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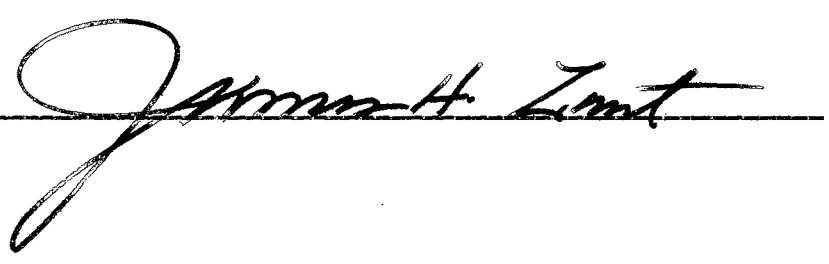
Scope of Report: This report has been designed to present the potential danger of the introduced plant pest, and the economic losses it can and has caused once it becomes established in our country. A plant pest, as defined in the Federal Plant Pest Act of 1957, includes the invertebrate animals, bacteria, fungi, and viruses that cause injury or damage to a plant or plant products. Within the framework of this definition, plant and animal taxa in which most of these important plant pests occur have been grouped according to their taxonomic relationship. A brief description of the pest and damage it causes is given under the group in which it occurs. Major emphasis has been given to the plant pest that has gained entrance into the United States from a foreign country, and its possible method of introduction whenever this information was available.

Conclusions: Our first line of defense against a foreign plant pest is to prevent its entry if possible. Any plant pest of little economic importance in its native habitat may become a serious pest if moved to a new area. Thus, introduced plant pests from foreign countries have caused the United States enormous economic losses.

The influence of man, as a carrier of plant pests, has sharply reduced the effectiveness of seas and oceans which in the past have somewhat excluded the introduction of these foreign invaders. As travel and transport grow in volume, cooperation from a well informed public, as to the potential danger of the introduced pest, will be essential if we are to stop the pest from penetrating our first line of defense.

ADVISER'S APPROVAL 

THE FOREIGN PLANT PEST

By

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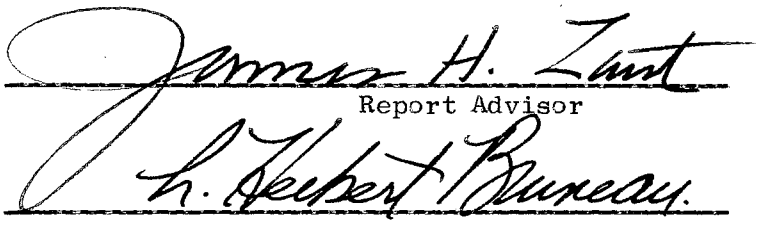

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Indebtedness is acknowledged to Drs. James H. Zant and Herbert L. Bruneau for their valuable guidance in the preparation of this report.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

More than fifty-percent of the serious economic crop pests of the United States are introduced species, the majority of which reached here through some man-made avenue of entry. The diversified crop and climatic conditions in the United States make us particularly vulnerable to plant pests. We have four defenses against these pests: (1) quarantine; (2) conservation of natural enemies; (3) environmental control; (4) chemical control. Of the above named weapons, all but "quarantine" are effective only after the plant pest has gained entry into the United States. In the constant war with these pests, it has been found to be better and cheaper to keep these invaders out than to have to fight those that get in.

The purpose of this report is to bring an awareness to the public of the enormity of the problem that is presented once a plant pest has penetrated our first line of defense (quarantine). Several incidents have been cited of a foreign plant pest being introduced through lack of information or an act of carelessness by the public to emphasize some of the consequences that can arise. The author has had some personal experience in this area, having been associated with Federal Plant Quarantine Service for several months. The author was amazed at the lack of foresight, knowledge, and understanding of a large section of our population in regard to plant pest dissemination.

Plant and animal kingdoms in which most of the important plant

pests are found have been classified. A further taxonomic breakdown is made when important pests are found primarily in only one class or order. Primary emphasis has been placed on introduced pests, and representative species given in this report have been selected for that purpose.

It is further believed that this essential information can best be presented in the biology classroom. Some students will have very little contact with this area of biology in study beyond highschool or in future occupations. Either for those who will continue in the broad field of biology or those who will not, each adult citizen will in some way play a role in plant pest control.

This report has not been designed to replace any part of the course curriculum but merely to supplement and reinforce an important area of biology. It is the opinion of the author that an informed citizenry is a vital part of our defense against the foreign plant pest.

CHAPTER II

PLANT PESTS VERSUS MAN

Man has always had his troubles with plant pests. When he first emerged as man, he was already pestered by flies, mites, and various other pests. In his early days, some organisms were of great help to him. Snails, grasshoppers, and similar forms of life could be found and eaten when other foods were not obtainable. Man's progress from primeval conditions was based primarily on changing various factors of his environment, and making it better suited for his own survival and increase. But, every change that has benefited man also benefited a host of other organisms. As man developed new weapons, and his primary enemies such as the leopard and tiger ceased to be a threat, plant pests became increasingly important as competitors to his way of life.

With increases in human population, large cities arose and it became necessary for man to increase his food supply. As man began cultivating crops for a source of food, plant pests which before had been of no real significance to him became a real menace. It permitted pests, which are in direct competition with man, to build up extensive populations. Among the earliest written records of man, the unmistakeable complaints of insects causing plagues show us clearly that they have shadowed the agricultural path of man since he first scratched the soil and planted seed. The Old Testament tells of plagues visited upon man in punishment of his transgressions. Three hundred years before Christ, Theophrastus was well familar with plant

diseases of his time, and in his writings we can recognize many of our plant problems of today.

