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# The "How" of the Three Sisters: The Origins of Agriculture in Mesoamerica and the Human Niche

Amanda J. Landon

Abstract: *The origins of agriculture in Mesoamerica have long interested archaeologists and antiquarians alike. The approaches used to understand the origins of the three sisters, maize, beans and squash, have changed over time as our understanding of the ecological context and ethnographic influences have changed. In this paper, I examine the history of the study of the origins of agriculture and assess the current evolutionary and ecological approaches to the topic. In Mesoamerica, the three sisters and humans shared a coevolutionary relationship in which humans invited the plants into the human niche and the plants thrived. Over time, the plants changed both genetically and morphologically, providing more of what humans selected for, while humans changed their behavior in order to care for the plants. Both humans and the three sisters now share a symbiotic relationship, where both the plants and the humans depend on one another.*

*Introduction*

The origins of agriculture have long captured the interest of archaeologists and naturalists (e.g. Sturtevant 1885, Thone 1936). Theories regarding the origins range from overpopulation (e.g. Cohen 1977), to the necessity for resource certainty (e.g. Flannery 1973), to Pleistocene extinctions (e.g. Pickersgill 2007). The transition from foraging to agricultural food procurement strategies in Mesoamerica took place over thousands of years and produced the familiar trinity: maize, beans, and squash (Flannery 1973). The relationship between these plants and the people who first cultivated them is best described not as a necessity but as a coevolutionary process. This process required both humans and plants to change their behavior and expand their ecological niches in order to allow for a new and changing relationship.

*Agriculture*

Cultivation refers to caring for plants whether they be domesticated or wild (Smith 1998). Domestication is the product of the way in which humans and plants interact. Humans select the best plants for the activities for which they are needed (Pearsall 1995). However, not all species are equally apt to thrive in humans' constructed environments (Smith 1998). Agriculture differs from low-level food production in that agricultural activities require a substantial amount of time each day while foraging activities become rare and possibly unnecessary. In addition, round 75% of the diet should come from domesticates (Winterhalder and Kennet 2006).

Agriculture originated in hilly or mountainous tropical or subtropical regions that, at the time of domestication, would have been rich in natural resources. There are at least six centers of domestication in the world (Mesoamerica, the Andes, Southwest Asia, Ethiopia and the Sahel, Southern China, and Southeast Asia), each of which produced at least one domesticated source of both carbohydrate and protein, such as a grain and a bean (Gepts 2004).

Theories for the origins of agriculture have changed over time. In 1968, archaeologist Cutler stated that humans brought knowledge of plants with them when they migrated from the Old World to the New World. They likely knew that planting seeds resulted in plants growing from those seeds. He identifies two of several steps through which humans would undertake in order to cultivate a plant, the first of which is doing no damage to plants identified as potentially yielding a good crop. Then, humans would have cared for certain plants through horticultural practices. According to Cutler (1968), domestication is something that humans figured out and then practiced.

In his 1973 work, Kent Flannery introduced a new question that changed the way archaeologists viewed agriculture, addressing its origins with not only "when" but also "why" (Smith 1997). Flannery (1973) presents agriculture as something that humans had to do rather than something that they wanted to do since the process led people to have to work harder and eat less nutritious foods. Bushnell (1976) provides a chronology for the origins of the three sisters, maize, beans and squash, and a few hypotheses regarding their origins. He discusses, for example, the rising water table at Oaxaca made irrigation possible and opened more areas for plant cultivation.

Hammond (1976) suggests people began settling in the Gulf of Mexico when the glaciers receded at the end of the Pleistocene due to the productivity of the new swamps and lagoons. Populations began increasing, leading to social complexity, which required agriculture. Cohen (1977) also argues that humans were forced into agriculture, a work-intensive and low diversity food procurement strategy, by overpopulation. Foragers experienced food shortages due to their populations increasing beyond the available resources, requiring them to look for a solution.

However, according to Hayden (1990), agriculture originated in fertile regions when aggrandizers who were taking advantage of new sociopolitical complexity encouraged food production in order to accumulate surpluses and gain power through resource management, gift-giving and feasts. Piperno and Pearsall (1998), on the other hand, revived the population and climate change argument by adding an ecological element. They assert that the origins of agriculture occurred at the end-Pleistocene shifts in climate and vegetation. Climate became warmer and wetter, causing warm, tropical-adapted vegetation to replace cool-adapted vegetation. The human solution to these shifts involved cultivating and domesticating plants. Yet these arguments do not address both why and *how* agriculture happened. Ecological niche construction theory predicts that agriculture is an evolutionary adaptation in which humans invited attractive plants into the human niche. Some of these plants accepted the invitation, while others did not (Bleed 2006, Smith 2007).

