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Diseases of Cypresses

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PART II

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by

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Preface to Part II

For some years the San Francisco station of the Division of Forest Pathology, United States Department of Agriculture, has had under investigation the Coryneum canker of cypress, a disease which has practically eliminated the Monterey Cypress as a useful tree in most of California. In the course of these studies a good deal has been learned about the susceptibility, under field conditions, of two or three of the commonly planted species of *Cupressus* but we were handicapped in undertaking any comprehensive tests of the relative susceptibility of other cypresses to the disease by the lack of sources of stock for test purposes, as well as the uncertainty concerning the true identities of some forms.

The initiation by the Rancho Santa Ana Botanic Garden of its project for a detailed botanical and horticultural study of the North American cypresses not only gave promise of resolving questions of identity of the native trees but it also provided, for the first time a possible source of authentic young stock of all native cypresses. At the same time the fact was apparent that any horticultural evaluation of the various species would be incomplete without as thorough rating as possible of their disease potentialities.

From these considerations the happy solution was reached of a cooperative undertaking between the two agencies on tests of susceptibility to the Coryneum canker. Participating in this cooperative effort was Stanford University, with its contribution of the facilities for the tests conducted on the Stanford campus. The results provide one more example of the value of a joint endeavor in scientific inquiry.

In keeping with the broad scope of the taxonomic and horticultural treatments by Dr. Wolf in Parts I and III of this publication, it has seemed appropriate to include in Part II not only an account of the field tests on susceptibility to canker, but also a brief review of other diseases recorded for other species of American *Cupressus*. In addition, advantage has been taken of the opportunity to bring the available information on Coryneum canker up to date, including a summary of much unpublished work on the subject by Dr. A. W. Dimock, carried out during the period of his former connection with our San Francisco station. We wish to express our appreciation to the officers of the Rancho Santa Ana Botanic Garden for the privilege of including this material in the present publication.

As indicated in the text, many individuals, firms and agencies have contributed, by one means or another, toward the successful conclusion of our work. To all of these we extend our thanks and appreciation. Nor can we forego mention of our appreciation for the fine spirit, cordiality and helpfulness on the part of the management and staff of the Rancho Santa Ana Botanic Garden which has been accorded to us throughout the period of our relations on the project. Cooperation under such conditions has been a real pleasure.

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PART II

Diseases of American Cypresses

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The environments in which the various members of the genus *Cupressus* have been able to persist in their native state, both in the Old and New Worlds, are characterized, as Joubert and Burollet (Joubert, A. and Burollet, P. A. Rev. des Eaux et Forêts **72**:85-93, 165-176, 245-252. 1934) have pointed out, by well marked dry periods and full insolation. Characteristically, also, the cypresses are inhabitants of slopes, ridge tops or headlands, very often rocky and invariably well drained. These features of the environment, coupled with the heavy deposit of slow-decaying, acidic duff that accumulates from the shed foliage, are inimical to the development of most diseases. In consequence the native stands of cypresses, to the extent that they have been surveyed for pathological condition, appear remarkably disease-free.

That this healthy state is primarily a result of the protective nature of the environment and not attributable to an inherent resistance to diseases in this group of trees is indicated by the susceptibility that various species have shown to pathogens when transplanted to situations to which they are not naturally well adapted. Thus cypresses native to warm, dry interior locations, such as *Cupressus arizonica*, *C. Macnabiana* and *C. nevadensis*, make poor growth and readily succumb to various diseases of foliage, twigs and bark when transplanted to the cool, moist atmosphere of the immediate coast in California. One or two species, such as *C. macrocarpa*, have shown considerable adaptability to soils and environments differing from those of their native habitats but, in general, the cypresses are not likely to do well when planted in soils or under climatic conditions to which they are not accustomed.

Diseases of New World Cypresses Elsewhere

Although the first introduction of a North American cypress into Europe took place as early as the 17th century (Jackson, A. Bruce. Gard. Chron. (Ser. 3) **57**:206-207. 1915) when specimens of *Cupressus lusitanica* were established around a monastery in Portugal from seeds undoubtedly brought from Mexico or Central America, it was not until about 200 years later that plantings of cypresses from this continent became common in the warmer parts of Europe. Monterey Cypress, in particular, because of its rapid growth and other favorable characteristics, became a favorite in the

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milder portions of the British Isles and on the Continent. In the last few decades of the 19th century and the early years of the present one, plantings of cypresses from North America were extended to many other warm-temperature parts of the globe, such as Chile, Australia, New Zealand, and southern and east-central Africa.

In this horticultural expansion of the New World cypresses it was almost inevitable that they should be tried in districts to which they were not climatically adapted and that losses and damage should be suffered in consequence. Thus, according to Miller (Miller, Philip. Gardener's Dict. 8th Ed. London. 1768) a large specimen, representing an early introduction of *Cupressus lusitanica* into England, was killed by the severe freeze of 1740 and large trees of the species by the very cold weather in 1762. Jackson (Jackson, A. Bruce. Gard. Chron. (Ser. 3) **57**:53. 1915) mentions the later heavy losses of *C. macrocarpa* from cold during the winter of 1860-61, when all trees of this species in the Thames Valley in England were killed as well as those in many other English localities. In some districts where trees were not completely killed by the cold they were severely injured.

Another type of non-pathogenic injury, which early gave trouble on an American species of cypress in the British Isles, was that from windburn on plantings of Monterey Cypress in exposed situations (Gard. Chron. (Ser. 3) **15**:144-145. 1894; (Ser. 3) **21**:83. 1897). While this did not cause permanent injury, the affected trees were rendered unsightly for some time on the exposed side and the species thus lost favor with some owners for use in situations subject to severe drying winds.

Though there have undoubtedly been many unrecorded instances of failures of North American cypresses when planted in unsuitable situations in other parts of the world, reports of losses or damage from diseases of these species as exotics have been few. In the Transvaal a disease of young plants of *C. arizonica* and *C. macrocarpa*, later determined to be a strain of *Phomopsis* close to *P. juniperovora* Hahn (Hahn, G. G. Phytopath. **16**:899-914. 1926), was investigated by Bottomly (Bottomly, A. M. So. Afr. Assn. Adv. Sci. Rept. **1918**: 613-617. 1919). A dieback of *C. macrocarpa* hedges in South Africa from a *Phomopsis* was also reported by Evans (Evans, I. P. Pole. Union So. Afr. Dept. Agr. Rept. **1918-1919**:79. 1920). A stem disease of young plantation trees of *C. macrocarpa*, which was found to be causing damage in a number of places in the North Island of New Zealand, was likewise attributable to a *Phomopsis* very close to *P. juniperovora*, according to the investigations of T. C. C. Birch (Te Kura Ngahere **3**:108-113. 1933). Both there and in the Transvaal the disease appeared to be primarily a wound parasite, entering through injuries to the bark suffered in the course of transplanting or cultivation.

In Kenya, the "pink disease," quite commonly injuring coffee trees and induced by the fungus, *Corticium salmonicolor* Berk. and Br., was also found to be killing branches of *Cupressus macrocarpa,* as reported by J. McDonald (Kenya Dept. Agr. Ann. Rept. for **1927**: 225-230. 1928). He observed that the disease was associated with abundant moisture and lack of ventilation (Kenya Dept. Agr. Bul. **7**H. 3 pp. 1929), a combination of environmental conditions to which Monterey Cypress is not well adapted. Another fungous invader of North American cypresses planted in the highlands of the tropics proved to be *Rhizoctonia bataticola* (Taub.) Butler, according to W. Small (Brit. Myc. Soc. Trans. **10**:287-302. 1926). Among the hosts of this fungus in Uganda were *C. macrocarpa* and *C. Benthami* (*C. lusitanica*), the roots of which were penetrated and killed. He later reported the same fungus in the roots of two young dead trees of *C. Lindleyi* (*C. lusitanica*) in Ceylon (Trop. Agriculturist **71**:77-79. 1928).

Pestalotia funerea Desm., a fungus ordinarily regarded as only weakly pathogenic and which C. M. Doyer (Meded. Phytopath. Lab. 'Willie Commelin Scholten', Baarn **9**, 72 pp. 1925), on the basis of many negative tests in Holland, classed as unable to infect conifers, has been associated for many years with a "gummosis" of *C. macrocarpa* in New Zealand, according to Birch (loc. cit.). He states that young seedlings of this species and of *Chamaecyparis Lawsoniana* (A. Murr.) Parl. are attacked under humid conditions and that older plants develop lesions when soil infested by the fungus is allowed to remain adhering to the stems for some time. By inoculation experiments he found that the organism was unable to penetrate uninjured stem tissue of *Cupressus macrocarpa* plants two or three years old but that it was able to establish itself and produce lesions where stems had suffered mechanical injury.

The only reference in the literature to wood decays in American cypresses planted in other parts of the world appears to be from Queensland, Australia, where a butt rot reported by J. H. Simmonds (Queensland Dept. Agr. and Stock Rpt. **1935-1936**, pp. 94-96. 1936) as causing appreciable loss in *C. lusitanica* and other conifers was ascribed to a fungus provisionally identified as *Hymenochaete Mougeotii* (Fr.)Cke.

None of the above reports indicates that the diseases referred to are particularly serious on cypresses or difficult to combat and for the most part they suggest the use of cypresses in locations to which they are not fully adapted. On American species of the genus in other parts of the world the only diseases that appear to be potentially serious are two that are characterized by the production of trunk and branch cankers.

One of these, induced by the fungus, *Coryneum cardinale* Wagener, was reported in 1933 by Birch (loc. cit.) as causing serious damage in plantations of *Cupressus macrocarpa* and *Chamaecyparis Lawsoniana* on North Island in New Zealand. In a later publication, Birch (New Zealand State For. Serv. Bul. **9**, 17 pp. 1938) listed *Cupressus sempervirens* and *Thuja plicata* as added hosts there. The disease, as it occurs in California, from which it was first reported, will be discussed in a later section. No information has been received concerning its present status in New Zealand.

The other canker disease, determined from inoculation tests to be caused by a fungus of somewhat similar type, *Monochaetia unicornis* (Cke. and Ell.) Sacc. (Nattrass, R. M. East Afr. Agr. Journ. **11**:82. 1945), has appeared within the last few years on planted *Cupressus macrocarpa* in Kenya, East Africa (Wimbush, S. H. Empire For. Journ. **23**:74. 1944). In symptoms and general appearance the disease is reported to be strikingly similar to the cankers caused by *Coryneum cardinale* described from California. This is borne out by the illustrations of a cankered cypress branch and stem accompanying Dr. Nattrass' note on the disease in the East African Agricultural Journal. In the pictures the diseased parts show so close a resemblance to the Coryneum canker as it occurs on thrifty Monterey Cypresses in California that the illustrations could readily pass as representing the latter disease. Kenya is deficient in good native softwood species and Monterey Cypress has shown much promise there as a timber tree because of its rapid growth, adaptability to different site conditions and the quality of its wood (Graham, R. M. East Afr. Agr. Journ. **10**:132-139. 1945). Accordingly, prompt measures have been taken to try to eliminate infected trees. In a recent letter Dr. Nattrass adds the information that the disease has spread to other parts of Kenya than the two localities in which it was originally found and that *C. lusitanica* and *C. arizonica* appear to be equally as susceptible as *C. macrocarpa*. Fruit-bodies of *Pestalotia funerea* appear on cankered bark but inoculation tests have shown that this organism is not primarily involved in the disease.

Diseases of Cypresses in North America

Although we know that, in general, the habitats of our native cypresses are not conducive to attacks by disease organisms, it is also true that no intensive survey for diseases has been made of many of the scattered native groves. In consequence, the very meager reports of maladies on our own native species in the wild undoubtedly fail to represent satisfactorily all of the pests and diseases to be found there.

A rust, *Gymnosporangium Cupressi* Long and Goodding, is reported (Long, W. H. Bot. Gaz. **72**: 39-44. 1921; Long, W. H. and Goodding, L. N. Mycologia **32**:489-492. 1940) to cause fusiform to subglobose galls with rough, exfoliating bark on *Cupressus glabra* and *C. arizonica* in two restricted locations in Arizona. The authors mention twig killing on only one heavily infected tree. From the field evidence, Long and Goodding conclude that the alternate host is unquestionably *Amelanchier mormonica* C. Schneid. at one of the locations. A similar rust, *G. meridissimum* Crowell, is recorded from two localities in Guatemala on *C. Benthami* (*C. lusitanica*) but without any indication of its pathological role or of the probable alternate host (Crowell, I. H. Canad. Journ. Res., Sec. C, **18**:10-12. 1940).

Reports of a "rust" attacking Monterey Cypresses in the native groves near Carmel, California were formerly received from time to time from visitors there. The organism referred to was invariably found to be an epiphytic alga, *Trentepohlia aurea* var. *polycarpa* (Nees and Mont.) Hariot, which is common on cypress in the direct path of the fine mist from wind-driven ocean spray along the rocky headlands near Carmel. It forms a bright vermilion mantle over the bark and twigs, living or dead, on the windward side of the trees but has no deleterious effect on the cypresses other than that of a slow smothering of small portions of the foliage at times. The fact that it often occurs where dying-back from wind and salt burn is prevalent, however, may lead one to conclude that the algal growth has been responsible for the damage. It is likely to be found especially at the head of small draws or depressions leading directly up from the rocky shore line and serving as wind channels up which the spray is swept from the breaking waves below. The nature and role of this epiphyte are now better understood by the public than formerly and reports of its serious action by alarmed lovers of nature are less frequent.

Heart rots are present in the natural groves of at least several New World species of *Cupressus* but the identities of the causal fungi have not been definitely confirmed for these areas. In the native groves of *Cupressus macrocarpa* near Carmel, California, however, it is almost certain that a brown, friable pocket rot found in old broken specimens there is the rot of *Polyporus basilaris* Overh. Decay from this fungus has been noted as very prevalent in old, planted Monterey Cypresses in Berkeley, San Francisco and Monterey, California (Bailey, Harold E. Torr. Bot. Club. Bul. **68**: 112-120. 1941). The greyish, annual fruit-bodies develop during the rainy season in furrows on the trunks of affected trees but are usually destroyed by insects after a few weeks. Field evidence indicates that this rot is by far the most common one in Monterey Cypress in California. However, one other wood-decay fungus, the little-known *Polyporus cutifractus* Murr., has been reported on living planted trees of the species at Stanford University and Berkeley, California (Rhoads, Arthur S. Phytopath. **11**:319-326. 1921). The type of rot produced has not been determined and no notion has been gained concerning its presence in the natural groves near Carmel.

A light brownish heart rot is quite common in some stands of *Cupressus glabra* in central Arizona, according to the observations of pathologists and foresters (L S. Gill, communications, February 12 and 18, 1946), but no sporophores have been found associated with it and attempts to isolate the causal fungus from decayed wood have been unsuccessful. Its identity thus remains undetermined. On the basis of characters shown by specimen FP89208 collected by L. S. Gill, S. R. Andrews, and D. E. Ellis along Rye Creek, Payson, Arizona and examined by me the decay evidently belongs in the white rot group. It tends to follow the growth rings, causing their separation in the later stages. Stems of rather small diameter may be affected.

