More Diseases* on Crops in the Tropics than in the Temperate Zone

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The work and development of phytopathology in the world is modern, progressive and far advanced. More publication of results comes from the temperate zone, however, than from the tropics. Much of the tropic zone (see definitions of it by such as Garbell (7), Hopkins (13), Köpen (15), Price (18), and Supan (22) is still frontier and difficulties hamper plant disease study. One of the problems is the fact that at least in the American tropics there are large numbers of diseases requiring attention from a modest supply of trained plant pathologists.

The tropics referred to in this paper is the American tropics (Neotropics), which includes as its core agricultural Latin America which is well described and mapped by U. S. Foreign Agricultural Service (4) workers. Confines of the whole Neotropics which is of great extent, are represented in the accompanying sketch map (Fig. 1). The American tropics employs in its agriculture more species of crop plants than are grown in the temperate zone, and in general tropical climates are well suited both to crops and plant diseases. The irregular shape of the outlines of this vast region follows ecologic delimitations. It includes much more than what is within dictionary definitions of the word "tropics" that can be given as: the part of the earth between the hypothetically drawn straight lines of the tropics of Cancer and of Capricorn, at distances of 23° 28′ north and south of the geographical Equator.

The thermal equator, also called the heat equator (13, 15, 19, 20, 22), as it occurs on the western hemisphere slants downwards from north to south, not following the geographical Equator and only touching it once, where they cross. The broad region of the Neotropics is a band with its more or less central line the thermal equator. Its north and south edges are limited to where there is year round growth of such freezing-sensitive plants as palms (27).

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* The diseases referred to are those listed, see footnote 2, and seen caused by viruses, bacteria, fungi, phanerogams, algae, lichens, a few minor element difficulties, and nematodes. With respect to the latter, comparisons have not been carried on as to whether there are more species in the tropics and whether there are more individuals although some believe it is probable. In the coolest agricultural regions of the United States this great class of parasites tends to be of less significance than in warmer places farther south. It is certain that nematode attack is very much more drastic in the warm tropics, and even in such a state in the U.S.A. as Florida, than in the temperate zone.

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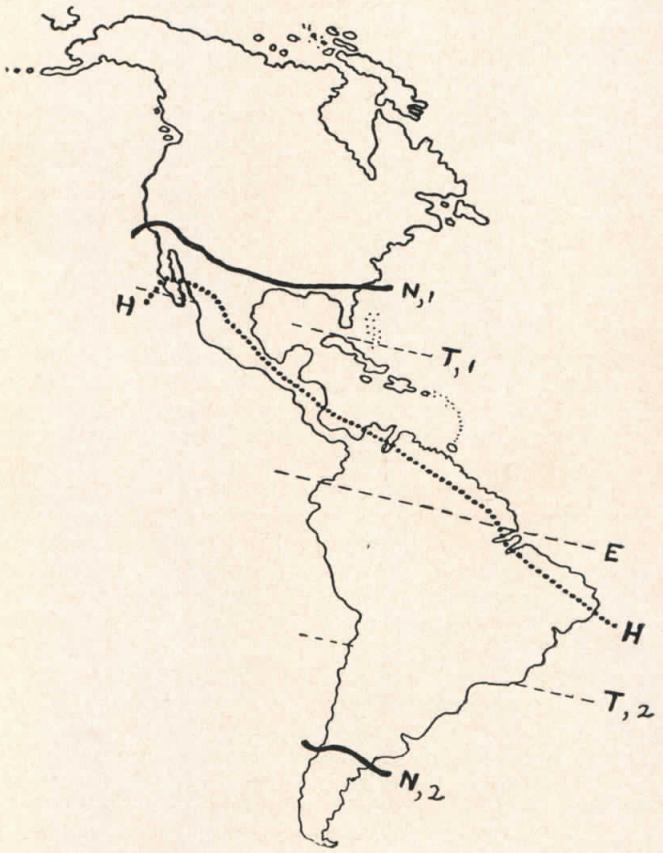

Fig. 1.—Sketch map of the western hemisphere. N: Natural approximate dividing line between region dominated by annual seasons of cold (winter) and region without such severe effect. T: Tropics of 1. Cancer, 2. Capricorn: H: Heat or thermal equator, see citations 13, 15, 19, 20, 22.

