

Capsicum spp. at the Preceramic Sites of
Huaca Prieta and Paredones, Chicama
Valley, Peru

Report written for Tom Dillehay, Vanderbilt University 2012

UCB Archaeobotany Laboratory Report #74

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ABSTRACT

The chile pepper (*Capsicum* spp.), a plant that was independently domesticated in a series of places including highland Bolivia, central Mexico, the Amazon, the Caribbean, and other locales, has a long history of cultivation and use in the central Andes of South America. Though identification of chile pepper species through fruit morphology is possible and has been completed by several botanists, species-level identification of *Capsicum* seeds has remained undetermined. This report presents a systematic procedure to identify *Capsicum* seeds to the species level by adopting a morphometric approach to compare attributes of modern *Capsicum* seeds to archaeological seeds recovered during excavations from various temporal phases at the Preceramic sites of Huaca Prieta and Paredones (7500-4000 BP) in north coastal Peru. Not only do we find that seed identification of *Capsicum* through attribute analysis is possible, our evidence suggests that the people who occupied Huaca Prieta and Paredones in the Preceramic period consumed various species of *Capsicum* early on before developing a particular taste for *Capsicum baccatum* in the Late Preceramic.

INTRODUCTION

Chile peppers, a staple of many cuisines around the world today, have their origins in the Western Hemisphere. Prior to Columbus' voyage to the Americas in the 15th century, chile peppers were cultivated to varying extents from the American Southwest down to Chile. The chile pepper (*Capsicum* spp.) consists of about 25

species, five of which represent domesticated taxa (Andrews 1984; Basu and De 2003; Davenport 1970; Esbaugh 1976, 1980, 1983; Heiser and Smith 1953; Heiser 1971; Naj 1992). These taxa include *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens*. The general consensus among botanists is that the nuclear origin area for the *Capsicum* genus is in highland Bolivia on the eastern slopes which is also the purported origin of the domesticated *C. pubescens*; from there, the wild *Capsicum* species radiated outwards through the Americas due to dispersal by birds and possibly humans. (Andrews 1984, 2006; Esbaugh 1983; Pickersgill 1977, 1988, 2009). *C. baccatum* is thought to have been domesticated in lowland coastal Peru, while *C. chinense* and *C. frutescens* may have more tropical roots in the northeastern Amazon (Moses and Umaharan 2012, Pickersgill 1972; Aguilar-Meléndez 2006, 2009; Hernández-Verdugo 1999, 2001; Perry and Flannery 2007). *C. annuum*, on the other hand, was domesticated in Mexico (Pickersgill 1972, Aguilar-Meléndez 2006). While botanists have painted a picture of *Capsicum* domestication based on the modern distribution of wild *Capsicum* taxa in the Americas as well as the presence of preserved *Capsicum* fruits with calyx morphology intact from archaeological sites, the lack of certainty surrounding the identification of *Capsicum* seeds to species-level has hindered this effort of tracing *Capsicum* species domestication and movements, with some proclaiming *Capsicum* seed identification to be a fruitless endeavor altogether (Andrews 1984). Based on our research and the results of this report, we argue the opposite. We feel strongly that the analysis of

both quantitative and qualitative traits of archaeological *Capsicum* seeds can indeed lead to species-level identification. Using data from Huaca Prieta and Paredones, our research lends strong insight into the unique histories of various *Capsicum* domesticates that are reflected in seed morphology.

BACKGROUND ON *CAPSICUM* RESEARCH

The chile pepper (*Capsicum* spp.) is a New World plant. It was first encountered by the West in the late 15th century during a quest for expanding the spice trade by Columbus and his men on the West Indian island of Hispaniola, a plant that the native Arawak Indians called *axí*, the precursor to the Spanish word for chile *ají*. The Spanish padres gathered seeds of native plants used for food and medicine in the New World and sent them to Spain; from the Iberian peninsula and Brazil, chile peppers were spread around the world to West Africa, India, and Indonesia by early Portuguese traders, finding their way into the heart and soul of many varied cuisines around the world (Andrews 1984). Nevertheless, chile peppers have long held a position of great esteem in the Andean world. Indeed, chile peppers were used in pre-Columbian times as an essential ingredient in the preparation of dishes, as the following passage written by the chronicler El Inca Garcilaso de la Vega illustrates:

Es el condimento que todos los Indios del Perú utilizan, sea en guisos, cocinados dentro de una comida, o asados, sin estos frutos ellos no pueden comer, también los españoles los llaman *uchu*, o “pimiento de las Indias,” aunque el nombre *axi* le es dado en el lenguaje usado por la gente de las Islas de Barlovento. En mi tierra hay gente que no puede comer si no acompañan su comida con este fruto, se consume un poco más que cualquier otra hierba cruda. Debido a que éstos se usan para dar sabor a las comidas fueron prohibidos en actos religiosos, ya que son muy estrictos (Garcilaso 1609).

As Garcilaso’s writing indicates, chile peppers (or *uchu*, *ají*, *rocoto/locoto*, *huayca*) were almost

a necessity in Inca dishes, with some unable to eat without it. Much like rice among the Japanese, one might surmise that the chile pepper had much to do with identity and self; we know, for example, that certain cultivars of chile pepper are restricted to specific regions in the Andes (e.g., highland, coast, and jungle), suggesting the possibility that different groups of people identified with these distinct species. Given its history of cultivation in the Andes, it is likely that chile peppers were prized long before the time of the Inca. Among the Nasca, for example, chile peppers are the second most depicted plant in Nasca ceramic iconography, commonly shown attached to mythical beings (Proulx 2009). *Capsicum* seeds have purportedly been found in deposits dating to as far back as 10,000 BP at Guitarrero Cave, though this date is disputed as *Phaseolus* remains from the site have been directly dated to around 3000-4000 BP (Kaplan and Lynch 1999, Moseley 2001, Pearsall 2008). Starch grains of *Capsicum* have also been recovered dating back to 6000 BP from Real Alto and Loma Alta in Ecuador (Perry et al. 2007). Combined with evidence obtained from sites like Huaca Prieta and the Mito site of La Galgada, the literature claims that the chile pepper was cultivated by at least 5000 BP (Moseley 2001). Given the greater time-depth of this study, it is possible that our chile pepper remains are among the earliest, if not the earliest, well-provenienced examples of cultivated *Capsicum* in the world.

The domestication of the *Capsicum* genus and its various species has been the subject of a fair amount of botanical research that has greatly informed our research. According to Barbara Pickersgill, domesticated species of *Capsicum* are fairly distinct and difficult to cross, producing sterile hybrids even when fertilization is successful (1972). Thus, cultivated species of *Capsicum* had distinct wild ancestors and were characteristic of different areas in pre-conquest times (Smith and Heiser 1957). Given these traits, the *Capsicum* genus serves as a potential proxy for studying human interactions in the Americas, as “[g]enera in which several species have been domesticated may thus be useful indicators of cultural contact if the place of

domestication of the individual species is accurately known and if the archaeological material can be assigned with certainty to a particular species or group” (Pickersgill 1972:99).

Given that the presence or absence of different *Capsicum* species can reveal valuable information about cultural contact, the ability to identify *Capsicum* plant parts is crucial. The identification of *Capsicum* in the archaeological record up to this point has remained unsystematic. Margaret Towle, for example, reported that the majority of *Capsicum* remains reported from coastal, Precolumbian Peru were *C. annuum*, which presents an unlikely scenario given that there are at least two species of *Capsicum* (*C. baccatum* and *C. chinense*) that are native to the central Andes (1961). Subsequent research has suggested that *C. annuum* is relatively restricted to Mexico and Central America in the pre-Colombian times. Even though wild progenitors to *C. annuum* exist from Mexico to Columbia, genetic studies have shown that the most parsimonious scenario for *C. annuum* domestication is in Mexico, due to the fact that all *C. annuum* plants have 2 pairs of acromere chromosomes while most wild taxa have one *except* for wild species in Mexico (Pickersgill 1972, Aguilar-Meléndez 2006). Furthermore, at Huaca Prieta, previous work by Barbara Pickersgill on *Capsicum* has revealed the presence of *C. baccatum* or *C. chinense* by the Late Preceramic (Pickersgill 1969). Pickersgill identified *Capsicum* pod remains housed in Margaret Towle’s collection at the Harvard Botanical Museum that were recovered from Junius Bird’s excavations in 1947-1948 (Bird 1985). These identifications were made based on calyx morphology (Pickersgill 1969). While most of her discussion centered on chile pepper pods, she reported the range of diameters for the seeds that were also recovered. While her data may be useful for arriving at a general sense of seed size, they do not lend very much insight to species-level identification. After our review of the literature, we decided that the best course of action would be to create our own pilot study to adequately address the identity of chile peppers at Huaca Prieta.

Project Overview and Goals

Chile pepper seeds from the Preceramic archaeological sites of Huaca Prieta and Paredones in the Chicama Valley of the desert North Coast of Peru were recovered through flotation of sediment samples during excavations led by Tom Dillehay of Vanderbilt University and Duccio Bonavia (Figure 1). These seeds were identified as *Capsicum* spp. by Victor Vásquez Sánchez of the University of Trujillo and sent to the McCown Archaeobotany Laboratory at the University of California, Berkeley for analysis. The *Capsicum* seeds we received represent three out of five phases over the 4000-year Preceramic occupational history of Huaca Prieta and Paredones (Figure 2, Dillehay et al. 2012) and were excavated from a variety of contexts representing these phases (Figure 3). Out of the approximately 750 seeds we received, 64 archaeological seeds were studied in this project (Table 1). Table 1 presents our archaeological database, including the sample, site, phase, number of seeds available, number of seeds analyzed, and context from which the seeds were retrieved. Our selection was based on the requirement of complete seeds in good condition including preservation of beak, center of seed, and seed margins. We selected 100% of these sub-sampled seeds from Phases 2 ($n=14$) and 4 ($n=28$). The majority of seeds we received came from the latest period, Phase 5. We analyzed 1-3 well-preserved seeds per sample (to arrive at a sense of all contexts). In total, 22 seeds were sampled from Phase 5. Given the sparse nature of the literature on *Capsicum* seed identification (with some notable exceptions such as Gunn and Gaffney 1974, Minnis and Whalen 2010, Martin 1946), we decided to record both qualitative and quantitative attributes of modern seeds we obtained from various sources listed in Appendix 1, drawing inspiration from Christine Hastorf, Maria Bruno and BrieAnna Langlie’s previous work on Andean *Chenopodium* (Bruno 2006; Bruno and Whitehead 2003; Langlie et al. 2011). Our first goal was to discover diagnostic traits of *Capsicum* in modern seeds that could be applied to our archaeological analysis. Our second goal was to apply these criteria to the archaeological

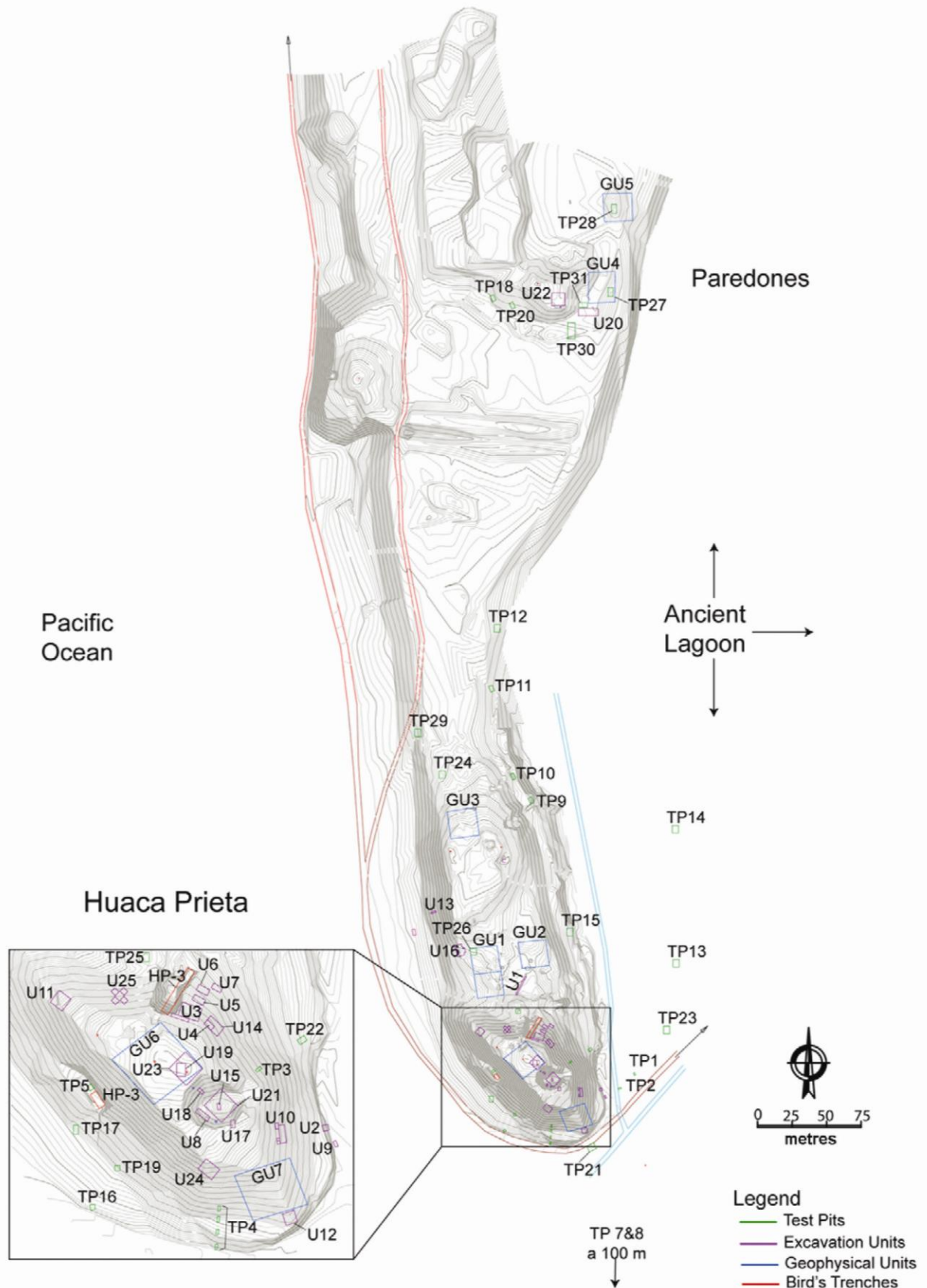


Figure 1: Map of Huaca Prieta and Paredones, Peru (from Dillehay et al., 2012)

