TROPICAL FRUIT CROPS AND THE DISEASES THAT AFFECT THEIR PRODUCTION

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Summary

Tropical fruits are important components of natural ecosystems. A limited number of the thousands of species that exist are important to humans, and only 50 or so are significant commercial products. Diseases affect all of these crops. The pathogens are

all in the Eubacteria or Eukaryota. The Eubacteria include single-celled pathogens without cell walls (the Mollicutes), or with Gram-positive (the Firmicutes) or Gram-negative cell walls (the Proteobacteria). Important Mollicute pathogens of tropical fruit include the phytoplasmas, and of the Proteobacteria include species of *Erwinia*, *Pseudomonas*, *Ralstonia*, *Xanthomonas* and *Xylella*. Multicellular pathogens in the Eukaryota are most important, and include the predominant fungi; species in the Ascomycota (*Botryosphaeria*, *Ceratocystis*, *Fusarium*, *Glomerella* and *Mycosphaerella* are common genera) and Basidiomycota (e.g. *Armillaria*, *Erythricium*, *Ganoderma* and *Rigidioporus*) (together they comprise the Subkingdom Dikarya) are more numerous and important than all other groups of pathogens combined. Other eukarotic pathogens include the fungus-like oomycetes (e.g. *Phytophthora* and *Pythium* spp.), nematodes (*Meloidogyne*, *Pratylenchus*, *Radopholus*, and *Rotylenchus* spp. are most important), parasitic plants (especially the green alga, *Cephalueros*) and protozoa (*Phytomonas*). Nucleic acid-based pathogens, the viruses (single- or double-stranded RNAs or DNAs encased in protein or lipoprotein envelopes) and viroids (nonenveloped molecules of a few hundred nucleotides) are also important, but have unclear affinities to the above life forms. Among the most damaging are *Banana bunchy top virus*, *Citrus triztesa virus*, *Papaya ringspot virus* and *Coconut cadang-cadang viroid*. The epidemiology of these diseases influences what strategies are used in their management. When they are available, disease-resistant host genotypes are often efficacious and cost-effective. These diseases are also managed with disease avoidance, exclusion, eradication and protection. Integrated combinations of these strategies are often needed to effectively manage these problems.

1. Introduction

Thousands of fruit species exist in the tropics, most of which are important components of tropical ecosystems. Some, such as figs, are keystones that influence community structure, the composition and abundance of associated taxa, and the survival and reproduction of community species. Many tropical fruit species are significant food and habitat resources. Complex and interdependent webs of fauna and flora are common in tropical systems, and species of plants that produce fruit play prominent roles.

Considered in this chapter is a small subset of this important group of plants, those that produce fruit whose pulp, mesocarp or juice are consumed by humans. Only about 300 of these fruits are considered major, and 50 are well known and important commercially. All of these crops are Angiosperms, and with the exceptions of members of the Magnoliid complex (i.e., annonas and avocado) and a handful of Monocots (banana, coconut, date, peach palm and pineapple), the important species are all Eudicots (tricolpates) (Table 1). Some of these plants, such as coconut and cashew, produce edible fruits but are also significant sources of other products (respectively, oil and fiber, and nuts). And other tropical plants that produce fruits are not considered here since their pulp or mesocarp are not significant; for example, only the seeds of cacao and coffee are important, and only the oil from the fruit of the African oil palm is utilized.

Few of these fruit are important foods, either locally or globally. Only a dozen or so of the major crop plants worldwide are tropical fruit. Rather than great economic or food

importance, they provide dietary variety. They are often nutritious and are usually significant sources of vitamins. They also contain important minerals and carbohydrates, and some, such as avocado, are uncommon botanical sources of fat.

To the nutritional and organoleptic attributes of tropical fruits one must add their monetary value and international significance. The annual production of six of these fruit exceeds 2 million metric tons, and another dozen or so are marketed worldwide (Table 2). In international trade, tropical fruit and their associated products have an aggregate annual value of ca US$20 billion. More significant, however, is their value in local markets and situations.

Only small percentages of most tropical fruits are exported outside the producing countries. About 2.5% of all mangos and papayas are exported, and exported quantities of other important tropical fruit, such as durian and mangosteen, are probably lower. In some cases, processed products are significant. For example, more pineapple is shipped in cans than as intact fruit, and about one-third of all citrus fruit is processed as juice.

