine ecosystems, estuaries, dry and moist subtropical forests) that would have been consistently exploited by their occupants. Topographic, hydrologic, edaphologic (the influence of soils on plants), and possibly climatic conditions may have facilitated the production of plants at varying scales on the periphery of the sites and beyond.

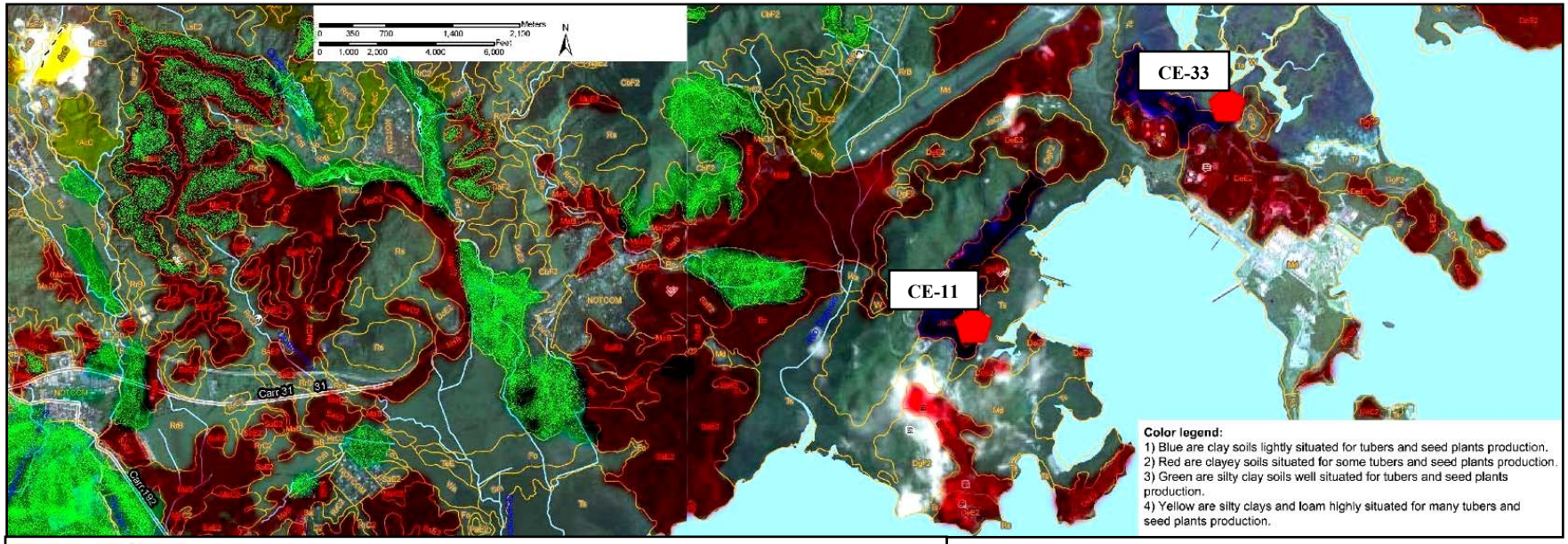
We know that familiarity with the rhythms of climate and other local geographical conditions is essential for plant procurement and production, and that the inhabitants of the studied sites had to organize plant production temporarily and spatially. Moreover, the particular requirements of these valuable plants had to be widely known to ensure their efficient exploitation or production through time. At the time these sites were occupied, the necessary social and cultural tool kit existed to locally extract and/or produce these plant resources. Certain agricultural practices such as slash-and-burn, the artificial displacement of soils (mounds and raised fields), the rotation of crop fields, and the management of forests for the benefit of the favored plants were likely undertaken by the occupants of these sites.

Figure 11.30 (top) shows the microregional distribution of potentially useful soils for the production of the plants identified in this study. Soils are color coded as to the range of suitability for the cultivation of plants: blue is less suitable, red is somewhat more suitable, green is well suited to cultivation, and yellow is highly suited to agricultural pursuits. Plants such as those identified in this study could have been produced in a variety of topographic situations (e.g., flat plains, steep slopes, ridgetops) where appropriate soils existed. Both CE-11 and CE-33 are located adjacent to areas where the suite of plants known to be important to the occupants of the sites could have been tended.

Figure 11.30 (left) shows that CE-11 and CE-33 are located within the dry subtropical ecological zone of eastern Puerto Rico, not far from the transition to the moist subtropical forests that cover much of the island. Remembering that in central-south America, cohoba trees thrive in transitional areas between the open lowlands and the semi-deciduous forests, it is likely that cohoba trees could have been easily integrated into the humanized landscape that characterized the peripheral area of these habitation sites. Table 11.6 shows the different situations in which

Table 11.6. Localities for producing and/or procuring the identified plants in this study (x **= possible; X = most likely).**

Plants	**Open Plot – Field**	**Partially Opened Plot – House Garden**	**Partially Closed Plot – House Garden**	**Forest Plot – Forest Management**
Zamia pumila (marunguey)		**X**	x	**X**
Zea mays (maize)	**X**			
Xanthosoma sagittifolium (white cocoyam)		**X**	x	**X**
Maranta arundinacea (arrowroot)	x	**X**	x	
Calathea sp.	x	**X**	x	
Manihot esculenta (manioc)	**X**			
Canna sp.	x	**X**	x	
Phaseolus vulgaris (domesticated bean)	**X**	x		
Legume/Fabaceae (wild bean)	x	**X**	x	
Bixa orellana (annatto)	**X**	x	x	
Anadenanthera peregrina (cohoba)	**X**	x	x	