Aside from insect pests, mistletoes and windburn are the only two other types of parasites or injuries that are definitely known to occur in natural stands of cypresses in North America. The mistletoes on Cupressus are of the leafy type belonging to the genus *Phoradendron* (Hedgcock, G. G. Phytopath. **5**:175-181. 1915; Trelease, Wm. The Genus Phoradendron. 224 pp. Urbana. 1916) and are quite limited in distribution. Where present, however, they are likely to be locally prevalent, as exemplified by the species *Phoradendron pauciflorum* Torrey on *Cupressus Sargentii* in Marin County, California. Here it often forms dense clusters on bushy trees of the host along ridge tops. According to Hedgcock, in the paper cited above, another species of mistletoe, later designated by Trelease as *P. densum* Torrey, occurs locally on both *C. arizonica* and *C. glabra* in Arizona.

English experience concerning the tendency of Monterey Cypress to windburn in exposed situations has already been mentioned. "Burning" or browning of foliage from the combined action of wind and of salt deposited from the ocean spray is common on the native trees of this species facing the sea near Carmel but the process is so continuous and so much a part of the adverse environmental conditions against which the trees must contend for existence that it is scarcely noted. Growth of foliage and branchlets on the windward side, where the trees are subjected to the full force of the strong salt-laden prevailing westerly winds in summer, is much reduced and such foliage as does succeed in developing there is gradually killed back. On the upper and lee sides, however, the thick, compact mass of foliage, twigs, branches and attached epiphytes offer sufficient protection to enable the foliar parts to remain alive. Through this continuing action year after year, aided by the mechanical force of the wind itself (Jepson, W. L. The Silva of California. Mem. Univ. Calif. **2**. 480 pp. 1910), a very marked lateral development of the crowns toward the lee side often results on exposed trees, creating the picturesque and grotesque shapes into which many of them have been molded. The physiologically more vigorous young trees are better able to withstand the wind and salt action and usually are more nearly normal in form.

In the Americas, as in other parts of the world, the extension of cypresses by planting in cultivated ground has brought them into contact with diseases not known to be present in the natural groves and to which they have proven to be susceptible. Among these is crown gall, caused by the bacterium, *Agrobacterium tumefaciens* (E. F. Sm. and Town.) Conn. Brown and Evans (Brown, J. G. and Evans, M. M. Phytopath. **23**:97-101. 1933) found numerous well developed galls of this common orchard disease on the roots of an ailing tree of C. *arizonica* at Tucson, Arizona, and Smith (Smith, Clayton O. Journ. Agr. Res. **59**:919-925. 1939), by inoculation of the crown gall organism into young plants, was able to produce galls on 9 out of 12 species of North American cypresses tested. Species failing to develop galls were C. *glabra,* commonly known in horticulture as Arizona Cypress, C. *guadalupensis,* and C *montana,* The fact that 18 out of 93 inoculations on C. *arizonica* resulted in galls, whereas none of the 175 inoculations on C. *glabra* developed galls, may be of significance with respect to the question of relationship between these two species, which some authors consider as only varieties of the single C. *arizonica.*

In an introductory paragraph of their paper, Brown and Evans (loc. cit.) state that a valuable quality of C. *arizonica* in valley plantings in Arizona is its resistance to Texas root rot, *Phymatotrichum omnivorum* (Shear) Dugg., which annually kills many shade and ornamental trees in southern Arizona. On the other hand, Peltier (Peltier, George L. Phytopath. **27**:145-158. 1937), in a list of susceptibility ratings based on the reports of Taubenhaus and associates, classes C. *arizonica* as moderately susceptible to the root rot. However, the latter group (Taubenhaus, J. J., Dana, B. F., and Wolff, S. E. Texas Agr. Exp. Sta. Bul. **393**. 30 pp. 1929), in their 1929 list, refer only to the Smooth Arizona Cypress, "*Cupressus glabra* Sudw." and it is probably this species to which their rating applies rather than to the rough-barked C. *arizonica* as shown in Peltier's list. There may thus be a difference in susceptibility to the root rot between these two species, just as Smith's results indicate a difference in susceptibility to crown gall.

Another root fungus that is responsible for the death of scattered Monterey Cypress in districts where the fungus is prevalent, is *Armillaria mellea* Vahl. ex Fr. commonly known in California as the "oak root fungus" because of its frequent occurrence in association with oak woodlands. Cypresses are more likely to be attacked when growing in sandy soils than in soils of heavier types. This fungus was also found on native Tecate (Forbes') Cypress in

Orange County, California (Hewitt, J. Lee. Calif. Dept. Agr. Bul. **25**:226-234. 1936) but there is no evidence that it is prevalent in the native stands of the species there.

The only potentially serious disease of young nursery cypresses reported in American literature is the one caused by *Phomopsis juniperovora* Hahn, usually termed the cedar blight fungus because of the severe damage inflicted by it on Eastern Redcedars. Injury by strains of this fungus to young cypresses in New Zealand and the Transvaal has already been mentioned. Hahn (Phytopath. **16**:900. 1926) records the isolation of the organism from naturally infected *C. macrocarpa, C. arizonica, C. Goveniana,* and *C. Benthami* (*C. lusitanica*) in the United States. Hahn distinguished two groups of strains of the fungus and determined by inoculation that seedlings of *C. arizonica* were susceptible only to strains of the A or typical group. In actual nursery operations in California and the Southwest, where most of the horticultural stocks of *Cupressus* species are raised in the United States, this fungus has given little trouble so far as we have been able to learn. The absence of serious damage is probably to be accounted for by the lower humidities during the growing season as compared with most other parts of the country, since the disease is favored by warm, moist conditions.

A stem canker which has been quite destructive to columnar Italian Cypress (*C. sempervirens* L. var. *stricta* Ait.) along the California coast has also been found occasionally on the Smooth Arizona Cypress and on killed-back branch tips of Monterey Cypress (Zentmyer, George A. Phytopath. **31**:896-906. 1941) but on both latter species, according to Zentmyer, the disease is of little significance. It has been shown to be caused by the fungus, *Cytospora cenisia* Sacc. forma *littoralis* Zentmyer. Another fungus, an undetermined species of *Coryneum* or a group of strains falling under this form genus, sometimes produces limited cankers or is associated with dieback of twig tips on non-vigorous trees of Monterey and other cypresses in cool, coastal situations (Dimock, A. W. Unpubl. Rept. Forest Pathology, San Francisco, May, 1938; Wagener, Willis W. Jour. Agr. Res. **58**:1-46. 1939).

Cypresses have been planted in many unsuitable situations in the warmer parts of the United States, as in other parts of the world, and failures on this account have been common. The unsatisfactory results of planting inland species, accustomed to dry sites and low humidities, in the cool, moist climate of the immediate coast of California have already been referred to. The blight on foliage of *C. arizonica,* ascribed to a Macrophoma-like fungus, possibly *Macrophoma Cupressi* (Cke. and Hark.) Berl. and Vogl., by Waterman (Waterman, Alma M. Pl. Dis. Rep. **25**:181-186. 1941) was probably the result of planting in a location to which the tree was not fully suited. Many trees have been set out in soils that were too wet or too alkaline and have succumbed after a sickly struggle. During the unprecedented cold spell of December, 1932 in northern California, numbers of young Monterey and Mexican Cypresses in the Sacramento Valley and at higher elevations in the Coast Ranges were killed by minimum temperatures that ranged as low as 10 degrees to 12 degrees F. (-12 degrees to -11 degrees C.).

In addition to cases in which the causes of death of cypresses can be assigned with reasonable certainty, trees die here and there for which no satisfactory explanation can be found. These instances may occur where previous growth has been good and adjoining trees remain normal. Death usually takes place rapidly and uniformly over the entire tree, suggesting that the source of the trouble is below ground. However, in cases that have been examined, the roots appear macroscopically quite normal and no discolorations are visible, either in the wood of these organs or in the main trunk. Further investigation of this type of dying is needed.

In the diagnosis of cypress diseases it is necessary to distinguish between injury caused by disease organisms and that from other causes, such as insects or mites. They are often associated. Many insects feed on cypresses, producing injury in varying degrees or killing attacked trees completely. For California the more important of these, working principally on Monterey Cypress, have been listed by Burke (Burke, H. E. Calif. Dept. Agr. Monthly Bul. **21**:358-369. 1932). They include three foliage feeders: the cypress webber, *Epinotia subviridis* (Hein), the cypress tip moth, *Argyresthia cupressella* (Wlshm.), and the cypress sawfly, *Neodiprion* sp., that cause the browning or stripping of cypress foliage, and two sucking insects, the arborvitae aphis, *Dilachnus thujafilinus* (Del G.) and the cypress bark scale, *Ehrhornia cupressi* (Ehrhorn), both of which may be locally prevalent and often kill heavily infested branches. The latter insect is also credited with the death of entire trees and in 1920, before cypress canker had become prevalent, was considered by Herbert (Herbert, F. B. U. S. Dept. Agr. Bul. **838**. 22 pp. 1920) to be the primary pest of Monterey Cypress in the San Francisco Bay region of California. Herbert also noted four additional species of scales which are associated with the cypress bark scale, and three mealy bugs which occasionally do some damage.

Burke lists two cypress bark beetles: one of them, *Phloeosinus cristatus* (Lec.), occurring chiefly in the interior and the other, *P. cupressi* Hopk., in the coastal districts of California. The first of these is the more aggressive, according to Burke, and has been responsible for the death of many Monterey Cypresses planted well outside of the natural range of this species. It is especially likely to attack trees suffering from drought or disease. Both species normally mine between the bark and wood but in addition have the curious habit of mining chambers in small branch tips. These commonly break later at the point of the mining, 6 or 8 inches back from the tip, and hang down for some time before they break off completely and fall. Burke records also the killing of small planted Monterey Cypresses by the Incense Cedar flathead borer, *Chrysobothris nixa* Horn, and the mining of the bark of larger trees by this species in southern California.

One other boring insect of cypresses mentioned by Burke is the cypress bark moth, *Laspeyresia cupressana* (Kearf.), the larvae of which mine the bark of cypresses, sometimes killing it in patches and causing it to become very rough and pitchy. In coastal districts a favorite site for activity is in the thickened bark at branch bases on Monterey Cypresses. Eventually the branch may become completely girdled at the base or the girdling may be so nearly complete that the branches are readily broken at the base by storm winds.

Of the mites which are deleterious to cypresses, the ilicis mite, *Paratetranchus ilicis* McGregor, is apparently one of the most common in southern California, according to Smith (Smith, Ralph H. Proc. Sixth West. Shade Tree Conf., Oakland **1939**:43-46, and Proc. Tenth West. Shade Tree Conf., Los Angeles **1943**:56-62), and in some instances has been an important cause of the dying of hedges there.

The Coryneum Canker

The disease that so far has proven to be the most damaging to cypresses is the Coryneum or cypress canker first reported from middle western California in 1928 (Wagener, W. W. Science (n. s.) **67**:584. 1928). Later evidence indicated that it had been present there since at least 1915 and was established at several places in southern California prior to 1928 (Wagener, 1939). The report in 1933 of its occurrence on North Island in New Zealand has already been mentioned.

Status in California

No detailed surveys for the disease have been made in California in recent years but from general field observations it is known to have become prevalent in some districts where it was formerly infrequent, such as in the citrus-growing sections of Ventura and Santa Barbara Counties. In the areas surrounding the native Monterey Cypress groves near Carmel, California a determined effort was made between 1936 and 1939, with the aid of the Civilian Conservation Corps, the California State Division of Parks, and the County Agricultural Commissioner of Monterey County, to find and eradicate all cases of the disease in the numerous plantings of Monterey Cypresses there. Recent inspections have shown that, while complete eradication was not achieved by the former campaign, the disease was so markedly reduced that it has been unable to regain a threatening status. It has not been found on any of the trees in the native Monterey Cypress groves, and with vigilance and a small additional control effort in surrounding areas the protection of these outstanding trees from the canker should be possible almost indefinitely.

Within the planted range of Monterey Cypress on the Pacific Coast, the coastal region of northwestern California is now the only extensive area that has remained entirely free of the disease. In many localities where it was formerly common a marked decrease in incidence has taken place in recent years, owing to the disappearance of susceptible host trees. A few representatives of former plantings have survived without appreciable damage, apparently either because of isolation or of inherent resistance to infection by the causal fungus. The large decrease in infective material brought about by the death and removal of susceptible trees in districts where the fungus has been present for some years now makes it possible to plant susceptible cypresses in some of them with a prospect that the trees will escape the disease for at least a few years.

With the exception of plantings in the coastal strip within a few miles of the ocean from Point Sur to the northern end of California, where climate and a range of protecting mountains paralleling the coast assist in isolating cypresses from inroads by the canker fungus, it is safe to say that three-fourths of all the Monterey Cypresses that have been planted and a considerable number of trees of other susceptible species, such as the Italian Cypress, have been lost as a result of its attacks. Losses of Monterey Cypresses in several districts in southern California where they are still fairly numerous, such as in western Ventura County, may be expected to continue during the next few years at an increasing rate unless concerted protective measures are taken to prolong the lives of the trees.

Description of the disease

The first evidence of an infection by the canker fungus on thrifty, young branches or stems of a susceptible host, such as the Monterey Cypress, is a browning of the live bark tissues around the point where the fungus has entered. This is commonly at a crotch or around the base of a foliar branchlet, though infection may also occur readily through wounds or sometimes through foliage Dimock, A. W. Rept. 1938). The infected bark swells slightly and resin exudation usually occurs from the surface of the developing lesion. Later the browned bark dies and dries out, becoming somewhat depressed in the process. The fungus advances more rapidly in a longitudinal direction than transversely, forming a canker roughly lenticular in outline with a ratio of width to length of approximately 1 to 3.5.

If the weather is not too dry the small black pustules in which the spores of the Coryneum are produced begin to appear on the surface of the dead bark of the central portion of the lesion within 4 to 8 weeks. They resemble tiny black blisters or shallow craters and are scattered irregularly over the bark surface. On older fibrous bark the presence of cork layers apparently interferes with the production of the pustules (acervuli) on the exterior layers and they develop mainly in the crevices where the inner phloem tissues are thinly covered. On hosts with smooth or cherry bark, such as *Cupressus lusitanica* or *C. Forbesii*, pustule formation is much reduced and in some instances may not occur. Accordingly the absence of pustules bearing the spores of *C. cardinale* on cankered bark does not necessarily signify that the canker was not induced by this fungus. In such cases the isolation of the organism in culture from the cankered tissues is necessary for confirmation of the presence of the disease.

A heavy flow of resin characteristically occurs from around the edges of a canker on thrifty trees, though in some districts very little resin flow may develop, even on trees making good growth. This has been noted chiefly near the ocean in southern California and may be occasioned by the lower and more even temperatures prevailing there as compared with locations further inland. The amount of resin exuded around the margins of cankers is also very much reduced on old or slow-growing trees and may be lacking completely on the surface though there is usually some noticeable resin infiltration within the diseased bark, even on old or non-vigorous trees. On most trees the infiltration of resin in the bark is very marked and is useful as a diagnostic aid in determining the presence of the disease. Cuts made into such bark after it has become dried out often show a purplish cast because of the resin content. The infiltration is ordinarily not uniform but occurs in rather irregular layers or streaks, probably associated with the location of the resin vesicles.