Phase	Time Span
1	7572-8930 BP
2	6538-7572 BP
3	5308-6538 BP
4	4107-5302 BP
5	3455-4510 BP

Figure 2: Chronology

- Phase 2
- Phase 4
- Phase 5

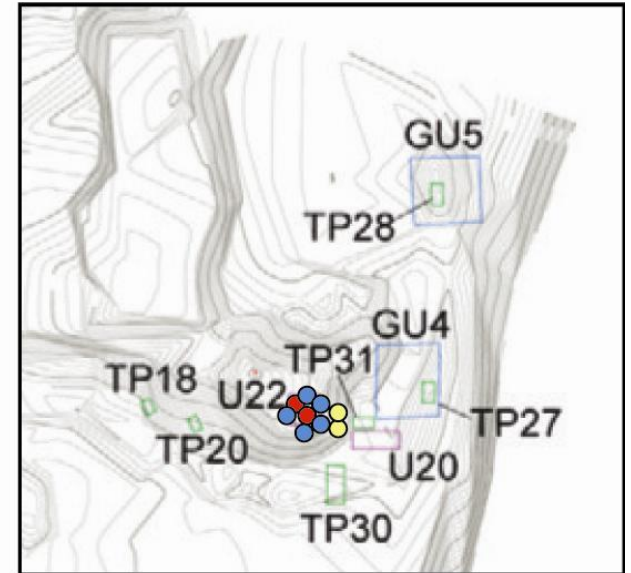
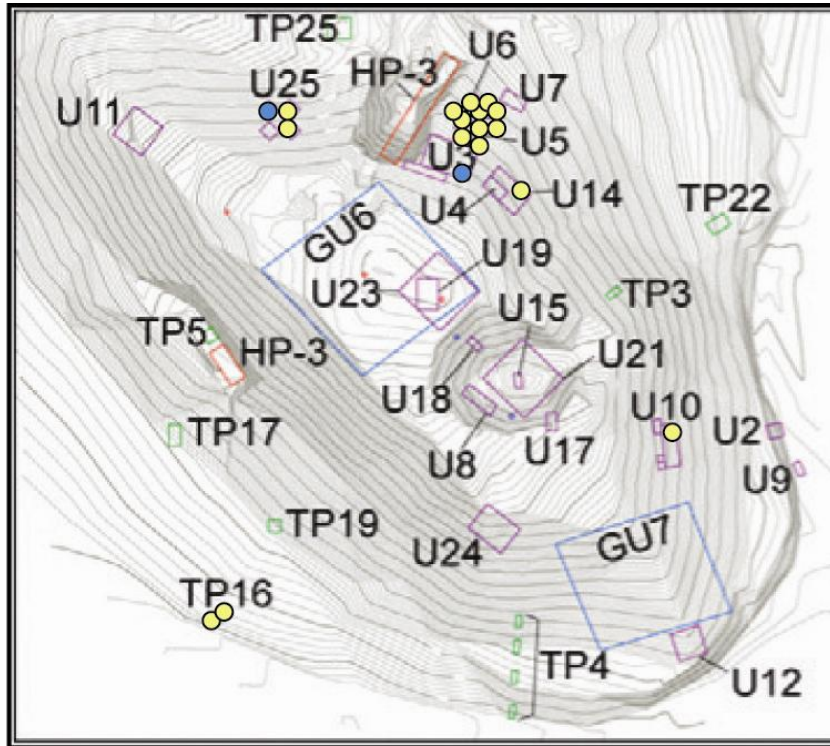


Figure 3: Location of Botanical Samples by Phase

	Sample No.	Site	# Available	# Analyzed	Context
Phase 2	553	Paredones	Fragments	0	Other
	563	Paredones	1	1	Other
	570	Paredones	13	13	Residential
Phase 4	518	Huaca Prieta	7	3	Feasting
	519	Huaca Prieta	3	0	Feasting
	525	Paredones	9	5	Other
	526	Paredones	9	3	Other
	543	Paredones	16	5	Other
	561	Paredones	2	1	Other
	562	Paredones	6	1	Other
	568	Paredones	90	6	Other
	569	Huaca Prieta	19	4	Feasting
Phase 5	15	Huaca Prieta	220	2	Feasting
	17	Huaca Prieta	34	1	Feasting
	28	Huaca Prieta	23	2	Feasting
	32	Huaca Prieta	11	1	Feasting
	43	Huaca Prieta	33	1	Feasting
	46	Huaca Prieta	36	3	Feasting
	48	Huaca Prieta	14	1	Feasting
	49	Huaca Prieta	58	1	Feasting
	59	Huaca Prieta	22	3	Feasting
	369	Huaca Prieta	17	0	Feasting
	405	Huaca Prieta	5	1	Residential
	440	Huaca Prieta	3	1	Feasting
	460	Huaca Prieta	17	1	Feasting
	469	Huaca Prieta	1	0	Feasting
	520	Huaca Prieta	1	1	Feasting
	527	Paredones	18	1	Other
	528	Paredones	31	1	Other
	531	Paredones	5	0	Other
	575	Huaca Prieta	16	0	Residential
	601	Huaca Prieta	2	1	Residential
602	Huaca Prieta	1	0	Residential	

Table 1: Archaeological Capsicum Seed Collection

seed data set and also to offer insights into early chile pepper use in coastal Peru in the specific context of Huaca Prieta and Paredones.

MODERN *CAPSICUM* METHODS

We determined that studying a comparative collection of modern *Capsicum* seeds from all five domesticated species was essential to the goals of this project. To that end, we amassed 44 distinct seed collections representing *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens* from different sources including vendors specializing in chile pepper cultivation and the USDA National Plant Germplasm System/Germplasm Resources Information Network (Table 2, seed sources are listed in Appendix 1). These seeds were photographed using an Olympus SZ-61 stereomicroscope (10x-30x) and an Olympus digital camera (model DP72) housed in the McCown Archaeobotany Laboratory. Close-up scanning electron microscopy (SEM) images of the testa were taken using a Hitachi TM-1000 located in the Robert D. Ogg Electron Microscopy Laboratory on the Berkeley campus. The Olympus MicroSuite program was used to take various measurements of the whole seed, the attachment scar, and the testa in the transverse cross-section. Qualitative assessments were also made of the seed shape and testa texture.

We recorded data for 27 attributes for the 44 *Capsicum* seed collections that are listed and defined in Figure 4. These attributes were selected based on the *Capsicum* literature, previous research experience with seeds, and observations were made concerning the nature of *Capsicum* seeds themselves

ANALYSIS

After we recorded measurements for the 27 attributes for each modern *Capsicum* seed variety, we ran a series of exploratory data analyses to seek the most productive differentiating measurements for seed identification, such as plotting two attributes against each other (y by x) and generating scatter plot matrices with multiple variables. From these plots, we determined that six

quantitative attributes combined to form diagnostic identifications of *Capsicum* seeds to species-level. Combined with our qualitative attributes, we have eight diagnostic characteristics. The two qualitative/nominal attributes include seed shape and testa texture. Our six quantitative attributes are (1) beak angle, (2) beak prominence, (3) the ratio of maximum seed length to perpendicular width, (4) whole seed sphericity, (5) the ratio of the thickest portion of the testa to the thinnest portion, and, (6) attachment scar sphericity. These diagnostic attributes are defined below:

Definitions

Seed Shape

The general shape of *Capsicum* seeds is relatively distinct from species to species with some overlap. These seed shapes are drawn in Figure 5 (note: names are our own creations and not necessarily standardized seed shape names).

Testa Texture

Testa texture refers to the appearance of the seed coat. The texture of the seed coat is diagnostic especially in the case of *C. pubescens*, which display an exaggerated reticulation pattern on the outer margins of the seed as well as *C. baccatum* which exhibits a tighter reticulation pattern (as opposed to the other species that tend to have a smooth surface). SEM photos of these various seed textures are shown in Figure 6.

Beak Angle

The beak is defined as the protruding area of the seed that differentiates *Capsicum* seeds from other similar-looking seeds of the family Solanaceae (Minnis and Whalen 2010). Figure 7, illustrates the morphometrics taken with the whole seed and shows how we measured beak angle. The beak angle (Fig. 7c) gives us a sense of how much the beak diverges from the rest of the body. A high beak angle, for example, is one of the diagnostic attributes for *C. frutescens* seeds.

Beak Prominence

	Common Name	Source	Associated Country
<i>C. annuum</i>	Kori Sitakame	Native Seeds SEARCH	Mexico/Southwest U.S.
	Coban	Native Seeds SEARCH	Mexico/Southwest U.S.
	Del Arbol	Native Seeds SEARCH	Mexico/Southwest U.S.
	Ordono	Native Seeds SEARCH	Mexico/Southwest U.S.
	Mirasol	Native Seeds SEARCH	Mexico/Southwest U.S.
	Pinguita de Mono	Refining Fire Chiles	Peru
	USDA#215743	Reimer Seeds	Peru
	USDA#439328	Reimer Seeds	Peru
	Inca Berry	Reimer Seeds	Peru
	Inca Glow	Reimer Seeds	Peru
	USDA#241662	USDA Germplasm Bank	Peru
	USDA#257159	USDA Germplasm Bank	Peru
	USDA#257178	USDA Germplasm Bank	Peru
	USDA#439328	USDA Germplasm Bank	Peru
	USDA#439330	USDA Germplasm Bank	Peru
	USDA#439331	USDA Germplasm Bank	Peru
	USDA#439336	USDA Germplasm Bank	Peru
USDA#439391	USDA Germplasm Bank	Peru	
USDA#640906	USDA Germplasm Bank	Peru	
<i>C. baccatum</i>	Aji Amarillo	Amazonas Imports	Peru
	Aji Panca	Amazonas Imports	Peru
	Aji Amarillo	Trade Winds Fruit	Peru
	Aji	Andean Seed Collection	Peru
	Aji Lemon	Pepper Lover	Peru
	Aji Panca	Peppermania	Peru
	Inca Berry	Peppermania	Peru
	Aji Chinchi Amarillo	Peppermania	Peru
	Queen Laurie	Peppermania	Peru
	Kaleidoscope	Peppermania	Peru
	Lemon Drop	Peppermania	Peru
	Aji Cristal	Peppermania	Peru
<i>C. chinense</i>	Aji Dulce #2	Trade Winds Fruit	Peru
	Limo Blanco	Peppermania	Peru
	Scarlet Lantern	Peppermania	Peru
	Aji Limo Rojo	Peppermania	Peru
<i>C. frutescens</i>	Tabasco	Native Seeds SEARCH	Mexico/Southwest U.S.
	Aji Chuncho	Pepper Lover	Peru
	USDA#215728	USDA Germplasm Bank	Peru
	USDA#260505	USDA Germplasm Bank	Peru
	USDA#315007	USDA Germplasm Bank	Peru
<i>C. pubescens</i>	Orange Manzano	Trade Winds Fruit	Peru
	Red Manzano	Trade Winds Fruit	Peru
	Yellow Manzano	Trade Winds Fruit	Peru
	Red Rocoto	Refining Fire Chiles	Peru

Table 2: Modern Capsicum Seed Collection

1. Seed Shape*

There are several categories of seed shapes. These include Oval, Circular with Fish Mouth, Teardrop, and D-shape (see Fig. 4).

2. Relational Length

This is defined as the length of the seed measured using the MicroSuite program. The seed was oriented with attachment scar facing right and in an "upright" position. Length was then measured on the 0° line (see Fig. 6A).

3. Relational Width

This is defined as the width of the seed measured using the MicroSuite program. The seed was oriented with attachment scar facing right and in an "upright" position. Width was then measured on the 90° line (see Fig. 6A).

4. RL:RW

This is the ratio of relational length to relational width.

