Shedding Light on the Nightshades (Solanaceae) Used by the Ancient Maya: a Review of Existing Data, and New Archeobotanical (Macro- and Microbotanical) Evidence from Archeological Sites in Guatemala

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Numerous taxa within the Solanaceae family are economically important today, and for New World taxa such as chilies and tomatoes, their histories are particularly well documented. What remains less clear, however, is the extent of nightshade used by the ancient Maya. This article reviews the ethnographic, ethnohistoric, and archeological evidence of some of the major taxa in this large family, as well as providing new archeobotanical evidence in the form of macro- and microbotanical remains from Maya sites in northwestern Petén, Guatemala. This new evidence sheds additional light on the Solanaceae used by the ancient Maya in both domestic and ritual contexts. The absence of certain taxa in this family in the archeobotanical record of this region does not necessarily imply that these were not used in the past. Instead, it indicates that systematic collection of samples needs to be implemented if archeologists are to fully characterize past plant use among the ancient Maya.

Key Words: Solanaceae, Maya archeobotany, Starch grain analysis, *Capsicum*, *Solanum*, *Physalis*, *Nicotiana*.

Introduction

The nightshade family (SOLANACEAE Juss.) is extremely well studied, not only because it includes numerous major crop species that are historically and economically valuable, but also as it is used to create biological model systems to study the development of fruits, pigments, and plant defense mechanisms (Mueller et al. 2005; Särkinen et al. 2013). In addition, this family produces a number of toxic alkaloids (Nee 1986). While important advancements regarding the early evolution of the Solanaceae family have been recently made (Wilf et al. 2017), there is much we still do not know about this family, namely their role and relative importance to the ancient Maya, a civilization that spanned present-day southern Mexico, Guatemala, Belize, and portions of Honduras and El Salvador between ca. 2000 B.C. and A.D. 900 (Fig. 1). This article provides a review of the current state of knowledge regarding this particular plant family, as well as providing new archeobotanical data on four different genera in the nightshade family recovered from Maya sites in northwestern Petén, Guatemala.

The Solanaceae Family

The Solanaceae family is "the third most important plant taxon economically, the most valuable in terms of vegetable crops, and the most variable of crop species in terms of agricultural utility" (Mueller et al. 2005:1310). Thus, it makes sense that this family is of high interest to the scientific community and to breeders alike. The Solanaceae are an extremely ecologically and morphologically diverse family that is composed of between 3000 and 4000 species, with approximately 90 genera (PBI *Solanum* Project 2017). The family is made up of a high number of economically important plants such as tomatoes (*Solanum lycopersicum* L.), potatoes (*S. tuberosum* L.), tobacco (*Nicotiana tabacum* L.), and chili

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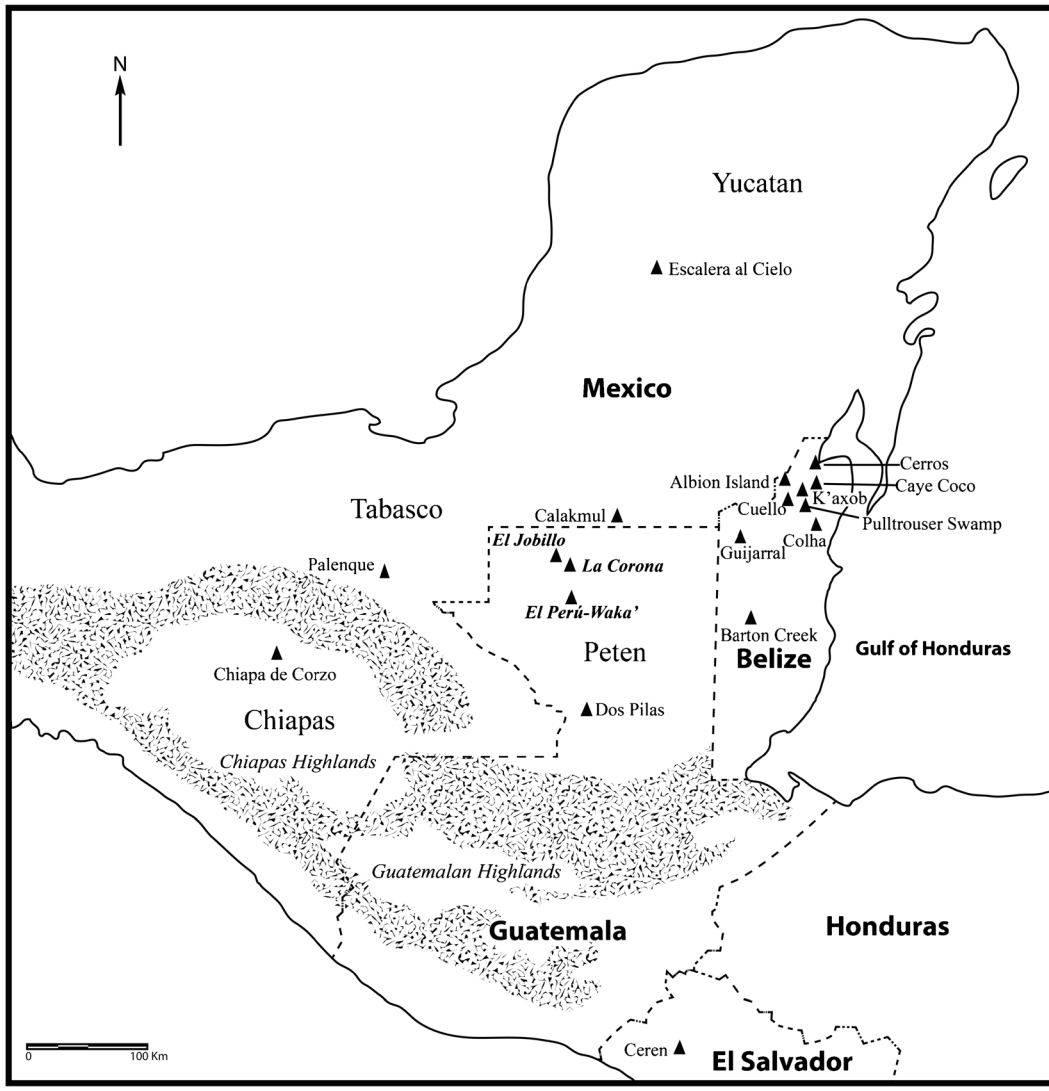