Dead foliage and other debris are readily caught in the exuded resin. In addition, in the cooler parts of California, a bark moth, *Laspeyresia cupressana*, is attracted by the pitchy bark and the larvae of the insect often mine the borders of cankers, pushing out the resinous, reddish-brown frass to the surface, where short sections of web spun by the larvae help to hold much of it in place. As a combined result the surface of cankers of any size is likely to present a very rough and untidy appearance. The insect seems to be much more numerous along the cool, immediate coast than at inland locations in middle California and invades a much larger percentage of cankers in coastal districts.

Lesions increase more rapidly during the first month or two after establishment than later. The slowing down in rate of canker extensions appears to be associated in part with defensive reactions of the host tree, such as the development of cork layers in bark just coming under the influence of the invading fungus. Mining of the edges of cankers by *Laspeyresia* larvae may also affect the later rate of extension as compared with that attained initially.

The over-all rate of increase in size of cankers is influenced by temperature, by the relative susceptibility of the host tree, by the growth vigor of the host and probably by other factors, such as the mining of margins by *Laspeyresia* larvae mentioned above. Measurements on the increase in length of cankers at Atherton, California, about 12 miles inland from the Coast and protected by a range of coastal mountains, averaged approximately 21 cm. per year as compared with 11 cm. for a similar group of cankers within a mile of the ocean near Lobitas, California.

The most rapid extension recorded at the Atherton location for the first 24 weeks after inoculation of healthy bark with the fungus was 14.5 cm. or at the rate of a little more than 31 cm. per year. Spread at a rate in excess of this is probably attained in especially favorable situations on highly susceptible trees of Monterey Cypress. The extension of cankers laterally around an affected branch or stem is much slower than in a longitudinal direction, as indicated by the 1 to 3.5 ratio of canker width to length already mentioned. Based on the Atherton measurements, the average increase in width of cankers is about 6 cm. per year, with a maximum of around 9 cm.

Cankers soon spread entirely around small stems or branches, girdling them. On larger parts a much longer time is required to bring about girdling. In places, the progress of the canker may be arrested for a time by the formation of layers of cork cells by the host tree, permitting the growth of callus tissue outside of the diseased area. This, and the increased growth of the remaining cambium as a result of its constriction by the canker, may result in a considerable deformation of the affected stem before girdling is complete. Large cracks sometimes are torn in the dead bark of the lesions by the development of ridges of callus tissue around the margins.

By the time girdling has occurred, the foliage on the affected part usually shows signs of distress, such as the yellowing and dropping of the older and less vigorous foliar parts. Except on twigs and small branches, however, fading and death of the entire foliage on the girdled portion of the tree does not follow immediately and may not occur for some weeks, depending on weather conditions and the season of the year. Sooner or later all of the foliage dies and gradually changes color from a greenish yellow to straw yellow and finally, after it has been dead for some months, to a dark brownish-red. Much of it tends to cling to the twigs, especially in protected situations, and several years may elapse before the dead branches become bare.

The dying of these individual branches or portions of the tree crown constitutes the chief symptom of the disease noticeable from a distance and the one likely to be observed first by the average person.

Dead twigs and branches on cypresses are the first indicators looked for in scouting for the disease. On small trees, however, and sometimes on large ones, where the girdling canker is situated low on the main stem, the entire crown may die uniformly. Moreover, the occurrence of dead branches or crowns is not, in itself, proof that the disease is present. Branch dying may result from the attacks of insects or mites or from the gnawing of bark by rodents. Strangulation by wires carelessly wrapped around a tree or branch at some earlier time is not uncommon. Cypresses may be killed by other disease organisms, such as *Armillaria mellea,* as noted in a previous section, from attacks by bark beetles or scale insects and from other causes.

The suspected presence of Coryneum canker, as judged from the occurrence of dead foliage, must therefore be supplemented by closer examination and the finding of the actual lesions bearing typical pustules of the Coryneum fungus before any conclusion concerning the presence of the disease can be reached. In many instances a microscopic examination or the isolation of *Coryneum cardinale* in culture from affected bark is necessary for a positive determination, because of the occurrence of other bark disturbances that may be mistaken for the true canker. This is particularly applicable to species such as *Cupressus lusitanica,* or to any host species planted in an unsuitable environment.

In California, Monterey Cypresses girdled by stem cankers caused by the *Coryneum* are very often attacked, about the time that the foliage starts to die, by one of the two principal species of cypress bark beetles occurring in the State. After the beetles have entered, the untrained observer may readily conclude from superficial appearances that the beetles are the cause of the dying. This erroneous belief became well established during the early years of the spread of the disease in California and still persists in some quarters. As already mentioned in the previous section, these cypress bark beetles are able to attack and kill trees while the latter are handicapped by drought or other environmental conditions, or where large populations of the beetles have been permitted to build up in the vicinity. An example of the latter type of situation was noted in a coastal county of southern California where irrigation was discontinued on a sandy plot of ground bordered by a cypress windbreak. The sudden withdrawal of water supply from the trees, after they had grown up under regular irrigations, was such a severe change that the bark beetles were able to make a successful attack. In these weakened trees they increased in such numbers that nearby normal trees were attacked and killed. Field experience indicates that such outbreaks are rather sporadic in occurrence, however, and do not ordinarily persist.

Stem cankers on the lower trunks of young, thrifty Monterey Cypresses from 5 to 20 years of age may reach a length of several feet (60-90 cm.) before the tree is girdled and killed. Such cankers characteristically involve the bases of lateral branches also, from within the cankered area, ordinarily extending out on them, depending on their size, for from 2 to 6 inches (5-15 cm.) from the main stem. These infected branch bases offer more favorable situations for the production of the spore-bearing pustules of the causal fungus than the main trunk with its heavier and better protected bark and, in consequence, most of the sporulation from such cankers occurs on these branch bases.

On stems or large branches of older, slow-growing trees, cankers are much less conspicuous and in cool situations close to the ocean cases have been observed that showed almost no surface indications of the presence of the disease. In most locations an abnormal cracking of the infected bark, accompanied by some exudation of resin, is a common symptom.

Within susceptible species, trees of any size, age, or degree of vigor are subject to attack. Those of normal, open-grown form appear to become infected more readily than those with closely sheared, dense foliage, such as the trees comprising sheared hedges. On young fast-growing trees, with open crowns extending to the ground, stem infections are most common, especially when the disease is first invading a planting. On older or more crowded trees branch cankers predominate.

Once established, the progress of the disease in a planting or district depends on the age and thrift of the trees, their comparative numbers, the temperature conditions in the area, and other influencing factors. Usually a gradual pyramiding of the incidence of cankers takes place, resulting in the death of increasing numbers of trees if the latter are relatively young, and in the dying of more and more branches in old specimens. Heavily diseased old trees become very unsightly and are often removed on this account before they are completely dead, or bark beetles may attack the main trunk in the last stages of the disease and complete the killing.

The length of time required to kill an individual tree following initial infection is very variable, depending on the size of tree and place of infection. For small seedling trees no more than a year may be needed while large old trees may live for 10 years or more after attack. Occasionally cypresses with some natural resistance may even throw off the disease and recover.

The causal fungus

The organism demonstrated to be the pathogen inducing the canker is an imperfect fungus described in 1939 as a new species with the following description:

Coryneum cardinale Wagener (Journ. Agr. Res. **58**:1-46)

Acervuli scattered, subepidermal, sometimes partially immersed, originating from a single primordium or confluent from several, at first closed, later erumpent and opening widely, surrounded by the torn epidermis, irregularly circular, oblong or lenticular in outline, 0.3-1.5 mm. diameter, black, the margins sporogenous and frequently persistent after opening, often reflexed; the stromatic layer often loculate or semiloculate, up to 300μ thick, 10-50μ under locules, subhyaline to light olivaceous; conidia oblong-fusoid, 5-septate, 21-26μ (18-33.5μ) x 8-10.5μ (7.5-12μ), the four median cells con-colorous, olive brown, 16.5-18.5μ (14-20μ), not or slightly constricted at the septa, end cells muticately short-conic to occasionally long-conic, hyaline; conidiophores simple or branched nonseptate or with one septum, hyaline, 15-55μ x 1.4-2.2μ; pseudoparaphyses filiform, somewhat sinuous, 40-60μ x 1.0-1.5μ.

On bark of branches and stems of Cupressaceæ, occurring on cortical lesions: California; New Zealand.

Type, FP83082 on *Cupressus macrocarpa,* Atherton, California, March 1934, W. W. Wagener, in herbarium of Division of Forest Pathology, San Francisco, California. In addition to the type and other specimens on *C. macrocarpa,* collections on the following hosts were cited from California: *C. sempervirens stricta, C. pygmaea, C. lusitanica, C. Forbesii, Thuja orientalis, Libocedrus decurrens* and *Juniperus chinensis femina.* One collection on *Cupressus macrocarpa* was listed from New Zealand.

Since publication of the above citations the following additional specimens have been added to the collections at San Francisco:

On *Cupressus Abramsiana*: 85020 Riverside, Calif., W. W. Wagener.

On *C. arizonica*: 85018 Anaheim, Calif., W. W. Wagener and C. B. Wolf.

On *C. Goveniana*: 85023 Riverside, Calif., W. W. Wagener.

On *C. Macnabiana*: 85021 Riverside, Calif., W. W. Wagener.

On *C. Sargentii*: 85022, 85024 Riverside, Calif., W. W. Wagener.

On *Thuja plicata*: 85019 Rancho Santa Ana Botanic Garden, Anaheim, Calif., W. W. Wagener, C. B. Wolf and P. C. Everett.

These were all from authentic host trees in plantings established by the Rancho Santa Ana Botanic Garden.

In addition the fungus has been cultured from a non-sporulating canker on *C. Bakeri Matthewsii* in the Rancho Santa Ana test planting at the Citrus Experiment Station of the University of California at Riverside, California. Birch's report of *Chamaecyparis Lawsoniana* as a host for the fungus in New Zealand has already been mentioned.

No perfect stage of the fungus has been found.

Acervuli of *Coryneum cardinale* begin as small subepidermal pads of stromatic tissue under the epidermis. These enlarge and thicken and one or more flattened cavities develop within each, evidently by a process of resorption of the original hyphae. The entire inner periphery of the cavities becomes sporogenous and gives rise to conidiophores and pseudoparaphyses. The first conidia are developed within the cavities while the latter are still closed but rupturing of the upper wall of the cavity and of the overlying epidermis soon follows and the acervulus opens widely. However, the torn stromatic covering tissue does not regularly disappear as in *Pestalotia,* for example, and may become reflexed over the edges of the ruptured epidermis of the host. Its sporogenous portions continue to function and produce conidiophores and conidia. There is no regularity in the shape or position of the cavities or locules that form within a stroma. Only a single one may develop or there may be two or three that open to form a single acervulus.

Of the species of Coryneum with spores characteristically 5-septate and having hyaline end cells, only 5 have apparently been described from conifers. Judged from descriptions, these seem to be distinct from each other but the discovery on the Pacific Coast of additional 5-septate forms on coniferous hosts is making the question of identities more complex. Adding to the uncertainty is the fact that at least one described species, C. *abietinum* Ell. and Ev. (Ellis, J. B. and Everhart, B. M. Acad. Nat. Sci. Phila. Proc. **1894**:322-386. 1895), is evidently quite variable. In the original description of this species the diameter of acervuli was given as 1.5-3.0 mm. and the spores were characterized as 3-4 septate and measuring 20μ x 10μ in size. In an amended description (Torrey Bot. Club Bul. **25**:501-514. 1898), published following receipt of additional material from the original collector in Newfoundland, the authors state that the acervuli are "erumpent through an orbicular or elliptical grayish disk 1-1.5 mm. in diameter" and give the spores as constantly 5-septate and $35\text{-}40\mu$ x $7\text{-}8\mu$ in dimensions. Material of this species was distributed by Ellis and Everhart as No.1269 of Fungi Columbiani. Measurements by me of 25 spores from this number in the set of Fungi Columbiani at the Connecticut Agricultural Experiment Station, New Haven, Connecticut gave an average of 31.8μ x 10.4μ ($29.5\text{-}38.5\mu$ x $9.6\text{-}11.5\mu$) for the spores, thus differing from the dimensions as reported in earlier description by Ellis and Everhart.

Whatever the true spore sizes of *Coryneum abietinum,* the spores and conidiophores are apparently long enough to differentiate the species from C. *cardinale.* Another 5-septate species, C. *Juniperi* All. (Allescher, Andreas. In Rabenhorst, L. Kryptogamen-Flora von Deutschland, Oesterreich, und der Schweiz, Aufl. 2, Bd. 1, Abt. 7, Leipzig. 1903), collected on a dead, rust-deformed branch of *Juniperus communis* L. in Bavaria, is characterized by an extensive stroma and by conidiophores $50\text{-}60\mu$ and longer, which distinguish it from C. *cardinale* in which the conidiophores range from 15μ to 55μ in length. A third species, *C. calosporum* Naum. (Naumov, N. [Naoumoff, N.] Bul. Sci. Oural. d'Amis des Sci. Nat. **35**, 48 pp. 1915), from the bark of *Picca excelsa* Link in the Ural region of Russia, is described as having a stroma ochraceous in color, rather than light olivaceous, as in *C. cardinale,* and with larger conidia than the latter species. No evidence of pathogenicity is mentioned in connection with any of the above species, whereas *C. cardinale* is almost invariably pathogenic as it occurs in nature.

A 5-septate species that likewise normally is pathogenic in action has been described by Milbrath (Milbrath, J. A. Phytopath. **30**:592-602. 1940) as *Coryneum Berckmanii* Milbrath on horticultural forms of *Thuja orientalis* L. and *Cupressus sempervirens* L. in Oregon and Washington. On susceptible hosts it causes a severe winter blight of foliage and smaller twigs. From a comparison of this fungus with *Coryneum cardinale,* Milbrath pointed out that *C. Berckmanii* is pulvinate, forming a different type of acervulus than *C. cardinale,* that its stroma is never loculate as it sometimes is in *C. cardinale,* that the spores average larger (28.8μ x 9.9μ vs. 23.5μ x 9.2μ) and that it is aparaphysate. He also demonstrated cultural differences.

In addition to the described species of Coryneum, at least two different types that do not seem to fit any described species have been found on conifers in California. One of these, a saprophyte or very weak pathogen, was reported as common on Cupressaceae in the coastal districts of California (Wagener, 1939). It was shown that while the spores of this form and of *C. cardinale* are closely similar in general size and shape, the end cells of those of the saprophyte tend to be papillate at the tips while the tips of the *cardinale* spores are blunt. Other differences pointed out are the greater uniformity in size and shape of the acervuli of the saprophytic form, the thinner character of its stromatic layer and the relative ease with which the conidia are detached from the conidiophores. Cultural differences between the saprophyte and *C. cardinale* were also shown to occur.