*The Three Sisters: Maize, Beans, and Squash*

Mesoamerica is a cultural region composed of Southern Mexico, Guatemala, Beliz, El Salvador, Western Honduras, Western Nicaragua and Western Costa Rica (Kirchoff 1943, McClung de Tapia 1992, Matos-Moctezuma 1994). In Mesoamerica, the transition between foraging and agriculture was not abrupt. It took between 5,000 and 6,500 years, with squash being domesticated very early and maize and beans appearing later, which is important when assessing the reasons that the transition could have taken place. Reasons that would have required an abrupt transition were likely not involved (see below).

Additionally, prior to widespread use of accelerator mass-spectrometry (AMS) dating, paleoethnobotanical remains had to be dated through radiocarbon samples from the same level. This led to some paleoethnobotanical remains, such as maize, being assigned to ages that were much earlier than the specimen itself. AMS dating allows the seed or other paleoethnobotanical sample itself to be dated. Buckler and colleagues (1998) and Smith (1997) report dates on maize, beans and squash that were dated to between 10,500 and 8,900 years ago, but they were probably intrusions in older layers. Fritz (1994) reports more accurate AMS dates on paleoethnobotanical samples that had previously been dated too early, shifting the date on domesticated maize about 1,000 years younger. Fritz (1995) calls for directly dating domesticated plant remains in the archaeological record through AMS, especially if the remains have been dated to before 7,000 years ago, due to the possibility of the specimens having intruded into older layers. More recently, Smith (1997, 2007) and other researchers (e.g. Pickersgill 2007) have confirmed a few older dates through AMS, but that does not underscore the importance of direct dating.

Around 7,000 years ago, agriculture emerged in Mesoamerica, including the domestication of maize, beans, and squash, causing major changes in the plants that people cultivated. Three sisters agriculture had spread across Mexico by 3,500 years ago, though they originated at different times. Early domesticates in Mesoamerica and other areas tend to have a high yield, thrive in a variety of habitats, are easy to store, and are easily manipulated genetically. They would replace native plants in less than a year and over time respond genetically to become more productive and more easily collected and/or prepared (Flannery 1973).

Caves in northeastern Mexico near Ocampo provide most of the evidence for the beginnings of agriculture in the region, including the domestication of the three sisters (Smith 1997). During the 1950s and 1960s, archaeologists were operating under what Smith (1997:346-357) terms "The Era of Incipient Cultivation" hypothesis, which states that the three sisters came to be domesticated at different times and in different regions of Mexico, and that there was a 5,000 or more year transition period between relying on foraging and relying on agriculture. By the 1970s, archaeologists knew more or less in which order domesticates appeared in different regions of Mexico, but did not know why agriculture began to be practiced with these plants (Flannery 1973).

The pollen record shows evidence of maize in wetlands earlier than in other areas, and domestication likely started in the wetlands of Mesoamerica because these areas privide the ecological requirements of wild varieties of maize, beans, and squash (Pohl et al. 1996). The peoples living in the Maya Lowlands probably began cultivating plants in the wetlands during drier times of the year. When the climate became wetter and the water table rose, the peoples had to construct canals to drain the fields. Canals and ditches appear in the archaeological record at around the same time as the Maya became a complex society (1,000-400BCE) (Pohl et al. 1996). Yet wild varieties of the major crops in Mesoamerica do not live in the regions with the most complete paleoethnobotanical sequences, so it can be difficult to study the process of domestication itself (Buckler et al 1998).

According to a study by Pearsall (1999), in the Jama Valley of Ecuador, plant domestication occurred while resources were rich and continued to be rich after domestication. A large variety of foods were exploited, which is probably adaptive in a region prone to natural disasters that would differentially affect resources. Due to catastrophic tephra events, indicative of volcanic activity, people tended to settle on the river alluvium where those who survived could still practice agriculture. After the third major tephra event recorded at archaeological sites in the Jama Valley, maize became the most abundant crop, suggesting that it was best adapted to post-tephra growing conditions. It may have allowed people to return more quickly to the valley after the third tephra event (Pearsall 1999).