As ancient times gave way pests continued to take their toll from the food supply. From time to time migration of whole populations were a result of disaster and famine caused by increased numbers of these pests. The story of a microscopic fungus which wrought havoc in Europe was equalled by few of Europe's many wars. In Ireland alone a quarter of a million people fell victim to starvation as whole fields of potatoes were destroyed by this fungus.

Man has a tendency to learn things the hard way. It took an epidemic which has practically exterminated one of our finest forest trees, the American chestnut, to awaken the United States to the dangers of an introduced pest. The chestnut blight fungus was a foreigner that sneaked into America from Asia. Starting its deadly work about 1904, it spread swiftly, destroying every chestnut tree in its path. Today there hardly remains a chestnut tree in the great forests of the East, which were once dominated by this tree. This disaster taught us what might be expected from unwelcome foreign pests; it was largely responsible for the establishment of the first National Quarantine Act of the United States.

Plant pest dissemination is influenced by many factors. Natural barriers which limit spread of plant pests include host selectivity of the pest, and climatic conditions. Conditional barriers include large water masses, desert areas, and mountain ranges. However, the influence of man as a carrier of plant pests has sharply reduced the effectiveness of seas, oceans, deserts, and mountains, particularly among those pests with weak natural means of dispersion. Many of these pests are such small forms of life they would have to be magnified

hundreds of times to be visible. If allowed free entry, such pests added to those we already have, would overrun farms and forests of this country. Agricultural products, from food to flowers, would soon be poor in quality or even scarce.

With the increased development of transportation to all parts of the world, organisms of many species have been carried to continents new to them. Here they have sometimes found favorable climates, ample acceptable cultivated hosts, and freedom from the natural enemies which kept their numbers in check in their original homes. Sometimes the results have been disastrous, for example, the entry of the European corn borer and the Japanese beetle into North America. These two species are of little importance in their native homes, but in the United States they have caused losses to crops in the magnitude of millions of dollars per year.

It is estimated that in 1952, each person in the United States paid out about one hundred dollars to cover damage caused by insects alone.[1] Most of this sum was paid by the increased cost of commodities of plant or animal origin, such as lumber, clothing, and food. Records of a few of the foreign plant pests that have brought trouble and loss to people in the United States are summarized below. These case histories and others that could be mentioned show that small incidents are enough to give these pests a destructive foothold.

Foreign Plant Pests That Have Invaded the United States

1. Name and nature of the pest.	European corn borer, Pyrausta nubilalis. Larvae of the moth feed on corn and certain

[1] Ross, Herbert H., A Textbook of Entomology (New York, 1959), p. 3-4.

other plants.

When and where found. — 1910, Massachusetts.

Arrived from where. — Southern Europe.

Start and consequences. — Broom factories in Massachusetts imported some broom corn infested with pinkish-brown worms in 1910. Seven years later, an agricultural experiment station scientist discovered this kind of worm infesting sweet corn in market gardens near Boston. Hiding in corn, the European corn borer spread until in 1949 its board bill reached an all time high of 350 million dollars. The borer is still in cornfields in 39 states.

2. Name and nature of the pest. — Japanese beetle, Popillia japonica. Grubs and adult beetles feed on over 200 kinds of plants.

When and where found. — 1916, New Jersey.

Arrived from where. — Japan.

Start and consequence. — A nurseryman who imported iris plants is believed to have introduced Japanese beetle grubs in soil balled around roots. This beetle caused little trouble in Japan, but in the United States it multiplied rapidly causing damage to foilage, flowering plants, fruit trees, ornamental plants and vegetable crops. In Eastern states, this pest costs nurserymen, farmers and city dwellers millions of dollars a year.

3. Name and nature of pest. — Pink bollworm, Pectinophora gossypiella. Eats the seed and damages the bolls of cotton.

When and where found. — 1917, Texas.

Arrived from where. — Mexico.

Start and consequence. — Oil mills in Texas presumably received some Mexican cotton-seed infested with the pink bollworm, a pest originally from

> India. The following year found the pest in cottonfields near the mills. In 1952 the pink bollworm cost our cotton growers 28 million dollars. The pink bollworm was introduced into Hawaii in 1909 and caused so much damage that the islands had to give up growing cotton.

Although at the present time the United States is faced with an overabundance of food, our present trend of population increase indicates food will be one of the vital problems of future generations. We are fighting an enemy who is threatening our future and such an enemy should be fought with the best available weapons. An informed public is one approach to a tightening defense against costly pest invasion.

CHAPTER III

TAXONOMIC GROUPING OF IMPORTANT PLANT PESTS

The definition of a plant pest, in its broadest sense, would include anything which affects the plant in such a way that man suffers economic loss. This would include environmental disturbances, which to a large extent are beyond human control. A more adequate definition for our present classification is given in the Federal Plant Pest Act of 1957. Section 102, part (c), defines a plant pest as: any living stage of: any insects, mites, nematodes, slugs, snails, protozoa, or other invertebrate animals, bacteria, fungi, other parasitic plants or reproductive parts thereof, viruses, or any organisims similar to or allied with any of the foregoing, or any infectious substances, which can directly or indirectly injure or cause disease or damage in any plants or parts thereof, or any products of plants.

Thus defined, plant pests may be classified into two large groups: pests found in the plant kingdom, and in the animal kingdom.

I. PESTS OF THE PLANT KINGDOM.

DIVISION: Chlorophyta (Green algae).

The algae are rarely plant pests but there are a few notable exceptions. The genus (Cephaleuros) is a green alga which contains several species of economic importance. The majority of algae are autophytes,

manufacturing their own food by photosynthesis.

DIVISION: Schizomycetophyta.

CLASS: Schizomycetes.

ORDER: Eubacteriales (Bacteria).