Another form, associated with elongate cankers on stump shoots and plantation trees of the Coast Redwood, *Sequoia sempervirens* (D. Don) Endl. in portions of Mendocino and Humboldt Counties, California, produces conidia not differing greatly from those of *Coryneum cardinale* and is capable of causing lesions in the bark of Monterey Cypress and Redwood, as has been demonstrated by inoculation. The conidiospores of this form are somewhat longer than those of *C. cardinale* (27-34μ vs. 21-26μ) and end in short papillate tips extending at an angle to the main spore axis; an angle similar to that formed by the setae in some species of *Monochaetia.* A less pronounced stroma is developed than in *C. cardinale*: in this respect it is quite similar to the saprophytic *Coryneum* previously mentioned. In culture it grows more slowly than *C. cardinale* and the surface of the colonies is not floccose as in the latter species. Lesions resulting from slit inoculations with the fungus into 7-19 mm. diameter stems of young plants of *Cupressus macrocarpa* reached variable sizes, the longest being approximately 80 mm., but in no case did the lesion girdle the stem and eventually all were arrested and callusing-over followed. While this fungus is able to produce ultimately restricted lesions on Monterey Cypress and more extensive ones on Redwood, the cypress canker fungus, *C. cardinale,* will not infect Redwood when introduced by inoculation (Smith, Clayton O. Phytopath. **28**:760-762. 1938; Wagener, 1939, p. 35), thus supporting the mycological evidence that the two are different. So far, the Redwood *Coryneum* has not been found on species of *Cupressus* as a result of natural infection but occasional cankers from it on cypresses may be expected in districts where these trees are planted near Redwoods affected by the fungus.

In the course of his investigations on the cypress canker, Dimock (Rept. 1938) obtained 17 isolates from dead cypress foliage and bark that appeared to belong in the genus *Coryneum,* judging from sporulation in culture. These were inoculated into Monterey Cypresses and all proved to be non-pathogenic under the test conditions. Almost all of the isolates showed some individuality in cultural characteristics but all grew more slowly and sporulated more readily in culture than *Coryneum cardinale.* In general, the mycelium of those isolated from bark was non-pigmented and appeared similar to the saprophytic *Coryneum* already mentioned, while the isolates from foliage nearly all showed some degree of pigmentation. No conclusion was reached as to whether these various non-pathogenic isolates represent a single variable species or more than one species. To test whether some of the variants might be the result of an heterocaryotic condition of the parent fungus, Dimock made a number of series of single-conidium cultures from the different strains. He states that, "In all cases, however, the cultures showed complete intra-strain uniformity while inter-strain differences persisted."

Cultural differences that apparently represent strains within *Coryneum cardinale* have also been noted. On malt or potato-dextrose agars typical colonies of this fungus develop a soft, floccose surface, shading in color from a dull white at the outer margin through light andover green (Ridgway, Robert. Color standards and color nomenclature. 43 pp. Washington, D. C. 1912) to deep andover green or grayish olive at the center. In most isolates the color of any particular part of the colony is quite uniform but some exhibit a rather speckled color pattern in the darker portion of the mat and in some the light colored margin is consistently wider than in the average typical culture. In addition to color differences in cultures grown under identical conditions, some strains show consistent differences in rate of growth.

A puzzling feature noted by Dimock in his study of various

Coryneum isolates in culture was the appearance in the culture tubes of components with *Cytosporina*-type spores. These were found in four different isolates of saprophytic forms and in one *Coryneum cardinale* isolate, usually some time after the initial culturing, and under conditions that would almost certainly preclude contamination as a source for the additional spore form. In the examination of *Coryneum* cankers it was noted on several occasions that *Cytosporina*-type spores were mixed with the regular *Coryneum* spores in acervuli, particularly when cankers had been soaked in water and placed in moist chambers to promote abundant spore formation. The relation of this *Cytosporina* form to the Coryneums with which it has been found in association remains to be clarified.

The mycelium of *Coryneum cardinale* in agar culture presents no microscopic characteristics that seem to be of any particular value in diagnosis. The young aerial hyphae are rather straight, hyaline to sub-hyaline, only occasionally septate or branched and 1.0μ to 1.8μ in diameter. With age they darken in color, sometimes becoming almost olivaceous, and thicken to as much as 8μ in diameter. Along with these changes they may become much branched and many septate, exhibiting great irregularity in the size and shape of individual cells. All intergradations between these old, thickened irregular hyphae and the slender, rather simple young ones are found. The submerged hyphae show the same variations to a lesser degree.

Most isolates of the fungus produce conidia only sparingly in culture and then usually only after the agar has dried down substantially. A few rarely sporulate in culture. The spores appear in small individual black masses scattered here and there under the mat of surface mycelium or shallowly immersed in the agar substratum in areas where the latter is thin, such as around the edges of an agar slant. Conidia are sometimes extruded in black, somewhat globular masses on the surface of the mycelial mat from embedded stromas. Both terminal and intercalary chlamydospores are produced rather commonly in culture. In colonies on agar media they have been observed only on the aerial mycelium.

Spore production from pustules on cankered bark depends chiefly on the presence of sufficient moisture to induce activity by the fungus. Outside of the coastal fog belt our normal summer season is too dry to stimulate spore formation, and pustules on the older, dry cankered bark remain practically dormant until the rainy season. However, they can be quickly reactivated at any time by placing cankered bark in a moist chamber or moistening it for a few hours by any other means.

Moisture in the form of free water or its presence in the air to the point of approximate saturation is also needed for spore germination. The process is sometimes quite uniform in time of initiation and rate or progress in any one lot of spores, but more often it is irregular and spores begin germination over a period of a number of hours. Normally an individual spore puts out one or two germ tubes but occasionally three are produced. In nearly all cases they issue from the first and fourth colored cells of the spore. When the germ tubes reach a length of from 3 to 8 times that of the spore, branching normally occurs. The mycelia from different spores anastomose readily and form an interconnected hyphal mat.

Temperature relations

From tests of the comparative growth of *Coryneum cardinale* on potato-dextrose and on malt agar plates held at the approximately constant temperatures of 6°, 11°, 15°, 18°, 22°, 26°, 30°, 33° and 35° C., the maximum increase in colony diameter was obtained in the 26° C. series. Limited growth took place at the 6° C. level, with steady increases at other levels up to 26° C. Growth at 30° C. was very sharply reduced and no growth took place in the 35° C. plates, though when these were returned to room temperature growth activity was resumed. Growth occurred at 33° C. but it was very limited. These results suggest that the minimum temperature for growth by the fungus is a little below 5° C., the optimum is near 26° C. and the maximum about 34° C. In contrast, the optimum for the saprophytic Coryneum from the coastal districts was found to be approximately 18° C. and there was no growth at 30° C. These low temperature characteristics undoubtedly have a bearing on the fact that the fungus has been found only in the cool coastal districts of the State.

A marked contraction was noted in most of the *Coryneum cardinale* colonies held at 30° C., with an accompanying disappearance of the filamentous margin characteristic for those grown at lower temperatures. The wrinkled, contracted state was followed after several weeks by a smooth type of growth. After long incubation at this temperature, sectoring and degenerative changes were noted in some of the colonies. All these reactions point to the conclusion that a sustained temperature of 30° C. is too high for favorable growth by the fungus.

Experience in germinating spores of the fungus at various temperatures suggests that optimum and limiting temperature levels for germination closely approximate those determined for growth of the organism. This conclusion is supported by a test reported by Dimock (loc. cit.) in which a parallel series of germination tests was run at 9 temperature levels ranging from 4 to 45° C. At the 4° level germination was very slow but 19 percent had put out germ tubes by the end of ten days. Maximum germination occurred at the 26-27° C. level and almost none at 35°, 38°, and 45° C. The latter temperatures proved to be lethal to nearly all of the spores subjected to them in a moist condition for a 10 day period, although in a dry state the spores probably could have survived in considerable numbers.

At 25° C. germination begins in a little more than 3 hours and at 21.5° C. in a little more than 3.5 hours. Temperatures during the winter rainy season in California, when most spore germination is likely to occur under natural conditions, average considerably lower than these levels, falling within 7° to 15° C. most of the time. Germination within the latter range is much slower than at temperatures over 20° C., as evidenced by the result of a test at 12.5 degrees C. in which not more than 10 percent of the spores had germinated after 14 hours. Accordingly most of the germination that occurs in nature in California may be expected to require from 12 to 24 hours or longer for initiation.

Dissemination

The means by which the canker fungus spreads to new sites and locations may be divided into several categories: transport by man, localized natural transport, and distance spread by natural agencies.

Locally the transfer of the fungus on pruning tools is a common means by which man aids in its dissemination. Numerous instances where this has occurred have been observed. Over longer distances the movement of nursery stock bearing spores or incipient infections of the fungus was undoubtedly a factor in the spread of the disease during the early years of its history before it was well understood and the threat that it offered was appreciated. The field evidence indicates that in recent years spread by this means has been negligible.

Of the natural means of local dissemination within individual tree crowns or plantings, rain or mist appears from tests to be by far the most important. Up to 700 spores per sq. cm. were caught on filter paper disks exposed under the drip from cankers during rains at the start of the rainy season in California. In sample counts of spores lodged on healthy cypress bark on infected trees Dimock (loc. cit.) found as many as 10,000 spores per sq. cm. a foot or so below active cankers. Other counts made from the bark surface of lower branches on a 30-foot tree, with large cankers about 6 feet below the top, showed that from 2500 to 5000 viable spores per sq. cm. were present. Surface soil under infected trees, when plated out, showed that the number of viable spores there ran as high as 7000 per gram of soil. These were almost certainly washed down from cankers on the trees by rains.

Spore trapping tests indicate that while very small numbers of conidia may occasionally be carried by winds during dry weather, this means of transport is not likely to be an important factor in the local spread of infective material as compared with water. During storms with rains accompanied by high winds, splash droplets of water containing spores may be carried locally for some distance. In view of the numbers of spores sometimes lodged on non-infected bark of cankered trees it is evident that birds, rodents, and insects may also assist in local spore dissemination by fortuitously carrying from place to place those that temporarily cling to their feet or bodies. Among the insects that might serve as transporting agents are the cypress bark beetles, which, as already mentioned, mine out short chambers in cypress twigs at certain seasons.

To obtain some measure of mined twigs as foci for Coryneum lesions, Dimock collected numbers of them and made tissue cultures from bark immediately adjacent to the edges of the mined chambers. From a total of 176 specimens cultured in this manner, *Coryneum cardinale* was recovered from 29 percent of old beetle wounds partially or completely healed over and from 16 percent of recently mined twigs. In addition, 6 lesions centering around *Phloeosinus* chambers yielded the fungus. Although these results show that it was established adjacent to an appreciable proportion of the beetle wounds they do not indicate whether the fungus was introduced by the beetles or whether the infections occurred from spores deposited in the wound by other means. From the fact that the mined twigs are usually near the branch tips on the outer fringe of the crown rather than in interior positions where they might be more nearly under established cankers, it would seem that in at least some of the cases the infective material probably was carried in by the beetles themselves. However, several attempts that were made to recover the fungus from the bodies of living beetles were unsuccessful.

Distance spread of the disease to new localities, aside from that chargeable to man, is probably almost entirely by wind and birds. All indications are that by either means the carriage of spores is very sporadic so that it is only here and there over a considerable period of time that initial infections become established in localities previously free of the disease. This is in contrast to many fungous diseases primarily adapted to wind transport, such as the rusts, the spores of which may be spread in quantities over a wide area within a single season.

Factors influencing infection

Spores of *Coryneum cardinale,* when protected in a dry situation, maintain their viability for many months. Dimock (loc. cit.) tested spores for germinative capacity from collections of cankered bark that had been stored in the herbarium for various periods and found one lot viable after 22 months of storage. In earlier, similar tests on 8 lots of material on hand for from 18 to 47 months, no germination was obtained by me in one lot after 20 months storage but 25 percent of the spores were found to be viable in another lot stored for 42 months.

In the open, spores could be expected to have a much shorter life because of the conditions of exposure. Dimock ran tests to determine the longevity of spores on glass slides exposed to the weather as compared with duplicates protected in a laboratory case. He found that the viability of the exposed spores dropped quite rapidly and after 21 days only 2 percent germinated, whereas 50 percent of the spores stored in the laboratory were still viable. Spores deposited on cypress foliage maintained their viability much better (Table III).

Table III

LONGEVITY OF SPORES OF *Coryneum cardinale* UNDER EXPOSED AND PROTECTED CONDITIONS (after Dimock)*

Spores	No. of Days	Protected Spores counted	Protected Percent viable	Exposed Spores counted	Exposed Percent viable	Av. temp. from start	Total rain from start	Remarks
	0	422	98	422	98			Checks
On	6	620	69	377	16	53°F	0	
glass	21	714	50	446	2	55°F	0.15″	4 rainy days
slides	81	600	39	600	0	53°F	9.06″	29 rainy days
	146	581	26					
	207	400	5					
	1	200	97	200	89	59°F	0	
On	7	300	92	200	78	61°F	0	
cypress	15	200	89	200	55		0.56″	2 rainy days
foliage	21	200	88	136	35		0.56″	2 rainy days
	48	200	78	70	29		0.56″	2 rainy days

Under some conditions spores apparently remain viable for a considerable time on cypresses. In my 1939 paper mention was made of a case in which spores were painted on selected spots on the stems of 6 small Monterey Cypresses and wisps of cotton were wrapped around the stems just below the portions to which the spores were applied to keep the latter from being washed down to other parts of the seedlings. The infested trees were enveloped with moist chambers for from 3 to 5 days. Afterwards they were placed outdoors for a time and then removed to a lath house but no lesions developed on any of the trees. After a year in the lath house they were considered free of the disease and were utilized as interplants on one of the field susceptibility test plots at Stanford University. A year later, or more than 2 years after the spores had been applied, lesions developed on 6 of the 12 trees used in the former experiments and in each instance only at places where the spores were originally applied although the trees were by then several times their size at the time of the original exposures. The wisps of cotton had not been removed

*Dimock, A. W. Unpubl. Rept., Forest Pathology, San Francisco, May, 1938.

during the intervening time and many of them still clung to at least one side of the stem. It is believed that some of the spores may have become lodged under the cotton and that the latter offered enough protection to keep them alive until they were able to gain entrance to the plants. However, it is hard to understand why all of them did not lose their viability through germination long before they were actually able to infect the trees as judged by the appearance of lesions.

The only other possibility that suggests itself is that germination and infection may have occurred promptly after the spores were applied but that for some reason the infections became arrested by the formation of phellogen before they were able to produce visible lesions and that they did not resume activity until the trees were planted out in the Stanford plot. However, from what we know of defensive reactions in the Monterey Cypress this possibility seems quite remote.

The ability of *Coryneum cardinale* to enter the host through wounds of almost any character or size, providing exterior moisture and temperature conditions are suitable for the fungus, has been well established. There is less certainty concerning its ability to penetrate unwounded foliage or bark.

As a test to provide some information on the size of opening through which the fungus can enter, Dimock (loc. cit.) made 1 to 5 pin punctures through surface-sterilized bark of crotches and smooth stems of young seedling Monterey Cypresses. Spore suspensions or mycelium from agar cultures of the fungus were applied over the punctures and were covered with adhesive tape. Lesions developed from 8 of 30 punctured areas to which mycelium had been applied and 4 of 59 areas on which spore suspensions had been placed. Most of the lesions appeared within one or two months but one did not develop until 11 months after the placing of the inoculum. The largest number of lesions developed from areas where 5 punctures had been made in the bark and the inoculum consisted of mycelium. These results suggest that the fungus is occasionally able to enter the host through very small wounds, though the possibility is not ruled out that it might have entered directly through the bark rather than through the punctures.