The main domesticated plants in Mesoamerica today are maize, beans, squash and pumpkins, chile peppers, and avocado (McClung de Tapia 1992). Each was domesticated separately, with the first two, squash and maize, appearing by 10,000 years ago and 6,300 years ago respectively (Smith 2001a). Plants belonging to the genus *Cucurbita* (squash) are the first known domesticates in Mesoamerica. At least two species were domesticated separately in Mesoamerica, and *C. pepo* was domesticated separately in both Mesoamerica and Southeastern North America (Flannery 1973, Pickersgill 2007). Squash thrive in wetter conditions, which were present in the early Holocene (Buckler et al. 1998). During the domestication process, squash peduncle morphology changed and seed size increased (McClung de Tapia 1992, Smith 1997).

Domesticated maize came from wild maize populations called *teosinte* in Western Central Mexico, and the process probably began before 9,000 years ago (Doebley 1990, Matsuoka et al. 2002, Pickersgill 2007). Buckler and colleagues (1998) suggest that climate change restricted ancestral maize to the Guerrero Lowlands where numerous populations were cultivated. The drier highlands would have adopted domesticated maize at a later date due to ecological factors. Maize was probably domesticated from a very genetically diverse wild plant, which would explain the domesticated variety's genetic diversity (Eyre-Walker et al .1998).

In Soconusco, Southern Mexico, people began using maize around 6,000 years ago in low quantities and over time intensified cultivation and reliance on maize (Kennet et al. 2006). During this transition, they still relied on foraging for some other food sources.

Maize cultivation likely did not provide a viable alternative to foraging until about 2,600 years ago in Soconusco as evidenced by maize agriculture being practiced in surrounding areas. Maize agriculture would have required more work for fewer yields until ceramic technology appeared in the region around 3,800 years ago. Before ceramics, one would have to soak dry maize and beans in gourds or other bowls and cook them without direct heat. Ceramics allowed them to cook dry maize and beans directly over much shorter periods of time (Kennet et al. 2006).

It is unlikely that maize was domesticated due to high population density in Mesoamerica because the number of people in that region was quite low when maize was first domesticated (Flannery 1973). Flannery (1973) suggests that maize agriculture arose in Mesoamerica in order to provide a more certain food source due to the high variability in productivity in wild food plants between wet and dry years. This scenario is unlikely, however, since early agriculture would not have provided a more certain yield, either (Gepts 2004).

Domesticated beans are rare prior to 5,000 years ago. When they appear in the archaeological record, they are often associated with maize. This pair of foods forms a complete protein since beans have the lysine that maize lacks (Flannery 1973). At least four species of bean were domesticated (*Phaseolus vulgaris, Phaseolus acutifolius, Phaseolus coccineus,* and *Phaseolus lunatus*) in different environments (Pickersgill 2007). They were probably not part of the main shift from foraging to agriculture, but were nonetheless important for agriculture in the region (Kaplan 1994, Smith 1997). Bean domesticates differ from wild varieties for four main reasons. The seeds require less soaking time due to being more permeable. The pods are limper, which decreases the number of beans lost during harvest as compared to shattering pods. The plants became annuals rather than perennials, enabling them to yield every year, and bean size increased very early in the process (McClung de Tapia 1992:53).

It is likely that foragers originally domesticated squash, peoples who had already been farming for at least 1,000 years domesticated maize, and peoples who managed a well-established squash and maize agriculture domesticated beans (Smith 2001b). Both maize and squash were first domesticated in Southern Mexico. Squash spread to Northern Mexico by 6,300 years ago, and both domesticates reached the American Southwest by 3,500 years ago. The common bean was probably first domesticated north of maize and squash. The three domesticates dispersed at different rates across Mexico, with maize moving faster than squash (Smith 2001b).

