Plant Diseases: How They Affect Global Food Security, and How They Are Affected by Anthropogenic Change

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But losses can be much higher when:
• Pathogens are newly introduced
• Weather conditions are optimal
• Crops are grown in large-scale monoculture
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Humans cause:
- Frequent transport of plants and microbes
- Climate change (temperatures & rainfall)
- Expanding, industrial-scale farming
Some High-Impact Crop Epidemics

**Stem rust of wheat: Biblical times – present** (widely planted crop, mobile and rapidly evolving pathogen; big concern about aggressive new race Ug99)

**Irish potato famine: 1846-48** (widely planted genetically uniform crop, pathogen introduction, cool wet weather)

**Southern Corn Leaf Blight: 1970** (widely planted crop, genetically uniform at one locus, selected for a virulent variant of an existing pathogen)

**U.S. Citrus Greening Epidemic: 2005 – present** (genetically uniform crop, introduced vector, then introduced pathogen)
**Types of Crop Pathogens**

- Fungus: 30%
- Bacterium: 16%
- Phytoplasma: 4%
- Nematode: 1%
- Virus: 47%
- Unknown: 2%

**Factors Driving Crop Disease Emergence**

- Introductions: 56%
- Weather: 25%
- Farming techniques: 9%
- Change in vector population: 7%
- Recombination: 2%
- Habitat disturbances: 1%
Best way to manage plant diseases: breed for disease resistance
Banana *Xanthomonas* Wilt in East Africa

A widely planted crop selected for an emerging pathogen
Bananas:

World’s 4th most important food crop

Less than 10% are grown for export; 90% are locally consumed

• Nutritious
• Productive
• Adaptable
Sub-Saharan Africa grows 1/3 of the world’s bananas
Bananas supply 30-60% of daily calories in Uganda, Rwanda & Burundi
Bananas are also a major source of cash income
Each Ugandan eats ~ 500 lbs of bananas a year.
In East Africa bananas are boiled, then mashed. This is matoke – also means food.
In 2001 a new banana disease appeared in Africa:

**Banana Xanthomonas Wilt, or BXW**
Symptoms of BXW:

- Yellowed, dying leaves
- Early fruit ripening
- Wilted male flowers
- Discolored, inedible fruits
The Guilty Party:

*Xanthomonas campestris pv. museacearum*, a rapidly emerging new pathogenic bacterium
Bacteria ooze from flowers & cut stems, are easily transmitted by pollinators & machetes
Impact of BXW in the African Great Lakes Region:

Production loss estimated at 53%

~$8 billion over past 10 years

Cooking banana prices up by 40% in Uganda

Increased hunger
A dying banana plantation is a family catastrophe:

- Food insecurity
- Internal migration
- Kids leave school
What was the origin of this new disease?
Ensete, native to Ethiopia, grown for its starchy roots
Ensete wilt, a minor disease found in Ethiopia in 1968
Inside infected Ensete stems……
Inside infected Ensete stems……
Genomes of BXW pathogen and an archived ensete wilt strain revealed:

Genomic footprint of an emerging pathogen: *X. musacearum* clearly descended from the ensete wilt pathogen

Studholme et al 2010 FEMS Microbiol Lett
Coffee Rust In Latin America

A little warmer and wetter was all it took
Coffee: Beloved Drug & Cash Crop

• 2nd most valuable commodity of developing countries, after oil.
• Global value ~$80 B/yr
• 16.1 B lbs produced worldwide
• Americans drink 22 gallons/yr/capita
• Grown in 50+ countries, all in the tropics
• ~25 million farmers
• Fair trade / organic has improved the lot of small coffee farmers
Coffee is produced in tropical highlands: it needs rich soils and cool nights.
Coffee is adapted to grow in shade, under forest canopy. High-quality Arabica coffee is shade-grown.

Sun tolerant varieties are lower-quality, but more profitable.
Coffee Is Grown in Biodiversity Hotspots

Shade-grown coffee preserves habitat
Coffee’s Historic Migrations: Ethiopia to Arabia
Coffee’s Historic Migrations: Ethiopia to Arabia to India
Coffee’s Historic Migrations: Ethiopia to Arabia to India to France
Coffee’s Historic Migrations: Ethiopia to Arabia to India to France to England
Coffee’s Historic Migrations: Ethiopia to Arabia to India to France to England to Ceylon ... 

Rapidly became extremely valuable crop for British colonial entrepeneurs
Coffee’s Historic Migrations: Ethiopia to Arabia to India to France to England to Ceylon ...

1869: Coffee rust disease decimates British plantations in Ceylon; economy collapses; British plant tea
Coffee Rust disease, caused by the wind-borne fungus *Hemileia vastatrix*

Causes rapid defoliation & death of trees

Obligate parasite; favored by monoculture

Fungal spore
Fungal spores emerge from a coffee leaf stomate

http://bioinformatics.cenicafe.org/
Coffee’s Historic Migrations: Ethiopia to Arabia to India to France to French West Indies to Brazil to Central America...

Now the most valuable export commodity for many Latin American countries
Coffee is popular & profitable; humans quickly spread the fungus around the tropical world.
Quarantines kept rust out of Latin America until 1970... then fungicides controlled it, mostly
But now:

Coffee rust regains foothold

Researchers marshal technology in bid to thwart fungal outbreak in Central America.

BY DANIEL CRESSEY

Where there is coffee, there is ‘coffee rust’. But the long stalemate between growers and the fungus behind the devastating disease has broken — with the fungus taking the advantage. As one of the most severe outbreaks ever rages through Central America, researchers are reaching for the latest tools in an effort to combat the pest, from sequencing its genome to cross-breeding coffee plants with resistant strains.

Caused by the fungus *Hemileia vastatrix*, coffee rust generally does not kill plants, but the Institute of Coffee of Costa Rica estimates that the latest outbreak may halve the 2013–14 harvest in the worst affected areas of the nation. This outbreak is “the worst we’ve seen in Central America and Mexico since the rust arrived” in the region more than 40 years ago, says John Vandermeer, an ecologist at the University of Michigan in Ann Arbor, who has received “reports of devastation in Nicaragua,...
Colombia 2008-10: Major Rust Outbreak

- Atypically warm, wet years
- Affected 33% of trees; serious losses
- Led to planting of rust-resistant hybrids of lower quality
- Growers planted more sun-tolerant coffee (easier to spray)
Increased rust in Central America in 2011, then a big epidemic in 2012-13

- 20% yield decline across Central America
- Production down 2.7 million bags
- $550 million in direct economic loss
- 374,000 jobs lost
- Guatemala, Nicaragua, Honduras, and Costa Rica declared state of emergency in 2013
- Losses likely to be higher next year
- Some small growers & co-ops went bankrupt
- It was a good coffee year in Indonesia
Rust has been in the Americas for over 30 years, but has never before affected > 5% of the crop

*What changed?*

- Genetic & virulence analyses found no new pathogen strain
- Average temps ~1.5°C higher; more and earlier rainfall
- Disease at higher altitudes than ever before
- Small-scale & organic shade-grown growers hit especially hard
First Int’l Emergency Coffee Rust Summit (held in Antigua Guatemala 18-19 April 2013)

“Rust was the explosive, but climate change was the detonator”

First plant disease epidemic caused by global warming?