To provide evidence on the latter possibility Dimock placed mycelium-bearing agar on the surface of smooth, surface-sterilized bark, uninjured so far as could be determined by visual inspection, of young Monterey Cypresses and covered it with adhesive tape. A total of 42 spots on small stems and 14 at crotches were treated in this manner. Not a single lesion resulted, indicating that some injury of the epidermis is necessary for infection. Against this experimental evidence is the experience of both Dimock and myself in finding incipient natural lesions where no associated injury could be detected, even with a hand lens or under a dissecting microscope.

Dimock also succeeded in obtaining several small lesions on foliaceous laterals and small twigs of young Monterey Cypress seedlings still bearing juvenile foliage by spraying potted plants with a heavy suspension of spores of *Coryneum cardinale* and covering them with bell jars. The fungus was reisolated from each lesion. On the other hand, cultures made from 28 brown foliaceous tips found on seedling trees in the Oakland hills failed to yield *C. cardinale* in a single case though many gave sapropyhtic Coryneum isolates. Moreover, out of a total of 26 positive infections with *C. cardinale*, obtained by tiny slit inoculations into foliaceous tips and small laterals, Dimock found that 20 became arrested before reaching the stem.

These results suggest that while entry through small foliaceous branchlets is possible it is not of frequent occurrence and that establishment of the fungus in foliar parts gives no assurance that it will succeed in reaching a larger stem.

Breaks in the epidermis of live, non-fibrous bark of young, thrifty cypresses may occur naturally in a number of species, particularly in situations where conditions stimulate rapid flushes of growth. These breaks are usually in the form of small cracks that apparently develop when the growth of the cambium is so rapid that the epidermal tissues are unable to accomodate themselves to the expansion rapidly enough. The conditions of the particular season seem to influence the prevalence of such cracks. On the Stanford plots they were quite common in the spring of 1937 when growth became very active. Most of the cracks were noted on main stems either just above or just below the junction of side branches and occurred chiefly on tall, open-crowned specimens. The bark rupturing was not noted on close-crowned, heavy-foliaged trees, even though the latter were often making the more rapid growth. Such openings remain only a short time before they are sealed by resin and wound periderm but during the time they are open they offer points of entry for the cypress canker fungus. Small wounds or breaks in the epidermis may also be caused by insects or by the claws of birds, by rodents, and by the rubbing of branchlets during windstorms.

The condition of the host tree seems to influence chances for infection and the progress of cankers. Within limits, trees under competitive stress seem to be less subject to the disease than those with ample room and nutrition. It is possible that this may be associated with the difference in growth rate between suppressed and thrifty individuals. Slower growth probably is not the only reason for the relatively greater observed freedom of closely clipped hedge trees from the disease as compared with open-grown trees. In addition to the more subdued growth, the interiors of clipped trees are usually less accessible to birds and a considerable accumulation of dust, lichens and small debris often coats the interior branches of hedge trees. This accumulation might readily prove an obstacle to the entry of *Coryneum*, or saprophytic fungi developing in it during moist periods might offer antagonism to the Coryneum fungus.

An unexpected demonstration of the influence of host environment on canker incidence was provided when field susceptibility test plots, to be described later, were discontinued at Stanford University. In compliance with the wishes of the University all trees were removed on completion of the tests except about 20 Monterey Cypresses that showed evidences of some resistance to the disease, as indicated by the absence of natural infection and the arrestment of cankers produced by artificial inoculation. The trees had been planted in a 6 x 6 spacing and had become quite crowded by the time the plot studies were concluded. The removal of all except the reserved trees, however, left the latter individually isolated and exposed. In a recent examination of these reserved trees it was found that almost all of them had developed the disease within the approximate year elapsing since they had been freed of crowding and competition. Most of the cankers that had developed were on the main stem or on the bases of branches emanating from it. In the case of one or two trees it was noted that branch cankers that had been in an arrested state during the final year or two in the plot had resumed activity and had extended considerably since the time of removal of surrounding trees.

Unfortunately no close watch of these trees was maintained during the time that the new cankers were becoming established or the arrested ones were regaining activity and as a result no reliable evidence was obtained concerning the mode of entrance or other aspects of the sudden onset of the disease after liberation of the trees from crowding. However, the increase in canker incidence following the opening up of the stand was so pronounced that there seems no question concerning the existence of a relationship between the two.

In the course of a program to protect the native groves of Monterey Cypress near Carmel, California, from possible damage by the cypress canker, the question arose concerning the protective value, if any, of the salt spray that is deposited on exposed trees along the rocky coast there. The question was explored by Dimock (Abst. Phytopath. **29**:823. 1939) who concluded from testing of salt deposits on bark of native trees in the groves and from experiments with sea water and salt solutions in the laboratory that no protective effect against the Coryneum by salt deposited from ocean spray could be counted on.

Susceptibility determined by inoculation

The successful inoculation of cypresses with the canker fungus was mentioned by Wagener in 1928 (Science (n.s.) **67**:584.) and by

Birch in 1933 (Te Kura Ngahere **3**:108-113.), but the first publication of detailed results of the inoculation of *Coryneum cardinale* into various coniferous hosts was by Clayton O. Smith (Phytopath. **28**:760-762. 1938). Twelve species of *Cupressus,* most of them collections by the Rancho Santa Ana Botanic Garden, and 10 species of other genera in the Cupressaceae were represented in the tests, as well as various other conifers and a few deciduous shrub or tree species. The tested trees varied from 6 to 30 mm. in stem diameter and were growing in 5-gallon containers in a lath house. From 1 to 5 trees of each species were tested by introducing the fungus into a single wound made with a 4 mm. cork borer through the bark on the stem of each.

Lesions with a radius at the end of two months of from 10 to 35 mm. resulted on all species of *Cupressus.* After 3.5 months, the stems of *C. Bakeri, C. Goveniana, C. Macnabiana, C. macrocarpa* and two out of four trees of *C. Sargentii* had been girdled. Other species on which the lesions were quite pronounced were *C. lusitanica* and *C. pygmaea.*

The tests on other Cupressaceæ resulted in lesions on *Thuja plicata, T. orientalis, T. occidentalis, Juniperus Cedrus, J. californica, J. virginiana,* and *Libocedrus decurrens.* Of these, the lesions of the last two species were quite limited in extent. No lesions developed on *Juniperus phoenicea, J. procera* and *Chamaecyparis Lawsoniana,* or on any of the 12 species fr m other families of conifers, including *Cryptomeria japonica, Sequoia gigantea* and *S. sempervirens.*

Three series of inoculations on a lesser number of possible hosts were reported by Wagener in 1939 (loc. cit.). With the exception of one group on young potted Monterey Cypresses in which spores of *Coryneum cardinale* were applied to scarified spots on the bark, all inoculum was placed under the live bark through longitudinal slits 6 to 10 mm. in length cut through it with a sterile lance. The inoculum consisted of spores of the fungus in about one-third of the tests and of mycelium from cultures of agar for the balance.

Four out of five cases in which spore suspensions were applied to scarified spots on small *Cupressus macrocarpa* seedlings and the spots were wrapped with moist cotton resulted in positive infections. The results of the two main series of tests, made on potted trees from 1.5 to 4 feet in height in a muslin-lined lath house in California, or, in the cases of *Juniperus virginiana* and *Thuja occidentalis,* in a cool greenhouse in New Haven, Connecticut, are combined in Table IV.

Table IV

SUMMARIZED RESULTS OF INOCULATIONS BY WAGENER WITH *Coryneum cardinale* INTO CONIFERS

Species inoculated	Inoculations				Character of positive lesions
	Total No.	Positive	Negative	Percent Positive	
Cupressus glabra	43	38	3*	88	Intermediate
" *lusitanica* and varieties	17	17	0	100	Mostly intermediate
" *Macnabiana*	5	5	0	100	Intermediate
" *macrocarpa*	16	14	0*	87	Extensive or intermediate
" *sempervirens indica*	4	4	0	100	Extensive
Cryptomeria japonica	16	4	12	25	Limited
Juniperus occidentalis	3	3	0	100	Limited
" *virginiana*	27	26	1	96	Intermediate to extensive
Libocedrus decurrens	10	0	10	0	None
Thuja occidentalis	41	38	3	92	Limited

In the cases where species were represented both in the Smith and in the Wagener series, the results show good general agreement but a few minor differences will be noted. On *Juniperus virginiana* the reactions obtained by me were somewhat more pronounced than the limited cankers developed on this species in the Smith tests. On the other hand, Smith obtained positive infection on *Libocedrus decurrens* while in ten inoculations I did not. Results on *Cryptomeria japonica* were negative in the Smith tests whereas I obtained limited cankers in 4 out of 16 trials on this species. The significance of these differences will be considered later.

Susceptibility from Field Tests

Tests of the susceptibility of possible host plants to a disease by the inoculation method are of value in delimiting hosts and in providing some indication of what may be expected under natural exposure in the open but they cannot be relied on as a safe guide for what is commonly termed "field susceptibility." For this there is no substitute for the exposure of potential host plants, growing in the open, to the particular disease organism under as nearly uniform exposure conditions as possible. A further qualification is that the site should be favorable enough to permit the host plants to make normal, healthy growth.

The late Professor J. I. McMurphy of Stanford University was one of the first to urge the desirability of a comparative field test of the susceptibility of various species of *Cupressus* and related conifers to damage by *Coryneum cardinale.* Possibilities for such

*Two cases with reaction doubtful.

a test were explored and with the generous cooperation of the University in providing the necessary ground and irrigation water the first test plot was established by the Division of Forest Pathology on the Stanford campus early in 1935.

On technical grounds, two considerations favored this choice of location for the plots. One was that it was in a district where the cypress canker fungus was prevalent. Another was that it was situated inland some 13 miles from the ocean behind a range of hills rising to over 2000 feet in elevation and on this account was climatically intermediate in character between the cool, somewhat humid immediate coast, to which several cypress species, such as *Cupressus macrocarpa* and *C. pygmaea,* are native and the much warmer and drier interior of the State, from which come such cypresses as *C. Macnabiana* and *C. nevadensis.* From previous experience with cypresses planted at Stanford University it was known that several species, including Monterey Cypress, the one to be used for interplanting in the plot tests, would do well in that area and there was reason to believe that the location would prove as nearly satisfactory for all coniferous species to be included in the tests as any available.

The representation of species included in the initial test planting, hereafter to be referred to as Plot 1, on the University grounds was limited by the availability of nursery stock of appropriate size. The planting was especially deficient in native species of *Cupressus.* Fortunately a means of overcoming this shortcoming was soon presented by an offer from the Rancho Santa Ana Botanic Garden, through its Founder and Managing Director, Mrs. Susanna Bixby Bryant, and its Botanist, Dr. Carl B. Wolf, to make available to us on a cooperative basis potted seedling plants of all known species and varieties of *Cupressus* native to California. These plants were being propagated from seed collected in the course of field work on the comprehensive study of native cypresses undertaken not long before by the Garden, as described in parts I and III of this publication. Needless to say the offer was most gratefully accepted.

To accommodate these additional trees, most of which were received from the Rancho Santa Ana Botanic Garden early in February 1936 and the balance a year later, a second plot adjoining Plot 1 was laid out on the Stanford campus*. To it were added a number of seedlings of *C. lusitanica* from Mexican seed and representatives of six lots of *C. arizonica* grown from seed collected in native stands in Arizona. A few remaining blanks were filled by ornamental junipers

*J. W. Kimmey, Associate Pathologist, Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering and A. W. Dimock, formerly Assistant Pathologist, Civilian Conservation Corps, assisted in the field work on the susceptibility tests at Stanford University, particularly on Plot 2. Their aid is gratefully acknowledged.

of varieties that had shown some preliminary indications of susceptibility.

Plot layout and composition. At the time that Plot 1 was established it was not definitely known whether additional tests would be undertaken and accordingly this plot was laid out as a unit by itself. It was made rectangular in shape, with a width of 15 rows of trees and a length of 25 rows. A 6 x 6 foot spacing was adopted in the anticipation that the tests could be completed in about 4 years and that a spacing of these dimensions would provide sufficient room for growth and at the same time would insure a desirably close proximity of the test trees to the susceptible interplanted Monterey Cypresses. Actually it was later found necessary to extend the life of the plots to nearly double that originally contemplated and a wider spacing would have been preferable.

Trees to be tested were alternated in each row with Monterey Cypresses and every other row was staggered so that each test tree in the interior of the plot was surrounded by Monterey Cypresses on all four sides. The corners were left unplanted and all spaces between the Monterey Cypress interplants on the outside of the plot were originally filled with seedlings of *Cupressus glabra* and a few trees supplied as *C. Macnabiana* but which later proved to be undoubtedly *C. Forbesii*. When Plot 2 was added a year later to accomodate the Rancho Santa Ana collections it was made continuous with Plot 1 on the westerly side of the latter and the exterior *C. glabra* trees on this side were replaced with other species.

Arrangement of the test trees within Plot 1 could not be carried out according to any set pattern, such as a Latin square, because of the unequal numbers of the various species available for the test. A partially randomized distribution of each species was accordingly worked out, which provided good dispersal of each over the plot but without any definite pattern. A few blanks remained after the original planting and these were filled the following year, together with replacements for losses during the first year from rabbits, insects, and failure of a few of the initially planted trees to become established.

One difficulty that became apparent as the trees in the plot grew and lost their juvenile form was the incorrect naming under which a few of the trees had been received. Thus one lot, received as *Cupressus Macnabiana*, failed to develop the definite foliage characteristics of that species, but instead proved to be typical of *C. Forbesii*. Two trees of another lot, received as *C. Macnabiana*, turned out to be in the *arizonica* group, probably *C. glabra*.

With these corrections, and excluding a few trees that died from other causes too early to give satisfactory indication of their susceptibility to *Coryneum cardinale*, the final representation of test species and interplants in the plot, and their sources, is shown in Table V.

Table V

TREE SPECIES AND SOURCE, PLOT 1, STANFORD UNIVERSITY, PALO ALTO, CALIFORNIA

Species	*Number of Trees*	*Source**
Test trees		
Cupressus arizonica	15	Propagated from seed from Clifton, Arizona supplied by W. H. Long
" *Forbesii*	9	Davis Nursery, California State Division of Forestry
" *glabra*	9	Davis Nursery, California State Division of Forestry
" "	18	Commercial nursery through Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture
" *Goveniana*	1	Seedling from type locality from E. P. Meinecke
" *guadalupensis*	20	Propagated from seed from Guadalupe Island, Mexico, collected by J. T. Howell, California Academy of Sciences
" *lusitanica*	22**	Davis Nursery, California State Division of Forestry
" *Macnabiana*	2	Devil's Canyon Nursery, U. S. Forest Service
" *Sargentii*	4	Propagated from seed from Lake County, California by J. B. Roof
" *sempervirens* (columnar form)	10	Five commercial nurseries
Chamaecyparis Lawsoniana (native forest form)	20	Union Lumber Company Nursery, Fort Bragg, California
Cryptomeria japonica	10	Davis Nursery, California State Division of Forestry
Juniperus occidentalis	3	Wild seedlings, Modoc County, California
" *virginiana*	12	Commercial nurseries, Seattle, Washington and Sherman, Texas
Libocedrus decurrens	8	Wild seedlings, Tuolumne County, California
Thuja orientalis	10	Davis Nursery, California State Division of Forestry
" *plicata*	10	Union Lumber Company, Fort Bragg, California
Total test trees	183	
Interplants		
Cupressus macrocrapa	139	Commercial nurseries
" "	47	Golden Gate Park Nursery, City of San Francisco, California
" "	1	J. B. Roof, San Francisco, California
" "	1	Point Lobos Reserve, California Division of Parks
Total interplants	188	

* Especial thanks are due the persons, firms or agencies specifically mentioned for their cooperation in supplying without cost or at nominal cost the seeds or plants credited to them.