Buckler and colleagues (1998) assert that increasingly arid conditions provided encouragement for cultivation in semiarid regions in Mexico, though cultivation began there later than other wetter regions. Smith (1997) reports evidence that agriculture actually spread from wetter into drier areas. McClung de Tapia (1992) asserts that people were forced into agriculture in order to intake enough protein. Between 12,000 and 9,000 years ago, the peoples living in the Tehuacan Valley relied heavily on hunting and less on plant foods for subsistence. By the end of the Pleistocene, the ranges of the animals that they hunted contracted, and the animals went extinct (McClung de Tapia 1992). The peoples had to rely more on plant resources as there were fewer sources of meat. Between 9,000 and 7,000 years ago (reported as early as 10,000 years ago in Smith 2001a), they began exploiting many of the plants that were later domesticated, including squash. Maize appears in the archaeological record between 7,000 and 5,400 years ago as meat resources decreased further. By 3,500 years ago, people were heavily dependent on agriculture and had developed irrigation techniques. By this time, they were also mostly sedentary (McClung de Tapia 1992).

Pearsall (1995), however, reports that there is no evidence that supports linking the megafauna extinction and climate change to plant domestication because domesticated plants were at first minimally productive and humans did not become dependent on domesticates until after thousands of years had passed. However, end-Pleistocene climate change broadened the areas in which plants that were later domesticated could live. Pearsall (1995) hypothesizes that in the Tehuacan Valley, the shift from foraging to agriculture started between 5,300 and 4,500 years ago based on in lake core records. In Mesoamerica overall, the shift was around 4,300 years ago. Then Pearsall argues that an increase in social and economic complexity and rising populations affected the direction of the evolution of agriculture.

Another approach to the origins of agriculture is to consider it a coevolutionary process between people and plants (McClung de Tapia 1992, Bleed 2006). Agriculture appeared due to domestication, which is a result of a symbiotic relationship between people and plants. The degree to which domestication progresses between humans and each plant varies, and not all plants will thrive under the relationship (McClung de Tapia 1992). Humans use plants for not only for food but also ritual, medicine, and craft. For example, some gourds were used as containers, which is important when considering agriculture from an evolutionary or nutritional perspective because not all domesticates were used only for food (Pearsall 1995).

Between 11,000 and 4,000 years ago, Mexico experienced significant climate change from dry and cold, to moist and warm, to the modern environment (Markgraf 1993). Between 10,500 and 8,500 years ago in Mexico, plants shifted their ranges along with changes in climate. Plants with similar ecological traits moved together over time, but not all plants living together at any given time would share those traits (Buckler et al. 1998). In middens, archaeologists uncovered changes in the plants being exploited that reflected which plants would have been in those areas as climate changed and plants shifted over time. These plants did not show up in the archaeological record due to cultivation, but due to human exploitation. They were available and therefore used (Buckler et al. 1998).

Domestication can also change the range and morphology of plants. The domestication syndrome refers to the morphological and genetic differences between wild and domestic varieties of a plant that usually diminish the domesticate's ability to survive in the wild, requiring it to depend on humans for care and protection (Pickersgill 2007). Domesticated plants usually no longer have the tendency for seeds to detach at maturity because the abscission zone disappears or becomes less brittle. The plants are generally larger, especially in regard to harvested parts, than wild varieties. They can become more varied in color or shape, especially if those traits correlate to different uses. Unlike wild varieties, they tend not to produce dormant seeds, which allows for the domesticated plants to germinate soon after being planted, avoiding fields being overtaken by weeds. They also differ from wild varieties in that they no longer need natural protections against predators, such as bitter chemicals that repel herbivores. Due to the spread of agriculture, the photoperiod for some domesticates changes as available light changes over space (Pickersgill 2007). Intensively domesticated plants tend to be incapable of thriving outside of human influence at all. In exchange for human protection and preferred attributes, such as higher caloric value or ease of harvest, many plants have, in a sense, "given up" their ability to protect themselves in the wild.

Recessive alleles, such as those related to a lack of protection against herbivores, present themselves in domesticated plants due to inbreeding. These alleles are harmful when they present themselves in wild plants, but domesticated plants survive due to human protection and intervention (Vaughan et al. 2007). Most plants that end up being domesticated are characterized by a genetic bottleneck from

domestication, had no genetic barrier to fast domestication, and are more inclined to domestication than other species (Gepts 2004).
There is a limit to the number of plants that people in any given region can domesticate, though that number is unknown (Gepts 2004). Some species were domesticated, such as goosefoot (*Chenopodium bushianum*) and marshelder (*Ira annua*) in Eastern North America, but became unimportant when other domesticates (maize, beans, and squash) were introduced. These introduced crops may have been agronomically or nutritionally appealing, or may have been introduced by a dominant culture (Gepts 2004).