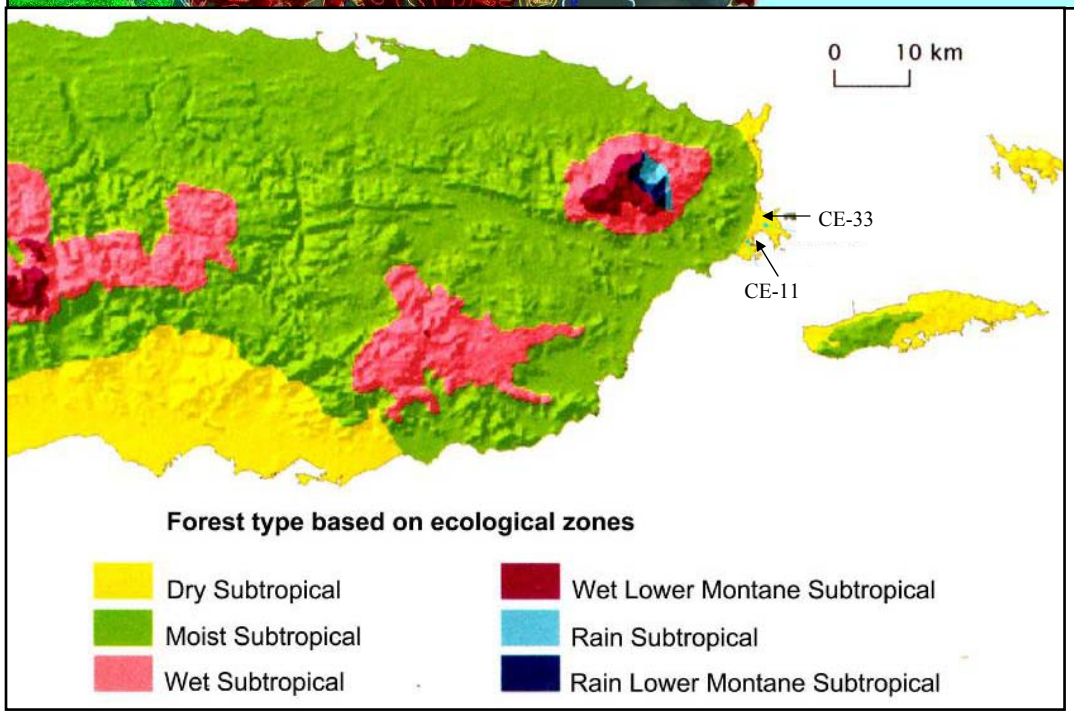


Figure 11.30. Soils and forest types in the region of CE-11 and CE-33.
Top: Soil map "collage" of the micro-region where CE-11 and CE-33 are located showing different soil type distributions potentially useful for plant production. Note: soils not considered here do not imply that people never used them for plant production, taking into account that some technologies (mounds, terraces, irrigation) could be used to adapt them for plant production). Source: modified from the web version of the Web Soil Survey of Eastern Puerto Rico (2010).
Left: Forest types of Eastern Puerto Rico based on the Holdridge Life Zone Classification System, showing current forest associations that may have existed during the human occupations of the sites (substantial changes are possible in prehistoric times). Source: modified from López and Villanueva (2006).

the plants identified in this study could prosper. As marunguey grows wild only in limestone or serpentinite hills, in this situation they were likely transplanted and tended in house gardens.

Beans could have also been grown in a house garden (chacras; see Oliver 2001) and maintained along with other useful cultivated and wild plants. However, both manioc and maize had to be cultivated in open fields, and therefore, such cleared agricultural plots must have existed in the areas surrounding these sites. There is little evidence for forest management in the suite of plants identified here.

CONCLUSION

Specific functions for the artifacts in this study have been proposed, based on the physical characteristics noted in the recovered starches and observed in the tools that were produced by human action. This information, coupled with use wear traces and other patterns observed in the artifacts such as indications of heat, allowed the interpretations outlined in Table 11.7. In general terms, the artifacts analyzed from CE-11 and CE-33 show the following patterns of use and plant processing: (1) a small coral milling base (Sample-1) was used exclusively in the maceration of raw cohoba seeds, or in the handling of cohoba powder previously processed with other tools, (2) stone manos were used to process (macerate/grind) both raw and cooked starchy stems, corms, and rhizomes of marunguey, cocoplum, and canna (Sample-2), and were used to grind maize seeds (Sample-7), (3) ceramic vessels were used for cooking mixed vegetable pastes containing maize, manioc, marunguey, and calathea (Sample-4 and Sample-5), and (4) griddles were used for cooking bread, tortillas, and bollos made from maize, marunguey, cocoyam, arrowroot, and beans; annatto was integrated as a condiment or colorant. Two different culinary processes were identified—the direct cooking of the vegetable pastes in pots, and the baking of

Table 11.7. Functional interpretation of the analyzed artifacts from both CE-11 and CE-33 based on the recovered starch grains and their characteristics.