The bacterial plant pests are found primarily in two genera, Phytomonas and Erwinia. At least 150 genera of flowering plants, belonging to more than 50 families, are known to be subject to bacterial pests.

ORDER: Virales (Viruses).

The viruses are infectious plant pests that are invisible with the light microscope. They are highly contagious, causing some of the most important diseases of plants.

DIVISION: Eumycetophyta (True fungi).

Familiar examples of fungi are the blue, green, and black molds common on decaying foods. The fungi are a large group of plants, all of them without chlorophyll or other photosynthetic pigments. Therefore, all are dependent plants. There are four important classes of fungi:

CLASS: Phycomycetes (Downy mildews and bread molds).

CLASS: Ascomycetes (Powdery mildews).

CLASS: Basidiomycetes (Mushrooms, smuts and rusts).

CLASS: Deuteromycetes (Imperfect fungi).

The above named classes all have so-called perfect stages (sexual stages). In the case of the Duteromycetes, the sexual

stage is unknown or has been lost in evolution.

DIVISION: Spermatophyta.

CLASS: Angiospermae (Flowering plants).

SUB-CLASS: Dicotyledoneae.

Some higher plants have become fungus-like in that they are more or less dependent upon other plants for food. They attach themselves to roots and stems of suitable host plants and send haustoria (feeding organs) into the tissues, absorbing plant juices.

II. PESTS OF THE ANIMAL KINGDOM.

PHYLUM: Protozoa.

CLASS: Mastigophora (Flagellates).

Certain flagellates are found in the latex of milky plants. They are carried from one plant to another by insects, but important plant pests in the protozoa are rare or lacking.

PHYLUM: Aschelminthes.

CLASS: Nematoda (Roundworms).

The unsegmented roundworms are important plant pests found mainly in roots of plants. Once established, they are difficult to eradicate. Among multicellular animals, the nematodes are probably second only to insects in numbers.

PHYLUM: Mollusca

CLASS: Gastropods.

ORDER: Stylommatophora (Snails and slugs).

Some snails and slugs feed on cultivated plants. Used as a source of food in some countries, these pests are kept under control. But, when present in large numbers, may do severe damage to garden, field plants, and even trees.

PHYLUM: Arthropoda.

CLASS: Insecta (Insects).

The insects are man's chief competitors, eating his crops and stored foods. They are the most abundant and widespread of all land animals.

CLASS: Arachnoidea.

ORDER: Acarina (Mites).

This order contains the mites which are serious plant pests. Many suck plant juices and injure leaves, buds, and fruits.

CHAPTER IV

DIVISION SCHIZOMYCETOPHYTA

CLASS: Schizomycetes.

ORDER: Eubacteriales (Bacteria).

The discovery of the role of bacteria as serious plant pests was made only some one-hundred years ago. Professor T. J. Burrill began working with a disease of unknown cause that was doing serious damage to pear and apple orchards of the Midwest. Professor Burrill, in 1861, proved that the disease which we now call fire blight was caused by a bacterium.

Bacteria are minute, unicellular, plant like, microscopic organisms which differ from true plants in that they lack chlorophyll. They reproduce by binary fission, and under favorable conditions cell division may occur at intervals as short as twenty minutes. Many kinds of bacteria, especially those that are serious plant pests, can live either as parasites or as saprophytes.

Among the symptoms of bacterial infections are galls, wilts, dwarfing, imperfect fruits, rots, cankers, and leaf spots. These symptoms are produced directly through killing of the host tissues or indirectly through toxin formation or mechanical interference with water transport as a result of gall formations.

Bacterial Blight of Cotton, (Pathogen, Phytmonas malvacearum).

Bacterial blight is the most common disease, and often the most serious general disease of cotton, occurring in nearly every field. It was first recognized in America in 1891 and is found wherever cotton is grown. It is impractical to grow the long staple Sea Island Cotton in the United States because of this disease.

Citrus Canker, (Pathogen, Xanthomonas citri).

This plant pest was first discovered in the Orient about 1865, and since then has become widely distributed throughout many of the citrus--growing countries of the world. It was introduced into the United States in 1910, or earlier, probably on trifoliate orange trees shipped from Japan to Alabama, Florida, Mississippi, and Texas; but it was successfully eradicated some years ago.

Apparently, the hosts of Xanthomonas citri consists of all commercially important species of citrus. The disease attacks all plant parts above the ground. The canker on the leaves begin as minute, yellowish-brown, translucent, raised spots, and are usually first visible on the lower surface; the appearance on the fruits are much the same.

The bacteria are transmitted by heavy rains and insects; also by man, through infected seeds, bulbs and tubers. The pest was distributed over wider areas chiefly in infected nursery stock, fruits and other plant parts. It was eradicated between 1914-1931 at a cost of over two-million dollars to the State of Florida alone.

These two introduced bacterial diseases illustrate the drastic action that must be taken once a pest has entered our country. Citrus canker was eradicated, but only at enormous expense. As a result of the bacterial blight of cotton, one variety of cotton can no longer be grown in the United States.

CLASS: Schizomycetes.

ORDER: Virales (Viruses).

Among the most elusive of plant pests are the viruses, too small to be seen with the microscope or to be retained by bacterial holding filters, but one of the most contagious. Viruses are transmissible from one host organism to another, and capable of causing some of the most destructive diseases of plants. They apparently do not increase outside living cells.

The isolation and purification of the tobacco mosiac virus, by Dr. W. M. Stanley in 1932, opened the way for more direct and more comprehensive studies of the nature of viruses than had been possible before. With the perfection of the electron microscope, particles in the size range of viruses could be photographed. Nearly all of the viruses, that have been extensively studied, have been found to be complexes of strains. The strains vary in virulence, kind of disease produced, host range and other characteristics. It may be assumed that these strains have arisen by a process similar to mutation. This tendency to mutate gives to viruses a high degree of adaptability.

