UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

The Efficacy and Economic Effects of Plant Quarantines in California

Report of a committee consisting of

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BULLETIN 553

JULY, 1933

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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EFFICACY AND ECONOMIC EFFECTS OF PLANT QUARANTINES IN CALIFORNIA¹

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FOREWORD

Early in 1930, the Board of Directors of the California State Chamber of Commerce requested the University of California to make a study of the efficacy of plant quarantines as applied to California, and of their economic effects upon the welfare of the state. It was my belief that since the whole question of quarantines and their administration has national and even international implications, it would be more satisfactory if the proposed study were undertaken by some national scientific agency, preferably one which had no connection with either federal or state government. Accordingly the matter was placed before two such organizations, but neither was able to undertake the project.

The University of California is not and should not be engaged in law enforcement. For this reason it is naturally reluctant to pass judgment on the activities of those organizations charged by law with quarantine functions. However, Mr. G. H. Hecke, then Director of the California State Department of Agriculture, and Mr. L. A. Strong, Chief of the federal Bureau of Plant Quarantine, both of whom have played important roles in the development of plant quarantine in California and in the country generally, concurred in the request that the University undertake this study. Therefore, after further consultation with those making the request, it was decided to accept the responsibility. Accordingly I appointed a committee to undertake this project, consisting of: Professor Harry S. Smith, Chairman; Professors Edward O. Essig, Entomology; Howard S. Fawcett, Plant Pathology; George M. Peterson, Agricultural Economics; Henry J. Quayle, Entomology; Ralph E. Smith, Plant Pathology; and Howard R. Tolley, Agricultural Economics.

The adoption of the principle of quarantine for the purpose of preventing or delaying the establishment of plant pests and diseases in areas where they do not exist has not been without criticism. These criticisms have in general been directed toward two aspects of the ques-

¹ Received for publication March 1, 1933.

tion, the one biological, and the other economic. It has been maintained by some that plant quarantines are unsound biologically; that there is little justification for the assumption that the dispersal of plant pests and diseases, which results from the action of one of the most powerful natural forces, can be prevented or even appreciably delayed by any reasonable effort. Such objections are usually voiced by biologists. Others have maintained that the plant-quarantine policy so interferes with trade that it is more detrimental to agriculture than the spread of plant pests and diseases would be. Another objection that is frequently heard is that plant quarantines may be, and sometimes are, used to exclude commodities from a market in order to gain a trade advantage. However, such procedure is not an honest application of the principle of plant quarantine.

The criticisms mentioned cannot be ignored or taken lightly. They are made by persons of high intellectual capacity and integrity whose abilities have won for them substantial recognition in either the scientific or the business world and whose opinions, because of this, must carry considerable weight. The principle of plant quarantine is not then so fully accepted as many California producers seem to believe. The conflicting views on the subject, both biological and economic, must be analyzed in a fundamental way; and even then, as pointed out in the report, it is extremely difficult to determine whether or not, or within what limits, the principle is a sound one. One reason for the diverse views on the feasibility of preventing the spread of pests and disease by quarantines is the fact that the problem does not lend itself to study by field or laboratory methods, hence experimental proofs are lacking. The Committee has expressed its belief, however, that an analysis of theoretical considerations and of the facts available permits the drawing of fairly reliable conclusions. Approaching the problem in this way, the Committee has concluded that there are no reasonable grounds for condemning the general idea of plant quarantine as being biologically unsound, but that the practical application of the principle is limited by a complicated set of conditions which must be considered and carefully weighed in each individual case, if the quarantine program is to be a sound one and is to accomplish the ends desired.

Assuming that within certain limits it is possible to exclude or to retard appreciably the spread of plant pests and diseases by the adoption of quarantine procedure, does California agriculture have anything to fear from the general development of quarantine throughout the United States and the world? This is a question to which careful consideration needs to be given. Agriculturally, California is essen-

tially dependent upon out-of-state markets. It is estimated that nearly 30 per cent of all carload shipments of fruits and vegetables produced in the United States originate in California. A serious curtailment of the markets for these products, by reason of quarantine action taken by other states or foreign countries, would be economically ruinous to California producers.

It is conceivable that the plant-quarantine program might develop to a point where the situation would be more difficult for California producers to meet than the control of new pests and diseases would be. The exclusion of California table grapes, oranges and lemons, or fresh deciduous fruits, from eastern markets would be a serious blow to the producers of these crops. And it needs to be remembered that a pest or disease often appears more serious to those who do not have it than to those who do. The point is that insects or diseases which are not considered to be of much importance here may appear to eastern growers and quarantine officials to be serious menaces and, from their viewpoint, may be interpreted as sufficient justification for a quarantine against California products.

It seems to me that California is possibly facing a real danger here, and that the state must be particularly careful not only to make certain that the quarantine policy has a sound biological basis, but to make sure also that its ultimate development will not bring about marketing problems more serious than the control of pests and diseases. Up to the present time this state has been fortunate in that there have been no anti-California plant quarantines of importance to interfere with the marketing of its products. With the rapid growth of the quarantine policy now taking place in other states and in foreign countries, it may be doubted if this fortunate condition will continue.

What can be done to lessen the possible danger from this source? The extent to which other states and countries will carry the development of plant quarantine is of course beyond the control of California. Nevertheless, I believe California can influence this development by setting an example in the reasonable use of scientifically sound quarantines, limited in application to cases of urgent necessity only. This will be certain to result ultimately to the advantage of California agriculture. Also, as pointed out in the report, intensified effort must be devoted to the development of methods for treatment of agricultural commodities to free them from pests and diseases to the end that they may move freely in the channels of commerce, in this way removing so far as possible the necessity for embargoes. In this direction lies one of the most important possibilities of reducing plant-quarantine barriers, thus

forestalling serious interference with the marketing of crops and at the same time preventing, so far as is reasonably possible, the spread of dangerous pests and diseases.

There is another aspect of quarantine policy which California might well stress. Plant quarantines are presented to the public almost exclusively as measures to benefit the producer. However, if such quarantines are efficacious in excluding destructive pests and diseases, their ultimate effect is more abundant production, or production of better quality, or lower cost of production, a portion of which gain is certainly passed on to the consumer. Therefore, since the consumer finally benefits when such results accrue, he should be as greatly interested in maintaining sound quarantines as is the producer. The general public has not been educated to view plant quarantines in this light.

Anyone who reads this report will be impressed with the extremely complicated nature of the plant-quarantine problem. To do it justice, intensive study is necessary along several distinct lines, such as agricultural economics, public administration, plant pathology, and entomology. The Committee feels that it has made only a beginning in this direction and that the problem merits much more extensive and detailed study than it has received, yet it seems undesirable to delay the report further. Because of the pressure of the regular work of the staff members serving on the Committee, it was not possible to detach them from their duties and permit them to devote their full time to the quarantine study. Instead, it has been necessary for them to carry on their regular duties and to devote only spare time to this work. This will explain the apparent delay in its completion. The Committee members have taken the task seriously and have attempted to approach the problem with unprejudiced minds. It is hoped that this report will prove of interest and value to the producers and other citizens of California.

The Committee acknowledges the valuable assistance generously rendered it in its work by several biologists, federal, state, and county quarantine officials, growers, and others in this and other states. It is particularly grateful to the Bureau of Plant Quarantine of the United States Department of Agriculture and to the Division of Quarantine Administration of the California State Department of Agriculture, the two agencies which are charged by federal and state laws with the responsibility of administering quarantine regulations. It is not to be expected that the officers of the above organizations and the members of the Committee, with their widely differing viewpoints, should find themselves in complete accord in regard to all phases of plant quarantine. Nevertheless the Committee feels it cannot conscientiously fail to

say that it believes this function of the state and federal governments, in which California agriculturists are so much interested, is in good hands. Contact with those organizations has convinced the Committee that it would be difficult to find a more efficient, earnest, conscientious, and devoted group of administrative officials anywhere.

C. B. HUTCHISON

Dean of the College of Agriculture
University of California

BERKELEY, CALIFORNIA,
March 1, 1933

THE PROBLEM OF PLANT QUARANTINE

*Definition of Plant Quarantine.*²—The term “plant quarantine” is used in this study to refer to legal restrictions on the movement of commodities for the purpose of preventing or delaying the establishment of plant pests and diseases in areas where they are not known to occur. Under the term “plant quarantine,” there might also be included regulations designed to aid in the extermination or eradication of newly established plant pests and diseases. In the final analysis, however, even this latter type of activity has as its principal object the protection of uninfested or uninfected areas.

RISE OF THE PLANT-QUARANTINE POLICY IN CALIFORNIA

The policy of using the police power to exclude dangerous plant pests and diseases is based on the premise that economically it is better to undergo considerable inconvenience and initial expense in an effort to exclude a pest or disease than to submit to the expense of controlling it for an indefinite period. It is generally recognized that with a few exceptions, such as grasshoppers, chinch bugs, the potato beetle, and some aphids, practically all the major insect pests and diseases of plants in the United States are those which have been accidentally introduced from foreign countries. Introduced organisms often develop much more vigorously than the native species.

It is probable that the idea of applying the principle of quarantine to the protection of areas from the introduction of plant pests and diseases originated with growers rather than with biologists. Fruit growers particularly, in the early days, had several rather staggering experiences with introduced insect pests, and it was perfectly natural that those living in areas as yet uninvaded should consider how they might protect themselves from similar misfortunes; and that growers having had these experiences should attempt to avoid others of a similar nature.

The story of the ravages of the phylloxera in the vineyards of France in the seventies and its effect on the wine industry in that country, and later in California; in the following decade, that of the San Jose scale

² The National Plant Board (1932) defines quarantine as follows: A quarantine is a restriction, imposed by duly constituted authorities, whereby the production, movement or existence of plants, plant products, animals, animal products, or any other article or material, or the normal activity of persons, is brought under regulation, in order that the introduction or spread of a pest may be prevented or limited, or in order that a pest already introduced may be controlled or eradicated, thereby reducing or avoiding losses that would otherwise occur through damage done by the pest or through a continuing cost of control measures.

and the cottony cushion scale in California; and about that time the introduction from abroad of several serious scale pests of citrus, the control of which cost the growers immense sums of money, cannot fail to arouse a feeling that, whatever may be the real merits of the course these growers pursued, it was a perfectly natural attempt to surmount an obstacle which to them appeared to be almost a calamity. And from that time to the present the growers of California have had before them continually these and other examples of the serious situation which may be brought about by the accidental introduction of insect pests and plant diseases into California, or any other new habitat, from abroad.

Probably no other group of growers of a single crop in the world has had such a succession of serious introduced insect pests as have the citrus growers of California. The cottony cushion scale, the black scale, the red scale, the purple scale, the citrus mealybug, the citricola scale, the citrophilus mealybug, and the citrus white fly, came in one after the other, each adding its share to the cost and difficulties of production of the citrus crop. Whatever critics of the California plant-quarantine policy may think of the methods used to avoid such consequences, they should have little difficulty in understanding the attitude of the growers toward this question. Growers realize that plant quarantines cannot completely protect them from all such invasions, but they believe firmly that the principle is sound and that it should be jealously guarded.

The importance of a pest or disease is often grossly exaggerated. It is not strange that growers sometimes demand extreme quarantine measures under these conditions. Whatever may have been true in the past, the Committee believes there is no longer any justification for such exaggeration.

Growers, particularly where well organized as in California, need not be unduly frightened in order to support plant quarantines, for they now have a sufficient appreciation of the burden entailed by the introduction of new pests and diseases of plants to make them fully alive to the desirability of avoiding such events by any reasonable action. In the long run support for plant quarantine will undoubtedly be weakened, rather than strengthened, by such propaganda, and those who indulge in it will deservedly lose the confidence of the producers and of the general public.

NATURE OF THE PROBLEM

To what extent, if at all, is the faith of the California grower in the efficacy of plant quarantine really justified? What are the economic consequences of the plant-quarantine policy from the standpoint of

trade relations and good will? These are the questions to which the Committee is asked to find answers, and which it has undertaken to do with a full realization of the difficulties involved, and of the obstacles which the nature of the problem itself places in the way of definite, positive conclusions.

There can be no question but that the feasibility of excluding pests and diseases of plants from free areas is dependent upon biological principles; and that one aspect of the study must consist, therefore, of an examination of the fundamentals underlying the geographic distribution and the dispersal of organisms. If the principle of plant quarantine is considered to be biologically sound, it is still necessary to examine each plant quarantine to determine whether it is based upon biological principles. Orton and Beattie (1923)³ have expressed this idea as follows:

We stand in danger of subjecting ourselves to ineffective and hampering regulations without adequate gain unless the quarantine procedure is based upon a firm scientific foundation of sound biological principles derived from properly coordinated facts relating to the nature of the parasites [pests or diseases] to be dealt with; their country of origin and geographic distribution; their host relations and the native home of the host; prevalence; climatic relations; manner of spread, and other factors. More studies of this character need to be made, but enough is known to enable some general principles to be established.

The evaluation of plant quarantine is, however, more than a biological problem. To be sound, not only must its objectives be reasonably probable of attainment from a biological standpoint, but it must be economically justifiable; it must have proper legal sanction; and it must not unnecessarily restrict the rights and the liberties of the people. Thus the problem will be seen to be an exceedingly complex one. Within the limits imposed by the regular duties of the individual members, the Committee has given serious thought to all these various aspects of the question.

SCOPE OF THE REPORT

The task assigned to the Committee was to determine the efficacy and economic effects of plant quarantines as administered for the protection of California agriculture. Such a study entails a consideration not only of quarantines enacted by the State of California but of those promulgated by the federal Secretary of Agriculture and established to protect California along with other states. The Committee has not undertaken

³ See "Selected Bibliography," p. 254, for complete data on citations, which are referred to in the text by author and date of publication.

to express an opinion as to the efficacy of federal domestic quarantines in protecting other states from infestation or infection; since obviously, in order to do this intelligently, it would be necessary to have a more intimate knowledge of the exact methods pursued in their enforcement than is possible to procure from this distance. Therefore the conclusions in regard to the efficacy of domestic plant quarantines are limited to the question of how effectively they, in combination with the California system, protect that state. The distance of California from most of these infestations and infections, coupled with the fact that there has been developed here a highly organized terminal system, makes the problem a very different one from that obtaining in the states surrounding the areas under federal domestic quarantines. As to direct economic effects (that is, the effect of the plant quarantines on trade relations) the Committee has confined itself to a discussion of such effects with reference to the state plant quarantines only. This is a rather delicate subject, especially in so far as international relations are concerned, and the Committee wishes to avoid any possibility of embarrassing the federal government by expressing opinions on this aspect of federal plant quarantines. Furthermore, while California has enthusiastically supported the work of the federal Bureau of Plant Quarantine, she is not in any sense officially responsible for these quarantines. The Committee has also avoided a discussion of intrastate problems, except where they have a direct bearing on the interstate situation.

Briefly, then, the scope of this study is the efficacy and economic effects of interstate plant quarantines promulgated by the State of California, and the efficacy of federal plant quarantines in the protection of California.

DIFFICULTIES IN THE STUDY OF THE PROBLEM

The soundness of the idea of plant quarantine from a biological standpoint is not unanimously agreed upon by biologists, although growers generally accept it as having been sufficiently demonstrated. The reason there is disagreement among biologists is that this question does not lend itself to study by the usual experimental method, and therefore conclusions in regard to it must be largely, if not entirely, of a theoretical nature. In the study of the dispersal of an insect or disease, the investigator cannot use the experimental method in such a way as to eliminate all variables except the application of quarantine procedure. For example, it is not possible to introduce a new insect pest into two localities, apply quarantine restrictions in one case and permit the other to spread without restriction, in order to determine scien-

tifically the effect of the quarantine. Even if this were possible, it would be difficult to select two localities with environmental characteristics sufficiently alike to eliminate the possibility that differences observed were caused by differences in the environment rather than by variations in treatment. If one undertakes to study the nature and rate of dispersal of two different species of insects, where quarantine has been applied against one and not against the other, one's conclusions may very properly be subjected to the criticism that the two are not at all comparable because the nature of dispersal of the two is different.

One might compare the nature and rate of dispersal of the cotton boll weevil, against which there has been no quarantine promulgated in the South except in a limited way and for relatively short periods, with that of the Japanese beetle, against which quarantines have been applied in an extensive way from the beginning. If such a study were considered to be a reliable method of determining the efficacy of plant quarantine, the conclusion would have to be that quarantines cannot effectively prevent the spread of an insect because the cotton boll weevil advanced across the Cotton Belt of the South at a remarkably uniform rate with no long jumps; while the Japanese beetle, in spite of the quarantine, has made several such jumps of from 270 to 575 miles, distances far beyond the limits of natural dispersal (Fox, 1932). Therefore, all that a scientist could conclude from such a study would be that a certain type of quarantine applied against the Japanese beetle will not entirely prevent long jumps; and that in its present environment either the nature of the cotton boll weevil is such that it is not transported to any extent by human agency, or it is extremely difficult to establish in a new habitat. The study would give practically no information upon which to base conclusions as to the efficacy of plant quarantines in general.

There seems to be no way in which this problem can be attacked in an experimental way, and conclusions reached as to the biological soundness of the plant-quarantine idea will have to be based largely on theoretical considerations, and for this reason may never meet with the unanimous approval of biologists.

Nevertheless the situation does not appear to be an entirely hopeless one. It is believed that sufficient circumstantial evidence could be secured to indicate beyond reasonable doubt whether or not quarantines are actually effective in preventing or retarding the dispersal of certain plant pests and diseases. The Committee is not in a position to secure this evidence in a comprehensive way. This would necessitate a national, and perhaps in some phases an international, investigation, with such financial support as would permit of the necessary travel and the

securing of first-hand information on such questions as the methods of distribution of various pests and diseases by human agency; the requirements that must be met before establishment of different pests and diseases can take place; the extent to which the avenues of transportation of these pests and diseases are actually closed by the quarantine; and the collection of various other kinds of data. A great deal of circumstantial evidence could also be secured by a study of the nature and rate of dispersal of various pests and diseases, some of which have had quarantines applied against them and some of which have not. As was pointed out above, one could not compare the dispersal of the Japanese beetle with that of the cotton boll weevil and draw any reliable conclusions regarding the general efficacy of plant quarantine. Nevertheless, if the dispersal of *many insect pests* and *many plant diseases* was thoroughly studied in this way, and the preponderance of evidence was either in favor of or against plant quarantines, conclusions could be drawn which would be *reliable beyond any reasonable doubt*. From the nature of the problem this is the best that can be hoped for. By such a study, many other kinds of evidence could be secured. For example, as mentioned elsewhere, there is an interesting case in connection with the insects of eucalyptus. The eucalyptus was introduced from Australia into California in the seed stage only. Although in Australia the eucalyptus has a large number of insect pests, not a single Australian species is known to occur on eucalyptus in California. At least two important insect pests of eucalyptus (*Gonipterus scutellatus* and *Phoracantha semipunctata*) have been introduced into South Africa from Australia, and several of these pests have found their way into New Zealand, where they are doing very serious damage. It is probable that nursery stock was responsible for the introductions in some of these cases and timber in others. If so, such evidence would indicate very clearly what could be accomplished by quarantine in connection with a perfect natural barrier. A comprehensive study, such as has been suggested, might reveal many other cases having a bearing on the question and the Committee urges strongly that such studies be carried out. The amount of money expended in the United States for plant quarantine would amply justify the relatively small sum necessary for an investigation of this kind.

However, such studies and observations as the Committee has been able to make, meager though they are, have convinced it that there is no reason to doubt that *under certain conditions* plant quarantines can be made effective and worth while. Probably only theorists would fail to agree to this. The important question is: What *are* the conditions

under which it is reasonable to suppose that plant quarantines *can be made effective*? Obviously the soundness of a plant quarantine from a biological standpoint is dependent upon biological features connected with the geographic distribution, environmental requirements, nature of dispersal, natural barriers, and other points relating to the particular organism under consideration. Therefore an attempt has been made to discuss these subjects in their relation to plant quarantine. Similarly, from an economic standpoint, the soundness of plant quarantine is dependent upon an extremely complicated set of economic factors having to do with supply-price relations, restriction of trade, cost of pest and disease control, cost of maintenance of quarantines, and many other considerations. From an administrative standpoint, it is dependant upon the extent of public support, and whether it is physically possible to do that which the biological requirements make necessary. And from a legal standpoint, it is dependent upon whether or not the necessary things can lawfully be done, and upon the attitude of the courts.

MATERIALS USED AND PERSONS INTERVIEWED

In making this study the work of many experts in the various fields has been extensively drawn upon; their publications are cited in the following pages. The Committee has also interviewed many persons qualified to express opinions of some weight on the subject.

The original draft of the manuscript has been read by the following: Mr. L. A. Strong, Chief, Bureau of Plant Quarantine, United States Department of Agriculture; Dr. C. L. Marlatt, Chief, and Mr. S. A. Rohwer, Assistant Chief, Bureau of Entomology, United States Department of Agriculture; Dr. K. M. Kellerman, Associate Chief, Bureau of Plant Industry, United States Department of Agriculture; Prof. Glenn W. Herrick, Professor of Economic Entomology, Cornell University; Dr. E. P. Felt, Editor, Journal of Economic Entomology; Mr. W. P. Flint, Chief Entomologist, Illinois Agricultural Experiment Station; Dr. T. J. Headlee, State Entomologist, New Jersey; Dr. W. E. Britton, State Entomologist, Connecticut; Dr. Geo. P. Clements, Manager Agricultural Department, Los Angeles Chamber of Commerce; Mr. D. G. Milbrath, Plant Pathologist, California State Department of Agriculture; Dr. L. D. Batchelor, Director Southern Branch of the College of Agriculture, University of California; Mr. A. C. Hardison, citrus grower and member of the California State Board of Agriculture; Mr. W. C. Jacobson, Chief of Rodent Control, California State Department of Agriculture; Mr. G. H. Hecke, fruit grower and formerly Director of Agriculture of California; Mr. A. A. Brock, Director of Agriculture

of California; Prof. G. F. Ferris, Entomologist, Stanford University; Mr. A. C. Fleury, Chief Quarantine Officer, California State Department of Agriculture; Mr. H. J. Ryan, County Agricultural Commissioner, Los Angeles; Mr. D. B. Mackie, Entomologist, California State Department of Agriculture; Mr. R. N. Wilson, Manager, Agricultural Department, California State Chamber of Commerce; Mr. R. H. Taylor, Executive Secretary, California Agricultural Legislative Committee; Dr. E. Carsner, Bureau of Plant Industry, United States Department of Agriculture; Mr. R. S. Woglum, California Fruit Growers Exchange.

It will be seen that the group selected to read the manuscript is composed of growers and their representatives; of plant-quarantine experts; and of entomologists and plant pathologists, some of whom have been critical of and some favorable to the use of quarantines for preventing the introduction and spread of pests and diseases. In this way the Committee has attempted to obtain the views of a fair cross section of that part of the public which is most interested in the plant-quarantine policy. It is not to be assumed that those who have read the original manuscript necessarily endorse it. They have made valuable suggestions, however, which have been adopted. To all those who have read the manuscript the Committee is very grateful.

THE BIOLOGICAL ASPECTS OF PLANT QUARANTINE

GEOGRAPHIC DISTRIBUTION OF PLANTS, PLANT PESTS,
AND DISEASES

Primitive Conditions.—It is commonly assumed to be a fact that, under primitive conditions, during a period of time such as may be measured by the recorded history of the human race, plants in a given area are practically in a state of equilibrium. This refers to the characteristics and distribution of plant species and also to the occurrence of pests and diseases. Minor fluctuations and changes occur as the years go on just as with any natural phenomena but in a broad sense experience and history indicate that in any one place entirely new kinds of plants or new pests or diseases do not suddenly appear so long as purely natural causes alone are in operation. Thus nature is said to be in a state of biological equilibrium. This idea has been expressed as follows:

In general, where a large area of land exists, sufficiently uniform as to climate and soil, and not broken by barriers which interfere with the migration of plants, its native flora is likewise uniform; that is, its whole extent is inhabited by the same, or by closely similar, species of trees, shrubs, and herbs. On the other hand, if an effective barrier exists, such as a high mountain range, an extensive desert, or a large body of water, the floras on opposite sides of the barrier are likely to be quite different. For example, the flora of the region west of the Rocky Mountains is very different from that of the area east of the mountains. Much of this difference to be sure is due to climatic differences; but when, as is frequently the case, two species of the same genus occur on opposite sides of the mountains, they are usually so different as to suggest that they have been separated and have undergone evolutionary changes in different directions during a long period of time. The flora of Madagascar and that of the adjacent coast of Africa are very distinct. Marked differences also exist between the floras of Australia and the Asiatic mainland.

The degree of similarity or difference between the floras of separate bodies of land, such as islands or continents, furnish valuable evidence as to whether or not such bodies of land were at one time connected; Thus, there is sufficient similarity between the floras of eastern North America and western Europe to render it probable that at a not very distant geological period, the two continents were connected by a strip of land that has now disappeared. (Smith, Overton, *et al.*, 1924.)

What is said here in regard to an equilibrium in the occurrence or identity of plant species, pests, and diseases, applies equally well to their biological relations. In an isolated primitive area there is the same tendency toward the establishment of a balance in the degree of destruction caused by pests and diseases. In such a region, where the struggle

between hosts and parasites and the competition for existence between living organisms in general has been going on undisturbed for ages, the more susceptible types have long since been exterminated and the principle of the "survival of the fittest" has become firmly established.

Influence of Man.—Experience shows, however, that if the above be true under natural conditions there must be other influences at work which decidedly upset such an equilibrium so far as the distribution of plants and plant pests and diseases is concerned. In a region like California, for instance, the plant population with its attendant pests and diseases is certainly radically different today from that of a hundred or even fifty or less years ago. Very little research is needed to show that these changes have been almost entirely coincident with the migrations and activities of man, particularly those of the white race. Disturbances of the biological equilibrium, like many other effects, good and bad, always follow in the wake of exploration, evangelization, travel, and "civilization." Such activities, so far as they affect the characteristics, distribution, and pests and diseases of plants, are of two kinds—agricultural and commercial.

Agricultural activities include plant breeding and selection, the creation of new kinds of plants by human effort; and plant introduction, the distribution of desirable plants and their establishment in new places by the transportation of living plants, cuttings, roots, bulbs, tubers, or seeds from one country or locality to another. Such activities, applying not only to food plants but also to ornamental, medicinal, and other supposedly valuable species, have probably always marked the migrations of man.

Commercial activities consist principally of the accidental introduction and establishment of plant species, pests, and diseases in new places by transportation of seeds and other agricultural or commercial products.

Reasons for Plant Quarantine.—The facts brought out in the quotation near the beginning of this discussion as to the primitive distribution of plants may be accepted as being true also for their pests and diseases. Originally, before the activities of man began, the plant pests and diseases of each sufficiently isolated region were probably different from those of every other region and the natural distribution or dispersal of such pests and diseases together with their relative destructiveness had reached an equilibrium. Since restless humanity began its activities, however, the dispersal of pests and diseases has followed closely the dissemination of plants themselves. Such distribution was at first disregarded or considered unavoidable, but the development of

agriculture, more knowledge of the nature of plant diseases and realization of the fact that their causes are specific and not inherently connected with their hosts, and an increasing number of disastrous experiences with introduced pests and diseases in various parts of the world, have brought to the people a somewhat belated realization of the desirability of curbing this form of immigration if it is possible to do so. This has led to the development of plant quarantine, and vigorous efforts have been made in many parts of the world to bring about the exclusion of plant pests and diseases, with varying degrees of success.

The possibility of preventing the spread of plant pests and diseases by quarantine measures is determined by fundamental biological factors involved in their dissemination and establishment. These biological factors may now be discussed.

PROBABILITY OF INTRODUCTION OF PLANT PESTS AND DISEASES

Nature of Diseases and Their Method of Dispersal.—The plant diseases which are of importance in relation to quarantine are mainly those caused by parasitic bacteria, fungi, and the so-called viruses. In a general way all these classes of diseases may be considered alike for the purpose of the present discussion. It should first be clearly understood that bacteria and fungi are themselves plants, just as much as the host plants or agricultural crops which they affect. Plant diseases are caused by specific organisms which though microscopic in size are just as definite in character and habit as ordinary plants or insects. Diseases cannot develop unless the microbes which cause them have been introduced and brought into contact with susceptible plants under favorable conditions.

These microbes live either within the tissues or upon the surface of the plants which they affect, some attacking the root, others the stem, branches, leaves, blossoms, fruit, or seed. Some attack only one kind of plant while others have several or many hosts. Some parasites are present inside the tissue of the commercial product or propagating material, as in potato scab, sweet potato diseases, crown gall, and carnation rust, and cannot be separated from infected parts. They spread to other plants by means of their extremely small, seed-like reproductive bodies called spores. These may easily be seen in mass with the unaided eye in the rusts, smuts, and molds, but individual spores are invisible except with the aid of a microscope. Parasitic bacteria often form a germ-containing slime or ooze on the surface of affected parts as in pear blight, walnut blight, and bacterial gummosis.

These fungus spores and bacterial germs vary considerably in vitality, some kinds being comparatively long-lived and resistant to ordinary influences (cold, heat, drying) while others are very delicate and short-lived. In the case of some diseases the fungus spores or other reproductive parts or bacteria may be transported on the plants or plant parts on which they developed, or are mixed with seeds of the same plants. In such cases it may be physically impossible to introduce seed or propagating material of some plants into new localities without carrying along certain diseases, unless stock can be obtained from places where the disease does not occur. With some cosmopolitan diseases like the common grain rusts and smuts, apple scab, peach leaf curl, and vine mildew it is doubtful whether such disease-free areas could be found. Some diseases occur only in certain areas, and propagating stock can be safely introduced from other places.

In other cases disease germs may be spread through the air by the wind or carried by birds, insects, animals, or human agencies; in fact, by almost anything which comes into contact with or even into the vicinity of affected plants and moves thence to other susceptible vegetation.

Nature of Insect Pests and Their Methods of Dispersal.—Plant-feeding insects are of greatly varied habits in their relation to their host plants and their means of dispersal. Some, like the fruit flies, certain weevils, and the codling moth, attack exclusively the fruit or seeds. Some are confined in their feeding to the vegetative portion of the plant aboveground, as typified by the black scale, borers, and aphids. Others attack only the roots and are subterranean in all or some of their stages. A few insects, such as the Japanese beetle, are not so limited in their feeding habits, but attack all portions of their host plants.

The dispersal of such insects is largely determined by their habits. Some species are capable of flying long distances or may be blown by the wind. Others are limited largely to movement on their host plants, although all species have definite, even though restricted, natural means of locomotion. Many insects, particularly weevils and other beetles, may be carried by commerce on or in commodities that have no connection with the host plant upon which they feed and develop.

Nature of the Pest or Disease in Relation to the Feasibility of Preventing Spread.—Factors, then, which affect the possibility and methods of preventing the spread of a given pest or disease by quarantine are the nature of the insect or the organism which causes the disease; the number of kinds of plants affected; the part of the plant which it affects; whether or not the part which is used for propagation or in commerce (root, tuber, bulb, plant, cuttings, seed, etc.) is attacked by

the insect or disease; whether or not the insect or spores may be carried on commodities other than the host; the nature of the spores in the case of a plant disease; whether the propagating or commercial material can be so handled or treated as to destroy any possibility of its carrying any living reproductive form of the insect or disease; and many similar questions. In some cases it may be perfectly safe to introduce the seeds of a plant, so long as living plants are excluded. In many other cases the insect or parasitic organism may live inside the seed, or the spores of a disease may be on or mixed with the seed, so that the latter must be quarantined against or disinfected in order to keep out the pest or disease. Fruit may in some cases be brought in with entire safety, if the pest or disease affects only the root or stem and there is no danger that spores may be attached to the fruit; or there may be a possible though not very probable source of danger (apple scab, citrus canker and melanose, brown rot, peach rust, grape mildew, scale insects) of introducing diseases or insects with market fruit. There seem to be few cases where commercial fruit forms a very important carrier of plant diseases.

In the majority of cases the living plants (nursery stock, florists' plants, etc.) or propagating parts like bulbs, tubers, roots, and cuttings, form the most dangerous carriers of pests and diseases. In cases where the parasite or insect lives in the soil and attacks only the underground parts of the plant, it may be sufficient to quarantine against roots and soil and allow cuttings and seed to enter (e. g., ozonium root rot, subterranean insects). In the case of an important article of commerce, like wheat, dried fruit, rice, or hay, it may or may not be necessary to adopt precautions. All these questions depend on the nature and habits of the insect or disease.

Topographical Relations.—In relation to the primitive distribution of insect pests and plant diseases and their spread to new localities there are three different situations which may be distinguished: (1) continents separated by oceans; (2) different areas on the same continent separated by pronounced natural barriers such as high mountains, broad deserts, or extensive areas where the host plant concerned is entirely absent; (3) areas on the same continent not isolated by barriers.

Knowledge of the history of insect pests and plant diseases is complete enough to justify the positive statement that so far as continents separated by oceans are concerned their natural distribution is entirely confined within such areas. No case is known where any plant disease within historical times has crossed an ocean from one continent to another without the agency of man, and there are few such cases with insects. The problem of preventing the introduction of pests or diseases

from another continent is therefore entirely one relating to human activities.

The question of the intracontinental spread of plant diseases and insects between areas separated by natural barriers is again answered by history and experience largely in the negative so far as natural influences are concerned. This is a question which particularly concerns California. The spread of plant diseases across natural barriers has been very well discussed by Butler (1917) and also by Orton and Beattie (1923).

The principal agencies, as pointed out by these writers, which might be expected to carry fungus spores and thereby spread plant diseases over long distances are wind, birds, and insects. There is abundant evidence to the effect that fungus spores are found many thousands of feet high in the air and that volcanic ashes, as well as much larger particles of soil and sand, are sometimes carried many hundreds or even thousands of miles by wind. The flight of migratory birds or insects is also known to extend to almost incredible distances and the fact that fungi and bacteria are often attached to the bodies of birds and insects is well established. Theoretically therefore it seems entirely possible that any of these agencies might carry pathogenic microbes across broad barriers or even oceans. Practically, however, there is little or no evidence of the actual establishment of plant diseases at long distances from their source by such means.

One of the most important phases of this subject is the question of what constitutes an effective barrier. Distance alone is apparently not effective in some cases, since on the North American continent, for instance, there appears to be a long-distance spread of grain rust from south to north, whereas from east to west movement of this sort is much less pronounced. This may be due to the fact that no real barrier exists to break the migration from south to north. (See fig. 1, page 107.)

In the case of California, at least so far as plant diseases are concerned, the barrier appears to be less effective on the north and on the southeast than on the east or west. (See fig. 2, page 108.) The natural barrier, particularly against pests and diseases of cultivated forage crops, may be broken down with the development of agriculture in the mountain valleys connecting California with Oregon and Nevada, and also it is possible that the extensive development of agriculture in southeastern California and southwestern Arizona, together with the adjacent districts in northern Mexico, may break down the barriers which naturally exist.

There is only one disease of importance to California which appears to have entered the state by natural methods of distribution. This is the asparagus rust, in which case the evidence that it spread across the United States by wind-borne spores from east to west via the southern border and entered California from the southeast, is at least as good as that for any other method of distribution. The only other possible means of spread, that by the shipment of affected plants, does not seem particularly probable in this case since at the time when this disease first appeared in the state eastern varieties of asparagus were not being grown here and growers were producing their own plants from home-grown seed. This fungus produces enormous numbers of light, dusty spores, and asparagus is grown abundantly enough to furnish a fairly direct line of communication across the southern and southwestern United States connecting across Arizona into southern California and thence northward. The recorded history of the spread of the disease indicates this. It may again be emphasized, however, that this is the only case where there is any evidence whatever of the establishment of a plant disease in California by natural methods of distribution.

A very strong probability of future entrance into the state by natural means is that furnished by the white pine blister rust. This disease has already advanced from British Columbia through the state of Washington well toward southern Oregon, and since its previous history has shown its ability to travel for a distance of several hundred miles by wind-borne spores, and since this disease attacks native plants which grow abundantly and continuously in the area including northern California and southern Oregon, there is no reason to doubt that blister rust will in time enter California by natural dispersal. The rust fungi are particularly well adapted to such long-range spread on account of their very abundant, dusty, light-weight spores. It would not be surprising if other rusts might come into the state by the same method, particularly as mentioned above from Oregon, Nevada, or Arizona, on timber trees or native plants or through some of the high mountain valleys, as the development of irrigation and agriculture connects California with adjacent states.

Practically all the major insect pests of California have been introduced through human agency, either on the host plant or on other articles carried by commerce. With the exceptions of forest insects, perhaps certain forage insects, and insects which have been successfully established in Arizona, which may of course reach parts of southern California by natural dispersal, there is little likelihood that plant-feeding insects could reach the interior valleys of California by this means.

The case of the entrance of a pest or disease which already exists in contiguous localities not separated by natural barriers and with similar climatic relations does not concern California, except in the instances just mentioned of limited contact with Oregon, Nevada, Arizona, or Mexico. Where there is no barrier whatever, the natural distribution of insects and plant diseases is so well provided for by nature that it is practically impossible to do more than to delay their spread by quarantine methods. Efforts to accomplish even this much are apt to produce the maximum amount of irritation and objection with a minimum amount of actual results of value. The spread of the chrysanthemum rust, carnation rust, chestnut blight, asparagus rust, white pine blister rust, walnut blight, pear blight, citrophilus mealybug, vegetable weevil, and many other diseases and insects which are able to spread through the air for considerable distances or which are extensively carried by commerce after they are once introduced into a state or district where no natural barriers exist, illustrates the impossibility of preventing such dispersal by quarantine. The blight or canker of the Monterey cypress which is now spreading over California and almost exterminating this species is another good illustration. Cypress trees isolated from any other by a distance of 20 miles or more have been destroyed by this disease. The same is true of pear blight and walnut blight. Such restrictions as intercounty or interstate quarantines between contiguous areas not separated by natural barriers cannot do more than slow down the advance of such diseases and insects.

In the case of diseases that do not give off aerial spores, like the ozonium root rot and crown gall, or of insects that are carried almost exclusively on the host plant, such as scale insects, the chances of using quarantine methods successfully for delaying distribution are much better. Even here, however, so much uncontrolled local movement of commodities takes place that it is doubtful if the results are commensurate with the expense and inconvenience. If the infested and noninfested districts are close together the danger of spread by any and every possible method of distribution becomes that much greater.

There may be cases where natural barriers do not coincide with state boundaries; such barriers may exist within the state itself. In California, for instance, the Imperial Valley is fairly well shut off from the rest of the state by deserts and mountains and, from a quarantine standpoint, is more naturally a part of Arizona and northern Mexico than of California. Southern California is also separated from the rest of the state by fairly definite natural barriers.

What has been said above about attempting to curb the spread of plant diseases and pests within areas of uniform character does not apply if an effort is being made to eradicate the pest or disease in the areas where it has already become established. In such cases strict quarantine to prevent further spread must of course be a part of the eradication program, and a great deal more expense and inconvenience can be justified if this is the aim of the quarantine. Cases are very rare, however, where eradication of a plant disease once established has been successful. The only example, in fact, is that of citrus canker in Florida, Alabama, Texas, and South Africa.

This is a disease which does not spread by the abundant distribution of spores through the air and therefore is more susceptible to eradication than one which is so spread. An example of the practical impossibility of eradicating a plant disease is furnished by the experience with chestnut blight in the eastern United States. In this case the fungus forms an abundance of spores on the surface of affected plants and these spores are so widely and easily distributed that eradication could be accomplished only by methods so radical and expensive that they would be impossible of practical application. The same is true of white pine blister rust. In California an attempt was made some years ago to eradicate pear blight. This proved to be practically impossible on account of the wide distribution of the disease and also on account of the great variety of hosts, both wild and cultivated plants, which made the task one of hopeless magnitude.

There are a few cases where insect pests have been successfully exterminated. These will be mentioned in more detail on later pages.

From the facts pointed out above it appears that, from the standpoint of plant quarantine, the continent isolated by oceans is the only geographical unit which can be considered safe from the natural distribution of pests and diseases. Next to this come districts well isolated by natural barriers like mountains, deserts, and extensive areas where no host plants of the disease or insect in question occur. In this case the degree of safety depends upon the completeness of the barrier. In districts with similar conditions and separated neither by natural barriers nor great distance, quarantine methods for the exclusion of pests and plant diseases are hopeless and without permanent value except as an adjunct to eradication or possibly in a few cases of insects and diseases which have no method of spread through the air and are not extensively carried by local commerce.

RELATION BETWEEN INTRODUCTION AND ESTABLISHMENT OF PLANT PESTS AND DISEASES

It is not ordinarily a simple matter for an insect pest or plant disease to become established⁴ in an area previously free from it, although this is contrary to the general view. Usually a complicated set of circumstances and conditions must exist before establishment can take place. Among these the following are important:

1. Pathogenic organisms in many cases must contact special types of wounds or abrasions in the tissue of the host before infection can take place. Sometimes a definite amount of the inoculum must be present before establishment can take place.

2. In many instances it is necessary that the insect or pathogenic organism arrive at its destination at a certain season only. This is particularly true of insects that have only a single generation annually, for the stage of an insect is often definitely correlated with the season.

3. The arrival of an insect or pathogenic organism must usually be synchronized with a particular condition of the host plant. For example, certain fruit-infesting insects or fruit-infecting diseases must arrive at a time when the host plant is in fruit; and often only when the fruit is in a certain stage or condition.

4. The introduction must ordinarily take place in the immediate vicinity of the host plant before it can result in establishment. Therefore, introductions of insects or diseases having a very restricted host list are less likely to result in establishment than those of more generalized habits.

5. Species which require alternate hosts, such as white pine blister rust, must arrive in a locality where both hosts occur in the proper combination before establishment will result.

6. Introduced insects must be fertilized females, or the insect must arrive in sufficient numbers in both sexes simultaneously so that the females will become fertilized. There are a few species of plant-feeding insects in which the females are able to produce female progeny without being fertilized, to which this requirement does not apply (H. S. Smith, 1929). In some cases a colony of sufficient size must be introduced so that the two sexes will meet when the second-generation adults appear. In many insects there is a strong instinct for immediate dispersal when the adult issues, and often several days must elapse before sexual ma-

⁴ In this study the word *introduction* is used to mean merely the entrance of an insect or disease into an area where it has not previously existed; while the word *establishment* is used to indicate the definite and presumably permanent colonization of the insect or disease in that area. It is important to make this distinction.

turity is reached. In such species, if the original colony is very small and the population sparse it would die out in the second generation. Unquestionably temporary establishment often fails to become permanent because of this requirement.

7. The organism must arrive in its new habitat in sufficient abundance to overcome environmental resistance due to unfavorable climatic conditions, host resistance, disease, and the attack of enemies. Of the progeny of a single female insect, a large percentage ordinarily fails to reach maturity through the operation of these factors. In the case of the European corn borer, it has been found that more than 90 per cent of the newly hatched larvae are unable successfully to make their way into the stalk. An extremely high percentage of scale "crawlers" are unable to settle successfully on their host plant. A majority of the progeny of a newly introduced insect succumbs to the attack of diseases or enemies of various kinds. Unfavorable meteorological conditions, such as excessive rain, wind, heat, cold, humidity, and dryness destroy young insects and pathogenic organisms in large numbers. In general it will be seen then that the likelihood of establishment resulting from the introduction of a single or a few scattered insects or plant pathogens is greatly lessened by the operation of environmental resistance.

To illustrate the infrequency with which introductions develop into establishment, it is of interest to consider certain cases where the establishment of insects has been purposely attempted. Swezey (1925) lists 133 species of parasites and predators purposely introduced into Hawaii which failed to become established. The California experience with the introduction of beneficial insects has been similar. If it should be argued that parasitic and predatory insects have more complicated environmental requirements than plant-feeding insects, it has been pointed out (Swezey, 1925) that of 17 lantana-feeding species purposely introduced into Hawaii, only 8 became established. In the intentional introduction of cactus insects into Australia, Dodd (1929) reports that out of 29 species which were introduced only 10 became established. If intentional introduction, where conditions are presumably made as nearly ideal as knowledge of the requirements of a species will permit, so often fails to result in establishment, how much more frequently must this be true in the case of accidental, haphazard introductions?

Elton (1927) discusses the question of dispersal [introduction] and establishment in the following words:

When such an animal [i. e., one reaching a new habitat] reaches its destination it may either die or survive. It usually dies; but, if it does not, we say that it has "established itself as an individual".... But in such cases the individuals are

unable to breed successfully, or else the young are unable to survive. The next state is, therefore, that the animal must "establish itself as a species." It does this if it is successful in breeding and starting a permanent population of its kind. Frequently a species may reach some new place and breed, and may establish itself for a short time but is then wiped out. This often happens because the animal is not adapted to some periodic factor which acts at fairly long intervals, e. g., a very bad winter or an epidemic. Or the species may die out simply because its numbers and rate of increase are not suitably adjusted to the new environment in which it finds itself. For instance, after big invasions of sand grouse or of cross-bills, pairs of birds have been known to breed in some localities for a year or two after their first appearance. But they usually die out in the end and no more are seen until the next invasion.

It is plain that an enormous wastage must occur while the establishing after dispersal [introduction] is taking place, and that only a tiny fraction of the original immigrants will ever succeed in establishing itself even temporarily. We cannot do better than quote here the words of Woods-Jones, who had a peculiarly good opportunity of appreciating the factors in dispersal and establishment of species, in connection with the arrival of new animals and plants on the Coral Islands of Cocos-Keeling. He says, "Those creatures that are settled and established are the elect, and they are appointed out of a countless host of competitors, all of whom have had equal adventure but have gone under in the struggle through no fault of their own. They are the actual colonists, the survivors of a vast army of immigrants, every one of which was a potential colonist." One particularly striking example was noted by him; occasionally huge flights of dragon flies would arrive (belonging to the species *Pantala flavescens*, *Tramea rosenbergii*, and *Anax guttatus*), and would live for some time and feed; but, owing to the absence of any permanent open fresh water in the islands, they never succeeded in establishing themselves permanently, although they actually laid eggs in temporary pools, which were not suitable for their breeding purposes. Another example of abortive colonization on a huge scale was encountered by sledging parties of the Oxford University Arctic Expedition whilst crossing the ice cap of North East Land in the summer of 1924. One day in August, all three parties in different parts of the country encountered vast swarms of aphids (*Dilachnus piceae*), usually found on the spruce of southern Europe, together with large numbers of hover-flies of the species *Syrphus ribesi*. These insects had traveled on a stormy gale of wind for a distance of over 800 miles, and had been blown in a broad belt across the island of North East Land (which is about the size of Wales). Since the surface is entirely covered with ice and snow, or else consists of very barren rocks with a high arctic flora, there was not the remotest chance of either aphids or hover-flies surviving. As a matter of fact the majority of them were wiped out by a blizzard which occurred three days later.

Abortive colonization is happening everywhere in nature, on a smaller scale, and the two examples quoted above are given in order to drive home the fact that dispersal [introduction] by itself may have absolutely no effect upon the distribution of a species, unless it is accompanied by effective establishment at the other end. . . . One of the chief difficulties facing an animal upon its arrival is that of finding a mate with which to cooperate in perpetuating its race. The chances of one individual copepod reaching a new piece of water by accidental dispersal may be small, and that of two individuals of opposite sexes doing so smaller still. But the chances of these two meeting and mating and bringing up young would seem to be extremely remote indeed.

That introductions so often fail to result in establishment is undoubtedly a matter of fundamental importance in plant quarantine. If every introduction of a plant pest or disease, or even a large portion of them, resulted in establishment, there would be practically no field for plant quarantines, for it is manifestly a practical impossibility in most instances to prevent *every introduction* by legal restrictions. Nevertheless, recognition of this fact immediately indicates that the use of quarantines for *preventing the establishment* of plant pests and diseases in areas where they have not formerly occurred may be a logical and reasonable procedure. The Mediterranean fruit fly has been intercepted hundreds of times on ships docking at California ports, and it would be unreasonable to suppose that all introductions had been intercepted. There seems little doubt but that failure of the fruit fly to become established in California up to the present time is explained by the fact that a complicated set of biological requirements must be met before such introductions can result in establishment. But *if such introductions happen frequently enough, sooner or later the right combination of circumstances is likely to occur and establishment will then result*. It is the function of plant quarantine to make these introductions so infrequent, so scattered, and so infinitely small that *establishment* will be greatly deferred or prevented altogether. It is concluded, therefore, that plant quarantines do not necessarily have to result in the interception of every individual of an insect or pathogenic organism in order to be effective and justifiable.

However, it must be recognized that there are varying degrees of "favorability" of introductions. A parthenogenetic scale insect, arriving fixed on its host plant, would fall in the category of extremely favorable introductions, since climatic conditions suitable for the development of the host are likely to be suitable for the development of the scale. Fertilization not being necessary, a single female can produce progeny, and the inability of the scale to disperse by flight compels it to remain on its proper host. At the other extreme are found such insects as have only a single host plant, a single generation per year, which are active flyers, and which are not parthenogenetic. It is evident then that the introduction of some types of insects into new habitats is much more likely to result in establishment than in the case of others. This is believed to be a partial explanation of the fact that so many species of Coccidae and Aphididae are of almost cosmopolitan distribution. It is also evident that these characteristics have a bearing on the importance of the method by which an insect is introduced. The inability of female scales to fly is favorable to their establishment if introduced on a

growing host plant, whereas it is unfavorable if introduced on fruits. Hence it may be maintained that the transportation of fruit is much less likely to result in the establishment of a scale than is transportation of its host plants.

The matter of wind dispersal is of interest in connection with establishment of pests and diseases in new habitats. It has been mentioned that there is no evidence that wind dispersal results in the establishment of colonies a long distance from their source. This is probably explainable on the basis of the "mass action" principle. It is a well-known fact that in the case of many diseases, a certain minimum amount of the inoculum must be present before infection takes place. Any lesser amount than this fails to result in the establishment of the disease. In insects a similar condition may exist, and it is probable that in most cases establishment will take place only when the introduction occurs in such a way as to provide a certain minimum density of insects. Any lesser number fails to result in establishment because of environmental resistance. (See p. 28 ff.)

The dispersal of pathogenic organisms and insects by wind is an established fact (Butler, 1917; Felt, 1928) and this presumably can take place over long distances. There are, however, no definite proofs that either insects or diseases have become established by wind dispersal at long distances, say several hundred miles, from their source. When such long-distance jumps take place it is more reasonable to assume that they are a result of carriage by man than that they result from wind dispersal. If such establishment results from wind dispersal, it would be logical to expect such occurrences to be much more general than is the case. Such insects as the gipsy moth are without much doubt carried hundreds of miles by air currents, yet this has not resulted in the establishment of new colonies a long distance from the source of infestation. The cotton boll weevil and the alfalfa weevil take to the air in large numbers at certain times of the year, but there is no indication that this has resulted in the establishment of distant colonies. Such jumps as have been made by the alfalfa weevil are easily accounted for by commercial transportation, and the cotton boll weevil appears to have made no long jumps.

It seems reasonable to assume that the density of live organisms traveling on air currents becomes less and less the greater the distance from the source. It would be expected, therefore, that in general there is a point beyond which the density is too low to accomplish infection or infestation. This would vary with the organism, the environment, and the velocity and prevailing direction of the air currents, but the general

hypothesis appears to be sound. It must be assumed, therefore, for the present at any rate, that wind dispersal is of little importance in long-distance jumps of pests and diseases, although it is undoubtedly of great importance in local or short-distance spread.

There is some actual evidence indicating that the probability of infection varies inversely with the distance from the source. For example, according to Gardner (1918), Bartholomew found the following relation in studying the dissemination of apple rust: near a bluff covered with infected red cedars, trees directly at the base of the bluff had 59 per cent of the leaves infected; trees $\frac{1}{4}$ mile distant had 54 per cent infected; and trees $\frac{1}{2}$ mile distant had 6 per cent infected.

Quayle (1916) demonstrated the existence of this same inverse ratio between intensity of infestation and distance from source to exist in the case of scale insects. His experiment consisted of suspending infested citrus branches on a pole set in barren ground. Tanglefoot sheets were suspended at distances from the source of 26, 46, and 70 yards on the lee side of the infested branches. The number of scale insects captured was 37 on the sheets 26 yards from the source, 17 on the sheets 46 yards from the source, and 9 on the sheets 70 yards from the source. No scales were captured on the sheets placed to the windward side of the infested branches.

THE PROBABILITY THAT PLANT PESTS AND DISEASES WILL BECOME IMPORTANT IF ESTABLISHED

The mere fact that a plant disease or pest has been established in a given district by no means insures that it will become of serious importance in that locality. Several different factors influence this.

Environmental Relations.—A hindrance to the development of plant diseases and pests of great effectiveness may be formed by differences in climatic conditions, such as distribution and amount of rainfall and humidity, or range of temperature. It is a well-known fact that the virulence and activity of plant diseases and the abundance of insects are very much affected by climatic conditions. A disease or pest, no matter how frequently introduced into a new locality, may never develop on account of unfavorable conditions. A few examples of this in relation to California may be mentioned.

Apple scab, an extremely destructive disease of apples in most parts of the United States and other parts of the world, was introduced into California very early in the history of the present era. Judging by experience elsewhere it might have been concluded that this disease would be a very serious handicap to the growing of apples in this state

and one that would amply justify a quarantine. As a matter of fact the disease, while it is something of a nuisance in certain districts, has never become of great economic importance and in most cases is very easily controlled. Apple black rot and bitter rot cause the destruction of millions of bushels of apples in the midwestern United States. It is highly probable that they were introduced into California in the early days when many other diseases were brought in without restriction. Yet if these two troubles have ever occurred here they are, practically speaking, nonexistent and of no economic importance whatever. The only possible reason for the freedom of California apples from these diseases must be looked for in unfavorable climatic conditions. Grape downy mildew (*Plasmopora*) and black rot cause immense losses in grapes in the eastern United States and other parts of the world, and if there were no knowledge to the contrary it might be thought that California viticulture would be in very serious danger. On the contrary it must be assumed that these diseases have many times been introduced into this state, yet they do not exist here. Neither *Plasmopora* nor black rot has ever been reported in California. The reason again must be looked for in unfavorable climatic conditions. Citrus melanose, which is a serious disease of citrus in Florida, occurs in southern California to a limited extent at the present time. Its economic importance, however, is nil, a condition totally different from that relating to the same disease in Florida. Here again unfavorable climatic conditions furnish the most probable explanation. Citrus scab is another troublesome disease in Florida which is known to have been introduced into California repeatedly on carloads of sour-orange stock in the early days before quarantines were placed, and yet the disease never persisted here. It apparently had ample opportunity to become established by spread from scab lesions if the climatic conditions had been suitable (Fawcett and Lee, 1926).

In all these cases the dry, rainless summer in California is undoubtedly the cause of the effects which have been described. Most fungus and bacterial diseases are favored by high humidity combined with medium or fairly high temperature. In other words, regions with abundant rainfall in the summer season are favorable to such diseases while a dry summer is extremely unfavorable. The same thing is seen in the variable outbreaks from year to year of most of the plant diseases which are of importance in California. Apricot shot-hole disease, peach rust, tomato blight, citrus blast, and many others develop extensively during seasons when unusually late rains occur in the spring or more abundant rains than usual early in the fall.

Plant-feeding insects in California provide many similar illustrations. The Florida red scale (*Chrysomphalus aonidum*) occurs in California but is not of the slightest economic importance. In Egypt, South Africa, Syria, and other regions it is a major pest of citrus. *Chrysomphalus dictyospermi*, the most important pest of citrus in Mediterranean countries, occurs in southern California commonly but does not attack citrus. The black scale (*Saissetia oleae*), a major pest of citrus in southern California and other parts of the world, occurs commonly on olives and ornamentals in central and northern California but is of no importance whatever as a citrus pest. The red scale (*Chrysomphalus aurantii*) seems unable to exist in northern California. The reason for these peculiarities is undoubtedly climatic.

California climatic conditions exert a deterrent effect on certain insect pests and plant diseases and not on others. The mild winter, for instance, may be more favorable to some than climatic conditions in other places. Some diseases and pests are of more economic importance in California than in the regions where they originated—this is true, for instance, of walnut blight; and it may be that this increased virulence is due to favorable influences exerted by the peculiarities of this climate.

Increased abundance in the case of insects established in new habitats is most often due to the fact that their insect enemies were left behind when the introduction took place. This is true of the citrophilus mealybug, which became a major pest in California, but which was unknown in its native habitat, Australia, until found there by a California entomologist. The citricola scale is a serious pest in California, and is undoubtedly an introduced insect but its native habitat is not even known.

There is probably no method known at present by which it would be possible to ascertain positively in advance whether or not climatic conditions in California would be favorable to a given disease or pest. Comparative studies may be made as to temperature and rainfall conditions in countries where an insect or disease is serious, and such studies may suggest that under California conditions it would be more serious or less serious than in its native habitat. The Japanese beetle, for example, seems to be limited in the Orient to the colder parts of Japan. It does not seem likely that it would thrive in the interior valleys or in the southern section of California. In the case of citrus canker, all the available evidence indicates that this disease would not flourish in California. The same is true of Philippine corn diseases and many other diseases which seem to require a combination of high humidity and fairly high temperature for development or, in other words, a rainy

summer season. On the other hand, it would seem unwise to admit to California a disease or pest of great potential economic importance to one of the staple crops merely on account of considerations of this sort, particularly if there were no serious objections to, or difficulties involved in, quarantining against it. Conditions vary in different parts of California, and even though a disease or pest might not prove serious in one part of the state it might become of great importance in another part and form a constant menace to the industry.

Host Relations.—Many diseases and pests have more than one host. It may therefore happen that a trouble which is serious on several hosts may be brought in upon an unimportant one and then establish itself upon some much more valuable crop after it reaches the state. In such a case it might happen that, even though the principal host was quarantined against, a disease or insect might be brought in and established here in this manner. In the case, for instance, of pear blight, many apricot and peach diseases, crown gall, and garden nematode it would have been necessary to have quarantined against a long list of hosts in order to have been certain that these organisms would not be brought in and become established upon some of the most valuable crops. The same is true of the citrus white fly.

A disease or pest may occur on a certain host in a given country in such a mild form that it attracts no attention but when introduced into a new country may find there much more favorable hosts and become very serious. This is illustrated in the cases of citrus canker and chestnut blight in this country and of the grape phylloxera in France. Again, an important host plant which does not suffer from serious diseases or pests in its native home may pick up a new disease or pest in a new place and then form a medium of spreading these to its own species in other localities. This is illustrated by the snapdragon rust, hollyhock rust, alfalfa crown wart, Philippine corn diseases, and Colorado potato beetle. All these cases illustrate the complexity of host relations in regard to the introduction and establishment of plant diseases and insect pests.

Virulence and Abundance.—The selection of diseases and insects to be quarantined against is governed most naturally by their destructiveness or economic effect in the countries where they occur upon a host which is of major importance in the country to be protected by the quarantine. The natural procedure is for each country to quarantine against what seem to be the most destructive pests and diseases that occur in other countries on its most important crops. This rule, however, as shown by experience is only partially reliable. Some of the most im-

portant introduced plant pests and diseases in California attracted very little attention in the countries from which they came or even were totally unknown there, whereas in this country they became very destructive. On the other hand, they may be much less serious in the new locality than in the old one. These effects are undoubtedly due in part to environmental or climatic relations already discussed or to a difference in species or variety of host plant.