Crop	Total production (MMT)[b]	Export production	
		Quantity (MMT)[b]	Value (millions US$)
Citrus, mainly *Citrus* spp.[u]	104.78	13.35 (12.7%)	8,655
Banana, *Musa* spp.[v]	89.44	15.1 (16.9%)	4,835
Coconut, *Cocos nucifera*[w]	48.15	2.59 (5.4%)	1,319
Mango, *Mangifera indica*[x]	25.0	0.61 (2.4%)	397
Pineapple, *Ananas comosus*[y]	13.26	2.47 (18.6%)	1,818
Papaya, *Carica papaya*	5.23	0.14 (2.7%)	90
Avocado, *Persea americana*	2.22	0.28 (12.6%)	361
Passion fruit, *Passiflora* spp.	1	n/a	n/a
Carambola, *Averrhoa carambola*	0.5	n/a	n/a
Tropical fruit[z]	n/a	0.13	93

[t]Production figures are in millions of metric tons.
[u]Includes fruit of all *Citrus* species, their hybrids, and kumquat (*Fortunella* spp.), a citrus relative. Export figure is for fresh fruit, fruit products, juice and juice concentrate.
[v]Includes both banana and plantain, which is a type of banana. Export figure is for fresh fruit only.
[w]Export figure is total for coconuts, coconut cake, desiccated coconut, coir, copra and coconut oil.
[x]Export figure is total for fresh fruit, juice and pulp.
[y]Export figure is total for canned fruit, fresh fruit, juice and juice concentrate.
[z]Export figure is total for fresh fruit of several different crops for which individual production figures are not available.

Table 1. 1999 production statistics for major tropical fruit crops[t]

The most notable tropical fruit is banana. Over 100 million metric tons are produced annually, and it is the world's fourth most valuable food after rice, wheat and milk (more citrus fruit are produced, but their total value is lower). As for most tropical fruit, a relatively small percentage of the bananas that are produced every year is exported. About 85% of the harvested total is consumed in the producing countries. For many people in Africa, the Americas and Asia, banana is a staple.

	Order	Family (subfamily)	Crop(s), taxa	Center of origin[v]	Major production areas
Magnoliid complex	Laurales	Lauraceae	avocado, *Persea americana*	Tropical America	Mexico, USA, Indonesia, South Africa, Chile
	Magnoliales	Annonaceae	*Annona* spp., cherimoya, ilama, soursop, sugar apple, custard apple; *Rollinia pulchrinervis*, biriba	Tropical America	Tropics
Monocots	Arecales	Arecaceae (Palmae)	peach palm, *Bactris gasipaes*	Central America	Tropical America
			coconut, *Cocos nucifera*	Southeast Asia	Philippines, Indonesia, India, Sri Lanka
			date, *Phoenix dactylifera*	N. Africa, Middle East	Iraq, Iran, Egypt
	Poales	Bromilaceae	pineapple, *Ananas comosus*	South America	Thailand, Philippines, Brazil
	Zingiberales	Musaceae	banana[y], *Musa* spp.	Southeast Asia	Tropical America, Africa
Eudicots (tricolpates)	Caryophyllales	Cactaceae	pitaya	Tropical America	Vietnam, Tropical America
	Oxalidales	Oxalidaceae	carambola, *Averrhoa carambola*	Southeast Asia	Tropics
	Malpighiales	Malpighiaceae	Barbados cherry, *Malpighia glabra*	West Indies, South America	Tropical America
		Clusiaceae [aka Guttiferae]	mangosteen (*Garcinia mangostana*	Southeast Asia	Asia
		Passifloraceae	passionfruit, *Passiflora* spp.	Tropical America	Tropical America
	Rosales	Rosaceae	loquat, *Eriobotya japonica*	China	Subtropics, tropical highlands
		Moraceae	breadfruit, chempedak, jackfruit, etc., *Artocarpus* spp.	Polynesia	Polynesia
			fig, *Ficus carica*	Southern Arabia	Turkey, Egypt, Greece,

					Iran, Morocco
	Myrtales	Myrtaceae	Surinam cherry et al., *Eugenia* spp.	Tropical America	Tropics
			jaboticaba, *Myrciaria cauliflora*	Brazil	Tropical America
			guava, *Psidium guajava*	Tropical America	global
	Brassicales	Caricaceae	papaya, *Carica papaya*	Central America	Brazil, Nigeria, India, Mexico, Indonesia
	Malvales	Malvaceae	durian, *Durio zibenthinus*	Southeast Asia	Southeast Asia
	Sapindales	Sapindaceae	longan, *Dimocarpus longan*, lychee, *Litchi chinensis*, and rambutan, *Nephelium lappaceum*	Southeast Asia	Tropics
		Rutaceae	citrus, *Citrus* spp.	Southeast Asia	USA, Brazil
		Anacardiaceae	cashew, *Anacardium occidentale*	tropical America	tropical America
			mango, *Mangifera indica*	India, Southeast Asia	India, China, Mexico, Thailand, Pakistan
			Hog plum, mombins, *Spondias* spp.	tropics	tropics
	Ericales	Sapotaceae	Caimito, *Pouteria caimito*	South America	Tropical America
			Sapodilla, *Manilkara zapota*	Central America	Tropical America
			Mamey sapote, *Pouteria sapota*	Mexico, Central America	Tropical America
		Actinidiaceae	kiwifruit (Chinese gooseberry), *Actinidia deliciosa*	Southern China	New Zealand, Chile
		Ebenaceae	persimmons, *Diospyros* spp.	diverse	global
	Solanales	Solanaceae	naranjilla, *Solanum quitoense*	South America	South America