Artifacts	Macroscopic Use Wear Patterns	Plant Microresidues	General Characteristics of the Microresidues	Type of Plant Organs Processed	Proposed Artifact Function
Sample-1 (milling base, coral)	coral polyps lightly eroded in the concave section	a) starch grains b) vessel elements-bordered pits and scalariform	starch grains well preserved and broken by grinding	seeds	grinding and/or mixing base for manipulate powder from hallucinogenic raw seeds (cohoba)
Sample-2 and **Sample-7** (manos/pestles, lithic)	pecked extremity and faceted edges	a) starch grains b) vessel elements-bordered pits	starch grains well preserved, broken by grinding and pounding; gelatinized	tubers and seeds	grinding/pounding of raw and cooked food organs
Sample-4 and **Sample-5** (pot fragments, clay)	traces of irregular heat (ext.); charred crust (int.)	a) starch grains	starch grains well preserved, broken by grinding and pounding; gelatinized	tubers and seeds	cooking food (e.g., mass/paste) of mixed vegetal origin
Sample-3, **Sample-6,** and **Sample-8** (clay griddles)	low to high patterns of heat	a) starch grains b) vessel elements-bordered pits and scalariform	starch grains well preserved, broken by grinding and pounding; gelatinized	tubers and seeds	cooking food (e.g., bread/tortilla) of mixed vegetal origin

bread, tortillas, or bollos on griddles. In a broader sense, this study highlights that the processing of plant tubers and seeds existed in two different, but mutually influential, social settings—domestic (cooking) and medicinal (and possibly ritual), as seen in the identification of cohoba.

Without any doubt, when we put the paleoethnobotanical information gathered here in the broader context of the studied archaeological sites across the Antilles, new knowledge is added about the sociocultural practices of the human groups who made use of these plants at the site, including information on subsistence and culinary regimens. Looking at the overall results, marunguey was the most common plant identified on the analyzed artifacts. Although this does not necessarily imply that marunguey was the main economic food plant, it does indicate that its use was consistent and "versatile," as it was recovered in multiple food-processing and cooking contexts. This wild plant must have been integrated in the broader cultivation systems of these sites, and at the same time we cannot discard the possibility that marunguey derivatives (e.g., flour) may have been part of regional trade (or exchange) networks. It is interesting to remember that in historic times, marunguey was used as a famine food—a food of last resort—and this certainly was not the case in prehistoric times.

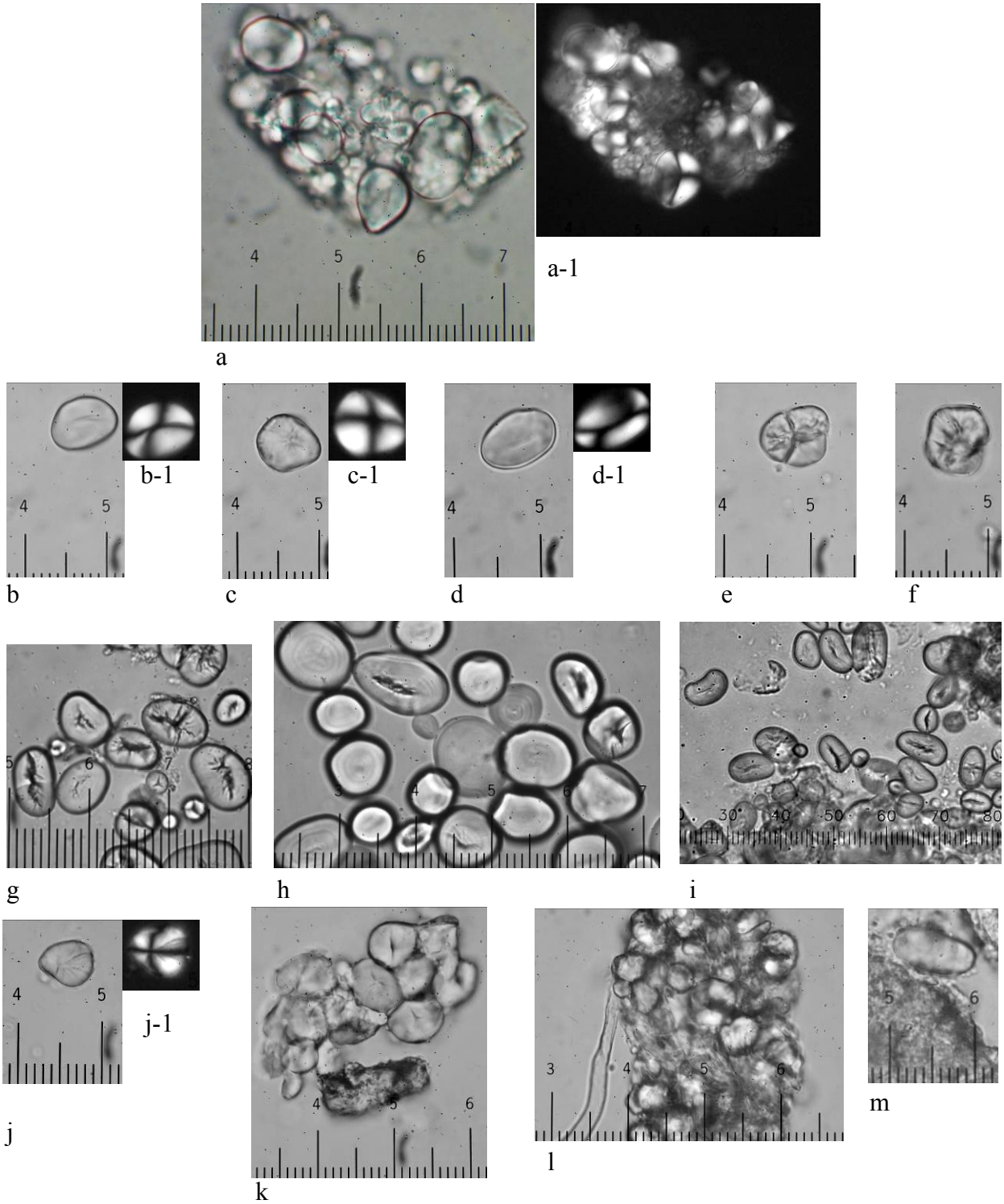
Maize was the second most common plant identified, and this demonstrates that the processing and consumption of maize goes well beyond previous assumptions about this plant. Maize has been interpreted as a "high-status" food resource in this region, supposedly consumed green or boiled by the indigenous elite (e.g., Newsom 2006, 2010; Newsom and Wing 2004). This species has been clearly and securely identified in 14 of the 15 Antillean archaeological sites studied by the author to date (including this study), and the contexts of its use range from domestic (communal, ordinary, everyday use) to its inclusion in ritual and/or magical-religious situations and/or artifacts.

