BIOTROPICA 33(1): 191–196 2001

Pollen Evidence of Maize Cultivation 2700 B.P. at La Selva Biological Station, Costa Rica[1]

Key words: agriculture; archaeology; Costa Rica; fires; La Selva Biological Station; maize; paleoecology; pre-Columbian; prehistoric; Zea mays *subsp.* mays.

As more and more forests are cleared in the Latin American tropics, there is a tendency to view remaining forests as particularly special examples of wild nature—old, stable, and unaffected by past human activity. This perception, however, may be inaccurate. A growing body of evidence indicates that today's "ever-wet" rain forests have seen major droughts, and that warm lowland forests have been significantly cooled; from sea level to mountain peaks, "pristine" forests have been cut and burned. Prehistoric human disturbance and shifts in climate undoubtedly have affected past forest communities, and today's forests may bear some imprints of these earlier influences. Thus it becomes important for modern ecological research to understand the long-term history of research sites (Hamburg & Sanford 1986). Unraveling long-term forest history and its possible links to modern patterns and processes may be particularly important at well established research stations that are the sources of large numbers of publications in tropical ecology (Clark 1985).

Here we add to evidence of the long-term human history of La Selva Biological Station in Costa Rica by reporting pollen evidence of maize cultivation much earlier than previously indicated. Located in the rainy Atlantic lowlands (10°26′N, 83°59′W, 30–150 m elev.), La Selva is a premier site for tropical ecological research (McDade *et al.* 1994). Mature rain forests at La Selva have been described as "pristine" or "virgin" (Frankie *et al.* 1974, Hartshorn 1983), but charcoal fragments and pollen grains in soils and sediments show that both mature and secondary forests at the research station occupy lands that were burned and cultivated by prehistoric inhabitants (Horn & Sanford 1992; Kennedy & Horn 1997; Kennedy 1998; S. Horn & R. Sanford, pers. obs.). Climate fluctuations also may have affected La Selva's

[1] Received 19 June 1999; revision accepted 26 January 2000.

TABLE 1. *Archaeological phases in the central Atlantic watershed of Costa Rica, after Snarskis (1981, 1984) and Quintanilla (1990). More recent interpretations have questioned the distinctiveness of the El Bosque and La Selva phases, which may overlap in time and represent different societies (M. Sánchez, pers. comm.). Reconciliation of these views with findings at La Selva Biological Station awaits the completion of an ongoing archaeological analysis by F. Sol (pers. comm.). Years B.P. by convention means years before 1950.*

Archaeological phase	Time span		Selected characteristics
	B.C./A.D.	Years B.P.	
La Cabaña	800–1550 A.D.	1150–400	Emergence of the highly organized caciques or chieftains who ruled Costa Rica at the time of European contact.
La Selva	300–800 A.D.	1650–1150	Further social differentiation. Stylistic changes in ceramics and house types and beginning of gold metallurgy.
El Bosque	300 B.C.–300 A.D.	2250–1650	Major increase in archaeological sites indicates a population boom that may have been related to full-scale adoption of maize agriculture and the colonization of new agricultural lands. Artifacts indicate increasing social differentiation.
La Montaña	1000–300 B.C.	2950–2250	Earliest securely dated ceramics in the central Atlantic watershed. La Montaña peoples were early agriculturalists who relied heavily on root and tree crops as food staples.

forests, directly and also through complex links to human population levels and activities, but the evidence for this is less clear (Horn & Sanford 1992, Kennedy 1998).

Initial archaeological work at La Selva by Quintanilla (1990) produced abundant ceramic fragments associated with the El Bosque regional archaeological phase (2250–1650 B.P.; see Table 1 for B.C./A.D. equivalents), and a few pieces corresponding to the earlier La Montaña phase (2950–2250 B.P.). Ongoing investigation by Sol (F. Sol, pers. comm.) has confirmed and extended Quintanilla's (1990) study. Sol has uncovered additional La Montaña and El Bosque phase material, along with ceramics diagnostic of the later La Selva archaeological phase (1650–1150 B.P.), and a small number of pieces that may date to the latest La Selva phase or possibly the earlier part of the succeeding La Cabaña phase (1150–400 B.P.)