5. Maximum Length

This is somewhat of a misnomer. For the majority of seeds, the maximum length (a.k.a. "maximum diameter") was generally measured from the attachment scar to the widest end of the seed. Given that this was mostly the case, all seeds were measured from the attachment scar to the widest end across the seed. Sometimes, (i.e., in the case of *C. frutescens*), the maximum length would turn out to be much shorter than max diameter, due to the shape of the seed (an oval on its side). See Fig. 6B.

6. Perpendicular Width

The width was measured 90° (perpendicular) from where the maximum length was measured (see Fig. 6B).

7. ML:PW

This is the ratio of maximum length to perpendicular width.

8. Aspect Ratio

Aspect ratio is defined as the ratio of the width of a shape to its height. This was calculated by MicroSuite.

9. Perimeter

The length measurement of the perimeter of the whole seed when laid flat. This is calculated by MicroSuite.

10. Sphericity*

Sphericity refers to how spherical an object is. The closer the measure is to 1, the more the object represents a sphere. Since the photos were taken in 2D, sphericity in this case means how close an object is to a perfect circle. This was calculated by MicroSuite.

11. Area

The extent of the Capsicum shape, measured in mm². This was calculated by MicroSuite.

12. Maximum Diameter

The greatest diameter, calculated by MicroSuite.

13. Mean Diameter

The mean diameter, calculated by MicroSuite.

14. Minimum Diameter

The minimum diameter, calculated by MicroSuite.

15. Testa Texture*

This is a description of the testa surface. Categories include smooth to broad, tight reticulation, and dramatic reticulation (see Fig 5).

16. Beak Prominence*

This is a ranking scale of the extent of the protrusion of the "beak" of the seed: the area above the attachment scar (see Fig. 9)

1=No Protrusion

2=Nub

3=Small

4=Medium

5=Long

17. Beak Angle*

Beak orientation in relation to body of the seed. To take this measurement, seed was oriented so that attachment scar pointed right. Generally, seed is oval in shape and oriented so that it sat "straight up". Procedure for measuring angle involved placing protractor so that 0° line lines up with right edge of seed. Vertex was then moved up so that it was located in the center of beak. Ruler was used to measure from vertex to tip of beak (see Fig. 6C).

18. Attachment Scar Length

The length of the longest horizontal distance of the attachment scar measured in MicroSuite (see Fig. 7A).

19. Attachment Scar Width

The width of the attachment scar, measured at the midway point of the attachment scar length in MicroSuite; perpendicular to length (see Fig 7A).

20. Attachment Scar Length: Relational Length

A ratio of the attachment scar length to the measure of relational length.

21. Attachment Scar Area

The area of the attachment scar opening, measured using tools in MicroSuite (see Fig. 7B).

22. Attachment Scar Sphericity*

This measure indicates how close the shape of the attachment scar opening is to a perfect circle. Calculations were made by MicroSuite.

23. Testa Thin (1, 2, 3)

Three measurements of testa width on the dorsal and ventral sides of the seeds (the thinnest areas, see Fig. 8).

24. Testa Thin Average

The mean of the three measurements above.

25. Testa Thick (1, 2, 3)

Three measurements of testa width on the margins of the seed in cross section (the thickest areas, see Fig. 8).

26. Testa Thick Average

The mean of the three measurements above.

27. Ratio (Thick to Thin)*

A ratio of the testa thick average to the testa thin average.

Figure 4: List of Attribute Definitions

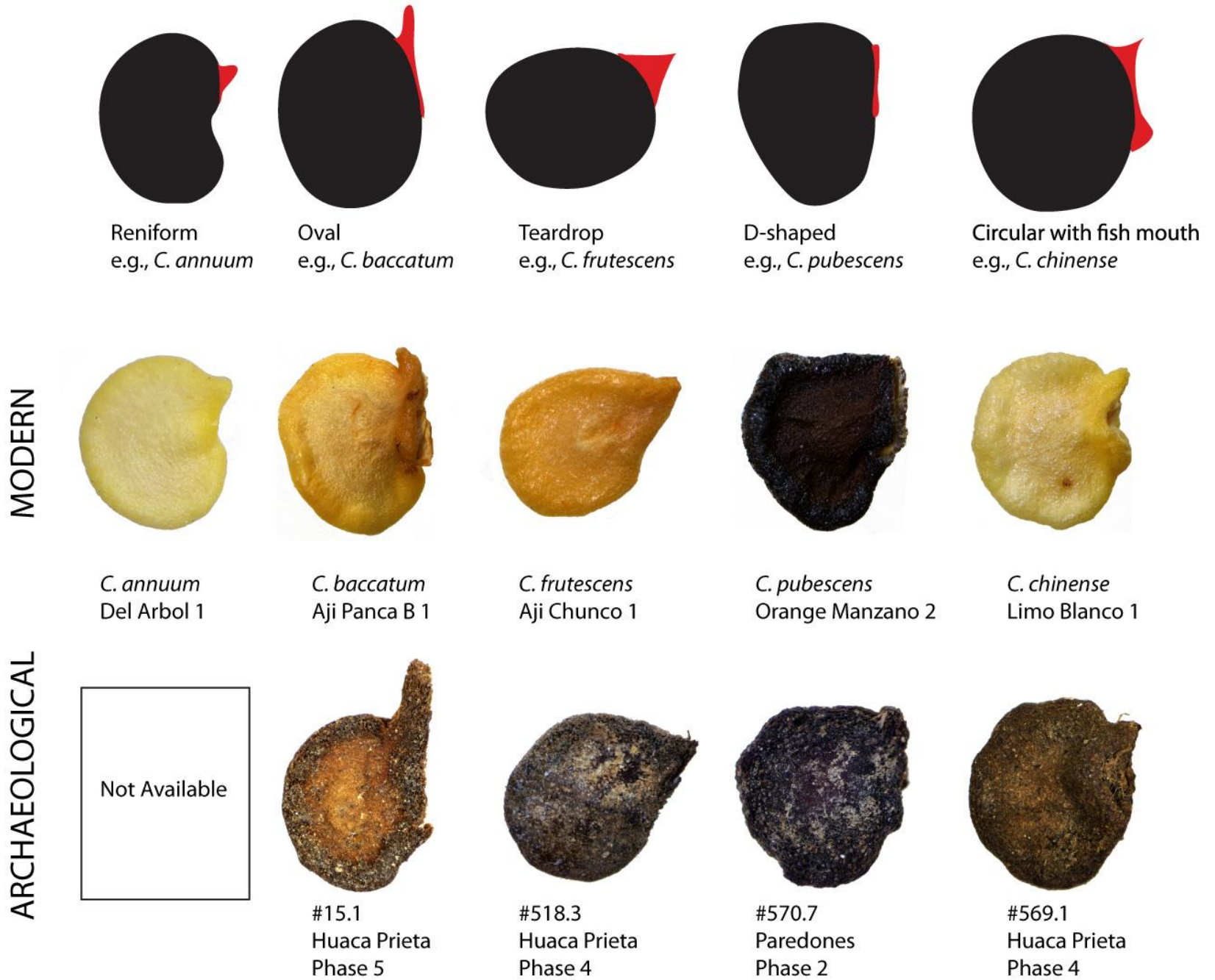
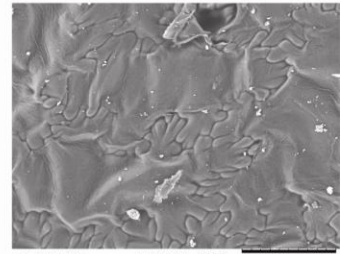
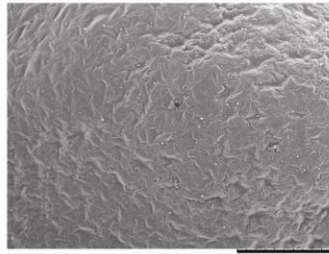
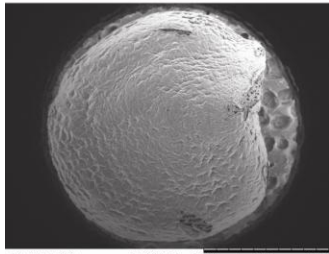


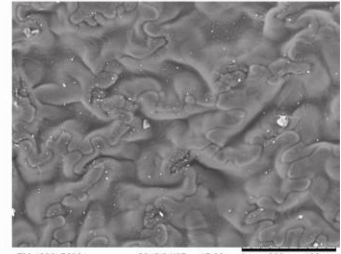
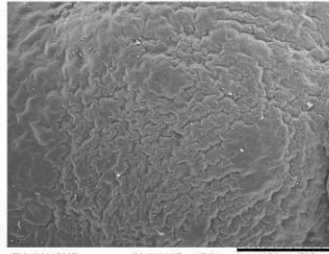
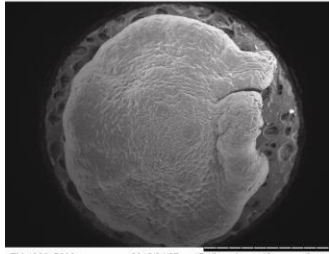
Figure 5: Capsicum Seed Shapes

A. SMOOTH TO BROAD RETICULATION

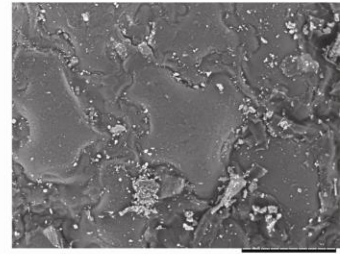
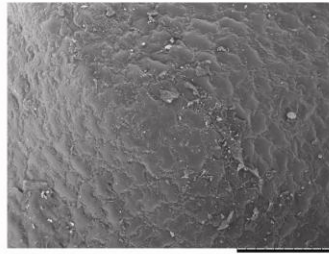
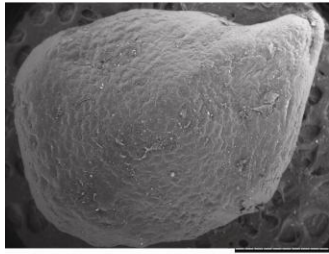
Capsicum annuum USDA #439391



Capsicum chinense Limo Blanco

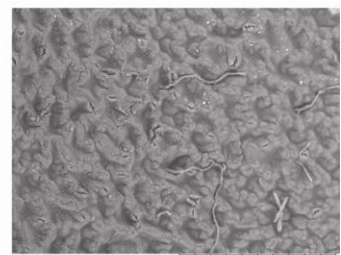
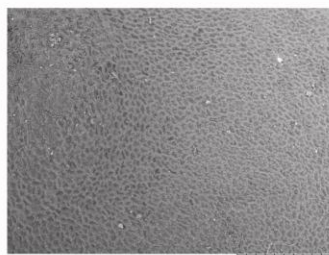
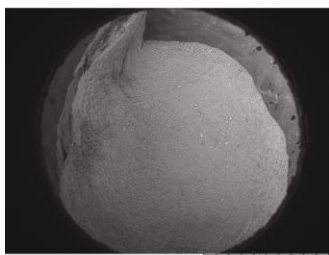


Capsicum frutescens USDA #315007



B. TIGHT RETICULATION

Capsicum baccatum Aji Amarillo



C. DRAMATIC RETICULATION

Capsicum pubescens Red Manzano

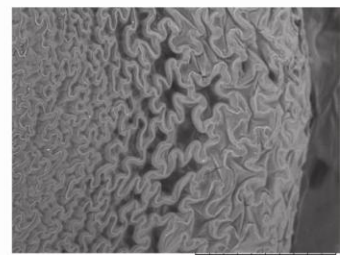
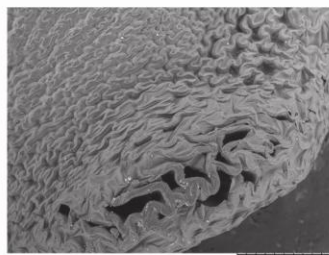
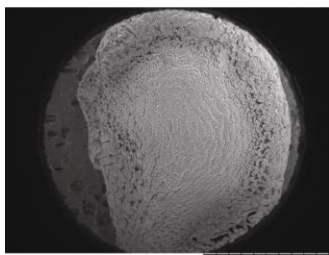


Figure 6: Testa Textures

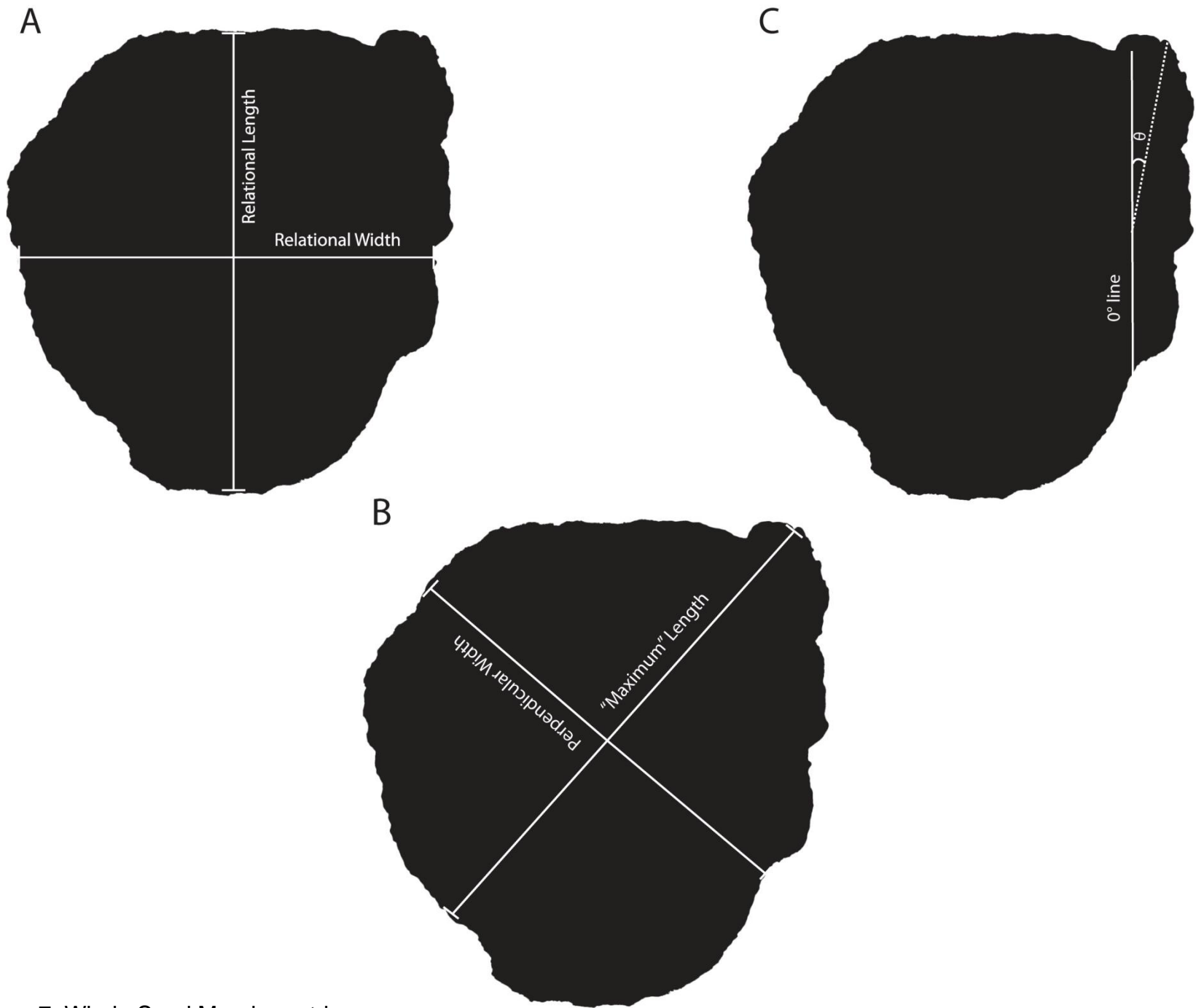


Figure 7: Whole Seed Morphometrics

Beak Prominence is depicted in Figure 8 and refers to how far the beak protrudes from the rest of the seed body and is an ordinal dataset based on a ranking scale (from 1-5).

Maximum Length: Perpendicular Width

This is a measurement of basic length and width. The length measurement was taken from the beak and the width measurement was taken perpendicular to the length measurement. All seeds were measured in the same manner (see Figure 7b).

Whole Seed Sphericity

Sphericity refers to how spherical (or in the two-dimensional sense, circular) a shape is and was calculated using the Olympus MicroSuite program. Photos such as those in Figure 9 show examples of 5 modern taxa and a few morphometrics. Note the sphericity measurement and the general shape of the seed.

Ratio of Thick Testa to Thin Testa

We made a transverse cross-section of the seed to measure thickness of testa which is often an important measurement in studying domestication as testas tend to get thinner as a result of directed selection pressure during domestication (Flannery 1973, Fritz and Smith 1988, Smith 2006, Bruno and Whitehead 2003, Bruno 2006). Noticing a great amount of variation in the measurements of the testa (especially at the outer margins), we decided to calculate a ratio of the thick testa to the thin testa. Three measurements taken for both the thick and thin testa areas and averaged (Figure 10). We found this to be a useful measurement, as there is a range of these ratio values [e.g., *C. annuum* has a low thick to thin testa ratio and *C. pubescens* which displays the highest thick to thin testa ratio (around 8:1)].

Attachment Scar Sphericity

The attachment scar or hilum refers to the area that is attached to the placental wall of the chile pepper fruit. We noticed that the shape of the attachment scar varied and decided to measure sphericity of the attachment scar shape (Figure

11). Figure 11A reveals the interior of attachment scar (as well as how measurements of length and width were taken) while figure 11B shows how the sphericity and area measurements were taken in Olympus Microsuite.

Summary

In summary, our morphometric attributes revolve around measurements of the whole seed, the attachment scar, and the testa in cross-section. Measurements of the whole seed include that of the traditional length and width measurements and beak angle, along with other measurements easily calculated by Microsuite and defined in Figure 4 (see Figure 7 for length, width, and beak angle measurements). Figure 11A and B show the attachment scar measurements we recorded that included length, width, area (as well as sphericity of the attachment scar shape). The measurements taken on the transverse cross section of each *Capsicum* seed is illustrated in Figure 10 while Figure 8 illustrates the ranking scale we used to rank beak protrusion. All 27 attributes were noted for the 44 modern seeds in our study sample. Figure 9 shows a selection of 5 seeds from each modern taxon with the beak angle, maximum length: perpendicular width, beak prominence and whole seed sphericity data noted for a sense of the variation among species in regards to the seed in its entirety. As is evident in Figure 9, *C. baccatum* displays the most prominent beak, with *C. pubescens* generally lacking or having very little beak protrusion. Furthermore, *C. chinense* tends to be the most circular in shape, which explains its higher sphericity value. Furthermore, while the beak of *C. baccatum* tends to protrude straight up on the right side of the side at an angle of near 0°, *C. chinense*, *C. frutescens*, and *C. annuum* have much higher beak angles. Figure 12 shows the variation in attachment scar shape among the 5 different *Capsicum* seeds as well as the sphericity. On average, *C. baccatum* tends to have the most linear-shaped attachment scar with a sphericity of <.03. *C. chinense*, on the other hand, generally exhibits a more circular attachment scar shape with sphericity as high as .33. Figure

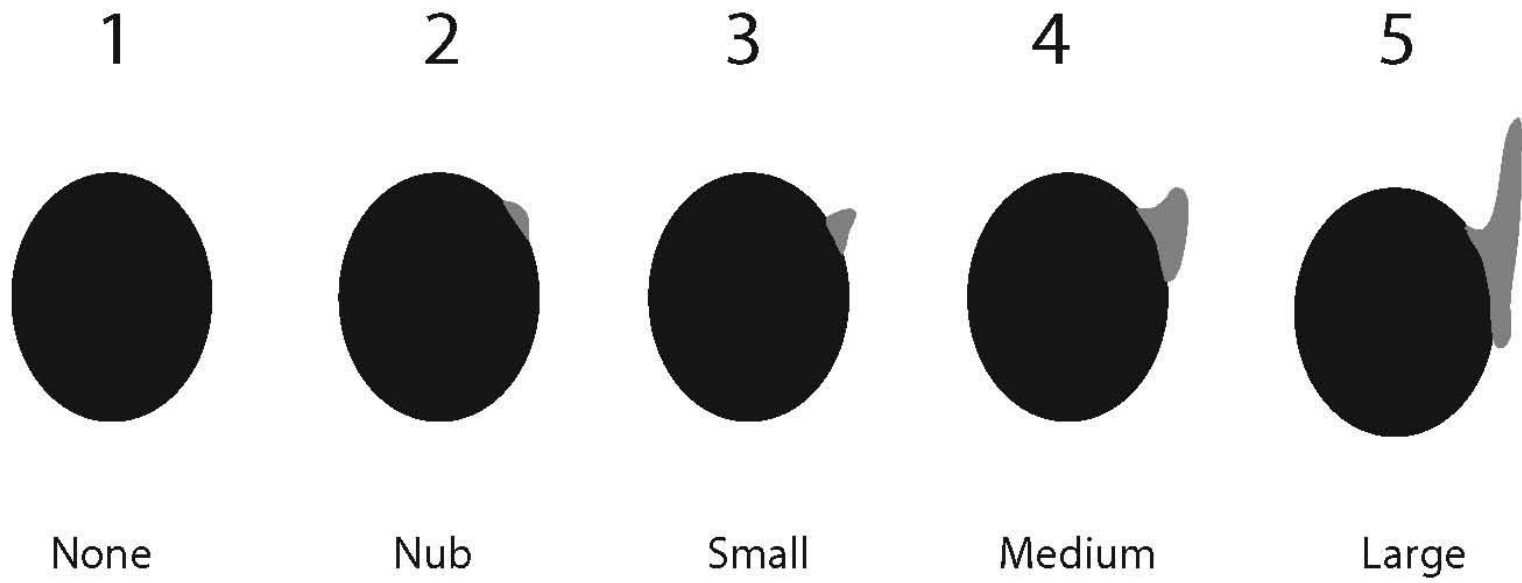


Figure 8: Beak Prominence



C. annuum
Kori Sitakame 1
Beak Prominence: 2
Beak Angle: 63°
Sphericity: .65
ML:PW: 1.069



C. baccatum
Aji Panca 1
Beak Prominence: 4
Beak Angle: 6°
Sphericity: .75
ML:PW: 1.142



C. chinense
Limo Blanco 1
Beak Prominence: 4
Beak Angle: 68°
Sphericity: .79
ML:PW: 1.123



C. frutescens
Aji Chuncho 1
Beak Prominence: 4
Beak Angle: 70°
Sphericity: .54
ML:PW: 1.162



C. pubescens
Red Rocoto 1
Beak Prominence: 1
Beak Angle: 26°
Sphericity: .85
ML:PW: 1.040

Figure 9: Comparison of Whole Seed Morphometrics

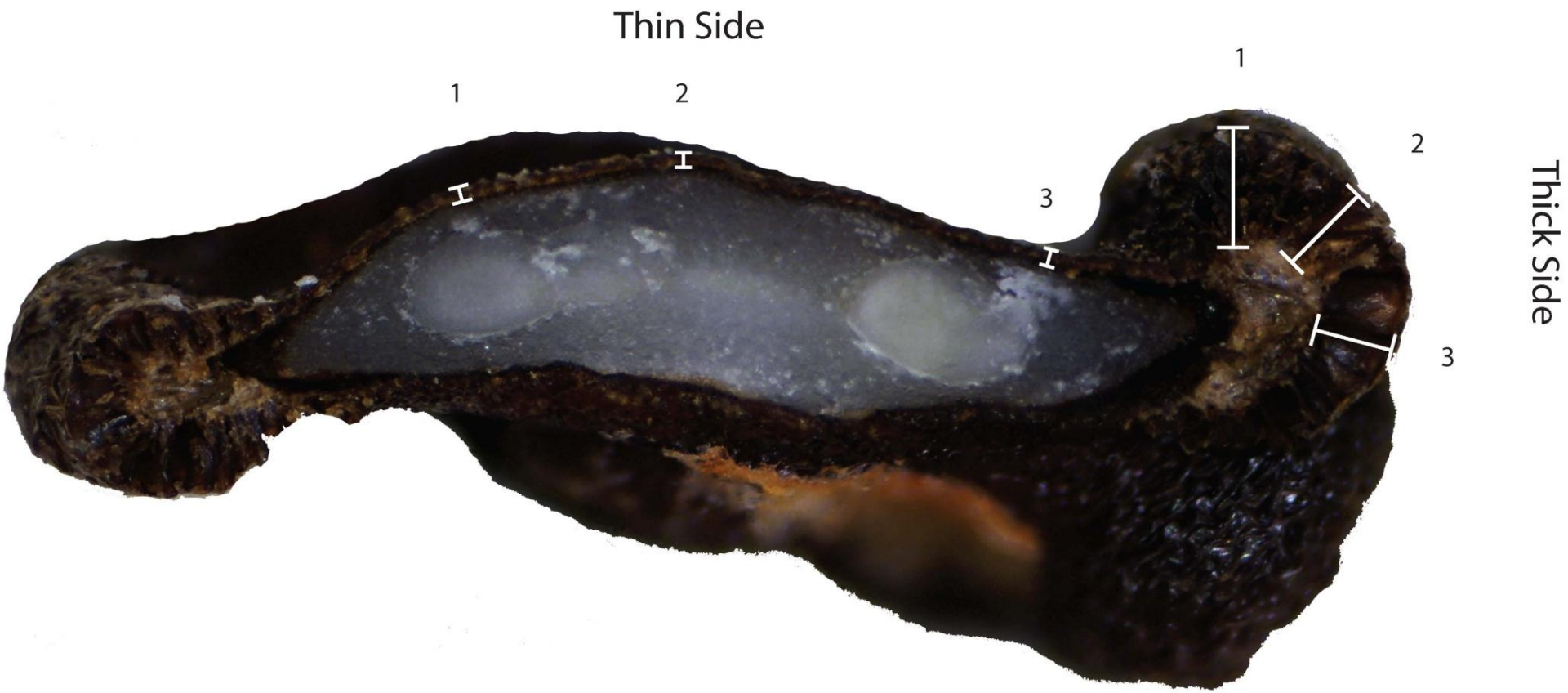
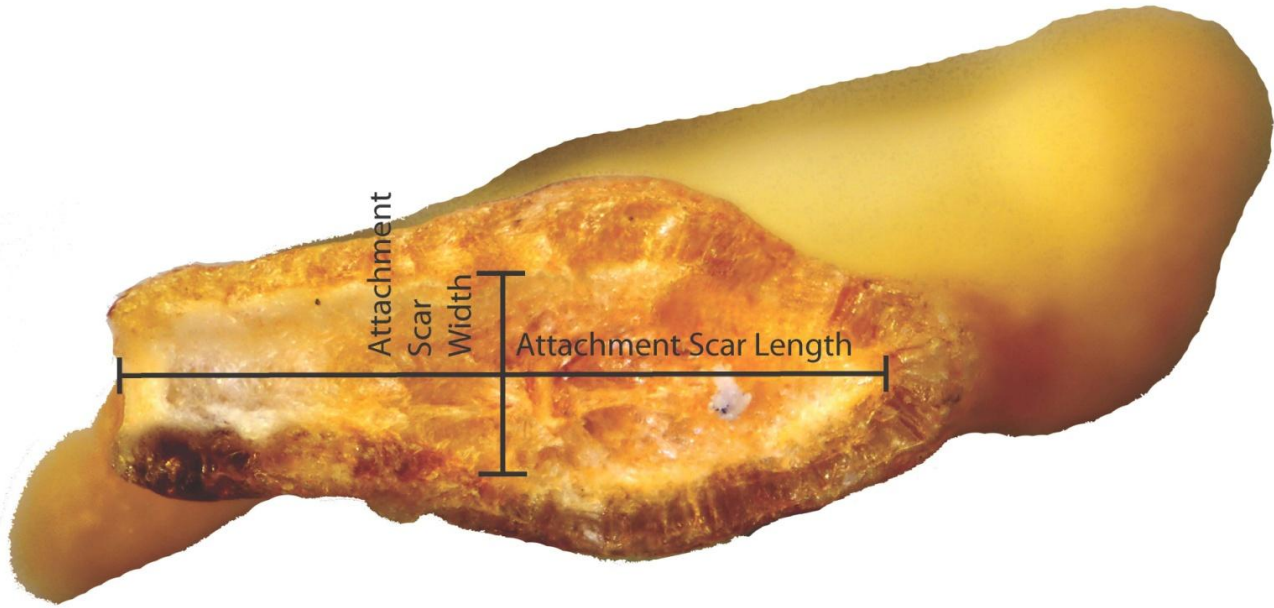