There should also be taken into consideration in this connection the rather common phenomenon that a parasitic organism of any kind is inclined to be more destructive in a totally new district than in its original habitat. The fact that in the new locality the hosts may be more susceptible or natural conditions more favorable does not seem entirely to explain this. It appears in many cases that the parasite becomes actually more virulent or aggressive when introduced into a new environment. It also happens in many cases that after a time the "biological equilibrium" becomes gradually established and the new disease is less virulent. A good example of this is seen in the case of asparagus rust. This European disease attracts very little attention in countries where it has always occurred and is scarcely mentioned as a serious asparagus trouble. When it first arrived in the United States it swept over the entire country and virtually destroyed the entire asparagus industry. Gradually, however, the rust has become less important until now asparagus growing has become rehabilitated and the disease is of minor importance. The same thing has occurred with carnation rust and chrysanthemum rust. This is partly a matter of host relations; a natural or artificial process of selection of types of the host plant more resistant to the disease usually takes place. It also seems, however, that the parasite itself becomes at first more destructive in a new habitat and then gradually subsides to a condition more nearly one of equilibrium. Here again, as illustrated by the cases mentioned, it is impossible always to foresee the behavior of a given pest or disease in a new locality on the basis of its occurrence in another place. No positive method can be prescribed by which this condition can be satisfactorily met in relation to quarantine. Undoubtedly there will always be cases where diseases and insects of insignificant importance in other countries will be allowed entrance into new localities and there become very much more serious, as well as cases where pests and diseases which are apparently of great importance elsewhere may be quarantined against unnecessarily because of incomplete knowledge of the factors which influence virulence and abundance. Here is an important field for research.

Vector Relations.—There are a few plant diseases which, to become established, require not only the presence of the proper host and parasite but also need a certain specific insect to transmit the parasite from one host to another. This, for instance, is the case with curly top of sugar beets and tomatoes, formerly called yellow blight on the latter host. In this case the disease attacks not only the sugar beet and tomato but a great many other hosts plants. It is necessary, however, that a certain specific insect, the beet leafhopper, be present in order that the disease may be transmitted or carried from one plant to another. The case is similar in a superficial way to those of malaria and yellow fever, which require certain mosquitoes to spread the disease and infect new victims. In the case of curly top, diseased plants might be introduced as frequently as desired into a new locality and might be planted in the midst of other healthy plants of the same kind without any spread of the disease unless the beet leafhopper were present to bring about the transfer. This factor may be the explanation for the nondevelopment of peach yellows in California. It seems almost certain that this disease must have been introduced in the past, since in early days peach trees were brought in freely from states which are affected with yellows. Practically all the other peach diseases of the world were introduced. There is no apparent climatic reason why peach yellows should not flourish in California, and so far as hosts are concerned it has them here in abundance. It is possible, therefore, that the missing link is some specific insect carrier which spreads peach yellows in the eastern states but is not present in California. It so happens that the western limit of peach yellows and the eastern limit of curly top almost exactly coincide at a line drawn north and south through western Nebraska, eastern Colorado, western Kansas, and central Texas. The nonoccurrence of curly top east of this line is known to be due to the fact that the beet leafhopper is a western insect and does not exist east of about this line. This suggests the possibility that the reverse condition may be true with peach yellows. Possibly a native insect of the eastern states reaches its westward limit at about this point and further west the disease is not able to spread on account of the lack of this insect.⁵

⁵ Since this manuscript was prepared, Kunkel (1933) has reported on an investigation of the possibility of insect transmission of peach yellows. He tested many species of insects and succeeded in transmitting the disease with one of these, the leafhopper, *Macropsis trimaculata* (Fitch). The distribution of this leafhopper is recorded in Van Duzee's catalogue as Ontario, Maine, New York, Pennsylvania, Michigan, Iowa, Kansas, and Colorado.

THE ECONOMIC ASPECTS OF PLANT QUARANTINES

The true purpose of quarantines is to avoid the undesirable economic consequences that result from the introduction and spread of various pests and diseases. The prevention of the spread of pests and diseases by the establishment and maintenance of quarantine regulations, however, produces other economic consequences which may also be undesirable. The problem resolves itself into a choice of the lesser of two evils.

An ideal plant-quarantine regulation would be one that excluded a plant pest or disease with no costs of enforcement and with no interference with commerce or travel. Some plant-quarantine regulations approach this ideal; the cost of enforcement is small, travel is not retarded, and goods after inexpensive treatment and inspection move freely in commerce; for example, the requirement that potatoes must be screened before coming into California in order to prevent the introduction of alfalfa weevil and Colorado potato beetle. Some plant-quarantine regulations are expensive to enforce, arouse antagonism, and restrict or completely prohibit the shipment of certain goods; for example, the exclusion of citrus fruit except from Arizona. The disadvantages of trying to prevent the spread of a plant pest or disease may in some cases be greater than the disadvantages of letting it spread, even if it is biologically feasible to prevent the spread.

The economic consequences resulting from the spread of plant pests and diseases or from the regulations preventing the spread of pests and diseases are not uniformly distributed among all people. Until adjustments are made some individuals benefit directly, others only indirectly, or not at all.

Over long periods and after adjustments have been made in production, prices, land values, wages, taxes, habits of consumption, etc., the effects of plant quarantines or spread of pests are diffused among all people. However, most individuals are primarily interested in the immediate and near-future effects on their own income and wealth. The effect on other individuals or groups is sometimes overlooked or disregarded and each group or class has a different point of view. Even a biologically justifiable quarantine that is beneficial to one group or from one point of view may be disastrous to another group. Measures designed for the specific purpose of limiting competition and giving one group artificial economic advantages over some other group may be administered in the name of quarantine. Many people do not distinguish between sound and unsound quarantines so that all quarantine measures

are under suspicion by some. The group or class inconvenienced by the measures may try to retaliate even if the quarantine measure is biologically sound; they are very sure to retaliate if the measures to which they object are only trade barriers disguised as quarantines. Retaliation may take different forms; the most obvious are quarantine measures affecting the same or some other products, but others may apply to market inspections, size and shape of packages or some kind of an informal boycott whereby consumers or merchants refuse to buy or handle products from certain areas. A "buy locally grown fruits and vegetables" campaign may be an effective form of retaliation. Therefore, measures designed for the specific purpose of lessening competition or for retaliation may be administered in the name of quarantines.

Even if the effects of the spread of plant pests and diseases and of the regulations to prevent this were fully understood and agreed upon, there would still be individual and class interests, because very few human beings are so socially minded that they are willing to sacrifice some of their present wealth and income or to forego some possible future private gain for the benefit of someone else or the rest of society.

Points of View.—The attitude of individuals, groups, or classes of people toward plant quarantines depends primarily on the direct or immediate manner in which such quarantines seem to affect them. The tourist, stopped for inspection of his baggage, feels immediately that he is inconvenienced and delayed. If this happens to be his only contact with quarantines and if he knows nothing about the purpose and other probable effects, he may conclude that plant quarantines are some form of graft and ought to be abolished. It may never occur to him that as a consumer of agricultural products in a distant city he may be continually but indirectly benefiting from plant quarantines by being able to purchase a great variety of agricultural products at low prices. To balance his small contribution of submitting to an inspection against the probable indirect benefit he receives necessitates a comprehensive knowledge of the biological bases for the quarantines and an understanding of the complicated economic interdependence of all people.

Some taxpayers may look only at the governmental expenditures for enforcing and maintaining plant-quarantine regulations. To them taxes seem high, and they may feel that plant quarantines constitute an item of public expenditure that they are helping to support without receiving in return any direct tangible benefits.

Growers as a class usually favor plant quarantines, because they have had unfavorable experiences with plant pests and diseases. They know that their crops are in constant danger of damage and destruction. The

cost of pest control and the loss of salable products is the most evident effect of plant pests and diseases to growers. Therefore, they usually favor anything which will reduce or keep these costs from rising and that will prevent damage or destruction of their products by new pests. However, their net benefits would be smaller if the costs of maintaining the quarantines were assessed against the crops instead of being paid from general tax funds. A few growers may oppose quarantines because they know, or at least think they know, how to produce high-quality products by controlling insects and diseases, and they may even hope that pests and diseases will destroy the crops of other growers so that the supply will be smaller and prices, as a consequence, will be higher. A few growers may object to plant quarantines because they think that such regulations are futile and expensive.

The dairy farmer may object to a quarantine which excludes alfalfa hay because he thinks that it raises his feed cost. The alfalfa producer on the other hand may favor such quarantines because he thinks that they prevent his costs of production from increasing and he may also think that prices of alfalfa hay are higher on account of the quarantine. The dairy farmer may not recognize the fact that if hay were cheaper milk production would be increased and he would receive lower prices for his milk. However, a quarantine which restricts shipments of alfalfa hay into California does not necessarily have an appreciable effect on prices, as will be discussed more fully later.

People in other states may object to California plant quarantines because it appears to them that such regulations exclude their products from California markets. To them the California quarantines may appear to be only trade barriers which ought to be removed. On this account they may foster retaliatory measures of any kind to exclude California products from their states. Producers in California may have similar opinions and favor plant quarantines because they think that such restrictions provide better local markets.

Classes and Groups in Society.—Since plant-quarantine regulations and the spread of plant pests and diseases do not affect all people alike, the question at once arises as to the number and kind of classes and groups of people who are to be considered in evaluating the economic effects. Obviously the advantages and disadvantages to different people must be compared in order to estimate the net benefit or loss to everybody or to society. But how many and which ones of the several groups of people shall be considered as constituting society?

How big is the concept of "society" to be: the producers of a particular crop in California, all the producers of a particular crop irrespective of

where they live, all the farmers in California, taxpayers in California, consumers in California, all the people in California, all the farmers in the United States, or all the people in the world? Perhaps some people would like to include Canada and a few countries of Europe and to leave the rest of the world out of consideration. However, the effects of a plant quarantine may be practically world-wide.

The federal quarantine regulation that restricted imports of bulbs into the United States altered prices of bulbs in practically all exporting and importing countries. To evaluate properly the effects of such a quarantine it would be necessary to consider the losses to producers and gains to consumers in all foreign countries, the gains to producers in this country, and the losses from higher prices and gains from healthier bulbs to consumers in this country. Perhaps the disadvantages to producers in Europe far outweigh the gains to people of the United States. But what can the producers in Europe do about it? They can cease to grow bulbs, stop buying prunes, raisins, other fruit products, automobiles, and anything else from the United States and produce their own products or get along without them. This would tend to be the ultimate result, without any legislation, because they cannot buy unless they have something to offer in exchange. However, they may hasten the change by enacting tariffs, quotas, embargoes, and other measures to restrict imports. Finally, producers of export commodities in the United States are indirectly affected.

If the people of other countries are excluded from the concept of society and the effects of plant quarantines on them are not considered, then the analysis is unfair, and the people of this country are favored at the expense of foreigners. Likewise, if the effects on producers and consumers in other states are not considered, and "society" is limited to the people of California, that is again unfair, and even more so if only the effects of plant quarantines on the producers of agricultural crops in California are considered and the effects on other people in the state are ignored.

State plant quarantines do not affect foreign countries. That is really a federal problem. The economic consequences of federal quarantines are fundamentally of the same nature as those discussed in this section except that other countries or sovereign states have to be considered instead of separate states with only limited sovereign powers. The Constitution of the United States of America prohibits trade restrictions between any of the 48 states and attempts to make this country one large free-trade area. The international aspects of federal quarantines are outside the scope of this report. The interstate effects of California

quarantines must be considered for both political and economic reasons. The state of California does not constitute a wholly independent society and since most of the volume of agricultural products produced in California is marketed in the other states the market in those states is of utmost importance to California agriculture. Therefore, in the discussion of state quarantines the size of the group to be considered as society must be limited primarily to the people of the United States. No serious error results from the exclusion of people in foreign countries. A state quarantine can then be considered as socially justifiable as long as it does not cause greater disadvantages to all the people of other states than advantages to all the people in the state maintaining the regulations. If fully understood, such a state quarantine creates no valid basis for the adoption of retaliatory measures by other states.

EFFECT OF PESTS AND QUARANTINES ON THE TOTAL SOCIAL INCOME AND ON THE DISTRIBUTION OF INCOME AMONG INDIVIDUALS AND GROUPS

The main causes of misunderstanding the economic effects of plant quarantines arise from such differences in points of view and concepts of society as were indicated above. Different ways of looking at the same problem give rise to such statements as: "plant pests and diseases cause three to four billion dollars of loss annually in the United States," and "plant pests and diseases increase the income to farmers by destroying part of the surplus." For example, during 1921 to 1923 when the boll weevil was not controlled the smaller cotton crops had a much higher total value. These statements, although contradictory, both contain some element of truth and indicate the need for a more complete understanding of the probable economic relations arising from control or failure to control such pests and diseases.

The losses from plant pests and diseases by individual growers are more easily visualized than losses and gains to groups of growers or to society. Such losses, therefore, have more weight in determining plant-quarantine policies, even though the sum of the individual losses does not equal the group or social loss.

The individual producer in a competitive society always secures the largest income for himself by obtaining the maximum production possible with the minimum of effort and expense. To him all plant diseases and pests whether controllable or not constitute handicaps which reduce the yield or the quality of his product and increase his costs of production. The larger his crop, the greater his income because his individual production is too small a part of the total production to

have any appreciable effect on price. If other growers also produce large crops he is still getting more income than he would be if their crops were large and his small. Of course, his income is greatest when his crop is large and the crops of other producers are small. Then he has a large volume to sell at high prices.

If insects and diseases reduced the volume of a certain crop uniformly on all farms, then the producers as a group and as individuals might, in a particular year, receive more total income for the small crop than for a larger crop. In such cases each of the producers would benefit or lose proportionately to his volume of production. However, all that the producers would gain in money the consumers would lose in money by paying higher prices, and aside from the money losses and gains, which balance for society as a whole, there would be a net social loss represented by the decrease in physical volume of the crop.

If pests reduced the total volume of production by causing complete failure or destruction of the crop on some of the farms, while other farms had normal yields, then the effect on the consumer would be the same as indicated above; and while the gross money income received by all producers might be larger than from a normal crop, growers with normal crops would receive far more than if the total crop had been normal, and other growers might receive nothing for their year's effort and cash expenses.

Society considered as a large group of producers and consumers has interests almost identical with those of individual producers. All pests and diseases constitute a handicap to production which reduces the amount of produce available for distribution among the members of society. In order to have enough agricultural products left after some of the potential yields have been destroyed by insects and diseases, a larger percentage of the population and of the productive capital available must be devoted to agriculture and a smaller percentage to other activities than would otherwise be necessary. If there were no pests and diseases, fewer people and less capital would need to be employed in agriculture to satisfy the demands for agricultural products, and the total volume of agricultural production would not be any appreciable amount greater. Less land would need to be cultivated and all land would have a smaller value per acre.

Estimates have sometimes been made of the monetary loss to society from plant pest and disease damage by multiplying the physical quantities of crops destroyed by some price, either an average price over a few years or the price during the current year. Such estimates are rather meaningless because: (1) if there were no damage by pests and

diseases, less productive effort—i. e., land, labor, and capital—would be devoted to agriculture, and the total volume of production would be approximately the same as it is now with pest and disease damages; and (2) even if the total production were larger then the prices would not be an average of past prices or the same as at present, but smaller, in some cases perhaps only equal to harvesting costs, and a part of the crops grown would not be harvested. Similar errors are involved in estimating quality damage by multiplying units of inferior quality by the spread in price between high and low quality. These relations will be illustrated and discussed more fully on page 47, under the heading “The Economic Aspects of Changing Volume and Quality of Production.”

On the other hand, it is also incorrect to assume that plant pests and diseases create value by destroying parts of the physical quantity of crops. Total benefits to society cannot be increased by wasting effort in producing something that is not wanted or by destroying part of products already produced, even though by such acts it may be possible to increase the income of a part of society by greatly reducing the income of the rest of society.

The real cost to society of plant pests and diseases is the amount of additional effort required to produce agricultural products on account of these pests and diseases. Since most of the consumers of California products are in other states and foreign countries, it is difficult to balance the effects on consumers against the effects on California producers. These costs to society cannot be measured in dollars and cents, and any statements attempting to show either losses or gains in money terms to society as a whole are meaningless. In the long run the consumers tend to pay all of the costs and to receive all of the benefits except when some form of monopolistic control intervenes, and then consumers continue to pay all of the costs but do not receive all of the benefits.

The purpose of plant quarantines should be to benefit all of society and not any particular group or class. It may be impossible to maintain such quarantines without giving some class or group temporary trade advantages, but such advantages should be incidental and not the purpose of quarantines. Even incidental trade advantages or disadvantages may lead to resentment and retaliation if not properly understood. Any quarantines specifically applied for creating trade advantages for a class or group are of a monopolistic character.

Monopolies are generally recognized as social evils because they enable an individual, group, class, state, nation, or other subdivision of society to gain at the expense of some other individual, group, class, state, or

nation, or at the expense of all the others combined. A monopolistic point of view embodies the idea of getting more for one's self regardless of whether or not there is more to be divided among all.

Conflicting self interests give rise to most of the economic problems. Unfortunately, many people see, or are willing to see, only one side of the question, and that is the one that relates to their own well-being. It is practically impossible to secure data in monetary terms that are of any importance except by isolating classes and taking a monopolistic point of view. For example, the cotton farmers, grape producers, or peach growers might temporarily at least increase their money incomes by reducing production, destroying part of the crop, or holding it off the market. If insects or frosts destroy part of the crop for them, then these producers temporarily gain without being accused of monopolistic action. On the other hand, larger yields of specific crops often bring smaller money returns to producers, but the consumers get more products for their money. With increased production there is a net social gain as long as consumers benefit more than producers lose. This tends to be true if the larger yields are due to more favorable temperature and rainfall or to a failure of plant pests and diseases to do their usual amount of damage. Under such circumstances society receives more products than it could have expected from the effort expended, and there is a net social gain. On the other hand, if the increased production is due to excessive plantings then effort is wasted in producing a product that is not needed. Concerted action on the part of producers to bring about a more favorable balance between crops by reducing surpluses caused by excess plantings of particular crops is socially desirable as long as it is not carried too far. If the land and labor now used in the production of such crops can be devoted to any other use that is socially desirable, then a change ought to be made by decreasing plantings. But the existence of such surpluses is no socially valid reason for removing quarantine restrictions.

The popular concept of a surplus is a quantity so large that it reduces prices and total returns to producers below the costs of production. However, large temporary incomes of the past have usually been capitalized into unwarranted land values, high rents, and high taxes, which in turn are included in the popular conception of costs of production. Therefore, any increase in production which tends to lower prices and returns to producers from what they have been is usually called a surplus. Whether or not the prices received for any given volume cover all costs of production has no direct effect on the current supply, although such prices and costs largely determine future supplies.

Careful distinctions must be made between the effects of changing the total volume on gross returns to all producers of a crop as a group and the effects of changing part of the volume on the gross returns to growers producing that part. For example, since growers in California produce only a small part of the total world supply of cotton, if half of the California cotton crop were destroyed by a pest, world prices might rise a little, but they would not double, and growers in California would receive smaller gross returns for their cotton. The total world crop might have a somewhat larger gross value, but the producers outside the state of California would gain or benefit on account of the misfortune to California cotton growers.

Many cooperatives have learned that they cannot increase prices by limiting or controlling part of the volume. To be successful in such attempts they must control nearly all of the supply, or the producers outside the organization will expand their volume to take advantage of the higher prices without paying any of the costs of control. The fundamental relations are the same for the effects of plant pest and disease damages on gross returns as for cooperative control of surpluses to increase returns. If the pest or disease reduces the crop in all areas where the crop is grown or can be grown, then all producers as a group may benefit temporarily, even if there is a social loss. If the pest or disease causes damage in only one area to a portion of the total crop, then the producers in that area lose while producers in the noninfested areas gain.

The effects of plant pests and diseases on the gross returns to farmers in California depend to a large extent on the proportion of the total market supply that is produced in California. For example, a new pest attacking cotton or wheat in California would result in a monetary loss to California producers practically in proportion to the physical reduction in the quantity produced. A new pest or greater damage by old pests on such crops as canning peaches or raisins may temporarily help the producers of these crops, because California produces almost the entire United States supply and a large proportion of the entire world supply. However, the effect of pest or disease damage to these crops on the returns to the individual producer whose crop is damaged tends to be the same as the effect on all producers in California of damage within the state to crops like wheat or cotton.

In general the greater the area outside California used for the production of specific crops, the greater the loss to California growers from pest damage to such crops in this state. Likewise, the greater the number of growers producing specific crops, the greater the loss to the individual grower from pest damage on his farm. However, the sum of the

losses to individual growers does not equal the loss to growers as a group. This is illustrated more fully by specific examples in the next section.

ECONOMIC ASPECTS OF CHANGING VOLUME AND QUALITY OF PRODUCT

Plant pests and diseases affect the gross returns to producers of farm crops by changing the total volume of physical goods available for marketing and by altering the quality of the product. Changes in volume are associated with inverse changes in prices, and the weighted average price of all grades in any season is largely determined by the total supply. The spread in prices for different grades above and below this average price is largely determined by the proportions of the various grades. The general quality of the crop may also have some effect on the average price for the season.

The supply of competing or substitute products, the value of money, purchasing power of consumers, general business conditions, and many other factors, often grouped together as demand, also have important effects on average prices, but their influence usually operates over a period of years.

The largest and best crops ever obtained are usually smaller than they would have been if there were no pest or disease damage. Pest and disease damage expressed as a percentage in most cases applies to the theoretically possible crop which is never harvested. The physical damage from pests and diseases to a given crop may never have been less than 5 per cent, or more than 25 per cent, with an average of about 15 per cent. The effects on price of variations in the amount of pest and disease damage above or below this average damage can be readily measured from the supply-price relations. But the long-time effects of an increase or decrease in the average amount of damage may be entirely different. For instance, if a new pest in the first year reduced average production of a crop by 20 per cent the prices would rise the same as if this reduction were caused by frost, drought, or any other circumstance. Consumers in the habit of buying this product would not change their habits promptly. However, if the pests continued to cause about this much damage year after year consumers would tend to shift to other products so that prices would fall, and when a new equilibrium became established the average unit price for the 20 per cent smaller crop might not be any higher than for the larger crops at an earlier period. No one can forecast the long-time effects on price of a permanent increase or decrease in the average supply. However, the effect on price of short-

time variations in supply, such as the annual changes in the damage by plant pests and diseases or the first effect of new pests or diseases can be shown clearly by the changes in supply, price, and total value of specific commodities. The physical changes in volume of California crops caused by the frosts in 1929 and by dry years provide data for illustrating this relation between supply, price, and total value.

*Illustrations of the Effect of Changing Volume.*⁶—

1. A small crop of peaches increased returns to growers. The effect on the clingstone peach crop of the frost in 1929 was very pronounced. Some growers harvested no peaches at all, others fewer tons than they expected, and a few full crops. To illustrate the difficulty of measuring these physical losses in monetary terms let us assume that a grower who on the average harvested 100 tons had no crop at all. His loss in physical terms was 100 tons. In 1928 the average price for peaches harvested was \$20 a ton. On this basis his gross monetary loss was \$2,000. However, the average price in 1929, when his physical loss occurred, was \$68 a ton. On this basis his loss was \$6,800. His net loss was smaller regardless of how the gross loss is figured because he saved harvesting expenses.

The individual grower can figure his monetary losses any way he desires, but individual losses cannot be combined to represent the total loss to all the clingstone-peach producers as a group. The frost reduced the total physical production of clingstone peaches from 414,000 tons in 1928 to 179,000 tons in 1929, a physical loss of 235,000 tons. At \$20 a ton this would equal \$4,700,000 loss and at \$68 a ton \$15,980,000. However, neither of these figures is correct.

In 1928, 344,000 tons of peaches were harvested and these brought the producers \$20 a ton, or \$6,880,000. The other 70,000 tons produced brought no income to the producers. If there had been no frost in 1929 the chances are that only the same amount could have been harvested and sold that year as in 1928 at a price of \$20 a ton. In 1929 all of the 179,000 tons produced were harvested, and these brought an average price of \$68 a ton, or \$12,172,000. The growers as a group therefore gained approximately \$5,292,000 of gross income on account of the frost. They also saved the costs of harvesting about 165,000 tons of peaches. The physical damage by the frost resulted in a monetary gain to the growers as a group but not to each individual grower.

The canners of clingstone peaches and through them the ultimate consumers lost about \$5,292,000, or all that the growers gained. Balancing

⁶ Based on data from California Crop Reporting Service, Fruit Growers' Exchange, Canners League, and other information as compiled by the Giannini Foundation for use in preparing the annual Agricultural Outlook reports.

the estimated money gains to growers against similar losses or added expenses for canners and consumers, one might conclude that the frost had no effect on the total money income of society and that it only tended to redistribute income. The loss to individual consumers was small, but the chain of economic effects did not stop at the consumers of peaches, because when they spent more money for peaches they had less to spend for other things, and the prices of all the commodities that consumers refrained from buying in order to pay higher prices for peaches were altered a little.

Although growers as a group received more money for peaches, the distribution of the money income among the growers resulted in great inequalities. Some individual growers received no income at all, others up to three times as much as they could have expected if there had been no frost. Most growers as individuals can get along without any unexpected gains, but they greatly fear the monetary loss which they suffer from damage to their crops by pests and diseases, frost, hail, and other causes for changes in production which do not affect all farms equally.

2. A small crop of prunes decreased returns to growers. In 1928 approximately 220,000 tons of prunes were produced and harvested. The growers received an average price of \$100 a ton, or a total of \$22,000,000. In 1929 frost cut production to 103,000 tons, farm prices increased to \$155 a ton, and the total farm value was \$15,965,000. Calculated on the basis of total value received for the two consecutive crops, the prune growers of California as a group lost \$6,035,000 on account of the frost. The consumers of prunes spent \$6,035,000 less for prunes, but they had 117,000 fewer tons of prunes to eat and paid \$5,665,000 more for the prunes purchased than a similar quantity cost them the year before. Calculated on the basis of physical loss times price, two different but larger estimates of the losses to growers are obtained; 117,000 tons at \$100 a ton, the price prevailing the year before, gives an estimated loss of \$11,700,000, and at \$155 a ton, the price prevailing during 1929, an estimated loss of \$18,135,000. Obviously both figures are too large. The \$6,035,000 quoted above comes the nearest to representing the monetary loss to the prune growers as a group, but this does not represent the loss to consumers or to society.

3. Larger shipments of oranges either increased or decreased total value of crop.

Larger shipments in 1929 than in 1927 decreased the value of the crop by nearly two and one-half million dollars. Slightly larger shipments in 1930 than in 1928 were associated with an increase of two and a quarter million dollars in spite of the business depression and lower general

price level. This may be accounted for partly by changes in demand, and partly by quarantine and eradication measures against the Mediterranean fruit fly in Florida. California growers tended to benefit from losses to Florida growers caused by curtailed shipments from that state. Yet year-to-year comparisons indicate that small shipments in both 1928 and 1930 had more total value than the larger shipments in 1927 and 1929.

TABLE 1
SHIPMENTS, PRICES, AND VALUE OF CALIFORNIA ORANGES

Year	Shipments, in 1,000 boxes	F.o.b. price per box	F.o.b. value
1927.....	12,168	\$4. 11	\$50,010,480
1928.....	9,144	5. 74	52,486,560
1929.....	17,720	2. 69	47,666,800
1930.....	9,305	5. 87	54,620,350

4. Increased shipments of table grapes increased total value.

In the case of shipments of table grapes, increases in value are associated with both increases and decreases in shipments in the short space of three consecutive years. From 1927 to 1928 an increase in shipments resulted in lower prices but not enough lower to offset the increased

TABLE 2
SHIPMENTS, PRICES, AND VALUE OF CALIFORNIA TABLE GRAPES

Year	Shipments, in tons	New York auction price per ton	New York auction value
1927.....	354,900	\$105	\$37,264,500
1928.....	411,440	95	39,086,800
1929.....	365,400	115	42,021,000

volume, and therefore, the larger shipments had a greater total value. From 1928 to 1929 a decrease in shipments resulted in more than enough change in price to offset the decrease in volume, and total value was increased.

These four illustrations indicate that any generalized statements of the relation of volume to price and value are very apt to be wrong because a larger crop may bring either more or less money, and this varies from crop to crop and from time to time, as all the other factors that affect prices change.

Even during a single season the supply-price relation for any crop depends to a considerable extent on the volume and price of competing crops or substitute products. If the frost in California in 1929 had damaged only peaches and no other fruit crops, then the chances are that prices and returns for the same production of peaches would have been smaller. Instead of a larger gain to growers as a group there might have been only a small gain or perhaps a net reduction in total value. Consumers do not eat peaches, pears, prunes, apricots, pineapples, bananas, etc., all at the same time. In many, and perhaps most, cases the choices made by consumers depend more on the relative prices of the different commodities than on habit, custom, likes, and dislikes. Competition between products is not limited entirely to products of the same class; vegetables may be used in place of fruits, and milk, eggs, and meat in place of vegetables. Some people may even substitute one group of products for another and cut down on food consumption in order to spend more for clothes, automobiles, or houses.

If the California production of wheat or cotton were used for illustrations there would appear to be a different relation between volume and value because California produces such a small portion of the total supply of these crops. The total world value of these crops would change with total world production but the total value of California production would be almost in direct proportion to the volume produced. The position of California in relation to all other areas producing such crops is similar to the position of the individual grower producing peaches as described in the first illustration.

These illustrations of changes in total value of crops accompanying changes in volume show how difficult it would be to make a composite estimate of the total damage to all crops from pests and diseases in terms of dollars and cents. Sometimes the growers as a group or class might gain, in other cases they would lose—a small change in volume may have one tendency, a large change just the opposite. The amount growers gain or lose in money is paid or saved by the middleman and the consumer. *The consumer always benefits from an abundance of production and should be more interested in maintaining plant quarantines that insure such abundance than growers as a group.*

A considerable portion of the production of many California crops is exported to foreign countries. In considering the probable economic effects of curtailed or increased production on consumers one may not wish to consider consumers in foreign countries and may think that if they pay higher prices then there is a net gain to people in California. However, it is well to remember that California has no monopoly on the

areas of the world that can grow certain crops. If the crops can be produced cheaper in other parts of the world, production will start there sooner or later, and this state may lose its foreign markets. The only safe way to keep markets, in the long run, is to be able to produce at least as good a product as can be produced in any other region, and to sell it for less. From this long-time point of view quarantines are justifiable if they help to keep costs of production down, help to produce a higher quality of product, and help to increase volume, even if the producers think there is a surplus and that production ought to be curtailed.

The consumers in other states of this country cannot be left out of consideration in any analysis of effects of changing volume. To succeed in the long run, growers in California must be able to produce as cheaply as in other states, and they must not attempt to gain advantages by anything but fair competition with other producers or to extract unwarranted prices from consumers, for such measures usually lead to retaliation of some kind, or expanded production in other areas.

The Effect of Changing Quality of Products.—The effects on price and returns to growers from changing the quality of product are very similar to those from changing the volume. The individual grower loses if the quality of his product is lowered and gains if the quality is improved, in the same way as if his volume of production were changed. The growers in one area gain if the quality in another area is lowered, or vice versa. If all of the supply is of poor quality (volume constant) the average price and total value may be just the same as if all of the supply were of high quality. In such a case the consumers get less for their money. If consumers substitute other products then average price for poor quality decreases.

Usually any characteristic of a product that commands a premium is said to represent high quality. The price differential for quality depends primarily on demand, which embodies the ideas and habits of consumers. Higher prices may be paid for brand or label names, general appearance, uniformity, size, color, texture, flavor, smell, vitamin content, mineral content, number of calories, freedom from germs causing human diseases, freedom from injurious chemicals, or any combination of such characteristics, whether real or imaginary.

The characteristics of a product used in determining grades may not correspond to those for which consumers pay higher prices, and consumer preference changes; therefore the relation of quality and grades to price is not fixed and permanent. There may be a limited independent demand for a particular characteristic of a product and the question of whether or not it commands a premium depends on both the absolute

supply of the grade embodying that characteristic and the proportion that this grade is of the total volume. The grade that commands a premium at one time may sell at a discount at another time or in another area. Sweet oranges may command a premium so long as they are scarce relative to sour oranges. Sour oranges may command a premium if scarce relative to sweet oranges. Russet grapefruit may command a premium if enough consumers think it is sweeter or better for any other reason, or it may sell at a discount if consumers dislike the color. It is immaterial whether the russet color is caused by pests or if it is the natural characteristics of some variety of grapefruit.

Some forms of pest or disease damage to plants affect both quality and volume of production at the same time. For example, beetles by destroying many of the leaves of the potato plants, reduce the size of the tubers. Measured in pounds or bushels the yield per acre is less if the tubers are small. This usually results in lower returns to the individual grower. If the tubers are so small that they sell at a discount relative to price of larger potatoes, then the individual grower also received lower returns on account of quality. However, some reduction in size of tubers may be an advantage because very large potatoes often sell at a discount, relative to medium-sized products. The lower prices for small units are often justifiable on a volume basis rather than a quality basis because the percentage by weight or volume of waste, peelings, rind, seeds, etc., is larger if the units are small. In the last analysis it is volume of edible material that counts, and since there is usually less food value in an equal number of pounds or boxes of small units than of large units the price is usually less per pound or box. But in terms of actual food value the small units sometimes are more expensive.

Market grades are to a large extent determined by the size of the units, and it is certain that as far as grades are based on sizes, if all the units were of equal size, there would be no spread in price. It is also probable that the price would then be the same as the weighted average price for all sizes of the same total volume when there are different sizes. Removing the small units from markets reduces the total volume marketed and affects average price because volume has changed. Increasing the size of the small units by cultural methods increases volume if the same number of units are produced; this may not change total volume or average price if accomplished by thinning, but it reduces the spread in price between the smallest and largest units. As the amount of product of the size that commands a premium increases, the premium paid for that grade decreases. Individual growers may increase their returns by shifting to quality products, but if all producers increase the supply of what

was high quality the consumers gain, and growers as a group may even receive smaller returns.

The term "culls" is often associated with pest and disease damage, but it has no single meaning and applies to small units as well as to damaged units and sometimes to the shape of the units. Odd-shaped fruit may sell at a discount even though it keeps as well and tastes as good as better-looking fruit.

The changes in quality more often considered as pest and disease damages consist of alterations in the condition or appearance of the units of product irrespective of the size of the units. It is difficult to make any clear-cut distinction between condition and appearance, but the term condition is used here to signify a physical characteristic of the product which is closely related to its keeping quality or food value as distinguished from its appearance. The ultimate consumer judges quality largely by appearance and even if he knows that there is no difference in food value he very likely pays more for a better-looking product. For example, there is no quality difference in scabby potatoes after they are pared and cooked, but scabby potatoes do not look as attractive and may not keep as well as healthy potatoes. The main social loss from potato scab may be the reduction in yields per acre rather than poorer quality. Spotted citrus fruit may contain just as much or more juice than better-looking fruit, and yet it usually sells at a discount because consumers usually purchase according to appearance. In most cases they have no other means of judging food value and therefore appearance is an important factor in causing different prices for different grades.

So far as pest damage alters only the appearance of the products there is practically no social loss from such damage. However, the distribution of income among individual producers is greatly altered by such damage. Some producers receive higher prices for their products, others lower prices, while the average price to consumers may not be changed at all.

The important quality damages by pests from a social point of view are those that affect either the keeping quality or the food value of the product or both. Demand for storage or processing for later sale is often more important in determining prices at the harvesting season than demand for immediate consumption. Diseased and damaged products often deteriorate to such an extent that unless consumed at once they cannot be eaten. The fact that clean, healthy products in many cases can be stored for later consumption tends to raise average prices at harvesting season because storage cuts down the supply available for immediate consumption. If the supply of products of quality fit for storage is small

then such quality commands a high premium. If such quality exceeds storage demands then the premium for storage disappears and only the premium for immediate consumption remains.

The social loss resulting from poor quality is to a large extent equivalent to a loss in volume of food available for consumption. If none of the product can be stored it may be necessary to waste considerable portions of the crops because people cannot consume all of it during a short season. If part of the supply is stored the percentage that spoils on account of poor quality amounts to a reduction in the volume available for consumption. The better the condition of the crop the greater the supply available for final consumption.

The difficulties of estimating quality damage from pests or diseases in dollars and cents are greater than those of estimating losses and gains from changing the volume. The same factors influence prices but the effects of some are more pronounced because price differentials for quality may increase or disappear because of changes in the reactions of the consumers without any change in the product itself.

The competition between grades of the same product is usually more important than competition with other classes or groups of products. For example, low-grade oranges, whether small, odd-shaped, off-color, spotted, sour, or rated cheaper for some other reason, are usually a better substitute for high-grade oranges than tomatoes, even though tomato juice may be used in place of orange juice. Yet, high-grade tomatoes may compete more directly with low-grade oranges than the average of all tomatoes competes with all oranges. Eliminating all low-grade oranges from the market may raise the price of high-grade oranges, but it does not necessarily follow that the gross value of oranges and the net income to producers of oranges will be increased thereby. The producers of peaches, pears, prunes, pineapples, grapefruit, tomatoes, or other rival or substitute products may benefit most. For some purposes (Marshall, 1930) it may be best to consider grades of oranges as different commodities, while for other purposes it may be best to group together commodities as distinct as oranges and tomatoes or even peaches and pineapples. For the purpose of discussing the effects of plant pests on quality and price, it appears best to consider all grades of one crop as one commodity, and on this basis estimates with some degree of accuracy can be made of losses to individual producers. For example, if grapefruit sells for \$6.00 a box and spotted fruit of the same size for only \$4.00, the individual grower whose crop has been spotted by insects or disease gets \$2.00 a box less for his fruit. If his crop had been of high quality, the spread in price would still have been nearly \$2.00 unless he

produces a very large portion of the total supply. However, it is incorrect to assume that all of the low-grade crop resulted in a \$2.00 loss per box, because if the supply of high quality were increased by reducing the amount of low quality, the price would fall below \$6.00 for high quality and rise above \$4.00 for the low quality with no loss and no gain to producers as a group from changing the quality. The average price for uniform quality might be anywhere between \$4.00 and \$6.00. It is even possible that the grade at first considered as of low quality might command a price higher than \$6.00 if there were very few spotted fruits and they were especially desired by some consumers.

Practically no studies have been made of the relation of quality to average prices for given volume, and before definite conclusions could be drawn for particular crops it would be necessary to collect a large amount of new data over a considerable period of time. The various estimates made of losses on account of quality damage for different crops apparently assume that average price and price of high quality are independent of total supply of all grades. This is such an unwarranted assumption that no such figures for total loss are quoted here.

ECONOMIC ASPECTS OF EXCLUDING PLANT PESTS AND DISEASES

Infestation by pests or infection by diseases may lead to higher costs of production, and smaller net returns to growers even if completely controlled so that volume of production is not decreased. If only partly controlled the decreased volume of production may bring prices just enough higher to offset the increased costs of production without materially affecting the growers' net returns. In such a case the consumers pay more for fewer products while the grower gets no benefit from the higher prices. However, the economic effects arising from the establishment of a new plant pest or disease which constitutes an additional handicap in production always results in a net social loss. For a considerable period of time this loss may fall on the grower only or on the consumer only, or be divided between them, or it may even result in a loss to the consumer in excess of the social loss because of some small temporary gain to the grower.

It may not be wise to incur great expenses to exclude a very destructive pest or disease which attacks only one unimportant crop or very few minor crops. Even if a pest completely destroys an important agricultural industry, the ultimate loss may be comparatively small, or it may be somewhat greater than the annual value of one crop, according to the next best use of the agricultural resources and time required to make changes. For example, if a grower can make an average net income of

\$2,100 annually producing sugar beets and only \$2,000 raising alfalfa, he naturally produces sugar beets. If his fields become infested with a pest which reduces this income from sugar beets below \$2,000, he will shift to alfalfa. His average annual loss is not \$2,100 but only about \$100, the difference between what he makes on alfalfa and what he could have made from sugar beets if the pest had not developed in his fields. Of course, the shift to alfalfa by many growers would affect the price of alfalfa and induce shifts to the next-best-paying crops. If the alfalfa weevil should materially affect alfalfa production in California, it is possible that other hay crops might be substituted with a much smaller loss than the present value of the alfalfa produced. Only when there are no alternative crops would there be a great loss, and then the loss would tend to equal the total investment plus the difference between what the individual earned as a grower and what he earns elsewhere, if he finds employment.

Excluding a plant pest or disease prevents a whole chain of economic effects. The economic consequences of their development on any particular crop are not confined to the effects on that crop alone but depend on all the shifts and changes brought about in other crops and all of the resulting price relations. Production of pears in many areas east of the Rocky Mountains was made practically impossible by pear blight. These areas turned to other crops, and because pears could not be produced there it became more profitable to grow pears in California and ship them east. The chances are that if there had been no pear blight in the East then the pear industry in California would have been of lesser importance. If a method of control can be established for pear blight, then the consumers of pears will benefit because pears will be cheaper. This will help the producers in California for only a very few years unless the disease can be controlled in that state but not elsewhere. If pear blight increases to such an extent that pears cannot be grown in California or any place else, then the consumers will have to learn to get along without pears. The loss to consumers in such a case is only the difference between the price of pears plus the satisfaction of eating pears and the price of and satisfaction of eating the next best substitute. A generation that never tasted pears would not miss them at all.

The cost of excluding plant pests and diseases must be compared to the cost of controlling them if introduced. The cost to producers of controlling a new pest or disease may be large, or it may be practically nothing at all. If it is a pest or disease that requires entirely different methods of control from those used for pests and diseases now present, that is, different sprays, new equipment, etc., then the costs are large.

If the new pest or disease is controlled by using the same sprays and the same number of applications as are used for the pests and diseases already present, then the added cost of controlling the extra pest or disease is practically nil.

The same kind of analysis holds true for the cost of enforcing or maintaining plant quarantines against specific pests or diseases. The added cost of enforcing a quarantine against a specific pest or disease when the service is already maintained for quarantines against other pests and diseases is very small except in peculiar cases. The total expenditure by the state government for maintaining plant quarantines (pages 80, 81) would not be changed very much by adding or removing one quarantine regulation.

If it is biologically possible to exclude a plant pest or disease and it is deemed advisable to maintain quarantines against any pest or disease, then it is necessary to balance the total costs of maintaining all of the quarantine regulations against all of the benefits derived from excluding diseases and pests. As indicated previously, many of the benefits derived from excluding pests and diseases are intangible future probabilities. The numerous ramifications of effects on producers and consumers not only in California but in other areas must be balanced against the costs and carefully weighed and considered in passing judgment for or against quarantines. It is difficult to compare figures on one side with intangible benefits on the other.

It is not only necessary to weigh benefits of excluding pests and diseases against costs but in many cases it is necessary to balance one type of income against another. For example, part of the population of California obtains a portion or all of its direct income from services and sales to tourists. If tourists resent plant-quarantine inspection to such an extent that they stay out of the state, which, however, does not appear to be the case, then these people in California have a right to complain against quarantines. But such losses, real or imaginary, must be balanced against the probable losses to agriculture if the pests or diseases became established. Under the conditions assumed above, it may be wiser to spend some money educating the tourists than to abolish the quarantine.

ECONOMIC ASPECTS OF EXCLUDING COMMODITIES

So far as plant quarantines exclude or interfere with the free movements of goods in commerce, they take on aspects similar to those of protective tariffs. The purpose of a protective tariff is to exclude goods and by so doing to raise prices for the purpose of giving an economic

advantage to some class within the protected area at the expense of the rest of the people in that area and those whose commodities are excluded. The popular statement that tariffs are supposed to equalize the costs of production, recognizes the advantages or gains from such tariffs to the protected producers without saying anything about the disadvantages to consumers and to the producers whose products are excluded. The necessity of considering all of the effects of tariffs on all groups of people is more evident in the world today than ever before. The distribution of the short and long-time, direct and indirect, advantages and disadvantages of a tariff give rise to numerous arguments depending on the various points of view taken.

An ideal plant quarantine as defined earlier has no resemblance to a tariff. At the other extreme are those quarantines which completely shut out certain goods and which may not only have more effect than protective tariffs but constitute absolute economic embargoes. Biologically feasible quarantines may require embargoes on certain goods for enforcement. In such cases the effects on trade must be carefully weighed against the disadvantages of letting the pest spread. Economic embargoes disguised as quarantines in name only tend to discredit all sound quarantines and should be avoided. The effects of quarantines or tariffs are numerous and complicated and may lead to permanent rearrangements of production and commerce.

Although all of the California state quarantines may be biologically sound, it makes a lot of difference whether or not people in other places believe that they are. If people in other states or areas think that the quarantines of the state of California are only tariffs in disguise, then they may try to retaliate by establishing quarantines or other restrictive measures against California products. Even if they do not pass restrictions of any kind, the loss of good will may react to the detriment of California producers and curtail the market for California products.

In spite of the fact that tariffs are a controversial subject, there are certain aspects of tariffs upon which there is almost no basis for disagreement, and these may be used in evaluating the direct economic effects of California quarantines, as distinguished from their effects in excluding pests and diseases. Tariffs, to be effective in raising prices by practically the amount of the tariff, must apply first to all of the product, and secondly to all forms of the product. That is, a tariff on wool if applied only against wool from New Zealand would not materially affect import prices if wool from Australia were admitted free and there were no differences in quality and transportation costs. Likewise a tariff on raw wool would not be fully effective if wool yarn

or wool cloth or finished wool clothing were admitted free. The degree of effectiveness of any tariff in raising prices depends largely on the amount of goods excluded. Unless the supply of the commodity within the protected area is reduced, prices there are usually not increased. However, this does not mean that there are no economic effects of the tariff. The prices in the exporting country may fall by the full amount of the tariff. The effects of most tariffs are distributed between the importing and exporting country. The amount of rise in prices in the protected area and fall in prices in the exporting area depends on the elasticity of demand and supply in all areas affected. Production is usually increased in the protected area. The exporting area often cannot or does not curtail production, and consequently world supplies are increased and prices fall everywhere. The immediate and the long-time effects may also be entirely different according to the adjustments made.

The other aspect of tariffs on which there usually is agreement is that an import tariff on a commodity produced in such volume that some or a large part of the supply is exported has no effect on prices unless there is some form of monopoly control behind the tariff wall. That is, it may be possible to ship out so much of the supply that prices are raised higher within the area than outside, and then the tariff prevents the goods from coming back. Freight rates may even act as a possible barrier and permit of a little monopolistic price raising in the local area. For example, it might be possible for the dairy cooperatives of the Pacific Coast to have surplus butter for shipment east and yet hold the price of butter in the Pacific Coast area a little above the New York price by shipping enough butter east to raise prices on the Coast to approximately New York prices plus freight west instead of letting prices fall to New York level minus freight east. In such a case, the consumers in the Pacific Coast area would pay a bonus to the producers in the area and perhaps a slight bonus to the consumers in the East. The extra amount of butter that would have to be shipped out of the area to raise local prices would tend to lower prices in the East. If enough butter were shipped out to lower prices in the East materially, then dairy producers dependent on those markets would have grounds for complaining about dumping and monopolistic practices.

For most of the commercially important California products affected by quarantine regulations, the proportion of the crop shipped to the distant markets is so great that the gains from trying to raise local prices above others would be very small. Moreover, hardly any group of producers is so highly organized that it can attempt to hold up prices to local consumers.

If the alfalfa producers should organize and try to ship enough alfalfa out of the state to raise local prices by selling the export alfalfa at a lower price than that charged for similar grade in the local market, then the dairymen of the state would soon rise up in arms and try to have the quarantine which prevents shipment of alfalfa hay into the state abolished, weevil or no weevil. If the lemon producers tried charging higher prices here than in other states they might succeed for some time, because only the consumers of lemons in this state would pay the higher prices, and consumers are not organized and cannot be readily organized.

Any group of organized growers might charge monopoly prices behind quarantine regulations in the same way that any organized group of manufacturers might charge monopoly prices behind a tariff wall. Neither may do so, but the possibility is always there. However, there is no evidence that any group of growers in California is deliberately hiding behind plant quarantines as a means of charging the consumers in the state higher prices. Even if they did the people in other states would have little or no basis for complaint. The persons injured most would be the consumers within this state. It is safe to say that the California plant-quarantine regulations in general have no effect at present in raising the prices of agricultural products of which a surplus above local consumption is produced for sale in other markets.

However, the problem cannot be dismissed as easily as this because there are seasonal and grade or quality variations which must be considered. A tariff of 42 cents a bushel on wheat imported into the United States has no effect in raising the price of soft wheat produced in the United States and exported to other countries, or at least so little effect up or down that it cannot be measured. Yet this tariff has been effective to some extent in raising the price of the best grades of hard milling wheats. In analyzing the effects of this tariff, each grade of wheat has to be treated as a more or less independent or different commodity.

The effects of California plant quarantines, as far as they exclude commodities, on the prices of the various products within the state and in other areas are as difficult of measurement as the effect of tariffs. An analysis of a few of the individual commodities showing the interrelated aspects of the problem indicates that these quarantines have no appreciable effect on prices.

Alfalfa production in California has been increased to such an extent that considerable amounts are shipped to eastern markets. Perhaps the

exclusion of alfalfa hay by quarantines in the past helped to stimulate expansion. However, the quarantines no longer have that tendency. Even with California on an import basis for alfalfa the quarantines could have only a very minor effect on price, because alfalfa hay ground by certified mills into meal, an important use for alfalfa, could readily be shipped into the state. Unless both the hay and meal were excluded the effect on prices would be very slight.

The effect of the quarantine on prices in the areas quarantined against likewise could not be much greater than the difference between the higher prices received for meal as compared to hay and the cost of grinding hay into meal. The effects in these areas, however, cannot be attributed to California quarantines alone because most other states free from weevil have quarantines against the same infested areas. Whether or not the presence of alfalfa weevil and the quarantine regulations against shipment of alfalfa hay out of certain areas has caused shifts in production or stimulated dairying in these areas could not be determined without detailed study in those states, and perhaps not after such a study because general economic conditions are changing so rapidly.

Cherries from noninfested counties in Idaho, Oregon, and Washington are excluded from California unless each "lot is accompanied by an official origin certificate, stating locality where grown, packed, and stored, and the names and addresses of grower, shipper, and consignee." Cherries from certain counties known to be infested are completely excluded, but the others may come in, and unless the difficulties and cost of securing an official origin certificate is made prohibitive the chances are that approximately as many fresh cherries are shipped into the state as if there were no cherry fruit flies and no quarantine regulations. Minor shipments between friends or boxes carried by tourists are excluded completely, but these quantities are not large enough to affect market prices. However, with the fly present in those states, if there were no regulations, more fruit unable to stand shipment east might be dumped in California markets, so that prices here would decline.

A detailed study of both the infested and noninfested cherry-producing areas might show if there has been a change in the total shipments going to California, or if there has only been a redistribution of shipments between infested and noninfested areas. So far as cherries from the infested areas ripen at slightly different seasons or are of a quality different from those produced in the noninfested areas, there may be an effect on prices of cherries in California. If the infested area spread so that all fresh cherries were excluded from California, the quarantine

might increase the price of cherries in California a little if the products had been coming on the market at the same time and competed. But cherries from other states tend to come on the market mainly after the crop in California has been harvested and, therefore, have little or no effect on the price of California cherries. The producers in other states might suffer from lack of markets if their cherries were excluded. The consumers in California might prefer to go without those later cherries rather than eat infested ones. They might prefer to save the amount they would have spent for such cherries or to consume candy, pears, peaches, or anything else in place of cherries. They might prefer to have only the early noninfested California cherries and therefore favor the quarantines.

Citrus fruits from every state except Arizona are excluded from California by quarantine regulations. Since California produces practically all of the commercial crop of lemons, the chances are that no lemons would be shipped into the state in commercial quantities even if there were no quarantines. It is, therefore, safe to assume that the state quarantines have no effect on the price of lemons in California or in other states of the Union.

Oranges are shipped from the state of California every month in the year. California produces nearly two-thirds of the entire commercial crop in the United States. Although there may be important quality differences between California oranges and other oranges, the chances are that there would be no commercial shipments into California from Florida, the other important producing area, even if there were no state quarantine regulations. Florida oranges practically do not compete with California oranges in any of the eleven western states. During the four-year period 1923-24 to 1926-27, the average annual carload shipments of Florida oranges were 4 to Colorado, 2 to Montana, 1 to Utah, 1 to Washington, and none to Oregon, Idaho, Wyoming, and New Mexico (Brooker, 1930). There were also no shipments into either California or Arizona, but both of these states excluded such oranges by quarantines. In view of the small shipment of oranges from Florida into the other western states, it is highly probable that no shipments would be made into California even if there were no quarantines; therefore, these regulations have no effect on the price of oranges in the state.

Grapefruit production in California exceeds the amount of California grapefruit consumed within the state. There are shipments every month to markets outside the state, but considerable quantities are shipped into the state from Arizona. Florida produces most of the United States' supply of grapefruit and ships fresh grapefruit into all

states in the Union except California and Arizona, which exclude shipments by quarantine regulations (Brooker, 1930). There appear to be important quality differences between the grapefruit grown in California and that grown in other states.

During the months of July, August, and September, Florida shipments are very small and at such times California grapefruit competes with Florida grapefruit on the West Washington market in New York City. During these months in 1930 prices were quoted⁷ for both on 10 different days. For example, on July 29, the day of greatest difference in price, California grapefruit was quoted at \$2.75 to \$6.70 a box and Florida grapefruit from \$5.13 to \$10.00 a box. The spread on that day, when low is compared to low and high to high, was from \$2.38 to \$3.30, the higher prices being for Florida grapefruit. During the other 9 days that both were quoted, the spread on quotations on boxes was not less than \$0.38 in favor of the Florida grapefruit. Quotations on boxes of grapefruit from both California and Florida were also reported in two other months of the same year, April 25 and June 18 and 27. On these days the lowest quotations for Florida grapefruit were \$0.95 to \$3.35 under the California price, but the highest prices for Florida grapefruit were from \$0.85 to \$1.12 above California prices. To some extent these prices indicate differences in quality, but some of the differences may represent differences in size of fruit and size of boxes.

Market reports for Portland for 1930 show that during 10 days in March and 10 days in April when prices for comparable size (adjusted for differences in sizes of boxes) Isle of Pines and California grapefruit were both quoted, the California product sold for \$2.00 to \$2.50 a box less. Similar reports from Salt Lake City show that for 2 days in March and 3 days in April there was no spread in price between the Florida and California grapefruit and the Isle of Pines product sold for \$1.00 more than either. In June and September Isle of Pines grapefruit sold for from \$0.50 to \$2.00 a box more than the California product. In November and December prices for California, Florida, and Texas grapefruit were all quoted on several days and for several different sizes of fruit. In each case the price quoted for California grapefruit was lower. This ranged from \$0.70 to \$2.20.

Since Florida ships grapefruit into all other states and since Florida grapefruit tends to command a higher price in nearby markets, the chances are that if there were no quarantine regulations fresh Florida grapefruit would enter California markets and sell in competition with that of California and Arizona.

⁷ Producers Price Current, weekly issues. New York City.

The effect of such competition upon local prices depends on a number of circumstances. If there are no monopolistic practices, the present price of California grapefruit in California is the price received in markets outside the state less cost of transportation to those markets. Since Florida grapefruit now competes with California grapefruit in those markets, the price of California grapefruit is already determined to a large extent by the price of Florida grapefruit. In order to ship grapefruit into California, Florida would tend to reduce shipments to other states, thereby lessening competition in those markets.

The effect on price also depends on consumer preference. Do some people in California eat Florida canned grapefruit now in preference to fresh California grapefruit? Quarantine restrictions do not shut out canned grapefruit, which is available at most stores. Is canned grapefruit a substitute for fresh grapefruit, or is it used on different occasions and for different purposes? If fresh Florida grapefruit would only take the place of canned Florida grapefruit in the California markets, then the effect on prices of California grapefruit would be nil. If the admission of fresh Florida grapefruit to the California market resulted in an increase in the total consumption of grapefruit, fresh and canned, within the state, the tendency would be to raise prices of all grapefruit in the United States because consumption would be increased relative to the total supply. However, the net effect would be probably too small to be of any significance. Even if some of the people in California who now eat oranges would shift their consumption from oranges to grapefruit if fresh Florida grapefruit were available, the effect on prices of grapefruit would still be insignificant.

Everything considered, it appears as if the quarantines excluding grapefruit have practically no effect on the price of grapefruit produced in California. Farmers of California by and large do not get higher prices for their grapefruit, and the consumers in the state, because they cannot buy fresh grapefruit from states other than California and Arizona, eat California or Arizona grapefruit, substitute canned grapefruit, or oranges, or go without. This quarantine results in practically no direct economic gain to growers in the form of higher prices. The disadvantages fall primarily on consumers in California and very little, if any at all, on producers in other states. Florida may even be benefited if it helps to build up a market for canned grapefruit. If the quarantine is necessary, that is, if the industry is dependent on keeping out certain pests and diseases, then there is a net social gain because more grapefruit is produced at lower cost than would be possible if the pests and diseases spread. Also there is a gain from the extension

of the season. California grapefruit is shipped to New York City only when Florida grapefruit is practically off the market.

If growers in California and Arizona produced less grapefruit than the amount consumed in these two states, then a quarantine regulation excluding other grapefruit would have considerable effect on prices; however, that is not the case, and production is increasing faster than consumption in these two states.

The potato is one of the few major commodities affected by plant-quarantine regulations of which California does not produce a surplus for export. However, potatoes are admitted if accompanied by an official certificate from points of origin establishing the fact that such potatoes were grown in noninfested areas, or that they were screened immediately before loading and placed in new, clean sacks. These regulations do not affect the supply of potatoes enough to have any effect on prices. Potatoes are usually screened before shipment anyway.

The main commercial agricultural products affected by quarantines have been discussed separately. However, many of the quarantine regulations do not apply to major products but to nursery stock, trees, plants, grafts, cuttings, scions, bulbs, seeds, and miscellaneous material that may harbor pests and diseases. Whether or not quarantines affect prices of such commodities depends on conditions surrounding each commodity. In any case the net effects could not be very great in total, as in practically all cases material may be brought into the state for propagating purposes by complying with prescribed regulations as to origin or treatment. However, the effects on individual producers or purchasers of these commodities as a group may be very important, even if insignificant to the state as a whole. In case some minor product is excluded and prices increased, the chances are that the advantages to nurserymen in the state are only temporary; that they last only until production and competition among nurserymen increases. Of course, there can be disadvantages to nurserymen in other states, and it is just as important that quarantine regulations applying to minor products be biologically sound as that those applying to major products be sound. The net social gain to be derived from the quarantine is smaller, but the chances of retaliation and ill will may be just as great.

EFFECTS OF QUARANTINES AGAINST CALIFORNIA PRODUCTS

Perhaps one of the important reasons for trying to keep plant pests and diseases out of California is a fear of the economic effects that would arise if the pests and diseases became established and other states and foreign countries excluded California products by quarantines. Since

California produces large quantities of agricultural products for shipment out of the state (about 10 per cent of the total production goes to foreign countries), any curtailment of the markets for these products is immediately reflected in lower prices and smaller income to growers and to most people of the state.

The adverse effects of any such probable quarantines might be greater than the direct damage caused by the pests or diseases. The effect of destruction of part of the crop by a pest or disease would tend to be offset temporarily at least by higher prices. The curtailment of markets by quarantines against California surplus products would be disastrous. Quarantines would be just as detrimental to California if they were established on account of a misunderstanding of the basis for her present quarantines as if such anti-California quarantines were established because some really dangerous pest or disease were present.

So far California has been very fortunate and has not had her markets curtailed to any appreciable extent by plant quarantines. Foreign tariffs and quotas, however, are curtailing the export markets for many California products. This, however, could be expected since the federal government of the United States has tried to protect such California agricultural products as lemons, walnuts, olives, beans, almonds, long-staple cotton, avocados, dates, figs, raisins, oranges grapefruit, honey, lambs, baby chickens, eggs, and many others. The foreign products have been excluded to a considerable extent from markets in the United States. Then why should not California products be shut out of the foreign markets? Almost any pest or disease in California might be used as a basis for quarantine restrictions, and quarantine regulations are not covered by the most-favored-nation clause of commercial treaties.