Fig. 1. Map of study area with archeological sites and regions mentioned in the text (figure elaborated by J.C. Melendez).

peppers (*Capsicum* spp.) to mention but a few. Many of these New World species have transformed cuisines in the Old World (Kiple 2007), to the extent that some "are loath to accept that chilli peppers are a phenomenon of less than a 450 year history" (Eshbaugh 2012). Solanaceae plants are distributed across both the Old and New World, but are most common and diverse in South America, with Central America and Mexico as secondary centers of diversity (PBI *Solanum* Project 2017). The genus *Solanum* is very large and makes up about half of the family (Nee 1986).

Solanaceae Utilization in the Maya Region Today

Ethnobotanical studies have revealed that contemporary Maya populations use numerous species within the Solanaceae family for a variety of applications, from culinary to medicinal ones (Cook 2016; Lentz and Dickau 2005). Yet, how different or similar was ancient Maya use of Solanaceous species? Regretfully, the iconographic record can only take us so far. While flowers and plants are commonly depicted on Maya vessels and other

paraphernalia (see Houston and Taube 2000), besides depictions of cigars that may or may not actually contain tobacco (a point which I return to later), there are currently no concretely demonstrable depictions of other Solanaceae plants available. Epigraphic information is available but is limited to mentions of tobacco (Loughmiller-Cardinal and Zagorevski 2016; Martin 2012), and possibly chili peppers (Stuart 2016). The ethnohistorical record does help somewhat, but its limitations need to be considered. Thus, one of the best resources at hand is the archeological record, and even so, we are limited by several factors. The more important one is the general lack of systematic recovery of flotation samples in the Maya area, especially from investigations in the past decades. Secondly, issues regarding preservation of organic remains in neotropical conditions need to be considered (Lentz 1999). Finally, the ways in which plants are processed will affect the recovery rates of archeobotanical remains. Yet, by combining different lines of evidence, which include the study of macro- and microbotanical remains, as well as organic residues, archeologists are slowly piecing together ancient Maya plant use. Although the focus of this article is the Maya, other study areas in Mexico and Central America are also considered to provide additional lines of reference.

First, let us consider the modern uses of nightshades in local cuisine. While non-native ingredients are also currently used in the preparation of foods, here we focus on native Solanaceae plants that may have been available to the ancient Maya. In contemporary local Guatemalan and Mexican cuisines, tomatoes, tomatillos (*Physalis* sp.), and chilies are commonly used and can be easily found in markets. Often, different varieties are available, in particular with regard to chili peppers. In Guatemala, traditional Maya dishes today include pepián (spiced meat stew) (Fig. 2), suban-ik (pork and hen stew), kak-ik (turkey stew), and jocón (green chicken stew). These dishes, in addition to some non-indigenous ingredients, are all prepared using tomatoes and tomatillos as well as a variety of chilies to give a distinct flavor and a range of spiciness to the food. In Mexico, these ingredients are often used to make sauces, jams, and the popular salsa known as *pico de gallo*. *Physalis* fruits are also used to prepare *recados*, *chirmoles*, and *guisados* (Villar Anleu 2008). These can also be boiled after husking the fruits, seasoned with salt and chili, and their pulp added to greens or meat (Breedlove and Laughlin 1993:217). The northern Lacandon Maya consume tomatoes as well as *Physalis* fruits, both raw and cooked (Cook 2016). The southern Lacandon are reported as eating "*tomatitos silvestres*" (wild tomatoes) that are only consumed cooked (Baer and Merrifield 1972:164, 207). Chilies are ubiquitous in foods: in fact, observations of Chorti Maya daily life led Wisdom (1940) to state that at least half the foods consumed contained this particular condiment (see also Atran et al. 2004; Cook 2016).

Fig. 2. Pepián as prepared and served in La Antigua, Guatemala (photo C. Cagnato).

Chilies are not only prized for its fruits, but the young shoots and leaves can also be consumed as potherbs once boiled (Gentry and Standley 1974).

Members of this family also play an important role in present-day rituals, performed by Highland and Lowland Maya communities. In the Maya Lowlands, rituals in which feasting is an extremely important part of the ceremony, and often include large numbers of participants, are carried out. One ritual in particular, which takes place in Yucatan (Mexico), is the *Ch'a chaak* rain ceremony, which consists of cooking ritual maize breads wrapped in leaves and placing them in a *piib* (underground oven). The preparation of stews and other ritual foods can last days. In this ceremony, tomatoes are used to prepare tamales (maize dough breads steamed in leaves and filled with a variety of meats and/or other plants) because they contain water, and thus are seen as being able to call the rains (Flores and Balam 1997; Salazar et al. 2012). A variety of chilies are also used, this time as condiments: *C. annuum* L. and *C. chinense* Jacq. (now identified as *Capsicum annuum* L. var. *annuum*) are used to flavor the food, while *C. frutescens* L. (now identified as *Capsicum annuum*) flavor the *atole*, which is a ground maize gruel (Flores and Balam 1997; Salazar et al. 2012). It should be noted that in ancient times, *C. annuum* and *C. pubescens* were likely the only species available to the ancient Maya (Powis et al. 2013).