This region, particularly the specifically Latin American part, is of critically increasing importance in world affairs (Cole (1), Frei Montalvo (6), Gordon (8), Guerra and Feder (9), Inter-American Development Bank (14), while its agricultural production is lagging behind population and nowhere is this more sympathetically and dramatically discussed than in those words by Harrar (10, 11). A continual guarantee of increasing agricultural productivity is absolutely essential for our tropics. In the last analysis successful crop growth is only insured by the control and amelioration of plant diseases, so many of which are found in the tropics.

Observations on disease abundance

During 1929, in a few days of observations, the writer saw more kinds of diseases on tomato, cucumber, squash and corn crops in tropical Honduras than he had ever seen in temperate zone areas of the United States. To him, some of these tropical diseases were new and some more severe in effect than those he knew in the temperate zone.

During 1931-34, diseases on vegetable crops in Florida were observed as especially numerous in comparison with states farther north. An interesting feature was that a crop growing in the coolest part of the state had fewer diseases, and many of them less severe, than was seen in the same crop in south Florida, where it is warmer and more moist. The coolest area has a type of weather that is like the continental type in the temperate zone. In the more extreme south the situation takes on characteristics of warmth, along with effects of the moisture-laden east wind that sweeps in off the Gulf Stream. This results in weather components that in south Florida are like the tropics and these definitely increase plant diseases (24, 25, 26).

In the summers of 1937 and 1939, notes were made in the temperate zone (Maryland, U.S.A.) on diseases of tomato, *Lycopersicon esculentum* Mill. From what was seen in visits during early, medium and late season, on over 40 acres of unsprayed plots in 17 scattered fields, there were 32 diseases. A few years later, 1944, a survey for diseases was made during part of one day in a 2-acre field of unsprayed Marglobe tomatoes in the tropics in El Salvador. In a short time 52 diseases were identified. Subsequently, after some years of gathering published and unpublished reports, it was evident the probable total number of tropical diseases[2] on tomato is close to 278 (see table 1).

At various times during 1922-27 in Wisconsin, U.S.A. in about 20 large fields of cabbage, *Brassica oleracea* var. *capitata* L., it was possible to find at intervals 9 diseases. In two days of surveys in 7 small truck gardens growing near sea level in Panama, in 1949 and in 1954,

FOOTNOTE 2. Total numbers of tropical diseases given for this and for other crops are results from work now in preparation (17) on a text «Neotropical Phytopathology. Vol. II. Lists of Diseases on Important Economic Crops.» A few hundred published references and other sources represent what is being used, and the large number of citations that would give the literature on it are not appended under the section *Literature Cited* in the present paper because of space limitations.

TABLE 1. *Numbers of diseases on certain important crops grown widely under relatively intensive conditions of cultivation.*

Crop grown	Numbers of diseases attacking in: Temperate zone Total	Tropics Total	Tropics Most severe[a]
Brassica oleracea capitata (cabbage)[b]	43	36	2
Citrus spp. (orange and relatives)	50[c]	248	14
Cocos nucifera (coconut)	—	35	3
Coffea spp. (coffees)	10	385-400	13
Cucurbita pepo (pumpkin-squash)	19	111	9
Ipomoea batatas (sweetpotato)	15	187	9
Lycopersicon esculentum (tomato)	32	278	20
Musa acuminata (banana)	8[c]	180+	10
Oryza sativa (rice)	54	550-600	16
Phaseolus vulgaris (beans)	52	253-280	25
Saccharum officinarum (sugarcane)	35-56[c]	450+	20
Solanum spp. (potatoes)	91	175	14
Theobroma cacao (cacao)	—	52	6
Zea mays (maize)	85	125	15

a From personal classification.
b Crop grown with great difficulty in warm tropics.
c Results from southernmost states in Continental U.S.A.