Without going into detail or questioning the biological or economic reasons for the temporary quarantine established against California baby chicks a few years ago, it may be well to mention this quarantine as an illustration of what may happen if there are real or imaginary reasons for establishing quarantines against California products. The owners of hatcheries in California at that time can testify to the immediate and disastrous effects of those regulations on an important established industry. In considering the effects, advantages, and disadvantages of any quarantine, the probable effect on the other party should always be recognized. Sometime the California products may be the ones quarantined against.

COSTS OF CONTROLLING PLANT PESTS AND DISEASES NOW IN CALIFORNIA

The costs of controlling the pests and diseases now in California are only partly related to the problem of maintaining state quarantine regulations. Most of the plant pests and diseases now in the state are either native or they came in before quarantines were established. However, there are a few pests, such as the alfalfa weevil and citrus white fly, which are found only in certain areas within the state borders and for which quarantines are maintained to prevent spread and to facilitate eradication measures. In such cases the cost of control, quarantine, and eradication are closely interrelated.

The costs of controlling the plant pests and diseases now present in the state cannot be contrasted directly with the costs of maintaining plant quarantines in determining whether or not quarantines are economically sound. However, some information of this kind is of considerable importance in forming opinions about quarantines.

The important question is: How much would the pests and diseases quarantined against add to the present cost of controlling pests and diseases if they became established in California? Such a figure, plus or minus the losses and gains to producers and consumers from changes in volume and prices resulting from additional pests and diseases, represents the amount that ought to be compared to costs of maintaining quarantines. Although it is possible to approximate the cash expenditures for maintaining present plant quarantines, it is practically impossible to make anything but a guess as to probable additional costs of control if more pests and diseases become established. One guess is perhaps as good as another, for in addition to the money costs there would be shifts and changes in the production of crops and many effects on producers and consumers which could not be measured in dollars and cents. Yet it is important that the nature of these effects be understood in order to have intelligent action on plant-quarantine matters. A discussion of present costs indicates the difficulties involved in trying to estimate the additional costs.

It is practically impossible to separate the total costs of controlling all pests and diseases now present into costs on account of native species and introduced species. In some cases the origin of the disease or pest is unknown. In many cases cultural practices, selection of kinds and varieties of plants, methods of pruning, spraying, dusting, etc., are directed at a group of native and introduced pests and diseases at the same time.

This makes separation of costs between species of pests and diseases impracticable. Moreover most records available do not show any separation but only total costs.

Expenditures by Growers on Account of Pests and Diseases.—Plant pests and diseases affect the welfare of the producers of agricultural products mainly through the effects on gross income and through expenditures for producing the crops. The effect of damage or lack of damage by pests and diseases on volume, quality, price, and value of crops has already been discussed. The expenditures to be considered here are the estimated combined cash outlays and the money value of farm operator's time and capital for controlling pests and diseases on farms. The expenditures for controlling pests and diseases by counties and the state government are partly borne by the growers. However, no attempt is made to determine the proportion of growers' taxes that finally go for pest and disease control. To include both farm taxes and the expenditures of tax funds by governmental agencies as expenditures of pest and disease control would lead to duplication in estimating costs to the people of the state as a whole.

The estimated expenditures by producers for controlling pests and diseases on the farms of California indicate approximately what the total of such expenditures was, not what it is or will be, even if no new pests or diseases are introduced. The total expenditures for pest and disease control tend to vary with volume, prices, returns, wage rates, and cost of materials. If prices are high, growers tend to increase acreage and expenditures for pest and disease control. With low prices for products, some acreage is abandoned and pest and disease control measures are generally curtailed. Wage rates and costs of spray equipment and material also vary, and sooner or later depreciation expenses become adjusted to cost of replacement rather than to the original cost.

The estimates of total farm expenditures for pest and disease control based on available data apply primarily to the normal state acreage during the period 1929 to 1931, before many of the costs have been adjusted to the lower present price level.

Some data on weed control could be obtained from the same records as were used for estimating expenditures of other plant pests without any appreciable increase of the time and effort involved. It is, therefore, included in the following tables, although it has only a minor relation to the problem of plant quarantines.

According to an analysis of available data⁸ as shown in table 3, the

⁸ Description of method of analysis and detailed tables by crops on file in Giannini Foundation Library.

growers of California expended approximately \$21,900,000 annually during the period 1929-1931 for plant diseases and pests other than weeds on the bearing, harvested, and summer-fallowed acreage of the important crops. (See footnote, table 3, for crops omitted.) Another annual sum of \$18,620,000 may be charged to weeds, making a total expenditure of \$40,520,000 for control of plant diseases, weeds, and other crop pests on important crops. If minor crops and nonbearing acreage of trees and vines were included, the total would be a little larger, perhaps between \$41,700,000 and \$43,520,000.

Of the \$40,520,000, approximately \$17,500,000 may be attributed as direct control of plant diseases, and pests other than weeds, and \$13,800,000 may be attributed to direct weed control. The remaining difference of about \$9,200,000 is a charge for depreciation of perennial crops which is not strictly a direct expense for pest and disease control in a narrow interpretation of the word control, because replacing trees, vines, etc., killed by diseases and pests does not control them, yet it constitutes an expense to growers for controlling their effects. Of this depreciation item about \$4,800,000 is attributable to weeds, mainly for shortening the life of alfalfa stands, and \$4,400,000 is attributable to pests other than weeds for shortening the life of other perennial crops.

It may be argued, in this connection and in the light of the discussion in the previous sections, that with most crops at present a smaller crop sells for more money, and that therefore growers as a group would be repaid financially if they did not spend their money to replace the trees killed by plant pests and diseases. For the group, this is possibly temporarily true of many crops, but the individual grower has to replace plants to stay in business. However, the point for discussion here is total expenditures because of pests and diseases and not the returns from these expenses, whether the returns be positive or negative.

By crop diseases and pests other than weeds is meant all bacterial, fungus, or virus diseases, invertebrates, rodents, birds, etc., which attack growing crops and are a source of expense to the grower in producing his crop.

The expenses as shown in table 3 cover the normal bearing acreages of 59 California farm crops, including farm gardens and commercial production of flower and garden seed for the year 1931. This includes almost all the important California crops that are subject to infestation by plant pests and diseases. (See footnote, table 3.)

The expenditures by growers are shown in tables 3, 4, 5, for groups of crops, i. e., pome fruits, stone fruits, grapes, citrus fruits, figs and

TABLE 3
ESTIMATED TOTAL ANNUAL FARM EXPENDITURES FOR PLANT PEST AND DISEASE CONTROL IN CALIFORNIA* 1929-1931
(Summary of tables 4 and 5)

Kind of crop	Total, all crops	Pome fruits	Stone fruits	Grapes	Citrus fruits	Figs and dates	Nut crops	Vegetable crops	Field crops
Number of crops.....	59	2	7	1	3	2	2	24	18
Acreage of crop.....	5,551,850	123,000	460,300	530,000	257,000	46,000	178,000	458,100	3,499,450

Expenditures									
For diseases and pests other than weeds.....	\$21,900,000	\$3,600,000	\$4,420,000	\$1,190,000	\$ 8,180,000	\$ 730,000	\$1,190,000	\$ 490,000	\$2,100,000
For weeds.....	18,620,000	670,000	2,110,000	2,610,000	2,190,000	300,000	670,000	2,700,000	7,370,000
Total for pests, diseases, and weeds..	40,520,000*	4,270,000	6,530,000	3,800,000	10,370,000	1,030,000	1,860,000	3,190,000	9,470,000

* Estimated total expenditures from data available. Wood lots and wild and tame hay other than oat, barley, and alfalfa hay are not included but there are practically no pest or disease-control measures for such crops; greenhouses and nurseries are not included because they are often not classed as farms and data were not available. Approximately 3,450 acres of small fruits, 15,000 acres of minor vegetables, and 239,100 acres of nonbearing trees and vines are not included on account of lack of data. However, judging from the data for other crops and general knowledge of these crops, the total expenditures for pests on such acreage would range between \$1,160,000 and \$2,500,000 and constitute an addition to the total estimated from data available.

dates, nut crops, vegetable crops, and field crops, because the data are not considered of enough importance in connection with quarantines to include separate tables for each crop. This classification by groups of crops indicates to some extent the relative importance of weeds and other pests to different types of crops. For example, weed-control expenses are nearly six times as much as other pest-control costs for vegetables, while insect and disease-control costs are about four times as much as weed control for citrus crops.

Table 4 shows the expenditures chargeable to pests and diseases for 16 major crops, with division into expenditures for labor, material, equipment, and other items. These expenditures are the actual cash outlays and the estimated money value of labor, material, equipments, and other items that may be charged to pests and diseases. The most important of these "other items" is depreciation charges. These figures were calculated from cost-account records kept for the separate crops in various parts of the state as part of the enterprise efficiency studies made by the California Agricultural Extension Service under the direction of L. W. Fluharty. These estimated expenditures are that part of the total cost of production for the various crops which could be attributed to diseases and pests. The percentage of different costs attributed to pests ranges from zero for such costs as planting, to 100 per cent of the costs for spray material.

Expenditures for pest and disease control for 43 other crops are shown in table 5. These estimates are based upon survey records of costs of production during the 1931 crop season compiled by R. L. Adams and L. A. Crawford, of the section of Farm Management of the Division of Agricultural Economics, University of California. These expenses are also that part of the total cost of production which could be charged to plant pests and diseases. No division of expenses into the various cost items, as in table 4, was possible because of the nature of the original records.

In general, the above estimates cover all of the important farm expenditures for plant pest and disease control on most of the crop acreage in the state. However, there are some minor items of expense which are not included. Certain items of overhead expense in the operation of the farm are made because of pests and diseases but they may not be included in the production record of an individual crop. For instance, growers cut the weeds about the buildings to prevent the spreading of seeds to adjoining crop land or orchards. Such items are generally not large, but in most cases are not included in the cost-of-production record

for any one crop, and therefore may not be included in the estimated expenditures for pest and disease control.

Growers are forced to rotate their crops because of pests and diseases. In so doing, they may have lost an opportunity to obtain a larger income by the production of certain crops. Such a reduction in income on account of pests and diseases constitutes a form of loss or cost to individual

TABLE 5

ESTIMATED* FARM EXPENDITURES FOR PEST AND DISEASE CONTROL FOR CERTAIN CROPS IN CALIFORNIA FOR 1931

Kind of crop	Total	Stone fruits†	Dates and figs	Vegetable crops‡	Field crops§
Number of crops.....	43	4	2	24	13
State acreage.....	2,079,850	78,300	46,000	458,100	1,497,450

Expenditures

For diseases and pests other than weeds.....	\$1,740,000	\$ 220,000	\$ 730,000	\$ 490,000	\$ 300,000
For weeds.....	5,780,000	330,000	300,000	2,700,000	2,450,000
Total for weeds and other pests and diseases.....	\$7,520,000	\$ 550,000	\$1,030,000	\$3,190,000	\$2,750,000

* Obtained by multiplying the normal state acreage for each crop by an average acre cost of crop-pest control for that crop as obtained from crop-survey cost-of-production records on representative farms compiled by R. L. Adams and L. A. Crawford of the Division of Agricultural Economics, University of California. These figures include actual expenditures and estimated value of family labor, use of equipment, and depreciation on capital value of orchards chargeable to crop pests and diseases.

† Avocados, cherries, olives, plums.

‡ Artichokes, asparagus, green beans, beets, cabbage, carrots, cauliflower, celery, chili peppers and pimientos, cucumbers, garlic, head lettuce, onions, peas, rhubarb, spinach, strawberries, sweet corn, tomatoes, cantaloupes, and other melons of this type; watermelons, pumpkins, and squashes; vegetable and flower seed; and farmers' gardens.

§ Corn, barley, oats, rice, rye, grain sorghum, sunflower seed, peanuts, mustard seed, hops, sweet potatoes, sugar beets, and root crops for forage.

growers. However, cost records for single crops usually do not cover such expenses, if they can be called expenses, and therefore the estimates do not include such items. Advantages from rotation of crops may offset such losses to individual growers. For the group of growers there may be no loss if volume of production is reduced and prices increased.

The figures in tables 3, 4, and 5 above are presented as the best estimates⁹ available of expenditures by the growers of California for control of plant pests and diseases on farms.

In determining the real costs, if such a concept is possible, of controlling pests and diseases to the growers of the state, it would be neces-

⁹ The errors of sampling may be considerable, but corrections were made whenever possible, by the method of weighting areas and in obtaining the percentage of various costs to attribute to pests and diseases. Only a part of the cultivation costs were attributed to weeds.

sary to take account of the expenditures for controlling pests and diseases, the physical damage as reduction in volume and quality, and the effect of this on price and returns. By carrying this line of reasoning out far enough, one might find that in the long run, as far as there are shifts and changes in agriculture, and if agriculture in spite of all pests and diseases provides as good a standard of living for rural people as can be obtained by people in other occupations, there are no real farm costs to growers as a group, for the consumers pay all costs in the form of prices for the products, and the only real costs of pests and diseases are the additional amount of social effort used to obtain the agricultural products.

The figures given above as approximate farm expenditures in terms of money can be used to form a rough approximation of the social cost of these pests and diseases. By taking \$40,000,000 in round numbers and using a rate of 40 cents an hour, as the average rate of wages¹⁰ in California during the same period, it will be seen that this is equivalent to 100,000,000 hours of human labor. Allowing 10 hours a day and 250 working days a year, this is equivalent to the annual work of 40,000 men. Assuming that most of the expenses other than labor on farms represent labor performed in other activities than farming, then this can be further divided into about 20,000 employed on farms and 20,000 in the other activities, making machinery, spray material, supplies, transporting and selling goods that would not be needed, if there were no pests or diseases. In other words, if there were no plant pests and diseases in California *more* than 40,000 fully employed men could remain idle or unemployed without changing the volume of production. One must say *more* than 40,000 men because in spite of all the effort directly and indirectly applied to the control of pests and diseases there is still a considerable amount of pest and disease damage. And if this did not occur the other indirect expenditures for pest and disease control made by counties, State Department of Agriculture, the University of California, and other agencies could also be dispensed with if there were no pests or diseases. The monetary expenditures by these agencies and on the minor crops and nonbearing acreage approximate \$5,000,000, and even at twice the hourly rate used before, this represents the full-time work of another 2,500 men.

Assuming that the productive effort applied directly and indirectly on each farm in California is equivalent to the full-time work of two men, then in terms of farms the expenditures for pest and disease con-

¹⁰ Some of the wage rates used in the records were lower than this, especially in the survey records for 1931 and for the value of unpaid family labor.

trol equal approximately 22,000 farms that could be dispensed with if there were no plant pests and diseases. This is roughly 16 per cent of the 135,676 reported in the 1930 census. If not needed and not used, then these farms would have no value and all other land used would be worth less money than at present.

Another interesting comparison can be made between the costs of pest and disease control and the gross farm value of agricultural crops in California. According to estimates made by the Bureau of Agricultural Economics of the United States Department of Agriculture, the gross farm value of agricultural crops for California was \$455,603,000 in 1930. The highest figure reached was \$554,244,000 in 1929, when frost reduced the volume of production of several crops. The six-year average gross farm value from 1925 to 1930 inclusive was \$500,000,000. Comparison of these estimates of gross farm value with the other estimates of expenditures for plant pest and disease control indicates that this control amounts to something like 8 to 10 per cent of the gross value of the crops.

Regardless of how pest and disease damage and control costs are measured, one thing is certain, that if there were no pests or diseases the whole economic organization of society would be different. There might be either a larger or smaller total population, more or fewer growers than at present, more leisure or more unemployed. Speculation as to what might be under impossible assumed conditions does not help to solve the problem of plant quarantines.

In the last analysis it comes down to this: *Would the pests and diseases quarantined against, if they became established, require more hours of human effort in agriculture and in other industries to maintain the same physical volume of production than it requires to keep the pests and diseases out by quarantine regulations?* Theoretically at least, the present costs of maintaining plant quarantines should not exceed the discounted probable future costs of controlling the pests and diseases now quarantined against. In practice it is necessary to make a guess as to the best alternative between one type of present expenditure and another type of future expenditure.

Costs other than Farm Costs for Controlling Plant Pests and Diseases Now in California.—Home owners and renters spend considerable effort and money in controlling plant disease and insect pests in their gardens. Even if their time is worth nothing and they work in the gardens for exercise, there is a lot of dissatisfaction in seeing plants and flowers destroyed by pests and diseases and the financial expenditures for poi-

sons and sprays, although small for each garden, amount to a considerable sum in the aggregate.

Nurserymen pay about \$20,000 annually for license fees to operate in California. Diseases and insects constitute the main reason why it is desirable to license and inspect nurseries. Part of the cost of licensing and inspecting nurseries is chargeable to plant quarantines. Reciprocal arrangements between states require inspection and certification of nursery stock before shipment out of this state and similar certification by other states before shipment into California. However, this item of fees for nurseries, which becomes revenue to the state, is only a minor item of the total cost to nurseries of attempting to control pests and in trying to propagate disease-free plants.

The counties of California spend considerable sums of money annually for the control of pests and diseases, but a comprehensive total of all county expenditures on this account cannot be obtained from the county budgets, partly because the same method of listing or classifying expenses is not used by all counties. For example, weed control may be a separate item of expense, or it may be combined with rodent control, or it may be part of the total expenditures by the county agricultural commissioners, or it may even be included with some other activity that from its name appears to have no connection with pest-control work. Then, too, not all of the counties engage in all of the various types of pest-control activities.

From the 58 counties of the state 55 budget reports were available for examination. All of the activities that were listed under names which implied some form of plant pest or disease control were tabulated to show total expenses by all counties reporting each activity, number of counties reporting, and the range in expenditures by the counties reporting the various activities. This information is shown in table 6.

A large part of the expenditures by the county agricultural commissioners are directly or indirectly attributable to controlling plant pests and diseases now in California. It would be possible to make a study and allocate the total expenditures of the county agricultural commissioners to the various duties or activities performed, but such an analysis would not add materially to an understanding of plant quarantines. The enforcement of interstate quarantines by examining shipments arriving by rail from out of the state is only one of the functions of the county agricultural commissioners. Quarantine inspection at the minor ports where no special plant-quarantine officers are stationed is also performed by the county agricultural commissioners. The inspection of intrastate shipments and the enforcement of intrastate plant

quarantine is also of some importance in most counties, but this activity is a part of the cost of controlling pests and diseases already in California. Of all the activities and functions performed by county agricultural commissioners, perhaps a majority of them are directly or indirectly related to plant disease and pest control.

Some of the educational activities of the farm advisors also have to do with plant pest and disease control. However, the share of their salaries attributed to such activity is included with the portion of the University's Agricultural Extension Service costs attributed to pests

TABLE 6

APPROXIMATE COUNTY EXPENDITURES* RELATED TO PLANT PEST CONTROL AS REPORTED IN COUNTY BUDGETS† FOR FISCAL YEAR ENDING JUNE 30, 1930‡

Expenditure for	Total expenditures by all counties reporting	Number of counties reporting	Range in expenditures of counties reporting	
			Low	High
County agricultural commissioners.....	\$1,338,800	49	\$2,100	\$263,000
Farm advisors.....	203,200	42	1,000	18,300
Rodent control.....	103,000	10	100	33,400
Horticultural pest control.....	126,200	5	1,900	48,300
Rodent and weed control.....	29,000	3	2,900	19,600
Puncture-vine control.....	9,700	3	150	8,900
Weed control.....	2,300	2	1,000	1,300
Pear-blight control.....	130	1	.....	.....

* Actual expenditures in most cases, others budget appropriations.
† Budgets of 55 counties examined. All counties do not have all items of expense listed, but the fact that expense items are not listed separately does not mean that no money was spent. Some budgets do not show detailed expenditures but group many items together under general headings.
‡ For a few counties data are for fiscal year ending June 30, 1929.

and diseases. The appropriations by counties for farm advisors' offices cover mainly office and traveling expenses. Only a minor part of this could be attributed to control of insects and diseases of plants.

The other items listed in table 6 are all related to some form of pest or disease control. Most of these figures do not have any direct bearing on the problem of state plant quarantines, but are very significant in indicating the broader aspects of the whole problem of quarantines, eradications, and control of plant pests and diseases.

Expenditures by the State of California for plant pest and disease control are made chiefly by two agencies, the State Department of Agriculture and the College of Agriculture, University of California, the former for regulatory work, the latter for education and research.

State expenditures for various types of pest and disease control by the Division of Plant Industry, Bureau of Plant Quarantine and Pest

Control, and administrative expenses of the Bureau, as classified in the budget for the eighty-third and eighty-fourth fiscal years, are shown in table 7.

The State Department of Agriculture expended approximately \$177,000 for pest control during the fiscal year ending June 30, 1932. This covers the expenditures classified under "pest control" in the budget of the Division of Plant Industry relating to Plant Quarantine and Pest Control. The general administrative expense of the Bureau of Plant Quarantine and Pest Control amounted to nearly \$9,000, part of which was the cost of maintaining quarantines. No attempt has been made to prorate any of the general overhead expenses of the whole Department of Agriculture or to allocate part of the expenditures by other divisions or bureaus to pests. Perhaps most of the work of the Division of Chemistry in connection with economic poisons relates to pest control. Even if this activity is self supporting from license fees, somebody has to pay and it may be regarded as one of the costs of controlling plant pests and diseases now in the state.

Approximately \$350,000 is spent annually by the College of Agriculture for research and educational work related directly to plant diseases and pests. The budgets for the Divisions of Entomology and Pathology at Berkeley and Davis amount to approximately \$180,000. Similar budgets at Riverside amount to \$82,000. It is also estimated that about \$87,000 is annually expended by the Agricultural Extension Service, for educational work on the control of pests and diseases. Some portion of the expenditures of other divisions of the College are also related to pest control; for example, the expenditures for irrigation investigations, farm machinery, agronomy, plant breeding, and horticulture. Even other activities of the College are in some small way tied up with the effects of pests on agricultural products, but no attempt has been made to estimate these amounts.

The discussion so far has indicated expenditures for plant pest and disease control by growers, home owners, nurseries, county governments, the State Department of Agriculture, and the College of Agriculture. To make the list complete it would be necessary to include the United States Department of Agriculture, the Forest Service, city and county park departments, cooperative organizations, canning and packing companies, warehouse shipping concerns, wholesalers, retailers, and florists. In fact, every individual or organization is affected to some extent by the pests now in the state.

However, in considering costs of plant pest and disease control, it is essential to remember that in most cases the costs to one group or class

become income to another. The growers' costs for hired labor equal the income to the farm laborers. The total cost to users of spray material and poisons for controlling pests equals the total gross income from such products to manufacturers, wholesalers, and retailers. It is, therefore, practically impossible to make any estimate of the net cost of plant pests and diseases to all of the people of California. If there were no plant pests or diseases the entire social and economic organization of the state would be different.

RECENT COSTS OF MAINTAINING STATE PLANT QUARANTINES

State plant-quarantine officials enforce both state and federal quarantines. Federal officials help to some extent to enforce state quarantines. The Post Office Department, the railroads, and express companies cooperate with state officials by not accepting goods for shipment when such goods are known to be excluded by quarantine regulations. Other states, by their systems of licenses and inspection, help to prevent shipment of infested material. The county agricultural commissioners, as previously pointed out, aid in the enforcement of state, and to some extent, federal quarantines. It is, therefore, difficult to arrive at any exact total cost of maintaining plant quarantines. However, the largest and most important item, that of state expenditures as listed in the budget, is shown in table 8. (See also table 11, page 141.)

The state government of California spends directly about \$275,000 annually to maintain plant quarantines. This is not a large sum compared to the amounts spent by growers and county governments for pest and disease control, and if the quarantines are biologically sound, this expenditure appears to be justifiable as a preventive measure.

TABLE 7
EXPENDITURES BY THE STATE OF CALIFORNIA FOR PEST CONTROL,
1929-30 TO 1932-33

Department of Agriculture, Division of Plant Industry, Bureau of Plant Quarantine and Pest Control	Expenditures		Proposed expenditures	
	Actual, July 1, 1929, to June 30, 1930	Estimated, July 1, 1930, to June 30, 1931	July 1, 1931, to June 30, 1932	July 1, 1932, to June 30, 1933
Administrative, general for Bureau.....	\$ 8,811	\$ 8,955	\$ 8,922	\$ 9,722
Pest control:				
Apiary inspection.....	7,555	6,860	7,095	7,025
Entomology.....	18,338	24,380	34,005	33,545
Nursery service.....	11,823	16,120	22,120	21,985
Pathology.....	10,537	12,902	14,520	14,370
Rodent and weed control.....	12,267	11,164	20,505	19,890
Predatory animal control.....	20,746	22,750	24,020	23,420
Plague control (rodent).....	37,287	50,000	20,182	14,855
Walnut husk fly.....	5,210	4,850	2,847	2,797
Dictyospermum scale.....	504	7,750	3,445	3,165
Citrus white fly eradication.....	17,570	12,694	11,930	8,655
Parlatoria date scale eradication.....	13,681	11,319	16,500	15,000
Total pest control	\$155,518	\$180,789	\$177,169	\$164,707
Revenue not deducted from above				
Acreage fees.....	\$ 1,551	\$ 1,670	\$ 2,200	\$ 2,400
Nursery licenses.....	18,854	18,400	20,000	20,600

Source of data: Budget of the State of California for the 83d and 84th fiscal years.

TABLE 8
EXPENDITURES BY THE STATE OF CALIFORNIA FOR MAINTAINING PLANT
QUARANTINES, 1929-30 TO 1932-33

Department of Agriculture, Bureau of Plant Quarantine and Pest Control, Quarantine Service	Expenditures		Proposed expenditures	
	Actual, July 1, 1929, to June 30, 1930	Estimated, July 1, 1930, to June 30, 1931	July 1, 1931, to June 30, 1932	July 1, 1932, to June 30, 1933
Sacramento.....	\$19,271	\$19,690	\$22,130	\$21,380
Ports (total).....	87,182	93,815	96,320	96,995
San Francisco.....	44,061	48,305	49,225	49,400
San Pedro.....	28,385	30,970	32,185	32,185
San Diego.....	10,683	10,155	10,510	11,010
Los Angeles.....	4,053	4,385	4,400	4,400
Border stations (total).....	172,585	193,650	147,950	147,550
Permanent.....	.....	99,940	108,850	108,350
Seasonal.....	.....	33,900	39,100	39,200
Train inspection.....	.....	59,810	.....	.....
Mediterranean fruit fly survey.....	29,010	11,850	10,025	9,025
Total quarantine service.....	\$308,048	\$319,005	\$276,425	\$274,950

Source of data: Budget of the State of California for the 83d and 84th fiscal years.

SOME ADMINISTRATIVE ASPECTS OF PLANT QUARANTINE

THE NEED FOR EXCHANGE OF AGRICULTURAL COMMODITIES

The development of agriculture and horticulture in new countries and their improvement in old ones has very largely resulted from the exchange of plant material between countries. California horticulture, for instance, is based entirely upon species of fruit introduced from other states or countries, and even the most popular horticultural varieties are in many cases not of local origin but have been introduced from without the state. If the various fruits, vegetables, and agricultural crops which are produced here are considered, it can readily be seen how much California agriculture has depended upon plant introduction from other parts of the United States as well as from Europe, Asia, Central and South America, and other parts of the world. From this point of view it is evident that the exclusion of plant diseases and pests by quarantining against nursery stock, seeds, or plants of certain kinds cannot be accepted as a desirable procedure without taking into account the interference with horticultural development which is thereby certain to occur. For this reason there has developed considerable hostility and antagonism to plant quarantine among the very people whom such restrictions are intended to protect. If commercial traffic in fruit, cereal products, and many other food materials is considered, it is easy to realize that plant materials which constitute the carriers of pests and diseases cannot be barred out of a country or district without thereby introducing many serious economic complications. Agriculture and horticulture cannot develop without an interchange of propagating material, nor can the world's commerce in agricultural products exist without incurring a possibility of the introduction of plant diseases and pests. The problem therefore is one of deciding how far it is possible to limit their spread without doing more harm than good to agriculture and commerce.

SYSTEMS OF PLANT QUARANTINE

Several quarantine systems have been in vogue, or have been suggested, for preventing the establishment of new plant pests or diseases in an area free from them. Of these, the following are the most common:

Inspection at Point of Destination.—Probably the first method of attempting to exclude plant pests and diseases from any given country or

district was that of inspection of imported plant material in order to detect and refuse delivery to anything which might show signs of infestation or infection. While this method in some cases has value it is needless to discuss at length the fact, which has been demonstrated repeatedly by experience, that it is impossible to prevent the introduction of most pests and diseases by this means. Not only is it physically impossible actually to examine all such material with the necessary care but in many cases it is impossible to detect the presence of disease even with the most careful examination. Furthermore, in the numerous instances where pests and diseases have been introduced with seed or with some commercial material not intended for plant propagation their detection would be manifestly impossible. A study of past introductions of diseases and insects will indicate very clearly many different cases where the importation could not have been prevented by point-of-destination inspection of the host.

Most plant-feeding insects which are likely to be transported on nursery stock or fruit have certain stages which are inconspicuous or hidden and are therefore not easily detected. In many cases inspection of every part of a plant, perhaps with a microscope, would be required to enable an inspector to say positively that it was free from infestation. This is particularly true of scale insects, which have a habit of secreting themselves beneath bud scales or bark. Many boring insects are detectable only with great difficulty in their early stages. This is also true of such fruit-infesting insects as the Mediterranean fruit fly, the orange maggot, etc. Relatively few insects are so conspicuous when occurring on nursery stock that the cursory inspection necessarily given in connection with commercial shipments is a reliable safeguard against infestation.

In plant diseases a considerable time must often elapse before conspicuous symptoms appear. The pathogenic organism may be present and the infection be well under way, but with no external evidence of its presence. From a quarantine standpoint, it is of course a practical impossibility to inspect for such diseases.

A sound quarantine will not ordinarily, therefore, permit the passage across the quarantine line of host plants and host fruits which originate in the infested or infected area merely on condition that inspection fails to reveal infestation or infection. Instead, quarantine should prohibit and prevent the passage across the quarantine line of all host fruits and host plants of a specific pest or disease even though they show no indication of infestation or infection. Such fruits and plants should be declared contraband and inspection should be limited to search for and

seizure of this contraband. Only in cases where such material can be treated, as will be discussed later, can this requirement be avoided.

Search for contraband in automobiles, in household goods, and in other commodities which for economic reasons cannot be excluded, is justified when done in connection with a quarantine which closes the major avenues of entrance of a pest or disease and when natural dispersal is prevented by barriers.

Inspection and Certification at Point of Origin.—Most countries as well as many states now require that all plant material shipped in must be accompanied by a certificate from the point of origin guaranteeing that the material has been carefully inspected and is free from pests and diseases of all sorts. Various schemes based on this system have been proposed in the past for the purpose of bringing about an international agreement whereby the contracting states agree to take the necessary legislative and administrative measures to insure common action against the introduction and extension of enemies of plants. The most pretentious scheme of this sort was that drawn up at the International Phytopathological Conference held at Rome in 1914. The object of this conference was to frame a convention to control the interstate circulation of horticultural products and prevent the spread of pests and diseases. The meetings were attended by delegates of some thirty countries and colonies and the convention as finally drafted received unanimous support subject to ratification of the governments of the countries concerned. Each adhering state was to set up a Phytopathological Service which service was to be charged with the responsibility of supervising nurseries and other establishments engaged in trade in living plants, of inspecting consignments intended for export and furnishing certificates to the effect that such stock was free from certain specified diseases. Each adhering state was to pledge itself not to admit such stock without a certificate.

The outbreak of war delayed ratification of this convention in most cases, and differences of opinion developed regarding its details and usefulness, and so the system has never come into general use and has never been adopted by this country.

The objections to any such system as this of shipping-point inspection are again those based upon the fallibility of human nature and the physical impossibility of detecting the presence of many plant diseases and pests in shipments of propagating or other plant material. Here again a study of past events will show that the introduction of only a small proportion, if any, of the common plant diseases and pests of California could have been prevented by such a system.

In spite of the fact that it is a physical impossibility to determine with certainty by inspection that plants and plant products are completely free from pests and diseases, such restrictions have often been attempted. In almost every case it has been found that inspection has failed to prevent infested or infected material from passing over the quarantine line. For several years, as a condition for the entry of European plants into the United States, the Federal Horticultural Board tested the policy of relying on certification of freedom from infestation, subject of course to inspection on arrival. This inspection revealed large numbers of plants infested with scores of different species of insects and diseases (Marlatt, 1921). The ineffectiveness of this system was responsible for the adoption of Quarantine 37, which now prohibits the entry of most foreign nursery stock into the United States.

Within recent years the discovery in England of several lots of American apples badly infested with the apple maggot resulted in the passing of a resolution by the Farmers Union of Great Britain favoring an embargo on American apples, since this pest does not occur in that country. This resulted in the adoption of an agreement whereby all apples leaving Atlantic Coast ports were required to be inspected and were accepted by the shipping companies only when accompanied by a certificate from the United States Department of Agriculture indicating that the fruit did not show presence of the apple maggot. However, even after this agreement, several maggot-infested shipments were reported as reaching England. (Gilbert, 1931.)

Numerous similar cases could be cited, but this is unnecessary since most attempts to exclude pests or diseases on the basis of inspection of the host are obviously unsound and dangerous; at the same time it is recognized that in many cases such products as fruit do not present the same degree of danger as do plants for propagation.

It is the opinion of the Committee that a quarantine cannot be made effective when reliance is placed solely on inspection of shipments of plants and plant products, either at origin or destination, to assure freedom from infestation or infection.

Complete Embargoes.—This leaves as an alternative the embargo method or, in other words, the absolute exclusion of certain material from the country to be protected. Under this method wide latitude exists in two principal respects, one relating to the kind of material to be excluded and the other the limitation of the areas from which the importation of such material is to be forbidden. Difficulties arise here from the very beginning since in the case of any specified disease or pest the areas where it exists may not be correctly determined or the kind of material

to be excluded may not include all that which is essential to prevent the importation of the pest or disease. All the questions which have been discussed before as to deciding what insects and diseases would be of importance within a given area, the various methods by which they might be introduced, the kind of material upon which they might come in, the avenues which must be closed to prevent introduction, and many similar questions tend to complicate this problem.

Controlled Introduction of Plants and Plant Products.—Finally it has been proposed, as the only safe system of plant quarantine to accomplish the desired results and at the same time not interfere unduly with the interchange of agricultural products, that a general control be set up over the shipment of all plant material. Under such an embargo it is then proposed that material could be admitted if originating in an uninfested area, or if it had been so treated or disinfected as to remove the danger of its carrying any disease or pest, or at least certain specific diseases or pests. This was done in connection with the fruit-fly campaign in Florida, where heat and cold were used to treat the fruit.

Ordinarily such treatment should be applied only to commodities which, so far as can be determined, are free from infestation but in connection with which it is recognized there is still an element of risk. In other words, treatment is applied only as an *additional* safeguard. The Mexican-fruit-fly quarantine regulations provide that fruit from some areas in Texas may move out on condition that it is subjected to certain methods of treatment. However, the United States Department of Agriculture specifies that this treatment is not considered as a means of authorizing movement of infested fruit. All infested fruit is required to be promptly destroyed. The requirement of treatment applies only to areas believed to be entirely free from the pest, with the object of eliminating any residual risk, even after intensive inspection.

In California rooted grapevines are permitted to move into areas where the phylloxera is not known to occur, provided inspection fails to reveal the presence of phylloxera, *and in addition* they are given the hot-water treatment.

In the case of some seed-borne diseases it is possible by chemical or other treatment to destroy the disease germs without spoiling the seed for planting purposes. There are other cases where treatment of nursery stock can be used to free the material from certain pests or diseases. Such methods as this would necessarily be combined with certification at shipping point. Under certain conditions, where there is no danger of escape of pests and diseases, such treatment may be given at destination.

Certification indicating the origin of commodities in areas free from the pest or disease is sound provided the organization issuing the certificate is reliable and has facilities for obtaining dependable data on the geographical distribution of the pest or disease to be excluded. This, unfortunately, is not always the case.

The method has been suggested by Swingle, Robinson, and May (1924), embracing the bringing in of only a very limited amount of propagating material like nursery stock, plants, scions, or cuttings, obtaining it if possible from a locality and from plants which are free from certain specific pests and diseases, inspecting the material very carefully and then planting it out in an isolated place for a preliminary period where it may be tested and observed to be sure that none of these enemies develop. After obtaining disease-free or pest-free materials by this method it can then be propagated and distributed as extensively as desired. This plan would apply particularly to the introduction of desirable commercial varieties of any useful plant into a region which was still free from certain diseases or pests.

Such a method would naturally be slow and would materially delay the introduction and multiplication of desirable new varieties. On the other hand, it would be of great service in preventing the introduction of certain specific pests and diseases which would be disastrous to an industry. This method might have prevented the introduction of chestnut blight, walnut blight, citrus canker, and various other diseases and many insect pests, had it been known before their introduction that they would prove destructive, but here again the importance of some of these pests and diseases was not known until after they had been introduced into the United States. The only completely successful procedure apparently would have been to have brought into this country *no* living trees or scions of citrus, walnut, or chestnut without preliminary testing as to freedom from *all* pests and diseases.

This procedure would still leave open the possibility of the introduction of pests and plant diseases on commercial material not used for propagating purposes, or on unsuspected hosts, vehicles, or other carriers. There is also involved in an attempt to keep a country or state free from plant pests by this method the administrative problem of intercepting all contraband material coming in by the various methods and avenues of transportation which might be open.

Controlled introduction of agricultural commodities under embargoes is the program followed by the Bureau of Plant Quarantine of the United States Department of Agriculture and largely by the California State Department of Agriculture. The Committee believes it is the only quarantine procedure which can be expected to prove successful.

AGENCIES OF ARTIFICIAL DISTRIBUTION

Where the activities of man constitute the only agency by which a plant disease or pest can be introduced from one district to another the feasibility of its exclusion by quarantine must naturally depend upon the nature of the possible agencies of distribution which exist between the two districts. These include routes of travel, commercial relations in the interchange of important products, and international or interstate traffic in agricultural products or horticultural material like nursery stock, plants, seeds, etc. In the case of districts on the same continent, as for instance in the relation between California and other parts of the United States, Canada, or Mexico, the nature and extent of vehicular travel is an important consideration.

In regard to this phase of the subject it may be pointed out that the danger of introducing a pest or disease from the Hawaiian Islands, for instance, would be very much greater than introducing it from some country which had no commercial relations with the United States, and therefore a quarantine would be much more justified.

RELATION OF AVENUES OF ENTRANCE OF PESTS AND DISEASES TO PLANT-QUARANTINE EFFICACY

The argument has been advanced previously that a plant quarantine does not have to result in a complete exclusion of the organism against which it is directed in order to be theoretically justifiable, for the reason that many introductions, for natural reasons, fail to result in establishment of the pest or disease. Obviously, however, this fact must not be used to justify partial quarantines, or to lessen the insistence upon plant quarantines as perfect and complete as the biological, sociological, and economic conditions will permit. In establishing a plant quarantine it is essential that rather complete knowledge be had as to the possible avenues of introduction of a pest or disease, to determine which of these avenues of entrance can be closed with proper regard for the economic phases of the problem, and then to judge whether or not it is worth while. There is, of course, room for errors of judgment here, and the only safe course to pursue seems to be to follow the policy that if quarantine action is to be undertaken at all it must be so complete as to leave open

only relatively unimportant avenues of entrance. If the economic situation will not permit this, then the quarantine cannot be reasonably justified. This point may be illustrated by a practical example :

The Mediterranean fruit fly is undoubtedly a serious menace to certain California fruit crops. Its importance is such that rather extreme measures are justified in the effort to prevent its establishment. The principal avenues by which introduction may take place from Hawaii are incoming lots of fruits and vegetables and plants with soil on the roots. These are rigorously excluded. It is also recognized that there is a slight possibility that adult flies may be brought in on ships from Hawaii. The only way to close this possible avenue of entrance would be to close California ports to ships coming from Hawaii, obviously not permissible because of economic considerations. In spite of this possibility, the fruit-fly quarantine is held to be justifiable because all the *major* avenues of introduction have been closed. Adult fruit flies may not have been actually found on ships coming from Hawaii, but it is assumed that this is a reasonable possibility because the adult fruit fly is known to live longer than the period necessary for the steamer journey from Hawaii to California. If large numbers of adult flies were frequently found on ships coming from Hawaii, it would then be reasonable to contend that the exclusion of fruit and vegetables would not be justified because there would still be a major avenue of entrance left open. The fact is that the danger of establishment from adult flies that might conceivably come in on ships is a very remote one, and to obviate this slight danger is an economic impossibility.

Not only must the provisions of a quarantine be such as to authorize and to provide for the closing of all the major avenues of entrance of a plant pest or disease, but it must result in the *effective* closing of these avenues. It seems to have become fashionable for some states and countries to declare plant quarantines against certain products with little provision for the practical enforcement of them. These quarantines not only are totally ineffective in protecting the area under consideration from invasion, but tend to place the whole idea of plant quarantine in disrepute. Such quarantines are undoubtedly responsible for much of the opposition to this function of government. Under few, if any, circumstances is a mere paper quarantine justifiable.

International law holds that blockades, in order to be binding on neutral nations must be effective, i. e., maintained by a force sufficient really to prevent access to the coast of the enemy. A plant quarantine, in order to be sound and justifiable must provide for the closing of the

major avenues of entrance of the pest or disease against which it is directed, *and must be maintained by a force sufficient actually to carry out its provisions.*¹¹

RELATION OF NATURAL DISPERSAL TO PLANT-QUARANTINE EFFICACY

The methods by which plant pests and diseases might gain access to areas previously free from them may be grouped in two general categories: *natural dispersal*, and *transportation through human agency*.

In natural dispersal are included all those methods of distribution which are not due directly to man's influence. It includes, among other things, natural locomotion by flight and crawling; the effect of wind, not only on flying insects but on wingless forms such as newly-hatched scale insects, young gipsy moth caterpillars,¹² red spiders, and on bacteria and fungus spores; carriage of young insects and pathogenic organisms by birds, on their feet and on nesting materials; carriage by other forms of life; and transportation by running water. Although due directly to man's influence, it would also be reasonable from a quarantine viewpoint to include in this category the purely local movement of teams, wagons, and orchard and farm appliances. It is important to distinguish between local dispersal, and long-distance transportation by human agency, which is brought about by the movement of goods, including nursery stock, fruit, and other plant products and by railway cars, ships, automobiles, airplanes, and other conveyances.

The natural dispersal of a plant-feeding insect or plant disease cannot ordinarily be prevented, or even appreciably retarded, by quarantine action. Man has no effective control over the agencies which make this dispersal possible, such as natural flight, wind, etc., and hence is powerless to prevent it. Records of the natural dispersal of many injurious

¹¹ "Probably nothing has so materially weakened the support which should be accorded the general principles of plant quarantine as the practice of issuing a prohibitive quarantine without making provision for compelling compliance with the prohibitive order. Too often the State Entomologist or the State Quarantine Officer writes a quarantine prohibiting the movement of a certain plant product out of a given district or into a given district, and then sits complacently in an office apparently either nursing the idea that the quarantine will automatically enforce itself, or placing an unjustified faith in human nature in the belief that in writing 'Thou shalt not' he has effectively and finally dissipated any desire individuals or companies may have had to even attempt to move any article restricted by the quarantine." (Strong, 1923.)

¹² The gipsy moth is one species for which wind dispersal is apparently of primary importance. The adult moth is incapable of flying, but the young larva is equipped with aerostatic hairs which enable it to float in the air and to be carried on a breeze 20 to 25 miles. The optimum wind velocity for its dispersal is 8 miles an hour, but it is capable of floating in wind currents ranging from 2 to 23 miles an hour. (Collins, 1923.)

insect pests and plant diseases exhibit a "steady, irresistible wave-like migration from year to year" (Herrick, 1929). This seems to take place regardless of whether or not quarantines or regulations have been applied against them. Attempts to prevent natural dispersal can be justified only in very special cases, where the importance of preventing the spread of a pest or disease is such as to warrant extreme measures, as for example in an eradication campaign, and where the biological and economic conditions are such as to make such measures reasonably certain of attaining their objective.

The rate of natural dispersal may presumably be reduced by intensive control measures, but such measures are probably not often justified for this purpose. In special cases intensive control measures may accomplish more in retarding the spread of a pest at less cost and inconvenience than a domestic quarantine would occasion. According to Fleury (1929) this has been true in connection with the citrus white fly in northern California. An example of the use of quarantine to prevent natural dispersal is found in the case of the gipsy moth, a nonflying insect, where an attempt is made to bring about practical eradication annually at the western boundary of the infested area, covering a zone of about 30 miles wide, a distance greater than the probable annual natural dispersal would be. These measures seem to have successfully held the moth east of this zone.

Another example of the use of plant quarantines to prevent natural dispersal is found where a temporary artificial barrier, in the form of a nonhost zone, is used. This type of quarantine is in general practicable only against a pest or disease having only a single host plant, or a very restricted host list. It has been used against the pink bollworm of cotton, and was at one time suggested for use against the cotton boll weevil. These restrictions seem to be sound enough biologically, provided they are established and administered with a full recognition of certain features, such as the maximum distance of potential natural dispersal annually. In only a very few extreme cases, like the examples given, can the use of quarantines for preventing the natural dispersal of an insect pest or plant disease be justified.

Regulations designed to prevent the purely local movement of commodities and appliances deemed to be carriers of a pest or disease are difficult to justify when it is recognized that other means of dispersal, not subject to control, will in all likelihood distribute the pest or disease over the same area in about the same time regardless of the regulations. Such new infestations or infections as might become established by local transport would be swallowed up before they become serious by the dis-

persal of the organism brought about by other means over which man has no practical control.

It is of course recognized that from an administrative standpoint cases will arise where it is difficult to determine whether commodities or vehicles in the process of transportation are destined for a local or for a distant point. However, this does not affect the principle, and the aim should be no interference with movements known to have purely local significance, except in support of an eradication campaign.

It is believed, therefore, that under ordinary circumstances a quarantine which ignores the effect of the natural dispersal of plant pests and diseases is unsound.

RELATION OF BARRIERS TO PLANT QUARANTINE

The natural dispersal of a plant-feeding insect or an organism pathogenic to plants presumably will result in its establishment over a continually enlarging area until finally it reaches a natural barrier over which it is unable to pass except by the agency of man. These barriers may be classified as topographical, biological, and climatic; although strictly speaking, they are closely interrelated, the topographical features being largely responsible for the climatic barriers and the climatic for the biological barriers. It is convenient, however, to group them this way for purposes of discussion. Whether or not a feature of the environment constitutes a natural barrier depends not only on the nature of the feature but on the nature of the organism under consideration.

Topographical barriers consist of high mountain ranges; large bodies of water, such as oceans, seas, and lakes; and deserts of wide expanse. Under some conditions distance itself becomes a temporary natural barrier. Biological barriers consist primarily of expanses of territory in which the host plants of an insect or disease are absent. It might also consist of an expanse of territory occupied by competitors, through the range of which another organism of similar habits might be unable to break, because of the competition. Climatic barriers consist of expanses of territory in which the meteorological conditions are such as to be unsuitable to the existence of the organism. The elements of climate which make up a barrier include, relative to a particular organism: excessive humidity, excessive aridity, unfavorable distribution of rainfall, excessive heat, excessive cold, etc.

Natural barriers may be absolute or partial according to whether or not they completely prevent, or only retard, the natural dispersal of the particular organism under consideration. Absolute natural barriers can

be traversed by an organism only through the agency of man. This fact is one of fundamental importance in quarantine work. Orton and Beattie (1923) have discussed this situation in the following way:

That in establishing plant-quarantine policies the problems of restricting parasites [pests or diseases] from foreign lands must be grouped separately from the problems of preventing or delaying dispersal of pests already locally established may appear self-evident to some, but that this important point is not yet properly acknowledged is shown by the report of the last International Phytopathological Convention held in Rome in 1914, which makes no distinction between contiguous and noncontiguous countries with respect to the methods to be adopted to prevent the spread of plant parasites. The representations made by European delegations to the Federal Horticultural Board during the past year have likewise ignored this basic principle and have included proposals for intercontinental exchange in plants that we must regard as extremely unscientific and dangerous.

While the above statement distinguishes merely between *contiguous* and *noncontiguous* countries, the Committee believes that the real distinction should be made on the question of whether or not a *natural barrier* intervenes. The question of contiguity is of itself not as important as the presence or absence of *natural barriers*.

Since dispersal of organisms across an absolute natural barrier is possible only through the agency of man, theoretically, at least, this dispersal is subject to his own control. High mountain ranges are usually traversed by relatively few passes through which commodities and vehicles may enter the area to be protected from invasion. A wide expanse of desert, sufficiently large to form a natural barrier, is usually traversed by relatively few arterial highways. A seacoast is usually supplied with relatively few seaports through which dangerous material might possibly enter. All these avenues of entrance, it may reasonably be assumed, are subject to control. Distance is a temporary natural barrier only. Plant quarantine may in some cases justifiably be used in connection with a distance barrier, the economics of the situation being the sole determining factor in this instance. Ordinarily severe plant-quarantine restrictions in connection with a distance barrier can hardly be justified except where the protected area is at such a distance from the infestation or infection that natural dispersal would require at least two or three years to effect a successful invasion. For example, the cotton boll weevil through natural dispersal progressed across the southern states at a rate of approximately 50 miles a year. It would have been difficult to justify quarantine measures designed to protect an area less than 100 or 150 miles in advance of this migration. The minimum distance which would justify quarantine action in such cases will depend upon whether the natural dispersal of the organism is slow or rapid. In

problems of this type, where distance is the only barrier, a serious difficulty is the fact that the transportation lanes leading from the infested or infected area are often exceedingly numerous and consequently almost impossible to control satisfactorily.

It must be concluded that such use of quarantines rests on very questionable grounds, and that, ordinarily, a plant quarantine can be considered sound only when supported by an effective barrier to natural dispersal.

SELECTION OF PESTS AND DISEASES FOR SPECIFIC QUARANTINE ACTION

The economic importance of plant pests and diseases varies all the way from mere nuisances to veritable plagues, the control of which is vital to the existence of the industry affected. It is a practical impossibility to develop such a comprehensive plant-quarantine program as would theoretically be necessary to give complete protection to the agriculture of any extensive area against the establishment of all plant pests and diseases. Such a program would be equivalent to depriving the people of practically all exchange of goods and of much of their social intercourse with other areas, a situation less tolerable than the plant pests and diseases. This being the case, it becomes entirely a question of judgment as to what pests and diseases shall be objects of attempted exclusion. From a horde of plant pests and diseases a selection must be made of those against which quarantine will be applied.

Since exclusion of *all* plant pests and diseases cannot be attempted it has been the general policy to apply specific quarantines only to those which have demonstrated that they are capable of doing serious damage to important crops; in other words, pests and diseases which are already recognized as of major economic importance. This policy seems to be justifiable in spite of the fact that some insects and diseases which are now of major importance were relatively rare until transported outside their native habitat. Such insects and diseases as the cottony cushion scale, citrophilus mealybug, Japanese beetle, chestnut blight, walnut blight, and citrus canker were unknown as major plant pests until they were introduced into this country. Many species of diseases and insects which are of no importance in their native homes are, therefore, potentially major pests or diseases when introduced into another country. This fact is well recognized by plant-quarantine experts but as a general proposition it must be largely ignored because of economic considerations. So far as international plant quarantine is concerned, danger from this source has been largely avoided in the

United States by the enactment of Quarantines 37 and 56, the federal nursery-stock and fruit quarantines. However, interstate quarantines of this type would cause serious economic complications and there would not be the same biological justification for them.

To justify quarantine action against a specific pest or disease there must be a reasonable chance that such a pest or disease can exist in the area it is sought to protect, and that it will thrive there. According to the National Plant Board (1932), "the pest concerned must be of such nature as to offer actual or expected threat to substantial interests."

Insects or diseases known to require certain conditions of temperature, air humidity, or combinations of temperature and humidity are not properly subjects for quarantines to protect areas where these conditions do not exist. Many insects are limited in their distribution to the temperate zones, through climatic requirements. Such organisms in general are not properly subjects for quarantine action to protect tropical areas, and vice versa.

In the practical application of plant quarantine, however, it must be recognized that there are many border-line cases where present knowledge of the environmental requirements of an insect or pathogenic organism is not sufficient to permit an accurate prediction as to whether it would thrive in a certain area. In cases of pests and diseases in regard to which there is reasonable doubt as to whether they would be important in the area to be protected the policy should be in favor of quarantine action only provided that one or both of the following conditions obtains: it is a pest or disease of major economic importance, attacking a crop important to the area to be protected; or the quarantine entails little expense and economic disturbance.

The argument is sometimes advanced that an insect may suddenly change its climatic requirements and thus become adapted to an environment in which it was formerly unable to exist. Such a possibility is so extremely remote as to eliminate it entirely from consideration as a basis for specific quarantine action.

However, the absence of a plant-feeding insect or plant disease from an area is not necessarily a direct effect of a climatic limiting factor. It may be owing to lack of a suitable host plant or a suitable succession of hosts. The Colorado potato beetle, for example, was for many years restricted to certain semiarid areas in the plains region east of the Rocky Mountains. The introduction of the cultivated potato, upon which it became a major pest throughout the humid sections of eastern United States, demonstrated that its limitation to the arid region formerly occupied by it was not climatic but was a result of the restricted

distribution of hosts suitable to its development. The importance of a proper succession of hosts is illustrated by the case of white pine blister rust, which requires that white pine and either currants or gooseberries be present in a region before the disease can thrive. It would be very useful to be able to determine definitely just what are the limiting factors, if there is a reasonable doubt as to whether or not a disease or pest will thrive in an area which it is sought to protect by quarantine. The expense and inconvenience entailed by plant quarantines would amply justify the relatively small appropriations necessary for more research on this general question of factors limiting geographic distribution.

In general, the rule seems to be justified that a quarantine against a specific pest or disease should be enacted only if there is a reasonable possibility that that pest or disease would thrive in the area to be protected.

USE OF PLANT QUARANTINES FOR PURPOSES OTHER THAN THE EXCLUSION OF PESTS OR DISEASES

One of the commonly heard criticisms of plant quarantines is that they may be, and are, used as a means of excluding commodities in order to avoid competition, on the pretext that they are necessary for preventing the establishment of pests or diseases. For example, the argument was at one time advanced that the fruit-fly restriction on Almeria grapes from Spain was really for the purpose of protecting the market for California grapes, and that the suggested danger of introducing the fruit fly was only a pretext. This claim was made not only in Spain but by the American importers as well. It has been stated that the real reason for the California quarantine against Florida grapefruit was that California citrus growers were afraid of the competition and that the citrus canker was only a pretext. It is recognized that a quarantine honestly enacted and conscientiously administered may incidentally result in the protection of certain commodities from outside competition and thus seem to give support to such contentions. However, this cannot be avoided and it is generally acknowledged by plant-quarantine officials that to use the quarantine power for this purpose is not only entirely unconstitutional and unlawful, so far as the individual states are concerned, but is an extremely dangerous practice from the standpoint of agricultural welfare, for it is certain not only to result in retaliatory measures which would be economically disastrous, but if persisted in will destroy the confidence of the public even in the sound and necessary quarantines.

Intense pressure is often applied to quarantine officials for a plant quarantine that will protect commodities from outside competition.¹³ There is no more certain way to break down the entire quarantine system than to use it as a pretext to cover up some ulterior motive. Plant quarantines should never be used for any purpose other than the exclusion of pests and diseases.

UNNECESSARY INTERFERENCE WITH MOVEMENT OF PERSONS AND COMMODITIES IN RELATION TO PLANT QUARANTINE

Although the only justification for a plant quarantine is the prevention or delay of establishment of dangerous plant pests and diseases, and although the accomplishment of this purpose is paramount to every other consideration, there is an obligation on the part of quarantine officers to go to the extreme in avoiding unnecessary restrictions. Freedom of movement of commodities between the states is one of the striking differences between the United States of America and many other parts of the world. The desirability of this freedom was foreseen by the drafters of the American Constitution and it has undoubtedly been an important factor in the great industrial development of this country.

Quarantine officers should continually have uppermost in their minds the necessity of keeping the restrictions at the lowest point compatible with the exclusion of the pest or disease, and as conditions change such modifications as are permissible should be made promptly. The exact location of quarantine lines in connection with domestic quarantines often has economic effects of extreme importance.

A plant quarantine, therefore, should be so drawn and administered that there is the least possible interference with the movement of persons and commodities consistent with the accomplishment of its purpose.

THE OBLIGATION TO RESCIND PLANT QUARANTINES

The use of the police power for preventing the establishment of pests and diseases carries with it the obligation to rescind quarantines where they are no longer serving the purpose for which they were intended. It is incumbent on the quarantine executive to maintain at all times an intimate contact with the biological and economic conditions surround-

¹³ "In this day of trade rivalry, which, I believe, is keener than ever before in the history of the world, those who are engaged in questions relating to legislation of this type may be in danger of being called upon to frame policies of a regulatory nature for trade or political purposes. To offset this danger, there is only one defense, and that is that all regulations must be framed with a scientific background and on a basis that will withstand the attacks of scientific men other than those particularly interested in the problem under consideration" (McLaine, 1929).

ing a quarantine, since these often change rapidly, sometimes in such a way as to render a quarantine which was entirely sound when enacted no longer justifiable.

California has recently rescinded two quarantines, one against the navel orange worm (*Myelois venipars*), the other against the strawberry root weevils (*Brachyrrhinus* spp.), indicating a recognition of the important principle that as soon as the necessity for quarantine restriction is removed, steps should be taken to rescind it. Florida modified the quarantine against California lemons on account of brown rot, and the federal Bureau of Plant Quarantine promptly rescinded the quarantine against Florida on account of the Mediterranean fruit fly when it was determined that there was no longer any necessity for it. The federal Bureau also rescinded, on July 23, 1921, the quarantine against the Mexican bean beetle; on March 1, 1930, the quarantine against the Asiatic beetle and the Asiatic garden beetle; on July 15, 1932, the quarantine against the European corn borer; and on March 1, 1933, the phony peach quarantine. It is only by scrupulously observing this principle that plant quarantine can remain free of suspicion of ulterior motives. The decision to maintain or to rescind a plant quarantine should be based solely on its efficacy in protecting valuable property from injury through the establishment of pests and diseases.

The rescinding of a plant quarantine can also have disastrous economic effects. The narcissus bulb industry of California and other states is built largely on the exclusion of Holland bulbs from this country by quarantine. If it should be decided that this is no longer necessary, and if the restriction should be suddenly removed, it would result in serious economic losses. It is a fundamental principle of plant quarantine, however, that a quarantine which has passed its usefulness should be removed promptly, otherwise it is being maintained for an ulterior purpose. How then is such a situation to be met? The Committee believes that in the case of international quarantines the growers' only recourse would be to ask for temporary tariff protection, restricting imports until such time as the economic situation could adjust itself. As between two different states there seems to be no way out but to remove the quarantine and accept the losses.

If a state or country does not recognize the obligation to rescind a plant quarantine promptly when its major usefulness is passed or when it ceases to be effective, it cannot expect and rightfully demand fair treatment in this regard from other states and countries.

ERADICATION OF INCIPIENT INFESTATIONS AND INFECTIONS

The statement was made earlier in this report that the possibility of eradicating an introduced pest or disease, if found before it becomes widespread, greatly increases the practical importance of plant quarantines and renders their use as a means of preventing the permanent establishment of such pests and diseases an entirely logical and sound procedure. In a strict sense, by the adoption of this policy, quarantine becomes only a part of the entire machinery required for the prevention of permanent establishment, which is the real goal of such governmental functions.