In the Highlands of Guatemala, the Maya perform rituals in which ancestors are fed through the burning of offerings, which range from food, plants, non-organic materials, and animal blood. In some rituals, boundaries of the circular hearth are clearly defined, followed by placing wood on the bottom level, with offerings in the form of food, plants, flowers, and animal blood placed on top of each other to burn (Brown 2004). Solanaceous plants like chili and tobacco (*Nicotiana* sp.) are burned in these offerings, with the former noted as being associated with *ceremonias negras*, which aim to get rid of negative influences and illnesses (Brown 2004). Moreover, both tobacco and chilies are included in Brown's *mal entierro* (evil burial) category. Chili peppers also play a role in Maya "coming of age" ceremonies; according to Faust (1998), they have a sexual connotation.

Tobacco is also a very important plant for the Maya today. For the contemporary Tzotzil and Tzeltal Maya of the Chiapas Highlands, "native tobacco is regarded as a prototypical medicine or "powerful substance" *(poxil)*, offering a range of therapeutic and protective benefits" (Groark 2010:14). Tobacco snuff is prepared after a series of steps that involve selecting the plant, deveining, pounding, and finally adding admixtures, principally lime (Groark 2017), although chilies can also be used (Robicsek 1978:21). For medicinal purposes, tobacco leaves are boiled and also mashed, then combined with other plants, including leaves from *Brugmansia* (Groark 2017), another genus in the Solanaceae family. Tobacco snuff also features during rituals and fiestas, whereby its smoke feeds the deities, who in turn protect the community (Groark 2017). The Lacandon Maya use tobacco extensively in their rituals, as well as for medicinal purposes (Cook 2016; Robicsek 1978). Wisdom (1940:51) notes that the Chorti Maya chewed tobacco almost exclusively for medicinal purposes.

The Maya produce some of their food in homegardens and agricultural fields, known locally as *milpas*, which are typically intercropped fields of maize, beans, and other plants such as chilies and tomatoes (Atran 1993; Ford and Nigh 2009). Although they may be planted separately from other crops in the *milpa*, chilies are more often than not planted in conjunction with other crops such as gourds and goosefoot (Atran 1993). In the Maya Lowlands, chilies are commonly planted (Atran et al. 2004; Baer and Merrifield 1972). Chilies are also planted in homegardens, a practice followed by the Kekchi Maya of Guatemala (Lentz 1999). Chilies are also used medicinally and are a good source of vitamins (Alcorn 1984; Cichewicz and Thorpe 1996; Roys 1931).

Homegardens also include various weedy species of the genus *Solanum*, such as *S. americanum* Mill., *S. nigrum* L., and *S. torvum* Sw. (Kellman and Adams 1970; Neulinger et al. 2013), with the leaves of *S. nigrum* and *S. americanum* eaten by certain Maya (Atran et al. 2004; Neulinger et al. 2013; Villar Anleu 2008). *S. americanum*, known as *hierba mora* or *macúy* in Guatemala, is one of the most common potherbs and found at most markets (Gentry and Standley 1974). It should be noted that *S. nigrum* is not native to Central America (Edmonds 1979). Species of *Solanum* are also used medicinally, including *S. umbellatum* Mill., *S. mammosum* L., and *S. torvum* (Atran et al. 2004; Balick et al. 2000; Cook 2016). Notably, Q'echi Maya women use the leaves of *S. americanum* to treat anemia and other women's issues, among many other medicinal applications (Balick et al. 2000; Michel et al. 2007). In

Tabasco, Mexico, *Solanum* species in general are considered *mal monte* (weedy) and noxious by farmers, as they are poisonous to humans and animals, with only *S. nigrum* kept as it is considered edible (Chacon and Gliessman 1982). In the Petén Itza region of Guatemala, the Maya plant tobacco and tomatoes, as well as the non-native potato. Tobacco is mentioned as being planted in its own separate portion of the *milpa* or in the orchards, while tomatoes are more often planted in conjunction with other crops, such as the chilies (Atran 1993:644, 679). The Lacandon Maya plant tomatoes in their *milpas* along with maize, beans, and squash (McGee 1990). Fedick et al. (2008) report that northern Lowland Maya grow tomatoes in limestone bedrock cavities. In the Chiapas Highlands, tobacco plants grow wild in homegardens, or are transplanted to homegardens from disturbed areas where the wild plants can be found growing freely (Groark 2010, 2017). The Chorti Maya usually planted tobacco in special plots or even in canoes or *ollas* and were later transplanted to the fields (Wisdom 1940). The Lacandon Maya also grow tobacco extensively (Robicsek 2004), and it is said that these plants are useful for fighting weeds that grow in the *milpa* (Cook 2016). Tobacco leaves, once collected, are wrapped in banana leaves and hung from rafters inside the Lacandon house (Boremanse 1998:35 citing Maler 1901:27–28).