From the microbotanical perspective**,** manioc is almost imperceptible, not only in this study but in all others studies that have been completed so far in the Antilles (e.g., Berman and Pearsall 2008; Dickau et al. 2007; Pagán Jiménez 2007, 2009; Perry 2001, 2004). It is important to remember that the preservation of starch grains in artifacts that have been subjected to extreme heat (griddles, ceramic cooking pots) has been proven over and over again in starch-grain studies (see Babot 2006; Haslam 2004; Henry et al. 2009; Messner and Schlinder 2010; Rodríguez Suárez and Pagán Jiménez 2008). It cannot be the case that all the manioc grains are being destroyed simply through the process of cooking. Even so, ancient manioc starch grains have been recovered from artifacts of almost all the cultural periods defined so far in the Greater Antilles, even though its occurrence within each assemblage is slight and it has not yet been found on griddles. Manioc has been documented on stone manos, showing that the tubers were pounded or macerated, and it has been identified on coral graters. The presence of a starch grain positively identified as one from manioc in the charred crust attached to a cooking vessel fragment from CE-11 is the first archaeological microbotanical evidence for the cooking of manioc in the Antilles. Variable processing methods of this plant, beyond the usually accepted beliefs (grating, squeezing, and cooking on griddles), are starting to be established, and here we add data on a new way of preparing and serving manioc, until now unknown for the Antilles: either as part of a mixed vegetable paste, or with the end product being a purée.

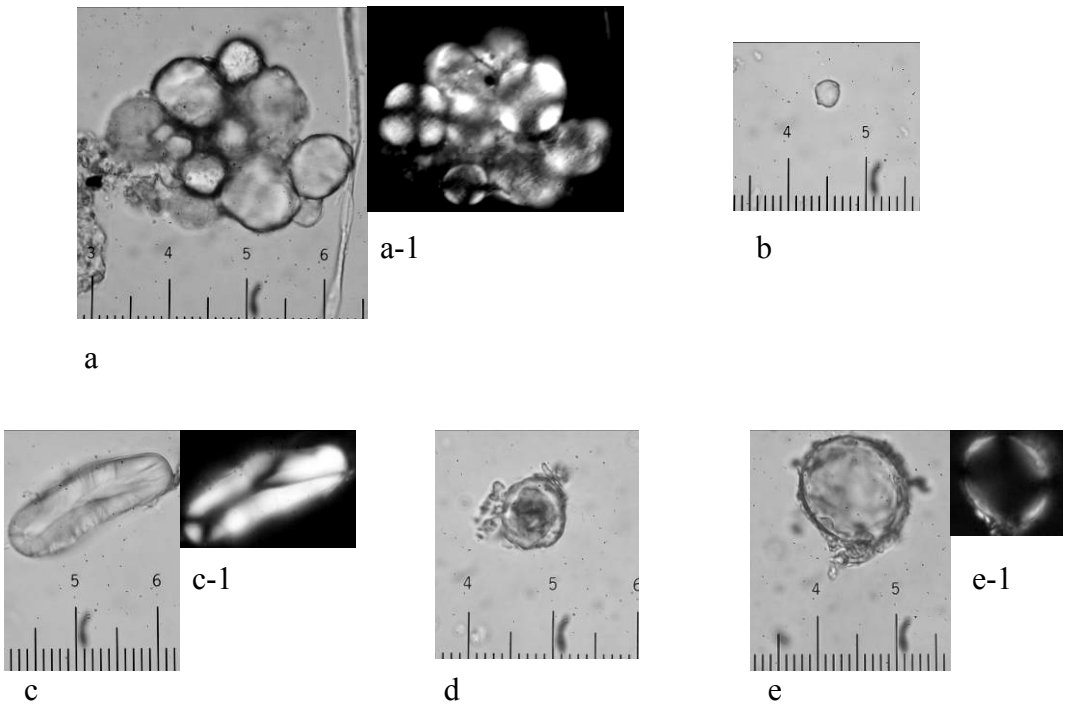
Finally, the tentative identification of cohoba and its potential uses at CE-11 move us into areas that go beyond the economic concerns that generally permeate the phytocultural approaches developed by tropical paleoethnobotanists. The possible use of cohoba within the context of a small habitation site dating to the Chican Ostionoid period opens new avenues for understanding cohoba use in the prehistoric Antilles, noting a broader range of situations where cohoba may have been utilized—in healing, as a stimulant, and as part of ritual or religious activities.