Plant quarantines, regardless of how efficiently they may be enforced, may in time permit the introduction and temporary establishment of a plant pest or disease. Some avenues of entrance cannot be closed for economic reasons, and methods of entrance unrecognized by the quarantine authorities may exist, or the element of inefficient or uninformed personnel may enter in. For any one of a dozen reasons, even the most carefully drawn and efficiently administered quarantine may develop a leak through which a pest or disease may enter the protected area, and if conditions are favorable, permit it to become established. This possibility has always been recognized and has been advanced by some as an argument in favor of the idea that plant quarantines are not justified. If they ever had merit, such contentions must now be given less weight because even the occasional failure of quarantine to prevent the temporary establishment of a pest or disease does not exclude the possibility in many cases of preventing *permanent* establishment, if followed up by the proper eradication program.

A practice similar to this has been in force in connection with human health almost since the beginning of quarantine, and it has also been used in connection with animal disease. For many years entomologists and plant pathologists have recognized that there is a possible place for such attempts in connection with plant pests and diseases, but it has been only in recent years that public recognition of the economic importance of such pests and diseases has been such as to make it possible to undertake the work. There is no doubt but that the early adoption of eradication as a method of pest and disease prevention would have saved the American people an enormous amount of wealth. In 1889 the gipsy moth, even then well known as a serious pest in Europe, was confined to an area $1\frac{1}{2}$ miles long by $\frac{1}{2}$ mile in width at Medford, Massachusetts. At that time Professor Fernald recommended

its eradication. Riley and Howard, of the Bureau of Entomology, urged that, "It can be entirely killed out with the expenditure of a little time and money." Public support for such an attempt, however, was not forthcoming; in fact it is reported that the suggestion met with extreme ridicule on the part of the Massachusetts Legislature. Since then over \$20,000,000 has been spent simply in an effort to check its spread, with no end in sight.

In recent years the public has come to recognize the dangers of introduced pests and diseases and, in general, they are inclined to support requests for authority and funds to be used for eradication purposes. As a result of this change in the attitude of the public, several practical demonstrations of its feasibility are now on record. The greatest projects of this kind ever undertaken occurred in Florida, where both the Mediterranean fruit fly and the citrus canker have apparently been eradicated. Also several incipient outbreaks of the gipsy moth and rather extensive colonies of the pink bollworm have been eradicated. In California the cloudy-winged white fly of citrus was eradicated at Bakersfield, and the pecan leaf case bearer was eradicated in southern California a few years ago.

A sufficient number of examples of eradication of plant pests and diseases can now be pointed out to demonstrate the practical feasibility of such attempts, and eradication can now be looked upon as the second line of defense against the permanent establishment of plant pests and diseases in new habitats.

Without question, there are many cases where introduced pests and diseases occur against which it would be inadvisable to attempt an eradication campaign. Whether or not such a program should be undertaken can be determined only after a most thorough analysis of the situation from economic, biological, and sociological standpoints. When these are all favorable, quarantine officials should not hesitate to urge this action. When such a problem arises, those responsible for the protection of agriculture from the establishment of new pests and diseases should ask themselves three questions: (1) Can it be eradicated? (2) Will it pay to eradicate it? (3) Will such an attempt inflict a heavy penalty on innocent people for the sole economic benefit of others?

The answer to the first question will depend not only on whether or not public support for the project is favorable, but also upon the biological aspects of the problem.

The availability of funds for defraying the cost of the project is the first essential; but, even with ample funds with which to carry on the work, it can hardly succeed unless there is a sufficient body of public

opinion favorable to it and willing to undergo certain inconveniences to help make it a success. However, the state of public opinion and the extent of financial support are relatively easy to determine. The most difficult part of the problem is related to its biological aspects.

One of the first things that must be determined is the extent of the distribution of the insect or disease. In most cases the feasibility of eradication will depend in a very material way upon the size of the area infested or infected. To undertake an eradication campaign without extensive scouting to determine the limits of distribution would be foolhardy. The type of insect or disease, its disseminative powers, whether it is subterranean or aerial, the part of the host plant it attacks or infects, how it may be transported, its seasonal history, its host list, and how it reacts toward different hosts under different climatic conditions, and many other points too numerous to consider in this report, must be studied and their relation to the eradication campaign determined. Of course the essential thing is to search for vulnerable points through which the insect or disease may be most advantageously attacked.

In the past theorists have stressed the view that since it is unreasonable to believe that the last individual insect or pathogenic organism can be found and destroyed, eradication of an insect pest or disease is an impossibility. This hypothesis needs to be examined carefully before it is adopted. The premise that the last individual insect or pathogenic organism cannot be found and destroyed is undoubtedly true in most cases, but the fact that certain insect pests and plant diseases have apparently been eradicated seems to indicate that it is not necessary to accomplish by artificial means the destruction of the last individual in order to bring about eradication. Evidently, in some cases at least, the destruction of the major portion of such organisms may result in completion of the job by Nature herself. It is not known definitely how this takes place; but, just as many introductions of pests and diseases fail for natural reasons to result in permanent establishment, the temporary colony dying out, so, apparently, if a pest is reduced to extremely small numbers, widely scattered, these organisms fail to persist and eradication takes place. It is probable that with many insects, under such conditions, the population becomes so sparse and the individuals become so widely separated that the sexes fail to meet and no progeny are produced, or that natural checks destroy the remaining individuals. In plant diseases, the amount of inoculum may become so reduced that host resistance and environmental influences are sufficient to prevent the infection from persisting.

The relative favorability of various host plants of an insect or disease is also worthy of careful study. Apparently many host plants are simply secondary in nature and become infested or infected only through population pressure as a result of extreme abundance on favorable hosts. This is a sort of overflow effect, and apparently these secondary hosts must be continually restocked from the favored host plants. For example, in connection with the attempted eradication of the citrus white fly in California it has been determined that, while the fly has been found on over 50 species of plants, it is able to persist indefinitely on only a very few of them unless they are in the immediate vicinity of favored hosts on which heavy populations develop (Mackie, 1931). Consequently, it has been possible to confine the actual eradication work to citrus, privet, gardenia, and two or three other favored hosts. The reduction of the fly on these hosts results in self-elimination on most of the other hosts. Similar effects have been noted in connection with other insects.¹⁴

Thus many plants undoubtedly act as merely secondary hosts to certain pests and diseases, and a definite knowledge of their exact status in this regard would in many cases greatly simplify the practical carrying out of eradication campaigns. Here is an important field for research, which is certain to yield results of great practical value.

Biologically speaking, it seems apparent that any insect pest or plant disease can be eradicated. As Ferris (1929) has stated, an area can be made a desert. But an important question that has to be answered is: Will it pay? This must be determined for each individual case. It will depend upon the economic effect the pest or disease would presumably have if permitted to become permanently established, and upon the cost of the eradication campaign. This must be based largely on the biological aspects of the infestation or infection and would vary greatly between different pests and diseases. In insects that attack only the fruit, such as the Mediterranean fruit fly, the theoretical requirements for eradication would be simple. The maintenance of a host-free period each year, long enough to prevent the issuing adults from ovipositing, would fulfill the theoretical requirements. The citrus white fly attacks only the leaves of its hosts and there is a period during the winter when all the flies are in the immature stages on the leaves of evergreen hosts. Theoretically, defoliation of the host plants at this time would result

¹⁴ "We found there a great many kinds of trees and shrubs which, under certain circumstances, might be slightly infested with San Jose scale, but if taken away from the influence of other infested trees, would free themselves of the insects, so we eliminated those from the fumigation requirements unless they were found actually infested" (Glenn, 1926).

in eradication. Other insects, such as the European corn borer, which not only have many cultivated hosts but also breed in the stems of many species of weeds, would be extremely difficult to eradicate. Thus it will be seen that the specific habits of the pest or disease under consideration have a very direct relation to the cost and feasibility of eradication, and this is one of the most important factors in determining whether or not it should be attempted.

The question of property rights is very important and difficult in connection with the attempted eradication of a plant pest or disease. There is a fine, but important, distinction between requiring a grower to *control* a pest or disease which if permitted to go uncontrolled may result in continual reinfestation of his neighbor's property, and requiring him to *eradicate* it. Granting that there is a reasonably effective and economical means of *controlling* the pest or disease it may be assumed that it is to the grower's advantage, as well as to the advantage of his neighbor, to adopt these measures. So long as such control measures are available he may be held liable for permitting the pest or disease to become so abundant as to be a menace to his neighbor, and to this extent he is responsible. However, he is not responsible for the *occurrence* of a pest or disease on his property, and if the mere fact of its existence on his property is held to be a menace to society, he should not be penalized for it if he used the ordinary methods of control. He would seem to be entitled to compensation for any considerable cost in excess of this, or for any destruction of his property beyond that required for control only.

The compulsory *control* of a pest or disease is a proper function of the police power, an intense infestation being recognized as a public nuisance. The compulsory *eradication* of a pest or disease, in so far as it deprives the grower of valuable property or puts him to expense in excess of what would be necessary for *control*, for the benefit of society, is an entirely different matter. The right to compensation for such purposes has been recognized in connection with the foot-and-mouth disease of livestock in California, and the destruction of plant property for like purposes seems to be a parallel case.

THE TOPOGRAPHICAL AND CLIMATIC FEATURES OF CALIFORNIA IN RELATION TO QUARANTINE

In order to understand the relations of plant quarantine to the introduction and spread of plant pests and diseases in California, it is first necessary to consider the geographical position of the state in respect to the rest of the North American continent, and its own more important topographical features. In the first place the whole Pacific area is separated from the middle and eastern states by dry prairies and by the Rocky Mountain range extending from Canada into Mexico (fig. 1). This great range is flanked on the west by a very extensive plateau or Great Basin area, which, in the extreme west and south, gives way to broad semiarid and desert regions. On the immediate eastern borders of California, Oregon, and Washington rise the massive Sierra Nevada and the Cascade Range. Anyone traversing the wide intervening spaces from the Rockies to the Sierra Nevada will be impressed with the extensiveness and formidableness of this area of mountains, rivers, forests, and deserts, and the effectiveness with which it separates the Pacific seaboard from the plains of the Middle West.

The relief map of California (fig. 2) shows also the peculiar isolation of California from the remainder of the Pacific Coast area. What impresses one most at first glance is the preponderance of mountains over plains and the generally rugged features of the state. The Sierra Nevada slope abruptly eastward into Arizona and Nevada, and more gradually westward. Through this barrier there are few natural passes and all of these attain high elevations of from 6,000 to 8,000 feet and are from 50 to 60 miles in length. On the extreme west, bordering the Pacific Ocean, is the continuous Coast Range, mountains much lower than the Sierra Nevada, but still considerably higher than the Appalachian Mountains of the Atlantic seaboard. Throughout its length there is but one great opening and that is the outlet of the rivers through the Golden Gate. At the north the two ranges meet in rugged mountains which are heavily forested along the coast and which give way to arid lava beds in the northeast. At the southern end of the San Joaquin Valley, the Tehachapi Mountains similarly connect the two great mountain systems. The entire southern portion of the state is made up of alternating high mountain ranges, valleys, and great arid stretches, some of which open toward the ocean and others, like the Salton Sea and Colorado River deltas, southward to the Gulf of Lower California, thus connecting this latter area with Mexico. In the middle

is the Great Valley, an extensive area of arable land 350 miles long and from 40 to 80 miles wide. It is watered by the Sierra Nevada and drained by the Sacramento and San Joaquin rivers. Admission to this valley is had only over high mountain passes on the north, east, and south, and by means of the natural outlet, the Golden Gate, on the west.

In such a cursory survey it is easy to overlook the many small valleys which lie adjacent to some of the semiarid and desert regions, the lava barrens, the foothills of the Sierra, and in the Coast Range. These small isolated valleys tend to render the mountains and deserts less effective as natural barriers.

From a plant-quarantine standpoint, California is peculiarly fortunate in the extremely small number of seaports and passes through which commerce can enter the state (fig. 2). There are only three main seaports, San Francisco, San Pedro, and San Diego, and five lesser ports, Eureka, Port San Luis, Gaviota, Santa Barbara, and Ventura. In the well over 1,000 miles of inland border there are only 30 passes through which automobile traffic can enter and more than half of these are closed for several months each year by the winter snows. There are only 6 main trunk-line railways entering the state. This condition, which is a result of the peculiar topography of California, is ideal for the development of an effective plant-quarantine system.

Not only is California isolated, topographically speaking, but it is further peculiar in having a climate different from that of any other part of this country. In the state, extending 700 miles long from the latitude of Savannah, Georgia, on the south (32.5°) to about that of Boston, Massachusetts, on the north (42°), there are to be found many gradations of climate which have a marked influence on the flora and fauna of the region. San Diego, which about corresponds in latitude to Savannah, averages 1° F warmer in winter and 13° F cooler in summer, whereas Monterey, near the middle of the state, which corresponds with Richmond, Virginia, averages 15° F warmer in winter and 11° F cooler in summer. These two places give a fair idea of the mildness of the climate along the coast. There are much greater extremes of climate in the arid southwest, in the high mountains, and in the Great Valley. In the cultivated areas summer temperatures sometimes rise above 110° F but for only brief periods. On the whole the climate is mild both in summer and winter, as may be seen from the large number and variety of tropical and subtropical plants which are raised in many parts of the state.

There are two definite seasons: a wet winter and a dry summer. Practically no rain falls during the latter season. The precipitation is

exceedingly varied and reaches its highest mark in the northern coastal areas and in the high Sierra Nevada, where the annual rainfall may vary from 25 to 90 inches for a season. The mean annual rainfall throughout most of the coastal plain and Great Valley is from 15 to 20 inches, while that in the arid regions may be below 3 inches. Therefore, a considerable portion of the arable land is under irrigation.

As a further means toward an understanding of the adaptabilities of plant and animal life to California it is interesting to note that the native flora and fauna are also extensive and varied. There are at least 3,727 species of native plants, representing most of the families in the plant kingdom (Jepson, 1925). Of these natives 1,416 species are endemic, that is, they occur naturally only in California. The number of species of animals as a whole is not known. Judging from the knowledge at this time, there must be about 100,000 distinct species of insects. Among the higher animals it is estimated that there are 600 species of birds and over 400 species of mammals (Rider, 1925). Natural barriers have confined large numbers of species to this particular area.

Granted then that California is peculiarly isolated as a geographical unit and that its soil and climate are capable of supporting an extremely wide variety of plant and animal life, how may these facts be related to the use of plant quarantine for protection of this region? Were topographical conditions in California such that all plant and animal life could naturally move freely across the borders—if there were no mountain barriers, no extensive deserts, and no bordering oceans—there would be less justification for the adoption of plant-quarantine restrictions for the protection of the agriculture of this state. A study of the relief map of the entire United States (fig. 1) will indicate that agricultural California is probably more perfectly isolated by natural barriers than any other large section of the country, hence, theoretically at least, it is better adapted to the use of plant quarantines. The great variety of climate, on the other hand, makes the protection of California from the introduction of pests and diseases a much more difficult matter than is the situation in other states because the numerous kinds of crops made possible by these conditions greatly multiply the number of pests and diseases which would find a suitable habitat here.

Another factor which subjects California to extraordinary risks of this nature is the extensive commerce with the Orient, Australia, and other parts of the world and the extensive tourist travel. It appears to be thoroughly demonstrated that areas having world commerce have been most subject to the introduction and establishment of foreign pests and diseases.

Fig. 1.—Relief map of the United States, showing natural barriers isolating California and the rest of the Pacific Coast area from the remainder of the United States. (Courtesy of U. S. Dept. Agr. Bur. Agr. Economics.)

Fig. 2.—Relief map of California, showing protection of agricultural valleys by natural barriers consisting of the Pacific Ocean and high mountain ranges; also showing seaports, border highway inspection stations, and railway entrances. (Copyright by H. A. Sedelmeyer.)

In general it may be said, then, that California, from the standpoint of pest and disease introduction is fortunately situated so far as natural dispersal is concerned by reason of barriers and is unfortunately situated in regard to the introduction and establishment of pests and diseases by human agency because of the great variety of crops grown and the exposure due to the extensive tourist travel and the foreign commerce that passes through her ports.

A BRIEF HISTORY OF PLANT QUARANTINE IN CALIFORNIA

The idea of plant quarantine in California was first conceived in connection with preventing the distribution of the grape phylloxera in 1881. The Political Code, Chapter LI, "An Act to Define and Enlarge the Duties and Powers of the Board of State Viticultural Commissioners, and to Authorize the Appointment of Certain Officers, and to Protect the Interests of Horticulture and Viticulture," Sec. 3 states:

The Viticultural health officer shall have power, subject to the approval of the Board, to prevent the spread of vine diseases and vine pests, by declaring and enforcing rules and regulations in the nature of quarantine, to govern the manner of, restrain, or prohibit the importation into the state, and the distribution and disposal within the state, of all vines, vine cuttings, debris of vineyards, empty fruit boxes, or other material on or by which the contagion of vine diseases and germs of vine pests may be introduced into the state, or transported from place to place within the state, to declare and enforce regulations approved by the Board for the disinfection of vines, vine cuttings, vineyard debris, empty fruit boxes, and other suspected material dangerous to vineyards, while in transit, or about to be distributed, or transported into, or within the state.

Section 8 of the same chapter extended the provisions of this act to include fruit and fruit trees and gave the Board power to establish such quarantine rules and regulations as were deemed necessary for the protection of fruit and fruit trees from the spread of insect pests.

In this first statement are embodied all of the important phases of the present state and interstate plant-quarantine systems. The full scope and complete enforcement of such a program was not realized by the originators and it was many years before it was even attempted.

To carry out the legal provisions of this early law only two officials, a Chief Executive Viticultural and Health Officer and a Chief Executive Horticultural and Health Officer, were appointed. On November 12, 1881, the latter formulated thirteen elaborate and exhaustive horticultural-quarantine rules for the protection of fruit and fruit trees providing for inspection, disinfection, prohibition, and condemnation. In addition he formulated fifteen rules for the control of the codling moth, scale insects, etc., some of which were of a quarantine nature. Likewise on November 16, 1881, the viticultural officer formulated three viticultural-quarantine rules and recommendations which had as their object the prevention of the further introduction and spread of the grape phylloxera.

Because of a lack of inspectors of any kind and inabilities of these two officials actually to inspect the large volumes of plant materials which were being introduced at that time, little or nothing of a real quarantine nature was accomplished. Although County Boards of Horticultural Commissioners were created in the same year (1881), no authority was vested in them for dealing with international or interstate shipments of plant products.

The law approved March 13, 1883, entitled "An Act to Create and Establish a State Board of Horticulture," reiterated the powers and duties relating to plant quarantine originally delegated to the Board of State Viticultural Commissioners and in addition empowered the latter "to appoint such quarantine guardians as may be needed to carry out the provisions of the act." Following this legislation the members of the various County Boards of Horticultural Commissioners, and their inspectors, were appointed quarantine guardians, and interstate inspection of incoming nursery stock and other plant products became an important part of the work of these county officials.

The law of February 18, 1885, not only directed the State Inspector of Fruit, the official agent of the Board, and the Quarantine Guardians, to gather and destroy all fruits infested with noxious insects within the state, but definitely provided for the inspection and disinfection of fruits and plants brought into the state from any foreign country or from any of the other states or territories. A penalty had been provided for failure to disinfect, but up to this time prohibition of infested materials was not enforced. Then, too, there were many counties without horticultural officials¹⁵ where no inspections or disinfections could be made.

The need for more stringent measures restricting the movement of infested plant materials resulted in the passage of the State Horticultural Quarantine Law, approved March 8, 1889, which provided:

1. For a state horticultural-quarantine officer.
2. That the person receiving fruit, vegetables, nursery stock, and other plant materials, notify the proper quarantine officer and hold such materials for his inspection.
3. That in the absence of a quarantine guardian the State Board of Horticulture was required to make arrangements for the inspection.
4. That where any plant products were actually found infested or if there was *reasonable cause to presume* that they might be infested,

¹⁵ On November 4, 1889, there were 57 quarantine guardians in 15 counties. These officials had no authority outside their own counties.

the entire shipment was to be disinfected before being released. (Thus arose the "*reasonable cause to presume*" clause.)

5. That any shipment of plant products infested with injurious insects of species not existing in the state were to be sent out of the state or destroyed at the option of the owner and at his expense.
6. That peach, nectarine, and apricot trees, and stocks for propagating them were prohibited from any district infected with peach yellows or peach rosette.
7. That the bringing in of the English or Australian wild rabbit, flying-fox, mongoose, or other animals detrimental to horticultural or agricultural interests was unlawful.

To carry out the provisions of this act Alexander Craw was appointed state horticultural-quarantine officer and inspector and stationed at San Francisco in 1890. He inaugurated the first seaport inspection and established the plant-quarantine service in the state. In fact the real history of plant quarantine in California begins with Craw's appointment. His report for 1891 (Craw, 1892) states that every steamship which arrived from China, Japan, Australia, New Zealand, the Sandwich Islands, and Central America was carefully inspected. "The Japanese, and other firms importing trees and plants, were cautioned and instructed to notify their consignors to carefully inspect their shipments before sending to this country; otherwise, if found infested upon arrival they would be subject to seizure. This had a salutary effect, for subsequent importations were remarkably free from insects." Three hundred and twenty-five thousand orange trees, which arrived at San Pedro, June 11, 1891, were held because they were infested with the mining scale, *Howardia biclavis* (Comst.), a serious pest, and after five fumigations and a dipping all trees were either killed in the process or died awaiting disposal by the courts. In order to condemn and destroy imported trees when found infested with insect pests and diseases it was necessary to bring action before the courts, which could declare them a public nuisance and order them destroyed. Such court proceedings resulted in long delays and proved a cumbersome method for the enforcement of quarantine regulations. These difficulties were overcome by the passage of the "Act creating a State Commissioner of Horticulture" approved March 25, 1903, and amended March 20, 1905, which definitely provided for the promulgation and enforcement of plant quarantine in California. Three sections related specifically to plant quarantine and gave the commissioner power, with the approval of the governor, to establish, maintain, and enforce such quarantine regulations as were deemed necessary to protect the agriculture of the state, to make rules

and regulations, to establish and proclaim quarantine lines, and to inspect and prohibit infested materials from passing over such lines. Under this Act the Commissioner of Horticulture established additional plant-quarantine stations at San Pedro and San Diego and appointed deputies to act at each. Quarantine Order No. 1, to prevent the introduction of the citrus white fly from Florida, was issued October 3, 1905, and amended to include Louisiana, March 2, 1906. Thus began the issuance of quarantine orders, regulations, circulars, etc., which have played a conspicuous part in the administration of plant quarantine in California.

The "Act Relating to the State Commissioner of Horticulture," approved April 26, 1911, enlarged somewhat upon the provisions of the Acts of 1903 and 1905. The County Horticultural Commissioner, or a member of the Board of Horticultural Commissioners, in the respective counties, was appointed as state quarantine guardian. On July 1, 1911, such guardians were named in 41 counties. The general policy of the enforcement of quarantine laws, regulation of international commerce at the seaports by the state officials, and the inspection by the quarantine guardians of railroad shipments arriving from outside the state, continued. There was a gradual strengthening of the inspection service by requiring county horticultural commissioners to qualify by state and county civil service examinations. Later the inspectors were required to take examinations given by the Director of Agriculture.

In order to meet the quarantine needs arising from the presence of the Mediterranean fruit fly in Hawaii and elsewhere, a new plant-quarantine law was framed at a special session of the State Legislature called on December 24, 1911, and was approved January 2, 1912. It repealed the quarantine law of 1899, and provided for :

1. Inspection of all plant products coming into the state.
2. Disinfection, removal, or destruction of all infested materials.
3. Marking of all shipments of plant materials brought into the state as to kind and origin.
4. Proper sealing of containers of infested plant materials passing through the state.
5. Prohibition of entry of hosts of the fruit fly family *Trypetidae* from all places where these flies are known to exist.
6. Prohibition of entry of peach stocks and seeds from regions infested with peach yellows and peach rosette.
7. Prohibition of entry of English or Australian wild rabbit, flying-fox, mongoose, or other animals detrimental to agriculture.
8. Penalties for violation of provisions of the Act.

In 1917 there began a rapid expansion of the plant-quarantine activities of the state. The annual quarantine budget grew from less than \$25,000 in 1916 to about a quarter of a million dollars in 1930. The port inspection was strengthened by better organization and increased personnel. The interior inspection work (freight, express, and mail) was improved by placing the quarantine guardians under the direction of the State Commissioner of Horticulture, and qualifications for the county horticultural commissioners (quarantine guardians) were raised by more strict examinations of candidates for these positions.

In 1919 there was organized, through the efforts of the California State Commissioner of Horticulture, the Western Plant Quarantine Board, which consisted of the plant-quarantine representatives of the eleven western states, Hawaii, Mexico, and British Columbia. The purpose of the organization was "to secure a greater mutual understanding, closer cooperation, and uniformity of action for the efficient protection of our plant industries against plant diseases and insect pests." This organization, which meets annually, has done much to improve the interstate quarantine in the West, and has materially raised the standards of quarantine work. The value of this method of cooperation was so obvious that the other states of the Union have organized themselves into regional boards, and these boards have in turn united to form the National Plant Board, for the purpose of improving the general interstate plant-quarantine situation in the United States and for cooperation with the national government.

In 1919 the office of California State Commissioner of Horticulture was abolished and the Legislature created in its stead a State Department of Agriculture presided over by a Director of Agriculture. This Department of Agriculture succeeded to the plant-quarantine activities and responsibilities of the State Commissioner of Horticulture, which are now administered by the Division of Quarantine Administration.

The very great increase in transcontinental automobile traffic, especially of tourists and campers, opened up a new avenue for the entrance of insects and plant diseases. California was greatly concerned over the possible introduction of the alfalfa weevil from the Great Basin area across the arid regions of Nevada and over the Sierra Nevada into the million acres of alfalfa grown chiefly in the interior and southern valleys of the state. To prevent the introduction of this pest, border inspection was instituted in 1921 when inspection stations were located on the two principal highways, U. S. No. 40 and U. S. No. 50, which entered California after traversing the alfalfa-weevil-infested

districts. The Colorado potato beetle, cherry fruit flies, the thurberia weevil, the pink bollworm, were all within short distances of the borders, and danger from these pests induced the state to extend border inspection to all highways entering California. The discovery of the Mediterranean fruit fly in Florida also had a part in strengthening the quarantine line around the state until at the present time every highway carrying interstate traffic is guarded.

The passage of the national plant-quarantine law, in 1912, greatly strengthened and assisted the plant-quarantine program in California, not only by taking over many of the difficult problems of international and interstate quarantine, but by the federal endorsement of a policy which California had struggled single-handed to maintain for many years. A complete history of the development of federal plant quarantine is to be found in the Service Monographs of the United States Government (Weber, 1930). In 1916 the inspection of mails was made possible for the first time by orders of the Postmaster General to close this important avenue of distribution of pests and diseases throughout the state and country. It is certain that many introductions had been made in this manner.

THE ADMINISTRATION OF PLANT QUARANTINES IN CALIFORNIA

Two agencies are engaged in the promulgation and enforcement of plant quarantines for the protection of California agriculture from the introduction of new pests and diseases: the Bureau of Plant Quarantine of the United States Department of Agriculture, and the Division of Quarantine Administration of the California State Department of Agriculture.

FIELDS AND INTERRELATIONS OF THE ENFORCEMENT AGENCIES

Plant quarantines may be promulgated by either of the two agencies mentioned. The federal government operates under authority of the Plant Quarantine Act, approved August 20, 1912, with its subsequent amendments. This Act provides that when the promulgation of a quarantine is contemplated, the Secretary of Agriculture shall, after due notice, hold a public hearing at which interested parties may be heard. It is also provided that in the case of domestic quarantines he shall give notice of such action to the common carriers and that he shall publish in such newspapers in the quarantined area as he shall select, notice of the promulgation of the quarantine.

The California State Department of Agriculture operates under Sec. 2319b of the Political Code (State Commission of Horticulture Act). While this Act does not require the Director of Agriculture to hold a public hearing preceding the promulgation of a quarantine, it has been the general practice in recent years to do so.

The functions of the two quarantine agencies are not entirely distinct, being in some respects very closely interrelated.

The Bureau of Plant Quarantine is responsible for the enforcement of all quarantines against foreign countries and localities. Since this field belongs solely to the federal department, no question can arise as to jurisdiction. International quarantines should be exclusively a function of the national government. They affect foreign relations and foreign trade, over which the states have no control, and they can have far-reaching consequences to which no state should be able to subject the nation as a whole.

The federal Bureau also exercises jurisdiction over the interstate movement of commodities deemed to be possible carriers of certain pests and diseases against which it maintains domestic quarantines designed to prevent or to delay the spread of such pests and diseases into states

which are not infested or infected. The jurisdiction over interstate or domestic quarantine is not very well defined. The Committee has been unable to find any statement of policy on the part of the federal Department of Agriculture as to just what it considers to be the respective jurisdictions of the two agencies, federal and state, as far as interstate quarantines are concerned. Since the State of California had already a well-developed quarantine policy at the time the federal act was passed in 1912, it is not surprising that there should have been some uncertainty when the federal Department of Agriculture entered the field. While there has been no serious difficulty between the state and the federal departments, this has been largely due to the fine spirit of cooperation between the federal officials and those representing the states, rather than to any clear distinction as to the respective fields.

Minor conflicts arising prior to 1924 caused the Federal Horticultural Board (now the Bureau of Plant Quarantine) to call a conference of federal and state quarantine officials in April of that year, with a view to clarifying the situation. As a result of this meeting, agreements were reached regarding certain administrative phases of plant quarantine, and it was recommended that states contemplating quarantine action should give prior notice to the Federal Horticultural Board, and that the Federal Horticultural Board would consider the needs of the states and, when practicable, would incorporate them in the federal regulations whenever the states presented such matters to the Board, preferably at the original hearing. It was expressed as the sense of this conference that, "all state quarantines should be so limited in subject and scope as not to conflict with existing federal quarantines, and that all state quarantines now in force which are in conflict with such federal quarantines should be modified so as to eliminate such conflict" (Anonymous, 1924).

Other understandings were reached which were later nullified by decision of the Supreme Court and afterward partially restored by Congressional action. The general result of this conference was an agreement regarding cooperation between the federal Department and the states, but the report fails to indicate that there was any substantial understanding arrived at regarding the respective jurisdictions of the federal and state governments, excepting that quarantine action taken by the federal Department was paramount to any state action against the same subject. A definite understanding regarding the fields of the federal and state agencies with respect to the subject of plant quarantines would be highly desirable. It is true that so far as present conditions are concerned there seems to be no serious complaint; neverthe-

less questions of jurisdiction may arise in the future which could be avoided by a clear statement of policy. This, it is believed, should come from the Bureau of Plant Quarantine of the United States Department of Agriculture.

It has been frequently suggested that the federal government should have exclusive responsibility for all interstate quarantines. Many feel that this would be desirable. The danger of interstate quarantines maintained by individual states lies in the fact that the nature, purposes, and benefits derived may not be fully understood, and in the possibility that such regulations may be used to gain trade advantages at the expense of some other state. Quarantine officials are fully aware of this danger, but attempts are occasionally made by legislative bodies to take control out of their hands as a result of political pressure from organized groups of producers or dealers. Quarantines resulting from such action are likely to be based on political expediency rather than on sound quarantine principles and are a source of great danger to the whole quarantine program and must be guarded against. Even biologically sound plant quarantines may lead to political difficulties and retaliatory measures unless fully understood. Ignorance or selfish interests may cause abandonment of quarantines important to social welfare. Unsound quarantines maintained for trade advantage are certain to cause trouble.

Exclusive federal responsibility for interstate quarantines would prevent the enactment of retaliatory or otherwise unjustifiable regulations, and quarantines could then be based on natural barriers rather than on state lines. However, this would be difficult to achieve and probably many of the states would oppose such a move. The most desirable features of such an arrangement could be brought about by Congressional action providing that no state could maintain an interstate quarantine without the approval of the Secretary of Agriculture. This would be somewhat similar to the California law which provides that no political subdivision (county or city) may enact a quarantine against another political subdivision without the written consent of the Director of Agriculture. The federal Department has ample authority to take over the administration of *all* interstate quarantines merely by taking action against the pests or diseases upon which the state quarantines are based, which then deprives the states of legal authority to act against the same pests and diseases. However, it is not probable that, in the present state of development, the federal government would feel justified in undertaking to enforce a quarantine which was of interest to only one or two states. Still, a state is entitled to protection under such conditions and should be permitted to protect itself, subject only to the

limitation that the necessity for and the nature of the quarantine meet with the approval of the Secretary of Agriculture of the United States.

At present it appears that the function of the federal agency is to undertake to prevent the spread to clean states of pests and diseases which either are newly established or which are of very limited distribution, by placing a quarantine on infested or infected areas. The function of the state agency is to prevent the entrance into that state of pests or diseases which are not known to be established, or which are not widely distributed there. This division of duties would seem, on first thought, to result in considerable overlapping, since the pests and diseases against which the federal quarantines are directed are in many cases the ones which certain states are most interested in excluding. However, the Supreme Court has held that the state is without authority to rule against pests and diseases which are subjects of federal quarantines, so it will be seen that there is no conflict. In practice this arrangement operates about as follows: The Bureau of Plant Quarantine, on the discovery of a newly established insect pest or plant disease, if it appears to be a menace, establishes a quarantine line around the infested or infected area. If it seems feasible and the seriousness of the situation seems to warrant it, an attempt is made to eradicate the pest or disease, but this must be undertaken under state authority. If such an attempt does not seem to be warranted, efforts are limited to prevention of spread. Against such pests or diseases the state agency can take no official action affecting interstate movement. Presumably, in many cases, this action by the federal agency can at the most only prevent "commercial jumps" and natural dispersal will be retarded little, if at all. This natural dispersal will result in the dissemination of the insect or disease over a wider and wider area until in time a point is reached where the cost of quarantine enforcement, from a national standpoint, is no longer commensurate with the results, and when, it is presumed, the federal agency will rescind its quarantine. However, this situation may arise before the pest or disease has invaded all the states. When this occurs, under the present interpretation of the law, the uninvaded states may invoke quarantines against such a pest or disease.

It may be said then that, under present practices, the field of the federal agency is international quarantines, and domestic quarantines against pests or diseases not widely distributed within the United States, the preventing of further dissemination of which is deemed to be a problem of national importance. The field of the state agency is quarantines designed to prevent the entrance into a state of pests and diseases occurring in other states, and against which the federal agency is

not maintaining a quarantine. However, the states are not excluded from assisting in their own protection from pests and diseases against which the federal agency is enforcing a quarantine. The Federal Plant Quarantine Act of 1912, as amended, provides that when any commodities are shipped into a state in violation of a quarantine established by the Secretary of Agriculture, such commodities "shall be subject to the operation and effect of the laws of such state" In some cases it is impossible for the federal Department, with the means at its disposal, to make its quarantines completely effective, and the interception of contraband material by California inspectors is a fairly common occurrence. If a state were deprived of the power to seize such contraband material, it would be continually subjected to danger in spite of the federal quarantines. This arrangement, by which the state quarantine officials are really acting as enforcing officers for the federal Department, seems to the Committee to be eminently practical and necessary. It provides a double check against the entry of plant pests and diseases into California.

As pointed out before, the field of international quarantines is reserved exclusively for the national government, and for obvious reasons. The inspection at maritime ports and international borders is carried out for the protection of the entire United States, and not for individual states. However, in spite of the fact that such work is recognized as an exclusively federal function, and is done entirely under federal authority, California is paying practically the entire cost for such protection of a considerable part of the west coast, since California covers approximately three-fifths of the Pacific shore line, and more than one-sixth of the entire shore line of continental United States. Such protection at all other ports, with the possible exception of some in Florida, is paid for by the federal government. This situation is a result of the fact that California entered the quarantine field many years before the federal government entered it, and had already a well-developed maritime port inspection service at the time the Federal Plant Quarantine Act was passed in 1912. The Committee is voicing no criticism of the development of this situation, but feels that the time has arrived when it should be corrected and the federal government should be asked to relieve the taxpayers of California of a part of this burden. The financial contribution to this work by the federal Department at the present time consists of the payment of a merely nominal collaboratory salary to each of the state inspectors, in order to give them legal authority to enforce the federal regulations; while the cost of the port inspection to the State of California is approximately \$100,000 annually.

A portion of the activities at the California ports has to do with interstate shipments, and therefore at present it is properly a charge against the State of California. It has been roughly estimated that about one-half of this work is federal, and should, therefore, be paid for by the federal government. Of course any adjustment of these charges should be made without reducing the efficiency of this service.

Quarantines enacted by the Director of the California State Department of Agriculture are enforced at the border stations by inspectors directly in the employ of the Director, and at interior points by county inspectors under the direction of county agricultural commissioners, who enforce the regulations of the State Department of Agriculture by virtue of the fact that the law makes them ex-officio state quarantine guardians.

ACTIVITIES RELATING TO PLANT QUARANTINE IN CALIFORNIA

The administration of plant quarantines in California is divided into five types of activities, as follows:

1. Maritime-port inspection (ships and water traffic)
2. Border inspection (automobile, truck, and stage traffic)
3. Interior inspection (freight, express, and mail traffic)
4. Airplane traffic inspection
5. Administrative functions

Maritime Port Inspection.—As previously pointed out, this function is conducted largely under authority of the Bureau of Plant Quarantine of the United States Department of Agriculture; but its immediate direction is relegated to the State Department of Agriculture, and its financial support is almost entirely supplied by the state government. Because many agricultural pests and diseases of economic importance occur in countries bordering on the Pacific Ocean and are not established in California, this maritime port work is perhaps the most important function of the plant quarantine agencies. The records of pest interceptions (to be given later) will indicate just how great is the menace from this source. All ships arriving at California ports are boarded, either at the time of health quarantine or immediately upon docking. The ship's storerooms, refrigerators, passenger and crew decks, and the cargo are searched for contraband. The baggage of passengers arriving from foreign countries is examined by the United States Customs inspectors, and any plant materials found are referred to the plant quarantine inspectors. Baggage from Hawaii is searched under authority of the federal quarantine against Mediterranean fruit fly and melon fly.

Whenever contraband material is found, it is either destroyed or is ordered shipped out of the state, according to the nature of the contraband. The state inspectors are assisted by certain county inspectors during times of heavy passenger traffic; and county agricultural commissioners, acting as state quarantine guardians and federal collaborators, care for the maritime inspection at the lesser ports of Eureka, San Luis Obispo, Santa Barbara, and Ventura.

During 1931¹⁶ 8,392 vessels were inspected, and 12,293 lots of contraband material (material arriving in violation of quarantine) were intercepted. Actual infestations and infections found were as follows:

Mediterranean fruit fly, 4 times in mangoes, 2 times in peppers, 2 times in avocados, 2 times in coffee berries from Hawaii.

Melon fly, 1 time in cucumbers from Hawaii.

Gipsy moth, 1 time on ornamental plants from Japan.

Citrus black fly, 1 time on mango plants from the Philippines.

Sweet potato weevil, 7 times from China, Straits Settlements, and Philippines.

Mexican bean beetle, 1 time on green beans from New York.

Japanese beetle (all dead) in holds and on deck of vessels from Pennsylvania.

Nut tortrix (*Laspeyresia splendana*) 14 times in chestnuts from Italy, Japan, and Switzerland.

Oriental fruit moth, 2 times on flowering cherry from Japan.

Philippine orange moth (*Prays citri*), 2 times from Java.

Rice stem-borer, 1 time in rice straw from Japan.

Citrus canker, 11 times from Japan and China.

Also large numbers of other recognized pests and diseases of agricultural crops, many of which would possibly be the cause of additional expense if they became established in California.

The maritime port work is a model of efficiency, and it is difficult to see how it could be improved. An enormous amount of material is handled with dispatch and thoroughness. So far as the Committee has been able to learn, there is practically no complaint regarding the conduct of this work. This is probably due to the fact that ship passengers naturally expect to have their baggage examined, and before the boat docks each passenger is provided with a printed pamphlet informing him of the quarantine regulations and their purpose.

If it is conceded that the general idea of plant quarantine is sound, it must be admitted that this port work is extremely important and remarkably well conducted. Since there is no possibility of natural dispersal of pests and diseases into California from transpacific countries, because of the ocean barrier, protection from that source is solely dependent upon the thoroughness with which this activity is conducted.

¹⁶ Records of California State Department of Agriculture.

It is possibly significant that many of the pests and diseases which occur in the transpacific area and which are frequently intercepted at California ports, have become established in other parts of the United States but have not become established in California. Among these are the Mediterranean fruit fly, the gipsy moth, the sweet potato weevil, the Japanese beetle, the Oriental fruit moth, and citrus canker. The failure of some of these organisms to become established in California might possibly be explained by lack of adaptability to this environment; but some of them at least thrive under conditions very similar to those in California, and it seems not unreasonable to conclude that this port inspection is responsible for their absence.

Border Inspection.—This activity is carried out under authority of state laws by officers of the State Department of Agriculture, with the exception of the Mexican border inspection, which is handled by the federal Bureau of Plant Quarantine. At the present time it is limited to search of automobiles, stages, and trucks, there being no search of passenger trains or of the baggage of passengers arriving by rail.

The necessity for border inspection arises from the fact that in parts of the United States to the east and north of California several major pests and diseases of plants occur which are not yet established in California. Most, if not all, of these pests and diseases are effectively prevented from natural dispersal into California by the natural barriers of high mountain ranges and broad deserts. For the most part, they can arrive only through human transport, and the border inspection is an attempt to close these avenues of entrance. At the border stations all automobiles and other vehicles (and their contents) entering the state by highway are carefully examined and plant materials and other contraband properly disposed of. A 24-hour service is maintained at these stations. Many of them are open only from May to the middle of October because heavy snows during the winter season close the highways to normal motor traffic.

An experienced inspector is in charge at each border station and he is held responsible for the activities of the men under him, both in the matter of efficient performance of their duties and in their relation to the public. In addition, two supervising officers make regular trips to each station, and thus a constant check is kept on the personnel.

During 1931, 847,320¹⁷ vehicles passed through these 28 border stations. As a result of this activity, material in violation of the following quarantine regulations was intercepted as follows:

¹⁷ From records of the California State Department of Agriculture.

Quarantine	Number of host interceptions
Citrus canker	5,268
Oriental fruit moth.....	3,712
Boll weevil and pink boll worm.....	1,575
Sweet potato weevil.....	1,426
Cherry fruit fly.....	1,903
Ozonium root rot.....	962
Alfalfa weevil	1,023
Citrus white fly.....	30
Nut tree insects.....	9
Colorado potato beetle.....	47
Chestnut bark disease.....	1
Filbert blight	2
Downy mildew	39
Pine blister rust.....	226
European corn borer.....	88
Bulb flies and nematode.....	182
Gipsy and brown-tail moths.....	8
Mexican fruit fly.....	6
Japanese beetle	62
Mediterranean fruit fly and melon fly.....	22
Avocado weevil	2
Date palm insects.....	7
Satin moth	34
Woodgate rust	3

These figures represent only the number of times that host plants, parts thereof, and other contraband materials from the areas under quarantine were intercepted. The number of actual infestations or infections in such material was very likely much smaller; since the presence of many diseases is difficult to detect, the actual number of interceptions of organisms is not known. However, it is of interest to note that during the year 1931 the interceptions mentioned included actual infestations of the following pests and diseases: cotton boll weevil, Oriental fruit moth, pink boll worm, pecan shuck worm, camphor scale, cherry fruit fly, apple maggot, alfalfa weevil, citrus white fly, citrus melanose. These are the only data available to the Committee specifying pests and diseases that were actually intercepted. The alfalfa weevil was actually intercepted 89 times with a total number of 396 live weevils.

The taking of extensive contraband does not in all cases give a measure of the importance of the quarantines. For example, the interception of 5,268 lots in violation of the citrus canker quarantine looks impressive, but when it is remembered that intensive inspection by experts in Florida for six years has failed to reveal the presence of a single case of canker, and the eradication work in the other Gulf States has been so effective that Florida has rescinded her canker quarantine against them, these numerous interceptions of contraband in violation of the canker quarantine cannot be considered to be of very great importance. Actual infestations of the Oriental fruit moth have been found only rarely,

although there were 3,712 interceptions of host fruits from infested states. However, it is important to prevent even infrequent introductions, particularly where there is no possibility of introduction by natural dispersal. The frequent interceptions of the alfalfa weevil alone has in the past been considered to justify the maintenance of border inspection.

The justification of this activity is necessarily related to the question of whether or not other important avenues of possible entrance are left open, since the Committee believes that this work is so thoroughly done as to leave little likelihood of much dangerous materials passing through the border stations. This brings up the question of train inspection. Dur-

TABLE 9*

COMPARISON OF INTERCEPTIONS ON TRAINS AND AT BORDER STATIONS

Quarantine	Host interceptions	
	Trains	Border stations
Oriental fruit moth.....	335 lots	3,712 lots
Citrus canker.....	513 lots	5,268 lots
Cotton boll weevil.....	4 lots	1,575 lots
Citrus white fly.....	7 lots	30 lots
Citrus from Japan, Mexico, and France.....	33 lots	0

* From official records of the California State Department of Agriculture.

ing the time the fruit fly occurred in Florida, search of passenger trains entering California was maintained; but on the removal of the federal quarantine this practice was discontinued. Many persons believe that the examination of automobiles and the baggage of tourists for contraband is not justified unless trains and passenger baggage are also examined. This is one of the frequent complaints heard at the border stations. Fortunately, some idea of the relative importance of these two avenues of entrance of pests and diseases may be had as a result of the train inspection carried on during the time of the fruit fly quarantine.

For the period October, 1930, to February, 1931, inclusive, when train inspection records were kept of all plant products found in passenger trains, quarantine violations were recorded as indicated in table 9.

No figures are available regarding actual infestation or infection of this material. On the basis of contraband, however, it is seen that there were only one-tenth as many violations of the canker quarantine on trains as there were at border stations; and of the Oriental fruit moth there were less than one-tenth. It should be pointed out that border inspection is compulsory, while the train passengers were simply

asked to submit voluntarily to search, which would tend to offset to some extent the difference in the amount of contraband. However, the difference is so great that the Committee believes the Department of Agriculture is justified in its stand, that the examination of baggage of passengers arriving by train is of relatively little importance, compared to the border inspection. With the eradication of fruit fly and citrus canker in the Gulf States, the greatest menace from train baggage has been removed. There is perhaps some risk in connection with the Oriental fruit moth, but the Department has tried to reduce this danger so far as possible by eliciting the cooperation of the Pullman Company and the news agencies which sell fruit on the trains.

As to the importance of the border inspection in general, the Committee feels there can be no question but that here is an important avenue of entrance of pests and diseases, and that it is being closed as effectively as can be reasonably expected under the circumstances.

Border inspection is unpopular with some tourists, and even with some of the residents of California; but the extent to which it reacts unfavorably on California welfare, from the standpoint of discouraging the visits of tourists and even the reduction of demand for California products, is probably not great, although several visitors have reported that they would never again come to California because of their dissatisfaction with the border inspection; several even maintained that they would never again use California products. There has been more criticism of the border inspection than of any other branch of the quarantine service, although even in that case it is not extensive, considering the large number of persons who are affected by it.

Through the courtesy of the California State Department of Agriculture, the Committee has examined the entire complaint files for 1930, 1931, and to April, 1932, inclusive. Most of the complaints fall in seven categories.

1. *Many travelers insist that the inspectors should take their word for it that they have no contraband.* The Department points out that almost daily contraband is found in the baggage of persons who insist, prior to search, that they have none of the materials quarantined against. This happens so frequently that the Department believes it would completely nullify the efficacy of the work if reliance were placed solely on the statement of the traveler. It is pointed out by the Department that these are not deliberate attempts to smuggle contraband into California, but it results ordinarily from the fact that the traveler forgets what is in his baggage.

2. *Border examination of automobiles is not justified unless the baggage of passengers arriving by rail is also examined.* This question has been discussed on a previous page. Since the amount of contraband arriving by train is apparently very small as compared to that arriving by automobile, the Committee believes that the Department is justified, under present conditions, in omitting train inspection.

3. *Inspectors are officious, overbearing, and discourteous.* This is a frequent complaint and one which the Department of Agriculture has tried earnestly to eliminate. It perhaps should not be surprising that in a large group of inspectors one will occasionally be found whose attitude toward the traveler is lacking in courtesy. The complaints seen by the Committee indicate without question that this condition occasionally exists. However, that the Department does not knowingly permit it is apparent from the following circular of instructions to inspectors, which they are required to read and sign as evidence that they fully understand what is expected of them:

We have repeatedly brought to the attention of all border inspectors the necessity for a complete compliance with these instructions, as well as the necessity for courteous and friendly treatment of all travelers, regardless of their attitude or demeanor toward the inspection.

It is unfortunate that occasionally an inspector is employed who does not observe these requirements, as his failure in that regard naturally reflects back against the entire personnel and organization.

This circular is to impress upon every inspector the necessity for fully meeting these requirements, with the understanding that confirmed failure to do so will result in instant dismissal from the service. This circular is further to impress upon inspectors-in-charge at various stations the necessity for making adequate observations to determine that all inspectors under their direction fully meet these instructions. Failure on the part of the inspection force at any station to comply with these requirements will indicate the inability of the inspector-in-charge to assume responsibility for the conduct of the station and will result in demotion.

We recognize the difficulty of this type of inspection and the fact that it will occasionally cause certain travelers to complain in spite of any measures that can be taken to prevent it. However, it is insisted that every inspector give no basis or cause for such complaint based upon discourtesy, unfriendliness, failure to assist in unloading and reloading baggage, and failure to properly explain the purpose and reasons for the inspection.¹⁸

There is no doubt in the minds of the Committee that both inspectors and travelers occasionally are at fault. Travelers often arrive at an inspection station late in the day—hot, tired, dusty, and perhaps having had motor or tire trouble. They are unexpectedly stopped and required to unload their baggage, when they are already in a bad frame of mind.

¹⁸ From California State Department of Agriculture Plant Quarantine Circular 58, October 9, 1931.

This is the last straw, and perhaps they do not always greet the request to unload enthusiastically. Sometimes, judging from the reports of inspectors, often confirmed by other travelers, they are decidedly insulting to the inspectors and indulge in language and accusations which it is difficult for the inspector to let go unchallenged. It takes men of exceptional self-restraint to handle such situations, but it is largely a matter of personality. This self-restraint is a prime requisite for employees in border inspection service.

The Committee believes that there is still room for improvement in the personnel for border inspection, from the standpoint of both scientific training and personality. The Committee is also convinced that the Department of Agriculture is making a most commendable effort to improve the situation, and every reasonable action is being taken to eliminate this cause of complaint. That it cannot be completely eliminated is obvious; but it should be reduced to the lowest possible terms. Many travelers interviewed by the Committee speak enthusiastically of the way the inspection is handled at the border, commenting particularly on the courtesy of the inspectors, and there seems to have been a decided improvement in that regard during recent months.

4. *The inspectors refuse to assist in the unloading, loading, and packing of baggage.* This complaint often appears, and undoubtedly has been justified occasionally; but such refusal of assistance is certainly not in accord with instructions to the inspectors. For obvious reasons many travelers prefer to handle their baggage themselves, but inspectors are instructed to offer to assist them. In this connection the following orders of the Department to inspectors will be of interest:

The necessity for courteously handling the traveling public has been frequently stressed by this office. Among other instructions in that connection, inspectors have been informed that they must aid and assist motorists in unloading and reloading baggage or camping equipment providing the traveler requests or desires such assistance. It is not expected that this aid will be forced upon travelers where they express a desire to unload, repack, and reload their own baggage or other equipment; but, where assistance is asked for by the traveler, or where such assistance seems desirable, the inspector should offer to aid and should do so in a courteous and friendly way, using every care not to mar or damage any baggage removed from the car.¹⁹

5. *Inspectors soiled the packed clothing of travelers by handling it with dirty hands.* This complaint appears to be rather trivial. Inspection stations are supplied with soap and a wash basin, and inspectors are required to wash their hands frequently. Furthermore, they are instructed to ask the traveler to lay back the clothing in baggage so that the inspec-

¹⁹ From California State Department of Agriculture Plant Quarantine Circular 49, February, 1931.

tors may view its contents without touching it. Inspectors are especially cautioned not to touch the contents of ladies' baggage.

6. *The traveler believes he should be exempt from search because of his social standing.* In the course of a year many important personages pass through the inspection stations. Accustomed as they are to receiving special favors everywhere, they are unable to understand why they should have to submit to search. However, such persons are just as likely to have contraband as their more lowly brethren, and it is obvious that they cannot be exempted from this requirement, and the Department has consistently refused to do so. It would be unsafe to permit the inspectors to use their own discretion in this matter; consequently it is an absolute rule that no one is exempt.

7. *Inspection is simply a graft to exclude fruit not grown in California.* The amount of fruit excluded is so small that it could have no possible effect on California markets.

From the above discussion it will be seen that many of the complaints are rather trivial and arise out of the fact that in their travels through the United States tourists are not accustomed to being stopped for such purposes. Some of the objections, such as lack of courtesy, etc., have undoubtedly been justified at times; but the Department is making a strenuous attempt (and the Committee believes an effective attempt) to correct this situation. There will always be some complaint so long as human nature is as it is. The remarkable fact is that while 847,320 cars passed through the border stations in 1931, only 23 people felt sufficiently aggrieved to write to the Department about it. Undoubtedly only a fraction of those who had objections to the treatment wrote in; but, even so, the record seems to be rather remarkable and speaks well for the administration of this particular activity.

Interior Inspection.—This activity has to do with the handling of all plants and plant products entering California by freight, express, or parcel post mail. It is provided by law in the case of freight and express, and in the case of mail by regulation through the Postmaster General, that the common carrier or postmaster shall hold at destination all plants and plant products until they have been inspected and released by a quarantine official. The handling of such incoming shipments is delegated mainly to the county agricultural commissioners, their deputies and inspectors, who are ex-officio state quarantine guardians. The only exception to this is in case of material arriving in the cities of San Francisco, Oakland, San Pedro, and San Diego, where such shipments are handled by inspectors in the direct employ of the State Department of Agriculture.

The orders of the Postmaster General provide that plants or parts thereof offered for posting must be labeled "plants," and when shipments arrive so labeled the postmaster must hold them for examination. This work is also conducted largely by the county inspectors. It is undoubtedly a fact that some contraband arrives by mail in California and is delivered without examination owing to the fact that it is not labeled "plants," largely because most people are ignorant of this requirement. There seems to be no way to correct this situation.

That the arrival of plant and other products from other states by freight, express, and mail is an important avenue of entrance for pests and diseases might be taken for granted. During the year 1931²⁰ the Department records a total of 86,953 shipments of plant materials arriving from other states by rail. These records are admittedly far from complete, but they are the only ones available to the Committee and the relation of number of shipments to amount of contraband is of interest. Of these shipments, 2,602 were refused admittance as being in violation of federal or state quarantine orders or regulations, or because they were found to be actually infested with important pests or diseases. These rejections may be summarized, according to the quarantine which they violated, as follows:

Quarantine violated	Shipments
State:	
Alfalfa weevil	417
Cherry fruit fly	24
Chestnut bark disease	2
Citrus canker	107
Citrus white fly.....	44
Colorado potato beetle.....	54
Downy mildew of hops.....	1
Eastern filbert blight.....	5
Grape phylloxera.....	85
Boll weevil and pink boll worm.....	270
Nut tree insects.....	20
Ozonium root rot.....	131
Oriental fruit moth.....	377
Peach yellows and rosette.....	1
Sweet potato weevil.....	53
State Quarantine Law.....	632
Federal:	
Foreign.....	284
Domestic.....	108

It is important to remember that these records represent only shipments in violation of quarantines, and do not necessarily indicate the frequency of actual infestation by insects or infection by plant diseases. Fortunately figures are available concerning this aspect of the work. *Actual* interceptions of pests were as follows:

²⁰ Records of California State Department of Agriculture.

Pest	Times intercepted
Nut weevil (<i>Balaninus</i> sp.).....	3
Strawberry root weevil.....	28
Citrus white fly.....	4
Grape phylloxera.....	1
Crown gall.....	13
Nematode.....	250
Mealybug.....	11
Cotton boll weevil.....	1
Peach tree borer.....	4
European earwig.....	14
Bulb flies.....	14
<i>Curculio</i> sp.....	5
<i>Aspidiotus britannicus</i>	16
<i>Chrysomphalus dictyospermi</i>	13
Pecan shuck worm.....	8
Oriental fruit moth.....	1

In view of the fact that the records are only fragmentary any attempt to estimate the importance of this activity on the basis of these records must be avoided. All that can be deduced from them is that certain important pests, and their normal carriers, have been intercepted, but the frequency of introductions can be determined only when more complete records are available.

It would be a serious error, however, to conclude that if the amount of contraband were small, the activity therefore is of little importance. It is undoubtedly true that the vast majority of shipments made to interior points in California are commercial shipments, made by nurserymen and others thoroughly familiar with the fact that contraband shipments or shipments infested with pests will be rejected. Therefore every care is exercised before shipment to make sure that the commodity can enter California without violating the quarantine regulations. If the number of contraband shipments intercepted at interior points is small, that fact may be accepted as being more nearly an indication of the effectiveness of the quarantine system than of the lack of necessity for it. Certainly quarantines cannot be made effective unless they are enforced, and if it is generally known that they are enforced and the amount of contraband is thereby greatly reduced, that is a condition to be desired and in no way lessens the necessity for the quarantine or its enforcement.

However, some criticism of the method by which this activity is conducted may properly be made. Perhaps the most important objection to the present system of handling the interior inspection is the unwieldiness of the organization and the extremely large number of points in the state where interstate shipments may be delivered. There are in California several thousand freight and express stations where contra-

band material may arrive. It would seem reasonable to conclude that the greater the number of inspection stations the greater is the risk that a mistake may be made or that dangerous material might be permitted to escape. While it is not within the province of the Committee to determine how this situation might be improved, it is obvious that it would be desirable to concentrate these incoming shipments to a greater degree, if a feasible plan could be worked out. There are only six trunk line railways entering California, over which interstate freight and express can arrive. At one time it was considered that it might be feasible to require railway and express companies to hold for examination *at the division points nearest the state line*, all shipments of plants and plant products, such material to be examined and reshipped to final destination or otherwise disposed of. However, there seem to be practically insurmountable difficulties in the way of carrying this out. Such an arrangement would take relatively few men, who could be specially trained for this work only, and it would certainly greatly increase efficiency and safety factors, but the expense and inconvenience of transportation would be very great. It might be possible to divide the trunk line railways into inspection sections such as could be covered by an inspector with sufficient frequency, and to assign an inspector to each section, the common carrier being required, as now, to hold the material until it is examined and passed, or otherwise disposed of. Such inspectors could also handle the mail shipments arriving in their section. In this way shipments destined to the small outlying stations could be examined for contraband at the trunk-line station.

There are strong arguments for some such change in the present system. The promiscuous scattering of contraband material over the state at several thousand freight and express stations greatly increases the possibility of the escape of pests or diseases. Also plant quarantine work, if it is as vital as the growers of California believe it to be, would best be entrusted to men especially trained for this purpose only. The inspection of interstate shipments is only one of many widely differing functions of a county agricultural inspector. It is believed that anyone who has examined the numerous federal and state quarantine regulations, and the almost daily changes and amendments, and noted their extremely complex requirements, will appreciate the fact that only a quarantine specialist can be expected to keep abreast of developments. A few of the counties are perhaps sufficiently manned that the functions of the inspectors can be segregated and this specialization made possible, but that is certainly not true of all of them.

These other activities of the county inspector do not perhaps preclude his becoming a quarantine specialist, but it is asking a great deal of a man to expect him to keep up-to-date not only on quarantine, both interstate and intrastate, but on insect, disease, rodent, and weed control, grove and nursery inspection, standardization of fruits and vegetables, and numerous other regulatory functions.

This arrangement, by which county officials are charged with the duty of protecting California agriculture from the introduction of pests and diseases from other states, is unique in the United States. The present system, like the port-inspection work, reflects the historical development of plant quarantine, and is an outgrowth of the fact that the counties entered the field prior to the time that the state undertook to exclude pests and diseases by an effective system. Like the port-inspection work, in which the state agency carries out a purely federal function, this has been a perfectly natural development and no one is to be criticized for it.