Radiocarbon determinations on charcoal fragments sieved from soils and sediments at La Selva have yielded calibrated ages ranging from 3210 to 700 years B.P. (Horn & Sanford 1992; Kennedy 1998; S. Horn & R. Sanford, pers. obs.). Many dates cluster near the beginning of the El Bosque phase, which may have been a time of drier climate in the circum-Caribbean region (Hodell *et al.* 1991, 1995), as well as a time of explosive population growth in the Atlantic lowlands of Costa Rica (Snarskis 1981, 1984). The fires that produced the charcoal we have dated may include cooking as well as agricultural fires in and near village sites, and hunting fires or wildfires in intact forest on soils too poor for agriculture. Wildfires may have spread from agricultural or other human-set fires, or were ignited by lightning during drought periods.

Pollen grains of maize (*Zea mays* subsp. *mays*; taxonomy as in Sluyter 1997a) preserved in sediments from the Cantarrana swamp (Fig. 1) indicate maize cultivation in the reserve between 700 and perhaps 300 B.P. and thus extend the record of human occupancy at La Selva into the later La Cabaña phase (Kennedy & Horn 1997, Kennedy 1998). Maize pollen is a poor disperser, rarely traveling more than a few hundred meters from parent plants (Purseglove 1972); its presence in the Cantarrana swamp sediments very likely signals La Cabaña-age cultivation of maize adjacent to, if not partly within, the swamp. No artifacts diagnostic of the later La Cabaña period have been found at La Selva, but a major site that encompasses this period, Cubujuquí, is located *ca* 20 km from the station (Gutiérrez & Mora 1988); a possible La Cabaña site, Cacaotal, is located *ca* 5 km away (Quintanilla 1990; F. Sol, pers. comm.). We envision the La Cabaña period as a time in which La Selva was occupied by a small satellite population of agriculturalists with links to major sites elsewhere.

Kennedy (1998) interpreted the absence of maize pollen in swamp sediments deposited before 700

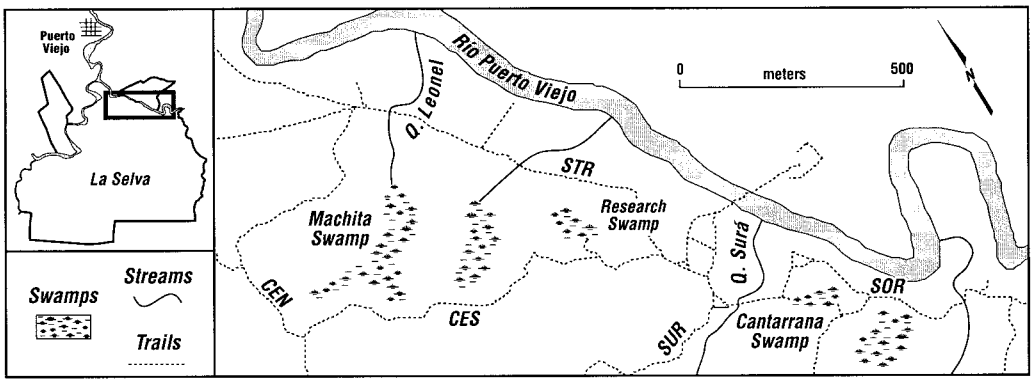

FIGURE 1. The Machita, Cantarrana, and other swamps on alluvial terraces of the Río Puerto Viejo, La Selva Biological Station, Costa Rica. Map was adapted from the La Selva GIS and maps in McDade *et al.* (1994). The Río Puerto Viejo flows toward the northwest.

B.P. at the Cantarrana site to indicate only the local absence of maize cultivation. She suggested that abundant microscopic charcoal in older sections of the Cantarrana core may have been associated with earlier cultivation of maize in neighboring areas outside of the Cantarrana watershed. Our analysis in this paper of a second swamp at La Selva supports this interpretation.

The Machita swamp (unofficial name) is located *ca* 1 km northwest of the Cantarrana swamp (Fig. 1), also on an alluvial terrace of the Río Puerto Viejo (Sollins *et al.* 1994.) In 1992, we cored the swamp sediments using a 5 cm diameter, square-rod piston corer (Wright *et al.* 1984; used in upper meter) and a similar but smaller (2.5 cm diam.) "UNAM"-type corer designed by Roger Byrne (used below 1 m depth). Our longest core, Machita 1992 IE, was recovered near the center of the swamp and spans 3.4 m, with some overlapping sections recovered from parallel holes. In 1997, we used a Colinvaux-Vohnout locking piston corer (5 cm diam.) to recover a 3.0-m-long core in three contiguous 1-m sections from a site closer to the edge of the swamp. Both cores appear to bottom out on saprolite.