Cohoba was tentatively identified in an artifact recovered from a late Ostionoid context in association with Santa Elena- and Esperanza-style pottery. Other identified plants found only in the later contexts in CE-11 were maize, manioc, and calathea. Bean, canna, and cocoyam were identified only in an earlier context in association with late Cuevas and Santa Elena ceramics. Marunguey was the one taxa found in both early and late contexts. Because there is a continuum of deposition across an approximately 200-year time frame at CE-11, these patterns may not be representative of true changes in plant use through time, but may be a factor of the small sampling universe that made up this study.

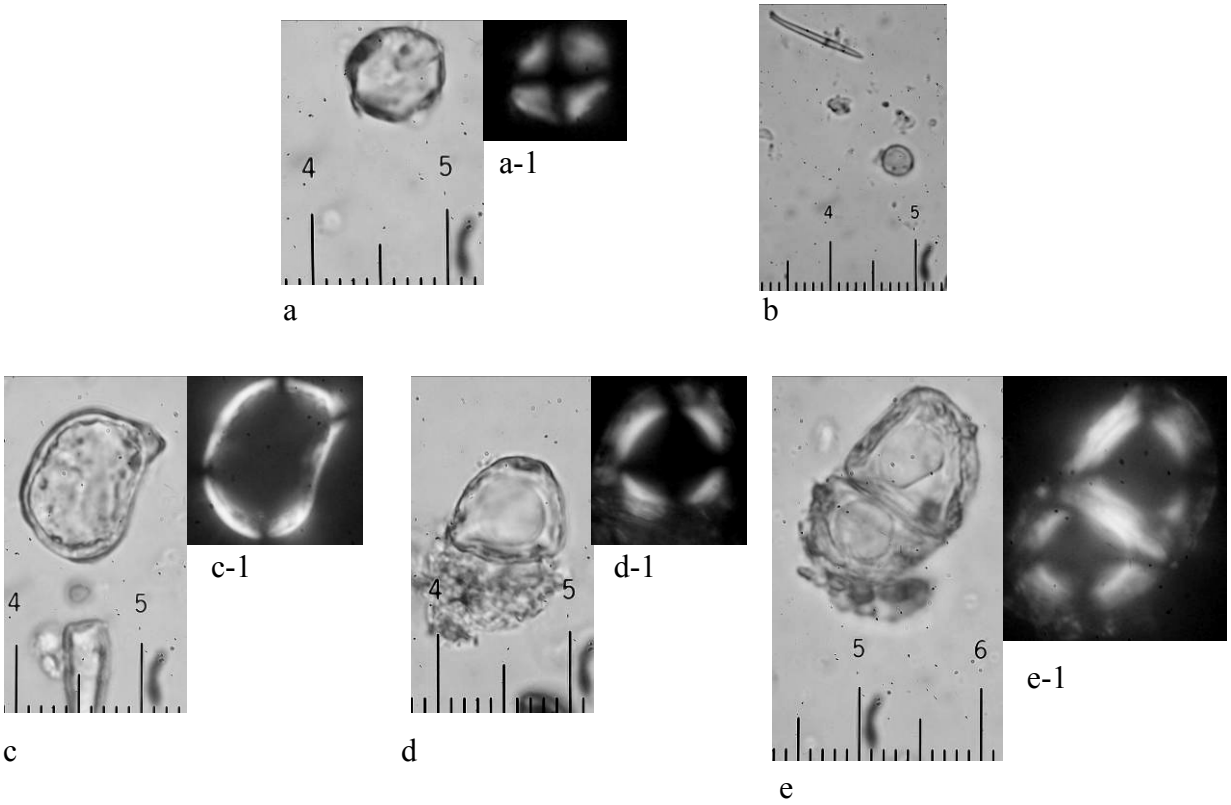
The plant assemblage identified in CE-11 and CE-33 can be viewed along with phytocultural practices connected through time and space across the island of Puerto Rico. While generally consistent with previous findings, the results of this study point toward what may be distinct culinary traditions determined by local cultures. Although similar plant products are used across the island, they can be created into locally distinct cuisine combinations, especially when considering the wealth of highly valued and accessible zoological ingredients that could be included into these recipes. This study provided new ethnobotanical information that allows us to better understand the people who made use of the spaces we now know as CE-11 and CE-33. Regardless of the importance that other animal resources clearly had for human subsistence, plants played a decisive role in the overall sociocultural framework in which the human groups in these regions were engaged.