There is an evolutionary process responsible for the emergence of agriculture in various locations around the world at about the same time, but attributing exactly the same cause to each instance prevents researchers from studying specific relationships that lead to domestication (McClung de Tapia 1992:143). Human behavioral ecology (HBE) and foraging theory can be applied on the level of an individual or small group, which differentiates it from other models that address society on a long term scale and its response to forces from the outside (Smith 2006). HBE and foraging theory focus on short time scales and local areas rather than simply assessing changes over generations. Domestication occurred in many areas around the world, and each area has its own domestication history. The transition from foraging to agriculture occurred not in one step, but in multiple steps that cannot necessarily be distinguished over long time scales (Smith 2006). When several crops are grown together, each crop has its own domestication history and can be considered separately in HBE and foraging theory. One must also determine why each crop is more important in some areas than others and why agriculture is developed in some areas later than others (Smith 2006).

There is an indirect connection between fitness and foraging, so optimal foraging does not necessarily lead to fitness in each individual case (Bettinger 2006:306-307). After researchers consider many cases, a pattern emerges that links fitness and foraging, which means that there is stronger evidence for the connection. Generally, HBE predicts that humans are economically rational: they will forage in such a way that increases fitness, decreases the time needed to forage, or decreases hazards (Bettinger 2006:306-307). HBE and foraging theory are ways of learning about past human behavior, not ways of showing that human behavior is dictated solely by evolutionary theory. Humans are animals that are subject to evolutionary theory and the laws of selection, as well as human culture (Bettinger 2006). HBE does not imply that the choices that individual humans make are controlled by any laws or rules, but that one can explain those decisions based on a "general law-like or universal principle that universally holds" (Smith 2006:294).

Domestication is part of human behavior and represents one way in which humans can welcome another species into the human niche. It is a result of preexisting resource management behavior practiced by humans (Smith 2007). Domestication appeared in similar environments in different world regions. These areas tended to be rich in resources and associated with large bodies of water. These settings would have provided a situation in which humans could experiment by interfering with many different species and settle into a sedentary lifestyle. Agriculture was therefore born not of necessity but of humans continuing to modify their environment to their own advantage (Smith 2007).

Indigenous peoples in Mexico interact with plants that they manage by systematic gathering, "let standing" (maintaining endemic plants in a human-constructed environment), encouraging growth, and protecting the plants. These activities all fall under *in situ* management practices (Casas et al. 2007:1102). If people practice *in situ* management on plants with favorable phenotypes, then artificial selection occurs. Casas and colleagues (2007) observed this phenomenon in modern populations in the Montaña de Guerrero region of Mexico who were managing herbaceous quelites, the guaje tree, and the columnar cacti. The managed plants had, over time, changed drastically in terms of physiology, morphology, and genetics from wild populations. Phenotypes that humans preferred occurred in higher numbers in managed populations. The authors suggest that *in situ* plant management could be a modern analogue to the processes that led to plant domestication and agriculture in the past. However, they caution that populations living in proximity to those who practice agriculture could have developed *in situ* management systems in response to that relationship.

Smith (2007) proposes that questions addressing the what, where, and when of agriculture are still uncovering important information, and questions regarding why are helping researchers understand agriculture on a more profound level, but that more needs to be done to address the *how* of agriculture. Future tracts for research include determining how culture and environment affected which species were domesticated and how domestication relationships between humans and plants are initiated.

*Conclusions: The "How" of the Three Sisters*

The transition between foraging and agricultural food procurement techniques took thousands of years in Mesoamerica and did not spread at the same rate to each place. In some areas, such as arid regions, maize based agriculture arrived later than it did in wet areas. The maize had to adapt from a wetter to a drier climate with the help of humans. If climate change is a major factor in the transition, its influence is not in forcing Pleistocene extinctions but in creating a warmer, wetter climate that diversified the vegetation in Mesoamerica. The plants that are now domesticated could live in a much broader area. Humans in this ecologically diverse area likely began experimenting with plants in a manner similar to *in situ* management. They protected the plants with attractive phenotypes, changing the phenotypes of the whole managed population, though the people were not necessarily consious of the process through which they were going. Some of those plants were more likely to thrive in the human niche, but they had to give up their natural defenses in return for protection. There is evidence for this transition in the archaeological record, represented by the size and morphology of different parts of the plant.