This method of enforcement violates a cardinal principle of administration, in that the Director of Agriculture is held responsible for protecting the agriculture of California from invasion by serious pests and diseases, yet he is given little authority over the personnel upon which he must rely for the actual discharge of this responsibility. It is true that this defect in organization has been recognized for a long time and that an attempt was made several years ago to correct it by enacting legislation to the effect that such quarantine guardians (i. e., the county agricultural commissioners, deputy commissioners, and inspectors) "shall be under the supervision, control, and direction of the Director of Agriculture" as far as this function is concerned. These county officers are appointed not by the Director of Agriculture but by the county boards of supervisors; and, while they are technically under the control of the Director of Agriculture, actually he has nothing to do with their salaries or promotion. Quarantine work is police work and it is essential that harmony exist between executive and subordinates. It is only through recognition of these requirements that an effective *esprit de corps* can be developed in the state quarantine service. It is but fair to both state and county officials to say that lack of cooperation has existed only to a very limited extent, and in general the official relations between these county officers and the Director of Agriculture has been such as to leave little cause for complaint; but the organization is such that there is the possibility of conflict.

Any practical solution of these difficulties must, however, take into consideration the fact that there is also maintained by the counties an intrastate inspection and pest-control service. It is not within the scope

of this study to consider whether or not these functions are desirable. The necessity for the continuation of the intrastate inspection and pest-control service is therefore taken for granted and this situation has then a direct bearing on the conduct of the interstate work. While it is believed that a force of state inspectors, specially trained for quarantine work and directly and solely responsible to the Director of Agriculture, would result in more efficient interstate quarantine enforcement and less likelihood of error or of friction with other states, it is recognized that this would add materially to the cost of quarantine enforcement. Such a solution of the difficulty, however effective it might be, seems not therefore to be practical under present economic conditions; and, if improvements are to be made in this service, it may be necessary to base them on the assumption that the county inspectors will continue to fill the dual role of interstate and intrastate inspectors.

The County Agricultural Commissioner is responsible to the Director of Agriculture for supervision of the work of the inspectors in his county in relation to interstate shipments. He is required by law to carry out the instructions of the Director in this regard. However, since he is not employed by the Director of Agriculture, and since his salary advancement or continuation in office is not in any way dependent upon his activities meeting with the approval of that official, there is discernible to the public at times evidence of serious conflict of views regarding the state policy. This leads to a lack of confidence in the interstate work on the part of those affected by this activity. These disagreements are practically always on controversial questions, and regardless of the merits of the contentions of either party, it seems unfortunate that it is possible for such situations to come to the attention of the public. It is important that the confidence of the growers and of the general public in the interstate quarantine work be unshaken, and this result can be accomplished only through the existence of a unity of purpose and action on the part of those engaged in its enforcement. A good executive welcomes and encourages the private criticism of his policies by his subordinates, but public criticism from the same source creates a difficult situation. This condition is not the fault of the individuals making up the quarantine personnel, and no personal criticism of either the county agricultural commissioners or the Director of Agriculture is intended. It is solely the fault of the system. It could be corrected by making the county agricultural commissioners joint state and county employees, in fact as well as in function. Such a change would be just from a fiscal standpoint, since the quarantine work is legally a state function, while the pest-control work is a local, county function. It should not cost the taxpayers

any more than at present, although it would shift a part of the cost from the counties to the state.

Airplane Traffic Inspection.—The Committee has made no special study of the quarantine work as it relates to airplane traffic. Reports of the State Department of Agriculture indicate that the importance of the airplane in this connection is fully recognized, and that the inspection work is efficiently conducted. During 1931, 1,561 airplanes arrived from Mexico, carrying 4,270 passengers. The Bureau of Plant Quarantine of the United States Department of Agriculture has designated Lindbergh Field, San Diego, as the only official port of entry in California for airplanes from Mexico.

Administrative Functions.—The State Department of Agriculture is charged with the administration of the following laws:

State Quarantine Law, providing for inspection for pests and disposition of all shipments of plants and plant products entering California from other states.

Shipment of Injurious Insects Act.

Date Palm Law.

U. S. Postal Laws and Regulations, pertaining to terminal inspection of plants and plant products arriving in California.

Section 2319-b and 2319-c of the Political Code, providing for the promulgation by the Director of Agriculture of quarantine regulations to protect the state from the introduction of insect pests and plant diseases, or from their dissemination within the state.

Sections 2322-f, 2322-g, 2322-h, and 2322-i of the Political Code, relating to the inspection of plants and plant products originating and moving within the state to prevent the dissemination of insect pests and plant diseases.

“Reasonable Cause to Presume” Clause.—Section 3 of the State Quarantine Law provides that “when any shipment of nurserystock, trees . . . or vegetables or fruit, imported or brought into this state, is found infested or infected with any species of injurious insect . . . or plant disease or there is *reasonable cause to presume* that they may be so infested or infected, which would cause damage or be liable to cause damage to the orchards, vineyards, gardens or farms . . . such shipment shall be immediately destroyed . . .” Provision is then made that if the nature of the insect or disease is such that no danger will be incurred by sending the shipment out of the state within 48 hours, such action may be taken in lieu of destruction.

The use of the “reasonable cause to presume” clause against interstate shipments is, the Committee believes, open to criticism from some

viewpoints. This law is based on the assumption that inspection of shipments is a sound and effective method of excluding plant pests and diseases from California. With this the Committee does not agree (pp. 83-87) although it does not maintain that inspection of shipments is never justifiable. It seems obvious, however, that the drafters of the State Quarantine Law, believing in this method but recognizing that in some cases inspection would not reveal the presence of infestation or infection, inserted this "reasonable cause to presume" clause to take care of such contingencies. The Committee believes it was not the intent of the Legislature that this clause should be used as a substitute for a quarantine. It is specifically provided in the Statutes (Sec. 2319-b Pol. Code) that "all quarantine regulations involving another state, territory, district, or foreign country shall be made by and with the approval of the governor." Also (Sec. 2319-e) "the governor may issue his proclamation proclaiming the boundaries of the quarantine and the nature thereof, and the order, rules, or regulations prescribed for the maintenance and enforcement of the same, and may publish said proclamation in such manner as he may deem expedient to give proper notice thereof." The Committee believes the Legislature wisely recognized that the enactment of regulations involving another state carried with it the obligation to proclaim that action and to give it wide publicity. This seems to be indicated by the fact that it is only in connection with *interstate* quarantines that the governor's approval is required. Not only is this a courtesy to which citizens of other states are entitled, but it is in the interest of the protection of California agriculture, since a knowledge of these regulations on the part of prospective shippers undoubtedly reduces the amount of contraband, as has been pointed out previously.

Specific regulations based on this "reasonable cause to presume" clause of the State Quarantine Law include those with reference to the Colorado potato beetle (Quar. Cir. 5) and grape phylloxera (Quar. Cir. 6). It is also the authority for restrictions against the European earwig, and perhaps other pests. A question may be raised as to the legality of these regulations, in view of the provision of the law that all quarantine regulations affecting another state shall receive the approval of the governor in writing. It seems to the Committee, for the reasons mentioned above, that these restrictions might better be replaced by formal quarantines.

The "reasonable cause to presume" clause is a useful and necessary weapon—not as a substitute for a quarantine, but as a basis upon which to establish quarantines, and for use in case of an emergency where there has been insufficient time to promulgate a formal quarantine. It is

also useful in rejecting contraband shipped in violation of the federal quarantines.

Scouting and Surveys.—If the policy of eradication of incipient establishment of pests and diseases is to become an integral part of the agricultural protection program, as seems to be the case, it is believed that this phase of the work merits further development by the State Department of Agriculture. The eradication of a pest or disease is contingent upon finding it before it becomes extensively distributed. Most insect pests do not attract attention of the general public until the infestation has become rather intense. Dispersal from the original center of infestation tends to maintain a low population density until a considerable territory has been occupied. For example, the alfalfa weevil has undoubtedly been established in central California for several years, yet it never attracted the attention of the alfalfa growers. It was found more or less accidentally by an entomologist, and in less than ten days a scouting program revealed it in five counties.

The presence of local district inspectors in practically all agricultural sections of California, to the number of close to 300, provides an opportunity for pest survey work probably not matched in any other part of the United States. These men, being in residence in all districts, are thoroughly familiar with the area to be scouted, and the transportation and maintenance cost could be kept at a low figure by utilizing their services. Trained leaders from the State Department of Agriculture could instruct the local inspectors in the methods to be used in the search for specific pests and diseases, and this combination should prove very effective, not only in the early discovery of introduced pests, but in the general training of the inspectors. A good start has already been made in this direction, in connection with scouting for the white fly and other citrus pests.

Technical Work in Treatment of Commodities to Alleviate Quarantine Restrictions.—Most of the unfavorable direct effects of quarantines have to do with the fact that they seriously interfere with the free exchange of commodities between states. To a certain extent this is unavoidable. The most promising field for improvement in the enforcement of plant quarantines lies in the development of improved methods of treatment, by means of which restrictions required for preventing the spread of pests and diseases can be removed to the greatest possible extent. The development of the heat and cold processes by the federal Department, in connection with the fruit fly eradication campaign in Florida, is an outstanding example of what can be done in this direction. There is great doubt if the fruit fly ever would have been exterminated

had it not been for the fact that in spite of the fly the producers were enabled to market the major portion of their crop, which tended to bring about a favorable public opinion undoubtedly essential in such a campaign. Important progress has been made in the use of vacuum fumigation for similar purposes.

It has come to be rather generally recognized that the transportation of living plants, for obvious reasons, is the most important means of artificial dissemination of plant pests and diseases. Rather severe restrictions have been and will probably continue to be necessary so far as the movement of plants is concerned, since they do not easily lend themselves to treatment necessary to free them completely of insects and diseases. Most nurserymen now recognize that these restrictions are necessary and that they are one of the unavoidable hazards of the nursery business, and all they ask is that such restrictions be kept to the minimum consistent with safety; that they be uniform so far as is possible; and that they be enforced fairly and impartially.

The greatest objection to plant quarantines has to do with embargoes on the movement of products for consumption or manufacture, such as fruits, vegetables, cotton, grain, etc. In the first place it must be admitted that the movement of such products, when infested or infected with pests or diseases, presents by no means so serious a menace to clean areas as do plants and seeds for propagation, with the exception of the hosts of certain pests typified by the fruit flies. With food products the chances of establishment of many insects or diseases are remote as compared to the chances when such organisms exist on plants or seeds which are planted in a suitable environment. Also food products represent a much simpler problem when it comes to the application of measures to free them from pests and diseases.

It seems, therefore, that the alleviation of quarantine restrictions, at least so far as commodities other than plants for propagation are concerned, lies in the direction of greater development of processes of disinfection and disinfestation, and that this is a responsibility of the agencies charged with the administration of quarantines. It is not too much to hope that in time practically any such product, after treatment, may be permitted to move into clean areas, thus eliminating one of the major objections to plant quarantines.

It is the belief of the Committee that a considerably greater amount of effort might well be devoted to the development of this field. Both the state and federal departments of agriculture have in the past made important contributions along this line.

Training of Quarantine Enforcement Officers and Inspectors.—No detailed information is available to the Committee regarding the training of men now engaged in plant quarantine work in California. For many years the county agricultural commissioners and inspectors (state quarantine guardians) were so poorly paid that these positions could not possibly be expected to attract men with special training; and the result was that, with some exceptions, they were filled with men who had little, if any, special knowledge which would qualify them for such work. Salary scales are now adequate and there has been a striking improvement in the personnel during the last ten years. This has been due to the fact that the higher salaries naturally attract men of better quality and this results in competition for the jobs; also to the fact that the examinations now required to be given applicants for these positions by the Director of Agriculture are such as to prevent a candidate from qualifying unless he has a considerable knowledge of the subject.

However, it is the belief of the Committee that a considerably higher educational requirement for candidates for some of these positions is now desirable and possible. This belief is concurred in by leaders in the agricultural industry of California with whom the Committee has conferred. A higher educational requirement is possible because the salaries are now such as to attract men of better training. It is desirable because much of the work is of a technical nature and can be best conducted by men who have a special knowledge of the technique concerned. Of course, it is not necessary for routine quarantine work that inspectors be trained entomologists, or trained pathologists. In fact it would perhaps, in many cases, be undesirable. The actual carrying out of routine quarantine activities does not necessarily involve a technical knowledge of entomology or plant pathology, since it is primarily concerned with the interception of contraband; but public relations, an important aspect of plant quarantine, require that an inspector have a definite and rather detailed knowledge of the pests and diseases which he is attempting to exclude. An inspector should be able to discuss these subjects intelligently, because he comes in contact with intelligent people. Many persons have formed an unfavorable opinion of plant quarantine because it was obvious to them that the inspector was not sufficiently well informed as to the pests and diseases his work was designed to exclude.

It is believed that administrative officers should be highly trained men, who have a technical knowledge of the subjects fundamental to plant quarantine administration. There are other important requirements for such officers, it is true, and all men with the training men-

tioned would not necessarily be qualified for this work; but technical knowledge should be *one* of the requirements.

Public health officials are required to meet certain educational standards, among which is a degree in medicine. There is a similar argument for high educational standards for plant health officials. It is the belief of the Committee that it might be worth while for some institution to establish a curriculum in plant quarantine administration, by means of which men could be given a special course of instruction to fit them for administrative positions in this field. So far as known, no educational institution in this country has undertaken to do this.

Candidates for the subordinate positions should be required to have some technical knowledge of entomology and plant pathology. Provision should be made for special training for these positions. The State Department of Agriculture is now giving a correspondence course in entomology for its inspectors.

NUMBER OF EMPLOYEES ENGAGED IN PLANT-QUARANTINE ENFORCEMENT AND COST OF ADMINISTRATION IN CALIFORNIA

Tables 10 and 11 summarize the number of persons engaged in the various activities having to do with plant quarantine in California and the expenditures of the various agencies so engaged. The figures are for the fiscal year ending June 30, 1931.

TABLE 10
NUMBER OF EMPLOYEES IN QUARANTINE ENFORCEMENT IN CALIFORNIA

Activity	Location	State*	Federal†
Maritime ports	Los Angeles	.....	4 collaborators‡
	San Diego	3 inspectors	4 collaborators
	San Francisco	19 inspectors	17 collaborators
	San Pedro	10 inspectors	9 collaborators
	Santa Barbara	1 quarantine guardian§	1 collaborator
	Eureka	1 quarantine guardian	1 collaborator
	Ventura	1 quarantine guardian	1 collaborator
	San Luis Obispo	1 quarantine guardian	1 collaborator
	Gaviota	1 quarantine guardian	1 collaborator
International border	San Ysidro	.....	{ 1 associate quarantine inspector 1 junior quarantine inspector
	Calexico	.....	{ 1 associate quarantine inspector 2 junior quarantine inspectors
Interior inspection	Various points	350 (approximately) quarantine guardians	53 collaborators
Border inspection	Smith River	4 inspectors¶	
	Redwood Highway	5 inspectors¶	
(Permanent stations)	Hornbrook	10 inspectors**	
	Dorris	4 inspectors¶	
	Malin	3 inspectors	
	New Pine Creek	3 inspectors	
	Cedarville	3 inspectors	
	Yermo	5 inspectors	
	Daggett	4 inspectors	
	Blythe	3 inspectors	
	Yuma	9 inspectors††	
(Seasonal stations||)	Sattley	2 inspectors	
	Dog Valley	2 inspectors	
	Truckee	8 inspectors	
	Brockway	2 inspectors	
	Stateline	4 inspectors	
	Woodfords	2 inspectors	
	Coleville	4 inspectors	
	Bridgeport	2 inspectors	
	Benton	1 inspector	
	Westgaard	1 inspector	
	Fort Bidwell	1 inspector	
	Eagleville	1 inspector	
	Susanville	4 inspectors	
	Merrillville	2 inspectors	
	Ravendale	2 inspectors	
	Delliker	2 inspectors	
	Clio	1 inspector	
Administrative, technical, clerical	Various, mainly Sacramento	12 employees	

* From official records of California State Department of Agriculture.

† From Service Monograph of the United States Government, No. 59, 1930, the Brookings Institution, Washington, D. C.

‡ Collaborators are state or county plant-quarantine officials who are appointed as federal officers at a nominal salary in order that they may have legal authority to execute the federal laws.

§ Quarantine Guardians are county quarantine officers who are designated by the state to execute the state quarantine laws.

|| These stations are open from about May to October, inclusive.

¶ One of these inspectors is employed seasonally only.

** Four of these inspectors are employed seasonally only.

†† Two of these inspectors are employed seasonally only.

TABLE 11
COST OF PLANT-QUARANTINE ENFORCEMENT IN CALIFORNIA, FISCAL YEAR ENDING
JUNE 30, 1931

Division of Quarantine Administration, California	{	Administrative.....	\$21,677.28	
		Maritime ports.....	93,916.73	
		San Francisco.....	\$49,888.05	
		San Pedro.....	29,772.80	
		San Diego.....	10,062.69	
		Los Angeles.....	4,193.19	
		Border inspection.....	153,963.29	
		Permanent stations.....	105,626.13	
		Seasonal stations.....	28,333.24	
		Train inspection.....	20,003.92*	
County Agricultural Commissioners	{	Mediterranean fruit fly survey.....	12,245.09	
		Total expenditures of Division of Quarantine Administration, California State Depart- ment of Agriculture†.....		\$281,802.39
Bureau of Plant Quar- antine, U. S. Dept. Agriculture	{	Expenditures for interstate quarantine en- forcement‡.....		90,000.00
		Port Inspection Service.....	4,119.70	
		Mexican Border.....	12,222.65	
All agencies in California	{	Total expenditures in California§.....		16,342.35
		Grand total.....		\$388,144.74

* Discontinued in 1931.
† From records of California State Department of Agriculture.
‡ Estimated by California State Department of Agriculture.
§ From records of Bureau of Plant Quarantine, United States Department of Agriculture.

AN ANALYSIS OF PLANT QUARANTINES ADMINISTERED
FOR THE PROTECTION OF CALIFORNIA
AGRICULTURE

The specific quarantines discussed in this section are subject to frequent change. Inquiries regarding the provisions of such regulations should be referred to the California State Department of Agriculture, Sacramento.

MEDITERRANEAN FRUIT FLY

Geographic Distribution.—The Mediterranean fruit fly, *Ceratitis capitata* Wied., now occurs very generally throughout the subtropical regions of the world, with the exception of southeastern Asia and North America. Its spread from equatorial Africa, where it is supposed to be native, to the Mediterranean basin and the islands surrounding the African continent, took place a good many years ago. But its spread to

TABLE 12
SUMMARY OF QUARANTINES AGAINST MEDITERRANEAN, MELON, AND OTHER
FRUIT FLIES

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
All fruits and vegetables, and plants or portions of plants used as packing for fruits and vegetables	Total, except that certain fruits may be imported under permit when it has been determined that they are not carriers of these pests	Fed. Quar. No. 56	All foreign countries except Canada
Bananas (noncooking type), pineapple, taro, and coconuts	Admitted after inspection and certification by U.S. Dept. Agr.	Fed. Quar. No. 13	Hawaii
Other fruits and vegetables	Total		

more remote points has taken place comparatively recently. It was found in Bermuda in 1865, Western Australia in 1897, New South Wales in 1898, Brazil in 1905, Hawaii in 1910, and Argentina within the last year or two, and had a temporary foothold in Florida in 1929. The more rapid transportation and the development of refrigeration for ocean steamers, making it possible to hold fruit for long periods, are factors bearing on the greater extent of spread in recent years. It is now recorded in the following countries: Bermuda; Brazil and Argentina, in South America; Hawaii; Union of South Africa, Algeria, Tunisia, Egypt, Uganda, Dahomey, Nigeria, Congo, British East Africa, Rhodesia, and Morocco,

in Africa; Western Australia, New South Wales, Tasmania, and Victoria, in Australasia; Palestine; Spain, Portugal, France, Albania, Greece, Italy, and Sicily, in Europe; Cyprus, Malta, Madeira, Canary Islands, Cape Verde Islands, Madagascar, and Mauritius.

Hosts.—The favorite host of the Mediterranean fruit fly is the peach, and next after this, in most of the countries where the fly occurs, the citrus fruits, with the exception of the lemon. Apricots, plums, and other deciduous fruits are also attacked. It has a large number of other, less common, hosts.

Life History and Habits.—The female fly punctures the fruit with her ovipositor and deposits her eggs in small clusters within the opening. These eggs develop into maggots which burrow further into the fruit. According to Back and Pemberton (1918), "During the warmest Hawaiian weather, when the mean temperature averages about 79.5° F, the egg, larva, and pupa stages may be completed in as few as 13 or as many as 33 days, according to the individual and its hosts. At this season large numbers pass through the immature stages in from 18 to 20 days." Therefore, there may be many generations a year. The larvae, when fullgrown, drop to the ground and pupate, later emerging as adult flies to renew the cycle.

Economic Importance.—The following general review of the economic importance of the Mediterranean fruit fly is by Back and Pemberton (1918) :

The economic importance of the Mediterranean fruit fly as a pest of fruits varies with the climate of its natural abode or habitat. Thus in France, near Paris, where it has been known to attack apricots and peaches, it has not become a serious pest, because of climatic checks. Such checks to the severity of its attacks have been noted in portions of Australia, South Africa, and elsewhere, and would be operative in continental United States except in portions of California and the southern states. On the other hand, in tropical and semitropical countries the fruit fly is capable of becoming a pest of first importance, and, as in the Hawaiian Islands, may be classed as the most important insect pest to horticultural development.

There are two factors that markedly determine the economic importance of the fruit fly, namely: climatic conditions and sequence of host fruits. The breeding season of the fly as depending upon temperature varies from three months, or at most four months, to twelve months. If there is a sequence of fruits for the twelve months and there are 15 generations in the same time the fruit fly would be a very serious pest, as it is in Hawaii. However, in localities where the climatic conditions are most suitable for abundance of the fruit fly, the favorite host, the peach, is not grown, or at least it is not an important crop. Where the fly is in-

active for one-half to two-thirds of the year, and at the end of that period it starts with a low population as it does under such conditions, increase is checked before it is well started.

In the Valencia section of Spain, for example, while there are hundreds of acres of orange trees still carrying in April and May their full quota of mature fruit, these fruits are not attacked at this time because the fly has not yet appeared from its winter quarters. This is in striking contrast to the situation as it existed in Florida in April, 1929. During the period that the fruit fly secured a temporary foothold there, more than 500 flies were taken at the same time on one citrus tree and two days later more than 200 additional flies were taken at one time from the same tree. Grapefruit, which appears to be the favorite of the citrus hosts, was very heavily attacked by the fly when it occurred in Florida.

The growing of peaches is undoubtedly restricted in many areas because of the fly. Peaches could otherwise be grown successfully in much of the fly area, particularly in the cooler parts of it. This would apply particularly to areas having climatic conditions similar to those of southern Spain. However, in the warmer parts of the fly area peaches would not be successful anyway. In Hawaii, Florida, and Egypt conditions are not suitable to the peach. In any consideration of the restricted growing of a particular fruit in the fly area, therefore, other limiting factors should receive attention.

In South Africa, while the Mediterranean fruit fly occurs abundantly in dooryard plantings, or in neglected orchard plantings, growers are able to keep the fly attacks at a minimum on the most susceptible host, the peach, by applications of bait sprays. Likewise citrus fruits and other hosts are protected very satisfactorily in most parts of South Africa.

In Egypt and Palestine oranges suffer from attacks of the fly in the late fall and in the early spring to a somewhat greater extent than is the case in Spain, because of the cooler conditions in the latter country. The growing of summer oranges is not extensively practiced in the Mediterranean area and such an industry would not be successful unless very careful attention was given to the control of the Mediterranean fruit fly. Valencia or summer oranges are grown in Australia and South Africa, but this variety of fruit does not remain on the trees through as long a season as is the case in California and the fly is further checked by treatments.

Methods of Control.—Fairly satisfactory control has been secured in some places by the use of poison syrup. When the adults emerge they must feed for several days before they can deposit eggs, and this is the

period during which the poison syrup is used, by spraying it over the trees.

Adaptability to the California Environment.—A member of the Committee (Quayle) has had an opportunity to follow the seasonal appearance of the fly in the field at Valencia, Spain. During the season of 1929, at this place, the adult flies were found in gradually decreasing numbers through December until the last of that month, when they had practically all disappeared. Breeding and egg-laying had stopped about the first of the same month. It was not until about June 1 that the flies reappeared in the spring. Thus there were five months when the fly was not seen and about a month more each at the beginning and end of this period when the fly was not very active.

At Cairo, Egypt, the fly, according to R. I. Nel,²¹ who has made a special study of the fly under Egyptian conditions, is active throughout the year. Winter conditions at Los Angeles are more favorable for the fly than those of Valencia, Spain, and not very much less favorable than those of Cairo. The fly occurs as a pest in localities with colder winters than those at Valencia, Spain. So far as temperatures are concerned, therefore, the Los Angeles region and perhaps most of the fruit-growing areas of California would be favorable for the fly. The fly occurs as a pest in northern Africa, southern Europe, Egypt, Palestine, and Australia, where conditions are as arid as those of California, and it also occurs in South Africa, where there is summer rainfall. It would appear, therefore, that conditions as regards humidity in California would not be unfavorable to the fly. The fly also occurs in parts of Australia where the maximum summer temperatures reach 120° F.

After climatic conditions, the host fruits of a region have most to do with the abundance of the fly. For the most favorable conditions these host fruits must mature more or less in sequence throughout the season. Where winter-maturing oranges or summer-maturing deciduous fruits are grown to the exclusion of other fruits, the fly will not become so abundant as where there are ripening fruits throughout most of the year.

In California conditions would be most favorable for the fly as regards the sequence of cultivated hosts; navel oranges would carry the fly well into or through the winter, and a wide range of deciduous fruits from loquats in the early spring to peaches, apples, and pears in the fall, and Valencia oranges throughout this entire period, would keep the fly going.

²¹ In conversation with H. J. Quayle.

Thus the three factors that make for the most favorable conditions for the fly, namely, suitable climatic conditions, host fruits, and sequence of host fruits, are met with in California. Obviously then the question as to whether the fly would be an important pest in the state is scarcely a debatable topic.

Methods of Dispersal and Avenues of Entrance.—Severin has demonstrated, according to Back and Pemberton (1918), that “adult males of the Mediterranean fruit fly can be carried by the wind distances varying from $\frac{1}{4}$ to $1\frac{1}{2}$ miles from points of liberation.” Severin also indicates that some of the flies which he liberated were carried out to sea, “miles away from points of liberation.”

Back and Pemberton (1918) have also pointed out that fruit flies in various stages of development can be introduced by way of the soil about nursery stock, in packing materials, and in postal and express packages. Public and private conveyances such as “railroads, automobiles, hawkers’ carts, carriages, etc., are all responsible for much spread in Hawaii. But the development of rapid transit and cold storage, and the increase in tourist travel, have been the greatest factors in dissemination in more recent times.”

This is all in addition to the most common method of dispersal, which consists of the transportation of infested host fruits and vegetables.

The greatest danger to California lies in the bringing in of infested host material through the California ports. The Hawaiian infestation presents a constant menace.

Efficacy of and Necessity for the Quarantines.—All of the foregoing would seem to be sufficient argument for keeping the fly out of the state, if this is possible. If the fly became established in California, it would be incumbent on the federal government immediately to place a quarantine on California fruits, as was done in the case of Florida. This quarantine would continue until such time as each of the susceptible states became invaded by the fly, which unquestionably would be a long period, or until the fly had been eradicated. In the meantime, in addition to the quarantine, California would be obliged to spend large sums of money each year to eradicate or to control the fly. If the fly became generally distributed throughout the United States, the quarantine against California fruits would be lifted, but the fight to control the pest would have to be continued until the end of time.

Since the fruit fly became established in Hawaii in 1910, it has been intercepted at California ports innumerable times. It may be argued that a favorable combination of conditions for establishment would be very rare, which is true, and it might be granted that if there had been

no quarantine California might still have no fly. But that favorable combination of conditions might occur next week, or next year. When it is recognized that this pest is now established in practically every fruit-growing country of the world where conditions are favorable, except the United States; when it is remembered that it became established in Florida through such slight exposure that it is not even known how it came in; when it is recalled that infested fruits were formerly intercepted on practically every ship arriving from Hawaii, it is difficult to escape the conclusion that this quarantine has been efficacious in keeping California free from this pest to the present time.

MELON FLY

Geographic Distribution.—The melon fly, *Bactrocera cucurbitae* (Coq.) is known to occur in the following localities: Hawaii, India, Ceylon, Japan, South China, Formosa, Java, Australia, and the Philippine Islands.

Hosts.—Back and Pemberton (1917) list as preferred cultivated hosts: cantaloupe, watermelon, pumpkin, squash, gourds, Chinese cucumber, Chinese melon, cucumber, tomato, string beans, cowpeas; as occasional cultivated hosts: eggplant, watermelon, *Passiflora*, figs, papaya, peach, mango, citrullus; and as wild hosts: *Sycos* sp. and *Momordica* sp. Other authors record as hosts kohlrabi, cabbage, and pepper, and one writer states that it infests dates and guavas in the Punjab.

Life History and Habits.—Adults live on honeydew, nectar, and juices of host plants. Eggs are deposited at random in small batches beneath the surface of the fruit, vegetables, or plant affected. The egg stage is short. Larvae feed and burrow in the tissues of the fruit, stems, and even the roots of their hosts. Mature larvae on leaving their host spring or jump in a manner like that of the Mediterranean fruit fly, until a favorable spot is reached, whereupon they burrow in the ground to a depth of not more than 1 inch, or pupation may occur within firm-textured fruit. Adult flies are described as rapid fliers and may be found at a considerable distance from their host owing to a roving tendency. But this is not considered an important means of dissemination.

Egg-laying begins 14 to 17 days after adults emerge and the complete life cycle varies from 29 to 43 days. Probably there are from 8 to 12 generations a year.

Back and Pemberton (1917) state that "As the females are capable of living many months, and of depositing eggs at frequent intervals throughout life, the generations so overlap each other that adults

present in the field at any one time may belong to generations started in any month of the year."

Economic Importance.—The melon fly has been indicated by various authors as having been of serious economic importance in the following countries: India, Ceylon, southern China, and Hawaii; and as injurious in Java, Australia, and Formosa. But in Hawaii the greatest damage has been recorded, and it is here that the melon fly was studied by Back and Pemberton (1914), who wrote:

The damage caused by *Bactrocera cucurbitae* Coq. to fruit and vegetables in the Hawaiian Islands is nearly, if not quite, as serious as that caused by *Ceratitis capitata* Wied.; less than 30 years ago excellent cantaloupes and watermelons were grown in profusion, but today *B. cucurbitae* is found on all the important Hawaiian Islands and these crops can only be grown on new land which is distant from old gardens. More than 95 per cent of the pumpkin crop is annually ruined and much havoc caused among the more resistant cucumbers.

Adaptibility to the California Environment.—This fly occurs over a wide range of latitudes with corresponding climatic conditions from Nagasaki, Japan, on the north to Queensland on the south. It seems, however, to be largely if not entirely limited to the tropics, at least so far as occurring in injurious numbers is concerned. Nagasaki, the coldest place from which it has been recorded, is of course not in the tropics, but is relatively warm, and the fly is not reported as being a pest there.

Back and Pemberton (1917) reported:

At an average mean temperature of about 68° F, which is the coolest mean temperature found by the writers in Hawaii, where host fruits are available for the fly and for observation, the egg, larval, and pupal stages are passed in from 40 to 45 days. It is difficult to state just what variations there may be in the length of the life cycle in still cooler climates, but it is capable of being great in the opinion of the writers. . . . The writers believe that with certain combinations of host fruits and temperatures the immature stages may require from 3½ to 4 months, or a sufficiently long time to carry the pest over any cool period likely to be experienced by the melon fly in any habitat where it can establish itself.

At an elevation of 4,500 feet, these men found adults ovipositing on young squash, the vines of which are killed by frost in winter. While it seems doubtful if this pest would be able to survive the California winters in any numbers, since it is not recorded as abundant in any district where frost occurs, there is not sufficient knowledge available to make certain of this point.

Methods of Dispersal and Avenues of Entrance.—Natural dispersal takes place by flight, and long jumps are made through transportation of its numerous hosts, both fruits and vegetables, in commerce. The

chief avenue of entrance is the arrival of infested hosts on vessels from Hawaii and possibly from Oriental countries.

Efficacy of and Necessity for the Quarantines.—Since it is not certain that the fly will be unable to live in California and since it is a serious pest of crops grown in a large way in this state, the quarantines (table 12, page 142) are desirable. The melon fly has been frequently intercepted by California port inspectors.

OLIVE FLY

Geographic Distribution.—Todd (1929) gives the present known distribution of the olive fly, *Dacus oleae* (Gmelin), as follows: northern Africa, Union of South Africa, East Africa, Egypt, Algeria, Morocco, Tunisia, France, Greece, Italy, Portugal, Spain, Sicily, Canary Islands, Balearic Islands. He also adds that he “did not observe its presence in the scattered plantings of Argentina and Uruguay and has no record of its presence in Chile and Peru. The American continents, therefore, appear to have the only olive-growing areas free from the olive fly, with the possible exception of Australia.”

Hosts.—It attacks primarily the cultivated olive but has been reared from wild species. There is a difference in the susceptibility of different cultivated varieties to attack.

Life History and Habits.—According to Todd (1929) adults became noticeable in the field in Spain during the latter part of July and through the first part of August. A single egg is usually deposited in each olive fruit, in contrast to the habit of the Mediterranean fruit fly, which may deposit many eggs in a single fruit. It is stated that the olive fly can deposit from 50 to 400 eggs in its lifetime. He found that the young maggot remains in the same olive, feeding only on the pulp, and that by the time it has about encircled the olive, it reaches maturity and pupates in a hollowed-out space, just beneath the epidermis of the fruit. Complete development from egg to adult is said to take only from 30 to 40 days. About the middle of September the females of the second generation lay their eggs in the olives while they are still green. Like the first generation they pupate within the olive. The third generation, which develops in the ripening olive, leaves the fruit at maturity and pupates outside in any convenient place, usually in the ground. The location appears to make little difference in the ability of the adult to emerge.

Economic Importance.—Todd (1929) further states that in the inland portion of Spain, which he visited in 1925, infestations were so

heavy that few uninfested fruit were found, while in the coastal section the infestation "did not exceed 10 to 15 per cent."

In France estimates of the annual loss have been placed as high as two-thirds of the olive crop. A loss of about 30 per cent of the crop in Greece is attributed to *Dacus oleae*. In Algeria *D. oleae* is reported as causing serious damage. In Italy it is a pest of national importance. There is no ripe olive industry outside of California. The olive fly is often cited as the reason for this.

Methods of Control.—Various kinds of poison baits and sprays have been used for control of this pest but none is very satisfactory. Silvestri has attempted to introduce parasites into Italy but this has not been a practical success.

Adaptability to the California Environment.—Todd (1929) points out:

European entomologists tell us that while the olive fly is present everywhere, it is most serious near the sea coast. The writer had an opportunity to observe the olive fly in various situations in Spain, including the province of Tarragona, Castellon, Valencia, Seville, near the sea coast, and Murcia, Toledo, Jaen, Cordoba, and Boda-joz, which are inland on the Iberian Peninsula.

From these observations in 1925, Jaen and Cordoba, located inland, on the foothills on the northern slope of the Sierra Nevada Mountains [i. e., in Spain], appear to be more seriously infested with the olive fly than Tortosa, Castellon, Valencia, or Seville, near the coast. The climatic conditions (rainfall, temperature, and humidity) in Jaen and Cordoba, where the olive fly was most abundant, approximate those to be found in the principal olive-growing sections of California (Butte, Sacramento, and Tulare counties).

It may be pointed out, however, that the fly is severe in the Balearic Islands, where coastal conditions prevail.

Methods of Dispersal and Avenues of Entrance.—European entomologists have indicated that the adult olive fly is an excellent flyer and it is believed to be able to cover considerable distances and thus to infest uniformly the olive yards over immense areas.

Todd (1929) points out that: "It is evident that the pupation of this third generation may take place anywhere nearby, and in this lies one of the dangers of its transportation to, and introduction into, our country. . . . It is fortunate that the pickling process kills the olive-fly larvae if any happen to be present, for that eliminates one of our greatest hazards in the introduction of this pest."

A single living adult of the olive fly was intercepted on olive seeds from Capetown, South Africa, in the eastern United States by the Bureau of Plant Quarantine of the United States Department of Agriculture. During the period October, 1931, to February, 1932, the federal

Bureau of Plant Quarantine reports that its inspectors intercepted at the port of New York, a total of 28 larvae and pupae of the pest in 7 different shipments from Italy. These were partly in baggage and partly in cargo.

It might be thought that there is very little likelihood that this fly can reach California from present sources, since no fresh olives are shipped commercially into California from Europe. The records indicate otherwise. It might also come in with olive seeds as mentioned by Sasser, or in miscellaneous merchandise originating near an infestation, in which the larvae might take refuge for pupation.

Efficacy of and Necessity for the Quarantines.—This pest would undoubtedly be a serious one in California, because it would possibly destroy her ripe-olive industry, and dangerous material should by all means be excluded. There are, however, no records of the olive fly's ever having been intercepted in California. The quarantines against this fly are summarized in table 12 (page 142).

WEST INDIAN FRUIT FLY

Geographic Distribution.—The West Indian fruit fly, *Anastrepha fraterculus* (Wied.), occurs in Brazil, Argentina, Peru, Colombia, Yucatan, Cuba, Puerto Rico, Antilles, Venezuela, Ecuador, the Guianas, Paraguay, Uruguay, Bolivia, Guatemala, Costa Rica, Haiti, Honduras, and the Bahamas.

Hosts.—Citrus, guavas, mangoes, cassavas, peaches, pears, cherimoyas, avocados, coffee berries, Japanese plum, persimmon, figs, apricots, and many other thin-skinned fruits are hosts of this fly.

Life History and Habits.—According to Rust (1918) :

The eggs hatch commonly in from 2 to 4 days into minute white larvae. . . . In summer the larval period averages from 12 to 15 days, which may be prolonged to several weeks by the cold of winter. Upon becoming full grown, the larvae leave the fruit and burrow several centimeters into the soil. . . . The pupal period also varies greatly, ranging from 12 days to several weeks, according to temperature. The adult feeds on fruit juices, sap, or honeydew and is able to live for astonishing lengths of time. . . . Oviposition begins upon the seventh or eighth day after emergence and may continue for a long period.

Economic Importance.—Conditions of fruit injury in Argentina are reported as follows by Rust (1918) :

In bad years, practically all soft or thin-skinned fruits were destroyed, and in recent years even the various species of *Citrus* have been in their turn badly infested. This latter condition is, however, of only recent date, for it is only within the last three or four years that any infestations of citrus fruits have been noticed, but dur-

ing this period the condition has become more and more widespread and the percentage of infested oranges has increased until during the autumn of the present year (March, April, and May, 1918) a loss was experienced of nearly 50 per cent of the oranges in some sections.

Conditions at present are worst in the Province of Tucuman, and it is in the central and southern portions of this province only that oranges are severely damaged. On the other hand, almost all thin-skinned fruits are more or less subject to infestation in most parts of northern Argentina.

Cassavas in Brazil have been reported as heavily infested, 80 to 90 per cent of the crop being destroyed.

In Peru, Walcott (1929) reports that deciduous fruits are produced in small amounts but their greatest enemy is this fruit fly. Its maggots,

TABLE 13
SUMMARY OF QUARANTINES AGAINST WEST INDIAN FRUIT FLY

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Citrus fruits, pineapples, bananas, plantains, avocados, dasheens	Admitted under certification by U. S. Dept. Agr. (but excluded from California by other quarantines)	Fed. Quar. No. 58	Puerto Rico
All other fruits and vegetables	Total		
All fruits and vegetables	Total, except under permit	Fed. Quar. No. 56	All foreign countries except Canada

according to him, are found in a great variety of fruits, especially peaches, pears, and cherimoyas. Apples are attacked more rarely, also avocados, and many wild and local fruits.

A very complete account is given by Rust (1918) of the seasonal change in hosts of this fruit fly:

In the region under discussion [northern Argentina] the first fruits to be attacked in the spring are probably the apricots, which soon are followed by the peaches, and it is the latter fruit which may be regarded as the principal summer host of this insect. . . . By the end of the peach season the flies have reached their maximum number and there is scarcely enough fruit for all to place their eggs in during years of heavy infestation, so almost any kind of fruit is used for oviposition, but only in certain kinds do the maggots succeed in developing. After the peaches have all been destroyed, the females turn their attention to later fruits, such as cherimoyas and guavas, each of which serve as host for one or more generations of the insect. Fruits then become somewhat scarce and not much is left except persimmons, which to some extent engage the attention of such females as are bent on oviposition. Thus pass the summer months of December, January, and February, and oranges will soon be

in condition to attack. . . . [the females] can pass long periods without depositing eggs and yet be in perfect condition to resume this function as soon as an opportunity is presented, so their numbers do not diminish to any very great extent during a short scarcity of fruit. By the end of February or the beginning of March, oviposition begins in oranges, but the fruit is generally too green. . . . But from the middle of March to the last of April, or even longer during favorable weather, larvae regularly develop in many of the oranges of this section. Especially is this true in thin-skinned varieties or those with a loose peel, such as the tangerines have.

No information is available on the control of this pest.

Adaptability to the California Environment.—Rust (1918) writes that:

The growth of *Anastrepha fraterculus* larvae on citrus fruits is slower than in other fruits mentioned and this may be due partly to the qualities of the fruits themselves, but it is more apt to be the effect of lower temperature which always occurs during the autumn and winter when the citrus fruits are ripening. . . . Thus we have *A. fraterculus* passing the coldest months of July and August as larvae in citrus fruits, as pupae protected by the soil, and as adults which have been seen to survive as low as -7° C.

But he states that "climatic conditions seem to be the decisive factor as to whether this insect will be severely destructive or only moderately so." Rust's observations may be summarized as follows:

If climatic conditions have been favorable to a heavy crop of early fruit, fruit flies are abundant, and consequently when oranges are ripe they become heavily infested. Unfavorable weather occurring early in the season may severely check the flies without seriously damaging the fruit trees and thus a good crop of comparatively clean fruit results. It has been found that neither frost nor rain has much adverse effect on *Anastrepha fraterculus* but heat and drought occurring together are a considerable check to the fly. Moreover, such conditions will produce a small crop of fruit, with the result that the fly will be checked in its multiplication and the fruit of the succeeding season will be comparatively free. Many larvae and pupae are killed outright by heat, and with the temperature much over 100° F larvae are often cooked in the fruit that falls in the sun before they can escape and enter the soil. Such a temperature is also fatal to emerging flies.

This fly probably presents a greater menace to California horticulture than is generally realized. It has been recorded as doing serious damage in localities where the temperature drops as low as 19.4° F.

Methods of Dispersal and Avenues of Entrance.—Entrance of this fly into new areas is by the bringing in of host fruits from the infested areas. It has been intercepted several times at American ports by the Bureau of Plant Quarantine of the United States Department of Agriculture, but not, so far as the Committee knows, at California ports.

Efficacy of and Necessity for the Quarantines.—There seems to be no doubt but that this fly would thrive in California and that the quarantines from this viewpoint are very desirable. They should prove effective.

MEXICAN FRUIT FLY

Geographic Distribution.—The Mexican fruit fly, *Anastrepha ludens* (Loew.), is known to occur in Mexico, Nicaragua, and northern South America. Fleury (1927) states that “undoubtedly it is a native of Mexico and, as the orange and mango are not indigenous to that country, it is probable that it originally attacked some native wild fruit, probably guavas.”

In 1927 infestations of *Anastrepha ludens* were found in the lower Rio Grande Valley of Texas. It is presumed that it had been present there for more than one season as it was found present upon further investigation in eleven towns in the district. Because of the eradication

TABLE 14
SUMMARY OF QUARANTINES AGAINST MEXICAN FRUIT FLY

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Mangoes, sapotas, peaches, guavas, apples, pears, plums, quince, apricots, mameys, ciruelas, and all citrus fruits excepting lemons and sour limes	Admissible under certification by U. S. Dept. Agr., but many of these hosts are excluded from California by [other quarantines	Fed. Quar. No. 64	Certain counties in Texas
Oranges, sweet limes, grapefruit, mangoes, achras, sapotas, peaches, guavas, plums	Total	Fed. Quar. No. 5	Mexico

campaign immediately carried out, the fly was not seen again until the spring of 1929, in Hidalgo County, and in November of the same year in Brownsville, Texas. The infestation was again cleaned up and as far as known has not reappeared.

Hosts.—All varieties of citrus fruits except lemon and sour limes are attacked. In addition, the following fruits are recorded as hosts: mangoes, sapotas, peaches, guavas, apples, pears, plums, quinces, apricots, mameys, and ciruelas.

Hoidale (1930) reports that “In the lower Rio Grande Valley grapefruit seems to be the preferred food, but where there is no grapefruit available, as in Matamoros, they thrive equally well in sour seedlings and oranges. They were also found feeding to a slight extent in sweet limes and in citrons.”

Life History and Habits.—Quayle (1929) points out that “The life history and habits of this species in general are similar to those of the Mediterranean fruit fly.” The eggs are laid within the skin of the fruit

in a small puncture made by the ovipositor of the female. They hatch in about 10 days and the tiny maggots eat into the pulp, decay sets in, and the fruit drops. After three weeks inside of the fruit, the maggots work their way into the ground and pupate and the fly emerges nearly a month later. Slightly more than 2 months elapse from egg-laying to the emergence of the adult. This record is based upon the conditions in Mexico. There are four broods a year, but Crawford (1927) points out that these are not sharply defined.

Marlatt (1930), reporting on the experiments carried on at Cuernavaca, Mexico, states that "Observations on the biology of *Anastrepha ludens* showed the premating period of the flies emerging in January averaged 25 days, and even males were alive after 5 months. One female deposited 298 eggs during a period of 47 days. The adults were believed to feed on wild yeast-like organisms that occur on the outside of fruits and elsewhere."

Economic Importance.—According to Hoidale (1930) :

In Mexico, the heaviest infestation appears to be in the state of Morelos, south of Mexico City. Crawford states that the loss to growers in that state through wormy and unsalable fruit amounts to 50 or 60 per cent of the crops. Darby states that in Cuernavaca the mango crop at certain times of the year often shows 100 per cent infestation. Every fruit inspected on several premises in Matamoros during November, 1929, was found to be infested.

Crawford (1927) from his study of the situation in 1913-14 states :

The actual amount of fruit lost through the ravages of this fruit fly varies with the location from year to year and from season to season, and is not the same for all host fruits. On the eastern gulf coast, for example, the loss is usually not more than 5 per cent of the total crop, and sometimes less. . . . In the northern districts the percentage of infestation is still less. . . . Still further north there is no infestation whatever, and the condition in most of the southeastern portion of the country around Jalapa is somewhat as on the east coast, even a smaller percentage of the fruit being affected. The attacks around Jalapa seem to be more periodic. In the west coast region there is some infestation, but this investigation did not develop to what extent. The region south of Mexico City, in the State of Morelos, has a more serious infestation. . . . An average loss of 30 per cent of mangoes, guavas, and oranges is probably more nearly within the facts of the case.

No information on the control of this pest is available. Perhaps the poison bait spray as used for other fruit flies would prove effective.

Adaptability to the California Environment.—"At Yautepec, the orange section of Morelos, thermometric readings reported for many years show the lowest temperatures to have been 46° and the highest 86° in the shade, and 117° in the sun" according to Professor Herrera, as reported by Isaac (1905) ; he continues, "A fall of the temperature to

43° is very exceptional, and at this temperature the flies become dormant and incapable of action."

Crawford (1927) states that "It is distinctly a tropical insect and must have good humidity and a temperature not much over 100° F."

Mackie (1928) in his investigations of this fly in the lower Rio Grande Valley reports that "in the regulated areas there are 'northers,' particularly during December and January, during which the temperature drops rapidly and sometimes falls considerably below the freezing point. What effect this may have on fruit-fly control will depend of course upon the temperature and the duration of the freeze." Isaac (1905) reports in this connection that "About 1903 the Morelos orange fruit worm [Mexican fruit fly] was introduced from Mexico and became established near Brownsville, Texas." A. F. Conradi, State Entomologist of Texas, reported that it had become fairly abundant in the Brownsville region, but since the freeze in February, 1905, when a minimum of 22° F occurred, he had been unable to find any evidence of the pest. Thomas (1927) points out that the winter before the infestation was discovered in the Rio Grande in 1927, had been unusually mild.

According to Crawford (1927) :

It has often been said that a series of different kinds of fruits is necessary that this fruit fly may live and thrive. Mangoes and guavas must fill in gaps between orange crops, and vice versa. This is not true in all regions. It is certain that citrus fruits in a single orchard can and do maintain the insect throughout the year. The gap between crops is filled in by off-season fruit in small quantities and by green fruit. It has always been said heretofore that green fruit is avoided by the ovipositing female as unfit food for larvae, but it has been established that eggs are deposited in very green grapefruit and that the development of the larvae is long retarded thereby.

If Crawford's conclusion that the Mexican fruit fly "is distinctly a tropical insect and must have good humidity" is correct, there may be some question as to the ability of the pest to thrive in California. Brownsville, Texas, is in a more nearly tropical life-zone and in addition it is subject to reinfestation, so that a period of mild winters gives the fly a chance to build up. Even at Brownsville, according to the records, it has not been able to persist indefinitely. California would not be subject to reinfestation from Mexico and there seems to be no doubt but that the winters and the low humidity here would be distinctly less favorable to the pest. Some of the quarantine experts feel that this fly is a greater menace to the citrus industry of California than the Mediterranean fruit fly. This opinion, however, does not seem to the Committee to be justified by the apparent climatic requirements of the fly.

Methods of Dispersal and Avenues of Entrance.—Hoidale (1930) states:

Very little is known at the present time about the flight of the fly. Based on circumstantial evidence in Mexico, it is thought that the fly does not range very far in search of food or material in which to oviposit. The chief means of dissemination so far as known at the present time is through the shipment of infested fruit from one part of the country to the other. During the past summer infested fruits from the southern part of Mexico could be found at will in the public markets of Matamoros and Reynosa, Tamaulipes.

After the Morelos orange maggot, now known as the Mexican fruit fly, reached northern Mexico, first on the local fruit markets and later attacking the fruit on dooryard trees, according to Fracker, it finally made its way to the Texas side of the river. The insect was found there by representatives of the Texas Agricultural Experiment Station in March, 1927.

Presumably the only likelihood of this fly's entering California is through the bringing in of infested host fruits. Contraband host material has been intercepted several times.

Efficacy of and Necessity for the Quarantines.—Since this pest is now known to thrive in the lower Rio Grande Valley of Texas, it is possible that parts of southern California would not be unsuited to it, and the Committee believes the quarantine is justified. So far as the Texas and Florida citrus areas are concerned, there seems to be no doubt as to the necessity for these quarantines. As to their efficacy, it is believed that the work is as thorough and complete as it is reasonably possible to make it.

CHERRY FRUIT FLIES

The cherry fruit flies, *Rhagoletis cingulata* Loew and *R. fausta* O.S. are both native to North America, where their early hosts were wild varieties of cherries. Although occasional reports appeared relative to the finding of fruit-fly larvae in cultivated cherries between the years 1883 and 1899 it was not until the latter date (Slingerland, 1899) that injury to cherries was definitely attributed to *R. cingulata*. *R. fausta* was not identified as a pest of cherries until 1907 (Illingworth, 1912) when it was discovered in British Columbia. In 1912 it was found together with *R. cingulata* infesting cherries at Ithaca, New York. Since that time both species are generally found together although *R. cingulata* has a somewhat wider distribution. Since they are similar in life history and habits and their distribution coincides to a large extent, they will be considered together in this discussion.

Geographic Distribution.—In general these fruit flies occur in the northern United States and also in Canada from the Atlantic to the Pacific. *Rhagoletis cingulata* occurs in Oregon but not *R. fausta*. *R. cingulata* has also been reported from Chile (Riesle, 1922).

Hosts.—*Rhagoletis cingulata* breeds in all varieties of cherries, but *R. fausta* seems to prefer sour varieties. Occasionally plums and pears are attacked.

Life History and Habits.—These insects have but one generation a year. The adults begin to emerge in the spring at the time that cherries are about half grown, and lay their eggs in the developing fruit. The young larvae mature rapidly and are ready to pupate about the time that the cherries are ripe. They then drop to the ground and burrow into the soil to a depth of about 1 inch and pupate. Usually only one larva is found in a fruit. The adult flies live about a month, during which time they probably lay 300 to 400 eggs. In the spring several days elapse between the time of emergence and oviposition, during which the flies feed, and this is the vulnerable point for their control.

TABLE 15
SUMMARY OF QUARANTINE AGAINST CHERRY FRUIT FLIES

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Cherry fruits	Total	Cal. Quar. Cir. No. 2	Certain counties in Idaho, Oregon, and Washington

Economic Importance.—These two fruit flies are classed as major cherry pests wherever they occur in cherry-producing localities. References in the literature, while positive as to the need of control measures in order successfully to produce cherries commercially in the presence of these pests, usually do not express definitely the amount of damage caused. Slingerland (1899), however, states: “At Belmont, Massachusetts, about one-third of a 6 or 7-ton crop was ruined by the maggots this year. The pest also destroyed from one-fourth to one-third of the crop of English Morello and Montmorency cherries in one orchard at Geneva, N. Y.” Caesar and Spencer (1915) state that from 5 to 99 per cent of the fruits were damaged in Ontario, Canada. In commercial canning even a low percentage of infestation may result in several wormy cherries per gallon of fruit, which would seriously affect the sale.

Methods of Control.—When the flies emerge in the spring they feed for a few days before laying eggs. In feeding they lap moisture and other materials from the surface of leaves and fruit. This habit of feeding and the fact that they do not lay eggs until a few days after emergence offers the opportunity for their control. The practice is to spray as soon as the first adults appear, using arsenate of lead; a second treat-

ment is applied about 1 to 2 weeks later; roadside and other isolated trees are sprayed, and all infested culls are destroyed.

Adaptability to California Environment.—Because of a lack of data showing the climatological limits of these cherry fruit flies, it is impossible to state with certainty whether or not they would thrive under California conditions. In the United States generally their range is northerly in localities having far colder winters than any of the cherry districts of California. However, it is probably best for the present at least to assume that these species would successfully maintain themselves wherever cherries are capable of growing, and that would include several localities in this state.

Methods of Dispersal and Avenues of Entrance.—In nature dispersal is confined almost entirely to the flight of the adult. In this manner it spreads throughout contiguous cherry plantings but is not likely to reach isolated localities. The shipment of fresh cherries offers the best means for spreading the pest to new localities and for long distances. Cherries when picked often do not show infestation externally. Many such cherries, however, upon arriving at the hands of the consumer show infestation either through the presence of brown rot or air holes of the maggots and may then be put into the garbage or tossed out where the larvae may pupate and establish the flies. Pupae may also be transported in balled plants and soil from cherry orchards.

Efficacy of and Necessity for the Quarantine.—The quarantine provides for the closing of the most important avenues of entrance. Numerous interceptions of infested cherries are made at the border stations each year. There is always a slight danger that such insects may be brought in in soil, particularly with nursery stock, but it is probably not sufficient to justify additional precautions in this case. This quarantine seems to be justified. There is a great advantage in producing cherries which are entirely free from worms.

For a discussion of the direct effects of this quarantine see page 62.

CITRUS WHITE FLY

The citrus white fly, *Dialeurodes citri* (Ashm.), was first noted in this country on the leaves of citrus trees in the orangery of the United States Department of Agriculture, Washington, D. C., in June, 1878. It is reported that the insect was first found in the northern part of St. Johns County, Florida, in 1879 and in other parts of the state in 1881, 1882, and in 1888 (Morrill and Back, 1911), and it is believed that some of these infestations originated from citrus trees obtained from Washing-

ton, D. C. It was later observed on orange trees at Crescent City and at Gainesville, Florida.

Geographic Distribution.—In the United States this insect is established out of doors in Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and Tennessee. Abroad it occurs in India, Japan, China, Chile, Brazil, Mexico, and Bermuda.

TABLE 16
SUMMARY OF QUARANTINE AGAINST CITRUS WHITE FLY

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Plants or cuttings of citrus and many species of ornamentals	Total for most species. Some may come in if defoliated at origin	Cal. Quar. Ord. No. 10	Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, Tennessee

Hosts.—The following plants are hosts of the citrus white fly: *Ailanthus altissima* (tree of heaven); *Allamanda neriifolia*; *Choisya ternata* (Mexican orange); *Citrus* spp.; *Coffea* spp. (coffee); *Diospyros kaki*, *D. virginiana* (persimmon); *Gardenia* spp.; *Hedera helix* (English ivy); *Ligustrum* spp. (privet); *Melia* spp. (Chinaberry, Texas umbrella); *Osmantha americanus* (wild olive); *Photinia arbutifolia* (Toyon); *Phyllanthus acidus* (Otaheite gooseberry); *Prunus carolina* (mock orange); *Severinia buxifolia*; *Smilax* spp.; *Thea sinensis* (tea); *Zanthoxylum clava-herculis* (prickly ash); *Cephalanthus occidentalis* (button bush); *Cinnamomum* spp. (camphor); *Ilex* spp. (holly); *Jasminum* spp.; *Lagerstroemia* spp. (crape myrtle); *Laurus nobilis* (sweet bay); *Lonicera* spp. (honeysuckle); *Sapindus* spp. (soap berry); *Syringa* spp. (lilacs).

Life History and Habits.—Berger (1930) describes the life history as follows:

The eggs are minute, light colored when fresh, and barely visible to the unaided eye. They are deposited in enormous numbers on the underside of leaves, as many as 20,000 having been estimated on a single citrus leaf, the surface of which is highly polished and to which they are attached by a short stalk. They hatch in 8 to 24 days, according to the temperature. The first-stage larvae are not much larger than the eggs, have six legs, and move about freely for a few hours, or until they insert their beak and remain stationary. The change from stage to stage consists in growth and shedding of each larval skin until the fourth stage is reached. The fourth stage larva changes to the pupa by a gradual development until the adult white fly is visible inside the larval skin.

The adult emerges through a T-shaped slit and after about 6 hours may begin to deposit eggs to the number of 250.

There are three regular, well-defined broods of the common or citrus white fly with sometimes a partial fourth brood in winter. The first brood of adults generally emerges in March, the second during June, and the third during August and September.

Economic Importance.—This insect is commonly reported as one of the worst insect pests of citrus occurring in Florida. It saps the vitality of the trees, impairs the flavor and keeping qualities of the fruit, and renders the trees and fruit unsightly through the extensive sooty mold that develops in the honeydew excreted by the insects. It frequently kills the inside wood.

Methods of Control.—The citrus white fly can be satisfactorily controlled by spraying, but this is expensive since two applications of oil per year are recommended. In Florida fungus diseases play an important part in keeping it down, particularly the summer generation, but this does not occur in California because of the dry climate.

Adaptability to the California Environment.—While this pest is limited to subtropical and tropical climates, it seems to be capable of occupying a wide range of habitats within these limitations, and probably is capable of thriving in practically any area where citrus is grown. It is abundant under humid conditions such as exist in Florida. So far as arid conditions are concerned, Woglum (1913) wrote:

In the Punjab [where the fly occurs] it was found that the humidity is comparatively low throughout the year. With the exception of a few light falls of rain in the winter, the rainfall during a normal year is confined to the so-called "monsoon period," occurring in June, July, and August and averages about 15 inches. Taken as a whole, the climate of Punjab is very comparable with that of portions of the arid southwestern United States.

From the above discussion there seems to be no reason to doubt that the citrus white fly would thrive in the California citrus areas. However, there is no need to guess at the matter, since it has already amply demonstrated that it is capable of being a serious pest in this state. Where it has become established, it has proved its ability to cause serious damage.