disease was common and it was easy to find 18 cabbage diseases. During the same period in 1954, 3 other small cabbage fields were visited in Panama growing at 300 feet elevation, in which 22 diseases were identified. Some years later, a restricted planting of cabbage was seen in a tropical valley in Costa Rica, grown between rows of bananas for shade, and in an area of much less than one acre 36 diseases were observed.

Plant diseases numerous in the tropics

During over 25 years diseases were searched for on trees of coffee, *Coffea* spp., brought to various points in the temperate zone. The several thousand individual tree seedlings examined were growing under the abnormal conditions necessary to their survival where winters occur: in central Europe and eastern U.S.A. in greenhouses, in Portugal and Florida in wind-and frost-protected slat houses. In all of these trees 10 diseases were seen. Meanwhile in research and reading it was learned that in the tropics the total number of coffee diseases is large as indicated in table 1, and is between 385 and 200. On species of *Citrus*, where they grow at the southern edge of the temperate zone U.S.A.[3], in Florida, Texas, Arizona and California there are about 50 diseases. In other producing areas of the tropics, from the West Indies to Argentina, on citrus the total disease number is close to 248.

Rice, *Oryza sativa* L., in the U.S.A. (Arkansas, Texas, Louisiana, Florida, California) is reported to have about 54 diseases. However, in lists from the world tropics the total number of diseases is near to 600. With beans, *Phaseolus vulgaris* L., it appears from the monograph by Zaumeyer and Thomas (29) that about 52 diseases are found on that crop in the U.S.A. From this authority, and in addition reports from other workers from Argentina to México, it is apparent tropical beans are subject to a total number of diseases of from 253 to 280.

Sugarcane, *Saccharum officinarum* L., is among the highly important crops that originated in the tropics and has been adapted to growth along the warmest edge of the temperate zone such as restricted areas in Florida, Georgia and Louisiana in the U.S.A. In plantings under those special, boderline ecological conditions of few occasional frosts, it has been found that the crop sustains attack from about 56 diseases. On reference to disease data and observations throughout the tropics including the Orient the total number of diseases that can be found on the crop under these conditions is close to 450. There are, of course, several other such specially important tropical crops with similar large numbers of diseases.

Certain crops seem to have fewer diseases

In some tropical crops the studies carried on have not resulted in reports of large numbers of diseases. It takes many workers with a

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FOOTNOTE 3. Plant disease numbers reported from the U.S.A. are largely based on listings by the U. S. Department of Agriculture (23), but include some in a few cases from other reports.

special type of interest in many parts of the world to make satisfactory and exhaustive disease surveys. This is specialized and meticulous work, requiring the best of training along with finest library and herbarium facilities. With so much other research needed on disease nature and control, little time has been available in some crop research for the detailed and almost endless apparently more academic studies of disease collections and mycological determinations.

For example in cacao, *Theobroma cacao* L., its plant pathology has been concentrated mostly in occurrence, distribution, and control of six highly destructive diseases all of which are capable of wiping out production unless controlled. Up to the present, wide spread disease collections from primitive areas has been economically impossible while still concentrating on the most critical problems of disease amelioration and control. Old and partly abandoned plantations that are richest in various undetermined disease attacks, many times approach conditions in the wild. Moreover, weed trees which grow mixed with abandoned cacao trees become as ragged and diseased as the ancient cacao, and in the tangle in nearby jungle and bush. In the wild, these are looked upon as something to be cut through or surmounted rather than to be studied mycologically. The same attitude readily carries over to planted, producing cacao. The writer found in some of his own work, the appearance of less spectacular blemishes, spots, defoliations, ragged growth, trunk decay, diebacks and other diseases, are so similar to the same effects in jungle that he di missed them for the time being as what might be expected and used his energy for the major problems. The writer believes, from all he has seen, that while at present reported cacao diseases total only about 52, the numbers that are actually present are many more and will someday be trebled at least if not quadrupled, when it becomes possible and feasible to carry on detailed mycological-pathological surveys.