The varieties of maize, bean, and squash outside of the human niche are less useful to humans than those within it. Domesticated squash are edible, while wild varieties generally are not domesticated. Beans are much easier to cook and collect, and maize grew in size. The useful, domesticated varieties are incapable of living outside of the human niche. They have adapted to living in the niche, and humans have changed their behavior in order to protect the plants. Agricultural societies are sedentary, which is required for caring for fields of plants. These societies now depend on agriculture to provide enough food to feed enormous populations. The entities involved must change their behavior, their phenotypes and their niche in order to accommodate each other (Bleed 2006). The current relationship is symbiotic and came about through coevolutionary processes.

Maize and beans have been grown together since beans appeared in the archaeological record. It is possible, since humans are selecting for preferred phenotypes, that these two varieties of plant grown together provide something that separately they do not. The combination of maize and beans creates a complete protein, but the first farmers might not have directly known that. Flavor, color, and appearance are also important traits that humans select in some plants (McClung de Tapia 1992).

Future studies should address what maize and beans offer when grown and eaten together, aside from but possibly related to the formation of a whole protein. Maize must also be processed before consumption in order to release niacin, a nutrient. There is archaeological evidence from the Maya Lowlands of processing maize with lime from *Pachychilus* and *Pomacea* snail shells (Moholy-Nagy 1978, Nations 1979). Future research should also address how lime processing, especially in the region where maize was domesticated, is related to the domestication process, and when in that process people began utilizing lime.

*Acknowledgements*

I would like to thank Dr. Daniel Osborne of the University of Nebraska-Lincoln and Dr. Peter Bleed of the University of Nebraska-Lincoln for their input. I would also like to thank the editors of the *Nebraska Anthropologist* for their suggestions and insight for improving this paper.

## References Cited

Bettinger, R.
2006 Agriculture, Archaeology, and Human Behavioral Ecology. In *Behavioral Ecology and the Transition to Agriculture*, edited by D. J. Kennet and B. Winterhalder, 304-322.

Bleed, P.
2006 Living in the Human Niche. *Evolutionary Anthropology* 15:8-10.

Buckler, E. S., D. M. Pearsall, and T. P. Holtsford
1998 Climate, Plant Ecology, and Central Mexican Archaic Subsistance. *Current Anthropology* 39:152-164.

Bushnell, G. H. S.
1976 The Beginning and Growth of Agriculture in Mexico. *Philosophical Transactions of the Royal Society of London* 275:117-120.

Casas, A., A. Otero Arnaiz, E. Perez-Negrón, and A. Valiente-Banuet
2007 *In situ* Management and Domestication of Plants in Mesoamerica. *Annals of Botany* 100:1101-1115.

Cohen, M. N.
1977 *The Food Crisis in Prehistory: Overpopulation and the Origins of Agriculture.* Yale University Press, New Haven.

Cutler, H. C.
1968 Origins of Agriculture in the Americas. *Latin American Research Review* 3:3-21.
Doebley, J. F.
1990 Molecular evidence and the evolution of maize. *Economic Botany* 44:6-27.
Eyre-Walker, A., R. L. Gaut, H. Hilton, D. L. Feldman, and B. S. Gaut
1998 Investigation of the Bottleneck Leading to the Domestication of Maize. *Proceedings of the National Academy of Sciences* 95:4441-4446.
Flannery, K. V.
1973 The Origins of Agriculture. *Annual Review of Anthropology* 2:271-310.
1986 The research problem. In *Guilá Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, México*, edited by K. V. Flannery, pp. 3-18. Academic Press, Orlando.
Fritz, G. J.
1994 Are the First American Farmers Getting Younger? *Current Anthropology* 35:305-309.
1995 New Dates and Data on Early Agriculture: The Legacy of Complex Hunter-Gatherers. *Annals of the Missouri Botanical Gardens* 82:3-15.
Gepts, P.
2004 Crop Domestication as a Long-Term Selection Experiment. *Plant Breeding Reviews* 24:1-44.
Hammond, N.
1976 The Early History of American Agriculture: Recent Research and Current Controversy. *Philosophical Transactions of the Royal Society of London* 275:120-128.
Hayden, B.
1990 Nimrods, Piscators, Pluckers and Planters: The Emergence of Food Production. *Journal of Anthropological Archaeology* 9:31-69.
Kennet, D. J., B. Voorhies, and D. Martorana
2006 An Ecological Model for the Origins of Maize-Based Food Production on the Pacific Coast of Southern Mexico. In *Behavioral Ecology and the Transition to Agriculture*, edited by D. J. Kennet and B. Winterhalder, pp. 103-136. University of California Press, Los Angeles.
Kirchoff, P.
1943 Mesoamérica, sus límites geográficos, composición etnica y caracteres culturales. *Acta Americana* 1:92-107.