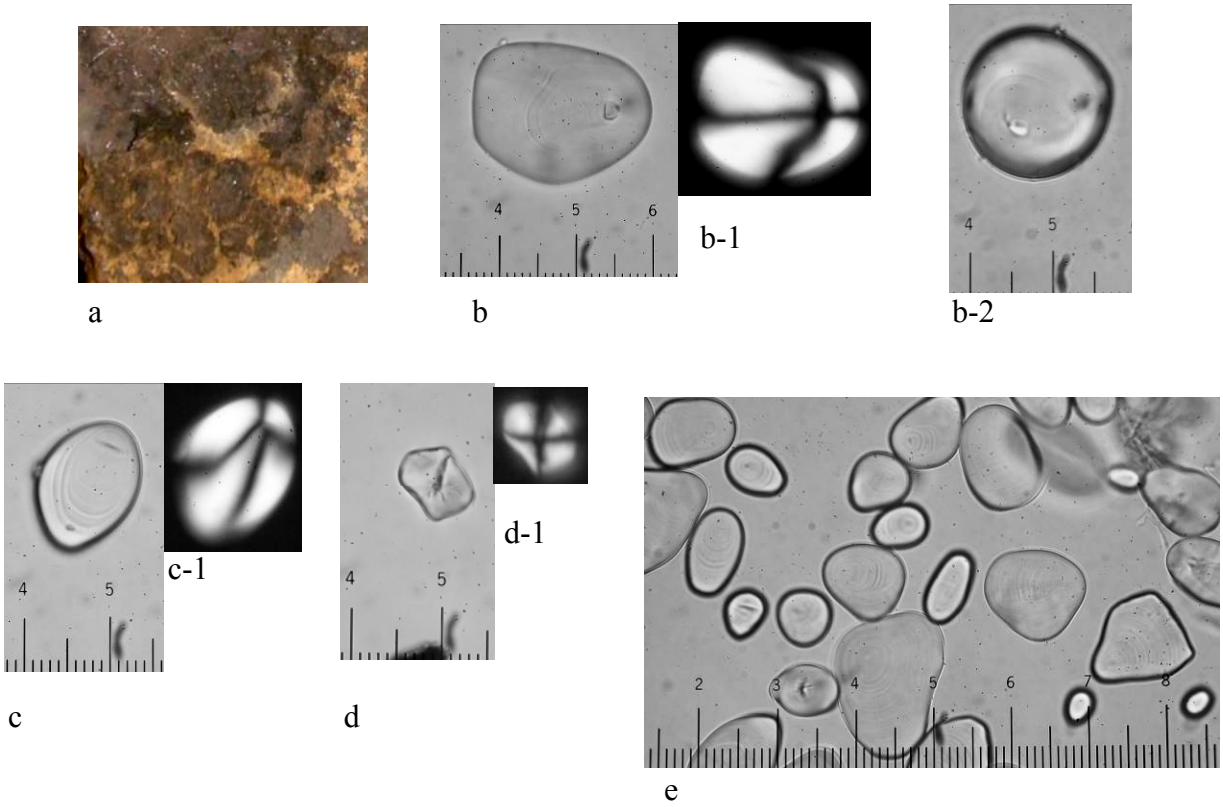
Starch Appendix Figure 11-A. Starch grains recovered from Sample-1 (coral milling base) (a-f). **a. starch grain cluster from cf. cohoba or *A. peregrina* (a-1, the same cluster cross-polarized in dark field); b. oval starch grain with a transversal fissure (b-1, the same cross-polarized); c. transovate starch grain with thin striations that are typical of *A. peregrina* (c-1, the same cross-polarized); d. oval starch grain (d-1, the same cross-polarized); e and f. broken starch grains probably by the grinding process.** **Modern starch grains of some Fabaceae genera from the comparative collection (g-i).** **g. *Phaseolus lunatus*; h. *Canavalia nitida*; i. *Macroptilium lathyroides*.**
Modern starch grains from *Anadenanthera peregrina* (j-m). **j. starch grain from mature seeds; k and l. starch grain cluster showing shapes, dimensions, and types of fissures that are common in *A. peregrina*; m. oval starch grain.**
Scale for all microphotographs (excluding "i"): space between major units (numbers)=37.5µm
Scale for microphotograph "i": space between major units (numbers)=25µm.



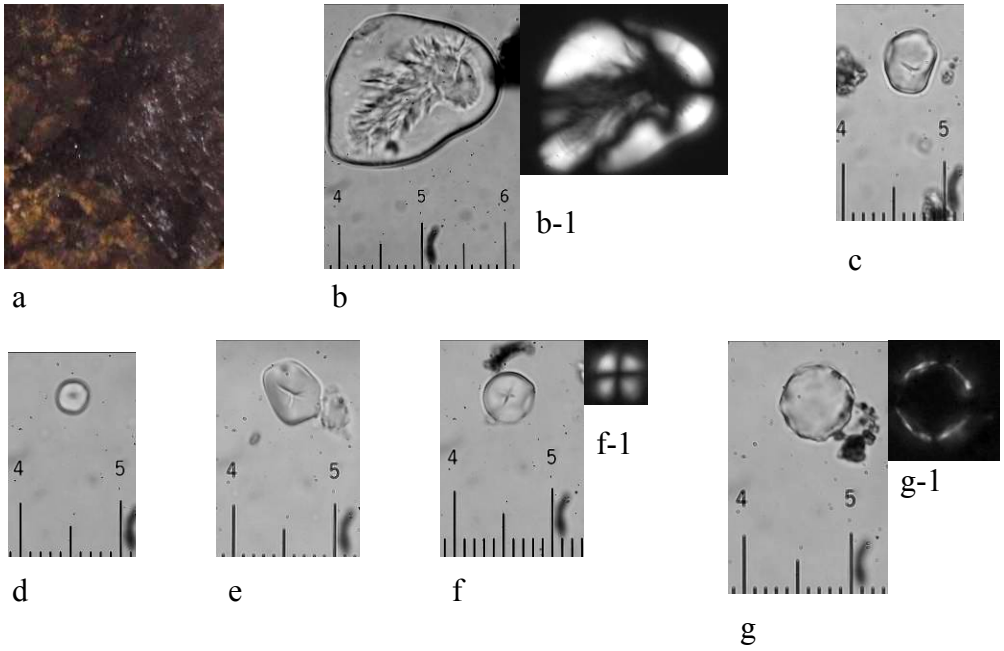
Starch Appendix Figure 11-B. Starch grains recovered from Sample-2 (stone mano).
a. cluster of *Zamia* sp. (a-1, the same cross-polarized in dark field);
b. a triangular starch grain from cf. *Xanthosoma sagittifolium*;
c. an elliptical starch grain from *Canna* sp. (c-1 the same cross-polarized in dark field);
d and e. (e-1 cross-polarized in dark field) are gelatinized and unidentified starch grains.
Scale for all the microphotographs: space between major units (numbers)=37.5μm.