Methods of Dispersal and Avenues of Entrance.—While the adults become extremely numerous and are able to fly, this provides for nothing more than very local dispersal. The real means by which it makes long jumps is transportation in the immature stages on its many host plants. It is not transported on the fruit.

The citrus white fly undoubtedly came in on nursery stock, and it is frequently intercepted in California on gardenias from the southern

states. Such plants, unlawfully shipped into California by mail, are a constant source of danger.

Efficacy of and Necessity for the Quarantine.—There is no doubt but that a considerable amount of effort and expense is justified to protect the citrus industry of California from this pest. It is evident that the quarantine has not kept the white fly out of California. It is the oldest California quarantine order now in force, having been enacted in 1905, but since the white fly was first found in this state in the spring of 1907, it probably came in before the quarantine. However, quarantines in those early days were largely of the paper variety. Quarantines as now administered should prove effective, excepting for the danger of host plants arriving which are not marked "plants" as required by State law and by orders of the Postmaster General.

Nevertheless, the situation is complicated by the fact that this pest now exists in northern California and in several areas in the citrus belt of southern California. The State Department of Agriculture is attempting to exterminate it, with fair prospects of success. While this campaign is being waged, the white-fly quarantine should by all means be continued. The eradication campaign is unquestionably justified, since the general distribution of this pest in California would greatly complicate the pest control program.

Direct Effects of the Quarantine.—The only direct economic effect is the exclusion of nursery stock from the southern states. This probably does not create any very great commercial disturbance, except that it is a source of some inconvenience to nurserymen. However, since the citrus white fly attacks such a wide variety of ornamentals, it is in the interest of the nurserymen, as well as the citrus growers, to keep it out of the state if possible.

GIPSY MOTH

The gipsy moth, *Porthetria dispar* (L.), was knowingly introduced into Massachusetts by an experimenter in 1869, who was interested in silkworms. With the possible exception of the European corn borer, probably no insect has been the cause of such extensive governmental appropriations as this pest.

Geographic Distribution.—This insect is now established in the United States over a large part of the New England states. It occurs rather generally in continental Europe, parts of Asia, and in Japan.

Hosts.—The most favored food plants are oak, apple, willow, linden, birch, and aspen. It also feeds on a large variety of other trees and shrubs, while the older caterpillars feed on various conifers.

Life History and Habits.—The gipsy moth hibernates in the egg stage, the eggs being deposited on the tree trunks, lumber, stone, or any other convenient article, during July to September. The eggs occur in buff-colored clusters covered with hair from the abdomen of the female moth. There are from 300 to 500 eggs in each cluster. Hatching takes place during the following spring when the trees begin to put out leaves, the young caterpillars feeding during May, June, and July. When full grown they measure about 2 inches in length. They remain in the chrys-

TABLE 17
SUMMARY OF QUARANTINE AGAINST GIPSY MOTH

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Coniferous trees, Christmas greens, forest plant products including logs, poles, trees, cordwood, and lumber; field-grown florists' stocks, shrubs and other plants and plant products, excepting fruit pits and seeds; stone and quarry products	Admitted under certification by U. S. Dept. Agr. as to freedom from infestation	Fed. Quar. No. 43	Certain counties in Connecticut, Maine, Massachusetts, New Hampshire, Vermont, and all of Rhode Island

alis stage for about two weeks, when the adults emerge. The female moth, though having well-developed wings, is unable to fly, but the male can do so.

Economic Importance.—This insect is capable of causing great destruction to forest trees, particularly of the broad-leaved varieties. At one time, according to Howard “The numbers were so enormous that the trees were completely stripped of their leaves, the crawling caterpillars covered the sidewalks, the trunks of the shade trees, the fences, and the sides of the houses, entering the houses and getting into the food and into the beds. They were killed in countless numbers by the inhabitants, who swept them up into piles, poured kerosene over them and set them on fire.” This was of course an extreme case; they have not often become so abundant; but during such an outbreak they become destructive and a decided nuisance. In some places considerable areas of timber have been killed by continued defoliation. They have not become serious orchard pests, although they feed on apple trees.

Methods of Control.—This consists of banding the tree trunks with tanglefoot, destroying the egg clusters by painting them with creosote, and spraying the trees with arsenicals. Control is fairly satisfactory but very expensive. In forest lands control is primarily a question of forest

management, consisting of removing the favored food plants which the young larvae must have if they are to develop.

Adaptability to the California Environment.—The gipsy moth is adapted to a large variety of climatic conditions, as is indicated by its geographical distribution.

There is no reason to believe this moth would not thrive here, so far as climate is concerned, since it does so in Italy, Sicily, southern France, and other Mediterranean countries with climates similar to that of California.

Methods of Dispersal and Avenues of Entrance.—The female moth is incapable of flying but nature has made up for this neglect by supplying the newly hatched larvae with aerostatic hairs which enable them to float in the air and they are thus blown many miles by the wind. In this way their natural dispersal is provided for. The egg masses are deposited on all kinds of objects such as stones, lumber, nursery stock, Christmas trees, etc., by which they are transported through human agency.

The only way this moth could enter California at present is through human agency, by being carried on the products mentioned above, in the egg stage, or on similar material from Japan. It has been intercepted several times from the Orient at San Francisco. Many years ago it actually appeared in a nursery at Oakland, but was exterminated before it became firmly established.

Efficacy of and Necessity for the Quarantine.—Apparently the principal danger to California from this insect would be its destructiveness to shade trees and ornamentals, particularly the oaks which are such an attractive feature of the California landscape. California commercial timberlands are practically solid conifers, and under these conditions the gipsy moth is unable to do serious damage. This is a federal quarantine, and so far it seems to have been very successful in preventing long jumps. The few isolated infestations which have been found in New York and New Jersey are believed to have been separate introductions from Europe. The port-inspection service in California has presumably prevented the establishment of this pest from Oriental sources. There is perhaps some danger from commodities other than plants, that come in from infested Oriental countries.

COLORADO POTATO BEETLE

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), was first collected by Thomas Say on the upper Missouri River in the summer of 1820. It gained economic significance in 1859 when it was noted as a serious pest of potatoes in Nebraska and by 1861 was also very

troublesome in Kansas, Missouri, and Iowa. An investigation of the habits of the insect revealed the fact that it occurred generally on the plains adjacent to the eastern slopes of the Rocky Mountains from Nebraska into Arkansas, where it subsisted on the native buffalo bur, *Solanum rostratum* Dunal. When potato culture reached these regions the Colorado potato beetle was attracted to the cultivated plants, which were greatly to its liking and which often suffered complete destruction from its ravages. From these initial infestations the beetle moved eastward throughout the potato-growing sections of the United States

TABLE 18
SUMMARY OF QUARANTINE AGAINST COLORADO POTATO BEETLE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Potato tubers	Must be certified as having come from a free area, or as having been screened immediately prior to loading	Cal. Quar. Cir. No. 5	All states except Nevada

and Canada. It crossed the Mississippi River into Illinois in 1864; arrived in Indiana in 1867; in Ohio, Pennsylvania, New York, Kentucky, and Ontario, Canada in 1869; in West Virginia and the District of Columbia in 1870; and in Virginia, Maryland, and Connecticut in 1874, having thus traversed the entire area from the western plains to the Atlantic seaboard in about twenty-five years. By 1876 it occurred in all of the states northeast of and including Colorado. By 1892 its spread throughout the southern states was completed.

Geographic Distribution.—In the United States, the native home of the potato beetle, this insect is now established in every state except Nevada and California, although in the Pacific Coast and southern states it is not widespread. On the Pacific coast it is a comparatively recent introduction, having reached Washington in 1913, Oregon in 1914, and British Columbia in 1919. Outside of North America it appeared at Cologne, Germany, in 1877, and was eradicated there. Later outbreaks were discovered and eradicated in 1887. In 1914 a 7-acre field was found infested at Stalle on Elbe; the beetle was eradicated there by destroying all the host plants and soaking the soil with benzol. A slight outbreak of the beetle was discovered in England in 1901–2 but this is reported to have been eradicated. In France an extensive infestation was discovered near Bordeaux in 1922, which included an area of 100 square miles. An attempt was made to exterminate it, but this failed. A good

deal of political difficulty has arisen in Europe over quarantines applied against France by Germany, Holland, Great Britain, Hungary, Denmark, and Italy, so that recently, according to press dispatches, Germany and Holland have proposed that the matter be referred to the World Court for settlement.

Hosts.—The potato is the favorite host of the Colorado potato beetle, although it feeds to some extent on other solanaceous plants such as the tomato, eggplant, nightshade, buffalo bur, etc.

Life History and Habits.—The Colorado potato beetle hibernates in the adult stage, in the soil. In the spring it emerges and as soon as potato leaves are available it deposits its yellow eggs on them, a dozen or so in a cluster. The larvae are little reddish grubs with black markings as they grow older. It is in this stage that most of the feeding takes place. When full grown the larvae enter the soil and pupate, later changing to adults. There are one or two generations a year according to the length of the growing season.

Economic Importance.—It is the most important pest of potatoes in the United States. It does very serious damage where not controlled, particularly in the northern states.

Methods of Control.—It is readily kept in check by spraying with arsenicals, and dusting seems to have been extensively used in recent years. It is necessary to repeat treatment about every 10 days during a period of approximately a month.

Adaptability to the California Environment.—The beetle is very hardy and seems to be capable of extending northward to the limits of potato culture. It has been a serious pest in Aroostock County, Maine, for many years. In the southern states it is much less serious, and this is thought to be because of the heat. Sometimes the larvae are killed by the sun, and hot soil seems to be very unfavorable for pupation. Although it originally inhabited an arid section of the country, excessive moisture does not seem to be at all injurious.

While it might be expected from what has been said above, that climatic conditions in the hotter parts of California would not be particularly favorable for the beetle, it has proved to be so hardy and adaptable that it would be unsafe to assume that it would not thrive here.

Methods of Dispersal and Avenues of Entrance.—This insect is a strong flier; it was by this means, aided perhaps by commerce, that it made its way across the United States. Long jumps necessitate, of course, carriage by human agency. This takes place in soil left clinging to potatoes, and the adults may be carried in vehicles and various articles of commerce. Just how it made the jump across the Atlantic seems not to

be known. Since potato plants are not shipped as such there is no danger from this source, but the tops of plants are used in some places to close the tops of the sacks.

Shipments of potatoes with soil attached seem to be the main source of danger. The beetle can perhaps reach California by natural spread, since it has been found in Colorado at more than 8,000 feet above sea level, hence there is no effective natural barrier completely protecting this state, although the barriers have undoubtedly delayed its westward movement.

Efficacy of and Necessity for the Quarantine.—The regulations seem to guard against introduction as well as it is reasonably possible to do. The culture of potatoes is a major industry in California and it is of course very desirable to exclude this pest.

Direct Effects of the Quarantine.—Since potatoes only are affected by the regulation, and since they are not excluded, but are merely required to be screened to free them from soil, a desirable practice regardless of the beetle, the quarantine has no objectionable features.

SWEET-POTATO WEEVIL

The sweet-potato weevil, *Cylas formicarius* (Fab.), is the most destructive insect pest of sweet potatoes wherever it occurs. The earliest published account of its economic importance is from Ceylon in 1856 (Reinhard, 1923). It was first found in the United States at New Orleans in 1875, and in Manatee County, Florida, in 1878. No quarantine restrictions, attempts at eradication, or prevention of spread were undertaken until nearly forty years later. During that time it spread in the United States along a large part of the coast line of the Gulf of Mexico. About 1917 efforts at eradication and prevention of spread were undertaken in several of the southern states. Georgia in six years secured eradication from an infestation comprising 340 square miles, and involving 1,185 properties (Harned, 1929). Encouraging results were also obtained in Florida, Mississippi, and Alabama.

Geographic Distribution.—Infestations of the sweet-potato weevil are scattered through the tropical and subtropical parts of the world, as follows: southern part of the United States; West Indies; Mexico; British Guiana; Hawaii; Friendly Islands; Fiji Islands; Guam; Formosa; Philippine Islands; Dutch East Indies; northern Australia; India; Ceylon; Mauritius; Madagascar; Africa.

In the United States it occurs along the eastern and western coasts of Florida, in two coast counties of Alabama, five southernmost counties

of Mississippi, lower part of Louisiana, and sixty to seventy counties in south and southeast Texas (Cockerham, 1930).

Hosts.—The food plants of the sweet-potato weevil are all Convolvulaceae, 7 species of *Ipomoea* being attacked (Graf, 1925). Sweet potatoes and yams are the commercial hosts and the others are wild morning-glories.

Life History and Habits.—The adult sweet-potato weevil is about $\frac{1}{4}$ -inch long. It is a dark metallic blue with reddish-brown thorax and legs. The female lays eggs singly in small cavities made with her long snout in the vines or exposed roots. After an egg is laid the cavity is closed

TABLE 19
SUMMARY OF QUARANTINES AGAINST SWEET-POTATO WEEVIL

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Tubers, plants, vines, cuttings, draws, and slips of sweet potatoes, morning-glories and yams	Total from infested area, commodities excepting morning-glories admitted on certification that they were grown in a noninfested area	Cal. Quar. Ord. No. 9	All states and districts; infested area; Louisiana, Texas, Florida, parts of Alabama, Georgia, Mississippi
Sweet potatoes and yams	Total	Fed. Quar. No. 29	All foreign countries
Sweet potatoes and yams	Total	Fed. Quar. No. 30	Hawaii and Puerto Rico

with a bit of excrement, making the location of the eggs hard to detect. Upon hatching, the larva bores into the vine or tuber and completes its development within the tissues of the plant. When the larva is mature it makes a cavity where it happens to be within the tuber or vine and pupates. The adult, issuing from the pupa, bores its way to the surface within a day or two. Boyden (1927) found that at an average daily temperature of 84.1° F a life cycle required 28 days (August 1 to 28), and at 66.5° F 97 days (January 1 to April 7) were required. Gonzales (1925) found that adults lived about 100 days and that females laid an average of 256 eggs. In the Philippines he found eight to nine generations a year. The adult has wings, but apparently seldom flies.

Economic Importance.—Reports from the infested localities consistently record the sweet-potato weevil as the most injurious insect pest of sweet potatoes. The damage occasioned by the pest frequently results in entire loss of crop and abandonment of sweet-potato growing in certain localities. Ritchie (1916) states that it caused a 25 per cent loss at St. Thomas, Jamaica. Smyth (1918) says that in Puerto Rico 75

per cent of the crop is destroyed at times and that cattle and pigs will not eat the badly infested tubers because they are too bitter. Chittenden (1919) states that losses of 25 to 50 per cent are commonly sustained. Reinhard (1923), in speaking of Texas, says that commercial growing in some sections had to be abandoned and that the annual loss throughout the state was estimated at 1,500,000 bushels of sweet potatoes.

Methods of Control.—Cultural control measures have been evolved that will aid greatly in reducing the amount of damage caused by the sweet-potato weevil. The control program is in general as follows:

- Use weevil-free seed or slips for planting
- Leave no tubers exposed above the ground
- Cultivate frequently to prevent cracks in the soil
- Harvest crop as soon as mature
- Burn all roots and vines left after harvesting the crop
- Destroy all kinds of morning-glories
- Destroy volunteer sweet potatoes
- Rotate crops

While this control program is efficacious, it entails additional labor, expense, and change of the farming schedule with which the grower in uninfested territory is not burdened. Regarding the value of the above control measures Harned (1929) quotes from J. H. Montgomery, Quarantine Inspector of Florida, as follows: “. . . . the necessity for retarding the spread (in Florida) is not nearly as acute as it was prior to the development by the United States Bureau of Entomology of a practical means of producing a profitable crop of sweet potatoes even in the presence of the sweet-potato weevil.”

Adaptability to the California Environment.—From all information available it appears that the sweet-potato weevil requires a climate that permits more or less continuous development, without a period of hibernation. Such a climate is found only in the tropics and subtropics. Hibernation has not been recorded from any locality where infestations occur. In the southern United States the beetle had been present for many years before any quarantine restrictions were applied against it; and yet, with free opportunity for dissemination through transportation of infested tubers to the northern states, it has not spread beyond the lower portions (except Texas) of the Gulf States. Cockerham (1930) states, “Since there have been only a few restrictive measures applied against this insect during the greater part of the fifty years or more it has been present in this country, it has undoubtedly been introduced into the north on several occasions, but the severe winters have probably prevented its becoming established.” Conradi (1907) in considering the

effect of winter temperatures on the sweet-potato weevil in Texas divided the state into three zones from south to north. The lower zone permitted more or less continuous breeding, the minimum temperatures not being low enough or of sufficient duration to kill the adults. In the next zone north temperatures killed the adults but did not kill the larvae in the tubers in the ground; while in the third or northernmost zone none of the stages survived the winter but the sweet-potato fields in that zone were subject to seasonal infestation from the continuous infestation farther south. The area of greatest damage in Texas consists of the lower tier or two of counties along the coast.

A comparison of the mean monthly temperatures of Merced, California, and of Austin, Texas, which is within the area of continuous breeding (Conradi, 1907) shows a difference of only 1.7° to 2.7° F for the months of December, January, and February. While the mean temperatures at Merced run slightly cooler, the minimum temperatures reached at Austin, though usually of short duration, are much lower than those at Merced. A study of the distribution in Texas indicates that the larvae and also perhaps the adults would survive the winters in the Merced area. Temperatures in other localities where sweet potatoes are grown in California approximate those at Merced. Wild morning-glories are also abundant in California, as they are in the southern states.

Methods of Dispersal and Avenues of Entrance.—The sweet-potato weevil presumably was brought to this country in infested sweet potatoes, perhaps from the West Indies. It was first found in the United States at New Orleans, in 1875, and at Manatee, Florida, in 1878; so that the introduction and establishment at these two places occurred prior to the above dates. Since no quarantine restrictions were in effect for many years, other infestations in the southern United States might also have had their beginning from imported infested tubers. A single infested sweet potato may carry many larvae and other stages of the weevil. Boyden (1927) states, "A potato, after remaining in the soil over winter, was removed on the tenth day of April, and it was found to contain 65 worms, 18 pupae, and 4 adults." Infested sweet potatoes from foreign countries are frequently intercepted by the federal and state quarantine services.

Although the sweet-potato weevil has fully developed wings, it has seldom been seen in flight. It crawls actively and may spread from one farm or field to another by that means. Its greatest opportunity of spread, however, must be through the transportation of infested tubers and slips for planting. That the weevil has not spread far north of the coastal belt of the southern United States is probably due to climatic

limitations. It is not able to withstand cold winter temperatures. Wild host plants (morning-glories) have undoubtedly been an important factor in the spread of this insect in certain localities, since the beetle could progress by crawling or short flights from one host plant to another. Boyden (1927) states, "The spread of the weevil along the coast in the seaside morning-glory (*Ipomoea pes-caprae*), which is now generally infested, is easily accounted for by the fact that the morning-glory grows in an almost continuous strip . . . on practically every sand beach in Florida." The infested area now extends along the southern coast from Jacksonville, Florida, to Brownsville, Texas.

The only important avenue of entrance is the bringing in of sweet potatoes, yams, or host plants, including morning-glories, from the infested areas.

Efficacy of and Necessity for the Quarantines.—The various quarantine enactments seem to cover the field, and there is no reason to believe that the pest cannot be excluded by this means. The growing of sweet potatoes in California is an important industry and this protection is desirable. There are probably no important direct effects, since commercial relations with other states are not appreciably disturbed by the quarantines so far as the Committee has been able to learn.

ORIENTAL FRUIT MOTH

The Oriental fruit moth, *Grapholitha molesta* (Busck) (*Laspeyresia*), was discovered in the United States in 1916 (Quaintance and Wood, 1916). It has proved itself one of the most important pests of deciduous fruits in this country.

Geographic Distribution.—The Oriental fruit moth occurs in the United States throughout the peach districts east of the Mississippi River. It also occurs in the southern part of the Province of Ontario, Canada. In Asia it is found in a large part of Japan, and in parts of China, Korea, and Manchuria. In Europe it is established in parts of France and Italy. It also occurs in Australia.

Hosts.—Peach is the preferred host. The other principal host plants are: apple, pear, quince, plum, apricot, cherry, nectarine, flowering cherry, and flowering quince.

Life History and Habits.—The Oriental fruit moth in many respects is like the codling moth. The eggs are disk-like and are laid usually singly on the foliage and fruit of the host plants. On peach trees the eggs are laid mostly on the lower surface of the leaves; and on apple and quince trees on the upper surface of the leaves. The incubation period

ranges from $3\frac{1}{2}$ to 6 days during the summer. Upon hatching, the young larvae seek either a tender twig or fruit and proceed to tunnel into it. The first mouthfuls are not eaten, but are laid aside. After the hole has pierced the surface the larva begins to feed. Before full grown, a larva may come out and reenter several twigs. Growth and development take place within either twig or fruit. Development is rapid and the larva is full grown in 6 to 15 days in summer. When full grown, the larva leaves the fruit or twigs and either drops to the ground and constructs a cocoon under bits of bark, fallen fruits, or other rubbish, and pupates; or crawls down the longer limbs to pupate in the rough bark

TABLE 20

SUMMARY OF QUARANTINE AGAINST ORIENTAL FRUIT MOTH

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Fruits and plants of the following: almond, apple, apricot, cherry,chokecherry,nectarine, peach, pear, plum, quince; all boxes, barrels, baskets, and other containers which have been used for handling above	Total, excepting commodities from Missouri are admissible when certified that they originated north of Missouri River	Cal. Quar. Ord. No. 3	Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Ontario, Canada; part of Missouri

or in the soil around the base of the tree. The cocoon and pupal period is of 12 to 15 days' duration in summer. In the fall, when cold weather approaches, the mature larva spins a cocoon in which it overwinters, pupating in the spring.

The grayish-brown moth, with a wing expanse of about $\frac{1}{2}$ inch, emerges from the pupa in 12 to 15 days during the summer. It lives from 12 to 15 days, during which time the female deposits up to 100, or more, eggs. The total life cycle from egg to adult averages about 30–33 days for the growing season. The adults are present from the middle of April to October, or longer or shorter according to the length of the growing season; and there are from 3 to 7 generations a year.

Economic Importance.—The Oriental fruit moth rivals in economic importance the codling moth, to which it is closely related. Hadley

(1927) says: "Probably it is the outstanding peach pest of the present day, and as yet no really satisfactory measures of control have been developed." Muramatsu (1919) states that it is one of the most destructive insects of Korea. Eddy, Bronson, and Clark (1930), speaking of South Carolina, state that the injury in two peach orchards of early varieties was 18 and 25 per cent respectively, and of thirteen late orchards 32 per cent, also that 12 per cent of the entire crop of the state was rendered unmarketable. Garman (1929) states that the damage in some instances reached 50–100 per cent. Kondo and Miyahara (1930) report that it is very destructive to various fruits, particularly young pears in Kwangtung, China, and that in 1926 from 70 to 80 per cent of the fruit was injured. The only conclusion to be drawn from a digest of the reports from entomologists in the various infested areas is that the Oriental fruit moth is an outstanding pest of deciduous fruits, and particularly of peaches.

Control.—From the discovery of the Oriental fruit moth in 1916, to the present time (1932), many state and federal entomologists have been at work endeavoring to develop control measures, but as yet there is nothing satisfactory to report. The usual stomach poisons are not successful because the larva does not feed on the first few mouthfuls while it is boring into a twig or fruit, and once inside it is safe from stomach poisons. Dormant sprays are not satisfactory because only 25 per cent of the larvae (Stearns, 1927) winter over on the tree, and these are not readily killed by dormant-strength sprays. Trapping the adult moths has not proved successful as a control measure. The eggs are laid mostly on the under surface of peach leaves, which makes it hard to secure good coverage. Even if well covered, there is a constant succession of moths from spring to fall, necessitating an impossible frequency of spraying for control of the eggs.

It is rather generally agreed that late fall and early spring plowing and cultivation will destroy most of the larvae hibernating on the ground, so this practice where feasible is usually advised.

Although close to fifty primary parasites have been recorded from the Oriental fruit moth in the United States, they do not hold the pest in commercial control. It is recognized that the parasites are of great value, especially in certain localities; yet the moth population generally remains at a sufficiently high level to cause serious economic loss.

Adaptability to the California Environment.—Judging from the areas of infestation the Oriental fruit moth is an insect of temperate climates. Within the temperate zone, however, it has a great range of adaptability to temperature and seasons, for in America alone it occurs

from Florida to Canada through at least 1,000 miles of latitude. Change in latitude in the eastern United States involves principally change in length of growing season, so that in Canada the Oriental peach moth has but three generations a year, whereas in Georgia there are six to seven. The number of generations a year is not necessarily an index to the severity of infestations, for the reports of the greatest damage seem to come from the northern half of the United States. It would seem that the climatic requirements of this insect coincide with the climatic requirements of its hosts, deciduous fruits. Harukawa (1925) says the species is fairly resistant to drought.

Since the Oriental fruit moth has shown an adaptability to a great range of temperature and length of growing season, as well as some resistance to drought, there is every reason to believe that California conditions would be well suited to its development. Since in Georgia there are six or seven generations, one should expect at least six or seven generations a year in California. In most sections of California the presence of late varieties of peaches, apples, pears and quinces would supply food for the development of the overwintering larvae. In Georgia, the absence of late hosts has been cited as the reason for the relative unimportance of the moth in the principal peach belt of that state. Concerning this, Snapp and Swingle (1929) state: "The Oriental peach moth has not been and is not now of any economic importance in the central Georgia peach belt. The chances are that it never will be a pest of major importance in that section, unless fruit that matures late in the season is planted, because no host is afforded for the maturity of the last three broods of larvae." They further state that in the northern part of Georgia, where apples are raised, considerably heavier infestations occur. From the data available, it seems reasonable to assume that the Oriental fruit moth would be a serious pest of deciduous fruits in California, particularly in view of the extensive production here of late canning peaches.

Methods of Dispersal and Avenues of Entrance.—Dispersal is accomplished through the flight of the adult moths, transportation of infested nursery stock, shipment of wormy fruit, and movement of fruit containers and cars.

The spread by flight is greatly aided by the large number of generations in a season; thus the same insect in four generations should advance a much greater distance each year than in one generation. Nursery stock in the winter or spring is likely to contain the hibernating larvae, eggs, or active larvae; and these may be transported great distances to new localities. The greatest general spread, no doubt, comes from the

shipment of infested fruit. The fact that the larvae frequently enter fruit through the stem, or otherwise, in such a way that the point of entrance is inconspicuous, makes it impossible to discard all wormy fruits in preparing the fruit for the market. The larvae crawl from the infested fruits to the containers, storerooms, warehouses, or cars, to pupate or prepare their hibernation cocoons. Cory (1925) states that, "one bushel basket and lid yielded 375 larvae. Many of these were completely hidden so that no inspection would locate them." Larvae may remain within pome fruits for long periods. Cagle (1930) found that immature larvae passed the winter in the insectary in apples, and Strong (1922) reports the interception of larvae in pears from Japan.

It is now quite generally agreed that the Oriental peach moth came to the United States on fruit or nursery stock from Japan. It was probably introduced into Japan at an earlier date from some other part of the Orient (Harukawa and Yagi, 1918). Infested nursery stock coming from Japan, during the late winter or spring months, could easily carry hibernating larvae and pupae and, when once in this country, the adults emerging would find a sufficient variety of host plants upon which to lay their eggs.

So far as California is concerned, probably the greatest danger of introduction of this pest is from nursery stock from the infested area. It could also come in in fruit, or in containers which have been used for fruit. There is practically no commercial movement of fruit to the coast but boxes of fruit from the east are frequently intercepted after being shipped here by well-meaning friends in the infested states.

Efficacy of and Necessity for the Quarantine.—The quarantine seems to cover the situation satisfactorily so far as a regulation is concerned, with the possible exception of the handling of the Missouri situation. This pest spreads so rapidly that it seems doubtful if this exception in the case of Missouri is a safe procedure. At best, it will be extremely difficult to keep this insect out since there are so many ways by which it can spread through human agency. In this respect it is similar to the codling moth, and the fact that the hibernating larvae spin their cocoons in anything in which fruit has been stored makes its distribution one of great difficulty to control. The Committee believes, however, that this insect is a real menace to the California deciduous-fruit industry, and that every reasonable precaution to exclude it is justifiable. Eradication of the Oriental fruit moth, should it gain a foothold, would be very difficult, and once in the state it would be practically impossible to prevent its spread.

Direct Effects of This Quarantine.—It is very unlikely that any extensive shipments of deciduous fruit would move to California from the infested area if there were no quarantine. The principal complaint in this regard comes from persons in the East who have attempted to ship apples to their California friends. The regulation undoubtedly works a hardship on some of the nurserymen, but in general they accept this as a necessary evil.

EUROPEAN PINE-SHOOT MOTH

The European pine-shoot moth, *Evetria buoliana* Schiff., although known to science in Europe since 1776, was not brought to the attention of entomologists in North America until 1914, when it was found to have been established on Long Island, New York, some years before.

Geographic Distribution.—According to Busck (1915) this insect is widespread in Europe, occurring from England to Russia and from Scandinavia to southern France. It also occurs in Siberia. In North America it is now established at a number of points in the United States and Canada.

TABLE 21
SUMMARY OF QUARANTINE AGAINST EUROPEAN PINE-SHOOT MOTH

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
All pines not excluded by Fed. Quar. No. 7	Total	Fed. Quar. No. 44	All European countries

Hosts.—It apparently attacks all species of the genus *Pinus* and does not breed on other conifers.

Life History and Habits.—According to Britton and Zappe (1927) :
The adult is a small, orange moth, which in August lays eggs singly in the newly formed terminal buds which are ready for next year's growth. The young larvae soon eat their way into the buds and excavate cells in which they spend the winter. The following spring the larva leaves its winter home and bores into the next bud, and thus destroys as many buds as may be needed for food. It also attacks the young shoots, feeding on one side, causing them to become curved and deformed. When mature the larvae pupate in an excavated shoot, and three weeks later the moth emerges. Apparently there is only one generation each year. Distorted and crooked growth called "bayonet shoots" follows the attack of this insect.

Economic Importance.—The European pine-shoot moth is economically important principally because it deforms the growth of trees. It does not defoliate them. In Europe the pine moth, *Panolis griseovariegata*, which feeds on the foliage, is a much more serious pest of pines because trees are killed after several defoliations.

Felt (1927) in regard to New York State, says: "[The pine-shoot moth] is now widely distributed throughout the state and causes some injury to ornamentals here and there, though the damage can hardly be considered as general and serious." Webber (1927) who made observations on it in Europe, states: "This insect, although of much lesser importance than *Panolis griseovariegata*, rarely, if ever, causing the death of a tree, must be recognized as a noxious one." Badly infested trees result in unsymmetrical growths, making the trees unsightly for ornamental purposes and affecting the commercial value of the timber. Later reports from the East indicate that this pest is becoming more severe, and that in some cases 75 to 95 per cent of the buds are killed.

Methods of Control.—The larvae working within the buds are so well protected that the use of insecticides has been found ineffective as a control measure.

Adaptability to the California Environment.—The ability of the European pine-shoot moth to endure climatic conditions over most of Europe indicates that it should also find some of the various climatic conditions in California suitable for its establishment and survival.

Methods of Dispersal and Avenues of Entrance.—The introduction was obviously made on pine nursery stock shipped from Europe, many shipments of which were made to the United States and Canada prior to the discovery of the established infestations. The nursery stock is shipped mostly during the time of year when the larvae of the moths are dormant in the buds of the trees. In Canada the moth was first discovered in 1925, in a shipment of trees from Holland. Following this a reinspection of pines imported during the two years previous disclosed infestations at 45 points in Ontario and in British Columbia (McLaine, 1925 and 1926). It was similarly established at a number of points in the United States. Detailed data on the rapidity of spread are not at hand. It is evident that establishments at a number of different places resulted directly from importations of infested trees from Europe, for Busck (1915) reported that the European pine-shoot moth was found in thirty-two nurseries and private estates in twenty localities in nine states. Redistribution by nurseries importing infested trees has also greatly aided in the spread. Natural spread is evidently rather slow. The moths are not on the wing long and the larvae are dormant for a number of months each year.

Presumably it could enter California only on pine nursery stock.

Efficacy of and Necessity for the Quarantine.—It is difficult to become greatly excited over this pest. It is perhaps desirable to attempt to

exclude such pests, however, particularly when it entails no great expense or economic disturbance. The Committee has been unable to find any reference to a federal quarantine around the infested area in the United States, and California has no state quarantine against this area. It seems illogical to have a specific quarantine against infested areas in foreign countries and none against infested areas within the United States. The quarantine does not seem to be of great importance, particularly since the general nursery-stock quarantines would exclude the host plants.

AVOCADO SEED WEEVILS

Under this caption should be included several species of weevils attacking avocados in Mexico and Central America. These, with localities from which recorded, are as follows :

<i>Heilipus lauri</i> Boh.....	Mexico
<i>Heilipus pittieri</i> Barber.....	Costa Rica
<i>Heilipus perseae</i> Barber.....	Canal Zone
<i>Conotrachelus perseae</i> Barber.....	Guatemala

TABLE 22
SUMMARY OF QUARANTINE AGAINST AVOCADO SEED WEEVILS

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Avocado seed, plants under 18 months of age, fruit of small purple, thin-skinned variety	Total	Fed. Quar. No. 12	Mexico and Central America

The literature regarding the habits and economic importance of these insects in their native localities is scant. They are frequently taken in avocados by quarantine inspectors and are usually found infesting the seeds. Regarding *Heilipus perseae*, Dietz and Barber (1920) state, "After hatching, the larvae often wander through the pulp before entering the seed, thus rendering a considerable part of the fruit inedible, especially when more than one larva occur in it. Once the larvae enter a seed they confine their activity to it." They further state that seeds infested with *Heilipus* larvae are subject to the attack of several kinds of dry rots. Popenoe (1919) gives first-hand information from Guatemala on what is presumably *Conotrachelus perseae* (Barber, 1919, p. 59) as follows :

One insect stands out above all others observed in Guatemala, both for the damage which it occasions and the apparent difficulty of controlling it. This is a small brownish-gray weevil (*Conotrachelus* n. sp.—Described by H. S. Barber, Proceedings of the Entomological Society, Washington, in press), whose larvae are found sometimes in mature avocados purchased in markets.

No external evidence of its presence is noticeable (at least to the unskilled observer) but on cutting the fruit in half the seed is found to be more or less riddled with large, round tunnels and 1 to 10 or more fat, wriggling larvae, varying from white to pinkish in color, greet the eye. While the larvae are rarely seen working in the flesh itself, they often burrow along the outside of the seed in contact with the flesh, discoloring the latter with their brownish powdery castings. In some avocados examined the seed had been so thoroughly honeycombed that it was reduced almost to powder.

Needless to state, a fruit attacked by this insect is rendered practically unfit for use. Even though the flesh itself may not have been damaged, the sight of the white larvae and their tunnels in the seed is sufficient to nauseate any housewife. The widely known Mediterranean fruit fly (*Ceratitis capitata*) produces no more disgusting results than this insect.

The distribution of this weevil in Guatemala seems to be wide. It was found from El Rancho on the eastern slope to Mazatenango on the western, and from Antigua in central Guatemala to the Vera Pax district in the north. The lowest elevation at which it was found was about 1,000 feet, the highest 5,300. It was seen most abundantly at Panajachel, where most of the fruits offered in the market in early January, 1917, were found to be infested. Little is known of its life history. The larva is about $\frac{1}{2}$ inch long, with a brown head, and 12 white segments composing its body. After tunneling in the fruit, it works out through the skin and drops to the ground, where it pupates, the mature weevil emerging some days later. Nothing has been learned with regard to the habits of the adult.

The range in altitude, between 1,000 and 5,300 feet, as noted above by Popenoe, shows sufficient variation to permit the assumption that this pest might become established in those localities in California where avocados are grown.

Methods of Dispersal and Avenues of Entrance.—Little information is available regarding the methods of dispersal of these weevils. Presumably they are able to fly, and they are of course transported in the seed and fruit. These weevils could enter California only in shipments of avocado seed and fruit.

Efficacy of and Necessity for the Quarantine.—It is of course desirable to exclude these pests, but perhaps some study should be made to determine whether or not they are limited to tropical conditions. It seems possible that they would not be able to survive frosts. The quarantine is probably reasonably successful in excluding the hosts of these insects.

EUROPEAN CORN BORER

Geographic Distribution.—The European corn borer, *Pyrausta nubilalis* (Hbn.), is an Old World insect, presumably indigenous to central and southern Europe, Asia Minor, and west-central and northern Asia. It also occurs abroad in China, Japan, Philippine Islands, East

TABLE 23
SUMMARY OF QUARANTINES AGAINST EUROPEAN CORN BORER

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Corn and broom corn, including stalks, ears, and all parts thereof; sorghum, Sudan grass, except cleaned shelled corn and clean seed; green shell beans and green lima beans in the pod; beets with tops; rhubarb; cut flowers and plants of chrysanthemum, aster; gladioli and dahlias, excepting bulbs and roots thereof	Must be accompanied by federal certificate certifying them to be free of infestation, except that beans in pods, beets with tops, rhubarb, require certification only from June 1 to December 31; certificates will not be issued covering corn stalks, ears, or other parts of corn, broom corn, Sudan grass or sorghums; there are no restrictions on movement of green corn on the cob from two-generation area Jan. 1 to June 14	Federal Quar. No. 43*	Two-generation area: certain counties in Maine, New Hampshire, Rhode Island, Connecticut, Massachusetts, New York, New Jersey
Corn and broom corn including all parts thereof; sorghum and Sudan grass, except cleaned shelled corn and cleaned seed	Same as above		One - generation area: certain counties in Vermont, Connecticut, New Jersey, Pennsylvania, West Virginia, Ohio, Michigan, Indiana, Massachusetts, New York
Following material in raw state: stalk or other parts of Indian corn, broom corn, sweet sorghums, Sudan grass, Johnson grass, sugar cane, pearl millet, napier grass, teosinte, and Job's tears	Total excepting broom corn for manufacturing brooms; cleaned shelled corn may be imported under permit	Federal Quar. No. 41	All foreign countries

* This quarantine was rescinded as of July, 1932. A California quarantine has since been promulgated.

Indies, and Guam. In the United States, it now occurs in Maine, New Hampshire, Rhode Island, Connecticut, New York, New Jersey, Vermont, Pennsylvania, Virginia, West Virginia, Ohio, Michigan, Wisconsin, Indiana (as of 1931). It was early introduced into Ontario, Canada. It is gradually spreading into new territory.

Hosts.—The host plants of the European corn borer are exceedingly varied, which makes it possible for the insect to live and even thrive in

many localities where the favored hosts are grown in only limited quantities or not at all. This variety of hosts enables the insect to become established practically throughout the entire possible climatic range and to build up large reserves outside of the cultivated areas, the adults of which then migrate into the fields and reinfest them. In foreign lands the major cultivated crops attacked are corn, hops, millet, hemp, and broom corn, corn (or maize) being the preferred host wherever available. Mugwort (*Artemisia vulgaris* L.) is the chief host in Belgium, and this and allied species are favored hosts in northern France. Pigweed (*Amaranthus retroflexus* L.) is also a favored host in France. Minor hosts include oats, barley, cotton, rice, kafir corn, bean pods, sunflower, mustard, barnyard grass, giant reed, fuller's teasel, green foxtail, nettle, thistles (many species), ploughman's spikenard, stiff inula, common reed, feterita, garden orach, tomato fruits, tumbleweed, wood amaranth, *Picris spinulosa* Guss., dock, grapevines, oak galls, and various grasses.

In America all varieties of Indian corn are usually preferred. In certain localities weeds such as cocklebur, barnyard grass, and smartweed are preferred to corn. Field crops, vegetables, flowers, weeds, and grasses are also subject to infestation when growing near corn. In summarizing the lists of all known American hosts Caffrey and Worthley (1927) list 18 plants severely attacked, 22 plants frequently attacked, 40 plants occasionally attacked, and 91 plants rarely attacked or which serve only as shelter for the larvae.

Life History and Habits.—Caffrey (1930) treats of the life history as follows:

In any discussion concerning the habits or seasonal history of the corn borer, the point should be emphasized that throughout a portion of its range in the Old World, as well as in the New World, it develops only one generation each year, whereas in other sections (usually in the more southern portion of its range) it develops two or more generations each year.

In the Middle West, where only a single generation develops annually, the corn borer passes the winter as a fully grown borer inside its tunnel in the stalks, stubble, or ears of corn. When these portions of the plant are split open, the borers usually are found within. . . .

As soon as warm weather begins in April, or May, the borers spin a thin silken cocoon, usually inside the same tunnel they use for winter quarters. Here the pupa is found in late May or early June. This pupa, or inactive stage, is brown, shuttle-shaped, and about five-eighths of an inch long.

During late June, throughout July, and in early August the moths to which the pupa have changed, emerge and fly to nearby or distant corn fields and lay their eggs on the developing corn.

The eggs hatch in about five days and the resulting borers reach full growth about the middle of August. They remain in this condition, usually within the tunnels

within the host plant, throughout the remainder of the summer, autumn, winter, and early spring, whereupon the cycle is repeated.

Economic Importance.—The insect was first noted as a pest of millet in Jugoslavia as early as 1835 and a summary of its record since that time as reviewed from Caffrey and Worthley (1927) is as follows: It was first mentioned as a pest of maize in Hungary early in the nineteenth century. It was estimated that, from total destruction in some cases, the loss to infested crops averaged at least one-fourth of the grain. In Hungary maize, broom corn, millet, and hemp are the principal crops attacked.

Losses to maize, hemp, and millet in Russia were reported from 1913 to 1920. The corn borer has been known in France since 1831 as a pest of maize, hops, and hemp. The greatest injury is to maize in the southern part of that country, where from 20 to 60 per cent of the stalks may be infested with the larvae. Although the insect has been known in Italy since 1884, it was not regarded as a serious pest until 1924, when maize in certain localities was found to have an average stalk infestation of 15 to 80 per cent. Some fields were practically free from injury. Other European countries report small losses to various hosts. In 1919 it is reported that 50 per cent of the maize crop in Guam was damaged in certain fields and damage was also done to grain sorghums and rice.

In North America the status of the corn borer as a pest is not very definite, and there seems to be a lack of unanimity of opinion on this question so far as entomologists are concerned. There is no doubt but that during the early years of its invasion it did very serious damage in Ontario, variously estimated as up to 90 per cent of the corn crop in some fields. In Massachusetts also it was at one time a serious pest of sweet corn. Taking the infested area as a whole, it is doubtful if up to the present time the corn borer can be ranked as a major pest, although there have been areas, particularly in the Great Lakes region, where considerable injury has occurred. What it will do when it reaches the great corn belt of the Middle West is only conjecture.

Methods of Control.—An enormous amount of research has been devoted to the question of control, primarily by the United States Bureau of Entomology. Dr. C. L. Marlatt, Chief of that Bureau, is quoted as having said before the recent hearing on the corn-borer quarantine held at Washington,²² with reference to the Bureau's work:

²² Hearing on European corn-borer quarantine held at Washington, D. C., March, 1932. Stenographic report by H. S. Middlemiss, Columbian Building, Washington, D. C.

As a result of these studies and of their practical application, a means of control has been developed along the line of adjustment of farm methods that is practical and not necessarily prohibitive in the matter of cost. Such means of control are now being practiced in the states where the heaviest losses have occurred. . . . We found that these farm controls or cleanup of corn stalks, etc., cost approximately \$2.00 an acre.

We believe, therefore, that a control for the corn borer has been worked out which is practical and can be applied when the conditions call for it.

It is true the farmers have not applied control measures in the western area, except in limited districts, for the reason that the corn borer has not yet reached widely the density of population to create a loss than can be recognized and no farmer will add to the cost of his production until forced to it by necessity, but the means and methods of control are known.

The Bureau is also carrying on extensive work in the introduction of parasites from foreign countries, but no striking successes have as yet been achieved by this means.

Adaptability to the California Environment.—This insect is extremely adaptable to climatic variations. It has a climatic range varying from the dry steppes of Russia, with a mean annual temperature of 44.6° F and an annual precipitation of 13.11 inches, to the humid tropics of Guam, which has a mean annual temperature of 81.7° F and an annual rainfall of 97.27 inches (Caffrey and Worthley, 1927).

There is no doubt but that the corn borer can become established in California. Just how abundant it would become here it is impossible to predict. Apparently its population density is determined largely by its biotic, rather than by its climatic, environment.

Methods of Dispersal and Avenues of Entrance.—The insect is a fairly strong flier, and natural dispersal takes place with considerable rapidity by this means. Transportation by human agency occurs through the movement of the various commodities listed in the preceding quarantine summary, particularly ear corn, stalks, certain green vegetables, broom corn, and such plants as chrysanthemums, asters, etc. It is supposed to have entered this country in shipments of broom corn.

The corn borer could enter California through importations of any of the materials listed, either from the Orient or from the infested eastern states. Contraband material is occasionally intercepted in California, but there is very little movement of such materials into this state. Live larvae of this pest have been intercepted in corn on the cob from Massachusetts. The Sierra Nevada will not provide a natural barrier to the dispersal of this pest, and it will in time undoubtedly invade this state by natural means.

Efficacy of and Necessity for the Quarantines.—So far as California is concerned this is one of those pests regarding which predictions as to what it would amount to here would be unreliable. California has no large corn industry, but it attacks other crops and might possibly prove serious on them.

JAPANESE BEETLE

Although the Japanese beetle, *Popillia japonica* Newman, has long been known to science, having been described by Newman in 1841 from specimens taken in Japan, it never attracted attention until it became established in North America.

TABLE 24
SUMMARY OF QUARANTINE AGAINST JAPANESE BEETLE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Farm, garden, and orchard products of all kinds; sand, soil, earth, peat, compost, and manure	Admitted under certification by U. S. Dept. Agr. as to freedom from infestation	Fed. Quar. No. 48	Connecticut, District of Columbia, New Jersey, Rhode Island, and portions of Delaware, Maryland, Massachusetts, New York, Pennsylvania, Virginia

In the summer of 1916 a few individuals of this species were found in a nursery at Riverton, New Jersey. At first they were thought to be a species from the southern United States, and they were not correctly identified until the summer of 1917. When it was determined that the species was of exotic origin, eradication measures were promulgated but did not get under way until the spring of 1918. The Japanese beetle evidently not only found more favorable environmental conditions in the eastern United States but also it was not decimated by important natural enemies as it is in Japan. Consequently the beetle became so firmly established in New Jersey that, despite strenuous eradication measures and efforts to prevent further spread of the insect for three successive seasons, the infestation increased in extent at an almost uniform rate until in 1931 it covered approximately 6,200 square miles of continuous infestation, with additional isolated colonies many miles out from the original point of infestation.

Geographic Distribution.—So far as known the Japanese beetle occurs only in Japan, in the United States, and possibly in Siberia. Clausen, King, and Teranishi (1927), who spent several years in the Orient in

search of parasites of the Japanese beetle, state: "*Popillia japonica* is found on all of the main islands of Japan, but does not extend to the Asiatic mainland. It is most abundant in Honshu and all of Hokkaido in the area where grasslands occur." As previously mentioned, it was first found in the United States in 1916 at Riverton, New Jersey, although it must have arrived there several years prior to that date. It now occurs in parts of New Jersey, Pennsylvania, and Delaware. Isolated colonies were found as far out as Boston, Massachusetts; Buffalo, New York; Columbus, Ohio; Norfolk, Virginia; and Charleston, South Carolina.

Its occurrence in eastern Siberia is reported by Engelhardt (1927), who states that it is abundant but is not a serious pest.

Hosts.—Clausen, King, and Teranishi (1927) list a total of 38 food plants of the adult of the Japanese beetle from Tokyo to Sapporo. Among these, the favorite food plants are: chestnut (*Castanea pubinervis*); Italian poplar (*Populus nigra*); Sedan (*Melia japonica*); wild grape (*Vitis thunbergii*); cultivated grape (*Vitis vinifera*); blind grape (*Cissus japonica*); wistaria (*Wistaria floribunda*); Itadori (*Polygonum reynoutria*); Kumaichigo (*Rubus crategifolius*); asparagus (*Asparagus officinalis*); and a fern (*Pteridium aquilinum*).

L. B. Smith (1928) states that the adult beetle has over 250 species of host plants in the United States, including almost all of the economic crops grown. The preferred food plants, however, number only about 25 or 30 species. Among these are: apple, quince, peach, cherry, plum, grape, blackberry, clover, soybean, corn; and the following shade trees: linden, birch, white oak, elm, horsechestnut, willow, and sassafras. Various ornamental shrubs are injured at times.

Larvae seem to prefer the roots of grasses, for they are found in greatest concentration in field pastures and lawns. They also feed on the roots of various field and vegetable crops and ornamentals.

Life History and Habits.—In the eastern United States the Japanese beetle has one generation each year. The adults appear about the middle of June and are present until about the middle of October. The adults in nature, with food, live about 45 days, and without food about 8 days. The egg-laying period is of 4 to 5 weeks' duration, during which time the females lay from 40 to 50 eggs. These are laid from 3 to 5 at a time, about 2 to 4 inches below the surface of the soil (L. B. Smith, 1928). The eggs hatch in 9 to 15 days; and the larvae form cells from 1 to 2 inches below the surface of the soil, where they feed on small rootlets at the top and bottom of the cell, usually following the course of the rootlets until they are consumed before attacking others. Upon the approach

of cold weather the larvae descend to a depth of about 7 inches and pass the winter in an inactive state. In the spring, activity is again resumed and the larvae move upward toward the surface of the soil and feed for about a month, transforming to pupae the latter part of May or the fore part of June. Adults emerge from 2 to 4 weeks later.

The adults are very active, especially during warm weather, and feed on the foliage, flowers, and fruit of many different kinds of plants.

In Japan, at Yokohama, there is also one complete generation each year, but at Koiwai, which is 300 miles north of Yokohama, 25 to 30 per cent of the beetles require two years for a generation, and at Sapporo, 520 miles north of Yokohama, 75 per cent undergo a two-year cycle. The winter temperatures at Sapporo are 11 to 18° F cooler than at Yokohama, and 7 to 11° F cooler than at Philadelphia. Clausen, King, and Teranishi (1927) state that the growing season at Philadelphia is nearly six weeks longer than at Koiwai or at Sapporo, and that this in a measure explains the more or less biennial cycle of *Popillia japonica* in northern Japan as contrasted with the normal one-year cycle at Yokohama and in America.

Economic Importance.—It is evident from the literature that the Japanese beetle is not a pest in Japan, even where it occurs in considerable numbers. This may be due in part to the presence in its native habitat of important natural enemies that keep its population below the point of economic injury. Clausen, King, and Teranishi (1927) state: "During four years' study of *Popillia* in Japan, the writers have not observed it as a serious pest, although Japanese entomologists have recorded it as at times doing considerable damage to soybean plants." They further state that the foliage of *Polygonum reynoutri* growing along the roadside bordering a field of soybeans was almost skeletonized during the summer of 1921 at Koiwai, but no damage occurred in the soybean field. Also considerable maize is grown at Koiwai but no damage is done to the silks on the green corn; whereas at Riverton, New Jersey, considerable damage is done to green corn.

No information has been found in the literature indicating that the larvae do any noticeable injury in Japan. Regarding damage to lawns and golf links in Japan, Clausen, King, and Teranishi (1927) say: "At Tokyo and Yokohama, where sod lands have been artificially produced in lawns and golf links, *Popillia* does not increase and take advantage of these breeding grounds."

In the infestation established in the eastern United States the Japanese beetle has increased to far greater numbers than in the most favorable areas in Japan, and has become of definite economic importance.

The adults are more injurious through their damage to foliage, flowers, and fruit than the larvae are to the roots of plants in the soil. It must be remembered that while the beetle is recorded as feeding on many different plants, there are certain ones that are more favored than others and that the number of species of plants that are actually damaged is only a small part of the total number of plants listed as hosts.

Smith and Hadley (1926) state:

Records which are by no means complete for the area as a whole show that in 1923 in the heavily infested area in New Jersey the loss due to injury to early apples was about 15 per cent of the crop and the percentage of the crop of early-ripening varieties of peaches lost through injury by the beetles has exceeded the loss in the case of apples.

As regards injury done to shade trees, Safro (1929) says:

Practically all coniferous trees are immune to Japanese beetle attack, with the possible exception of larch and bald cypress. Of deciduous trees, such species as sweet gum, magnolia, tulip trees, most of the maples, common locust, and catalpa are among the practically immune species. . . . The linden (basswood), horsechestnut, and elm are considered most susceptible to injury.

While the larvae have been recorded as feeding on the roots of various ornamental plants, shrubs, flowers, and vegetables, their presence is usually not noticed except in pasture lands, hay meadows, and especially golf courses. Commercial plantings of strawberries have been seriously injured by the larvae.

Control.—As previously pointed out, eradication measures were attempted for three successive seasons (1918, 1919, and 1920). Over \$100,000 was expended in these efforts by the United States Department of Agriculture and the State of New Jersey. Regarding the attempt at eradication, Smith and Hadley (1926) state:

A thorough study of the situation showed that, in spite of the work, extensive eradication or even reasonable control had not been secured; on the contrary the insect had rapidly increased in numbers year by year and the area of infestation had become greater each season. . . . All thought of a policy of eradication was given up.

Although eradication seemed hopeless, efforts for control were continued along various lines. It was found that plants could be pretty well protected with lead arsenate. Smith and Hadley (1926) state: "It has been found that any plants which can be sprayed with an arsenical poison may be successfully protected against the attacks of the Japanese beetle." Beetles are repelled by the presence of lead arsenate on the foliage of plants. A mixture of 3 pounds of lead arsenate and 2 pounds of flour to 50 gallons of water is recommended for early-ripening and

late-ripening apples, as well as for cherries, grapes, and ornamental trees. For peaches of the Carmon variety, or late-season varieties, use 1½ pounds of lead arsenate, 2 pounds of flour, and 3 pounds of unslaked lime to 50 gallons of water. No means of protecting raspberries and blackberries has yet been recommended.

MacLeod (1929) states that properly sprayed plants received 80 to 90 per cent protection from lead-coated oleate lead arsenate. He further states that 20,000 trees and shrubs received 77,525 gallons of spray in one treatment, at a cost of \$2,200. This would average 11 cents a plant.

The control of the Japanese beetle has undergone considerable change during its brief residence in the United States. Carbon disulfide emulsion was first used to kill the subterranean larvae with considerable success, but has been quite generally discarded for the following methods: (1) Mechanical traps in which geraniol or eugenol are used as attractants for the adults. (2) Electrical traps also baited with the attractants to kill the adults. (3) Arsenate of lead (coated arsenate of lead and green arsenate of lead) is employed as a spray to kill the foliage-eating adults, and also worked into the soil to kill the root-feeding larvae. (4) Hot water at temperature of 120° F for 70 minutes for destruction of larvae in the soil about the roots of plants, and (5) natural control by the use of insect parasites.

Adaptability to the California Environment.—In their observations of the habits of the Japanese beetle in Japan, Clausen, King, and Teranishi (1927) found that the beetle is progressively more abundant from the south to the north. Sapporo on the Island of Hokkaido, where the beetles are of greatest abundance, is 11 to 18° F cooler than Yokohama. They state that they believe this is because the Japanese beetle is adapted to the colder climate.

The moisture of the soil must be about what is required for the growth of mesophytic plants. These conditions exist on the Island of Hokkaido, in northern Japan, and also in the eastern United States. Quoting further from Clausen, King, and Teranishi (1927):

On the Island of Hokkaido, natural and agricultural conditions more nearly approach those of our eastern states. There are large areas of natural forest similar in makeup to our own forests, the trees consisting of oak, maple, beech, magnolia, chestnut, birch, and pine. The extent of waste lands compares with that of Pennsylvania. Agricultural land holdings in this region are somewhat larger than in Honshu and the method of cropping is somewhat similar to that in America. Corn, wheat, oats, barley, rye, millet, and some rice are the chief grains grown. Grass lands suitable for grazing are more abundant here than elsewhere in Japan, and dairying and stock farming are resulting industries.

Smith and Hadley (1926) state:

As far as the climate is concerned, the Japanese beetle has apparently found in western New Jersey and eastern Pennsylvania exceedingly favorable conditions for its multiplication and establishment. Since the beetle's first appearance in 1916, no climatological condition has offered any check to the rapid numerical increase of the species. Occasionally it has been found that when the eggs are laid in very sandy soil, and the weather is particularly dry, many of the young larvae are destroyed owing to the dry condition near the surface of the ground. No condition of heat has been noted which has been injurious to the larvae or eggs, provided the soil is moist.

They further state that areas which were flooded for two or three weeks at a time, during rainy periods, had no apparent injurious effect on the larvae. Also that third-instar larvae successfully passed the winter 2 inches below the surface in plowed ground during three winters when a minimum of 8° F was recorded 4 inches below the surface.

From its distribution in Japan, and the observations made by entomologists who have studied it there to the effect that it is a cool-climate insect, it seems probable that the Japanese beetle would not thrive in the warmer parts of California. The fact that there is relatively little grass land in this state also would be unfavorable to the beetle. This is not, however, an argument against reasonable attempts to exclude it.

Methods of Dispersal and Avenues of Entrance.—It is very probable that the Japanese beetle was introduced into New Jersey on iris roots from Japan (Dickerson and Weiss, 1918). About 1911 iris roots imported from Japan were first planted in the nursery originally infested. Two or three seasons later azaleas were also imported from Japan by this nursery, but not previous to 1915. The infestation probably had its beginning prior to 1915.

Smith and Hadley (1926) state:

It is believed that larvae of the Japanese beetle came into the United States in the soil about the roots of certain nursery plants, presumably azalea or Japanese iris. . . . The comparatively short existence of the insect as an egg, pupa, or adult, the relative long period as a larva in the soil, and the season of the year in which shipments from Japan to this part (New Jersey) of the United States are commonly made furnish a basis for this assumption.

Living larvae of *Popillia japonica* have often been found in the soil about the roots of coniferous and other types of nursery stock in infested nurseries within the Japanese-beetle area. Larvae of a closely related species have been brought to North America (Vancouver, B. C., in the month of May) about the roots of plants from Japan (Anonymous, 1920).

The natural spread of the Japanese beetle is due almost entirely to the flight of the adults. This takes place from the middle of June to the

middle of October. The larvae, being in the soil, are not capable by their own efforts of appreciably increasing the extent of an infestation. The adults are very active on the wing, especially during warm weather, and they have been largely if not entirely, responsible for the almost constant annual increase of the infestation. This increase has been at the rate of from 3 to 5 miles a year, more or less in all directions, but influenced somewhat by the prevailing wind (Fox, 1932).

Of course, the spread of the Japanese beetle has not been limited to natural conditions. Man has added other means of dispersal, the most important of which are transportation in soil about the roots of potted and balled plants, movement of all kinds of plant and soil products, and railroad and other vehicles passing from infested to noninfested localities. Through such means isolated colonies have been established many miles beyond the borders of the continuous infestation. Fox (1932) states:

It is of interest to contrast the distances to which, from 1918 to 1931, the Japanese beetle has been carried through its own efforts with those to which it has been conveyed through artificial agencies. The former range from 35 to 60 miles, whereas the distances in miles from the original center of the distribution area to certain of the more distant points at which Japanese beetle colonies are recorded are approximately as follows: Boston, Massachusetts, 270; Buffalo, New York, 290; Columbus, Ohio, 430; Richmond, Virginia, 250; Norfolk, Virginia, 250; Charleston, South Carolina, 575.

The most important avenue of entrance of this insect into California is by means of balled and potted nursery stock. Live larvae have been intercepted at the border stations, in soil about a plant brought from the East by automobiles. Adults can be carried long distances but it is unlikely that they would make the trip to the coast successfully, since freight trains are too slow and passenger cars from the infested area do not come west of Chicago. Dead beetles have been found in ships from Philadelphia at San Pedro, which seems to indicate that they are too short-lived without food to enter California by this means.

Efficacy and Economic Effects of This Quarantine.—Since nursery stock is the most likely avenue of entrance, and since the shipment of nursery stock from the infested area is carefully supervised and regulated by the federal Bureau of Plant Quarantine, it is believed that so far as California is concerned, all is being done that is reasonably possible to make the quarantine effective. Since colonies now occur several hundred miles from the center of the infestation, it is evident that the quarantine is not entirely preventing spread by human agency. This probably cannot be avoided by any reasonable quarantine procedure, since vehicular traffic is too extensive to permit of really effective con-

trol in that part of the country. The quarantine certainly reduces the opportunity for long distance jumps.

So far as California is concerned, there are probably no very important direct economic effects of this quarantine. Some nursery stock is excluded, but all necessary stock can be secured from the infested area if certified by the federal government.

ALFALFA WEEVIL

The alfalfa weevil, *Phytonomus variabilis* (Herbst) (*P. posticus* Gyll.), was accidentally introduced and established in Utah from the Old World. It was first found near Salt Lake City in 1904, and has gradually spread until at the present time it occurs in Utah, Oregon, Idaho, Wyoming, Colorado, Nevada, and California.

Geographic Distribution.—This insect is rather widespread, occurring in all of Europe, southern Siberia, Turkestan, Asia Minor, Persia, Arabia, Canary Islands, and northern Africa, and some localities in the United States.

Hosts.—It is apparently a pest of alfalfa only, although it breeds on several species of legumes, and deposits its eggs in almost any plant, and even in dead twigs.

Life History and Habits.—In the Great Basin area of the United States it seems to hibernate exclusively in the adult stage, in hay, rubbish, soil, or any protected place. When the weather grows warm in the spring the adults become active, seek the fields, and begin oviposition, which is accomplished by boring holes in the stems in which they insert their eggs. These hatch, and the resulting larvae crawl to the top of the plant where the tender growth occurs, upon which they feed. When they become full grown they drop to the ground and spin a lacy cocoon at the base of the plant in which they transform to the adult. There is a single generation a year. In southern Europe the life history is somewhat modified, since the warm winters permit the eggs to be deposited in the fall and more generally throughout the year. This results in a decided "uneven hatch" condition.

In the Great Basin region injury was caused by the feeding of numerous larvae on a single plant, so that its growth was finally stopped. When this crop was cut, the larvae dropped to the ground, where they fed vigorously on the buds of the new growth and prevented it from developing. Such fields often remained bare for several weeks until the larvae had completed their growth, when the alfalfa again was permitted to resume its normal development.

Economic Importance.—When first introduced into the Great Basin area, this pest was extremely destructive, often practically ruining the entire crop. As its distribution became more general it encountered differing climatic conditions so that in many places it has rarely caused serious damage, and with the passage of time there also seems to have been a rather general reduction in the severity of injury. In the San

TABLE 25
SUMMARY OF QUARANTINE AGAINST THE ALFALFA WEEVIL

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Alfalfa hay, other hay and straw	Total	Cal. Quar. Ord. No. 7	Idaho, Utah, Wyoming, certain counties in Colorado, Oregon, and Nebraska
Alfalfa meal, etc.	Must be from mills approved by Director of Agriculture		
Salt grass packing from Utah	Must be harvested between Oct. 1 and April 1		
Potatoes	Must be screened and placed in clean sacks		
Household effects	Must be free from hay or straw		
Railroad cars	If used for transport of hay or live stock in infested area, must be cleaned of hay or straw		
Used alfalfa machinery	Must be free from hay and straw		
Automobiles, trailers and other vehicles; luggage, household and camping effects	Must be placed in quarantine until inspected		
Alfalfa seed	Must be placed in new or cleaned containers		

Joaquin Valley of California, where it was discovered this year (1932) in five counties, it has done no damage whatever, although presumably it has been there several years. In its native habitat it is of little or no economic importance.

Methods of Control.—A very satisfactory control has been developed by the United States Bureau of Entomology (Reeves, 1927). This consists of spraying or dusting with arsenicals, at a cost of around \$1.25 an acre. Dusting with equal parts of commercial calcium arsenate and dusting sulfur has also proved effective as a control measure. Considerable work has been done in the introduction of parasites from Europe and one of these, *Bathyplectes curculionis*, has become well established,

and at times destroys as high as 90 per cent of the larvae present in the field. This high percentage of parasitism is said to be of very little economic importance because of faulty synchronization of the seasonal history of the parasite and weevil.

Climatic Requirements.—An extensive study of this subject has been made by Cook (1925). He concludes from a survey of the research formerly published on the weevil: (1) that so far as temperature is concerned the limiting extremes are 0° F and 120° F; (2) that warm, dry spring weather is essential for its rapid multiplication, since such weather shortens the season of oviposition and results in a maximum number of larvae at one time; (3) that cold, damp spring weather not only retards development but is favorable to increase of fungus enemies.

Adaptability to the California Environment.—It seems logical to conclude, from this careful study of Cook's, that the alfalfa weevil is adapted to exist under such climatic conditions as are found in most of the alfalfa-growing sections of California. It may exist here, however, and still not be of economic importance. There may be some question as to its ability to survive the high soil temperatures of the Imperial and Coachella valleys. There is also a possibility that the establishment of this pest in the interior valleys may result in a change in its seasonal history to a condition similar to that occurring in Italy, where the hatch, instead of being concentrated over a relatively short period of time is spread out over many months, making its damage much less serious. That this will be the case seems to be indicated by its behavior up to the present in the San Joaquin Valley and the San Francisco Bay region.

Methods of Dispersal and Avenues of Entrance.—This insect is a strong flier, and it is believed to be capable of making flights of as much as 20 miles a year. The adult beetles have a habit of secreting themselves in various types of commodities and vehicles and are thus easily carried in commerce. The larvae and adults have been found in large numbers in camping equipment which has been used in an infested field.

There are six principal avenues of entrance of this pest into California. These are:

1. Shipments of hay or alfalfa products
2. Potatoes originating in an infested district
3. Household goods originating in an infested district
4. Freight cars which have been used for hauling hay
5. Other railway cars
6. Automobile tourists

Efficacy of and Necessity for the Quarantine.—Shipments of alfalfa hay, if it has been grown or stored in infested territory, are prohibited

entry into California through the operation of Quarantine Order No. 7. The weevil frequently goes into hibernation in the rubbish at the bases of hay stacks, and the exclusion of this material undoubtedly closes up an important avenue of entrance. Alfalfa meal was formerly excluded, but investigations showed that there was no reasonable probability that weevils could survive the grinding process. The meal itself, therefore, presented no danger ; but where manufactured in infested territory and during the season when the adults were active, i. e., April 1 to October 31, the possibility of contamination of the material after grinding was evident. Regulations were inaugurated which permit the importation of alfalfa meal into California under condition that the mill be so constructed and operated as, in the opinion of the Director of Agriculture, to prevent danger of infestation after manufacture and under condition that it is packed in clean containers and shipped in clean cars. Shipments during the active season of the weevil may be made only from especially equipped mills. This regulation also permits the use of salt grass for packing, provided it has been cut and removed from the field between October 1 and April 1.

Potatoes sacked or stored in contact with infested alfalfa have been found to bear live weevils, and in order to prevent their transportation it is required that they be passed over a screen prior to loading in the car, that they be placed in new or freshly laundered bags, and that adequate precautions be taken to prevent reinfestation after cleaning.

Shipments of household goods are permitted entry only on condition that they contain no hay, grain, or straw except that for necessary food for livestock to the state line. Alfalfa seed, nursery stock, vegetables, and fruit are also excluded from these shipments.

Freight cars in which infested hay has been transported are probably one of the most dangerous sources of dissemination of this pest. A detailed study of this question has been made by Larrimer and Reeves (1929). They reported as follows :

The freight cars from which baled hay was unloaded at alfalfa meal mills were carefully examined, after being "cleaned out" preparatory to their return to service. Over 50 per cent of those which had been loaded with hay baled from the shock, as well as nearly 40 per cent of those which had carried hay baled from the stack, contained living weevils. One car contained 66. Twenty of these cars were reexamined in the freight yards 3 miles distant several days later, after they had been returned to the railroad company. Eight of these which had had the weevils replaced after the original examination were found to contain weevils—two of them more the second time than the first.

In view of these facts, and of the limited time available for the examination of any one car, it is probable that all cars which have carried alfalfa hay grown in

Utah, Idaho, Nevada, eastern Oregon, southern Wyoming, western Colorado and parts of eastern California contain living alfalfa weevils for an indefinite time thereafter, both in winter and in summer.

Six hundred and twenty carloads of hay arrived at Ogden, Utah, during the first eleven months of 1928. Only a few of these were reloaded with alfalfa meal. Some of them were used again for short trips with alfalfa hay. Many were used for local freight of various kinds. Automobile cars and most foreign-line cars went east pursuant to standing orders. Several were traced to New York, Omaha, Los Angeles, and Portland. Cars not subject to prompt return drifted with the regional movement, which at the season of most of these examinations was toward the lumber mills of the Pacific Northwest. Several of these again carried hay for longer or shorter distances en route.

Only a small percentage of the weevil-infested cars are loaded with alfalfa meal. Most of those which leave the weevil territory carry other, and unsuspected, merchandise.

It seems obvious from this study that freight cars which have been used for hauling alfalfa originating in infested territory present one of the greatest dangers of transportation of the pest to clean areas. To obviate this danger, Quarantine No. 7, Regulation 6 was devised, which requires that all freight cars which have been used in the transportation of livestock or alfalfa hay and other hay and cereal straw, in or through any part of the infested territory, shall be cleaned and freed from such products by the common carrier before they may enter California.

The effectiveness of this regulation naturally is dependent upon the thoroughness with which it is carried out. The statement of Larrimer and Reeves, above quoted, that the cars they inspected, nearly 50 per cent of which contained weevils, had been "cleaned" by the common carrier, throws considerable doubt on the effectiveness of this requirement. The "cleaning" methods in use at that time evidently were decidedly ineffective, and probably were of little or no value in preventing the spread of the pest. The Committee at this time has no knowledge of a change of methods which would make this "cleaning" efficient. If such a change has been made, the question arises, what means has the Department of Agriculture of knowing that cars coming into California have been so cleaned? Is it safe to rely on the common carrier to carry out their legal obligations in this matter? The regulation provides that cars found within the state which have not been so cleaned shall be placed in quarantine until sterilized to the satisfaction of the quarantine officer making the inspection. It is obvious that any great number of cars coming into California under these conditions would practically nullify the effectiveness of the requirement because many weevils could escape before the regulation was carried out.

The previous discussion has had reference only to cars which have actually been used in the hauling of hay originating in infested districts. To what extent does the weevil find its way accidentally into other railway cars? Reeves, Miles, *et al.* (1916) state that :

The weevils occur rarely in baggage, express and freight cars, and somewhat more often in passenger cars. . . . Webster records that "In one instance 27 were taken in the vestibule of one sleeping car on a train in Salt Lake City one day in July of last year, and have been found on freight cars within sight of the Idaho line."

To what extent this condition occurs at the present time, it is difficult to say ; but at any rate, it is an avenue of entrance which cannot be effectively closed by any reasonable requirements.

Modern interstate travel by automobile, particularly where the travelers spend the night in camping outfits, is undoubtedly one of the greatest dangers, so far as this pest is concerned. In many places on the highways entering California, volunteer alfalfagrows luxuriantly and in some places this is infested. Bedding placed near or upon such plants often becomes infested with both adults and larvae of the weevil. The extent of this danger is indicated by the report of the State Department of Agriculture for 1927, which reveals the fact that weevils were found during that year in 296 automobiles and a total of 2,111 weevils were intercepted. Schweis (1930) of the Nevada Department of Agriculture reports that the bedding from one camp yielded 110 adult weevils, and at a California quarantine station between 400 and 500 were taken from a single camping outfit. Reports for succeeding years show a considerable decrease in both the total weevils found in camp outfits and the number of cars containing weevils. This is attributed to the fact that cabins have been provided in automobile camp grounds for tourists, which greatly reduces the hazard.

Before the discovery of the alfalfa weevil in the San Joaquin Valley, it had seemed to the Committee that the weevil situation was as adequately cared for as was reasonably feasible, with the possible exception of the freight-car situation mentioned above. Just how the weevil was introduced into the Valley is not definitely known, but the Committee believes that it probably was introduced in freight cars, large numbers of which are stored on sidings in this area, or that it came in with livestock in connection with the annual rodeo held at Livermore. Either of these explanations seems more likely to be correct than the theory that it came in in camping equipment. However it was introduced, it is now evident that one of the most important California quarantines has failed. No one is to be criticized and the Committee believes that the De-

partment of Agriculture did all that was reasonably possible to prevent the introduction of the weevil.

A discussion of the direct effect of this quarantine, i. e., through the exclusion of commodities from California, will be found on p. 62. Since the weevil now occurs in five counties in the San Joaquin Valley and since the danger of dispersal from this infested area is far greater than the danger of its arrival from other states, the question will arise as to the rescinding of the interstate quarantine. It is doubtful if the intra-state quarantine, i. e., No. 8, can prevent considerable commercial jumps of the weevil, and it cannot, of course, prevent natural dispersal, which is likely to be rather rapid because of the strong winds and the ability of the weevil as a flier.

It now seems possible that the weevil will not prove to be a serious pest in the warmer parts of California. There are also excellent prospects of bringing about a successful biological control. If this is definitely indicated, in a few years, the quarantine should then be rescinded. There are certainly no reasonable grounds for the statement sometimes made that the weevil will ruin the alfalfa industry of California.

SATIN MOTH

The satin moth, *Stilpontia salicis* (L.), is a close relative of the gipsy and browntail moths, and like these is also common in Europe. In 1920 its presence was discovered in North America at Medford, Massachusetts, and also at New Westminster, British Columbia. Having established itself in a new locality without the inhibition of its usual natural enemies it has become a more serious pest to poplars and willows in America than it is generally to these plants in Europe.

Geographic Distribution.—The satin moth is generally distributed over Europe and various parts of Asia. It occurs in the British Isles, Sweden, France, Germany, Poland, Hungary, Spain, Italy, Russia, the Balkan Peninsula, Corsica, Armenia, Asia Minor (northern), Altai, Siberia (southeastern), Urga, Amur, Chosen (Korea), China, and Japan; in British Columbia, Canada; and in the United States in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Washington.

Hosts.—The food plants are various species of poplar and willow. Burgess (1927) lists the following as favored food plants: white poplar (*Populus alba*); Lombardy poplar (*Populus nigra italica*); Carolina poplar (*Populus deltoides*); balm of Gilead (*Populus canadicans*); large-toothed aspen (*Populus grandidentata*); shaking aspen (*Populus tremuloides*); and golden willow (*Salix vitellina*). In British Columbia

Glendenning (1929) records the cottonwood, *Populus trichocarpa*, as a host plant. Birch has also been recorded as a host in Europe.

Life History and Habits.—The adults of the satin moth are large white moths having a wing expanse of approximately 1½ to 2½ inches. They emerge in the late spring and early summer. Mating and egg-laying take place shortly after emergence and the moths die in 1 to 3 weeks. The average number of eggs laid by 46 fertilized females was 571, one moth depositing over 1,000 eggs (Burgess, 1927). The eggs hatch in about 2 weeks and the young larvae begin feeding on the epidermis of the leaves of the host plant. The second-stage larva spins a small cocoon or hibernaculum in crevices and depressions in the bark and other places.

TABLE 26
SUMMARY OF QUARANTINE AGAINST SATIN MOTH

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
All species and varieties of <i>Populus</i> and <i>Salix</i> trees and parts thereof capable of propagation	Total	Fed. Quar. No. 53	Rhode Island and portions of Connecticut, Maine, Massachusetts, New Hampshire, Vermont, and Washington

Within this it molts and the third-stage larva hibernates until the following spring. About May it again becomes active and feeds on the epidermis, skeletonizing the leaves. The fourth, fifth, sixth, and seventh stages consume the entire leaf tissue with the exception of the larger veins. A seventh-stage larva when full grown is about 1½ inches long. Pupation takes place within cocoons made on leaves, in crevices, on buildings or other places, and the adults emerge in about 10 days. There is but one generation a year.

Economic Importance.—Throughout Europe the satin moth is a recognized pest of poplars and willows, although infestations are not usually extremely serious because of the large number of natural enemies present there. Brown (1931) says “Fortunately in Europe the satin moth seldom occurs in abundance over a long period of years at the same point, for a large number of natural enemies keep the insect fairly well in check.” Tullgren (1918), in speaking of Sweden, states that in 1915 and 1916 large plantations of willows and poplars were badly injured by the larvae in June. Burgess (1927) says:

In severe infestations the trees are defoliated, and enormous numbers of the large caterpillars migrate in search of food. They then become a nuisance, dropping on

pedestrians, crawling up and down trunks of trees, upon sidewalks, and buildings, and even entering dwellings. The feeding of small larvae early in the fall is sometimes so severe as to cause a browning and premature dropping of the leaves.

Glendenning (1929), in speaking of British Columbia, states that thousands of acres of native cottonwood, *Populus trichocarpa*, were defoliated to the extent of 80 to 100 per cent.

Methods of Control.—The use of a spray composed of 6 pounds of lead arsenate (powdered) and 100 gallons of water has been found to be effective against the feeding larvae (Burgess, 1927). The egg masses, being covered with a white secretion, can easily be located and should be daubed with crude coal-tar creosote to which a little lampblack has been added.

Adaptability to California Environment.—The distribution as known indicates a preference for the climates of the temperate zone, infestations having been recorded from the subtropics to the subarctic. Data are not available showing the actual climatic limitations of the species, but this insect has such a wide range in Europe and Asia that it must be assumed that it would thrive in most if not all parts of California.

Methods of Dispersal and Avenues of Entrance.—Spread is principally confined to flight by the adults, movement of objects bearing egg masses, and movement of trees bearing hibernating larvae. The adults are strong fliers, and natural dispersal, which has been very rapid in the newly infested areas in the United States and Canada, has been due chiefly to flight. Since the moths frequently lay eggs on various objects other than trees, their eggs may be carried to new localities in the movement of sundry materials from infested areas, but this would occur only for a period of about a month during the summer. The greatest danger of spread by human agency is through the transportation of trees and wood bearing the hibernating larvae. They are dormant for 6 months more or less and cannot be easily detected by inspection, hence in the infested areas in the United States shipments of poplars and willows are prohibited to points outside of the quarantine area.

The infestations in the New England states and British Columbia presumably originated from imported infested nursery stock. The third-stage larvae hibernate in inconspicuous, small, silken cells known as hibernaculae in crevices on the bark of trees and therefore they can easily be transported long distances on such stock.

Efficacy of and Necessity for the Quarantine.—The quarantine provides for the closing of the most important avenue of entrance, i. e., nursery stock. The possibility of transportation of eggs on materials

other than nursery stock seems not to be covered, but perhaps this is not important. It is likely, however, that this moth will in a few years reach California by natural dispersal from Washington.

PINK BOLLWORM

The pink bollworm, *Pectinophora gossypiella* Saund., was first discovered in the United States on September 10, 1917, at Hearne, Texas, and on October 15, at Beaumont, Texas, in the vicinity of oil mills which had received Mexican cottonseed. At Beaumont some of the infested seed was illegally sold for planting and in this way the insect was distributed over a radius of from 12 to 15 miles. On October 25 of the same year a much more extensive infestation was discovered at Trinity on Galveston Bay. This area included about 7,000 acres of cotton. In spite of the enormous task of eradicating the insect in the state of Texas, the Federal Horticultural Board appealed to Congress for adequate funds to undertake the immediate control and eradication of the new pest. An initial appropriation of \$50,000 was augmented by emergency appropriations amounting to \$850,000. Texas appropriated \$10,000 and the wholesale campaign was prosecuted with such thoroughness during 1917 that not a single pink bollworm was found in 1918 in the areas known to be infested in 1917.

In the spring of 1918 an infestation was found in the great bend of the Rio Grande River and another on the Pecos River. These areas were cleaned up during the fall and winter of 1918-19. Proper legal precautions were taken to prevent the planting of cotton in the previously infested areas, to create cotton-free zones, and to exclude or treat cottonseed and other possible carriers coming across the boundary from Mexico. The infestation in Cameron Parish, Louisiana, was discovered and cleaned up in 1919; that at Shreveport, Louisiana, was discovered in 1920 and cleaned up in 1920, and recleaned in 1922 and 1923. A small infestation discovered in the Mesilla Valley, New Mexico, in 1920 has not been completely cleaned up. Infestations were discovered at El Paso, Texas, in 1920, and Ennis, Texas, in 1921. The former still exists, whereas the latter was cleaned up. The Marilee infestation, also in Texas, was found in 1921, and cleaned up in 1921, 1922, and 1923. The Carlsbad infestation in New Mexico was discovered in 1920 and reappeared in 1921, but has since disappeared without any clean-up measures. In 1927 a new infestation of pink bollworm was discovered in the Santa Cruz Valley, Arizona, and a clean-up program was begun which is not finished at this writing (1932). Efforts to eradicate the pest in the different localities

have in many cases been successful and these campaigns have been conducted with great efficiency. In eastern Texas and in Louisiana it appears that complete extermination has been procured, but in western Texas and in New Mexico and Arizona the clean-up campaigns are not

TABLE 27
SUMMARY OF QUARANTINES AGAINST PINK BOLLWORM AND COTTON BOLL WEEVIL

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Bagging that has been used as container for cottonseed, lint, or any form of unmanufactured cotton	Total	Cal. Quar. Ord. No. 5	Entire United States
Seed cotton and cottonseed, lint, linters, waste, sweepings, etc.	May be brought in under permit, from noninfested districts		
Ginning and milling machinery	Permit and certificate from state entomologist stating that it has been cleaned and fumigated		
Used cotton picking bags, railroad cars that have been used for hauling cotton	Must be sterilized and cleaned		
Automobiles, trailers, trucks, and other vehicles; baggage, implements, household and camping effects	Must be quarantined and inspected	Fed. Quar. No. 8	All foreign countries
Cottonseed, seed cotton, and cottonseed hulls	Total		
Raw cotton, including waste, fabric used in wrapping cotton, cottonseed cake, meal, oil, etc.	Admitted under federal permit		
Seed cotton, cottonseed, and cottonseed hulls	Total	Fed. Quar. No. 47	Hawaii and Puerto Rico
		Fed. Quar. No. 52	Parts of Texas, New Mexico, and Arizona
		Fed. Quar. No. 61	Parts of Arizona

yet finished. The discouraging news of the discovery of seven newly infested counties in western Texas in 1928, brought the total infested area up to 300,000 acres right on the border of the main Cotton Belt.

In summarizing the situation at the close of the year 1931, the Insect Pest Survey Bulletin, of the United States Department of Agriculture Bureau of Entomology (Anonymous, 1931) states:

Scouting for the pink bollworm in the crop year 1931 has not yet been completed on December 1, the date of the last available report. The scouting thus far indicated relatively heavy infestation in Presidio County and the southeastern corner of Hudspeth County, Texas; light infestations in Brewster, El Paso, Reeves, and Ward counties, and a trace in Midland and Pecos counties, Texas. On November 12, 13 and 14 a study of 14 fields in the Big Bend area in Presidio County, the most heavily infested section in the United States, indicated 21 per cent of unpickable bolls. In New Mexico slight infestations were found in Chaves, Dona Ana, Eddy, and Otero counties, and in Arizona in Graham, Greenlee, and Maricopa counties. Scouting and the examination of gin trash in the Salt River Valley (Maricopa County) indicate progress in the direction of the elimination of infestation.

Geographic Distribution.—This pest is supposed to have originated in India. It now occurs in Egypt, Sudan, Mesopotamia, Ceylon, Burma, Siam, Straits Settlements, China, Japan, Korea, Philippines, East Africa, North Nyasaland, Tanganyika, Zanzibar, western Africa, Italian Somaliland, Brazil, West Indies, Mexico, Hawaii, and Puerto Rico; and in the United States proper it occurs in certain counties in Texas, New Mexico, and Arizona. It is believed to have been eradicated from Louisiana.

Hosts.—This insect seems to be restricted to cotton.

Life History and Habits.—S. D. Smith (1930) describes the larva as follows:

The pink bollworm larva feeds mostly on the inside of the cotton boll and as soon as it hatches out, tunnels through the lint to the interior of a seed, where the bulk of its food is obtained. When first hatched, the color is creamy white, the somewhat large head being almost black, and shiny. The pinkish color starts to appear when the worm is about one-fourth of an inch long and as growth continues becomes more pronounced. When full grown, the worm is about one-half an inch long. The pinkish color is due to bands of pigment in each section which are somewhat distinct in the early stages, but as the larva increases in size, the color bands seem to spread until the whole body is suffused with its characteristic color.

Its injury consists of destruction of lint, seed, and blossoms. The insect hibernates as a larva within cottonseed or in gin or other trash. Some of the larvae spend two years in the quiescent stage, which has an important bearing on eradication campaigns.

Economic Importance.—Clausen (1931) reports that "worst of the cotton pests is the well-known pink bollworm, *Pectinophora gossypiella*, which according to Okamoto, infests an average of 50 per cent of the bolls each year in Chosen. It also occurs in Japan and in Taiwan, largely in the district about Tainan, and is spreading rapidly."

According to Gough (1917):

Pectinophora (Gelechia) gossypiella was imported into Egypt less than 10 years ago, and its increase has been enormous. The July infestation of 1916 was due to the progeny of moths which had hibernated as larvae, and the increase in numbers continued uniformly, owing to the breeding being continuous and unchecked, till the maximum was reached during the third week in September, at which time there were at least 4,500 individuals to each 1,000 cotton plants. This pest now occurs wherever cotton is grown in Egypt; in the last week of October 87 per cent of the green bolls in Lower, 78 per cent in Middle, and 60 per cent in Upper Egypt were attacked by it.

In Hawaii the infestation of cotton by the pink bollworm in 1915 ran from 50 per cent to 99 per cent of all the bolls—so severe in fact that the cultivation of cotton was practically abandoned. The damage caused by this insect in Mexico has been investigated by a joint body representing the Mexican and American commissions, which visited many plantations in the Laguna. It reported that the loss to the crop of 1917 chargeable to the pink bollworm was not less than 30 per cent.

Methods of Control.—The artificial control measures against the pink bollworm as practiced in Japan (Clausen, 1931) “are chiefly cultural, and consist of cultivating and harrowing the soil to kill the larvae and pupae, the gathering of fallen buds in late July and early August, and the burning of old plants and rubbish at the end of the season.”

Artificial control in the growing crop is difficult for the reason that the insect is from two to four brooded and the larvae feed within the boll, which would necessitate many thorough applications of poison sprays or dusts.

Extensive tests with insecticides in many parts of the world have not given entire satisfaction, and in most countries the control of the moth by predacious and parasitic insects is being tried.

From the investigations so far conducted in this country, there is little doubt but that the insect can be sufficiently controlled so that cotton culture will continue, but the additional cost would be great.

Adaptability to the California Environment.—If one may judge from the fact that it is a major pest under such widely differing climatic conditions as occur in Hawaii and Egypt, the pink bollworm is capable of existing under any climatic conditions where cotton is grown. There is no reason to doubt that the pink bollworm would become a serious pest of cotton in California, as it has in Egypt.

Methods of Dispersal and Avenues of Entrance.—Because the larvae of the pink bollworm can live several months during the hibernating period, it has easily been spread, chiefly through commercial channels in cottonseed, in seed cotton for ginning purposes, and in baled cotton.

Thus it was carried from its native home in India to many distant regions. From new centers of infestation it was again relayed to others. As an illustration, it was carried from India to Egypt in 1906–7 in large shipments of seed cotton or poorly ginned cotton. From Egypt it was carried to Brazil and Mexico in 1911, 1912, and 1913 in cottonseed. The first infestations in Texas are traceable to the importation of Mexican cottonseed for making oil and for planting.

When once established in a region its dispersal is largely by the natural flight of the adult moths, but it may also be transported artificially in any of the above-mentioned ways or by carrying portions of the infested plants.

Coad (1929) reports that moths have been taken abundantly by the use of airplanes at elevations up to 3,000 feet. He submits strong circumstantial evidence that moths are blown from the Laguna sections of Mexico into the Big Bend section of Texas.

The infestation in Arizona is probably not yet sufficiently close to California to permit its entrance by natural dispersal, i. e., by flight, and the federal Bureau of Plant Quarantine is making a strenuous effort to eradicate the Arizona infestation, the reduction in moth population making it much less likely to invade California by that means. Its most evident avenue of entrance is through shipment of the commodities mentioned in the quarantine summary, i. e., cottonseed, and unmanufactured cotton products.

Efficacy of and Necessity for the Quarantines.—These quarantines, so far as California is concerned, are most essential regulations for the protection of agriculture. There can be no question as to the menace of the pink bollworm to the California cotton industry, and every reasonable and sound procedure should be followed in the effort to keep it out. Actual interceptions of live pink bollworm larvae have been made every year at the ports, coming from China, India, and Hawaii. Contraband material and live larvae have been intercepted at both the border and interior stations and there is some danger from automobile travelers who bring in cotton bolls and plants as curiosities. It is believed by the Committee, however, that both the state and federal departments of agriculture are doing all that is reasonably possible to exclude this pest. The very fine work of the federal Bureau of Plant Quarantine in connection with the long-continued fight against this pest is especially commendable and should be given every support. The future safety of the California cotton industry from the pink bollworm is entirely dependent upon the successful eradication of it in Arizona.

COTTON BOLL WEEVIL

The cotton boll weevil, *Anthonomus grandis* Boh., was described in 1843 from specimens received from Vera Cruz, Mexico. This was years before it appeared in the Cotton Belt of the United States. In 1892 it did damage at Brownsville, Texas, and probably had crossed the Rio Grande by natural spread from Mexico a year or two prior to that time. Since 1892 it has spread almost throughout the southern Cotton Belt and beyond question has been the most destructive cotton pest in the United States.

Geographic Distribution.—The distribution of the cotton boll weevil is as follows: Mexico (in the cotton districts on both the Atlantic and Pacific coasts); Yucatan (western coast); Guatemala; Costa Rica; and Cuba (5 western states); United States (90 per cent of the southern Cotton Belt from the northeastern limit to about the last third of Texas). The variety *thurberiae* Pierce occurs in Arizona.

Host Plants.—The cotton boll weevil, so far as known, is confined almost exclusively to cotton for reproduction. Adults occasionally feed slightly on other plants but there is no record of breeding on plants other than cotton, excepting that the variety *thurberiae* breeds on the wild cotton plant *Thurberia* in a part of Arizona.

Life History and Habits.—The adults pass the winter in almost any kind of protection that they can find. Hibernating weevils may be found in grass and weeds along fences, in dead leaves and cotton stalks, and about cotton gins, and barns. The adults begin to come out of hibernation early in the spring and continue until early June. They feed at first on the tender, terminal growth of young cotton plants, but attack the squares or buds as soon as they appear, eating cavities into them and laying an egg in each cavity. There is usually one egg to a square. Each female may lay from 100 to 300 eggs. The egg hatches in about three days and the larva completes its development within either the square or the boll, which it hollows out by its feeding. Within the cavity formed by its feeding the larva pupates and the adult eats its way out of the square or boll ready to mate and begin the life cycle again. Life cycles may be as short as 15 to 25 days, so that there may be as many as eight or ten generations a year. Late in the season the beetles spread by taking flights in short stages which may advance them 20 to 50 miles or more. Hibernation begins after heavy frosts. Adults may live as long as 50 days in the summer and 6 months during winter.

Economic Importance.—Metcalf and Flint (1928) state: "The most recent estimates place the current loss at 3,000,000 to 5,000,000 bales of cotton a year, or from 20 to 40 per cent of the normal production."

Methods of Control.—When the first squares appear on the young cotton plants a calcium arsenate dust or a poison syrup is applied to the tips of the plants. As the season progresses three to four applications are made, at intervals of 4 days, using 5 to 7 pounds per acre. Cost of airplane dusting averages about \$1.00 an acre for each application (Metcalf and Flint, 1928).

In addition to the poisoning, the crop should be made as early as possible, and as soon as the cotton is picked all plants should be cleaned up by burning or deep plowing. Hibernation places should also be cleaned up.

Adaptability to the California Environment.—The most effective climatic limitations are dryness, low winter temperatures, and high summer temperatures.

Regarding dryness, Hunter and Pierce (1912) state, "Dryness is the most important check the boll weevil experiences. The insect has repeatedly advanced into western Texas but has invariably been prevented from gaining a foothold by the dry climate of that region." They further state that the practice of irrigation in dry regions may counteract the effects of the lack of precipitation and enable the weevil not only to maintain itself but also to cause considerable damage.

In reference to low temperatures the same authors state:

An analysis of the minimum temperatures reached in the regions where the weevils were most affected indicates that such control was the result of a temperature of 12° above zero [F].... Although the information at hand is rather incomplete, we can nevertheless hold out some hope that regions having a minimum temperature of from 5° to 10° above zero will have little trouble from the boll weevil.

High summer temperatures kill the larvae within the squares and bolls. Fenton and Dunnam (1929) found that, "The greatest mortality in fallen squares was due to heat, averaging 41.18 per cent in 1925 and 25.73 per cent in 1926.... In fallen squares it increased from 16.95 per cent July 2, to 70.09 per cent August 17; and in hanging forms from 11.95 per cent July 13 to 27.08 per cent August 10."

In the climatic limitations previously mentioned, viz: dryness, low temperature, and high temperature, low temperatures can be disregarded as a climatic limitation in the California cotton districts because the minimum temperatures of those localities are not low enough to be a serious hindrance to the weevil. Dryness and heat, however, are extremely pronounced in the California cotton areas and even with irrigation should serve as more effective checks to the weevil than the same

factors do in the southern states. It seems therefore that the typical cotton boll weevil could hardly exist in any great numbers in the cotton districts of this state. The variety *thurberiae*, which persists in Arizona on wild growth, is evidently not so susceptible to low humidity and might possibly thrive under California conditions.

Methods of Dispersal and Avenues of Entrance.—Since 1892, the cotton boll weevil has spread north and east from Brownsville, Texas, at an average rate of about 60 miles a year, infesting an average of more than 20,000 square miles of new territory annually since it crossed the Rio Grande (Metcalf and Flint, 1928). This spread is brought about by the seasonal dispersal which occurs during the latter part of each year. During the time of dispersal the beetles advance by successive short flights that may disseminate them 20 to 60 miles by the end of the season.

While it is definitely known that the weevil is carried by human agency in cotton bolls, etc. (it has been intercepted in contraband shipments to California many times), the Committee has seen no indication that it has ever become established in a new locality in this way.

There seems to be no possibility that the true cotton boll weevil will ever reach California by natural dispersal. If the variety *thurberiae* should become widespread in Arizona, it could reach the cotton fields of the Imperial and Coachella valleys by this means. The most likely avenue of entrance is the bringing in of cotton bolls by tourists, or the sending of such material to California by mail. There is some danger of course from freight cars which have originated in the infested districts, and from various commodities in which the adult weevils have sought protection for hibernation.

Efficacy of and Necessity for the Quarantines.—The quarantines against the cotton boll weevil are summarized in table 27 (page 201). Because of the danger of the transportation of adult weevils in merchandise, it is extremely difficult to make a quarantine against such an insect effective. Failure of this insect to become established here may be due to unfavorable environmental conditions, rather than to the efficacy of the quarantines. However, this is one of those cases where climatic effects should be disregarded since it is a major pest of one of the important crops of California, and the quarantines entail little economic disturbance. Such cotton commodities as are necessary for manufacture in California may enter under permit from the Director of Agriculture. The Committee believes therefore that the quarantines are justified.

NUT-TREE INSECTS

Certain insect pests attacking nut trees—the pecan leaf case bearer, *Mineola indiginella nebulella* Riley, and the pecan nut case bearer, *Acrobasis hebescella* Hulst, do not occur in California, but are rather important pests in the southeastern states. This quarantine is designed to keep California free from these pests. While the pecan is not yet an important crop in California, plantings are increasing. It is felt also that since these pests are known to attack walnuts and might prove serious on that crop in this state, it is desirable to attempt to exclude them.

TABLE 28
SUMMARY OF QUARANTINE AGAINST NUT-TREE INSECTS

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Hickory, pecan, and walnut (<i>Hicoria</i> spp. and <i>Juglans</i> spp.) trees, plants, and parts thereof including grafts, scions, and cuttings	Total, except that budwood or scions may be imported under permit from Director of Agriculture	Cal. Quar. Ord. No. 12 N. S.	All states and districts east of and including Montana, Wyoming, Colorado, and New Mexico

Since these pests could possibly become serious if established in California, and since the quarantine entails little inconvenience or economic disturbance, the Committee believes that the quarantine is desirable, and that it should prove effective.

PEACH YELLOWS AND PEACH ROSETTE

Nature and Cause of the Diseases.—Peach yellows is characterized by a pronounced yellowing of the foliage, production of wiry, sickly shoots, premature ripening of the fruit, and death of the affected tree. Rosette is similar to yellows but its progress is more rapid and the leaf symptoms are somewhat different. These are both infectious diseases which seem to belong to the “virus,” class, but the cause is not positively known.

Hosts.—All varieties of peach and related trees like the apricot and nectarine are said to be affected by yellows and rosette. The same or similar diseases have also been reported on almonds and plums.

History and Geographic Distribution.—Peach yellows occurs only in America. It was first noted in the vicinity of Philadelphia more than a century ago. In 1806–7 the disease was apparently confined to the Philadelphia section, including territory in New Jersey and Delaware. From

this time on yellows spread northward and northeastward, reaching Connecticut by 1814, and Massachusetts a few years later. It was first reported from western New York about 1824, from Ohio in 1849, from Indiana about the same time, from Michigan in 1866, and from Ontario in 1878. The disease spread southeastward through Delaware and Maryland and finally reached Arkansas and northeastern Texas. The present range of yellows includes the territory from Massachusetts south to the Carolinas, the southern boundary including most of Tennessee and crossing Arkansas and Oklahoma, the northern boundary cross-

TABLE 29
SUMMARY OF QUARANTINE AGAINST PEACH YELLOWS AND PEACH ROSETTE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Peach, nectarine, or apricot roots, trees, cuttings, grafts, buds, or pits	Total	State Quar. Law Sec. 6	Central and eastern United States

ing New York and the peach districts of Ontario and Michigan, and the western boundary reaching into Missouri and Kansas. Yellows has not been reported west of the Rocky Mountains.

Peach rosette is known chiefly in Georgia and South Carolina (Heald, 1926). No positive cases of these diseases have ever been known to occur in California.

Economic Importance.—Before the practice of immediate removal of diseased trees was started, the peach-growing industry was nearly wiped out in some parts of the eastern United States and in sections of Michigan. In the affected districts a loss of from 1 to 25 per cent of the trees annually, even where the diseased trees are promptly removed, is not uncommon.

Possibility of Control.—The prompt removal of trees just as soon as yellows or rosette is evident is the only method which makes possible the maintenance of peach orchards in localities where these diseases prevail. Trees showing symptoms of yellows on a single branch cannot be saved by cutting off the affected parts, since the disease is systemic, and apparently healthy parts are already harboring the infective principle.

Adaptability to the California Environment.—There is considerable variation in climatic conditions in different parts of the district in which these diseases occur, ranging from Massachusetts to Florida and from the Atlantic Coast to eastern Kansas. This includes most of the more

humid portions of the United States where peaches are grown and covers a wide range of temperature conditions.

So far as evidence or information is available it appears to be true that peach yellows and rosette have never occurred in any of the semi-arid portions of the United States. This includes New Mexico, Arizona, western Texas, Utah, Colorado, California, and the Pacific Northwest. It is undoubtedly true that in earlier days thousands of trees of peach nursery stock have been imported into these states from eastern nurseries in districts where yellows and rosette occur. There are reasons for believing therefore that on account of some natural factor these diseases are unable to develop and spread in those parts of the country west of a line passing approximately through Nebraska and Kansas. Whether this is due to unfavorable climatic conditions or to the absence of some insect vector is not known. In the light of the recent investigations of Kunkel (1933), the latter seems to be the most probable explanation (see p. 37).

Methods of Spread and Avenues of Entrance.—The only method by which peach yellows and rosette have been transmitted artificially is by budding or grafting from affected to healthy trees. By this method the diseases are spread very readily. It is very evident, however, that some other method of distribution occurs in nature, since the disease spreads from tree to tree in the orchard or districts to others closely adjacent. The only method by which peach yellows or rosette can be transmitted over considerable distances or natural barriers is by the shipment of infected nursery stock. If either of these diseases is once established in a few trees in a new district it is to be presumed that it will then extend to adjacent healthy trees by some unknown method of distribution.

The spread of these diseases in the eastern United States has taken place mainly by an unknown method of dispersal from tree to tree. Since these diseases can be readily transmitted by budding from affected trees it is probable that they have also been spread by shipment of affected nursery stock. It is not known, however, that either of these diseases has ever been introduced into any district far removed from previous infestations. The only way in which these diseases would be likely to enter California would be on nursery trees shipped from some of the eastern states.

Efficacy and Importance of This Quarantine.—If there is any danger of establishing peach yellows and rosette it seems quite certain that the total exclusion of peach and related nursery trees would keep out these diseases.

WHITE-PINE BLISTER RUST

Nature and Cause of the Disease.—White-pine blister rust is a true rust which attacks the stems and needles of white (five-needled) pines, causing a weakening and eventual death of the trees. The causative organism is the fungus *Cronartium ribicola* Fisch. Like many other rusts this species does not confine its attacks to a single host but has another stage on plants of an entirely different kind, in this case on various species of currants and gooseberries (*Ribes*). This relation is the same as that between wheat and the barberry bush in wheat rust. Blister rust

TABLE 30
SUMMARY OF QUARANTINES AGAINST WHITE-PINE BLISTER RUST

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Plants of 5-leaf species of pine, all species of currants and gooseberries	Total	Fed. Quar. No. 63	Points east of western boundary of Minnesota, Iowa, Missouri, Arkansas, and Louisiana, also Washington and Oregon
		Fed. Quar. No. 7	All Europe, Asia, Canada, and Newfoundland

is unable to spread directly from one pine to another but is obliged to go first from pine to currant or gooseberry and thence back to other pines (Hubert, 1931).

The white-pine blister rust is one of the most damaging of forest-tree diseases; it has made the growing of many species of pines in the Old World practically impossible. Its rapid spread and fatal attack is most pronounced upon seedlings and young trees and has resulted in almost total loss of such trees in many regions. In mature trees the progress of the disease is relatively slower. In mature white pines it may take twenty-five to thirty years from the time of infection before the trees are entirely killed, but with the slow dying of the older trees and the rapid destruction of reproduction there comes a time when the entire stand is wiped out.

Hosts.—The white-pine blister rust is capable of infecting nearly all of the five-needled species of pine and is restricted to this group of trees. The following are the hosts native to the United States and Canada: *Pinus strobus* (eastern white pine), *P. monticola* (western white pine), *P. lambertiana* (sugar pine), *P. flexilis*, *P. albicaulis*, *P. aristata*, *P. balfouriana*, and *P. strobiformis*.

Of the alternate hosts a large number of more or less susceptible species of currants and gooseberries both native and cultivated occur in this country and many of them in California. There is a marked difference, however, in the susceptibility of different species and the primary infections in a given locality usually occur upon only a limited number.

History and Geographic Distribution.—This rust is believed to be of Asiatic origin and was first reported from the Baltic provinces of Russia in 1854 where its host is presumed to have been *Pinus cembra*. The disease became most conspicuous in Europe after the introduction of the American white pine, *P. strobus*. The disease was well distributed throughout Europe in 1883 and appeared in England in 1892. It was imported from Europe into the northeastern United States on seedlings of *P. strobus* between 1898 and 1908. The rust is now generally distributed throughout the northeastern and Great Lake regions of the United States wherever *P. strobus* is found and has more recently been introduced into the Pacific Northwest on pine seedlings shipped from France to Vancouver, B. C., in 1910. In 1921 it had spread to Washington and in 1930 the infection was rather general in Washington, Oregon, and Idaho, with small centers of infection in western Montana. This disease has never been observed in California but exists in Oregon near the southern border. For several years the United States Department of Agriculture has been carrying on work on the eradication of susceptible species of *Ribes* in northern California in order to delay the attack of blister rust upon the valuable sugar-pine forests.

Economic Importance.—In its original indigenous form in the Old World this disease attracted no attention since no very susceptible host was at hand. In Europe blister rust is very destructive to the introduced white pine of the United States (*Pinus strobus*). In portions of the United States outside of California, where the disease has become established, its very great economic importance has already been discussed.

Possibility of Control.—Since the blister rust fungus needs two types of plants, the white pine and species of *Ribes* (currant or gooseberry), to complete its life cycle, the control of this rust has been centered upon the destruction of the latter hosts. That the effective eradication of the cultivated and native *Ribes* surrounding any given area of white pine forest, particularly in the Pacific Northwest and California, is a herculean task needs scarcely to be emphasized, but this appears to be the only possible method of control of this disease. This method, which is based upon the inability of the rust to spread from *Ribes* to pine for more than a relatively short distance, was developed in the eastern part of the United States. In the eastern states over 800,000 acres are annually being

placed under protection by this method, and during the decade 1918–1928 more than 6,000,000 acres of white-pine land have been cleared of *Ribes*. The method consists of the removal, by pulling or by use of chemical sprays, of the *Ribes* growing within 900 feet of any susceptible species of pine. A second removal is necessary after a period of six or seven years or longer according to local conditions.

Adaptability to the California Environment.—This rust, like most other fungus diseases of plants, requires considerable humidity for its successful spread from one host plant to another. Its rapid spread and development, however, in many different parts of the United States where climatic conditions are very dissimilar indicates that its distribution is not likely to be narrowly limited by any local climatic conditions where susceptible hosts occur. The distribution of white-pine blister rust in the United States up to date is not sufficiently extensive to indicate whether or not climatic conditions in California will be unfavorable to the disease. The prospective damage from blister rust in California is great, since one of the most important timber trees in California, the sugar pine, is threatened. The danger is not so much to present stands of mature timber as to reproduction.

Methods of Dispersal and Avenues of Entrance.—White-pine blister rust is spread locally mainly through the agency of wind. The form of the disease which attacks currants and gooseberries is not capable of reinfecting the same hosts but only white pines. The spores in this stage are very short-lived and are able to spread the disease only over a very short range and only under favorable conditions, of which abundant moisture is the most essential. The spread from *Ribes* to white pines probably does not take place over a distance of more than a few hundred yards. The wider local distribution of white-pine blister rust originates in the spread from affected white pines to susceptible species of *Ribes*. The spores which come from the pine trees are relatively long-lived and are carried long distances in the wind. In this way infection of currants and gooseberries has been known to take place at distances of 150 miles or more from the nearest infected pine trees.

The spread of the disease over greater distances, across natural barriers such as oceans, or regions several hundred miles in extent where no host plants exist, can take place only through the agency of man and by means of the transportation of living plants, either pines, currants, or gooseberries, which are already infected with the disease. It is undoubtedly in this manner alone that the disease has been spread from one continent to another or between two regions which are completely isolated. Although this disease was indigenous in parts of the Old World

it attracted no attention until the white pine of the eastern United States was introduced into Europe. Upon this more congenial host the blister rust first showed its serious importance. After it had become abundant in Europe the disease was apparently scattered to other countries through the agency of infected white-pine seedlings shipped from nurseries. In this manner blister rust was introduced into the eastern United States and independently into British Columbia. At these two foci on the Atlantic and Pacific coasts infection of currants and gooseberries first took place and the blister rust was then spread by wind westward and eastward until it now threatens a large part of the white-pine acreage over the entire country. Blister rust might be brought into California in the same way by which it was introduced into New England and British Columbia, that is, the importation of infected nursery stock. In addition to this preventable method there is the practical certainty of the eventual introduction of the disease from southern Oregon by wind-borne spores. By the eradication of currant and gooseberry (*Ribes*) plants, the possibility of the establishment of the disease by this method may be lessened.

Efficacy and Importance of the Quarantines.—So far as the introduction of infected plants is concerned it seems feasible to exclude this disease by quarantine but this cannot prevent the natural dispersal of blister rust. It is desirable to delay the entrance of blister rust into California as long as possible. Were it not for these quarantines new foci of infection might become established at any time in any part of the state where *Ribes* or white pines are growing, by introduction of affected seedlings. In this way blister rust might get a start in sugar pine much further south in the state than it would reach by natural dispersal for many years. No quarantine on pine or *Ribes* existed either in the United States or Canada at the time when blister rust was first introduced. The complete exclusion of such plants would have kept out this disease.

FLAG SMUT OF WHEAT

Nature and Cause of Disease.—Flag smut of wheat occurs in the leaf blades and sheaths, forming black stripes running lengthwise. The causative organism is *Urocystis tritici*. The infected plants are dwarfed and rarely produce heads. The black stripes are filled with the dusty, dark-colored spores of the fungus, which are scattered over the grain and contaminate everything with which they come in contact. The spores are also blown about by wind and thus infest the soil.

Hosts.—This disease affects only the wheat plant. There is considerable difference in the susceptibility of different types and varieties.

History and Geographic Distribution.—Flag smut was first reported from Australia in 1868. Since then it has been found to be widely distributed in Australia and in Japan, India, South Africa, China, and southern Europe (Brittlebank, 1920).

In the United States the disease was first discovered in Missouri in 1918 and has also occurred in parts of Illinois and Kansas. A considerable effort has been made by federal and state authorities to suppress the disease in the affected regions (Tisdale, Dungan, and Leighty, 1923).

Flag smut has never been observed in California.

Economic Importance.—Flag smut is reported to be a disease of major importance in Australia, frequently causing the destruction of

TABLE 31
SUMMARY OF QUARANTINE AGAINST FLAG SMUT OF WHEAT

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Wheat and wheat products	May be entered if treated so as to destroy spores	Fed. Quar. No. 59	India, Japan, China, Australia, South Africa, Italy, and Spain

half or more of the wheat crop in affected fields where no control is practiced. Serious losses are also reported in China. In this and other countries where the disease has been introduced its effects have not as yet been very serious. In fact the damage from flag smut in the districts where it occurs in the United States has declined since the disease was first observed. At the present time in the Middle West this disease is of practically no importance as compared with the ordinary smuts of wheat.

Possibility of Control.—Australian writers agree that seed treatment kills seed-borne spores of flag smut, but that it is less effective in controlling smut where the soil contains spores from previous crops of affected wheat on the same or neighboring fields. Experience in this country has shown that the same seed treatment which is applied to wheat for ordinary smut is very effective in controlling this disease and also that many wheat varieties are resistant to flag smut.

Adaptability to the California Environment.—Flag smut is generally thought to be favored by a mild winter climate, since low temperatures destroy many of the spores which may be present in the soil. A dry summer with fall rains and fall-seeding of grain is also favorable to this disease, since the smut spores persist in the dry soil and germinate with and infect the grain when the first rains occur. It would appear, there-

fore, that conditions would be more favorable to flag smut in California than in the midwestern states. The prevalence of the disease in Australia leads to the same conclusion.

Methods of Dispersal and Avenues of Entrance.—Flag smut is spread locally by the dusty spores blown in the wind or attached to anything which passes from one wheat field to another. Over longer distances the disease is carried on grain, straw, or any material which may have become contaminated with smut spores. This disease is probably spread from one country to another most commonly through the medium of seed grain from infected fields. In the case of the outbreak in the central United States discovered in 1919 it was at first thought that flag smut had been introduced into Illinois on wheat from Australia, brought into this country during the War in 1918. This wheat was intended for milling purposes only, but some of the contaminated by-products such as bran, or even the grain itself, might have escaped into the fields. Sometime later, however, it developed that flag smut had been found in Missouri in 1918. This could not have come from wheat imported from Australia in that year, for it had to be present at sowing time in 1917 in order to infect the crop of 1918. However, this does not preclude the possibility that it came from Australia or some other country in shipments of wheat or other products to which the spores might adhere (Tisdale, Leighty, and Koehler, 1927). Probably the only way in which flag smut could reach California would be through the introduction of wheat, wheat straw, or some other spore-contaminated material from a district where flag smut occurs. Such material would have to be brought into contact with seed wheat in order to establish the disease here.

Efficacy and Importance of This Quarantine.—There was no quarantine against wheat from Australia or other countries until after flag smut had been observed in the United States. By preventing the importation of raw wheat from affected districts into California the chances are good for keeping out flag smut. It is always possible, of course, especially since the disease is already in this country, that it might be brought in on straw, hay, packing material, or some other unsuspected carrier. The exclusion from California of wheat which might carry flag smut seems important, since this disease is a very serious one in Australia where conditions are similar to those here. A question might be raised as to the consistency of quarantining against foreign countries but not against portions of the United States where flag smut occurs.

CITRUS MELANOSE

Nature and Cause of the Disease.—Melanose is a disease of citrus, caused by the fungus *Phomopsis citri* (perfect stage *Diaporthe citri*) which rarely injures the tree but disfigures the fruit and damages its quality. Characteristic markings occur on all young parts, leaves, stems, and fruit. These markings consist of brown, raised dots or areas scattered over the surface. Sometimes the whole surface of the fruit becomes rough, cracked, and scabby. The same fungus also induces “stem-end rot” of citrus fruits.

History and Geographic Distribution.—Melanose was first noticed in Florida in 1892 and was thought to be a recent introduction. Since then

TABLE 32
SUMMARY OF QUARANTINE AGAINST CITRUS MELANOSE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Citrus fruit, trees, scions, etc.	Total	Cal. Quar. Ord. No. 6, N. S.	Florida, Texas, Louisiana, Alabama, Mississippi, Puerto Rico

the disease has become important in middle Florida. It has been found all over Florida and the Gulf states and has also been reported in Mexico, Brazil, the West Indies, Japan, California, China, Australia, New Zealand, Algeria, Egypt, South Africa, Sicily, Spain, and Palestine. In Florida the greatest degree of injury from melanose appears to occur in a band or zone through the middle part of the peninsula, between about $27\frac{1}{2}^{\circ}$ and $29\frac{1}{2}^{\circ}$ north latitude.

It has been known for a long time that a fungus closely resembling the melanose organism already exists in California (Fawcett and Lee, 1926). The characteristic roughening of the fruit is rarely seen here but Fawcett has found a fungus connected with a stem-end rot of lemons and occasionally on oranges, dead twigs, and bark of citrus trees, which has recently been shown to be identical in form to *Phomopsis citri* (Fawcett, 1932). Similar fungi which appear to be identical in form have been found in most other citrus-producing countries. The distribution and original habitat of *Phomopsis citri* are somewhat unknown. Apparently the melanose fungus has been present in California for a long time, but because the climatic conditions were unsuitable for the occurrence of anything but occasional mild forms of melanose, it neither attracted attention nor resulted in commercial damage.

Economic Importance.—Melanose is an important citrus disease in Florida on account of the damage which it causes to the quality of oranges and grapefruit and the loss from the related disease, stem-end rot. Rhoads and DeBusk (1931) make the following statement:

The 1923–24 citrus crop of 20,000,000 boxes graded about as follows: Bright and fancy, 20 per cent or 4,000,000 boxes; golden, 45 per cent or 9,000,000 boxes; russet, 35 per cent or 7,000,000 boxes. In a survey of 32 representative packing houses throughout six of the leading citrus producing counties, made by the junior author, it was found that 59 per cent of the golden and 61 per cent of the russet fruit were due to melanose.

Possibility of Control.—According to Rhoads and DeBusk (1931), “A single application of 3–3–50 bordeaux mixture plus 1 per cent of oil as emulsion, applied shortly before May rains set in, has been found by several years of experimental work to give an excellent control of melanose as a rule.” The same application greatly reduces the amount of stem-end rot that may be expected to develop in the fruit during marketing.

Conditions which promote the accumulation of dead twigs and branches in the trees are favorable in Florida to melanose. It is therefore true that under Florida conditions inadequate irrigation or fertilization, frost damage, or insect injury tend to increase the disease which is more readily kept under control in vigorous, well-kept trees.

Adaptability to the California Environment.—Rhoads and DeBusk (1931) describe the favoring conditions as follows:

Another important factor necessary for the development of melanose is moisture, in the form of either rain or heavy dew or fog. The spores of the causal fungus developed in the pustules are imbedded in a gelatinous matrix, which swells when moistened. The spores are then forced out of the microscopic mouths of the pustules in minute, tendril-like masses, after which rains or the drip of water from dew or fog wash them down over the young leaves, twigs, and fruits, thereby leading to the infection of these susceptible parts. . . . The severe outbreaks of melanose can be traced definitely to rainy periods occurring as a rule in May or early June.

Melanose in Florida seems to be very definitely a disease which develops only in warm, rainy weather of summer. Since the California climate differs in being dry, as a rule, in May and June there seems to be little probability that melanose will ever be any more serious in California in the future than it has been in the past.

Methods of Dispersal and Avenues of Entrance.—The melanose fungus reproduces mainly on dead twigs and bark of citrus trees, where it produces an abundance of spores. The fungus may be spread locally by wind, rain, birds, insects, etc., but for long-distance distribution it undoubtedly requires the agency of man. The shipment of nursery stock

with this fungus growing on some of the twigs is probably the usual method. Distribution on fruit is much less probable.

There is no certainty as to where this fungus was originally native and the history of its spread is unknown. Recent study indicates that the causal agent of the disease is already present in most countries where citrus is grown.

Necessity for This Quarantine.—In view of the fact that the melanose fungus is now definitely known to occur in California, having been here many years, the Committee believes that this quarantine is no longer justified and that it should be rescinded.

CITRUS CANKER

Nature and Cause of the Disease.—Although citrus canker has been described as one of the most destructive plant diseases known, the principal effects are not so much an actual killing of the tree as a disfiguration and spoilage of the fruit for market. Canker causes a development of brown, corky, scabby spots and areas on all parts of the tree above ground, especially on the fruit, leaves, and twigs when they are still fairly young and tender. The affected growth becomes disfigured and weakened and the fruit is ruined for market. Under favorable conditions the disease spreads rapidly and becomes very abundant, injuring a large percentage of the fruit.

Citrus canker is a bacterial disease, caused by *Bacterium citri*, which attacks all varieties and species of citrus to a greater or less extent. These bacteria live and multiply abundantly in the affected tissue and are easily carried from one tree to another.

Canker is considered the worst disease of citrus trees which has ever been introduced into this country and its eradication after it had become well established in Florida must be looked upon as an achievement of the greatest importance to the citrus industry.

Hosts.—Citrus canker varies in its seriousness in different species and varieties of citrus. Of the important citrus fruits in Florida the disease is most virulent on the grapefruit and next on the sweet orange. There is some difference in susceptibility between the different varieties. The Washington Navel orange is very susceptible. The lemon in Florida is somewhat less susceptible than the sweet orange, the Satsuma orange is less susceptible than the lemon, and the Mandarin orange is very resistant.

History and Geographic Distribution.—Canker is not widely distributed throughout the citrus-growing countries of the world but is very

prevalent in the Orient (Berger, 1914*a*). It is usually believed to be native to China but has been present in Japan and the Philippine Islands for a long time. Some recent evidence from old herbarium specimens indicates that it may have originated in India (Fawcett and Jenkins, *Phytopathology*, in press). The disease also spread to many parts of the Orient, the Hawaiian Islands, North Australia, and South Africa.

TABLE 33
SUMMARY OF QUARANTINES AGAINST CITRUS CANCKER

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Citrus fruit	Total	Cal. Quar. Ord. No. 1, N. S.	All of the United States, except Arizona
	Total except oranges of the Mandarin class may enter under permit	Fed. Quar. No. 28	India, Siam, Indo-China, Malayan Archipelago, Philippine Islands, Oceania, (excepting Australia, Tasmania, and New Zealand), Japan, including Formosa and islands adjacent to Japan, Union of South Africa
Citrus seed	May be imported under permit and treatment	Cal. Quar. Ord. No. 1, N. S.	All of the United States, except Arizona
Citrus trees, scions, etc.	Total	Cal. Quar. Ord. No. 1, N. S.	All of the United States, except Arizona
	Total	Fed. Quar. No. 19	All foreign countries and localities

In the United States citrus canker was observed in a single case in Florida in 1912, and again in 1913. It was probably first introduced at some time between 1908 and 1911. The disease was not generally recognized as a serious menace until 1914, and its true cause was not discovered until 1915. It seems therefore that canker did not attract attention as a serious citrus disease anywhere in the world until it had been introduced into Florida. The disease has been found in Texas, Mississippi, Alabama, Louisiana, and Florida (Berger, 1914*b*). It has never been observed in California or Arizona nor in Cuba or Puerto Rico. After canker was discovered in Florida it spread rapidly, and a vigorous campaign was started by state and federal authorities to eradicate the dis-

ease from Florida and the other Gulf states. As a result of this energetic campaign there has been no commercial damage to Florida citrus groves from this disease since 1922 and no infections have been found since 1927. It appears that canker has been completely eradicated from Florida, Alabama, Mississippi, and Texas, and all except one noncommercial area in Louisiana. It also appears to have been eradicated from Northern Australia and South Africa.

Economic Importance.—In Japan the Satsuma and other types of citrus which are commonly grown are not very susceptible to canker and the disease is not considered serious. In fact, it had attracted very little attention there and was generally confused with scab before its outbreak in Florida. On sweet oranges in Japan, however, there is considerable loss from canker (Tanaka, 1918).

In Florida both climatic conditions and the types of citrus most commonly grown seem to be particularly favorable to the development of this disease. The grapefruit, which is of especial commercial importance in Florida, is very susceptible, and the sweet orange is also very readily attacked. Citrus canker is therefore of much greater concern to Florida than to any other part of the world where the disease has occurred. In view of the rapid development of canker which took place in Florida between the time of its first appearance and the commencement of the eradication program and the destructive effect which it showed during that period, there can be little question that the Florida citrus industry would have been very badly affected if the disease had been allowed to continue. Unless some method of control could have been found it seems reasonable to believe that a very large percentage of all the oranges and grapefruit would have become affected in a disastrous manner.

During the eradication campaign it is stated that between 1914 and 1931 more than \$2,500,000 of state, federal, and private funds were spent in combating citrus canker in Florida alone and the total cost of this disease to the state was much greater than this, since in the eradication campaign 257,745 grove trees and 3,093,110 nursery trees were destroyed incidental to the eradication of this disease, which occurred in 515 properties scattered through 26 counties.

Possibility of Control.—Some control of citrus canker has been obtained in the Orient (and in South Africa before eradication) by spraying the trees. By this means it is possible to prevent the disfiguration of the fruit, at least to a certain extent. The possibilities of such control are very limited, however, especially where conditions are favorable to the disease, so that in Florida and also in South Africa campaigns were undertaken to eradicate canker from the affected regions. This work was

carried out by a systematic inspection of citrus groves and nurseries and immediate destruction by fire of all affected trees as soon as discovered. By this method, which was repeated as long as any case could be found, eradication was successfully accomplished in Florida and, according to Doidge (1929), in South Africa.

Adaptability to the California Environment.—The climatic conditions most favorable to citrus canker have been studied quite thoroughly by Peltier (1926) with the following conclusions:

Considering the temperature factor alone citrus canker could develop in all the citrus regions of the world some time during the growing season. The period over which it would be active depends on the number of months having a mean temperature of 68° F or above. The disease would be most severe at points having the greatest number of months with mean temperatures of 80° F or above. Temperature is in no case a limiting factor for the development of canker in any of the citrus regions of the world. Considering the moisture factor, a deficiency of precipitation during the growing season is the limiting factor in the development of citrus canker. Whenever the temperature and precipitation curves are ascending and rounding curves as they are for localities like the Gulf Coast states, China, and even South Africa, conditions essential for the development of canker are at hand, as these same conditions stimulate the rapid growth of the host plants and thus make them more susceptible. On the other hand, no canker has ever been found in those localities where, while the temperature curves are ascending and rounding ones, the precipitation curves are descending. In California when the highest monthly mean temperatures are reached the amount of precipitation is at its lowest point. If most of the annual rainfall occurred during the summer months rather than during the winter season, canker could develop to some extent as conditions would then be similar to those prevailing in South Africa and at Laredo, Texas, in 1916. The amount, frequency, and seasonal distribution of precipitation is a limiting factor. Apparently the seasonal distribution is the most important factor to consider, for on the seasonal distribution of rainfall depends to a large extent the development or inhibition of this disease in the citrus regions of the world.

According to the observations and conclusions of Peltier it does not seem probable that citrus canker would thrive under California conditions, owing to the dry summers. It will be seen from Peltier's conclusions that for the development of this disease it is necessary to have a combination of wet weather and high temperature. In other words, citrus canker is most active in regions with a warm, rainy summer, and least likely to develop in places where the summer is dry and rainfall occurs mainly in the cooler part of the year. This would suggest that citrus canker might not flourish in California, or that if it should become established it might be rather easily controlled and eradicated. If it should become established here, however, it might result in anti-California quarantines, even though it occurred in a very mild state.

Methods of Dispersal and Avenues of Entrance.—Canker is spread locally by wind, insects, pruning or other tools, and by any agency which might pass from one citrus tree to another. Over long distances the disease may be carried either on nursery stock or on citrus fruit, since both the tree and the fruit are attacked. In the case of the introduction of citrus canker into the Gulf states, and no doubt elsewhere into new countries, the disease has spread by means of infected nursery stock. In this country it appears to have been introduced first on seedling trees of trifoliolate orange shipped from Japan to Texas, Mississippi, Alabama, and Florida, where it spread to other varieties. It was also introduced on Satsuma orange trees shipped from Japan. In Florida, canker also developed in shipments of trifoliolate orange trees from Texas. There is no evidence that the disease has ever been spread over long distances on citrus fruit. The most probable method by which citrus canker might be introduced into California would be by the shipment of infected citrus nursery trees from the Orient. If such trees should be brought in and planted in this state the disease would presumably develop on them. After that it might either continue to develop and spread to other adjacent trees, if conditions were favorable, or otherwise it might die out and disappear. Next in importance would be the danger of the introduction of canker on affected citrus fruit, probably either sweet oranges or grapefruit. In this case the only way in which the disease could become established here would be for orange or grapefruit rinds having cankers that contained live germs of the disease to be thrown out and left in some place close to citrus trees. Even then the likelihood of the establishment of the disease in such trees is not very great. Since no case of canker has been found in Florida since 1927 there would seem to be very little danger of its introduction on citrus fruit from that state.

Efficacy of and Necessity for These Quarantines.—There were no specific quarantines against citrus canker in force when it was first introduced into the United States, and in fact the disease had never been definitely recognized or described. Trifoliolate and Satsuma orange trees were being brought in from the Orient to the Gulf states at that time. In California there was no embargo against Oriental citrus trees, but a quarantine inspection service has existed for many years, during which period many incoming shipments have been refused entrance on account of scale insects. Success in preventing the introduction of citrus canker into California seems to depend mainly upon excluding affected citrus nursery trees or fruit from the Orient or other infected areas. Under an efficient system of border and maritime-port inspection, local county inspection of all incoming nursery stock, and close supervision of citrus

districts by quarantine officers, there would seem to be comparatively small chance for any contraband material carrying this disease to be introduced. The Committee believes, in view of the fact that citrus canker has been eradicated from Florida, that the quarantine against that state should be rescinded. This would apply to fruit only, since citrus nursery stock is excluded at present by the citrus white fly quarantine. Florida and the federal government have spent millions of dollars in eradicating this disease. If California refuses to recognize successful eradication campaigns and to modify her quarantines accordingly, she cannot expect much consideration from other states when conditions are reversed.

The federal quarantine against foreign countries must of course be retained.

OZONIUM ROOT ROT

Nature and Cause of the Disease.—This disease (also called cotton root rot, Texas root rot) affects the roots of the host, causing wilting and death of affected plants. The disease spreads extensively from plant to plant, killing the host in an everincreasing area. The cause of the root rot is a soil fungus, *Ozonium omnivorum*, which spreads the disease in the field by its growth underground. The fungus produces spores on the surface of infected soil, but no evidence has been found that such spores serve to spread the disease.

Hosts.—The *Ozonium* fungus has a great variety of hosts, and is able to attack many cultivated crops and native plants. Probably the most important are cotton and alfalfa. Many vegetables and deciduous and citrus fruit trees are also susceptible.

History and Geographic Distribution.—*Ozonium* root rot was first recognized in Texas as early as 1888. The indications are that the fungus may have been an inconspicuous one on native plants which found more favorable conditions with the extensive planting of cotton and other susceptible hosts. The disease has now been found in Arkansas, Arizona, New Mexico, Oklahoma, southeastern California, and Mexico. The cases in California occur mainly on cotton and alfalfa in the Palo Verde, Imperial, Yuma, and neighboring valleys, and in most instances appear to have been indigenous on native vegetation.

Ozonium root rot was first found in California at the government date garden at Indio in August, 1928. The infection was at first supposed to have been introduced with rooted nursery stock from Arizona. It had extended over about four acres of land. Agents of the State Department of Agriculture immediately made an extensive survey of the Colorado River region and discovered apparently indigenous cases of the disease

near Blythe and Yuma. In 1930 an infested area of 1.6 acres was found on cultivated land near Indian Wells, Riverside County, about 5 miles from Indio. Soon after the discovery of the first infestation at Indio a special appropriation of \$25,000 was made by Congress to attempt to eradicate this fungus from the government date garden. With the co-operation of the California State Department of Agriculture the soil in the infested area was saturated with a solution of formaldehyde to a depth of 6 feet, with apparently successful results. The same method of treatment was afterward applied to the Indian Wells infestation.

TABLE 34
SUMMARY OF QUARANTINES AGAINST OZONIUM ROOT ROT

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
All plants with soil, roots, and all soil	May be admitted if free from roots and soil or if certified to be from a nursery free from disease	Cal. Quar. Ord. No. 13, N. S.	Arizona, Arkansas, Texas, Oklahoma, and New Mexico
		Cal. Quar. Reg. No. 2 (revised)	Small areas in eastern Riverside, Imperial, and San Diego counties

Economic Importance.—This disease is considered to be one of major economic importance, particularly in relation to the cotton crop in Texas. Texas at that time (1919) produced 2,700,000 bales. The losses from root rot that year were placed at 10 per cent, or a total of 313,900 bales. In 1920 Texas produced 4,200,000 bales. The losses from root rot that year were estimated at about 15 per cent.

The Texas Agricultural Experiment Station, in cooperation with the United States Department of Agriculture is carrying on an extensive study of root rot.

Possibility of Control.—The only methods of control for this disease lie in crop rotation and cultural practices. By such methods it has been shown that the fungus can be greatly restricted in its abundance in the soil. This is not an easy task, however, and cannot be accomplished without a very determined effort. Absolute eradication under field conditions is scarcely probable.

Adaptability to the California Environment.—This disease has thus far been most abundant in Texas and Arizona on cotton and alfalfa. The cases in California occurred in the desert region tributary to the Colorado River and adjacent districts. No cases of ozonium root rot have

ever been reported outside of the southwestern group of states and northern Mexico. This fact makes it appear probable that conditions in that region are peculiarly favorable to this fungus. It has been shown that heavy soil and abundant soil moisture in summer are favorable to the growth of the fungus, while in dry, sandy soil it makes less progress. High temperatures are also conducive to the development of the disease. Evidence to date indicates that conditions in the Colorado River region are favorable to this disease.

Judging by experience with the extensive plantings of cotton and alfalfa in the San Joaquin Valley and other parts of the state, ozonium root rot is not present in California except in Imperial, eastern Riverside, and San Diego counties. Climatic conditions in the San Joaquin Valley are enough like those in Imperial Valley and Arizona so that, in the heavily irrigated alfalfa and cotton soils, the *Ozonium* fungus would apparently find there a congenial environment. The further spread of this fungus in California, especially its extensive development in the San Joaquin Valley, would probably upset present agricultural practice to a considerable extent. By better cultural methods and crop rotation the disease might be held in check and in fact agricultural practice might eventually be improved. Nevertheless, if ozonium root rot should become abundant there would probably be considerable destruction of cotton and alfalfa, and the raising of these and other field crops would be interfered with. The disease might also constitute a serious problem in orchards and vineyards comparable to oak root fungus (*Armillaria*).

Methods of Dispersal and Avenues of Entrance.—This fungus spreads locally in the field by growth from root to root in the soil. It may be scattered more widely in the same region through the movement of infected roots or soil by flood water. The distribution of the disease over larger distances, as from state to state or country to country has never been known to occur in any specific instance except possibly the case at Indio, California. According to Peltier, King, and Samson (1926), "No instances are known where root rot has appeared in a field after it has produced healthy crops of a susceptible plant for a number of years, even though root rot may be present in neighboring fields."

If such spread could occur it would presumably take place only by the transportation of infected roots and soil. No evidence is available of any other possible method of distribution. This quarantine is therefore directed against plants with roots and soil attached, grown in infected soil. There appears to be no natural method of distribution by which this disease could be carried from its present location to those portions of California lying west of the Sierra Nevada. Transportation on roots

of nursery plants would probably be the only means of distribution—if it is possible to carry the disease by this method.

Efficacy of and Necessity for This Quarantine.—The circumstances of the occurrence of this disease at Indio certainly suggest strongly that ozonium root rot may be transported with nursery stock. Such an occurrence would readily have been prevented by this quarantine. The disease is important enough to justify active attempts toward preventing its further occurrence in California. Some criticism has been directed at the provision which permits introduction of rooted stock from the quarantined districts when “accompanied by an official-signed certificate of the state of origin establishing the fact that the material was grown on premises free from the rot” and defining “premises” as “not smaller in area than would encompass a radius of at least 100 feet.” This brings in a principle which is not recognized in any of the other quarantines herein discussed. This exception is based on the fact that the *Ozonium* fungus, so far as known, spreads only underground and can attach itself therefore only to roots of plants which have stood in such infested soil.

CHESTNUT BARK DISEASE

Nature and Cause of the Disease.—This is a destructive disease which kills the bark and cambium of twigs, branches, and main trunk of the chestnut tree. The dying of the bark forms cankers which soon girdle the branches and trunk, thus killing the whole top of the tree. This is one of the most completely destructive and rapidly spreading plant diseases which has ever occurred in this country.

Chestnut bark disease, or chestnut blight as it is often called, is caused by a fungus, *Endothia parasitica*, which grows in the bark and rapidly destroys it wherever the parasite becomes established. Spores are produced in great abundance in little pustules on the surface of the canker and affected bark, and these spores serve for the distribution of the disease (Heald, 1926).

Hosts.—The fungus which causes chestnut blight has been reported on a number of species of chestnut as well as several other kinds of forest trees. It is, however, of no economic importance on the latter. The Japanese and Chinese species of chestnut are so resistant to the canker fungus that little injury results from its attacks. On the other hand, the American chestnut is very susceptible and soon succumbs to the disease. This is a good illustration of an imported parasite that has found a more susceptible host in its new habitat. Evidently this fungus has lived on the chestnut trees in Asia for ages without materially damaging them,

but upon being introduced to our American species it at once became a menace to its existence. The European chestnut is very susceptible. The eastern chinquapin and the western chinquapin, while not immune, are much more resistant than the American chestnut. The fungus has been made to grow slightly in one or two species of oak by artificial inoculation but under natural conditions it probably is never a parasite of oak trees. It has been found growing naturally to a certain extent on the dead bark of a number of species of forest trees.

History and Geographic Distribution.—This disease was first noted in this country in the New York Zoological Park in 1904 but had apparently existed in that vicinity for a few years before that time. The dis-

TABLE 35
SUMMARY OF QUARANTINES AGAINST CHESTNUT BARK DISEASE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Trees and scions of <i>Castanea</i> and <i>Castanopsis</i>	Total	Cal. Quar. Ord. No. 2 N. S.	All states and districts east of and including Montana, Wyoming, Colorado, and New Mexico
		Fed. Quar. No. 37	All foreign countries and localities

ease spread rapidly and was soon recognized as a menace to the chestnut forests of the eastern United States. By 1908 chestnut bark disease was reported as serious in portions of Pennsylvania, New Jersey, New York, Connecticut, and Massachusetts. In 1914 the range of the disease had extended so that it was generally prevalent from southern Vermont, New Hampshire, and eastern New York, southward into northern Virginia and westward to central Pennsylvania, or in other words, over a district representing the principal range of the growth of this valuable native tree. At the present time the native chestnut has been almost exterminated and as a commercial timber tree seems to be doomed. An orchard infection has been reported from British Columbia and also one of two trees from southern Oregon, localities in both cases where chestnut is not native. These appear to have been eradicated.

The origin or native home of this fungus was one of the early questions for discussion, and two opposing views were held: (1) that the causal fungus was an obscure native of the United States that suddenly assumed prominence on account of unfavorable conditions for its host,

winter injury or drought; (2) that the disease had been introduced into this country from some foreign country, possibly Japan, with importations of nursery stock. This question was not settled until 1913 when the disease was discovered in China on native chestnuts by Meyer, an agricultural explorer of the United States Department of Agriculture. The disease was also found in Japan in 1915 and it is now generally believed that chestnut blight was originally a native disease of the Orient and that it was brought to this country on nursery stock.

The rapid progress of the disease in Pennsylvania, where the chestnut is a very important and valuable native tree, led to the establishment by the Pennsylvania Legislature in 1911 of the Pennsylvania Chestnut Tree Blight Commission with an appropriation of \$275,000 for the investigation and scientific study of the problem and especially to ascertain the extent of the blight and to devise ways and means by which it could be stamped out. The investigations were also supported by liberal appropriations by the federal Department of Agriculture and were continued cooperatively until 1913, when the Pennsylvania Commission went out of existence. As a result of these efforts much information was obtained concerning the disease, but its progress was not materially arrested nor was any method discovered of preventing its development or keeping it under control. This disease has never been definitely proved to exist in California, although there have been cases of chestnut trees dying in a more or less similar manner.

Economic Importance.—This disease is apparently of no economic importance in the Orient since the local species of chestnut are practically immune to its attacks. In this country the situation is a very different one. The chestnut is, or was, one of the main forest trees of southern New England, New York, Pennsylvania, and southward in the Allegheny Mountains to Alabama. Its wood was used extensively for furniture, finish lumber, telephone poles, railroad ties, and cord wood. Some idea of its value may be gained by noting the value of cut timber for several years before the blight fungus had wrought its destruction. In 1907 the total cut of chestnut for all purposes, including lumber, posts, poles, rails, cross ties, and tanbark, was valued at \$19,188,219. In 1909 the value of all chestnut timber produced was again estimated at about the same figure. The chestnut has particular value as a timber tree in semicultivated or old-settled regions on account of its rapid growth and habit of sprouting repeatedly from the stump, thus making possible the regular harvest of the timber crop in a more or less definite rotation. The tree is also highly prized as an ornamental and has been used extensively in parks and large estates. In addition to all

this the chestnut is a valuable nut tree, furnishing in its wild state a large harvest of edible material without cost. Beyond this the tree has long been propagated and cultivated in definite horticultural varieties both in Europe and in the Orient and such culture is gaining rapidly in this country. When one reflects that the canker disease has within less than 25 years practically exterminated this species over most of its natural range, the great economic loss reflected by its ravages can be readily appreciated.

Possibility of Control.—In spite of the expenditure of hundreds of thousands of dollars in the investigation of this disease by state and federal authorities, no method of control has been found, and the disease is still unchecked. The chestnut as a timber tree seems to be doomed. The only hope of control lies in the growing of resistant varieties for the production of edible nuts. Such varieties are already available, and new ones are being produced by selection and breeding from the Oriental species.

Adaptability to the California Environment.—The history of the chestnut blight disease in the Orient gives little information as to its climatic relations since its occurrence there is of such minor importance and the trees which it attacks are not of the same species as the American chestnut. The history of the disease in this country shows its ability to flourish over a rather wide range of localities, at least those in which the chestnut is a native tree. Since the tree itself does not occur naturally in semiarid localities and in such districts is not grown commercially where the bark disease exists, there is no opportunity of determining definitely the climatic limits of this disease. Like most fungus diseases which attack the twigs and branches of trees this one requires rainy weather or considerable atmospheric moisture for its development and undoubtedly is greatly favored by abundant rainfall during the growing season. Stevens (1917) showed some evidence that dry weather reduces the spread of the disease, but found that infection may take place at almost any time during the year when there is sufficient moisture. In California infection might take place and the disease spread during the rainy season.

The chestnut tree itself is at the present time so comparatively uncommon and unimportant in California that this subject cannot be discussed in a very satisfactory manner. The chestnut-bark-disease quarantine was established in this state more with the idea of protecting a promising future industry than for the benefit of one which already existed. It still remains to be seen, therefore, whether the edible chestnut will become a horticultural crop of any great importance in this

state and, if so, in what part of the state and under what conditions the industry will be located. It seems almost certain that in this climate of rainless summers a disease of this sort could not flourish and develop as rapidly as it has in the eastern United States. Some analogy may be drawn from the case of a number of fungus canker diseases of fruit trees (some of the apple-tree diseases, for instance) which have been introduced into this state but do not flourish here to any serious extent. On the other hand some fungus canker diseases like walnut melaxuma are very destructive in California. Some of these diseases are able to develop and spread during the rainy season. It is likewise to be considered that any chestnut industry in California would probably be entirely of a horticultural nature, with trees of cultivated, improved varieties and not a timber-producing industry. It might be possible to utilize varieties which are resistant to this disease. On the other hand, it might be said that as a rule the varieties derived from the American chestnut are of better quality and more popular here than are those of the European or Oriental types. It is very likely that such a disease as this could be kept under control more successfully in an orchard planting than in native forest trees. Conditions similar to the extensive native chestnut forests of the Atlantic states would never exist here.

Methods of Dispersal and Avenues of Entrance.—Chestnut blight can be spread over long distances only by the shipment of affected nursery stock. The fungus produces an abundance of spores on the surface of the affected bark and spreads locally by wind, insects, birds, and rain. The spores have been known to survive for several months and are produced from every canker in enormous numbers. After the disease is once introduced into a locality its local distribution wherever there are chestnut trees is very easy and cannot be prevented. There were no quarantines in force when chestnut bark disease was first introduced into the United States which could have prevented its introduction. Japanese chestnut trees were being brought in freely from the Orient and probably, to some extent at least, into California as well as into other states.

Chestnut blight might be brought into California in the same way in which it was introduced into the eastern United States, that is, the importation of chestnut nursery stock, either from the Orient or from any of the eastern states where the disease occurs. There is no other method by which the disease is likely to be introduced.

Efficacy of and Necessity for These Quarantines.—The growing of chestnuts might become an important industry in California from the very fact of the destruction of chestnut trees in the East by the blight.

From this point of view it is important to keep out the disease. The present embargo on chestnut nursery trees would seem to form a feasible method of excluding this disease from California. Nurserymen here already are supplied with most of the important commercial varieties and a limited amount of stock of promising new varieties can be introduced under proper regulation. The business of shipping chestnut trees into California is of extremely small importance to anyone. There seem to be no specific objections which can be raised against these quarantines. Since the disease which it attempts to exclude is of such an unusually virulent nature, and since the chestnut industry has some promise of future development in California, the maintenance of this embargo seems desirable.

POTATO WART

Nature and Cause of the Disease.—Wart is a disease of growing potatoes which causes the formation of warty excrescences on the tubers. It is caused by a fungus, *Chrysophlyctis endobiotica*, which develops in the affected parts.

TABLE 36
SUMMARY OF QUARANTINE AGAINST POTATO WART

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Potato tubers	Total	Fed. Quar. No. 3	Newfoundland, Great Britain, Germany

History and Geographic Distribution.—Potato wart has been known in Europe for some time and was reported in Newfoundland in 1909, where the disease became widespread. It appeared in eastern Canada in 1912 and in a small area in Pennsylvania and West Virginia in 1918. In all the places of its occurrence wart has been easily suppressed or even eradicated by crop rotation, soil treatment, and use of immune varieties. The disease has completely disappeared in Canada and several other countries and in the United States has never appeared in commercial potato-growing districts (Heald, 1926).

Potato wart has never been observed in California.

Economic Importance.—In England wart is considered one of the most serious diseases of the potato, while in Germany and some other countries it is taken to be of little importance. This difference may be partly accounted for by the fact that there is a great variation in the susceptibility of varieties. Some kinds of potatoes are very badly affected while others are practically immune.

Adaptability to the California Environment.—Potato wart has thus far occurred only in cool humid climates. Soil conditions would probably be more important, however, than atmospheric relations. Abundance of soil moisture is favorable to the disease. There is no reason to believe it would not thrive in California.

Methods of Dispersal and Avenues of Entrance.—Potato wart is spread in tubers used for seed or by the peelings of affected potatoes thrown out in gardens where potatoes are afterward planted. It was probably brought into the United States on potatoes which were shipped from Europe in large quantities prior to the establishment of this quarantine in 1912. The disease could be introduced only on living tubers.

Efficacy of and Necessity for This Quarantine.—There is no apparent reason why this disease would not flourish here, and on susceptible varieties it might prove very destructive in a region like the Delta potato district. It should be easy to exclude by strict enforcement of the present quarantine.

WOODGATE RUST

This is a gall-forming rust, caused by a species of *Peridermium*, which occurs on Scotch pine. It is called woodgate rust because it was first found at Woodgate, New York, in 1925. It has not yet been positively

TABLE 37
SUMMARY OF QUARANTINE AGAINST WOODGATE RUST

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Trees or branches of several species of pine	Total	Fed. Quar. No. 65	Several counties in New York State

determined whether this rust was introduced from some foreign country or whether it is a form which already occurs in the western United States on one of the native species of pine. It has been shown by inoculation that woodgate rust can infect the ponderosa (western yellow) pine, Monterey pine, and digger pine, as well as several other species. These native pines are already subject in California to a similar disease. The woodgate rust has no alternate host so that it cannot be controlled by eradicating another plant, as with the currant and gooseberry in the case of the white-pine blister rust, or the barberry in the case of wheat rust (H. Metcalf, 1930).

If this rust is a foreign species which is not in California at the present time it might form a menace to an important timber tree, the ponderosa

pine, as well as to the Monterey pine, which has considerable value for ornamental planting. It is not likely to find its way into California otherwise than on nursery stock of Scotch pine, and there is no reason why this plant should be shipped into the state. On account of the possible damage to valuable timber trees, and until the identity of this rust is established, this quarantine seems justified and capable of enforcement.

HOP DOWNY MILDEW

A destructive mildew of hop shoots and foliage was first described in Japan in 1905, and since then has appeared in most countries of the world where hops are grown. The disease is present in Oregon, Washington, and in British Columbia, but has not been found in California.

TABLE 38
SUMMARY OF QUARANTINE AGAINST HOP DOWNY MILDEW

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Sets, roots, and cuttings of hops	Total	Cal. Quar. Ord. No. 14 N. S.	All parts of Canada and the United States

It is caused by one of the downy-mildew fungi, *Pseudoperonospora humuli*. Downy mildews require a large amount of atmospheric moisture for their development and no case is known in California of a downy mildew seriously attacking any crop grown in the summer season. Fungi of this class attack the spinach, cabbage, lettuce, alfalfa, onion, beet, tomato, and potato here during the rainy season, but disappear during the summer. The well-known downy mildew (*Peronospora*) of the vine does not occur here at all, although it probably has been introduced many times. This can only be accounted for by the rainless summer. However, hops are grown extensively in districts in Sonoma and Mendocino counties where there is much fog and the possibility of rain as late as June and as early as October. It is possible that this disease might cause considerable damage in such localities.

PHONY PEACH

This is a serious, communicable disease of peaches of unknown cause, apparently of the nature of a virus or mosaic disease (Neal, 1920). It has been shown that the disease spreads only through the roots. It causes a stunting of the trees and much loss of production. The disease was first

observed in Georgia and has spread considerably in recent years (Hutchins, 1929). Efforts are being made by federal and state authorities to eradicate the phony disease by destroying all affected trees. The original quarantine (1929) covered only portions of Georgia and Alabama. Subsequent amendments have extended the quarantined area to that shown.

TABLE 39
SUMMARY OF QUARANTINE AGAINST PHONY PEACH DISEASE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Peach and nectarine trees or roots	Trees may be shipped under permit from nurseries where for 2 years there has been no phony peach within 1 mile	Fed. Quar. No. 67*	Alabama, Georgia, Louisiana, Mississippi, South Carolina, and portions of Arkansas, Florida, Illinois, North Carolina, Tennessee, and Texas

* Quarantine rescinded as of March 1, 1932. Host plants excluded from infected area by fruit moth quarantine (table 20).

There is no reason to think that this disease would not flourish in California. The only way that it could be widely distributed would be by shipments of infected nursery stock, so that the quarantine from the California standpoint seems well justified.

CORN DISEASES

This quarantine is directed against a number of destructive corn diseases which are not known to occur in the United States at the present time (Stevenson, 1926). Some of these troubles would probably flourish in California while others might not. The causative organisms are *Pero- nospora maydis*, *Sclerospora sacchari*, *Physoderma zeae-maydis*, and *Physoderma maydis*.

TABLE 40
SUMMARY OF QUARANTINE AGAINST CORN DISEASES

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Seeds and other portions in raw state, of Indian corn and closely related plants	Entry allowed under permit and treatment	Fed. Quar. No. 24	India, Siam, Indo-China, China, Malay- an Archipelago, Aus- tralia, New Zealand, Oceania, Philippines, Formosa, Japan

RICE DISEASES AND INSECTS

This is a general embargo against bringing viable rice seed into this country on account of the danger of introducing a number of serious pests and diseases which do not at present occur in this country and

TABLE 41
SUMMARY OF QUARANTINE AGAINST RICE DISEASES AND INSECTS

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Seed or paddy rice	Total except under regulation from Mexico	Fed. Quar. No. 55	All foreign countries except Mexico

which could be introduced only in this manner (Stevenson, 1926). The diseases are caused by *Sclerospora macrocarpa*, *Entyloma oryzae*, *Oospora oryztorum*, and *Melanomma glumarum*.

There appears to be no reason to question the necessity and probable effectiveness of this quarantine.

BAMBOO SMUT

This smut, caused by a fungus, *Ustilago shiraiana*, affects various species of bamboo in Japan and China. The disease attacks the growing points of young branches and causes a witches' broom effect, masses of dark brown smut spores breaking out beneath the leaf sheaths. Infected parts are stunted and considerably damaged (Stevenson, 1926).

TABLE 42
SUMMARY OF QUARANTINE AGAINST BAMBOO SMUT

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Seeds, plants, or cuttings of bamboo for propagation	Total	Fed. Quar. No. 34	All foreign countries

The disease attracted attention in this country because of its appearance in 1910 at the Chico, California, Plant Introduction Garden on bamboo plants imported from Japan. A similar introduction occurred in Florida. Eradication was successfully accomplished in both places. As a result of these introductions this quarantine was set up, establish-

ing an embargo against propagating material of any species of bamboo from any part of the world.

Although bamboo may not be considered a plant of great economic importance in California, the quarantine seems desirable, unobjectionable, and effective for the protection of a desirable plant material against disfiguration by this pest. Plenty of propagating material of a large number of species of bamboo is already available in this country.

FILBERT BLIGHT

This is a fungus twig blight of the hazel or filbert, native to the eastern United States, and caused by *Cryptosporella anomala*.

TABLE 43
SUMMARY OF QUARANTINE AGAINST FILBERT BLIGHT

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Trees, plants, or cuttings of the filbert and hazelnut	Total	Cal. Quar. Ord. No. 4 N. S.	All states east of and including Montana, Wyoming, Colorado, and New Mexico

Filberts are of little economic importance in California at present but might become so in the future. Consequently it is desirable to guard against the introduction of diseases. This regulation also is of value to the state of Oregon, where filberts are a more important crop.

NARCISSUS BULB QUARANTINE

This quarantine provides that interstate shipments of narcissus bulbs must bear a certificate signed by an inspector of the federal Bureau of Plant Quarantine, stating either that they have been found apparently free from the bulb nematodes (*Tylenchus dipsaci*, *Aphelenchus subtenuis*) and the greater bulb fly (*Merodon equestris*), or that they have been treated according to certain methods prescribed by the United States Department of Agriculture. This regulation violates in several instances what the Committee believes to be fundamental principles of plant quarantine.

The Secretary of Agriculture is authorized to quarantine areas within the United States in order to prevent the spread of a dangerous plant disease or insect infestation "new to or not theretofore widely prevalent or distributed within or throughout the United States." This clause,

quoted from the federal Plant Quarantine Act, is of course subject to various interpretations, but in this instance it is interpreted by the federal department in a very different way from what is true in the case of every other plant disease or pest. One or all of these pests occur in every commercial narcissus-producing section of any importance in the United States. It cannot therefore be considered as a measure to prevent the introduction or establishment of a pest or disease in a locality where it has not previously occurred, unless “locality” is interpreted to mean an area as small as individual plantings, an interpretation which scarcely seems justified so far as the federal government is concerned.

TABLE 44
SUMMARY OF QUARANTINE AGAINST BULB NEMATODES AND THE GREATER
BULB FLY

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Bulbs of the genus <i>Narcissus</i>	Must be accompanied by federal certificate certifying that they are free of pests, or that they have been disinfected	Fed. Quar. No. 62	Each state of the entire United States

It provides for the movement of host plants if inspection fails to reveal infestation. As has been pointed out elsewhere, the Committee believes that it is futile to attempt to prevent the spread of pests and diseases on the basis of inspection of the host plant, and that would seem to be particularly true of such organisms as nematodes which, when scarce or immature, would be practically impossible to find.

It also provides for the movement of host plants when treated according to methods prescribed by the Department, yet representatives of the Department state that a complete kill of the pests is not secured by this treatment. To permit the movement of infested host plants to supposedly clean areas, under treatment which admittedly does not give a complete kill, hardly seems consistent with the quarantine idea.

There are other inconsistencies in this quarantine. For example, it is recorded by the Department that this nematode has 144 species of host plants, among which are many cultivated plants including potatoes, sweet potatoes, onions, strawberries, alfalfa, and many others, none of which, so far as the Committee has been able to learn, is subject to these restrictions. There are no requirements for the sterilization of the soil in which the infested bulbs have been grown and in which the nematodes can survive, and the pest is easily spread in irrigation water.

It is understood that this quarantine was originally promulgated in the hope that these pests could be eradicated. It is believed that the methods pursued will not result in anything like eradication, and it is difficult to believe that the quarantine will even result in protecting any area from the establishment of these pests.

The facts are that Quarantine 62 is not a *quarantine* measure, in the sense that quarantines are designed for the purpose of protecting free areas; but is in reality only a *control* measure. As such, it undoubtedly is useful, but it is questionable whether such activities are properly a function of the government, and particularly of the national government. Since this regulation obviously will not prevent the infestation of clean properties, but serves only to *reduce the damage* incurred by individual producers, it seems to the Committee that it is properly a problem for the individual producer, just as any other producer of crops must control his plant pests and diseases in order to succeed. There seems to be no reason why a bulb grower should not voluntarily treat his propagating material before it is planted, or suffer the loss, just as a grower of any other crop has to do.

In the hearing on this quarantine before the federal Bureau of Plant Quarantine, held in Washington, D. C., March 28, 1932, one of the arguments almost unanimously advanced by the speakers was to the effect that if the federal quarantines were removed they greatly feared the possible action of the individual states. This quarantine does not differ from any other federal quarantine in this respect, and the same argument could be advanced against the rescinding of any federal quarantine, and undoubtedly will be so advanced in the future. This argument, in order to be consistent, should go further and advocate the taking over of all interstate quarantines by the federal government.

In the case of Quarantine 62, however, the argument that it is necessary to retain the federal quarantine in order to prevent more stringent, or unfair, state regulations has little weight, since Quarantine 62 itself authorizes the individual states to require additional protection if they desire it, and the presence of a federal certificate on a shipment of bulbs will not render them exempt from these additional state requirements.

The treatment of bulbs is undoubtedly desirable as a control measure, but the Committee believes that this type of regulation is scarcely worthy of the attention of the federal Bureau of Plant Quarantine.

GENERAL FRUIT AND VEGETABLE QUARANTINE

This quarantine, like the following, recognizes the fact that inspection of commodities is not a reliable safeguard against the introduction of pests and diseases, and also the fact that insects and diseases of no apparent importance in their native habitat may become of major importance if introduced into this country. It is of course of primary value in connection with the exclusion of various species of fruitflies (*Trypeti-*

TABLE 45
SUMMARY OF FRUIT AND VEGETABLE QUARANTINE

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
All fresh fruits and vegetables	May be entered under permit only when the Secretary of Agriculture has determined that there is no danger of introducing pests and diseases	Fed. Quar. No. 56	All foreign countries except Canada

dae). Such a quarantine appears to the Committee to be of very great importance, particularly if administered with good judgment, as seems to be true in this instance. The Bureau of Plant Quarantine is desirous of avoiding any regulations which interfere unjustifiably with international trade and has adopted as liberal an attitude toward the issuing of permits for imports of fruits and vegetables as is consistent with proper protection. It is to be hoped that the development of methods of disinfection and disinfestation will gradually reduce the necessity for these restrictions.

GENERAL FOREIGN-NURSERY-STOCK QUARANTINE

As will be seen, this is a general nursery-stock, plant, and seed quarantine. For several years after the enactment of the federal quarantine law of 1912, the United States Department of Agriculture permitted the entry of the commodities mentioned, under certification by the officials of the country of origin as to freedom from pests and diseases, but subject to inspection upon arrival in this country. In spite of the certification large numbers of plants continued to arrive infested or infected with many dangerous pests and diseases which did not occur in the United States. It was finally decided that the only way this country could be safeguarded against the ultimate establishment of these pests

and diseases was to exclude such commodities. This resulted in the promulgation of Quarantine 37.

This quarantine, however, provides many exceptions to the complete exclusion of all nursery stock and seeds. Its aim is to reduce so far as is reasonably practical the danger of entry of pests and diseases of plants, and at the same time to permit the entry under proper safeguards of such materials as are vitally necessary for the development of agriculture, including gardening. For example, there is provision for the unlimited importation of certain classes of plants which are deemed neces-

TABLE 46
SUMMARY OF QUARANTINE AGAINST FOREIGN NURSERY STOCK

Commodity affected	Degree of exclusion	Quarantine	Districts quarantined against
Nursery stock and other plants and seeds	General, except that some species of bulbs, seeds, scions, etc., may come in under permit; special permits may be issued for other stock when deemed necessary by U. S. D. A.	Fed. Quar. No. 37	All foreign countries and localities, also Philippines and Guam

sary for the development of the horticulture of the country, including certain bulbs, rose stocks, certain fruit stocks, scions, and buds, and many kinds of seeds. There is provision for the importation under proper safeguards of limited quantities of many other kinds of plants for the purpose of supplying the country with new varieties. And there is provision for the importation of propagating stock for any necessary experimental, educational, or scientific purpose.

Efficacy of and Necessity for the Quarantine.—Only by the promulgation of such a quarantine as this is it possible even to hope to protect the agriculture of this country from introduced pests and diseases. Not only has it been demonstrated that inspection is not a reliable safeguard against such introductions but, as pointed out elsewhere in this report, it is a fact that many of the most serious pests and diseases are species which were so rare in their native habitat that they were either entirely unknown or were considered to be of no economic importance, hence there would have been no reason to promulgate specific quarantines against them, and their hosts would have been permitted unlimited entry into this country. There is no doubt but that there still exist in foreign countries numerous species of insects and diseases which, though of no importance in their native habitat, would prove serious if established in

the United States. Quarantine 37 is designed to prevent such occurrences. It is difficult to see how any quarantine system could be made effective against the introduction of foreign pests and diseases without such a provision.

There is no good reason why such a quarantine should not effectively accomplish what it is designed to do, and the Committee believes it is clearly justifiable and very important. There has been a great deal of criticism of this quarantine on the ground that it interferes seriously with international trade. It does, of course, but even though there are objections to it, Quarantine 37 is so essential to the protection of American agriculture that the objections are far overbalanced by the advantages of the regulation. It is the very backbone of the American plant-quarantine policy.

SUMMARY AND CONCLUSIONS

Plant quarantines serve a useful purpose in preventing or delaying the spread of pests and diseases, provided they are maintained within reasonable biological and economic limits.

The feasibility of preventing or delaying the spread of plant pests and diseases into new habitats depends primarily on fundamental biological factors related to dispersal.

Under primitive conditions plants and their insect and disease-producing parasites were in a state of equilibrium so far as dispersal is concerned. They had already occupied all those parts of the earth's surface in which they were fitted to exist, except where they were excluded by natural barriers. There was also established and maintained a sort of equilibrium in the degree of damage caused by plant pests and diseases.

The organisms causing plant diseases affect various parts of the host and they spread to other plants by means of spores, or by means of resistant cells or cell aggregations. They may be transported while attached to some part of the host, or they may be carried by wind, streams, birds, insects, etc. Plant-feeding insects vary greatly in habit, attacking various parts of their host plant either above or below ground. Some insects are capable of flying considerable distances or are blown by the wind. Dissemination of others is limited largely by the movement of their host plants. Many species, such as beetles, may be carried by commerce in commodities which have no connection with their host plant.

In the spread of plant pests and diseases to new localities, three different topographical situations may be distinguished: (1) continents separated by oceans; (2) areas on the same continent separated by pronounced natural barriers such as high mountains and broad deserts; (3) areas on the same continent not separated by natural barriers. So far as continents separated by oceans are concerned, the natural distribution of pests and diseases is practically confined within such areas. Therefore their escape to another continent can take place only through the agency of man. The intracontinental spread between areas separated by natural barriers presents a somewhat similar situation, but a topographical feature may be a natural barrier for one organism and not for another, and such barriers may be only partial. Ordinarily a plant quarantine can be considered sound only when supported by a barrier preventing or greatly retarding natural dispersal.

Where the activities of man constitute the only agency of dispersal, the efficacy of quarantine depends upon the nature of the intercourse between the infested and the clean districts.

Plant quarantines do not necessarily have to result in the interception of every individual of an insect or pathogenic organism in order to be effective and justifiable, since a majority of introductions fail to result in establishment because of environmental resistance. Even intentional establishment of plant-feeding insects is often difficult.

The mere fact of the establishment of a plant disease or pest in an area new to it does not necessarily mean that it will become of serious importance in that area. Both the climatic and the biotic features of the environment influence the virulence and abundance of organisms. No method has yet been developed by which it is possible to ascertain positively in advance whether or not environmental conditions in a new habitat are favorable to a given plant disease or pest, but in some cases the evidence is so conclusive as to leave no reasonable doubt.

Many plant diseases and pests have more than one host, and new host plants introduced into an area may pick up a local disease or pest which may then become of major importance. Plant diseases often become more destructive or pests more abundant in a new habitat than they were in their native home, because of reduced environmental resistance, or because they find more suitable host conditions.

There are four principal systems of plant quarantine: inspection at point of destination; inspection and certification at point of origin; complete embargoes; and controlled introduction.

It is the opinion of the Committee that in general a quarantine cannot be made effective when reliance is placed solely on inspection of shipments of plants and plant products either at origin or destination to determine the presence of infestation or infection. A plant quarantine, to be effective, must either: (1) exclude host plants or parts thereof which may carry the pest or disease, originating in the infested or infected area; (2) permit the entry of hosts from the infested or infected area only if they have been produced and packed under such conditions as to preclude their carrying the pest or disease; (3) permit the entry of hosts from the infested or infected area only if they have been subjected to treatment which will free them from live infestation or infection.

A plant quarantine, in order to be effective and justifiable, must provide for the closing of the major avenues of entrance of the pest or disease, and must be maintained by a force sufficient actually to carry out its provisions.

Because of the existence of innumerable species of plant diseases and plant-feeding insects, it is necessary practically to compromise between exclusion of all insects and diseases with complete cessation of exchange of commodities, and the unrestricted exchange of commodities with extreme risk of introduction of dangerous pests. This compromise must take the form of a program of controlled exchange with reduced risk. Therefore the rule seems to be justified that a quarantine against a specific pest or disease should be promulgated only if there is a reasonable chance that it would prove serious in the area to be protected, unless the regulations are inexpensive to enforce and are such as to create little or no economic disturbance.

Insect pests and plant diseases often appear more serious to those who do not have them than to those who do. Exaggeration of the danger from pests and diseases is unnecessary and in the long run will weaken public support of plant quarantines.

Plant quarantines should never be used for any purpose other than the exclusion of pests and diseases.

A plant quarantine should be so drawn and administered that there is the least possible interference with the movement of persons and commodities consistent with the accomplishment of its purpose.

If the major usefulness of a quarantine has passed, or if it becomes evident that it is no longer effective, it should be promptly rescinded. If a state or country does not recognize this obligation, it cannot expect and rightfully demand fair treatment in this regard by other states and countries.

The possibility of eradicating a pest or disease greatly increases the importance of the quarantine policy. The failure of a quarantine to prevent the incipient establishment of a pest or disease does not exclude the possibility of preventing *permanent establishment*, since it may be followed up by a successful eradication campaign. Eradication campaigns should be undertaken only after a most thorough analysis of the situation from economic, biological, sociological, and legal standpoints. When these are all favorable, quarantine officials should not hesitate to urge this action. It is not necessary to accomplish by artificial means the destruction of the last individual of the pest or pathogenic organism in order to bring about eradication. In some cases at least, the destruction of the major portion of such organisms will result in the completion of the job by Nature herself.

The question of property rights is an important one in eradication campaigns. In the compulsory *eradication* of a pest or disease, in so far as it deprives the grower of valuable property or puts him to expense in

excess of what would be necessary for mere *control*, the citizen is deprived of his property for the benefit of society and should be entitled to compensation. The right to compensation for such purposes has been recognized in connection with the eradication of the foot-and-mouth disease in California, and the Committee believes the destruction of plant property for like purposes is a parallel case.

The immediate effects both of the spread of plant pests and diseases and of quarantine regulations to prevent their spread are to reduce the total income of society and to alter the distribution of the income among the members of society. The ultimate effect of the spread of pests and diseases is to increase the amount of human effort necessary to produce a given amount of agricultural products. The ultimate effect of quarantine regulations, if successful, is to prevent such an increase. From a broad social point of view a quarantine is economically justifiable so long as it requires less effort to maintain the quarantine than it would take to overcome the damage caused by the pest or disease.

In order to make an intelligent choice between the alternatives of preventing the spread of pests and diseases by establishing quarantines and of overcoming the damage by pests and diseases if introduced and established, it is necessary to consider first the biological possibilities of preventing the spread; and second, all of the economic, social, and political consequences that would result from the spread of the pest or disease and from the attempts to prevent such spread. The economic consequences resulting from the spread of pests and diseases or from quarantine regulations are more numerous and far-reaching in changing the distribution of income among individuals and classes of people than in changing the total income to society.

The economic consequences change and vary from time to time, place to place, and group to group. The short-time effects on any group or class of people often are just the opposite from that of the long-time effects. The effect on individuals is often the opposite from that of the effect on the class or group to which the individual belongs. The short-time effects on the distribution of income tend to disappear as shifts and changes are made in production, consumption, wages, rents, land values, etc. The ultimate long-time effect tends to be only the net change in the amount of productive effort devoted to agricultural pursuits.

Most people are more interested in the short-time effects on their own incomes than in the long-time effects or in the effects on other people or on society as a whole. In evaluating plant quarantines all classes of people and all points of view must be taken into consideration.

Plant-quarantine regulations and the spread of plant pests and diseases affect some people directly and others only indirectly. The direct economic consequences of quarantines are :

1. Public expenditures to maintain quarantine regulations. Taxes produce a long sequence of events depending on the shifting, incidence, and diffusion of the tax burden. Taxes are often collected from persons who receive no immediate or direct benefits from the quarantines.
2. Interference with the movement of persons and commodities across quarantine lines. The economic consequences resulting from the interference with commodity shipments depends upon the amount of goods excluded and the costs involved. If the costs of inspection, certification, and treatment are very small, or if they are paid by tax funds, then there are only insignificant changes in the volume of commodities transported and in the prices received or paid. If the goods are completely excluded by the quarantine regulation the effects are equal to the effects of an economic embargo and necessitate changes in production, consumption, or both.

The indirect economic consequences of quarantine are :

1. The prevention of changes in supply and price that would result from the establishment and spread of a new pest or disease.
2. Changes in the markets, supply, price, demand, and consumption of other commodities and services than those directly affected by the quarantine. These effects arise from what people think or believe about quarantines. A quarantine may be socially desirable, but if many people believe that it is undesirable or resent the effect it has on them, they may try to retaliate by applying other restrictions or by purchasing goods from other sources, or by using substitutes. These indirect effects of quarantine may be more important than the direct effects.

The total losses and gains resulting from plant-quarantine regulations or from the effects of new pests cannot be measured in dollars and cents for all classes or groups combined. The producers and middlemen receive in dollars and cents the amount that all consumers pay. However, since a large part of the consumers and some of the producers are in other states and in foreign countries, the monetary incomes to people in a particular state may be greatly altered by the spread of diseases and pests and by quarantine regulations affecting the movements of commodities.

The long-time effects on money incomes to people of a particular state from new pests and diseases or adverse regulations will be to re-

duce their total money income because no single state has a permanent monopoly on the productive agricultural resources of the world and has no lasting assurance that consumers will continue to want the products grown in that state. The only way to maintain incomes from crops permanently is to raise commodities that consumers want and to produce and market these commodities more cheaply than they can be placed on the markets from other potentially or actually competing areas.

The short-time effects on money incomes vary with different crops, according to other economic conditions that happen to prevail. In general, for crops for which there is now a surplus, the short-time effects of a new destructive pest or disease would be to increase prices and the total money returns to producers as a group. For some crops the prices would not rise enough to offset the decreased volume, and total returns to producers would be smaller.

If the pest or disease can be, and is, effectively controlled, then gross money value remains the same as it would be if the pest or disease were not present, while producers receive a smaller net income by the amount of the costs of controlling the pest or disease.

The individual grower always receives a smaller gross income and a smaller net income from a crop damaged by pests and diseases than from an undamaged crop, unless he produces a very large proportion of the total supply; and then, like all producers of the crop as a group, he may receive a larger income. The best interests of the individual producer require maximum production on his part, while the monopolistic interests of producers as a group may require curtailed production. The consumer, however, always benefits from an abundance of production.

The biological nature, and the probable direct and indirect economic effects of each new plant pest or disease, must be carefully compared and weighed against the probable direct and indirect effects of a quarantine against it. Only after such consideration is any one qualified to offer an intelligent opinion for or against a particular quarantine. Each quarantine should be considered on its own merits rather than on the merits of the whole system of quarantine procedure.

The plant-quarantine policy arose in California as a result of the disastrous experiences fruit growers had with several serious insect pests which were not native to this state.

There has been a steady growth of the plant-quarantine program in California since the time of the phylloxera era in the seventies. Personnel and appropriations have increased with rapidity in recent years and a gradual improvement in the conduct of the work up to the present time is observable.

California is probably more fortunately situated from the standpoint of the feasibility of plant quarantine than any other section of the United States, because the principal agricultural areas are surrounded by high mountains, deserts, and the ocean, which constitute barriers to natural dispersal of pests and diseases. With regard to the introduction and establishment of pests and diseases through human transport this state is unfortunately situated because of the great variety of crops resulting from the varied climatic conditions, because of exposure due to extensive foreign commerce passing through her seaports, and because of her extensive tourist travel.

Between 10 and 20 per cent of the productive effort now applied directly and indirectly to agricultural production in California is used to overcome the undesirable effects of the pests and diseases already present in the state.

Admitting that under certain conditions plant quarantines may prevent or delay the establishment of new pests or diseases, there is still the possibility that the general growth of the plant-quarantine policy now taking place throughout the United States and other parts of the world may become a serious problem for California, because this state is probably more dependent upon outside markets than is any other state in the Union. Serious restrictions on the distribution of farm products might conceivably become a more difficult problem for the California producer to meet than the control of new pests and diseases. If California should maintain unfair and unnecessary quarantines this would greatly increase the danger of restrictions against her products on the part of other states. The losses to the state may be just as great from retaliatory measures as from justifiable quarantines established against any major or minor pest. If new pests become established then the chances of quarantine regulations in other areas against California products are very great. It would be unwise for the state to abandon the principle of quarantine, because of the danger that diseases or pests would enter and other areas would then establish quarantines against California products. It is quite as unwise for the state to maintain any unnecessary or unimportant plant quarantines because they may produce similar results. For purely selfish reasons therefore, if for no other, it is essential that California quarantines be based on sound biological and economic principles and that they be fair to, and considerate of, the other states.

The economic effects that would arise from quarantines or other restrictions imposed by states and foreign countries against major products shipped out of California would result in considerable losses both

to society and to the producers in California if such regulations restricted shipments. Consumers in other areas would have to get along with fewer or no products from California and the prices in California would immediately fall and remain low until restrictions were removed or production curtailed.

California plant-quarantine regulations have no appreciable effect on prices received by California producers for such major crops as alfalfa, cherries, potatoes, oranges, grapefruit, lemons, and cotton. The effects of quarantine regulations on the supply and price of minor commodities, especially nursery stock, varies according to the amount of shipment in or out of the state for specific grades and varieties. No generalized statement of effects can be made. The indirect effects from quarantines on minor products may be just as important as those arising from quarantines relating to major products.

The exclusion by quarantines of noncommercial quantities such as samples, souvenirs, lunches, etc., carried by tourists or shipped to friends, have no direct effect on prices but often cause misunderstanding and resentment, and the indirect effects may be of considerable importance.

The consumers in California are chiefly affected by such quarantines as that which completely excludes fresh grapefruit from all areas except Arizona. Consumers in the state do not pay higher prices but substitute canned grapefruit, other products, or buy fresh California or Arizona grapefruit, which is produced in sufficient quantities for shipment out of these states, and therefore cannot command higher prices for local consumption than in other states.

The numerous plant quarantines, both federal and state, are of varying degrees of importance and effectiveness from the California standpoint. Some pests, like the fruit flies, are undoubtedly menaces to California horticulture, and it is felt that any reasonable effort to keep them out is justifiable. Since most of them occur in such localities that they cannot reach California by natural dispersal, it is believed that these quarantines have been, and should continue to be, effective. Other pests and diseases, such as the pink bollworm, Oriental fruit moth, phony peach disease, etc., are also potentially serious to California and the quarantines are amply justified from this standpoint, though the existence of these pests and diseases in continental United States makes it much more difficult to exclude them by quarantine methods. The danger to California from the Japanese beetle, satin moth, peach yellows and rosette, downy mildew of hop, and many others is not so evident, although the Committee believes it is desirable to attempt to exclude them,

particularly where the quarantines create no important economic disturbance.

Federal Quarantine 56, the general foreign fruit and vegetable quarantine, and Quarantine 37, the general foreign nurserystock quarantine, with their provisions for necessary exceptions, are essential to the protection of American agriculture.

The Committee believes the quarantine against citrus melanose is no longer justified, on the ground that it has occurred in several citrus sections in California for many years and is of no importance; and that the citrus canker quarantine against Florida is unjustified on the ground that this disease has not been found in Florida for nearly six years and has apparently been eradicated. It is believed that these two quarantines should be rescinded. The federal domestic bulb quarantine is very difficult to justify, either on the grounds of necessity or effectiveness.

Two administrative agencies are concerned with interstate plant quarantine in California, viz., the Bureau of Plant Quarantine of the United States Department of Agriculture, and the Division of Quarantine Administration of the California State Department of Agriculture. The federal agency is responsible for all foreign quarantines and for certain interstate quarantines. The state agency is responsible for certain interstate quarantines against pests and diseases not quarantined by the federal agency. The state agency is prohibited from promulgating quarantines against subjects covered by the federal agency, but is authorized to act against shipments coming in in violation of federal quarantines.

The maritime-port inspection work is handled by the state inspectors under appointment as collaborators of the federal government. Because of the existence in countries bordering the Pacific of many serious plant pests and diseases not yet in California, this activity is undoubtedly very important. It is conducted with thoroughness and with little complaint.

Border inspection is carried out by state inspectors under state authority. This activity seems to be justified by the fact that several important pests and diseases occur in other states but not in California. Among these are the pink bollworm, the Mexican orange maggot, the Oriental fruit moth, the Japanese beetle, the gipsy moth, the Colorado potato beetle, the cherry fruit flies, the white-pine blister rust, and the phony peach disease. Many of these are frequently intercepted at the border stations. There is objection on the part of a few travelers to this border work, although many of their complaints are trivial.

The interior inspection, i. e., inspection at freight and express stations and post offices, is handled by the county agricultural commission-

ers and their inspectors under authority of the Director of Agriculture. The published records of this activity show relatively few interceptions of contraband or of major pests and diseases. However, this is explained by the fact that knowledge on the part of shippers of the existence of the quarantines and of a strict policy of examination at destination undoubtedly precludes the shipment of material which would otherwise come in in much larger quantity. The amount of contraband is not therefore a measure of the necessity for the quarantines but is a partial measure of the efficacy of the quarantines. If the California quarantine program is to be worth while, this activity is essential.

The Committee believes there are weaknesses in the system for handling the interior inspection of interstate shipments which would justify a comprehensive study with the view of eliminating them. The promiscuous scattering of possibly infested or infected material over the entire state, where it may be delivered at several thousand stations, is in itself dangerous. If at all feasible, it would be desirable to examine these shipments for contraband before they become so widely scattered.

The Director of Agriculture is legally responsible for all interstate quarantine activities of the state. He is dependent upon the county agricultural commissioners for the actual conduct of this work. While these latter officials are required by law to carry out the instructions of the Director, there is evidence at times of serious disagreement between state and county officials regarding quarantine policies. This tends to cause a loss of confidence on the part of the public. The Committee believes this situation could be corrected by making the county agricultural commissioners joint state and county officers, in fact as well as in function.

The Committee believes that the "reasonable cause to presume" clause of the State Quarantine Law should not be used as a substitute for a quarantine. The statutes require that all regulations affecting another state shall have the written approval of the Governor and that he shall issue a proclamation of the quarantine. This, it is believed, is a courtesy to which citizens of other states are entitled, and therefore it is believed that regulations affecting interstate shipments should be replaced by formal quarantines.

It would be desirable, when conditions permit, for the State Department of Agriculture to develop more fully its scouting and survey work, in order to increase the chances of eradicating newly established pests and diseases. This can probably be done most effectively and economically in cooperation with the county agricultural commissioners through the local inspectors. The development of new and improved methods for treatment of plants and plant products for alleviation of quarantine

restrictions is a promising line of activity which might well be given increased attention. Many objectionable features of plant quarantine might be removed in this way. Both federal and state departments of agriculture have done commendable work in this line.

Increased attention should be given to the training of quarantine personnel, and the educational standards for some of the positions should be raised.

The State of California employs approximately 140 individuals in quarantine work and the federal government employs 5 in California; the counties employ approximately 350 agricultural commissioners, deputies, and inspectors, most of whom are engaged in part-time work in interstate quarantine. For the fiscal year ending June 30, 1931, the cost of plant-quarantine enforcement in California, exclusive of intrastate work, was as follows: United States Department of Agriculture, \$16,342; California State Department of Agriculture, \$281,802; counties (estimated), \$90,000. Total \$388,144.

In spite of the fact that international quarantines are enforced exclusively under federal authority, the State of California is paying practically the entire cost for protection of about three-fifths of the Pacific shore line of the United States from invasion by foreign pests and diseases. It is believed by the Committee that the federal government should relieve the California taxpayers of this burden.

The Committee believes it would be desirable for Congress to enact legislation providing that interstate quarantines promulgated by states be subject to review and possible disapproval by the federal Secretary of Agriculture. This would prevent retaliatory, unfair, or otherwise unjustifiable state quarantines, which are likely to cause trouble in the future.

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