Lentz, J. A. Gifford, M. E. Danforth, and J. K. Jusserand
1996 Early Agriculture in the Maya Lowlands. *Latin American Antiquity* 7:355-372.

Matos-Moctezuma, E.
1994 Mesoamérica. In *Historia antigua de México*, edited by L. Manzanilla and L. López-Luján, pp. 49-73. Consejo Nacional para la Cultura y las Artes, Instituto Nacional de Antropología e Historia, Universidad Nacional Autónoma de México, Porrúa.

Matsuoka, Y., Y. Vigouroux, M. M. Goodman, G. J. Sanchez, F. Buckler, and J. Doebley
2002 A single domestication of maize shown by milti-locus microsatellite genotyping. *Proceedings of the National Academy of Sciences* 99:6080-6089.

McClung de Tapia, E.
1992 The Origins of Plant Cultivation in Mesoamerica and Central America. In *The Origins of Agriculture: an International Perspective*, edited by C. W. Cowan and P. J. Watson, pp. 143-172.

Moholy-Nagy, H.
1978 The Utilization of *Pomacea* snails at Tikal, Guatemala. *American Antiquity* 43:65-73.

Nations, J. D.
1979 Snail Shells and Maize Preparation: A Lacandon Maya Analogy. *American Antiquity* 44:568-571.

Pearsall, P. M.
1995 Domestication and Agriculture in the New World Tropics. In *Last Hunters-First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, edited by T. D. Price and A. B. Gebauer, pp. 157-192.
1999 The impact of maize on subsistence systems in South America: an example from the Jama river valley, Coastal Ecuador. In *The Prehistory of Food: Appetites for Change*, edited by C. Gosden and J. Hather, pp. 419-437.

Pickersgill, B.
2007 Domestication of Plants in the Americas: Insights from Mendelian and Molecular Genetics. *Annals of Botany* 100:925-940.

Piperno, D. R. and D. M. Pearsall
1998 *The Origins of Agriculture in the Lowland Neotropics*. Elsevier, London.

Pohl, M. D., K. O. Pope, J. G. Jones, J. S. Jacob, D. R. Piperno, S. D. deFrance, D. L. Lentz, J. A. Gifford, M. E. Danforth, and J. K. Josserand.
1996 Early Agriculture in the Maya Lowlands. *Latin American Antiquity* 7:355-372.
Smith, B. D.
1997 Recnsidering the Ocampo Caves and the Era of Incipient Cultivation in Mesoamerica. *Latin American Antiquity* 8:342-383.
1998 *The Emergence of Agriculture.* Scientific American Library, New York.

2001a Low-level food production. *Journal of Archaeological Research* 9:1-43.
2001b Documenting Plant Domestication: The Consilience of Biological and Archaeological Approaches. *Proceedings of the National Academy of Sciences* 98:1324-1326.
2006 Human Behavioral Ecology and the Transition to Food Production. In *Behavioral Ecology and the Transition to Agriculture*, edited by D. J. Kennet and B. Winterhalder, pp. 289-303.
2007 Niche Construction and the Behavioral Context of Plant and Animal Domestication. *Evolutionary Anthropology* 16:188-199.
Sturtevant, E. L.
1885 An Observation on the Hybridization and Cross-Breeding of Plants. *The American Naturalist* 19:1040-1044.
Thone, F.
1936 First Farmers. *The Science News-Letter* 30:314-316.
Vaughan, D. A., E. Balázs, and J. S. Heslop-Harnson
2007 From Crop Domestication to Super-Domestication. *Annals of Botany* 100:893-901.
Winterhalder, B. and D. J. Kennet
2006 Behavioral Ecology and the Transition from Hunting and Gathering to Agriculture. In *Behavioral Ecology and the Transition to Agriculture*, edited by D. J. Kennet and B. Winterhalder, pp. 1-21. University of California Press, Los Angeles.