**Identity questionable for one tree.

In addition to the trees listed in Table V, 10 small trees of *Cupressus lusitanica*, from seed collected in Costa Rica and propagated at the Chico Plant Introduction Garden of the Division of Plant Exploration and Introduction, U. S. Department of Agriculture, were planted late in 1936 but were lost within six weeks from freezing injury during the extremely cold weather in January 1937. Some other early losses occurred but were replaced with extra stock except for one plant of *C. Goveniana*.

The two species of junipers in the plot did not appear to be well adapted to the site conditions and, in addition, suffered damage from mites during one or two seasons. Therefore they made poor growth and in the latter years of the plot were further handicapped by competition from the much larger surrounding trees. *Thuja orientalis* also suffered somewhat from competition, especially for light, in the later years of the plot.

One portion of the plot apparently received some moisture from deep sub-irrigation from a leaky water pipe about 40 feet outside of the plot boundary. Growth of the Monterey Cypress interplants in this portion of the plot was so rapid that it was necessary to resort to topping and a certain amount of side pruning to prevent them from shading out the adjoining test species. The topped trees later developed new tops.

When Plot 2 was established in 1936, the land available did not permit a fully rectangular layout pattern and an extension of part of one end of the plot at an angle was found to be necessary to accommodate the number of trees that it was expected would be available. The same 6 x 6 spacing used in Plot 1 was followed and the second plot was made 29 rows wide, with a minimum length of 27 rows and a maximum length on the westerly side of 37 rows. The same alternating pattern of test trees and interplants as used in Plot 1 was employed on this plot.

In order to obtain a distribution of each propagation number to be tested over the plot without following any set sequence, the staked plot was considered as consisting of 5 parts, a central section and 4 corner sections. These were not definitely marked off but were merely kept in mind as general divisions when the plants were distributed. Each lot of test trees was placed individually by one person, who would take a potted tree, walk to one of the parts of the plot and set the tree down at an unoccupied stake without attempting to select any particular stake or location for it. Where a lot consisted of 5 trees, one was placed in this manner within each of the five general portions of the plot; if it was made up of 10 trees, 2 were placed in each portion. The result was a semi-random distribution by which each lot was assured good dispersal without restriction to a set pattern.

To equalize chances for exposure to infected interplants as much as possible, an extra tree was planted of each lot when one of its number fell in a position on the edge of the plot. In that case the extra tree was also planted along the outside edge of the plot so that such lots consisted of 4 trees in inside positions and 2 trees in outside positions.

As already noted, Plot 2 was set up primarily to accomodate native cypresses propagated by the Rancho Santa Ana Botanic Garden. In order to provide for replants in case of losses during the first season and to provide extra trees for the lots with outside positions, the Garden supplied either 7 or 12 of each propagation lot. The extras were held in readiness for later use in a shelter near the plot. Fortunately almost all of the trees in the original planting became well established and only a few replacements were needed. The stock supplied by the Rancho Santa Ana Botanic Garden for the plot is listed in Part III, Table XVII of this publication.

Not enough stock was available of all of the cypress collections of the Rancho Santa Ana Botanic Garden to permit the inclusion of all of them in the Stanford test plot. The remaining blanks were filled with other species, as already mentioned. These are listed in Table VI along with the Monterey Cypress interplants on the plot.

Table VI

SPECIES AND SOURCE OF TREES, OTHER THAN THOSE FROM RANCHO SANTA ANA BOTANIC GARDEN, PLOT NO. 2, STANFORD UNIVERSITY, PALO ALTO, CALIFORNIA

Species	*Number of Trees*	*Source*
Test trees		
Cupressus arizonica	5	Propagated from seed from Bonita Canyon, Cochise Co., Arizona
" "	4	Propagated from seed from Cherry Lodge, Cochise Co., Arizona
" "	9	Propagated from seed from Faraway Ranch, Cochise Co., Arizona
" "	8	Propagated from seed from Rucker Canyon, Cochise Co., Arizona
" *lusitanica*	11	Propagated from seed from Canada del Batan, D. F. Mexico
Juniperus chinensis femina	6	Del Amo Nursery, Compton, California
" " *torulosa*	1	Del Amo Nursery, Compton, California
" " "	2	Clark's Nursery, San Jose, California
" *virginiana glauca*	3	Clark's Nursery, San Jose, California
Interplants		
Cupressus macrocarpa	373	Commercial nurseries
" "	64	Point Lobos Reserve, California State Division of Parks
" "	21	J. B. Roof, San Francisco, California

In connection with the stock for Plot 2, listed in Table VI, we are indebted to the following for seed or plants supplied either without cost or at nominal cost for the experiments: L. S. Gill, Senior Pathologist, Division of Forest Pathology, U. S. Department of Agriculture, Albuquerque, New Mexico; Sociedad Forestal Mexicana, C. L. and its Secretary, Ing. Gilberto Serrato A., Mexico City, D. F., Mexico; Del Amo Nursery, Compton, California; California State Division of Parks and Custodian R. A. Wilson, Point Lobos Reserve; and J. B. Roof, San Francisco, California.

As in Plot 1, Monterey Cypresses were interplanted between each test tree. Most of them had been raised in flats to a considerable size before planting out and considerable root damage resulted in separating them. About 14 percent failed to become established and replacements were necessary the following winter.

When completed, Plot 2 contained 442 test trees and 458 Monterey Cypress interplants. No substitutions of other species or lots of trees were made on this plot after its establishment.

Exposure to the fungus. According to the original plans for the plots, branches on all four sides of the Monterey Cypress interplants opposite the surrounding test trees were to be inoculated with *Coryneum cardinale* as high up as feasible. The purpose was to expose the test trees as uniformly as possible to adjacent spore sources. It was found impractical to carry out these plans on Plot 1 but branches on the interplants on Plot 2 were inoculated during the fall of 1940, when all but the replacements had been established for four years. Bits of acervulus-bearing bark from the surface of sporulating cankers were used for inoculum and these were introduced into longitudinal slits about 1.5 cm. in length on the under side of the selected branches. Each inoculation was wrapped with raffia, which was removed after about a month. The site of inoculation was made as high as possible but varied considerably, depending upon the availability of branches of sufficient size. They averaged about 6 feet (1.8 meters) in height and 2 feet (0.6 m.) distant from the main stem of the inoculated tree. Diameters of branches at the point of inoculation varied from about 8 to 20 mm. On some trees no branches large enough for inoculation occurred at anywhere near the desired height on one or more sides of the tree and inoculations there were omitted. Several interplants were too small to provide any branches suitable for inoculation.

The cankers developed from the branch inoculations did not prove wholly satisfactory as spore sources, partly because many inoculations had to be omitted, as mentioned above, and partly because of the limited size of cankers on small branches, which were soon girdled on susceptible trees. In addition, part or all of the branch cankers on 20 or more trees became arrested before they had caused girdling of the branches on which they were located and spore production from these was usually very limited. Accordingly the decision was made to supplement the branch cankers by inoculations on the main stems. Cultures of the *Coryneum* on agar plates were used as inoculum for the stems and it was introduced by means of a flamed scalpel into slits cut in the bark of the main stem of each tree at 7 to 8 feet (2.1 to 2.4 m.) from the ground. Each slit was then covered with a patch of 1-inch waterproof adhesive tape. Only one inoculation was made into stems 1.5 inches (3.8 cm.) or less in diameter but two were placed on opposite sides in larger stems. Several of the interplanted trees, December 1936 replacements in every case, were still too small to be worth-while inoculating. Aside from these, all interplanted Monterey Cypresses in Plot 2, and about 23 trees on the western side of Plot 1, were inoculated in the stem during the first half of August, 1941. Other demands on time prevented the completion of the inoculations on the latter plot.

Good sized cankers, a foot or more in length, with many spore-bearing pustules developed from nearly all of the stem inoculations but on a few trees the development was limited. This always occurred on trees on which the cankers from branch inoculations had become arrested after a limited development, suggesting that the trees were partially resistant to the disease. Since the stem diameters of the interplants in all parts of the plot varied considerably, the quantity of spores produced was likewise quite variable.

In addition to the infective material from the cankers initiated by inoculation, many cankers developed from natural infection on the interplanted trees. On Plot 1, where exposure to the fungus was chiefly from spores from naturally initiated cankers, the disease became established in places soon after the plot was planted and, by the time observations were concluded, cankers of natural origin were present on all but 17 of a total of 187 Monterey Cypress interplants on the plot, or on 91 percent. Individual infected trees were graded for presence of the disease in four classes, as follows:

Slight—Only one or two very small cankers present.

Light—One or two cankers present, larger than under the previous class but not extensive.

Moderate—Several cankers present, or one or two extensive ones.

Severe—Extensive cankering of the main stem and a few to many branches. Spore production in quantities.

Of the total interplants, 95, or about 51 percent, were rated as moderately infected, and 61, or 33 percent, as severely infected. Eighty-two of the infected trees, or 44 percent of all interplants, died from the disease before the termination of the test but since the fruiting pustules on cankered bark usually retain their spore-producing capacity during moist periods for many months after the death of the host part bearing the canker, the dead trees remained effective as spore sources for at least a year after their deaths and very probably for a longer time.

On Plot 2, natural infections to supplement the cankers produced by inoculation did not become as prevalent as on Plot 1, and 26 percent of the interplants failed to develop any cankers by natural means during the life of the plot test. However, 54 percent of the interplants, well distributed over the plot, were rated as moderate or severe with respect to diseased condition from naturally established cankers. On this plot only 42 of the 458 interplants, or 9 percent, died from the disease up to the time the last records were taken, or only about one-fifth as many as on the adjoining Plot 1 in proportion to the total number of interplants present. However, Plot 1 was continued for a year longer than Plot 2 and many additional interplants would have died on the latter plot within an additional year. Although the distribution of spore-bearing cankers, considering those of both inoculated and natural origin, on the plots was not as uniform as had been hoped for when the tests were first planned, ample spore sources were present to provide the necessary infestation of the test trees on all parts of the plots.

Results. Test trees on Plot 1 were rated for presence of the disease from a detailed inspection of each tree at the end of the test period, supplemented by any previous notes concerning the disease status on the particular tree. The ratings applied were the same as those used for the Monterey Cypress interplants: slight, light, moderate and severe classes.

Records on Plot 2 were kept in more detail and the location and dimensions of all cankers, both from inoculation and from natural infections, were recorded. The final ratings, under the same classes as for plot 1, were applied from the records rather than directly from a tree inspection.

The results for Plot 1 are summarized in Table VII. For Plot 2, a preliminary list of lots of trees among which cankers were found and the ratings for each are given in Table VIII. The information is combined in Table IX into a summary by species for all test trees in Plot 2.

Table VII

SUMMARY OF INCIDENCE OF CANKERING FROM *Coryneum cardinale*, STANFORD UNIVERSITY, PLOT NO. 1

Species	Total Trees	None	Degree of cankering Slight	Light	Moderate	Severe	Total with cankers	Percent with cankers
Cupressus arizonica	15	15					0	0.0
" *Forbesii*	9	9					0	0.0
" *glabra*	27	27					0	0.0
" *Goveniana*	1	1					0	0.0
" *guadalupensis*	20	20					0	0.0
" *lusitanica*	21	16*	1	2	2		5	23.8
" *Macnabiana*	2	1		1			1	50.0
" *Sargentii*	4	4					0	0.0
" *sempervirens*	10	9			1		1	10.0
Chamaecyparis Lawsoniana	20	20					0	0.0
Cryptomeria japonca	10	10					0	0.0
Juniperus occidentalis	3	3					0	0.0
" *virginiana*	12	12					0	0.0
Libocedrus decurrens	8	8					0	0.0
Thuja orientalis	10	10					0	0.0
" *plicata*	10	10					0	0.0

* Includes four trees with surface disturbance of bark in which *Coryneum cardinale* may have been present.

Table VIII

Incidence of Canker from *Coryneum cardinale* by Propagation Lots, Stanford University, Plot 2. Only Lots with Cankered Trees Included.

Propagation number	Species	Source	Number of trees	Degree of cankering					Total with cankers
				None	Slight	Light	Moderate	Severe	
2133	*Cupressus pygmaea*	Fort Bragg, Mendocino Co.	5	3		1		1	2
2134	" "	" " " "	6	1		3		2	5
2135	" "	Mendocino City, Mendocino Co.	5			2	2	1	5
2137	" "	Anchor Bay, " "	10	7	1			2	3
2144	" *Macnabiana*	Houghs Springs, Lake Co.	10	8	1	1			2
2148	" "	Reiff, Lake Co.	10	8			2		2
2141	" *Sargentii*	Occidental, Sonoma Co.	10	9	1				1
2146	" "	Cooks Springs, Colusa Co.	10	9			1		1
2147	" "	Reiff, Lake Co.	10	8		1	1		2
2149	" "	Aetna Springs, Napa Co.	10	8		1	1		2
2151	" "	Cobb, Lake Co.	10	9		1			1
2157	" "	Cedar Mountain, Alameda Co.	5	3	1	1			2
2158	" "	" " " "	5	4	1				1
2167	" "	Chorro Cr., San Luis Obispo Co.	5	2	1	2			3
2168	" "	" " " " " "	6	5		1			1
2173	" "	Pine Mtn., " " " "	10	9			1		1
2174	" "	Los Burros, Monterey Co.	10	7		3			3
2177	" *macrocarpa*	Point Lobos, " "	5	1	1	1	2		4
2178	" "	" " " "	5		1	4			5
2179	" *Goveniana*	San Jose Cr., " "	5	1		2*	2		4
2181	" "	" " " " "	5	4	1				1
2182	" "	Huckleberry Hill, Monterey Co.	5	3		1	1		2
2184	" *macrocarpa*	Cypress Point, " "	10	1		5	3	1	9
2185	" *Abramsiana*	Bonnie Doon, Santa Cruz Co.	5	4		1			1
2186	" "	" " " " "	5	2			3		3
2330	" *Forbesii*	Mt. Tecate, San Diego Co.	5	4	1				1
2331	" "	" " " " "	6	5	1				1

* Canker on one tree not definitely from *Coryneum cardinale*.