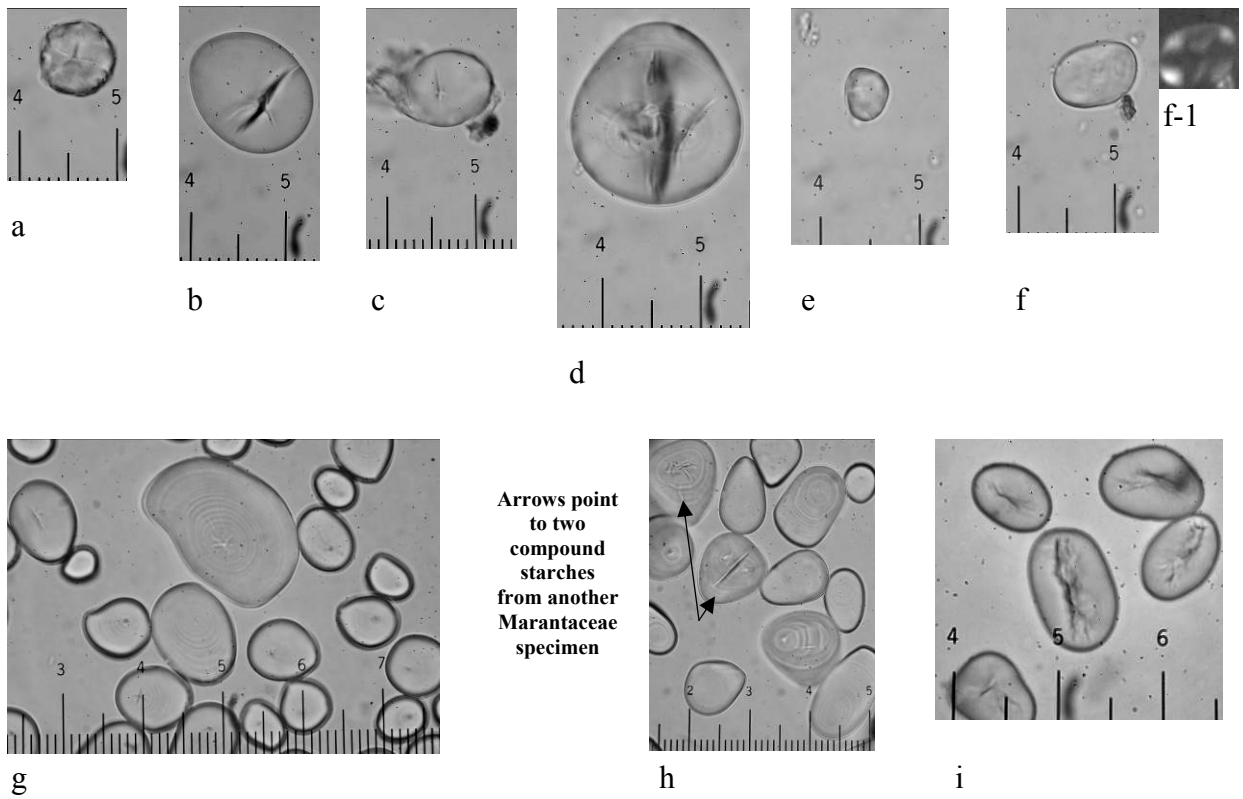
Starch Appendix Figure 11-C. Starch grains recovered from Sample-3 (griddle).
a. starch grain from cf. *Zamia* sp. (a-1 the same cross-polarized in dark field);
b. a starch from *Xanthosoma sagittifolium* and a raphide (top, left);
c. oval/kidney shaped starch grain (probably from *Phaseolus vulgaris*, c-1, the same cross-polarized in dark field). Note the large depression (vacuole) that covers almost all the surface of this starch grain, which corresponds with the dark section at the interior of the body in picture c-1;
d (d-1) and e (e-1). three starch grains not identified that shows the same central depression pattern (vacuole) observed in c.
Scale for all the microphotographs: space between major units (numbers)=37.5µm.