Ground cherry species (*Physalis* spp.) are noted as growing in disturbed areas, as well as being planted in *milpas* (Breedlove and Laughlin 1993), with *P. angulata* L. being consumed for its fruits (Balick et al. 2000), to which Duke (2009:537) notes that green (unripe) fruits are toxic, while the ripe ones are edible. The medicinal applications of species within *Physalis* are extensive, notably for *P. angulata* and *P. pubescens* L. (Balick et al. 2000; Duke 2009). Other species in the nightshade family such as *Jaltomata procumbens* (Cav.) J.L. Gentry are consumed for their leaves, which are eaten as a potherb as well as for their fruits that are sometimes eaten fresh (Lentz and Dickau 2005). Further afield in the Valley of Toluca, Mexico, *Jaltomata procumbens* and *Solanum stoloniferum* Schltdl. & Bouché are gathered from maize fields as forage for domestic animals and contribute to the income of the farmers (Vieyra-Odilon and Vibrans 2001). Some other nightshades, which also grow weedy in maize fields, are used for their medicinal applications, such as *Datura stramonium* L. (Vieyra-Odilon and Vibrans 2001); more specifically in Guatemala, their dried leaves have been reportedly smoked to help relieve asthma (Gentry and Standley 1974:42).

Ethnohistorical and Ethnographic Data

One of the issues with ethnohistorical sources is how accurately scholars can determine the botanical species described by these early writers. Thus, although such sources are indeed valuable, in some cases, these should be treated with some caution. Early written sources that deal with the Maya region are limited, and thus, those from early Spanish colonists in Mexico have also been included.

Bishop Diego de Landa mentions in his book that smoking occurred during certain Maya rites, and this was translated by Tozzer (1941:106) as referring to tobacco. But, as cogently noted by Robicsek (1978:12), it is possible that Landa was referring to the smoke produced by censers, and not necessarily that of tobacco. There is also some confusion regarding another source, Spanish chronicler Juan de Villagutierre de Soto-Mayor, who writes about the possible use of cigars by the Lacandones (Robicsek 1978). Other sources are probably more accurate, at least according to Robicsek (1978, 2004). These include the Descripción de San Bartolomé which mentions chewing tobacco, and another Spanish manuscript dating to 1696 that describes a feast of the cigars among the Lacandon Maya of Cholti. Finally, Landa (Tozzer 1941:106) describes an event whereby Lacandones made cigars from their first tobacco of the year; these were subsequently lit and offered together with the braziers. Further north, Bernal Diaz del Castillo describes a feast held by Moctezuma II, ruler of the Aztec Empire, where it is said that he inhaled smoke from tubes that contained herbs they called tobacco (Robicsek 1978). Other sources also mention tobacco use by the Aztecs. For example, the translators of the Florentine Codex, originally written by Sahagun (1963), identified *picietl* as tobacco, which was used medicinally: after pounding the leaves and adding lime, it could be rubbed on body but also chewed. Tobacco is also mentioned as having medicinal properties in other ethnohistorical documents (see Robicsek 1978:39–43).

Chili peppers were identified as *pimiento* or black pepper in Spanish, when first encountered by Columbus (Kiple 2007:118) and appear as such in later works. Landa (Tozzer 1941:90–91) wrote that in the morning, the Maya would take their drink, presumably made of ground maize, warm, with ground chili pepper. Another drink known as

pinole, which is made from parched maize, ground, and water, was mixed with chili or cacao. Avendano y Loyola, a Spaniard present during the Conquests of the Petén Itza, wrote that the local Itza Maya sowed chili peppers two or three times a year along with other crops (Atran 1993).

Tomatoes and husk tomatoes (tomatillos) have seemingly not been described in ethnohistorical documents written on the Maya; thus, we have to consider other sources. Making the task harder, colonial period writers did not distinguish between the tomato and the husk tomato, although they seem to have thought that the latter was more popular in Mexico (Kiple 2007:118). It is not clear whether tomatoes or husk tomatoes were in fact listed on a tribute list to the governor of Coyoacán in 1550, but it is certain he received either one of them in large quantities, given that one list mentions he received 700 of them a week (Coe 1994:48). Sahagun (1963) may also have mentioned the genus *Physalis*, identified as *coztomatl* (possibly *P. costomatl* Moc. by Anderson and Dibble), which produced sweet and edible fruits, and when cooked, the fruits would become yellow. He also notes that these plants grew all over, in gardens, plains, and mountains.

Another genus that is missing from colonial period sources on the Maya is that of *Datura*. Sahagun (1963) may have mentioned this plant, which he calls *tlapatl*, and noted that it was used medicinally, for example for treating gout.

Archeobotanical Data

Finally, I consider the archeobotanical data recovered thus far from the Maya region. It should be noted that only carbonized macroremains are considered here, as uncarbonized remains are unlikely to be ancient (see Morehart 2011). In some cases, seeds have been identified only to the family-level, as was the case from material from excavations at K'axob and Guijarral in Belize (Dedrick 2014; Goldstein and Hageman 2010), as well as data recovered from La Corona, which is discussed in the following section.

Tobacco has been identified both in Maya epigraphy and in the form of organic residues inside a ceramic vessel, but iconographically, this is a different story. On a well-preserved mural at the site of Calakmul, a glyph reads "tobacco person" (Martin 2012). At Palenque, a carving on a doorjamb shows a deity smoking a cigar (Robicsek 2004:33). Ceramic vessels also provide some information: on a vessel from Burial 196 at Tikal, a person seemingly smokes a cigar (K2698), while numerous other painted polychrome vessels show individuals smoking (e.g., vessels K1728, K1272, and K3264; MayaVase Database n.d.; see also Coe and Kerr 1982). While there is no doubt over the validity that cigars and the act of smoking are represented on various ancient Maya media, what remains a mystery is what was *actually* smoked. Robicsek (1978:111) writes, "The only thing we know for certain is that the Mayas smoked something. This something was most likely tobacco, a conclusion based on archaeological material found at Classic and post-Classic sites, stone monuments, ceramic artifacts, and codices". Flasks that are believed to have held tobacco have also been recovered featuring "codex-style scenes and inscriptions, and some display tobacco leaf or deity motifs" (Groark 2010:13). More recently, nicotine alkaloids were recovered inside an eighth century codex-style flask, proving that tobacco was indeed used by the ancient Maya (Zagorevski and Loughmiller-Newman 2012). Tobacco seeds have been harder to come by in the archeological record, probably due to their very small size. An exception is the site of K'axob where one carbonized seed was recovered from inside a hearth (Dedrick 2014). Although there is currently no formal proof, scholars have hypothesized that enemas, which are often depicted on ancient Maya ceramic vases (Stross and Kerr 1990), may have contained tobacco (De Smet 1985), while others have proposed they contained alcoholic beverages (Miller and Taube 2015:85).