Table IX

SUMMARY OF INCIDENCE OF CANKERING FROM *Coryneum cardinale*, STANFORD UNIVERSITY, PLOT NO. 2

Species	Total Trees	None	Degree of cankering Slight	Light	Moderate	Severe	Total with cankers	Percent with cankers
Cupressus Abramsiana	10	6		1	3		4	40.0
" *arizonica*	26	26					0	0.0
" *Bakeri typica*	10	10					0	0.0
" " *Matthewsii*	10	10					0	0.0
" *Forbesii*	59	57	2				2	3.6**
" *Goveniana*[1]	20	13	1	3[2]	3		6	30.0
							(7)	(34.5)
" *lusitanica*	11	7	2*	2*			2	18.2
							(4)	(36.4)
" *Macnabiana*	87	83	1	1	2		4	4.8**
" *macrocarpa*	20	2	2	10	5	1	18	90.0
" *nevadensis*	10	10					0	0.0
" *pygmaea*	26	11	1	6	2	6	15	60.0**
" *Sargentii*	136	118	4	10	4		18	13.3**
" *Stephensonii*	5	5					0	0.0
Juniperus chinensis femina	6	6					0	0.0
" " *torulosa*	3	3					0	0.0
" *virginiana glauca*	3	3					0	0.0
Totals	442	371						16.1

It will be noted that very few test trees in Plot 1 developed cankers and most of these were on *Cupressus lusitanica*. The disease may have been somewhat more prevalent on this species than indicated by the ratings because of the uncertainty concerning the disease status on four trees listed among those without cankers. These four had canker-like deadened areas on the outer bark which did not extend to the cambium, bore no Coryneum pustules and may have been caused entirely by the activities of the pitch moth larvae that infested the bark in each case. However, no cultures were made from these particular trees and it may be that *Coryneum* was present on part or all of them. Resin flow may develop from C. *lusitanica* without attack by *Coryneum* and in the Stanford plots it proved to be more subject than any other species to attack in the twigs and at branch crotches by *Phloeosinus* beetles, in addition to the fairly common infestation of pitchy bark by pitch moth larvae. To the complications that may be caused by the work of these insects in the field, diagnosis of *Coryneum* on the Mexican Cypress is added the fact that the fungus dces not produce fruiting pustules as readily on its bark as on that of species with a more fibrous bark. Accordingly the field rating of the Mexican Cypress for Coryneum attack is more difficult than for

[1] Identity of one tree not certain.
[2] Canker present on one tree not definitely from *Coryneum cardinale*.
* Apparent canker on one tree not positively from *Coryneum cardinale*.
** Percentages based on 55, 84, 25 and 135 trees respectively, eliminating extra border trees to better equalize the comparison.

other species, unless supplemented by laboratory cultures, and ratings applied are likely to be less reliable than for most other susceptible hosts.

The single infected tree out of 10 of the columnar form of *Cupressus sempervirens,* the familiar Italian Cypress, probably does not afford a true comparison of the susceptibility of this species. All of the Italian Cypresses on the plot were planted in 1937, two years after the plot had been established, and replaced small trees of *C. lusitanica* killed by frost. They were therefore in the plot for a shorter period than the bulk of the trees under test there and, because of their late start, suffered somewhat from competition by the larger surrounding trees. As a result they averaged much smaller in size than other species represented in the plot, with the exception of the junipers, and thus were at a double disadvantage from the standpoint of exposure to the disease.

Noteworthy among the results was the absence of cankers on the 20 authentic Guadalupe Cypresses in the plot. The authenticity is emphasized because there is reason to believe that some of the rather scarce stock offered in the nursery trade under this name is not true *C. guadalupensis.* The trees in the plot grew almost as rapidly, both in height and diameter, as the interplanted Monterey Cypresses and in a number of places adjoined very heavily diseased specimens of the latter, with branches interlaced, so that they were fully exposed to the canker fungus. In character, growth rate, ability to compete with surrounding trees, and freedom from pests and diseases, Guadalupe Cypress was outstanding among the test species represented on either Stanford plot. It undoubtedly deserves wider horticultural use than is now possible because of the scarcity of reliable stock in the nursery trade.

The Arizona Cypress, *Cupressus arizonica,* and its close relative *C. glabra,* did well on the plot, although slower in growth than either Monterey or Guadalupe Cypresses, and both remained entirely free of cypress canker. Other species well represented on the plot, but not so well adapted to the site conditions there as the species of true cypresses that remained free of cypress canker, were the so-called Lawson Cypress or Port Orford Cedar, *Chamaecyparis Lawsoniana;* the Japanese Cryptomeria, *Cryptomeria japonica;* the Eastern Redcedar, *Juniperus virginiana;* the Oriental Arborvitæ, *Thuja orientalis;* and the Western Redcedar, *T. plicata.*

The incidence of cypress canker among the test trees on Plot 2, as summarized in Table IX, demonstrates the relatively high susceptibility of the coastal cypresses from northern California, *Cupressus Abramsiana, C. Goveniana, C. macrocarpa,* and *C. pygmaea.* Closely approaching the least susceptible of these, but with the actual rating for the plot somewhat doubtful because of two cases in which the presence of cypress canker was not definitely established, was the

Mexican species, *C. lusitanica.* Rating close behind this species, with 13 percent of the trees infected and with a larger basis of test trees than for any other cypress, was the inner coastal species, *C. Sargentii.* By reference to Table VIII it will be seen that the infected trees were not concentrated in any particular lot, or lots, from a particular locality, unless it might be in Lot 2167 from Chorro Creek, San Luis Obispo County, but were rather generally distributed over all of the lots.

The only other species in the plot contracting the disease were *Cupressus Macnabiana,* with 4.8 percent of the trees infected, and *C. Forbesii,* with 3.6 percent diseased. The affected trees of McNab Cypress were limited to lots from two localities out of the nine represented in the plot; Lot 2144 from Hough's Spring, Lake County, and Lot 2148 frcm Reiff, the same county. These locations are only about 20 miles apart. The Forbes Cypresses contracting the disease were of Lots 2330 and 2331 from Mt. Tecate in San Diego County, only one out of five localities for this species represented in the plots. Out of each lot only a single tree was infected and each of the latter to only a slight degree, emphasizing the low susceptibility of this species under the test conditions.

These plot results are not absolute; they represent only the susceptibility under one set of conditions. That the latter were very probably not ideal for the establishment of the fungus is indicated by the canker development on some of the interplants after surrounding trees had been removed, as described in a previous section. The relative susceptibility of the various species and geographical races as shown in these plot tests must, therefore, be compared with their susceptibility in other locations and under other conditions before safe opinions cencerning their over-all potentialities in this regard can be reached. What the plot tests did provide was probably as uniform an exposure to the disease as can be achieved in one environment.

Susceptibility in Nature

Few of the New World species of *Cupressus* have been widely used horticulturally in California. Accordingly, the general notes accumulated in the State over the past eighteen years on susceptibility of cypresses and other conifers to Coryneum canker include no information concerning the susceptibility to canker of most of our native cypress species. For them, the only available sources for data by which to compare the results obtained on the Stanford plots have been the cypress plantings on the grounds of the Rancho Santa Ana Botanic Garden and the experimental plantings of *Cupressus* made by the Garden in various locations in southern California, as described in Part III.

Examinations for Coryneum canker, most of them in company with Botanist C. B. Wolf of the Rancho Santa Ana Botanic Garden, were made at the Rancho Santa Ana Botanic Garden, the Rancho Santa Ana test plot, the Citrus Experiment Station plot at Riverside, California, the Wardman planting near Anaheim, California, the Limoneira experimental windbreak near Santa Paula, California, and the Hagen Ranch planting near Chatsworth, California.

One of the most satisfactory records for a location in which the disease was prevalent was that obtained during these examinations from the Citrus Experiment Station plot at Riverside. It was supplemented by Dr. Wolf's records for the plot. A summary is given in Table X. Since the data were obtained chiefly from a single inspection without rechecking they are to be regarded as approximate rather than exact.

Table X

CYPRESSES WITH CORYNEUM CANKER OR DEAD FROM CORYNEUM, CITRUS EXPERIMENT STATION PLOT, RIVERSIDE, CALIFORNIA.

Species	Trees				Total cankered and dead, Coryneum	Percent cankered and dead, Coryneum	Remarks
	Total	With Coryneum cankers	Dead from Coryneum	Dead cause ?			
Cupressus Abramsiana	28	21	1	1	22	79	
" *arizonica*	20	0	0	0	0	0	
" *Bakeri typica*	10	0	0	0	0	0	
" " *Matthewsii*	10	1	0	0	1	10	A single, very small canker.
" *Forbesii*	84	7	1	0	8	10	Cankers on 2 trees may not be Coryneum.
" *Goveniana*	20	4	12	0	16	80	
" *lusitanica*	10	1(?)	0	0	1(?)	10(?)	Presence of Coryneum not certain.
" *Macnabiana*	25	10	1	0	11	44	
" *macrocarpa*	15	2	13	5	15	100	
" *nevadensis*	20	0	0	0	0	0	
" *pygmaea*	18	8	6	0	14	78	
" *Sargentii*	59	18	3	4	21	36	
Totals	319	72	37	5	109		

The same high susceptibility of the four northern California coast species, the Gowen, Monterey, Santa Cruz and Mendocino Cypresses, is evident from these Riverside plot figures as it was from the Palo Alto results but damage has been more severe on the Riverside plot. Aside from this general greater severity, the chief difference from the Palo Alto plot data is the greater relative proportion of *Cupressus Macnabiana* bearing cankers. The 44 percent of diseased trees of this species in the Riverside plot raises it above *C. Sargentii* with only 36 percent, as compared with 4.8 and 13.3 percent respectively for these species in Palo Alto Plot No. 2. It is perhaps also worth mentioning that the lots of *C. Macnabiana* most heavily infected at Riverside were different from those bearing cankers at Palo Alto: Lots 2125, from Whiskytown, Shasta County, and 2143, from Pieta Road, Lake County, having the greatest percentages of trees affected at Riverside, whereas the only ones with any disease at Palo Alto were Lots 2144 and 2148, both from Lake County. One lot of *C. Sargentii*, No. 2167 from Chorro Creek, San Luis Obispo County, was quite susceptibile at both locations. Another difference shown by the Riverside plot was the appearance of one small canker on a tree of *C. Bakeri Matthewsii*, the only infection recorded on *C. Bakeri* at any location. Aside from this one case, the typically interior species, *C. arizonica*, *C. Bakeri* and *C. nevadensis*, on the plot were without cankers. About 10 percent of the Tecate Cypress showed cankers but those on two trees were recorded as not positively caused by Coryneum. One tree had evidently been killed by the disease, however, and two others bore large cankers, thus indicating greater susceptibility to the disease than was suggested by the Stanford plot results.

Tallies for disease incidence at the Rancho Santa Ana test plot in the plantings at the Rancho Santa Ana Botanic Garden were less complete, principally because of losses of trees from uprooting during a severe windstorm, but they agreed with the Riverside data in showing a somewhat greater incidence of *Coryneum* in *Cupressus Macnabiana* than in *C. Sargentii*, with only two lots of the former species free of the disease. All of the four northern California coast species had been removed because of canker and the inland species of *C. Bakeri*, *C. nevadensis*, and *C. arizonica* were free of the disease. However, in a planting of over 60 *C. nevadensis* near the reservoir in the Botanic Garden one tree was found with an unmistakable Coryneum canker and two others with cankered stems probably caused by Coryneum. Tecate Cypress in the Rancho Santa Ana test planting showed very little of the disease and it was noted that one tree of this species, the first of any species in the entire planting to contract the disease, had practically recovered owing to the arrestment of the canker and the development of a new main stem.

In the Wardman windbreak planting near Anaheim, practically all of the coast species, such as C. *macrocarpa* and C. *Goveniana*, had been removed because of killing by the canker and the inland species were quite evidently not suited to the location. No definite *Coryneum* was found on C. *nevadensis* but the trees were either dead or in poor condition. Two small Coryneum cankers, one sporulating, were found on C. *arizonica* here, in contrast to its freedom from the disease elsewhere. The identity of the fungus was checked microscopically and by culture.

In the Limoneira test row near Santa Paula, California the canker was less prevalent than at Riverside or in the Anaheim district but scattered Tecate Cypresses were noted with lesions from the disease. *Cupressus Macnabiana* was quite evidently not suited to the environment here and practically all specimens were sickly. In addition, many more of this species were cankered by *Coryneum* than at other locations surveyed. The Hagen planting at Chatsworth was composed for the most part of inner-coastal or inland species and because of the hillside location, the loose soil, and the drier climate at this location they were doing much better there than in the plantings closer to the coast. Cypress canker was not especially prevalent and only one McNab Cypress was noted as affected. Curiously enough, however, one tree of C. *nevadensis*, Lot 2160, was found to bear a canker of considerable size near the base.

Of the old-world cypresses, only the fastigiate and, to a very much lesser degree, the horizontal form of the Italian Cypress, *Cupressus sempervirens*, are cultivated in California in sufficient numbers to give any real index of their susceptibility to Coryneum canker in ordinary horticultural use. Field evidence indicates that both forms are only moderately susceptible to the canker, the close habit of the fastigiate form no doubt aiding in its protection just as close, repeated shearing of Monterey Cypress seems to reduce the danger of attack by the canker fungus on this species.

Naturally acquired infections of Coryneum canker have been found on a few trees of other coniferous genera than *Cupressus* in California. Several cases have been noted, for example, on planted *Libocedrus decurrens* in both the northern and southern portions of the State and at the Rancho Santa Ana Botanic Garden the disease has appeared on a number of trees of *Thuja plicata* in a young planted block of this species. Other evergreens on which the disease has been found are *Juniperus chinensis femina* and *Thuja orientalis*. All of these species were represented in the Stanford plot but none contracted the canker. Smith (loc. cit.) obtained lesions of limited extent by inoculation on all of the above species except the Chinese Juniper, which was not represented in his tests, but my introduction of the fungus into *Libocedrus decurrens* resulted in no infection. *Chamae-*

cyparis Lawsoniana has failed to take the disease in California either by inoculation or from field exposure, but Birch, as already noted, has found it on this species in New Zealand.

The basis for differences such as these in test results or between them and the status of the different species with respect to canker as found in general plantings is to be looked for either in the differences in resistance to diseases which exist among individuals within a species population, or to differences in environment favoring either the pathogen or the host. Individuals possessing more than average resistance to a given disease are found in practically all natural plant populations and the fact is utilized by plant breeders in selection and hybridizing to develop disease-resistant races of plants. Conversely, in a species characterized by high general resistance to a disease there are likely to be individuals showing a greater than average susceptibility. Judging from inoculation and field evidence, the cases of *Libocedrus decurrens* with the canker disease represent instances of the latter type.

The stock used in the experimental cypress plantings by the Rancho Santa Ana Botanic Garden and in most of Plot 2 at Stanford University consisted of replications of seedlings from the same parent trees and was thus unusually uniform. Accordingly, the differences in canker incidence between plantings can be credited almost entirely to differences in environment and in exposure to the disease. The effect of site differences on prevalence of the disease was particularly evident on *Cupressus Macnabiana* in the Limoneira planting as compared with the Hagen planting but lesser differences associated with local conditions were present in all of the plantings.