Virus diseases produce a wide range of symptoms and types of injury to plants. Sometimes they kill the plant in a short time, but more often they cause lesser injuries that result in reduced yields and lower quality products. With respect to general type of symptoms produced, most viruses are of two rather clearly defined groups: those that cause mottling or spotting of leaves, and those that cause a yellowing leaf curling, dwarfing, or excessive branching.

Tobacco (Tomato) Mosaic, (Pathogen, Marmor tabaci).

One of the best known of all viruses is the mosaic virus of

tobacco. This virus is a serious pathogen and has been of value in studies on the nature and properties of viruses in general.

Tobacco mosaic virus occurs wherever susceptible plants will grow. It was the first virus shown to be contagious (Mayer in Holland, 1886), the first to be filter passing (Iwanowsky in Russia, 1892), the first to be extensively studied with regard to properties and strains, and the first to be prepared in crystalline form (Stanley, 1935). The tobacco mosaic attacks many species of plants; tobacco, tomato, pepper, and petunia are the most important economic hosts.

The most common symptoms of tobacco mosaic are: leaf mottling of light and dark green patches, leaf distortion with blister-like areas, irregular or unnatural leaf shape, stunting of the entire plant, and in some cases widespread necrosis.

Tobacco mosaic virus is the most resistant and the most highly infectious of all viruses. It withstands heating almost to boiling, is quite highly resistant to alcohol and other germicides, and retains infectivity in the dried state for many years. The virus enters plants through scratches or abrasions due to rubbing or handling of the leaves. The pest is spread from one plant to another either through the agency of man, handling diseased then healthy plants, or by means of several species of aphids. The virus multiplies rapidly and passes to the apical meristem by way of the phloem vessels. In about eight to ten days after inoculation, the first symptoms are seen in the new leaves; a clearing of veins, mottling and distortion.

Peach Mosaic,(Pathogen, Marmor persicae).

Peach mosaic first appeared in Texas in 1931 where it had apparently been present for several years; the same year it was found

in Colorado. In 1933 it appeared in California, in 1936 in New Mexico and Arizona, and since has been found in Oklahoma and Old Mexico.

Peach mosaic is one of the most important of the virus diseases of tree fruits. Only stone fruits, species of Prunus, are affected by the peach mosaic virus. Losses from peach mosaic are of two kinds: the low and poor quality yield from affected trees, losses from the regulatory programs which include destroying nursery stock and fruit bearing trees, as well as the cost of inspection.

Peach mosaic is not an easily identified disease because other troubles, excluding mosaic, may produce symptoms resembling those of mosaic. The new leaves are variegated or mottled with light green or yellow patches and are crinkly or distorted. The fruits are typically small and irregular in shape. They are bumpy, especially on the crease side, and are usually late in ripening. Seen from a distance, affected trees appear thin with clusters of yellow leaves, rather than evenly green.

The virus cannot be transmitted mechanically, and its rapid spread suggests that a highly effecient insect vector is responsible for its distribution. It can be transmitted by grafting and budding, which are means for its propagation and dissemination in the nursery stock trade. Unlike some viruses, that of mosaic cannot be removed from peach tissues by heating without killing the tissues.

The viruses mentioned above are within our boundaries and the expensive problem of control now arises. In the case of tobacco mosaic, some commercial tobacco has been produced by selective breeding which makes them essentially immune to the virus. The control of peach mosaic has been purely a regulatory problem; the only direct approach

CHAPTER V

DIVISION EUMYCETOPHYTA

Fungi are characterized by two important features: they are non-green plants devoid of chlorophyll, and the plant body is composed of branching threadlike structures called hyphae. Fungi grow in the soil, on the living and dead bodies of plants and animals, and on other organic materials such as foods and leather. Characteristically, fungi reproduce by the formation of tiny bodies collectively called spores. With suitable moisture and temperature, the spores germinate to form special food-absorbing hyphae (haustoria) which may grow between the cells or penetrate directly into the cells of the host. The manner in which the spores are produced and the appearance of the fruiting body in which they grow is the scheme upon which virtually all classification of fungi is based.

The manner in which fungi cause disease in the host is varied. In general, the fungae hyphae interfere with the normal functioning of cells. Cells may be stimulated to divide at an abnormal rate, producing tumor-like tissue which interferes with normal growth. The hyphae may interfere with the translocation of water and many form toxins which injure or destroy the host.

CLASS: Phycomycetes (Algae fungi).

The vegetative hyphae are usually continous with no cross walls. The asexual spores are either motile or nonmotile and are typically

enclosed within a thin-walled sac, the sporangium.

Late Blight of Potatoes, (Pathogen, Phytophthora infestans).

This disease is of considerable historical interest, as mentioned earlier in the report, causing the migration of thousands of families from areas where the potato was the chief source of food. It is believed that the potato was first brought to Europe from South America. In a new habitat it grew abundantly, apparently free from disease. In the early half of the nineteenth century an epidemic of potato blight raged over Europe and in 1845 the crisis was reached. The blight destroyed millions of acres of cultivated potato crops in Europe, the United States, and Canada. Although it was recognized that a fungus was associated with the disease, it was believed that the fungus was the result, not the cause. As a consequence of the many investigations which followed, proof of the pathogenic nature of the fungi was obtained. Thus was born modern plant pathology, the science of plant disease.

The fungus producing potato blight grows on the leaves of the host, where it produces dead areas. The hyphae grow between the cells of the leaves and produce sporangia on the lower side of the leaf. The spores released by the sporangia are spread to the leaves of other potato plants where they germinate, but some fall on the soil, germinate and penetrate the potato tuber. As a result, the tubers may be rotted by harvest time or develop rot during storage. If potatoes containing the fungus are used for seed purposes, the hyphae grow up through the tissues of the stem to the leaves, from where the infection is spread.