Chili peppers have been recovered from a range of sites and also in multiple forms, ranging from seeds at Barton Creek, Cerros, Cuello (one seed was possibly from a wild variety due to its small size), and Ceren (Cliff and Crane 1989; Lentz et al. 1996; Miksicek et al. 1991; Morehart 2011), peduncles at Dos Pilas and Ceren (Cavallaro 2013; Lentz et al. 1996), calyxes at Barton Creek and Ceren (Lentz et al. 1996; Morehart 2011), starch grains at Escalera al Cielo and Caye Coco (Rosenswig et al. 2014; Simms 2014), wood charcoal at Cuello (Miksicek et al. 1991), but also in residue form at the Preclassic site of Chiapa de Corzo, situated in southern Mexico (Powis et al. 2013). While Chiapa de Corzo is not a Maya site per se, it confirms the presence of chili peppers in the immediate region. The site of Ceren in El Salvador has yielded thus far the most abundant assemblage as diverse parts of the

chili pepper plant are represented. The excellent preservation and in situ recovery allowed finding chili pepper seeds inside ceramic vessels that may have been placed there for storage, while it was also argued that chilies were likely hung in clusters from rafters to store or dry (Lentz et al. 1996). Finally, pollen grains of this genus are reported from Colha in northern Belize (Jones 1994).

Seeds of the genus *Solanum* have been reported from Cuello (Miksicek et al. 1991), K'axob (Dedrick 2014), Ceren (Slotten 2015), as well as two Preclassic (2000 B.C.-A.D. 250) sites in Belize, Pulltrouser Swamp and Albion Island (Lentz 1999). Wood charcoal of this genus has also been reported from Cuello (Miksicek et al. 1991). One possible seed in the *Physalis* genus has been reported from K'axob (Dedrick 2014), and wood charcoal of *Dunalia arborescens* (accepted name, *Acnistus arborescens* (L.) Schltdl.) was also recovered from Ceren (Slotten 2015).

New Archeobotanical Data from Maya Sites in Northwestern Petén, Guatemala

In this section, I discuss the recovery of Solanaceae seeds and starch grains; new evidence recovered from three sites in northwestern Petén, Guatemala, within the Laguna del Tigre National Park, a protected reserve that is part of the larger Maya Biosphere developed by the Guatemalan government. The larger two sites, La Corona and El Perú-*Waka'*, are located about 40 km apart and are both along routes that are believed to have been important for the movement of trade goods that connected diverse resource-rich areas (Canuto and Barrientos 2009; Freidel and Escobedo 2006). The third site, El Jobillo, is a smaller site approximately 2.5 km northwest of La Corona (see Fig. 1). These remains were obtained from flotation samples, as well as from starch grain analysis performed on a variety of artifacts: *manos* and *metates* (grinding stones) as well as ceramic sherds. The methods used to recover these data are presented elsewhere in detail (Cagnato 2016, 2017) and will therefore not be repeated here.

The Solanaceae evidence from a sealed feasting deposit at La Corona has been treated elsewhere (Cagnato 2018) and therefore will be briefly covered here. The feasting remains, dated to the eighth century A.D., were placed inside a *chultun* (a human-made underground pit). Flotation samples contained a total of 17 seeds belonging to the Solanaceae family with at least two genera identified, namely *Physalis* and *Solanum*. The *Physalis* seeds resemble the seeds of *P. philadelphica* Lam., while one *Solanum* seed is similar to those produced by *S. americanum* (Fig. 3a), a black nightshade. Four pairs of seeds were not identified beyond the family level as they were stuck together and poorly preserved (Fig. 3b), yet retained their diagnostic seed coat and shape, which was enough to determine that they were likely *Solanum* seeds. In another *chultun*, also located at La Corona, and associated with a residential group, another *Solanum* (cf. *torvum*) seed was recovered. The *chultun* was likely used as a midden and contained other plant remains along with ceramics (Cagnato 2017).

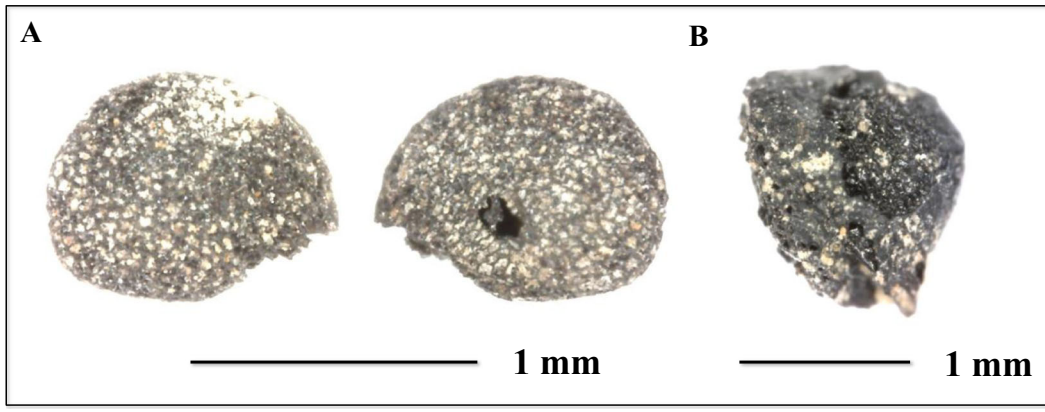

Fig. 3. **a** Probable *Solanum americanum* seed (dorsal and ventral views) recovered from feasting remains deposited inside a *chultun* at La Corona. **b** Solanaceae seeds stuck together recovered from the same context (Photos C. Cagnato).

In addition to the data listed above, chili pepper starch grains have been recovered from a range of artifacts from La Corona (Cagnato 2016). A late eighth century (Late Classic) assemblage was composed of two grinding stones, excavated by Perla Barrera (2013). These were recovered from a feasting deposit associated with an elite structure 13R-7 situated at the core of the site. This deposit yielded more than 630 sherds, obsidian, shell fragments, including some that were worked, and figurine fragments (Perla Barrera 2013). On one of the grinding stones, two chili pepper starch grains were recovered, measuring 23.4 × 21.1 µm (µm) and 20 × 18 µm. The second grinding stone had a large cluster of approximately 11 starch grains (similar to those shown in Fig. 4); the grains from the latter measured on average 27.2 by 23.4 µm. In addition, seven artifacts, consisting of grinding stones but also of ceramic sherds belonging to jars, were recovered from ninth century (Terminal Classic) contexts (Fernández Aguilar 2011; Ponce 2013), and tested for the presence of starch grains. The artifacts were associated with the final occupation of Structure 13R-10, also situated at the core of the site (see Cagnato 2016). All these artifacts had evidence that chili peppers had been processed on them or had contained them (in the case of the jars). In addition to the presence of single grains, one particular grinding stone tool had a large cluster of chili pepper starch grains (Fig. 4). The starch grains from the Terminal Classic on average measure 25.2 µm wide (smallest = 15; largest = 35). Starch grains of domesticated chili peppers have diagnostic features, which are outlined by Perry et al. (2007) and include the grains being circular in outline, between 13 and 45 µm, and with a central depression when viewed in flat view. Viewed from the side, they have a diagnostic linear figure that may or may not extend the entire length, seen very clearly on this particular grain recovered on one of the tools from La Corona (Fig. 5). Wild chilies produce smaller starch grains that are under 13 µm long (Perry et al. 2007).

At El Jobillo, 11 starch grains were also recovered from three *metates* fragments found inside a *chultun*, which was likely used a midden during the final occupation of the site. However, while the radiocarbon dates obtained from the wood charcoal recovered inside the *chultun* clearly postdate the Classic period occupation, the ceramics span the Early to Terminal Classic (Cagnato 2017). One artifact in particular was especially rich in grains compared to the other fragments, as seven of the 11 grains recovered in total were found on this one fragment. The grain length ranges between 17 and 37 µm (average = 26 µm), and some exhibit damage like fissures and breaks, that are likely the result of grinding (Fig. 6). The date of this particular deposit remains unclear as the ceramics were dated to different time periods (Cagnato 2017), but nonetheless, the evidence suggests that occupants at the site of El Jobillo utilized chili peppers.

At the archeological site of El Peru-*Waka*' macrobotanical evidence of Solanaceae seeds in the form of *Solanum* (Fig. 7), *Physalis*, and one possible chili pepper were recovered from a unique context, a monumental fire shrine (Cagnato 2016; et al., forthcoming). One possible tobacco seed fragment, poorly-preserved, has also been identified from funerary contexts associated with Burial 61, where Lady K'abel, queen of *Waka'*, was buried in the Late Classic period (Navarro-Farr et al. 2013). Finally, three grinding stones recovered from various

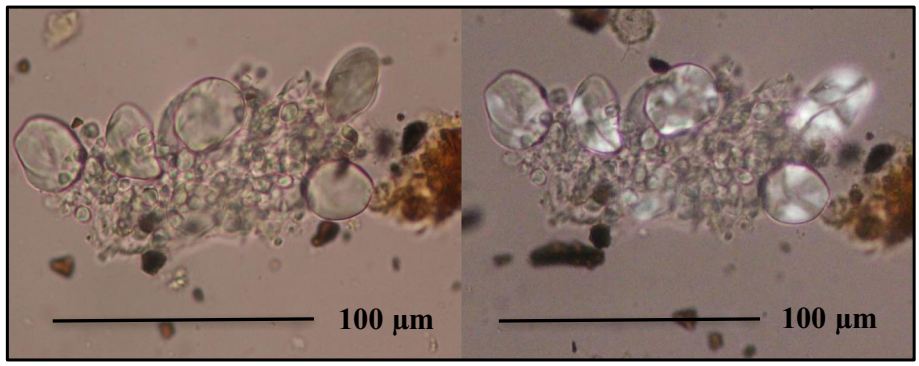

Fig. 4. Chili starch grain mass viewed under transmitted light (left) and cross-polarized light (right). Grains recovered from a *mano* fragment associated with a storage area in Structure 13R-10 at La Corona (Photos C. Cagnato).