Figure 10: Transverse Cross-Section Morphometrics

A



B

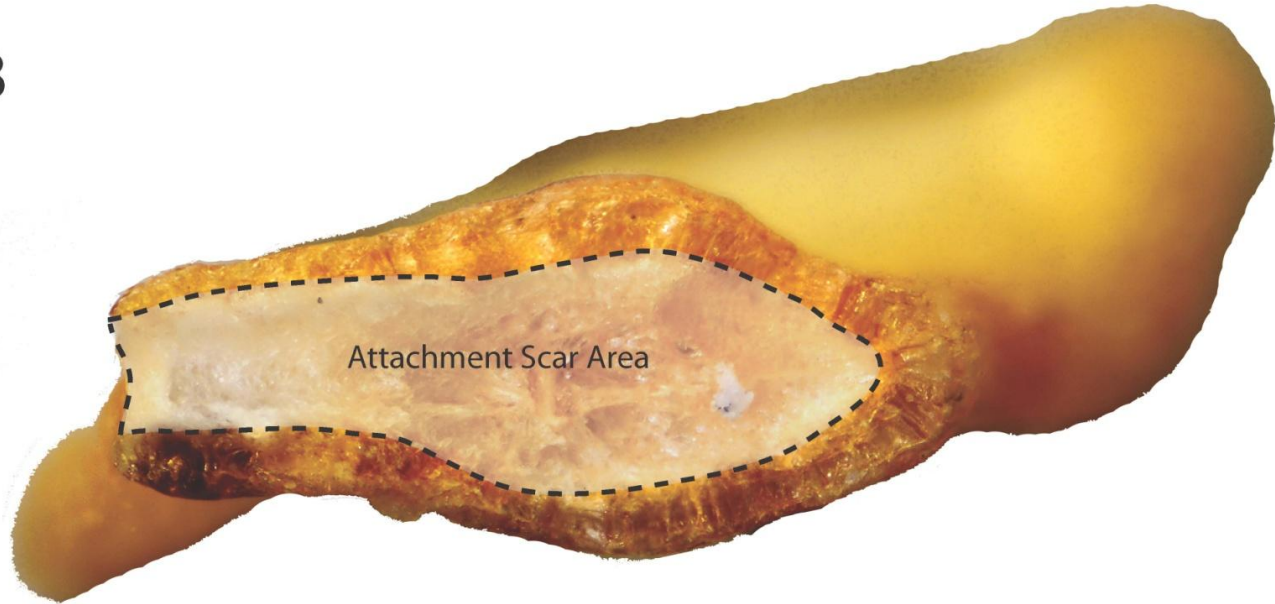


Figure 11: Attachment Scar Morphometrics



Capsicum annuum
Del Arbol 1
Attachment Scar Sphericity: .10



Capsicum baccatum
Aji Panca B 1
Attachment Scar Sphericity: .03



Capsicum chinense
Limo Blanco 1
Attachment Scar Sphericity: .3



Capsicum frutescens
Tabasco 1
Attachment Scar Sphericity: .05



Capsicum pubescens
Orange Manzano 2
Attachment Scar Sphericity: .06

Figure 12: Comparison of Attachment Scar Sphericity

13 presents drawings of the margins of the seeds in the transverse cross-section. While *C. annuum* appears to have thin margins all-around its cross section, *C. pubescens* has the greatest ratio of thick to thin testa. Using these major attributes, we have created a general guide to species-level *Capsicum* identification that is analogous in function to a dichotomous key. The same eight attributes were used for the archaeological seeds, which will be discussed later in this report.

SUMMARY OF MODERN *CAPSICUM* SEED IDENTIFICATION

A basic how-to guide is presented in Figure 14 that utilizes the most diagnostic traits of *Capsicum* seeds (both quantitative and qualitative) and is meant to facilitate identification. We've expressly left out seed sphericity and ML:PW because they are not useful unless used as part of a complex when doing statistical analyses. Based on our work, the following descriptive summaries of the unique characteristics of each *Capsicum* taxon that correspond to Figure 14 are presented below:

Capsicum annuum

C. annuum seeds tend to be more reniform or kidney-shaped with a small protruding beak that extends approximately 50-65° from the seed body. Out of all the *Capsicum* domesticates, *C. annuum* has the smallest thick testa to thin testa ratio, meaning that the margins of the seed are much closer in size to the dorsal and ventral sides of the seed testa. *C. annuum*, like *C. chinense* and *C. frutescens*, also exhibits a very smooth testa texture, with little to no reticulation.

Capsicum baccatum

C. baccatum seeds are oval in shape with a prominent, elongated beak. The attachment scar is most often linear in shape, with a sphericity value averaging .01. While the testa texture of *C. baccatum* is reticulated, the reticulation occurs in a much tighter pattern than in *C. pubescens*.

Capsicum chinense

C. chinense is generally circular in shape with a "fish mouth" attachment opening that comprises the beak protruding at a wide angle and a small "lip" beneath it. The beak is generally prominent (medium) and the attachment scar shape is also more circular, hence the great attachment scar sphericity (with an average value of .12). *C. chinense* exhibits a smooth surface texture with little hint of reticulation at the epidermal level.

Capsicum frutescens

C. frutescens is "teardrop" shaped with a protruding beak that forms the tip of this particular shape. Its beak is relatively prominent (medium) and it is distinguished by the high beak angle (>67°). Its testa texture is generally smooth, much like *C. chinense* and *C. pubescens*.

Capsicum pubescens

C. pubescens is easily distinguished in modern seeds by its black seed color while the others are yellow or tan. Its shape generally resembles that of an oval or the letter "D". *C. pubescens* seeds are also characterized by very thick margins and generally the greatest thick testa to thin testa ratio. The surface of *C. pubescens* seeds is also highly reticulated, with particularly dramatic reticulation around the seed margin. Furthermore, *C. pubescens* displays little to no beak protrusion.

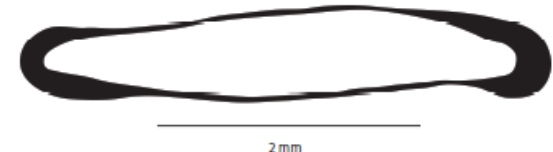
Inspired by Glynis Jones' work with using discriminant analysis to parse out different crop processing activities, we conducted discriminant analysis on the modern *Capsicum* seed data set using our six diagnostic, quantitative attributes (1987). In Figure 15, it is immediately apparent that *C. baccatum* and *C. pubescens* separate out completely. The other three species are also somewhat separate with a little overlap; this is not surprising considering the fact that *C. chinense*, *C. annuum*, and *C. frutescens* are more closely related (Esbaugh 1983). Thus, from our study of the five modern domestic *Capsicum* taxa, we believe that the six attributes that we identify are sufficient to identify both modern and archaeological *Capsicum* seeds. We now turn to the sample of Preceramic *Capsicum* seeds to



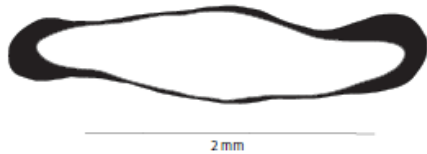
Capsicum annuum
(Kori Sitakame #1)
Ratio (thick:thin): 3.44



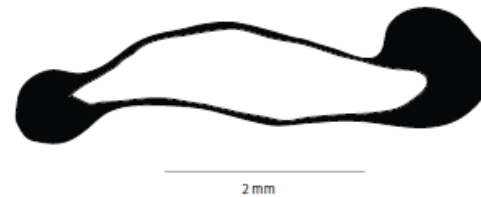
Capsicum baccatum
(Aji amarillo pepper #1)
Ratio (thick:thin): 4.89



Capsicum chinense
(Limo Blanco #1)
Ratio (thick:thin): 3.78



Capsicum frutescens
(Aji Chuncho #1)
Ratio (thick:thin): 4.75



Capsicum pubescens
(Red Rocoto #1)
Ratio (thick:thin): 5.92

Figure 13: Comparison of the Transverse Cross-Sections/Seed Margins

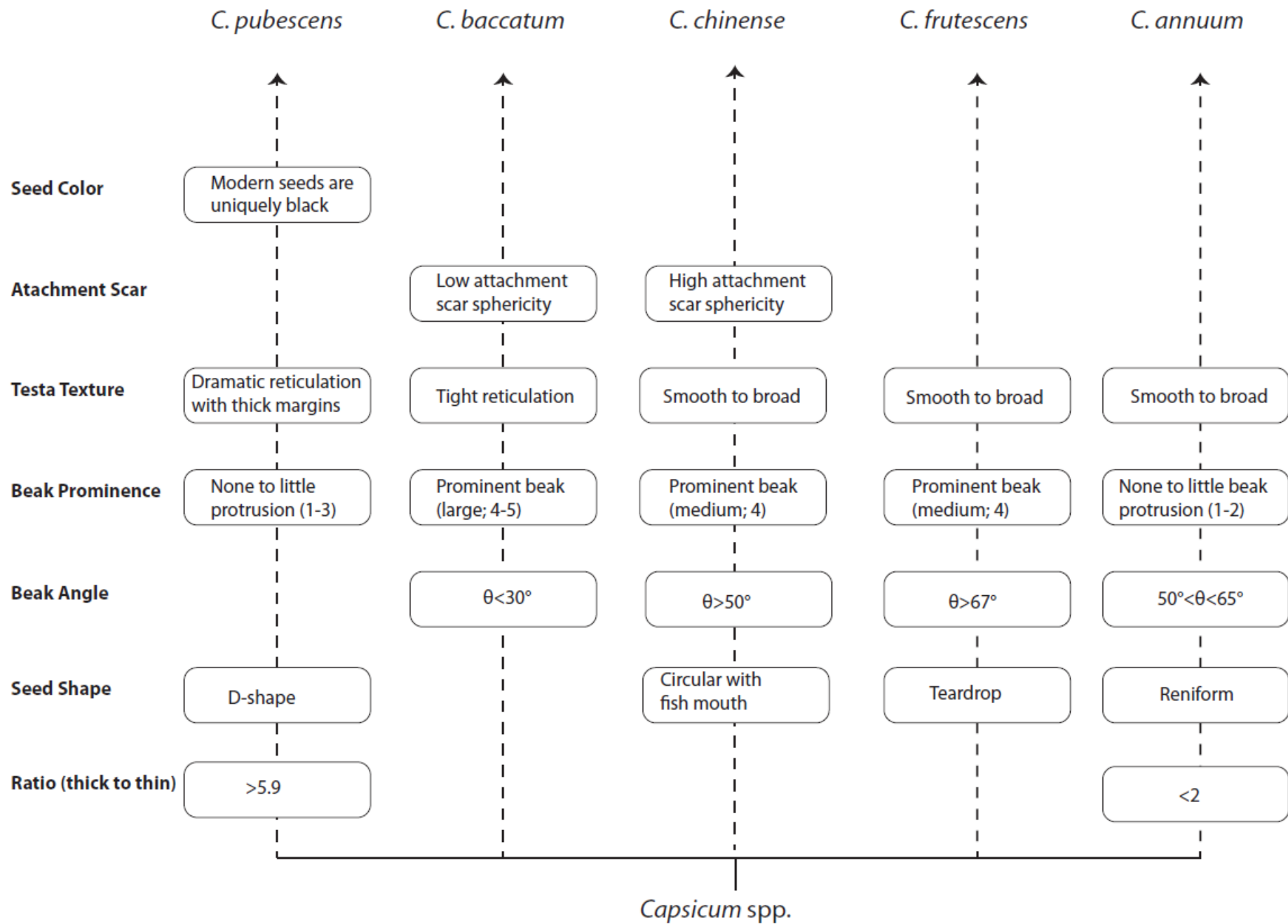


Figure 14: Guide to Capsicum Identification

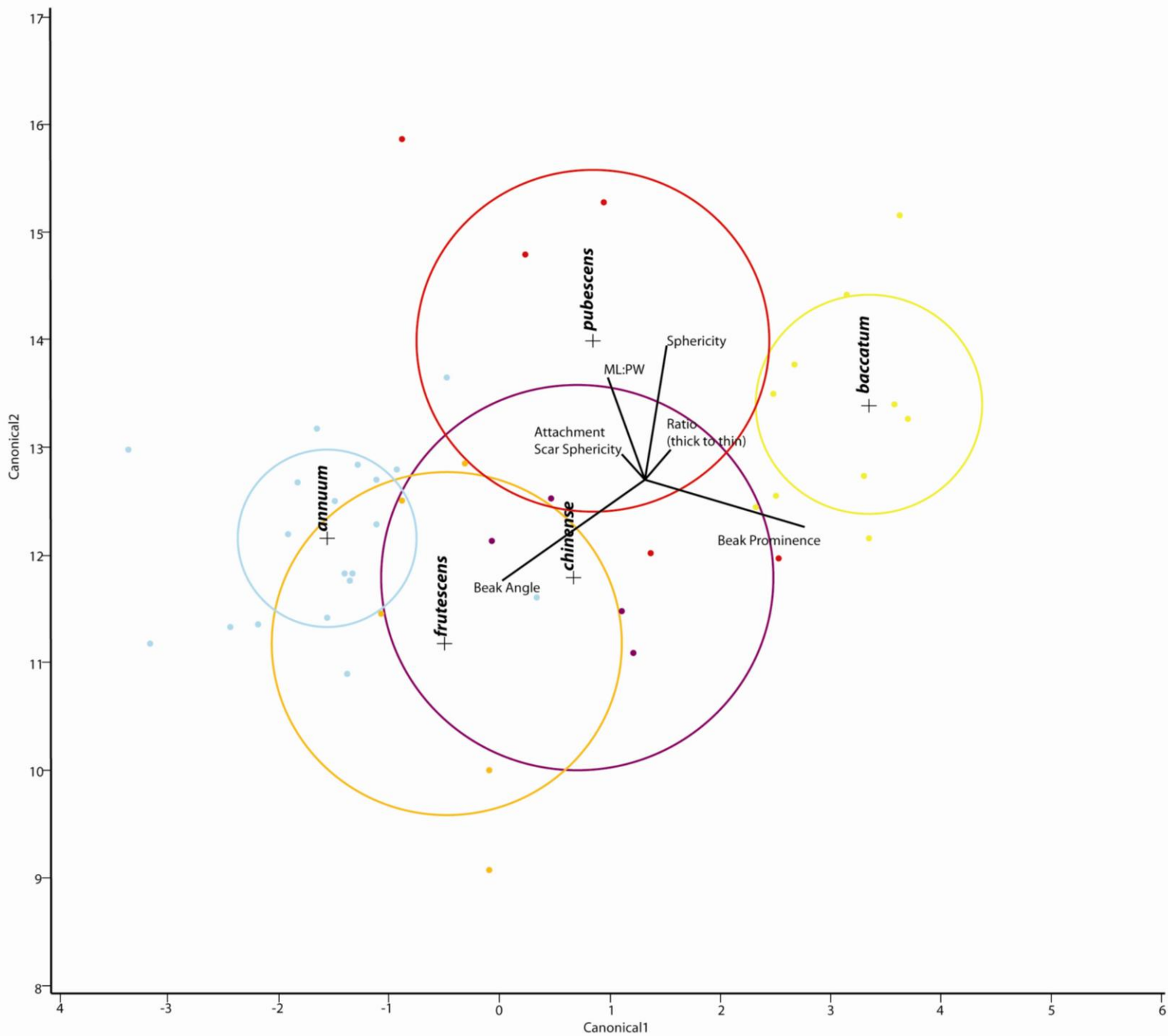


Figure 15: Discriminant Analysis of Modern Seeds

identify their species from the recent archaeological excavations.

THE ARCHAEOLOGICAL *CAPSICUM* SEEDS FROM HUACA PRIETA AND PAREDONES

With these criteria in hand, we turn now to the 64 archaeological *Capsicum* seeds recovered and analyzed from phases 2, 4 and 5 at Huaca Prieta and Paredones (8900-3500 BP). We subjected the archaeological seeds to the exact same treatment as the modern seeds, recording the values or observations for each of our individual attributes.

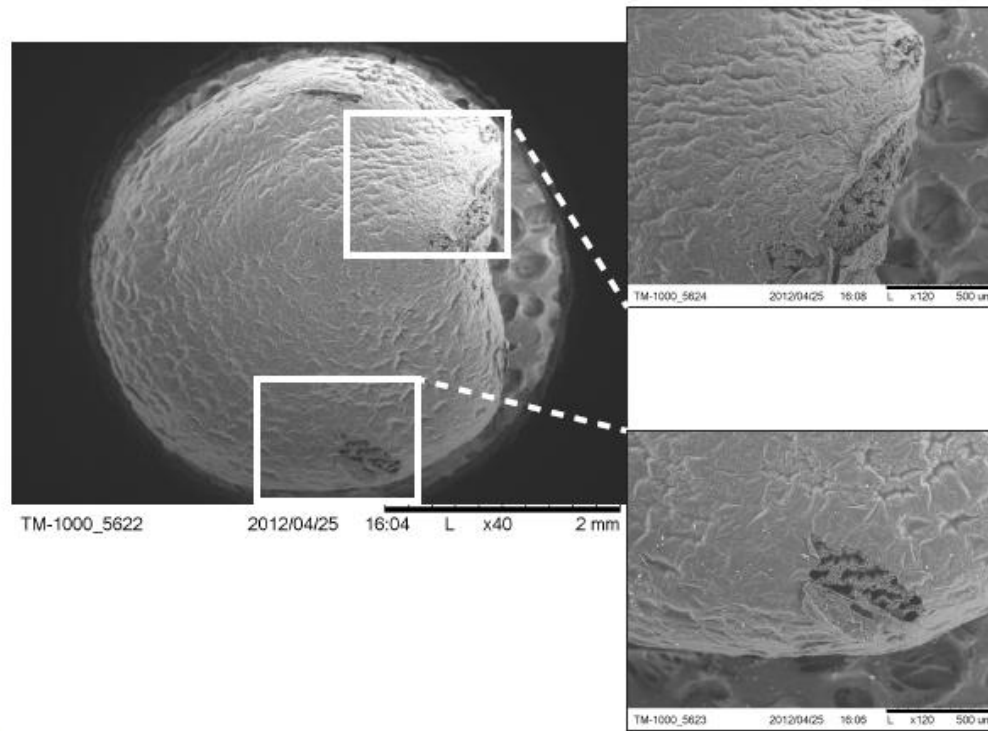
In our study of the archaeological seeds, we recorded data for all attributes, noting in particular the eight diagnostic attributes we focus on for identification. Based on our analysis and previous experience with the modern seeds, we preliminarily identified each seed to a particular species (leaving question marks when in doubt), and immediately began noticing temporal patterns suggesting change in species/varieties through time. While archaeological seeds are not always in as good shape as modern ones, the ones we sampled from the population we received were sufficiently well-preserved to allow us make all the measurements we were interested in. There were, however, a few taphonomic variables that we encountered that hindered some of our qualitative assessments. One, for example, is the effect of seed browning. As mentioned above, seeds of *C. pubescens* can be readily distinguished by their dark brown to black color. Unfortunately, one cannot rely on color when looking at archaeological specimens (or older *Capsicum* seeds), as seed browning can occur rather quickly depending on environmental conditions (Boonsiri et al. 2007, Lee et al. 1991). Furthermore, the testas in the archaeological seeds were not perfectly preserved, with the epidermis often missing which left a distorted view of the seed surface (see Figure 16). Unless there is a way to remove the epidermis of modern seeds to reveal the underlying reticulate structure, it is not possible to compare the testa texture of modern to archaeological seeds without preservation of the entire testa.

Changes in Chile Pepper Preference through Time and Space at Huaca Prieta

As mentioned above, we immediately began noticing differences among various phases from our preliminary analysis of the archaeological seeds. We observed much more variation in the earlier phases (Phase 2 and 4) contrasted with rigid homogeneity in the seeds from Phase 5. In a similar fashion to the modern seeds in Figure 15, we subjected our data (comprising of the measurements from the 6 strongest quantitative attributes) to discriminant analysis. Figure 17 shows the result of this discriminant analysis with the archaeological results overlaying Figure 15. One can see immediately that the three phases contain different *Capsicum* taxa. Phase 2 is most aligned with *C. pubescens* (our highland *Capsicum* or rocoto), while Phase 4 seems to veer towards *C. frutescens*, *C. baccatum*, and *C. chinense*. Phase 5, on the other hand, aligns with *C. baccatum* as predicted. Interestingly enough, the discriminant analysis confirms our initial species-level identifications.

At this point, we would like to delve more into these intriguing patterns regarding temporal and spatial changes at Huaca Prieta and Paredones. As the reader may recall, the map in Figure 3 reveals the provenience of the seed specimens by phase. It is interesting to note that all seeds from Phase 2 were recovered from Paredones which is considered a domestic/habitation area. Table 1 displays the number of seeds we studied from these three temporal phases.

Many of the patterns we observed in the data provide much food for thought. We would like to emphasize, for example, that based on our analyses, *C. annuum* is completely absent in the archaeological collection, reaffirming our belief that the species domesticated in Mexico should not appear so early on in Peru. In Figure 18, we present a bar chart showing presence of *Capsicum* species at both sites through time (the species-level identification were made by Katherine Chiou after the study of modern *Capsicum*s). The chart reveals that the earlier phase occupations (Phase 2) contained a diversity of species including *C. chinense* (21%),