The potato blight fungus also causes late blight of tomatoes. The symptoms on tomato leaves are similar to those on the potato, and the fruits are readily infected and subject to rot at all stages of growth. That the blight is still with us was evidenced as late as 1946; an

epidemic swept through the Eastern United States causing losses estimated at millions of dollars.

CLASS: Ascomycetes (Sac fungi).

Ascomycetes constitutes one of the largest groups of the fungi. They include the powdery mildews and blue and green molds; causing such diseases as chestnut blight, Dutch elm disease, apple scab, black rot of sweet potatoes, and leaf spot of alfalfa. The hyphae usually have crosswalls. Spores of the perfect stage are produced within an enlarged sac known as an ascus, which usually contain eight spores (ascopores).

Chestnut Blight, (Pathogen, Endothia parasitica).

This is one of the most tragic lessons of the effect of an introduced pest on a susceptible native crop. The blight is an introduced disease from Asia, first found in New York in 1904 and has practically eliminated the valuable chestnut tree from American forests. The fungus is a wound parasite that produces large sunken cankers on branches and limbs, killing individual limbs and ultimately the entire tree. The ascospores are readily spread by the wind, insects, and birds. Although many control measures were tried, all failed, and the disease has run its course until the host species (chestnut) has been practically wiped out.

Dutch Elm Disease, (Pathogen, Ceratocystis ulmi).

Nearly all of our imported diseases have entered on seeds, fruits, and plants. The Dutch elm disease is one that did not. Burl elm logs, with bark attached, were shipped into the country for making veneer for furniture. The logs were infected with the fungus of Dutch elm disease and infested with bark beetles which spread the disease. The importations of the logs were traced and a number of places where the fungus had become established were located. By then, the disease had become established in the native wild elms in the New York-New Jersey area and

attempts to control the disease were unsuccessful. The American elm, one of our valuable shade and forest trees, is not completely disappearing but costly spraying is necessary to prevent eradication.

The first visible symptoms of the disease are a wilting of the branches followed by yellowing and dying of the leaves. Freshly cut cross sections of infected twigs and branches show a brownish discoloration of the vascular elements of the sapwood. The bark beetles are the chief means of spreading the spores of the fungus. As the bark beetle goes through his tunnels the spores adhere to his body and legs. When the beetle moves on to feed on healthy trees the spores are deposited in the feeding wounds. Thread-like masses of hyphae soon penetrate the conducting tissues, resulting in a rapid wilting. Continued infection results in death of the tree.

CLASS: Basidiomycetes (Smuts and Rusts).

As in the Ascomycetes, the hyphae of the Basidiomycetes have cross-walls that divide them into separate cells. An important difference is that the spores of the perfect stage (basidiospores) are borne upon the apex of club-shaped specialized hyphae (basidia) which are usually one-celled.

Although the common mushroom and toadstools are found in this group, it is the rusts (Uredinales) and smuts (Ustilaginales) which are the important orders containing the plant pests.

Corn Smut, (Pathogen, Ustilago zeae).

The most important smut diseases are found in the cereal grains, wheat, barley, rye, oats, sorghum, and corn. The name "smut" refers to the black and dusty masses of spores formed within the tissues of the host plants. Spores formed are of two general types: teliospores and basidiospores. Corn smut occurs in nearly all regions where corn is grown. The first indications of the smut is the appearance of swellings of various sizes. Upon rupture of the host tissue, spores (teliospores) are released to fall upon the soil where they commonly lie dormant until the next growing season. Upon germination of the teliospore, a basidium is produced which in turn produces basidiospores. The basidiospores are carried to the corn by the wind, where they infect the host tissue, producing large swellings on any above ground part of the plant. In the United States the crop loss resulting from corn smut has varied from less than one percent in some states to as much as fifteen percent in some other states.

The Rust Fungi:

The rusts are obligate parasites requiring living plant cells on

which to feed. They are responsible for some of our most destructive plant diseases.

The rusts may be divided into two groups on the basis of their host relationships. One, the heteroecious rusts include species which require two unrelated hosts to complete their life cycle. Certain of the spores are produced on one host and other spores on a second, or alternate host. In the other group, the autoecious rusts, the life cycle is completed on the same host species. Some important heteroecious rusts are white pine blister rusts which have currant and gooseberry as alternate hosts; apple rust on apple and red cedar; stem rust on wheat, and European species barberry (Berberis vulgaris).

Stem Rust, (Pathogen, Puccinia graminis).

One of the best known and most important of all plant diseases, stem rust has been a major factor in grain production for many years. It is believed that stem rust was introduced into the United States on barberry bushes brought over by the early colonists. This particular rust fungus produces five types of spores: (1) The urdeospores that spread the rust from grain plant to grain plant; (2) The dark teliospores that can infect nothing. They fall to the ground where they may resist winter temperatures and the following spring germinate and produce basidiospores; (3) The basidiospores then carry the rust to the barberry bush where, (4) pycniospores are formed that have only the function of sexual fusion and reproduction; (5) The aeciospores result from this sexual fusion and carry the infection from the barberry back to the grain plant.

This rust has appeared in epidemic form on numerous occasions in the United States, especially areas of the upper Mississippi Valley.

The elimination of the alternate host, barberry, has been effective in some areas as a means of control. Since 1918, the United States Government in cooperation with thirteen of the central states have attempted to eradicate the barberry bush. Complete eradication of the barberry will not eliminate the pest because of infection by uredospores blown up from the Southern United States where it can overwinter on wheat. In wheat sections protected by mountains, where no uredospores are blown in from the outside areas, and the only infection of wheat is from the barberry, eradication of the bush gives almost one-hundred percent control.