Any pathologist-mycologist working through many areas looking at cut and fallen fronds of all ages from coconut palm, *Cocos nucifera* L., soon realizes that numerous kinds of infections occur that have never been determined. At present there are some 35 diseases considered affecting the crop in the Neotropics. The probabilities are that there are more likely to be upwards of a hundred that will be found by workers in the future. The oil palm, *Elaeis guineensis* Jacq., is another plantation tree holding its coar e fronds, or leaves, high above easy examination by pathologists. Because of its new position as an increasingly valuable agricultural crop in Latin America, there is only a small number, 15, of diseases thus far reported in it in our tropics. Another palm, the date, *Phoenix dactylifera* L., was introduced into the American tropics many years ago. It is of course a tropical tree producing under irrigation in desert conditions. It has not been planted in many parts where it seems possible it might do well in our tropics, but has had about 33 diseases listed on it thus far in the Neotropics. This small number is not the ultimate, for the writer himself has seen at least 4 more diseases than those reported.

Diseases obscured by technological changes

Some critically important tropical American food crops are currently undergoing so much change through use of special plant breeding methods and application of special technology in spraying, fertilization, herbicides, spacing, cleaner cultivation, mechanical growing and harvesting, foliage feeding and the like that they are now practically new crops. Through such applications, Latin Americans are swiftly making some of the most desired advancements, and much of it is being done before mycologists and pathologists in their less hurried fashions have exhausted all opportunities to study the widest range of diseases.

It is hardly expected that technological specialists could or would stop teamwork of pathologist-horticulturist-soils scientist-physiologist-geneticist-engineer to carry on detailed collections under all kinds of primitive conditions, develop herbaria, and make determinations on all kinds of possibly new disease attacks. Very many diseases are now being automatically circumvented by new technical applications on such as: the potato, *Solanum tuberosum* L. (*S. andigenum* Juz. & Buk.); on wheat, *Triticum aestivum* L.; on grain sorghum, *Sorghum vulgare* Pers.; on barley, *Hordeum vulgare* L.; on maize (corn), *Zea mays* L.; on rubber, *Hevea brasiliensis* Muell.-Arg.; and on some of the new special bananas, *Musa acuminata* L.

However, the question is had technology been slower, what might we have expected? In the case of potatoes there are reported a total of about 175 diseases and on maize there are about 125. Judging from what is believed to be the case, through observation and study on several other crops, the writer is inclined to think it probable these crops have had reported less than half the numbers of diseases that would attack them in the Neotropics.

There are many tropical crops, other than those mentioned, that are much diseased and with much more potential susceptibility than our present lists show. The large numbers of diseases in the Neotropics, combining those in published and unpublished lists, have been so impressive to the writer he has said (28) that for every one disease in the temperate zone there are probably 10 in the tropics. Indeed, there are no objectively paired studies to give exact information on this. However, it is the writer's personal judgement that this comparison is conservative.

Groupings of diseases

Although the diseases are so much more numerous in the tropics than in the temperate zone, certainly not all tropical diseases are equally dangerous. The writer finds he is driven to speculate on this, because economics and supply of trained scientists are limited so there cannot be exhaustive study on all disease possibilities. There has to be a basis for choice, as to what deserves the most of the available research attention. It is not possible to do more than give suggestions

TABLE 2. *Examples of organisms observed being "nudged out"[a] by secondary or parallel attack of other(s) that are not hyperparasites*