The Machita swamp sediments consist of clays and silts of varying organic content with dispersed macroscopic and microscopic charcoal. We processed 31 (1-cc) samples for pollen analysis from the 1992 core sections and 6 from the 1997 sections, using standard procedures (HF, HCl, KOH, and acetolysis; Berglund 1986) and silicone oil as a mounting medium. We prepared one to five microscope slides from each level processed, and scanned each fully at 100× magnification in search of the pollen of maize or other cultigens. Samples taken at depths below 276 cm in the 1992 core sections and below 70 cm in the 1997 core sections contained very little or no pollen. The absence of pollen in most of the 1997 core samples was likely due to oxidation and consequent destruction of pollen in sediments near the edge of the swamp, which may be more likely to desiccate during unusual dry periods than the central portion of the swamp (from which we recovered the 1992 core sections). The absence of pollen at depths below 276 cm in the 1992 core sections may indicate that this lower portion of the core is already in saprolite rather than swamp deposits.

On 100 slides scanned, we identified 46 grains of maize (Table 2). The maize pollen grains at the Machita site ranged from 63 to 87 μm in maximum dimension, with pores 11–16 μm across. These values are within the size ranges reported by Whitehead and Langham (1965) for pollen grains belonging to modern races of Mexican maize mounted in silicone oil, and are similar to the size ranges for prehistoric maize pollen grains found at the Cantarrana swamp (Kennedy & Horn 1997) and other sites in Costa Rica (Clary 1994, Northrop & Horn 1996) and Mexico (Byrne & Horn 1989, Sluyter 1997b). Although pollen grains of maize overlap in size with those of the teosintes (*Zea mays* subsp. *parviglumis* H. H. Iltis & Doebley, *Zea perennis* (Hitchc.) Reeves & Mangelsd., and other *Zea* L. spp.; Sluyter 1997a, b), none of these "wild maizes" is native to Costa Rica (Pohl 1980).

The deepest maize grains in the Machita swamp (248 cm depth) occurred within a 6-cm section of the 1992 IE core (244–250 cm depth) with abundant charcoal fragments. Charcoal sieved from this section yielded an AMS radiocarbon date of 2540 ± 60 radiocarbon years B.P. Based on the CALIB

TABLE 2. *Pollen of maize (*Zea mays *subsp.* mays*) in the Machita 1992 IE sediment core. Lowercase letters after depths indicate core sections for intervals with overlapping sections from parallel holes. The 80- to 112-cm sample came from a short section that was homogenized during extrusion, such that a more specific depth could not be determined.*

Depth (cm)	Slides scanned	Maize grains observed
0	3	0
16	3	0
32	5	0
40	3	2
48	3	1
56	3	4
64	3	0
80–112	3	1
134	3	0
142	3	0
150	3	1
166	3	8
182 b	5	0
196 b	5	0
201 a	3	3
208 a	3	8
212 b	5	2
216 a	3	1
224 a	3	3
228 b	5	0
232 a	3	2
240 a	3	6
248 a	5	4
256 c	2	0
266 c	2	0
276 c	2	0
296 c	2	0
308	3	0
324	3	0
340	3	0
344	2	0

calibration program (Stuiver & Reimer 1993) and the calibration data set of Pearson and Stuiver (1993), the age of the charcoal corresponds to 2720 B.P., or 770 B.C. The "maize zone" in the 1992 core extended upward from this charcoal-rich section of the core to a depth of 40 cm. We also found maize pollen at 40 cm in our 1997 core, but none in lower samples in which pollen preservation is poor for any pollen type. In our widely sampled 1992 core sections, there were some gaps in maize pollen occurrence between 40 and 201 cm, but between 201 and 248 cm, the distribution was nearly continuous (Table 2). No radiocarbon date is available for the uppermost maize grains in the Machita sediments, but extrapolation from a sedimentation rate of 0.089 cm/yr (calculated from the radiocarbon date) suggests that the uppermost maize pollen grains may have been deposited *ca* 450 years ago. This age is consistent with the inferred age of the maize pollen in the Cantarrana swamp (Kennedy & Horn 1997), again pointing to a late-La Cabaña age occupation at La Selva.

Taken together, the maize pollen in the Cantarrana and Machita swamp sediments point to maize cultivation around those sites beginning *ca* 2700 B.P. and extending (possibly with gaps in time) to perhaps 300 years B.P. The presence of maize pollen in sediments deposited *ca* 2700 years ago at the Machita site documents the cultivation of maize during the La Montaña regional archaeological phase (Table 1). Snarskis (1981, 1984) and Quintanilla (1990) regarded the La Montaña phase as being a time

when subsistence was based on root crops, with seed crops such as maize only gaining importance during the succeeding El Bosque phase. We cannot infer from our pollen data the relative dietary importance of maize, but we know that the crop was being grown at this time. Other crops surely were also under cultivation, but we have found no evidence of them. Pollen of manioc (*Manihot esculenta* Crantz) is large and distinctive, and if preserved, would have been noticed in our scans. We did find several grains of Cucurbitaceae pollen along with the maize grains, but these may have derived from wild rather than cultivated species.

The Machita maize pollen grains constitute some of the oldest direct botanical evidence of maize cultivation from the Atlantic watershed. Interestingly, the calibrated age for the lowest maize-bearing sediments in the Machita swamp (2720 B.P.) matches exactly the calibrated age for maize-containing basal sediments of Laguna Bonillita in the Río Reventazón valley 70 km southeast of La Selva (Northrop & Horn 1996). The recent compilation by Blanco and Mora (1994) of archaeobotanical finds in Costa Rica reported the earliest evidence of maize in the central Atlantic watershed as being from the Severo Ledesma site near Guácimo (approximately midway between La Selva and Laguna Bonillita), where archaeologists recovered a carbonized maize cob associated with El Bosque-phase ceramics (Snarskis 1981). The La Montaña-age maize pollen at La Selva and Laguna Bonillita is older than the inferred age of the Severo Ledesma maize cob; however, older evidence of maize exists outside of the central Atlantic watershed. In a controlled archaeological excavation at the Tronadora Vieja site near Volcán Arenal in northwestern Costa Rica, Mahaney *et al.* (1994) recovered a maize kernel in association with 5000-year-old charcoal.

Because maize is a plant that requires human cultivation for survival, we can infer from the distribution of maize pollen that sedentary agriculturalists were present at La Selva by 2700 B.P. This interpretation is consistent with archaeological findings, which include artifacts diagnostic of the La Montaña phase (Quintanilla 1990; F. Sol, pers. comm.). F. Sol (pers. comm.) has recently delineated a new La Montaña phase site (Tolomuco) located <300 m from the Machita swamp. We suspect that the charcoal fragments and maize pollen in the Machita swamp sediments record settlement, forest clearing, and maize cultivation within or very near the watershed of the swamp. This interpretation appears consistent with detailed analyses and dating of soil charcoal in the watershed by Harrell and Sanford (K. Harrell, pers. comm.).

Considerable research attention has been focused on natural forest dynamics at La Selva. Although rates of gap formation fall close to the middle of the range of those reported for other tropical and temperate forests, close monitoring of tree mortality within permanent plots has revealed the La Selva forest to be among the most dynamic forests measured (Denslow & Hartshorn 1994). Our pollen data, and companion studies of soil and sedimentary charcoal (Horn & Sanford 1992; S. Horn & R. Sanford, pers. obs.; Kennedy 1998) and archaeology (Quintanilla 1990; F. Sol, pers. comm.), indicate that La Selva also has a dynamic human history that reaches back at least 2700 years. Further study of the spatial and temporal aspects of this human history, in combination with detailed studies of vegetation and soils such as described by Clark (1998), may help determine the extent to which modern biological patterns and processes at La Selva bear imprints of pre-Columbian human dynamics.

We thank the Organization for Tropical Studies for permission to carry out research at La Selva; Robert L. Sanford Jr., Lisa Northrop, Glenn Hyman, David Fernandes, and Brandon League for field assistance; and Felipe Sol, Ifigenia Quintanilla, and Maureen Sánchez for stimulating discussion. This research was supported by grants to S. Horn from NSF (SES-9111588), the National Geographic Society, and the University of Tennessee, and grants to S. Horn and R. L. Sanford Jr. from the A. W. Mellon Foundation.

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