The most widely applied method of plant pest control is prevention. The principle of prevention is important, because once a parasite has become established it is difficult and frequently impossible to kill without injuring the host. Rusts and smuts are plants; any attempt to control these pests with chemicals will undoubtedly be injurious to the plant hosts which they infect.

CHAPTER VI

DIVISION SPERMATOPHYTA

CLASS: Angiospermae (Flower plants).

SUB-CLASS: Dicotyledoneae.

A great majority of seed plants are autophytic, manufacturing their own food by photosynthesis. A few of them have other means of obtaining their nutrition; the saprophytes, which feed on dead organic matter and the parasites which feed on living plants. The parasites are the serious plant pests.

The parasitic seed plants are largely found in two orders: Tubiflorae, which contains the Broomrapes and Dodders; the Santalales in which the Mistleto family (Loranthacea) is found. These seed plant parasites differ in the extent and manner of their parasitism. They may be entirely dependent on a host or partially so (hemiparasitic) and they may parasitize either stems or roots. With the exception of the Broomrapes, (which at times are destructive to tobacco, hemp, and clover) the root parasites are not highly injurious to their hosts. In contrast, the stem parasite may seriously harm the host plant.

Dodders, (Family, Convolvulaceae).

Dodders are found in the genus (Cuscuta). Of the one-hundred species of Dodder, about half are not found in the United States. The species that are here have caused serious losses, especially in alfalfa and clover seed producing states. Vegetables, ornamentals, young

nursery stock, and even nursery trees may occasionally suffer appreciable losses from Dodder.

A few of the most important species of Dodder found on economic plants in the United States are:

Small-seeded alfalfa Dodder (Cuscuta planiflora); an introduced species from Europe which is established in Western states and is particularly injurious to alfalfa.

Clover Dodder (Cuscuta epithymum); a reddish-stemmed introduced species found in various parts of the United States, particularly on clover and alfalfa. As it rarely sets seed in the United States, it is most important the first year in crops grown from imported seeds.

Chilean Dodder, (Cuscuta racemosa chileana), is an introduced species. The seeds have been found to be mixed with red clover and alfalfa seed from South America.

Broomrapes, (Family, Orobanchaceae).

The Broomrapes belong to the genus Orobanche, and all members are complete root parasites. They appear as clumps of whitish, yellowish, brownish or purplish annual stems arising from the ground at or near the base of their host plants. The germinating seed makes contact with a fibrous root of its host and becomes fused with the tissues of the host.

About sixteen species of Broomrape are regarded as pests of many crop plants; three are found in the United States. Our most serious pest (Orobanche ramosa), on hemp, was probably introduced from China or Japan. It attacks a number of crops but it is serious only on our hemp.

Both Dodder and Broomrape are transmitted by shipments of impure

seeds; prevention is therefore the first principle of control. Travelers, thoughtlessly carrying small packages of impure seeds from one locality or country to another, may be the chief means of propagating these pests.

CHAPTER VII

PHYLUM MOLLUSCA

CLASS: Gastropoda.

ORDER: Stylommatophora.

The Phylum Mollusca, which includes the snails, is a large group of animals extremely divergent in form. Because of their great diversity and large numbers, mollusks are found in nearly all regions and habitats on earth. They eat every possible kind of food, some are cannibalistic, eating their own species. With such diversification it is small wonder that many are of considerable economic importance to man.

There are six classes of mollusks characterized by different modifications of the locomotor organ, basic structure of the shell, degree of development of the nervous system, sense organs, and by structure of the radula or teeth. Of the six classes, the Gastropoda are the most varied; including snails, slugs, sea-hares and limpets. It is the order Stylommatophora that we find the land snails and slugs which are mainly herbovarous and are of the most concern as agricultural pests.

Among the most serious foreign pests already established in the country are the slugs, Limax maximus, Limax flavus, and Deroceras reticulatum. The snails, Helix aperta and Otala lactea have become established in California and large sums of money have been spent in combating them. Theba pisana, a serious pest of citrus crops and at one

time well established in California, has been successfully eradicated.

Land snails and slugs are mainly nocturnal, but following a rain may come out of their hiding places during the day. Temperature and moisture are the main factors to account for their nocturnal habits, and not the presence of darkness. Snails are more adaptable to unfavorable environmental conditions, such as drought. They can cover the aperture of their shells with a mucous sheet, the epiphragm, which hardens and thereby prevents desiccation. Some snails have been known to remain in this dormant state for years, only to come out and resume activity when they are moistened.

Giant African Snail, (Achatina fulica).

One of the most serious threats to this country in recent years has come from the giant African snail, Achatina fulica. About the turn of the century, this voracious eater with an enormous reproductive capacity began its immigration from East Africa via human agencies. In the intervening years this snail has spread to India, Ceylon, the mainland of China, and the East Indies. Its dispersal in the Pacific Islands, nearly denuding some of them of vegetation, was greatly facilitated during World War II by the rapid conquest of this area by the Japanese. They introduced the snail as a supplemental food source to many new places including New Guinea, New Britain, and New Ireland. The snail was introduced into Hawaii in 1936 and has subsequently cost the taxpayers some $200,000 for control measures, not accounting for the damage to plants in that area.[2] In 1948 it was brought to

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[2]Burch, John B., Some Snails and Slugs of Quarantine Siginificance to the United States (ARS 82-1, U.S. Dept. Agri. 1960) p. 2.

California on returned war equipment, but an intensive campaign prevented its spread.

CHAPTER VIII

PHYLUM ASCHELMINTHES

CLASS: Nematoda

Among multicellular animals, nematodes are probably second only to insects in numbers. Many are free-living in soil and water, and many others are parasites in the tissues or fluids of animals and plants. Some are restricted to pecular habitats: the roots of plants, seeds of wheat, and gums from tree wounds. They are mostly small or minute, just a little too small to be easily seen with the naked eye. A single acre of soil may contain hundreds of millions and generation time may be less than a month in warm climates.