[x] Taxa are listed based on their phylogenetic relatedness.
[y] Probable center of origin in which the crop evolved and primary center of diversity occurs.
[z] Includes plantains, as well as dessert and cooking bananas.

Table 2. Taxonomy, origins and production zones of the major crop plants[u]

2. Significance of Diseases

Diseases are often the most important constraint to the production of tropical fruit. They indirectly reduce yields by debilitating the plant, and directly reduce the yield or quality of fruit before and after they are harvested. They range from esthetic problems that lower the marketability of the harvested product to lethal problems that devastate local or regional production.

Virtually every important tropical fruit is affected by one or more serious diseases. Diseases determine how and where a crop is produced, what post-harvest treatments are utilized, in what markets the crops are sold, and whether production is sustainable and profitable.

3. General Categories of Plant Pathogens

Infectious diseases of plants, i.e., conditions that disturb or harm their normal growth or development, are caused by diverse pathogens. Among the prokayotes, i.e., organisms that lack a nucleus or nuclear envelope, only the Domain Eubacteria contains plant pathogens; none are known in the Archaea (formerly the "archaebacteria") (Figure 1). Pathogens in the Eubacteria include single-celled microbes without cell walls (the Mollicutes), or with Gram-positive (the Firmicutes) or Gram-negative cell walls (the proteobacteria). The Eubacteria are more phylogenetically diverse than the relatively complex pathogens in the Domain Eukaryota (there is inverse correlation between genome size and an organism's ability to evolve). However, those in the Eukaryota predominate as plant pathogens. They include an array of multicellular life forms, including fungi, fungus-like oomycetes, nematodes, parasitic plants and protozoa.

A third group of pathogens, referred to here as nucleic acid-based pathogens, have unclear affinities to the above life forms. Viruses are single- or double-stranded RNAs or DNAs that are usually encased in protein or lipoprotein envelopes. They are simple pathogens, with genomes of a few thousand to a million nucleotides (nt) that encode 1 to 12 proteins; they replicate only within living cells of their hosts. Even simpler are the viroids, which are the smallest of all infectious disease agents. They are circular, nonenveloped molecules of a few hundred nucleotides, and a tropical fruit, avocado, is the host of the smallest of these pathogens, *Avocado sunblotch viroid* (246-250 nt).