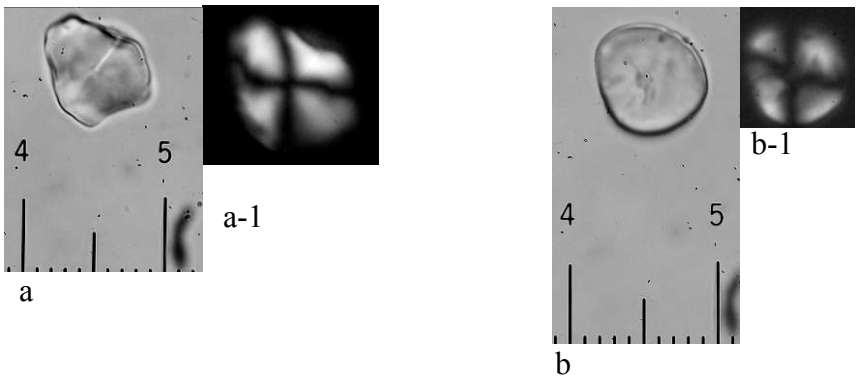
Starch Appendix Figure 11-D. Starch grains recovered from Sample-4 (ceramic pot).
a. detail of charred residues adhered to inside of vessel;
b. *Calathea* sp. (b-1 the same cross-polarized and b-2 rotated with prominent lamellae and eccentric vacuole [open hila];
c. *Calathea* sp. (c-1 the same cross-polarized);
d. cf. *Zea mays* (d-1 the same cross-polarized) showing a large linear fissure and many thin/radial striations;
e. modern starch grains from the tubers of *Calathea rufibarba.*
Scale for all microphotographs: space between major units (numbers)=37.5μm.



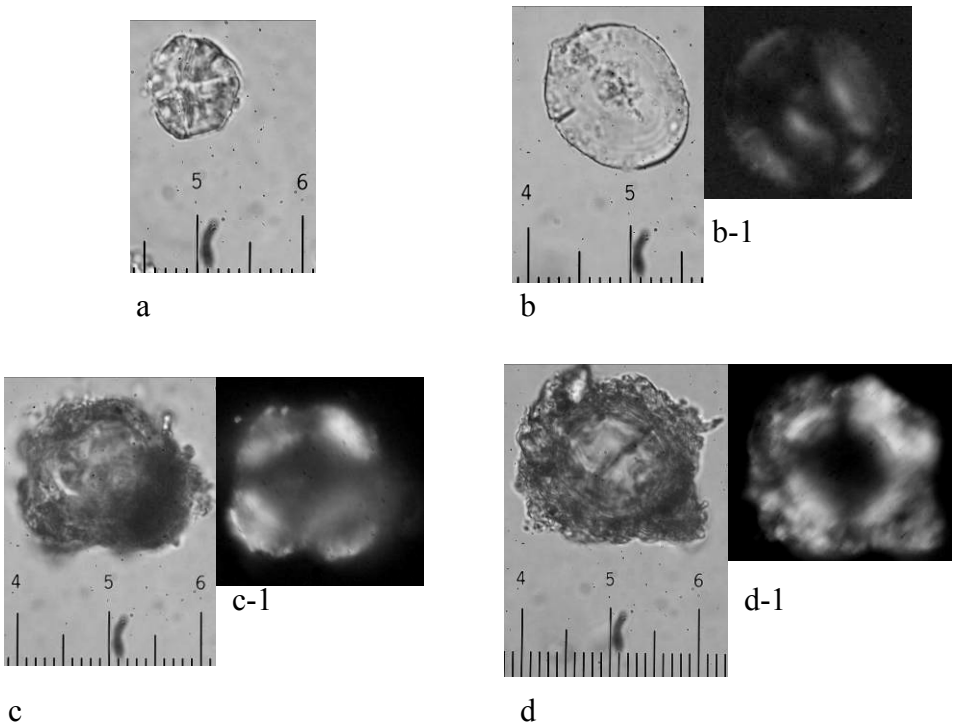
Starch Appendix Figure 11-E. Starch grains recovered from Sample-5 (ceramic pot).
a. detail of charred residues adhered to inside of vessel;
b. cf. *Zamia pumila* (b-1 the same cross-polarized);
c, d, and e. *Zea mays*;
f. *Manihot esculenta* (f-1 the same cross-polarized);
g. not identified and gelatinized (g-1 the same cross-polarized).
Scale for all microphotographs: space between major units (numbers)=37.5μm.



Starch Appendix Figure 11-F. Starch grains recovered from Sample-6 (griddle).
a. pentagonal starch grain from *Zamia pumila*;
b and c. *Maranta* cf. *arundinacea* starch grains (compare with modern starches of this species in image g);
d. a compound body from *Maranta* cf. *arundinacea* (compare with the compound starches seen in another Marantaceae, i.e., modern starches of *Calathea rufibarba* in image h);
e. starch granule from *Zea mays*;
f. archaeological starch tentatively ascribed to *Bixa orellana* (f-1 the same polarized compare with modern starches of *B. orellana* in image i);
g. modern starch grains of *Maranta arundinacea*;
h. modern starch grains of *Calathea rifibarba*;
i. modern starch grains of *Bixa orellana*.
Scale for all microphotographs: space between major units (numbers)=37.5μm.



Starch Appendix Figure 11-G. Starch grains recovered from Sample-7 (stone mano).
a. *Zea mays*. Note the hilum at the center of the body and a lineal fissure that begins in the hilum and runs to the border (a-1 the same cross-polarized);
b. maize starch grain with signs of damage in its surface (b-1 the same cross-polarized and with the extinction cross partially affected). Note in both cases the prominent "double" border.
Scale for all microphotographs: space between major units (numbers)=37.5µm.



Starch Appendix Figure 11-H. Starch grains recovered from Sample-8 (griddle).
a. damaged starch from cf. *Zamia* sp.;
b. Leguminosae-Fabaceae starch grain partially affected (b-1 the same cross-polarized);
c and d. starch grains with heavy signs of gelatinization (c-1 and d-1 the same cross-polarized).
Scale for all microphotographs: space between major units (numbers)=37.5µm.