Nematodes can be roughly broken into two types: (1) those which form cysts (Genus-*Heterodera*); (2) those which do not form cysts (Genera-*Pratylenchus*, *Ditylenchus*, *Meloidogyne*, and many others).

Damages to plants attacked by these pests are due primarily to the feeding habits of the pests on plant tissues. All important plant parasitic nematodes have a special feeding organ, known as a stylet or spear. It is hollow and the nematode uses it to pierce plant tissue and suck out the plant juices. Consequently, nematode damage interferes with the growth of the plant; the type of damage varying with the species of pest attacking the plant. Root nematodes form galls and completely destroy part of the root system. Stem nematodes cause damage to leaves and stems.

The Golden Nematode, (Heterodera rostochiensis).

This pest was first discovered in Long Island, New York, in 1941, and is responsible for from 30 to 70 percent reduction in potato yields in areas where it has been found. It is considered to be potentially more dangerous than any of the insects and diseases affecting the potato industry. The golden nematode is believed to have been introduced into this country on soil adhering to motor vehicles shipped from Europe.

Nematodes in the genus Heterodera are parasitic in the roots of plants. The above ground plant parts are stunted and subject to wilting, resulting in poor yields. By using a small hand lens, enlarged females can be seen protruding from the tubers. Under certain environmental conditions, the female may form a protective covering of her body to protect the young larvae. When the female dies, this protective covering containing the young larvae is called a cyst. The cyst breaks off from the tuber and the larvae in the cyst remain viable in the soil for long periods of time.

Little is known of the origins of the many plant parasitic nematodes, but information as to their distribution indicates that man has been largely responsible for their multiplication and spread from place to place. Being so small they are often unnoticed contaminants of plants, roots, bulbs and tubers used for planting. It is probable that some of the worst of the nematode pests have moved from country to country around the world with such material. They are transported over long and short distances in soil adhering to farm implements and vehicles or to the feet of men and animals. Drainage water carries them from field to field. Some species may be blown about by the

wind.

Except under greenhouse and seedbed conditions, complete and permanent eradication of the parasites is not practicable. The most that can be accomplished is to reduce the nematode population to a low level. This is generally accomplished by planting resistant crops which will starve out part of the nematode population. Since we cannot wipe them out we must learn to live with them and keep the damage down to a minimum.

CHAPTER IX

PHYLUM ARTHROPODA

CLASS: Insecta

ORDER: Diptera

While many forms of life have struggled to maintain their numbers with the spread of human civilization, insects have increased rapidly and have actually become the dominant form of animal life. Why have the insects been so successful? There are four excellent reasons that have enabled them to compete successfully in our modern world. Small size is a distinct advantage. Insects escape attention until the damage they have done has become noticeable. Shelter is no problem and small amounts of food will maintain an insect; when food source becomes a problem in one locality, the insect can easily travel to another. Adaptability gives the insects another advantage. Many organisms are so definite as to their requirements that they cannot leave a specific environment. Insects range far and wide over the land and many seem equally at home in a great variety of conditions. Rapid rate of reproduction is still another advantage. A single individual may lay from a hundred to several thousand eggs. A very important fourth advantage is that many insects are beneficial and have been cultivated by man.

Fully half of the known species of insects are phytophagous, feeding on the tissues or juices of plants. Every cultivated crop has more

than one insect pest, and some important crops such as corn, cotton, wheat, and tobacco have a hundred or more. Human foods are eaten or ruined by ants, cockroaches, and weevils and dirtied by house flies. Stored cereals are damaged by grain weevils and moths; woolen clothing, carpets, furs, and feathers are riddled by clothes moths and carpet beetles. Books are damaged by silverfish, beetle larvae, and termites. Many insects act as intermediate hosts for various diseases of man and larger animals. A large number of these are native pests but many have been introduced from other countries, where free from their natural enemies, they have caused enormous economic losses to man.

Mediterranean Fruit Fly, (Ceratitis capitata).

This plant pest may be found throughout the sub-tropical regions of the world with the exception of Southeastern Asia and most of North America. It was found on oranges in the central plateau of Costa Rica in April, 1955, marking its first appearance on the North American continent since it had been eradicated in 1929-30. Follow-up surveys showed the fly to be widely distributed in Costa Rica. Most decidious and sub-tropical fruits are attacked, at least to some extent by the Mediterranean fruit fly.

In 1956 the discovery of the fruit fly in citrus groves near Miami, Florida was announced. It is believed to have entered in the cargo or passenger luggage of airplanes arriving in Miami. The insect had spread over twenty-eight counties before it was brought under control. Eradication required about sixteen months, and the principal weapon was aircraft application of bait sprays. Federal and state appropriations toward the eradication campaign amounted to millions of dollars plus damage to the fruits.

The adult fruit fly lays her eggs just under the skin of the fruit. The larvae burrow through the fruit and render it unfit for food. When the larvae are full grown, they drop to the ground and pupate in the soil, emerging later as adult flies.

In 1960, for the second successive year, no Mediterranean fruit flies were taken in the thousands of traps operated in Florida, scene of the reintroduction of the pest in 1956. This pest has become firmly established in Costa Rica with a general infestation, ranging from light to heavy enough to cause serious economic damage. This plant pest, so close to our shores, has caused considerable concern to citrus and vegetable growers in Florida, Texas, Arizona, and California. Strict quarantines and cooperation by all groups concerned have so far prevented re-entry of the fly.

CLASS: Insecta.

ORDER: Coleoptera.