The inadequacy of results of inoculation tests as a guide to probable field susceptibility is illustrated by the almost complete freedom of *Cupressus glabra* from Coryneum canker in field plantings as compared with its almost uniform susceptibility from inoculation. Results from inoculations with *Coryneum cardinale* are likely to be of greater indicator value if they are made on stems large enough so that these cannot be rapidly girdled by lesions that may be produced, and if the tests are followed long enough to determine whether the lesions continue to spread until girdling occurs or whether they become arrested and callus over. For example, lesions developed from inoculation into *Cupressus glabra* spread at about the same rate as those into a susceptible species such as C. *macrocarpa* for the first few months but later they are almost certain to become arrested, with subsequent callusing-over of the margins, whereas those on the Monterey Cypress normally continue to progress until the stem is girdled and killed. Thus the fact that a given cypress species will take the disease may be less important from the horticultural standpoint than the ability, or the lack of it, on the part of the host, to overcome the disease fungus after it has become established.

Relative susceptibility ratings. From the data presented it is evident that susceptibility is not an exact attribute and cannot be closely rated for a species as a whole under all the conditions that may prevail where it occurs. However, differences in general susceptibility do exist and distinctions on a broad, general basis are possible.

In the following list an attempt has been made to classify the North American species of *Cupressus* and other native and exotic conifers, on which enough information is available to form a judgment, into five general groups according to their susceptibility to *Coryneum cardinale* from natural exposure in the open. No attempt has been made to determine relative rating within any particular group; in fact, the division between the last two groups is not at all definite and it may well be that a different assignment in the case of one or two species would be preferable.

Indicated Field Susceptibility to
Coryneum cardinale

Very susceptible

Cupressus macrocarpa

Quite susceptible

Cupressus Abramsiana
" *Goveniana*
" *pygmaea*

Moderately susceptible

Cupressus lusitanica
" *Macnabiana*
" *Sargentii*
" *sempervirens horizontalis*
" " *stricta*

Slightly susceptible

Cupressus Forbesii
" *nevadensis*
Juniperus chinensis femina
" *virginiana*
Thuja plicata

Not susceptible

Chamaecyparis Lawsoniana
Cryptomeria japonica
Cupressus arizonica
" *Bakeri typica*
" " *Matthewsii*
" *glabra*
" *guadalupensis*
" *Stephensonii*
Juniperus californica
" *Cedrus*
" *occidentalis*
Thuja occidentalis
" *orientalis*

Cupressus montana is not included in the above list because of lack of sufficient observations on it, but judging from its general characteristics it would undoubtedly fall in the last group. In the next to the last group, C. *Forbesii* is probably more susceptible than the other species grouped with it, rating between them and the preceding group. None of the species in the last two groups would be liable to contract the disease except under favorable exposure to the causal fungus and then only by a few less resistant individual trees.

Origin of the Disease

In an earlier paper (Wagener, 1939) three possible sources for the *Coryneum* causing the cypress disease were suggested: (1) local origin as a relatively innocuous, unnoticed fungus on some other native host from which it has transferred to Monterey Cypress; (2) local origin as a pathogenic variant from a normally saprophytic indigenous strain on *Cupressus;* and (3) introduction from some foreign country on a relatively resistant host. In connection with the latter possibility it was pointed out that the apparent centralization of the disease around the urban centers of San Francisco and Los Angeles during the earlier years of its spread would fit in well with the theory of introduction. Dwarfed Japanese conifers became very popular in California and were introduced from Japan in considerable numbers before the present quarantine regulations governing the entry of foreign plants were put into effect and inconspicuous cases of diseases could readily have come in on them.

No additional clues as to the actual origin of the disease have been discovered in the intervening years since that report. However, the finding of the Redwood *Coryneum* and of various saprophytic forms in this genus in California have emphasized the fact that much still remains to be learned concerning the less conspicuous fungi in the native flora of this region and that *Coryneum cardinale* might readily have been present here as a native without recognition until it became active on Monterey Cypresses planted outside of their native range. Even so, entry by importation still remains as an equal possibility, since much also remains to be known concerning the lesser fungi of other lands bordering the Pacific. The second possible origin suggested, that of the appearance of the fungus as a pathogenic variant from a native saprophyte, now seems less likely than the other two possibilities.

Control

Direct methods. Coryneum canker does not lend itself well to control by the usual means, such as by surgery or sprays, because the fungus causing the disease is deep-seated in the bark and wood and because the close habit of growth of many species of cypresses makes the discovery and treatment of individual cankers difficult. This is in contrast to Coryneum diseases affecting chiefly the foliage and small foliaceous twigs, such as the "Berckman blight" of Oriental

Arborvitae, which can be satisfactorily controlled by fungicidal sprays, as Milbrath (loc. cit.) has demonstrated.

Attempts at controlling individual cankers by removing the dead and discolored bark for one to two inches beyond any signs of discoloration have not been successful. Healing around the edges of such treatments was prompt but in each case reinfection occurred at the edges within a few months, apparently because of the progress of the fungus through the wood from the limits of the former canker. In tests to obtain a measure of the depth of penetration of the fungus into the wood below cankers, Dimock (1938 report) was able to isolate *Coryneum cardinale* to a depth of as much as 10 mm. below the wood surface. When shellac was applied over wood from which cankered bark had been stripped, Coryneum pustules formed on the surface of the wood under the shellac coating in some cases. Thus for the successful removal of cankers on cypress trunks not only is it necessary to strip off all affected bark showing the least sign of discoloration in the region of the cambium and a zone of apparently sound bark around it for one to two inches, but also to chisel out all wood below the cankers to a depth of ½ inch (13 mm.) for recent cankers and 1 inch (25 mm.) for older and larger ones.

On small trees this removal of wood would weaken the stem too much to be practical. In any event the average canker is too extensive by the time it is discovered to make removal practical unless it is confined to a branch, which is usually not the case.

In the few instances where the removal of individual cankers by means of hand tools is feasible, the surfaces of the resulting wounds should be promptly treated to kill any of the fungus that may have been transplanted to the fresh wood on the tools and to prevent reinfection from spores that may be deposited before the cut tissues have had time to heal. No extensive tests on the disinfection of such wounds against *Coryneum* have been made but in ordinary circumstances bordeaux paint, made by mixing powdered bordeaux with water to a paint-like consistency, will prove satisfactory. A stronger solution, such as the mercuric chloride-mercuric cyanide mixture recommended by Thomas and Ark (Thomas, H. Earl, and Ark, P. A. Calif. Agr. Exp. Sta. Bul. **586**. 43 pp. 1934) for disinfection in the treatment of fire blight cankers, is more certain in its action but is difficult to handle because of its poisonous character. The newly developed fungicidal tree paint formula of gilsonite varnish with 0.2 percent phenylmercury nitrate (Walter, James M. U.S. Dept. Agr. Circ. **742**. 12 pp. 1946) recommended for treating branch cuts in the control of the canker stain disease of planetrees or sycamores may also be of value.

Following the removal of cankers, a fungicidal spray should be applied to the affected trees, with particular attention to complete coverage on the bark of twigs, branches, and the main trunk. The purpose is to kill spores of the *Coryneum* that may be lodged there and thus to minimize chances for early reinfection of the trees. In a series of plot tests with different spray materials a low-lime bordeaux of 4-2-50 composition (4 pounds copper sulphate, 2 pounds spray lime, 50 gallons water) proved to be the most effective (Dimock, 1938 report) though the nature of the disease makes accurate comparisons between spray materials on a field basis very difficult. To the spray should be added a small amount of spreader-adhesive, such as rosin-fish oil soap, calcium caseinate, or one of the other commercial products marketed for this purpose. In place of the bordeaux it is probable that some of the newer spray materials that have recently been introduced, such as ferric dimethyldithiocarbamate, marketed under the trade name of "Fermate," will prove equally effective.

In most cases, as already indicated, the disease is so well established in a tree by the time its presence is discovered that removal and burning of the tree are the only feasible control measures that can be employed. The removal of diseased trees is particularly important in a district where the disease is just in the process of establishment. Wherever such trees are removed the adjoining trees should be sprayed as a precaution to kill any Coryneum spores that may have been carried to them.

In windbreak plantings of Monterey Cypress it sometimes happens that the Coryneum canker has become too thoroughly established for any hope of complete eradication but the owner desires to prolong the life of the windbreak as much as possible. This can be done by a combination of spray program and the removal by pruning of as much-cankered material as can be reached (Wagener, Willis W. and Dimock, A. W. Calif. Citrograph **29** (2): 31, 43. 1943). The first spray should be applied in the fall in California, about the time of the start of the fall rainy season. Its purpose is to kill spores of the fungus lodged on the bark and foliage and to discourage spore production from developed pustules on any cankers that may be present. Two spray applications a year will probably be all that the owner will feel economically justified in applying for windbreak preservation. If so, the second should be put on about the end of winter or early in the spring, just before the trees start the main flush of spring growth.

A two-spray program of this sort, supplemented by the removal of cankered material, will not preclude the establishment of additional cankers but will reduce their numbers sufficiently to add many years to the effective life of a windbreak. If the windbreak is trimmed, the best time to do this, from the standpoint of holding the disease in check, will be just preceding or just after the application of one of the sprays. If diseased branches are cut in the process, the pruning tools should be disinfected with denatured alcohol before proceeding with the trimming of sound parts of the tree as the fungus can readily be transplanted on the trimming tools.

Substitution of resistant species. Where susceptible cypresses have been destroyed and replacements are needed, or where new cypress plantings are being made, the most practical solution of the Coryneum disease problem at the present time is the use of a species sufficiently resistant to the fungus to reduce chances for damage to a minimum. Among such species are the Arizona, Tecate, Guadalupe, and Smooth Arizona Cypresses. The relative horticulural merits of these species and the conditions under which they may be expected to succeed are discussed by Dr. Wolf in Part III. While none of them seem to be quite the equal of the Monterey Cypress in growth rate and versatility, one or two do not fall far behind in these respects, and a choice can be made from among the resistant forms to fill most requirements quite acceptably. In some respects and for some localities they will offer characteristics superior to those of the susceptible species heretofore favored.

Selection and breeding of resistant forms. One other possibility that offers no immediate aid but may provide an additional alternative for the future is the discovery or development of resistant forms of Monterey Cypress from which planting stock can be propagated. In districts where the disease has been prevalent for some years occasional cypresses of this species remain, presumably because of inherent resistance to the fungus, though in some instances these may represent merely trees that have managed to escape the disease. An organized search would undoubtedly reveal more of these untouched trees.

In order to test such trees to determine how many possess sufficient resistance to the canker to be promising as a source of future stock it will be necessary to propagate from them vegetatively to provide test stock. Monterey Cypress is said not to be difficult to root from green cuttings but whether the trees showing resistance to the disease will root with the same facility as is reputed for the species as a whole remains to be determined. Moreover, Camus (Camus, A. Les Cyprès [Genre Cupressus]. 106 pp. Paris. 1914) states that stock of Monterey Cypress reproduced from cuttings is not so vigorous nor so long-lived as seedling stock. Whether this is uniformly the case and whether the vegetatively propagated stock is sufficiently inferior to make it unsuitable for horticultural use is likewise not yet definitely known. If trees developed from rooted cuttings or by grafting do prove to be satisfactory and demonstrate sufficient resistance to Coryneum canker to make them acceptable, Monterey Cypress stock can again be made available to the horticulturist in districts where the disease has forced the species out of use.

The development of resistant forms of Monterey Cypress through breeding or of resistant hybrids through crossing with other species would be a much slower and more costly method of arriving at a similar goal. Practically nothing is known concerning hybridization in the genus *Cupressus* and no records have been found of experimental crosses under controlled conditions. Breeding for disease resistance in trees is at best slow, even in species like the cypresses, which can be induced to produce seed at a relatively early age, and would be justified only if suitable resistant forms could not be obtained by selection and vegetative propagation.

Summary

The habitats to which members of the genus *Cupressus* are native are, in general, not conducive to diseases and the native stands are remarkably disease-free. Many of them become diseased, however, when transplanted to environments to which they are not adapted.

Heavy losses from cold were suffered among the early plantings of *Cupressus lusitanica* and *C. macrocarpa* in England during especially severe winters there. Windburn also occurred on *C. macrocarpa* in exposed situations there.

Diseases on New World cypresses introduced in other parts of the globe have not been serious except for a canker caused by the fungus, *Coryneum cardinale* on *Cupressus macrocarpa* in New Zealand and a recent, potentially serious disease of much the same character on the same host in Kenya, East Africa. The latter disease has been attributed to the fungus, *Monochaetia unicornis,* first described from the United States.

In North America a rust, *Gymnosporangium Cupressi,* has been reported as causing galls on *Cupressus glabra* and *C. arizonica* in two restricted locations in Arizona, and a similar rust, *Gymnosporangium meridissimum,* from two localities in Guatemala. What has often been regarded erroneously as a "rust" on native Monterey Cypresses near Carmel, California, is in reality an alga that grows on trees exposed to ocean spray and is non-pathogenic.

A brown, friable pocket rot of the heartwood of native Monterey Cypresses is probably caused by the fungus, *Polyporus basilaris.* The rot from this fungus is quite common in old planted Monterey Cypresses at several points in California. Another wood-decay fungus, *Polyporus cutifractus,* has been reported from planted trees of the same host in California. An unidentified light brownish heart rot is quite common in some native stands of *Cupressus glabra* in Arizona.

Two species of leafy mistletoes are locally prevalent in scattered native stands of cypresses: *Phoradendron pauciflorum* on one or more species of *Cupressus* in California and *P. densum* on *Cupressus arizonica* and *C. glabra* in Arizona. Windburn aids in the shaping of native Monterey Cypresses on the immediate coast in California.

Among the diseases contracted by cypresses planted in cultivated ground is crown gall, from *Phytomonas tumefaciens* on *Cupressus arizonica*. The Smooth Arizona Cypress, C. *glabra*, failed to develop galls on inoculation. The latter species is reported to be moderately susceptible to Texas root rot from the fungus, *Phymatotrichum omnivorum*. Another root fungus, *Armillaria mellea*, occasionally attacks Monterey Cypress in California and has been found on native Tecate Cypress in that State. The cedar blight fungus, *Phomopsis juniperovora* has been isolated from several species of cypresses but causes no serious losses in them. Several other diseases of minor types have been found on North American cypresses, especially when planted in unsuitable environments. Some dying of cypresses occurs for which the cause is not known.

Injury from diseases may be confused with insect damage. Many insects may be found attacking or feeding upon the foliage, bark or wood of cypresses, with some killing attacked trees. In California, the more important insect enemies of cypresses reported by entomologists include several foliage feeders, two or more sucking insects, two common species of bark beetles, a bark moth, and a mite.

The disease that has so far proven to be the most damaging to cypresses is the Coryneum canker, present in California since at least 1915 and also occurring on North Island in New Zealand. It has spread through most of the planted Monterey Cypresses in California but has not yet been found in the native groves of the species. The coastal region of northwestern California still appears to be free of the disease, which is estimated to have caused the loss of three-fourths of the planted Monterey Cypresses in the State.

Cankers commonly start at a crotch or around the base of a foliar branchlet though the fungus may also become established through wounds. Infiltration of affected bark by resin and exudation of resin are characteristic reactions induced by the disease. The pustules of the causal fungus are produced on the bark surface and appear in about 4 to 8 weeks after tissues are attacked. Rate of canker extension depends partly on the individual character of the host and partly on temperature. Rate of increase in length of cankers averaged about twice as great at a station 12 miles inland as on the cool, immediate coast. