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DISEASES OF MAIZE IN THE LOWLAND TROPICS AND THE COLLAPSE OF THE CLASSIC MAYA CIVILIZATION

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RESUME

Breeding for disease and pest resistance is a major if not the most important challenge for food crop improvement in the tropics. It becomes more important when production becomes more intensive, and especially when production becomes year-round. Farmers in the past have relied on seasons of severe cold or drought and on fire, to purge their environment of major crop diseases and pests. The maximal effective use of tropic soils, however, drives us toward continuous year-round cropping, creating an ideal situation for epibiotics and evolution of crop diseases and pests.

A plant pathologist's most useful contribution in the tropics can thus be to create and sustain excellent epiphytotics as an adjunct to plant breeding. This is particularly true for a cross-pollinated crop like maize, where selection is often based on individual plants or on segregating progenies (half-sib), and where "escapes" readily destroy effectiveness of the breeding program.

In tropical maize, we have generally failed to make significant improvements for the small farmer, who is generally more interested in the reliability than in the high yield of new varieties. Reliability is often a function of extraordinarily high levels of resistance to important local pests and diseases. Our failure appears to stem in part from a lack of recognition that some maize diseases of limited importance to the "mixed vegetable garden", become of very great importance to intensively cropped maize, especially if grown year-round (e.g. DM, CSS, MMV, blight, rust, tarspot, etc.)

Few major early civilizations of man developed in the lowland tropics, and none survived for long. The greatest was unquestionably that of the Classic Maya of Mexico and Central America. The Maya "tamed" the lowlands for almost 1000 years, developing a maize-based civilization of about 2 million people in Northern Guatemala and the Yucatan Peninsula. In the 9th. century, AD, however, they abandoned their major ceremonial centers (over 1000 of them) and rich farmlands (perhaps one million hectares). The abandonment or "collapse" of the Classic Maya is considered one of the most puzzling mysteries of anthropology. The collapse was simply a desertion. There is no convincing evidence that foreign invasion, human disease, sustained drought, socioeconomic decadence or other factors caused the abandonment. Despite the excellence of their architecture, homes, centers of business, etc., no other people subsequently repopulated the major Classic Maya sites until the 19th. century.

It is proposed that the Maya abandonment of the 9th. century followed a long-sustained failure of their major food crop, maize. The diseases of maize are reviewed, and those of greatest severity in lowland humid tropics are highlighted. Maize mosaic virus (MMV) is suggested to be the most probable cause of the abandonment. MMV is confined to lowlands, it can cause complete crop failures, and it

occurs only where maize culture is intensive and essentially year-round. Resistant maize varieties were not available to the Classic Maya. The disease is believed to have come from the Caribbean via wind-borne leafhoppers infected by MMV from Arawak maize of Jamaica (700 miles from Yucatan) or Hispaniola in the late 8th. century.

MAIZE MOSAIC VIRUS
(MMV)

Names: "enanismo rayado", "corn stripe", "sweet corn mosaic"

Hosts: Maize, teosinte (suspected: Rottboellia, Axonopus, Panicum)

Virion: Bacilliform (bullet-shaped), 90 nm x 255 nm

Vector: Peregrinus maidis (Ashmead), formerly "Delphax maidis".
Persistent throughout life of larva and adult

Host Range of Vector:
Excellent-Maize, teosinte
Fair - Sorghum bicolor, S. sudanense, Brachiaria mutica, Digitaria dec.
Poor - Saccharum spp., Pennisetum purpureum, Coix lachryma-jobi

Symptoms:
Long, unbroken chlorotic stripes along leaf veins; rarely stippled or freckled, as with MSV (maize streak) or MRFV (rayado fino)
Dwarfing of plant, its severity dependent upon time and titer of infection; major dwarfing of upper nodes and husks
Mosaicism or blotching on sheath, but rarely on leaf (as seen with MDMV (maize dwarf mosaic) or CSS (corn stunt spiroplasm)
Rarely or never seen: "crazy top", purpling of leaves, necrosis

Distribution: Mexico, Belize, Guatemala, Nicaragua, Peru, Venezuela, Caribbean islands (incl. Cuba, P. Rico, Jamaica, Virgin Isl., Trinidad), Tanzania, Malagasy, Mauritius, Guam, Fiji, Hawaii, Australia (Qsld.)

Sources of Resistance: Homozygous Mv/Mv = all Caribbean races, composites like Antigua 2D; inbreds AA8, B14A, B68, CMlll (India), Hi30, Mp68:616, Tx29A, Tx601. Gene Mv is present in many cultivars hybrids and composites with Caribbean parentage (e.g., Pioneer's X304B, X306, X105, etc.)

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Table 2. Potential importance on 0 - 3 scale** of tropical maize diseases in the Petén (wet lowlands) vs. dry lowlands (e.g., Chichen Itzá) and highlands (Kaminaljuyu).

DISEASE	Wet low-land	Dry low-land	High-land
FOLIAR DISEASES			
1. No. leaf blight (Helminthosporium turcicum)	2	1	3
2. So. leaf blight (H. maydis)	3	2	0
3. Helminthosporium carbonum	1	1	1
4. Common rust (Puccinia sorghi)	0	0	2
5. Southern rust (P. polysora)	2	1	1
6. Tropical rust (Physopella zeae)	1	0	0
7. Tarspot (Phyllachora maydis)	1	0	1
8. Curvularia leaf spots (C. spp.)	2	1	1
9. Brown spot (Physoderma maydis)	1	1	1
10. Zonate leaf spot (Gloeocercospora sorghi)	1	0	0
11. Bacterial leaf stripe (Pseudomonas rubrilineans)	1	0	0
12. Banded leaf & sheath blight (Corticum sasakii)	1	0	0
13. Eyespot (Kabatiella zeae)	0	0	1
14.* Others (Phyllosticta and Cercospora leafspots, Colletotrichum anthracnose, Septoria blotch)			
SMUTS & ERGOT			
1. Common smut (Ustilago maydis)	0	0	1
2. Head smut (Sphacelotheca reiliana)	0	1	2
3. False smut (Ustilaginoidea virens)	0	1	0
4. Ergot (Claviceps gigantea)	0	0	1
DOWNY MILDEWS			
1. Sorghum (Sclerospora sorghi)	2	2	0
2. Crazy top (Sclerophthora macrospora)	1	0	0
3.* Others (Sclerospora maydis, philippinensis, and other species)	3	3	0

Table 2 (Con't)

DISEASE	Wet low-land	Dry low-land	High-land
STALK ROTS			
1. Diplodia maydis	1	1	2
2. Fusarium roseum (Gibberella zeae)	0	0	2
3. Fusarium moniliforme (G. fujikoroi)	2	1	1
4. Charcoal rot (Macrophomia phaseoli)	1	2	2
5. Pythium spp.	2	2	0
6. Bacterial (Pseudomonas spp., Erwinia sp.)	2	1	0
7. Late wilt & black bundle (Cephalosporium spp.)	2	2	0
8. Anthracnose (Colletotrichum sp.)	2	1	0
9.* Others (Aschochyta, Botryodiplodia, Helminthosporium, Nigrospora)			
EAR AND KERNEL ROTS			
1. Diplodia spp.	1	0	2
2. Pink ear rot (Gibberella zeae = F. roseum)	0	0	2
3. Fusarium moniliforme (G. fujikoroi)	2	2	1
4. Nigrospora cob rot (N. oryzeae)	1	1	1
5. Grey ear rot (Physalospora zeae)	1	1	0
6. Botryodiplodia, Rhizoctonia, Cephalosporium	1	0	0
7. Stored grain rots (Penicillium, Aspergillus)	1	1	1
VIRUSES AND VIRUS-LIKE DISEASES			
1. Maize mosaic virus (MMV)	3	1	0
2. Maize dwarf mosaic virus (MDMV)	2	2	1
3. Corn stunt spiroplasm (CSS)	2	2	1
4. Maize rayado fino virus (MRFV)	1	1	0
5.* Others (MRDV, MSV, MCDV)			

* Diseases that are temperate or unknown in this region

** Scale: 0 = absent or rare; 1 = minor importance; 2 = moderate importance; 3 = major importance

(Credits in text: B.L.Renfro, A. Ortega, C. de Leon)

Table 3. Resistance to MMV among 62 races of maize under natural epiphytotics in Hawaii, 1970-1977. Percent infected plants in parentheses.

MEXICO (23 total races)	
Arrocillo Amarillo	SUSC (100%)
Bolita	SEGR (65%)
Cacahuacintle	SUSC (100%)
Chalqueno	SUSC (100%)
Chapalote	SUSC (95%)
Celaya	SUSC (95%)
Comiteco	SUSC (90%)
Conico	SUSC (100%)
Conico norteno	SUSC (100%)
Harinoso de Ocho	SUSC (100%)
Nal-Tel (13 acc)*	SUSC (90%)
Jala	SUSC (100%)
Olotillo	SEGR (60%)
Palomero Toluqueno	SUSC (95%)
Pepitilla	SUSC (95%)
Reventador	SUSC (95%)
Tabloncillo	SUSC (100%)
Tehua	SUSC (100%)
Tepecintle (8 acc)	SUSC (95%)
Tuxpeno	SUSC (95%)
Vandeno	SUSC (100%)
Zapalote Grande	SUSC (100%)
CENTRAL AMERICA (11 total races)	
Dzit-Bacal	SUSC (85%)
Imbricado	SUSC (80%)
Oloton	SUSC (90%)
Salpor	SUSC (90%)
San Marceno	SUSC (100%)
Salvadoreno	SUSC (90%)
CARIBBEAN (7 total races)	
Chandelle (=Canilla)	RES (25%)
Coastal Tropical Flint	RES (35%)
Cuban Flint (=Argentino)	RES (20%)
Early Caribbean	RES (10%)
Haitian Yellow	RES (15%)
St. Croix	RES (40%)
Tuson	RES (35%)

COLOMBIA & VENEZUELA (26 total races)	
Amagaceno (2 acc)	SUSC (95%)
Andaqui	SUSC (90%)
Cabuya	SUSC (100%)
Cacao	SUSC (90%)
Cariaco	SUSC (95%)
Chococeno (3 acc)	SUSC (100%)
Clavo (3 acc)	SUSC (95%)
Comun (3 acc)	SUSC (95%)
Costeno (2 acc)	SUSC (95%)
Guirua	SUSC (85%)
Montana	SUSC (90%)
Maiz Dulce	SUSC (95%)
Negrito	SUSC (95%)
Pira	SUSC (100%)
Pollo	SUSC (90%)
Puya (2 acc)	SUSC (85%)
Puya Grande	SUSC (80%)
Sabanero (2 acc)	SUSC (90%)
Yucatan	SUSC (95%)
OTHER SOUTH AMERICA (103 total races)	
Avati Moroti	SEGR (60%)
Avati Djakaira	SUSC (95%)
Caingang	SUSC (95%)
Canario de Ocho	SUSC (90%)
Calibaqui	SUSC (85%)
Cateto	SUSC (85%)
Coroico	SUSC (100%)

* acc = accessions, diverse original collections of the race.