Primary parasite	Being "nudged out" by:	Disease involved
Cephaleuros minimis	**Diplodia theobroma**	Cacao, twig damage
Cephaleuros virescens	Pyrenomycete, undetermined	Lagerstroemia, leaf attack
Cercospora coffeicola	**Valsa**-like organism	Coffee, twig die-back
Cercospora hibisci	**Diplodia** sp. & bacteria	Jamaica sorrel, leaf spot
Colletotrichum sp.b/	**Colletotrichum** sp. c/	Hevea, leaf spot
Colletotrichum sp.	**Tryblidiella rufula**	Bougainvillea, stem disease
Dothidella parryi	**Gloeosporium agaves**	Agave, leaf spot
Erysiphe polygoni	**Diplodia** sp. & **Pestalotia** sp.	Bean, mildew
Fusarium oxysporum cubense	Soil bacteria	Banana, wilt (root attack)
Fusarium solani	**Diplodia** sp.	Sweetpotato, root rot
Helminthosporium sp.	**Xylaria (apiculata?)**	Guineagrass, culm attack
Hemileia sp.	**Penicillium** sp.	Orchid, petal attack
Marasmius perniciosus	**Schizophyllum commune**	Cacao, withches' broom (ageing)
Melanconium sacchari	**Nectria** sp.	Sugarcane, rind disease
Mycena citricolor	**Pestalotia funerea**	Cinchona, leaf spot
Nigrospora oryzae	**Cladosporium zeae**	Corn, dry ear rot
Pellicularia koleroga	**Fusarium (roseum?)**	Bungalan, thread blight
Sclerotium rolfsii	Bacteria and fusaria	Squash, soil rot
Septobasidium sp.	**Capnodium** sp. & **Pestalotia** sp.	Inga, felt disease (ageing)

a Replaced and overgrown.
b Slow growth type.
c Fast growth type

of differences. Although expressed as clear cut, the groups must be recognized only as approximations so long as there is still so much to be developed in the science of phytopathology in the Neotropics. In the first group, the writer thinks it possible that only three to five percent of all reported crop diseases in the Neotropic need to be classed as those that are the most severe. These are largely the diseases upon which plant pathologists are at work most conscientiously. These serious diseases are what may be considered the elite, the real killers, and the most limiting in the future of a crop. It is true the percentage is small, however, when based on a total that reaches a few hundred, the actual number is large of the active enemies needing detailed understanding and control on a crop to ensure it against failure.

There is a secondary group of diseases that makes up probably more than half of the total list. They are common sorts, often collected at times almost accidentally along with the first or the elite group. Members of both groups are widely distributed although the secondary types are thus classified because they are not so severe in effect, and usually are not spectacular killers. Crops appear to live with the latter and are more or less tolerant of their attacks. At times some may be disturbing under unusual conditions and when invading a planting at the time there is a large supply of aging tissue to infect. It is from this second group, probably, that there may come in the future the variants able to take positions among the elite disease producers.

In the writer's concept, another group is made up of those infrequent parasites, found here and there, and not always seen every year. In this tertiary group are the rarer types and those that are described but not common. This is a controversial group, no doubt. Some of these perhaps are from races of weak parasites that through mutation and accidental selection recently emerged as "taking the first step" towards becoming more common as disease organisms. Among these the writer includes at present certain types that appear to be able to replace by over running, or "nudging out", see table 2, other parasitic organisms. This group composes possibly 30 percent of the total number of listed disease producing agents.

There is a last, although best defined group of all, that appears in connection with disease determinations. This fourth category is of the few, but potentially helpful, hyperparasites. Their presence, naturally, tends to reduce severity of disease attacks. They have never been given the major attention they deserve in the tropics, and are practically forgotten in the temperate zone. It is estimated that hyperparasites may make up about 10 percent of a fungus list given in connection with a tropical crop if these organism can be specially collected. As results now stand the percentage is a small fraction of this.

Discussion

There is no doubt that compared with the temperate zone there are many more plant diseases in the tropics, as has been reviewed and as is seen with respect to specific numbers in certain cases in table 1. This situation is a recognized but not much discussed phenomenon.