B. #570.2 (Paredones Phase 2)

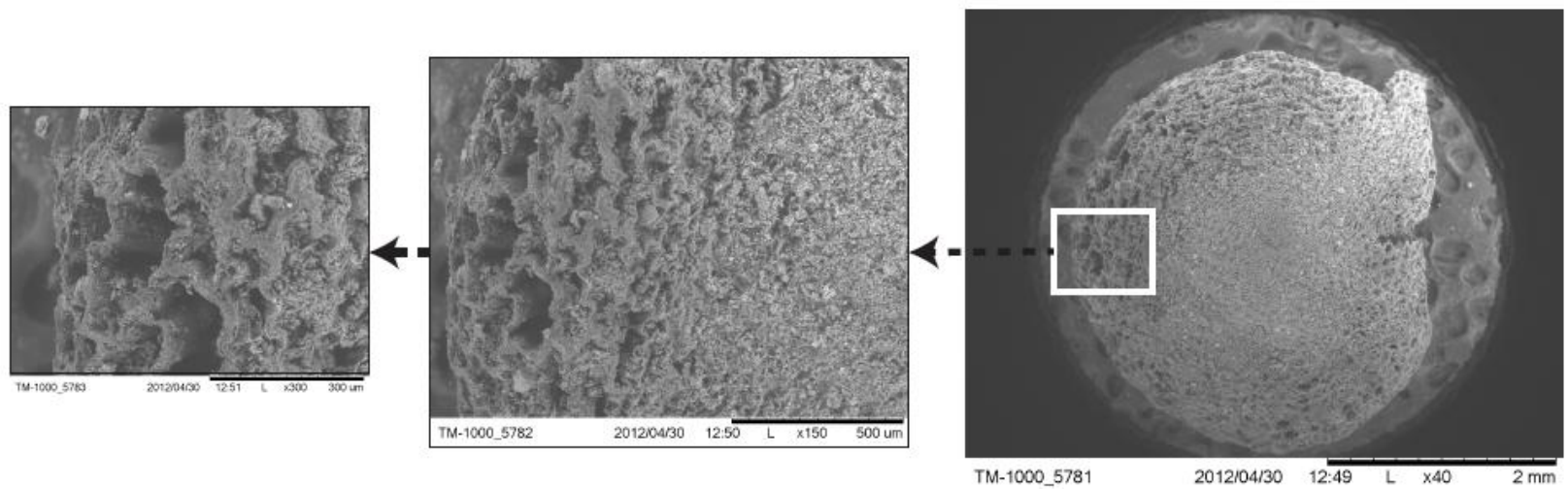


Figure 16: Preservation Issues in the Testa Surface

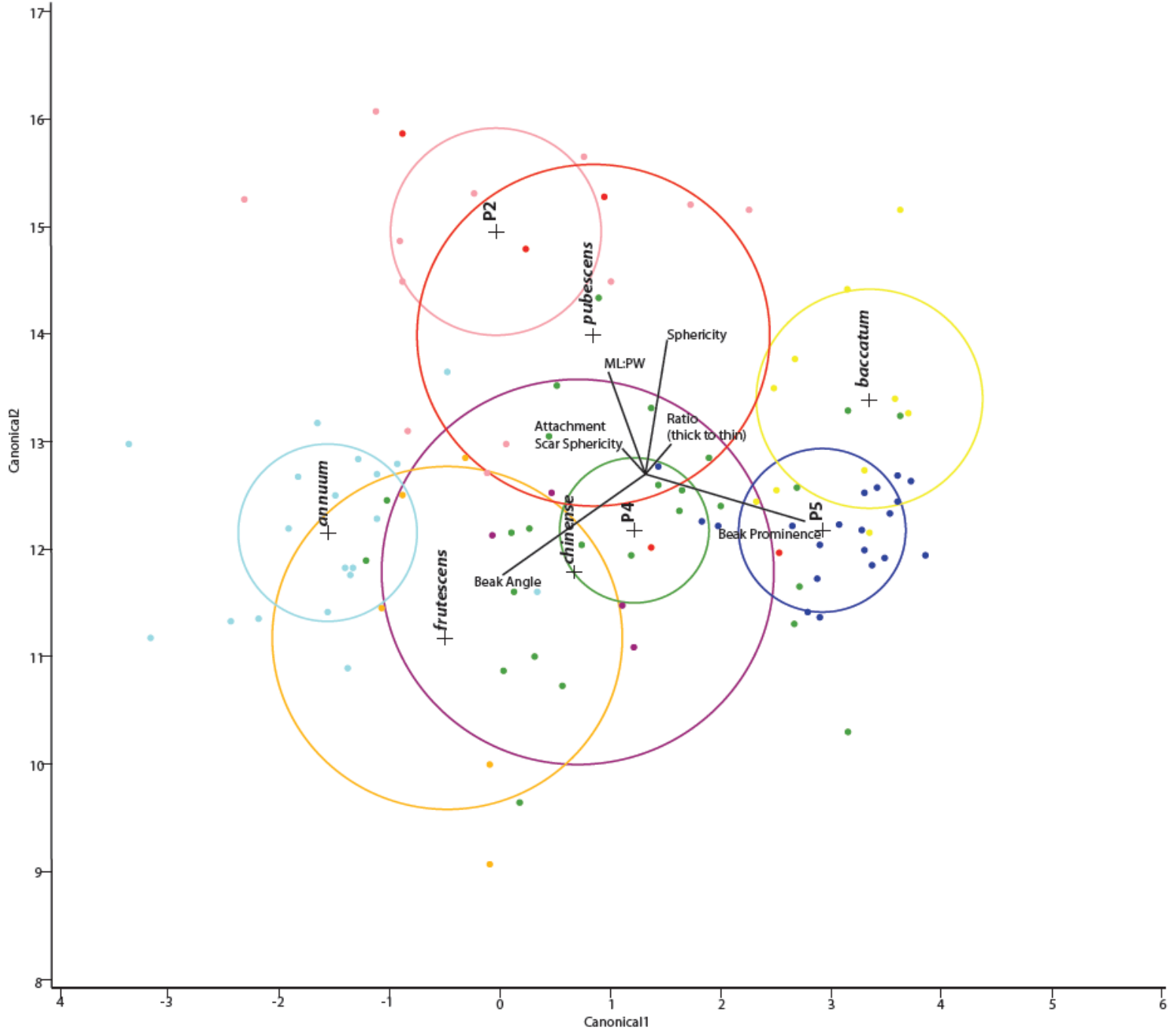
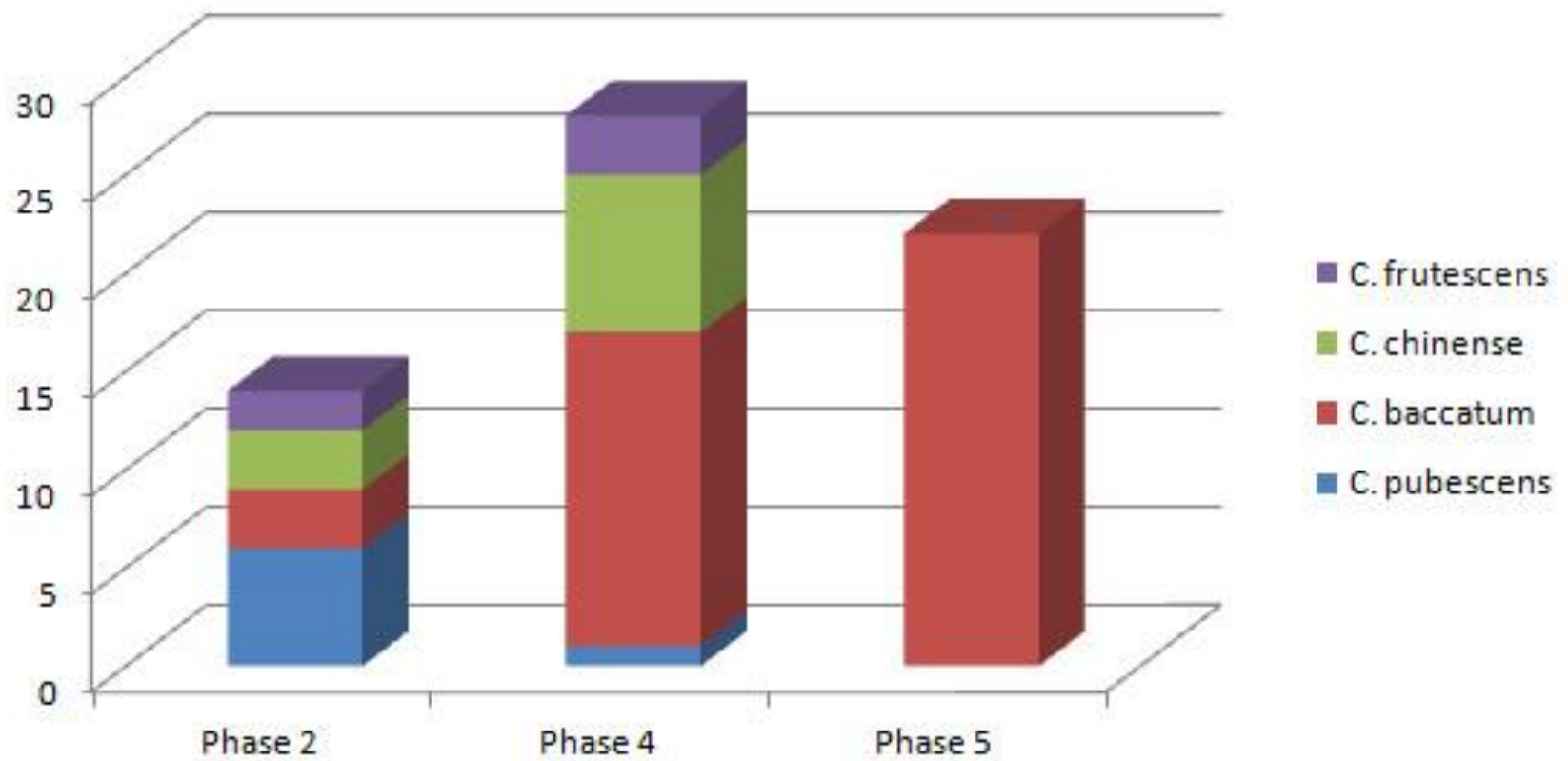


Figure 17: Discriminant Analysis of Modern and Archaeological Seeds



	<i>C. pubescens</i>	<i>C. baccatum</i>	<i>C. chinense</i>	<i>C. frutescens</i>
Phase 2	3	6	3	2
Phase 4	1	16	8	3
Phase 5	0	22	0	0

Figure 18: Presence of Capsicum Species by Phase

C. frutescens (14%), *C. baccatum* (21%) and *C. pubescens* (43%). These species could have been grown on the coast, but a far likelier scenario is that *C. pubescens* was grown in higher eastern slope elevations as it is today. Phase 4 is dominated by *C. baccatum* (comprising of 57% of seeds we studied) followed by *C. chinense* (29%). Phase 5 is comprised entirely of *C. baccatum*. All of these species, aside from *C. baccatum* are thought to be from the eastern valleys and the highlands, suggesting that the early chile peppers were brought in by trade and movement of people. In Phase 4 (4100-5300 BP), *C. baccatum* becomes far more prevalent (note: this corresponds to Pickersgill's research which identified *C. chinense* and *C. baccatum* at Huaca Prieta during this time). In Figure 19, we separate the data from the two settlements by phase. Here we clearly see differences in access or valuations of these two areas. Paredones contains a lot of diversity, while Huaca Prieta has little and is always dominated by *C. baccatum*. The dominant *C. baccatum* is clearly valued at Huaca Prieta throughout the phases but not so much at Paredones earlier on. By 4500 BP, both sites are completely dominated by *C. baccatum*; in fact, ALL seeds we analyzed from both sites in Phase 5 were identified as *C. baccatum* showing a clear focus on local production of chile peppers by then. For future research, we would love to be able to analyze some Phase 3 seeds to further track these interesting developments.

Based on the contexts from which the seeds were collected, we can see that the *C. baccatum* seeds are closely tied with feasting locales (Figure 20). *C. pubescens* and *C. frutescens* were encountered in domestic contexts whereas *C. baccatum* was found mainly in feasting areas (Dillehay pers. comm.). *C. chinense* is spread throughout, yet seems to be mainly in the civic areas (a.k.a. the context designation "other") of Paredones. With more contextual clarification, the designation of "other" could allow deeper interpretation of the seeds recovered from those proveniences.

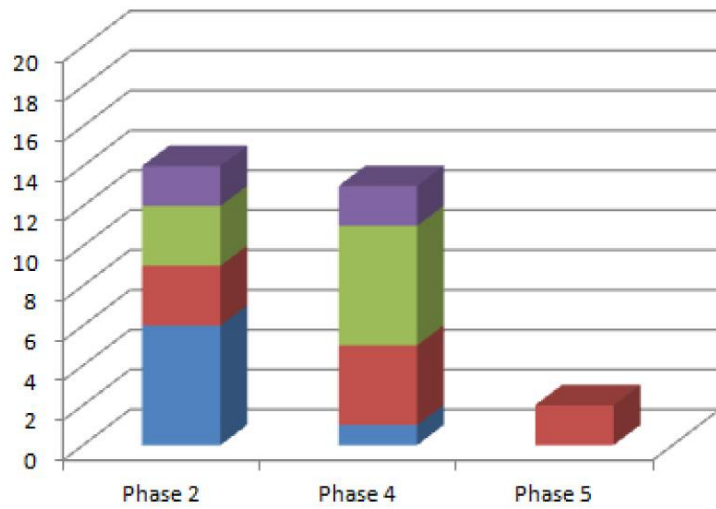
This Chile Pepper is King: C. baccatum as the Haute Chile of its Day

C. baccatum is the species of chile pepper that is thought to have been domesticated along the western coast of Peru. The overwhelming presence of this species suggests that sometime after Phase 2, there was an increased focus on local production and consumption of peppers in this region of the coast, whereas earlier, it is likely that most peppers were traded in to the area (note: it would be interesting to conduct an analysis of strontium isotopes to confirm this hypothesis). In this manner, we are confirming what Barbara Pickersgill observed in the *Capsicum* fruit data; by the Late Preceramic, *C. baccatum* is being consumed at Huaca Prieta. Based on the contexts we were given, it is clear that from Phase 4 onwards, *C. baccatum* is dominant in the feasting contexts, suggesting high valuation as perhaps a luxury or desired good. Indeed, by 4500 BP, *C. baccatum* became the chile *du jour*—by that time, we can say that *C. baccatum* is found in a variety of contexts including feasting/ceremonial locations as well as domestic, residential contexts. Due to the increasingly dominant presence of *C. baccatum*, we decided to investigate whether or not we can chart changes in *C. baccatum* through time. In Figure 21, we plotted *C. baccatum* seed area against time using the two phases of data we have (Phase 4 and 5) with the modern examples of *C. baccatum* (we lacked sufficient numbers of *C. baccatum* in Phase 2 to include it in Figure 21). This figure displays the fairly marked size shift that occurred during this time span in history, suggesting that once people along the coast began to grow their own peppers, one of the traits they were clearly interested in was larger fruits; sure enough, along with larger fruits came larger seeds.

CONCLUSIONS

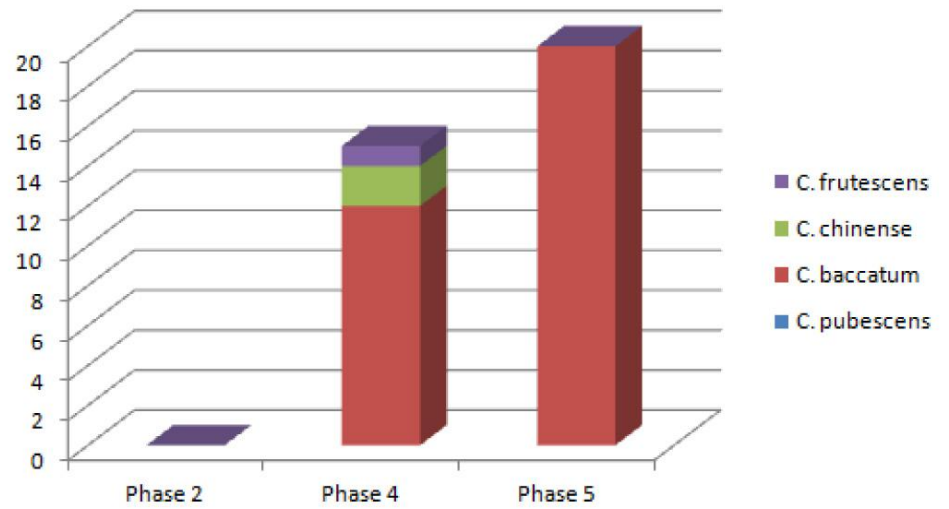
This report on the archaeological *Capsicum* seeds we were sent has led us to develop an identification system for these seeds that we believe is successful for these coastal specimens. The project has allowed us to identify the archaeological specimens as well as show how their source and also production probably shifted through time at these sites. We can identify trends at these sites not only in terms of

Paredones



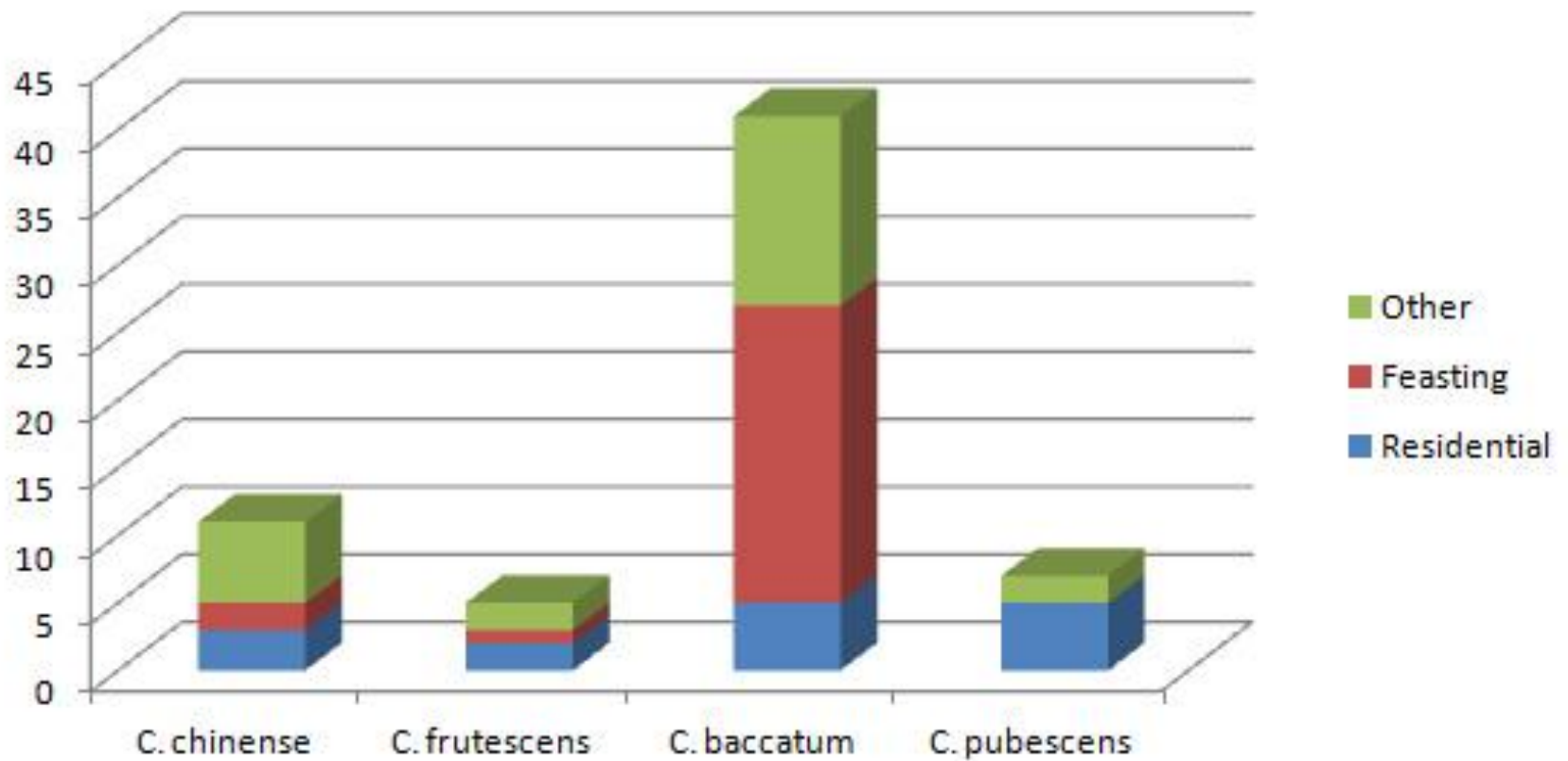
	<i>C. pubescens</i>	<i>C. baccatum</i>	<i>C. chinense</i>	<i>C. frutescens</i>
Phase 2	6	3	3	2
Phase 4	1	4	6	2
Phase 5	0	2	0	0

Huaca Prieta



	<i>C. pubescens</i>	<i>C. baccatum</i>	<i>C. chinense</i>	<i>C. frutescens</i>
Phase 2	0	0	0	1
Phase 4	0	12	2	1
Phase 5	0	20	0	0

Figure 19: Presence of Capsicum Species by Phase and Site



	Residential	Feasting	Other
<i>C. chinense</i>	3	2	6
<i>C. frutescens</i>	2	1	2
<i>C. baccatum</i>	5	22	14
<i>C. pubescens</i>	5	0	2

Figure 20: Presence of Capsicum Species by Context

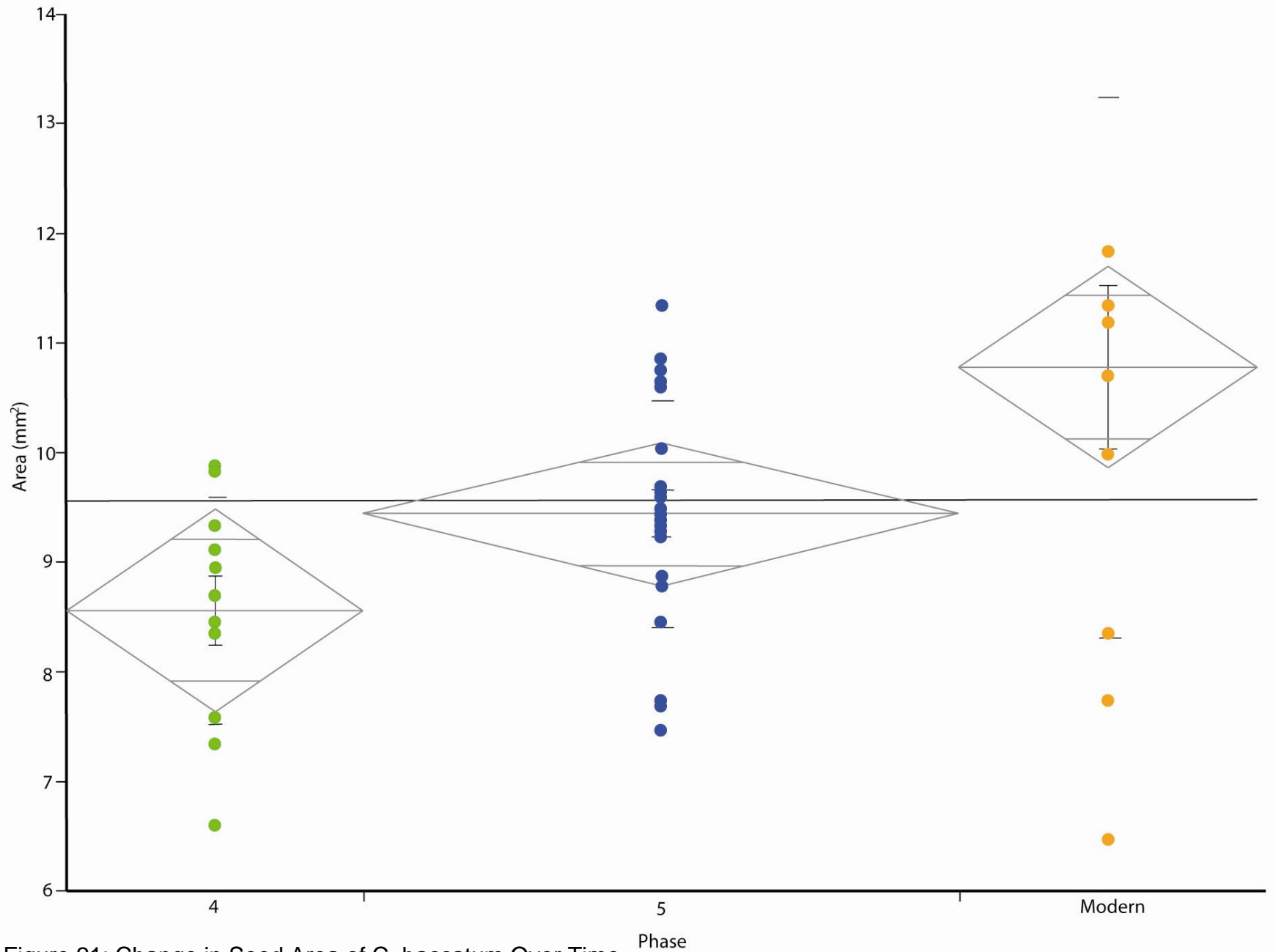


Figure 21: Change in Seed Area of *C. baccatum* Over Time
(Phase 4, Phase 5, Modern)

size selection, but also regarding changes in taste and in particular, the focus on *C. baccatum* as people moved away from consuming other exotic taxa. This increased value of *C. baccatum* is also observed in their depositional locations such as in areas of feasting. The opposite is true for the highland *C. pubescens*, which were most often found in households. In terms of future research, it would be of value to have more specific contextual information and greater temporal spread to solidify and confirm some of the exciting trends we see in the chile pepper data.

ACKNOWLEDGMENTS

First and foremost, we would like to wholeheartedly thank Professor Tom Dillehay for allowing us to work on these wonderful plants and for his support for the project. We would also like to thank Victor Vásquez for his work on the identification of *Capsicum* seeds in the Huaca Prieta and Paredones samples. In terms of the SEM work, we would like to acknowledge Dr. Guanwei Min's training and advice concerning SEM imaging of the *Capsicum* seeds. Special thanks to the USDA Germplasm Resources Information Network (USDA-GRIN) and especially Dr. Mark Bohning, Dr. Bob Jarret, and Tiffany Fields for helping us find rarer specimens of *Capsicum*. We would also like to thank our chile pepper seed vendors, and in particular Beth Boyd from Bayou Traders for working with us to obtain various *Capsicum* species. Last, but certainly not least, we would like to thank our peers in the McCown Archaeobotany Laboratory, especially Alan Farahani, Rob Cuthrell, and Theresa Molino for offering advice and critical insight into our project.

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Appendix 1: Seed Sources

Native Seeds SEARCH
3061 N. Campbell Ave.
Tucson, AZ 85719
(520) 622-5591
info@nativeseeds.org
<http://www.nativeseeds.org>

Amazonas Imports
10848 Cantara St.
Sun Valley, CA 91352
(818) 982-1377
<http://www.amazonasimports.com>

Refining Fire Chiles
13409 Bubbling Lane
Lakeside, CA 92040
(619) 504-9777
rfire@cox.net
<http://www.refiningfirechiles.com>

Reimer Seeds
PO Box 206
Saint Leonard, MD 20685-0206
mail@reimerseeds.com
<http://www.reimerseeds.com>

National Plant Germplasm System (USDA)
10300 Baltimore Blvd.
Rm. 102, Bldg. 003, BARC-WEST
Beltsville, MD 20705
<http://www.ars-grin.gov/npgs>

Trade Winds Fruit
P.O. Box 9396
Santa Rosa, CA 95405
service@tradewindsfruit.com
<http://www.tradewindsfruit.com>

Andean Seed Collection
McCown Archaeobotany Laboratory
Department of Anthropology
University of California, Berkeley
65 Kroeber Hall
Berkeley, CA 94720
hastorf@berkeley.edu
<http://archaeobotany.berkeley.edu/>

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pepperlover.com@hotmail.com
<http://pepperlover.com>

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Bayou Traders Peppermania
P. O. Box 2528
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