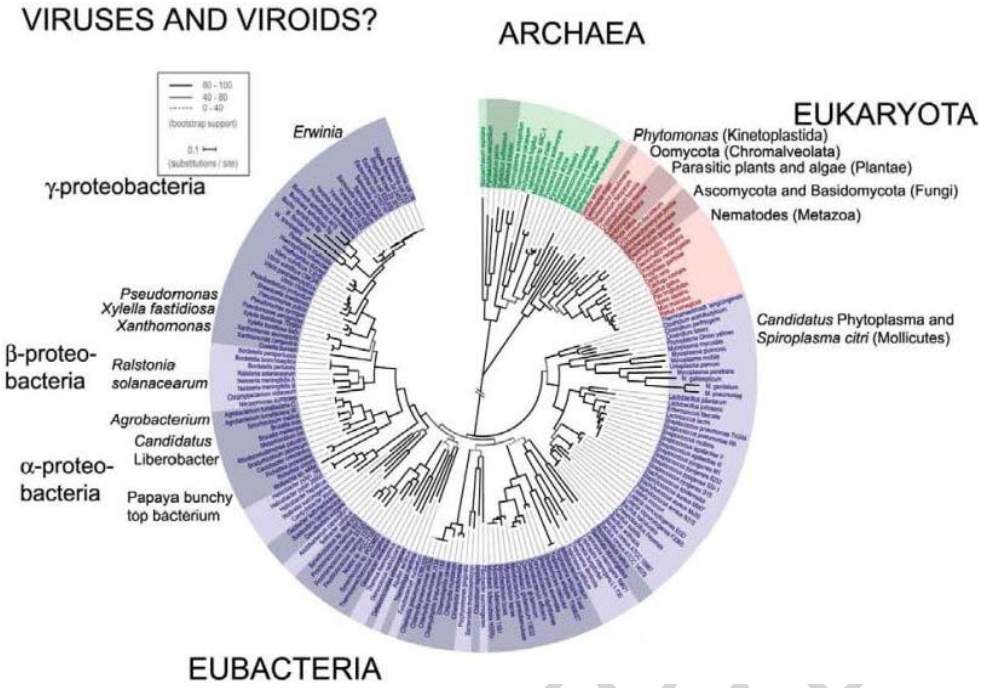

Figure 1. Phylogenetic placement of different groups of plant pathogens. Groups are superimposed on a tree of life that was generated for 191 taxa and 31 genes for which lateral gene transfer had not occurred. Amended from fig. 2 in Ciccarelli et al. 2006 with permission from Peer Bork.

4. Tropical Fruit Pathogens and the Diseases that they Cause

Fungi are the most prevalent and important plant pathogens. In descending order, significant but less frequent diseases are caused by viruses, bacteria, oomycetes, nematodes, phytoplasmas, viroids, parasitic plants and protozoa. In the following sections are described representative pathogen taxa and the diseases that they cause on tropical fruit. They are listed in the phylogenetic hierarchy that is noted in Figure 1. This list is followed with a brief discussion on disease interactions, and the chapter ends with an overview of the epidemiology and management of these diseases.

Fundamental to understanding these disease problems is the host:pathogen interaction (i.e., the "pathosystem"). The different causal agents can be divided into two categories, generalists and specialists. Generalists impact diverse host taxa. Examples include pathogens that affect seedlings ("damping-off" oomycetes, such as *Pythium* spp., and fungi, such as *Rhizoctonia solani*, are examples) and fruit (such as the soft-rotting γ-proteobacteria in the genus *Erwinia*). There is usually no host resistance to diseases that are caused by the generalists. Host-specific pathogens impact far fewer host species than the generalists. They can often be classified as coevolved or new encounter, based on whether or not they have had an evolutionary history with their host(s) (Table 3). Host resistance to coevolved pathogens is common and has been used extensively in the management of the diseases that they cause. Since host resistance to the new encounter pathogens is available less frequently, managing these diseases often relies on other measures (see below).

	Pathogen (disease)	
Crop	**Coevolved**	**New encounter**
avocado	**Sphaceloma perseae* (scab)	**Phytophthora cinnamomi* (phytophthora root rot)
banana	**Fusarium oxysporum* f. sp. *cubense* (Panama disease), **Mycosphaerella fijiensis* and *M. musicola* (Sigatoka leafspots)	**Ralstonia solanacearum* phylotype II (Moko disease), * *Xanthomonas vasicola* pv. musacearum (xanthomonas bacterial wilt)
citrus		**Candidatus* Liberibacter africanus, *Candidatus* Liberibacter asiaticus and *Candidatus* Liberibacter americanus [huanglongbing (greening)]
coconut		*phytoplasmas (lethal yellowing, Awka wilt, coconut lethal disease, etc.), *Bursaphelenchus cocophilus* (red ring), *Phytomonas* (hart rot),
mango	**Fusarium mangiferae* (malformation)	**Fusarium sterilihyphosum* and **Fusarium* sp. (malformation); **Ceratocystis manginecans* (seca, sudden wilt)
papaya		**Papaya ringspot virus* (papaya ringspot), **Phytophthora palmivora* (fruit, root and stem rot), **Candidatus* Phytoplasma australasia (papaya dieback, yellow crinkle and mosaic)
pineapple	**Fusarium guttiforme* (fusariosis)	

Diseases marked with an asterisk are serious production constraints.

Table 3. Selected coevolved and new encounter pathogens of tropical fruits.

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Biographical Sketch

Randy C. Ploetz graduated from Purdue University in 1974 with a B.Sc. in Forestry and in 1976 with a M.Sc. in Plant Pathology. In 1984, he received a Ph.D. in Plant Pathology from the University of Florida, and in 1986 joined the faculty at the university's Tropical Research and Education Center. He was promoted to professor in 1996, and received the University of Florida Research Foundation Professor Award in 2004 and the International Service Award of the American Phytopathological Society in 2008. Randy was Editor-in-Chief of APS Press from 2000 to 2002, a Senior Editor on that editorial board from 1995 to 2000, and an Associate Editor for *Phytopathology* from 1995 to 1997. He is a former President of the Florida Phytopathological Society and former Vice-President and managing Editor for refereed papers for the Florida State Horticultural Society. He has written over 300 publications on tropical fruit diseases, edited/written four books, and is writing a two-volume book for Springer-Verlag, *Tropical Plant Pathology*.