It is of great importance both practically and academically, and the tropical plant pathologist may rely upon it as a true principle upon which he can depend. It serves to emphasize, as nothing else can, that phytopathologists have now, and will continue to have in the future, more responsibility for insuring crop production in the tropics than in any other region on earth.

The larger numbers of plant diseases in the tropics than in the temperate zone are for several reasons. In the tropics there is no yearly season of long severe freezing-dormancy to inhibit production of spores and other propagules, and there is no cutting down on the multitudes of generations of parasites; this unbridled multiplication allows much more chance of variation (mutations) that increases greater possibility of more species of disease organisms attacking wider host ranges. The tropics, with its ecological zones so close together in many places, and its plethora of variant hosts and variant parasites, allows far more probabilities, for occurrence of alternate hosts and for developing more sexual stages of fungi, than is found in the temperate zone. Every sexual fusion insures in spores resulting from it, more heterozygosity. This provides an opportunity for mixing of types and thus more chances of redistribution and envolving of new and different virulence races.

In the tropics, except in very limited and very special areas, growing vegetation is always present and there is a perpetually renewed supply of differently matured host tissues in the whole gamut from the very young through intermediate stages to the very old. Upon these various vegetative stages, parasites with differing requirements can find suitable situations for subsistence. As every botanist knows compared with the temperate zone, there are many more species of higher plants to serve as hosts in the tropics. The remarkable variability in morphology, physiology, and disease susceptibility normally present in a tropical plant community or formation, is likewise accompanied by just as remarkable variability with respect to species and types of tropical parasites as are normally to be found in and on the tropical plants.

The profound effects of differing environment is another reason plant diseases are so numerous in the tropics. Researchers and collectors, in less than a day of travel, can take advantage of passing through several distinct ecological zones in the tropics as has long been shown by numerous workers [e.g. Schimper (20), Köppen (15), Holdridge (12), Merriam (16), and Hopkins (13)], some of whom drew their conclusions before the beginning of the present century. Relatively few hundreds of feet of travel up and down tropical hillsides, and to a slightly different valley or mountain side exposure, discloses marked effect on local climates and so-called micro-climates. This is easily reflected in many and varying disease occurrences. Through the close juxtaposition of climatic differences it is possible to go readily in a few hundred feet, and thus quickly in less than a day's time, to various disease zones [e.g. Echandi (3), Fernandez-Valiela (5), Cox and Large (2), Roger (19), de Segura (21), Wellman (27)]. In comparison in

the temperate zone of the U.S.A. the same range of climate variations are found much farther apart. It often requires days of travel, maybe a thousand or more miles, to collect diseases of very great difference due to effects from the ecological zones. Plant and parasite occurrences are likewise greatly affected by soils and soil conditions, and these seem uniquely variable under tropical conditions.

Summary

Field observations on certain crops made in the temperate zone over many years and large fields, showed occurence of from 9 to 32 diseases, in the tropics examinations on comparatively much fewer plants in a very short time the same crops were seen to have 36 to 52 diseases. When extensive studies of many reports were consulted total numbers of tropical diseases in some cases were more than quadrupled. On consulting hundreds of lists and reports certain very well studied tropical crops have totals of from 250 to 600 diseases, certain others much less studied have only from 35 to 52. It is apparent technological advances may tend to obscure occurrence of some of the diseases in some crops. The large numbers of diseases can be grouped into categories: 1. About 3-5 percent are elite, the worst killers. 2. About half of all the diseases are less severe, common, often widely distributed. 3. Approximately 30 percent are more sporadic and some are apparently replacing others. 4. A last group is small, made up of hyperparasites. Several reasons are discussed respecting diseases being more common in the tropics than in the temperate zone. It appears evident, plant pathologists have much graver responsibilities to maintain healthy crop production in the tropics than any place else on earth.

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