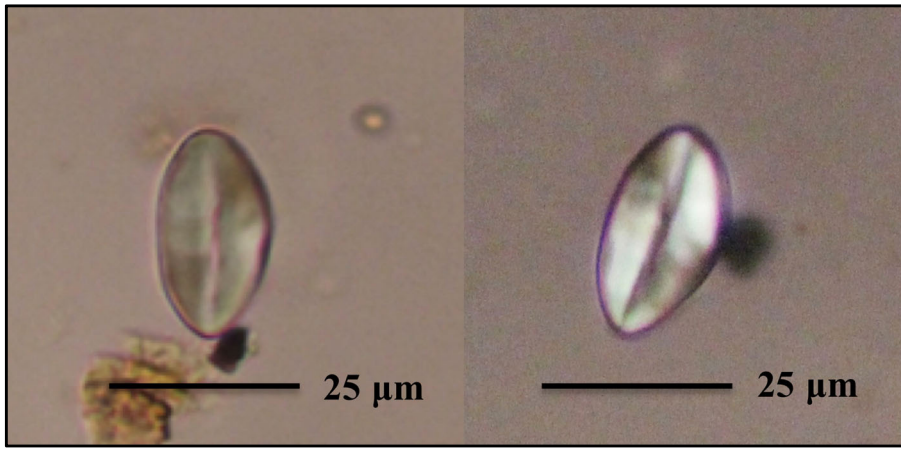

Fig. 5. Chili pepper starch grain viewed from the side under transmitted light (left) and under cross-polarized light (right). Grain recovered from a *mano* fragment associated with a storage area in Structure 13R-10 at La Corona (Photos C. Cagnato).

dense dedicatory, termination, and other kinds of ritual deposits around Structure M13–1, which were created after the end of the royal period in the ninth century (Navarro-Farr and Arroyave Prera 2014), had starch grains belonging to chili peppers. One of the *metate* fragments was found in an excavation unit situated southwest of the *adosada* (frontal platform) of Structure M13–1, where Terminal Classic sherds and obsidian were also recovered (Navarro-Farr et al. 2013). In addition, two *manos* were recovered from excavations along the southern wall of the *adosada*, where over 2000 Terminal Classic sherds were recovered among other artifacts (Navarro-Farr et al. 2013). The starch grains recovered from the above-mentioned artifacts measured between 18 and 24 µm in length.

Discussion

When we consider both the time depth of Maya culture and its extent across a vast geographical area, it becomes clear that relatively little evidence concerning the ancient use of Solanaceae plants has been unearthed thus far. While this paucity could be interpreted as a sign of the unimportance

Fig. 6. Damaged chili pepper starch grain, demonstrated by fissure (arrow on left photo) and distorted extinction cross shown by arrows on right photo. Grains recovered from a *metate* fragment discovered inside a *chultun* at El Jobillo (Photos C. Cagnato).

Fig. 7. *Solanum* seed (ventral and dorsal views) recovered from fire shrine on Structure M13-1 at El Peru-*Waka'*.

of taxa within the nightshade family, we must keep in mind that past archeological projects seldom implemented systematic flotation or carried out protocols to recover microbotanical remains. Yet, when flotation has been implemented or residues collected from artifacts, Solanaceaeous seeds and starch grains, in particular those belonging to chili peppers, have been reported.

In the absence of macrobotanical remains, the recovery of starch grains and other microremains have greatly enhanced our understanding of past plant use. While not all taxa and plant parts will produce diagnostic starch grains, numerous taxa in the nightshade family produce morphologically distinct grains, including *Lycianthes*, *Solanum*, *Physalis*, and *Jaltomata* (Perry et al. 2007:SI). When we consider the manner in which chili peppers are prepared, namely grinding the seeds and fruits, the probability of actually recovering the seeds is rather low (Morehart 2011). The identification and ubiquity of chili pepper starch grains have thus served to increase our knowledge regarding the relative importance of this particular plant. Today, chili peppers are extremely important and are used at almost every meal, and it could be argued that this was also the case in the past, as evidenced from the high ubiquity at which remains of chili peppers in macro- and microbotanical form are recovered. Ubiquity measures the frequency of a particular taxon, rather than its abundance (VanDerwarker 2006:72), and this was calculated by counting the number of artifacts on which starch grains are recovered and divided by the number of total artifacts studied. In addition, the recovery of chili pepper starch grains from ceramic sherds from La Corona and from residues from artifacts at Chiapa de Corzo indicates that chili peppers may have been also important for spicing and flavoring *atolli* and other beverages made from cacao, for example (Coe 1994; Lentz et al. 2014). Although it is not possible to determine with certainty whether the Maya at La Corona were using *C. annuum* or *C. annuum* var. *annuum*, the size of the starch grains recovered suggests that they were utilizing domesticated chili peppers.

The low recovery rates of tobacco seeds can be understood on the one hand by the very small size of the seeds, and on the other by the fact that the seeds themselves are unlikely to be carbonized as tobacco smoking implies the use of the leaves. However, the presence of even a couple of seeds in the archeobotanical record indicates that the collection of flotation samples should be an essential part of any archeological project. In the absence of larger quantities of tobacco seeds from the archeobotanical record, combined with the fact that these do not produce diagnostic starch grains (as observed on crushed *N. rustica* seeds) nor are typically processed in ways that would allow the recovery of microremains even if these were present, the strongest form of evidence currently comes from organic residues, such as those discovered by Zagorevski and Loughmiller-Newman (2012). Testing additional artifacts to discover whether certain vessels or containers, believed to have held tobacco snuff, will be important to determine this with certainty. In addition, tools perhaps used to mash the leaves and used for processing the tobacco into snuff may

eventually provide some additional lines of data if and when they are tested. While there is no doubt that the ancient Maya utilized tobacco, the numerous depictions of what look like cigars, which have been argued to contain tobacco, may have been prepared using a variety of ingredients. As is the case of contemporary Maya people who combine admixtures to their snuff (Groark 2017), it is possible that other plants or herbs may have been smoked in the past (see Robicsek 2004, footnote 4), or that hallucinogenic additives such as excretions of the *Bufo marinus* toad may have been added (see Martin 2012). Careful microbotanical analyses and residue studies will be important on this particular topic.