Khapra beetle, (Trogoderma granarium).

The Khapra beetle is a member of the coleopterous family Dermestidae. It is the only member of that family which has gained international prominence as a primary pest of stored grains. Wheat is the preferred host but barley, oats, rye, and other cereal products are attacked. It is believed that this insect was originally a native of India, Ceylon, and Malaya. It has since been spread by commerce to many countries of the world; the United States is the most recent to succumb to its invasion.

When an adult emerges from a pupa, it remains quiescent within the last larval skin for a period of one to ten days, depending upon the temperature. Fertilization occurs, followed by oviposition one to six days later. Each female lays about seventy eggs and these hatch in about four to five days. Hence, a generation may occur in as little as thirty-five days under optimum conditions. The damage to the stored product is done in the larval stage. It consists of feeding on the seeds themselves, and contaminating the grains with fecal pellets and cast larval skins.

The first known infestation of this insect occurred in California in 1953. Surveys since then have revealed its presence in two other states, Arizona and New Mexico. With our present large surpluses of food that must be stored, pests of these foods become a major problem.

It is becoming more and more urgent that the United States develop a through knowledge of agricultural pest problems that exist elsewhere in the world. Pest-control officials were able to move effectively

against the Mediterranean fruit fly in Florida, partly as the result of research work accomplished after the first invasion. It is important that any incipient infestation by a plant pest be detected while the area involved is small and controllable.

CLASS: Arachoidea.

SUB-CLASS: Arachnida.

ORDER: Acarina (Mites).

The mites are small to microscopic, with head, thorax, and abdomen fused closely and unsegmented. A slender anterior region often jointed to the body bears the mouth parts. The eight legs are laterally placed and often bear bristles. The sexes are separate. In most species there hatches from the egg a six-legged larva that feeds and molts into an eight-legged nymph having no genital opening. With further feeding and molt, this transforms into the adult sexual stage.

Mites abound as to species and individuals in soil, humus, stored foods, fresh and salt waters, on plants, and as parasites of both plants and animals. Many species attack leaves and cause defoilation of crops, while others may attack stored products and bulbs and roots of bulb crops. Members of several species produce blisters and galls on several commercial crops, notably orchard trees.

Citrus Bud Mite, (Aceria sheldoni).

This fruit pest came to the attention of entomologists relatively recently, having been discovered on lemon trees in California in 1937. It was at once associated with certain abnormalities in the growth and development of lemon foilage and fruit which had formerly no satisfactory explanation. Subsequent investigation showed that the bud mite was widely distributed in southern California. The widespread distribution, coupled with the fact that the characteristic malformations of foilage and fruit caused by the mite had been periodically noted by citrus growers for at least twenty years previous to its

discovery, indicates that it had been in the state for many years. Since citrus is the only known host of the mite in California, it is generally supposed to have originated in some region where the tree is native and to have been introduced into California on one or more of its varieties. In the United States, the mite has been restricted only to California. While the mite occurs on lemons, limes, oranges, grapefruit, and other citrus varieties, it is principally a pest of lemons.

The adult mites are about 1/150 inch long, and are light yellowish or pinkish. They inhabit the bud, the developing blossom, or the area beneath the button of a fruit. The area on which the mites feed becomes blackened, sometimes destroying the entire bud. The most noticeable abnormalities are found among the fruits, which may assume very curious and grotesque shapes.

The mites have many species of natural enemies, mainly predators. Insecticides that kill natural enemies without controlling the mites result in severe damage by the latter.

In California, the citrus red mite (Panonychus citri) may be considered to be the citrus pest of greatest economic importance. In Texas the citrus rust mite (Phyllocoptruta oleivora) is by far the most important of the citrus pests.

CHAPTER X

CONCLUSION

Since the time of Washington and Jefferson, Americans have beautified and enriched their native land by bringing in foreign plants and seeds for propagating desired plant varieties not previously grown in this country. Many of the most useful and popular plants grown in the United States at the present time are descendants of early plant imports. Unfortunately, however, seemingly healthy plants can harbor dangerous pests. The fact that plants and seeds are imported for growing in farms, gardens, and forests all over the country makes it particularly important that they do not carry dangerous pests with them. Soil, whether alone or attached, is a potential carrier of plant pests. Packing materials can carry pests. Souvenir alligators, brought in by returning tourists from South America, were found to be stuffed with seed cotton that was infected with the pink bollworm. A pest lurking in a suitcase or lunch-box could cause as much damage as one in a large commercial cargo, and is much harder to detect.

If our present trend continues, the task of defending our agriculture resources against foreign plant pests will be bigger and more difficult in the years immediately ahead. The steady growth of travel and transport to the United States shows no sign of slackening. When the St. Lawerence Seaway was opened to deep draft vessels in 1959, cities far inland became ocean ports and exposed the very heart of our

midwest grain and livestock centers to direct pest invasion from abroad. One of the first stowaways riding the seaway was the grain-devouring khapra beetle, found in the hold of a German ship at Cleveland.

In our constant war with plant pests three principles of control have gradually emerged:

(1) It is better and cheaper to keep out plant pests than to have to fight those that get in.

(2) If pests get in, it is better and cheaper to eradicate them, than to live with them.

(3) When the pest cannot be eradicated by practical means, then the third and last line of action is to set controls to minimize the damage.

Of the above listed principles of control, keeping out plant pests is a responsibility of every person of the United States. Laws and regulations spell out public responsibilities. It is maintained by the Department of Agriculture that people fail to do their part in pest exclusion because they do not understand their responsibilities, rather than from a deliberate intent to foil the law.

Knowledgeable support on the part of importers and transportation employees and others immediately concerned with moving plant products into the country has made a significant contribution to the defense against foreign pests. Additional support from an informed public will add its part to this defense.

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