The recovery of other genera such as *Solanum*, *Physalis*, and *Acnistus arborescens* across sites in the Maya region suggest that the ancient inhabitants lived in a diverse landscape composed of homegardens and *milpas*, perhaps similar to those that exist today. The manner in which these plants were utilized and in what sphere (domestic, ritual, medicinal) has also to be further considered. The *Solanum* (cf. *americanum*) and *Physalis* (cf. *philadelphica*), recovered at La Corona for example, may have been used to prepare a range of dishes (e.g., tamales, stews) and sauces that would have been served during the feast (Cagnato 2018). The *Solanum* (cf. *torvum*), recovered in another midden context at La Corona, could have been used in a similar manner. *Acnistus arborescens*, only recovered as wood charcoal, produces fruits that can be consumed and made into preserves (Williams 1981). Perhaps the ancient Maya also took advantage of this plant in the same manner, but more specimens are necessary to make any sweeping claims. Beyond their dietary uses, some of these taxa have clear medicinal applications that have already been outlined. The species recovered in the *chultun* for example may have been used to cure or prevent certain ailments, a common practice in Europe for plants that today we consider as spices (Houston et al. 2006 citing Dalby 2000).

We also have some evidence that provides information on the processing of some fruits in the Solanaceae family. In order to determine how seeds changed when exposed to high temperatures, I experimentally carbonized seeds and dried fruits of tomatoes, husk tomatoes/tomatillos, and a black nightshade (*Solanum americanum*). Fresh specimens of the same species were also burned. While the dry seeds did not stick together (even when the entire berry was carbonized), the seeds of the fresh specimens did. Thus, it could be argued that the seeds found in the archeological record may have been burned while fresh. *Comales* (ceramic griddles) have been recovered from various sites in the Maya Lowlands, including at La Corona (Ponce 2013), and it is therefore likely that in some cases, fresh fruits were roasted on the griddle, as is still done today to prepare certain dishes. In addition, the presence of damaged chili pepper starch grains on jar sherds suggests that these were ground up and added to beverages likely made of maize, among other ingredients (see Cagnato 2016).

Finally, the ritual importance of plants within this family is evident. Contemporary data indicate that tobacco plays a central role in ritual events, and this was likely to be true also in the past, exemplified by the recovery of a possible tobacco seed in a royal burial at El Peru-*Waka*', and if the cigars, depicted on elite Maya polychrome vases, indeed contained tobacco. Chili peppers also seem to have played a role in ceremonial acts, but are more frequently associated with domestic activities, at least in the archeobotanical record to date. In the case of the nightshades found inside the fire shrine at El Peru-*Waka'* (*Physalis*, *Solanum*, and cf. *Capsicum*), these were likely used as offerings to feed and appease the gods, and request in turn for the rains to come, a practice that continues to this day, as exemplified by the *Ch'a Chaak* ceremonies in the Lowlands and the rituals performed in the Highlands (Brown 2004; Flores and Balam 1997). The chili pepper seeds and calyx recovered inside Barton Creek have also been interpreted as offerings to the gods by Morehart (2011). The multiple roles held by Solanaceae taxa as food, medicine, and elements of rituals have to be further considered and studied.

The evidence available thus far from sites in northwestern Petén, but also further afield, reveals that the ancient Maya used a relative small number of species within the Solanaceae family compared to those that were available to them. Some species such as those listed by Lentz and Dickau (2005) namely *Datura stramonium*, *Jaltomata procumbens*, *Cyphomandra betacea*, *Lycianthes lenta*, *Solanum lycopersicum* (listed as *Lycopersicon esculentum*, a name no longer valid; Tropicos 2017), and *Solandra grandiflora*, have economic uses today, but have yet to be reported from the archeological record in the Maya region. One reason could be due to the fact that not all these species have a natural distribution in the area, although they are currently present. However, considering that archeologists have just begun to scratch the surface in terms of

systematically collecting macro- and microbotanical samples, it is not surprising that the evidence at hand seems rather poor. In addition, different taxa will preserve differently in the archeological record; some will produce distinct starch grains while others may only show up as organic residues or as wood charcoal. Also, depending on the mesh size that is selected during flotation, only certain seed categories may show up. Finally, there are also difficulties in differentiating between the hundreds of species within this genus when confronted with often poorly preserved or fragmented carbonized seeds. Needless to say, different avenues of data collecting are essential if we are to refine nightshade use, but also plant use in general among the ancient Maya. The absence of certain taxa in the archeobotanical record thus far does not necessarily mean these were not used in the past; in fact, it indicates that archeologists have much more work to do to fully characterize past Maya plant use. Overall, considering the extent of the ecologically diverse environments in which the ancient Maya lived, it is highly likely that Solanaceae use was more varied than what we currently see in the archeobotanical record.

Conclusions

The Solanaceae family is today an economically valuable resource to people around the world. Although some taxa in this large botanical family have been recovered archeologically across select sites in the Maya region, there is much that we still do not know regarding the use of nightshades in the past. What is certain is that chilies seem to have been one of the most ubiquitous plants used in the past, a pattern that continues to this day. Other taxa are slowly coming to light, but only continued efforts in the systematic recovery of ancient plant remains will help to shed additional light on past Maya practices, including culinary and ritual ones that involve the use of species in the nightshade family.

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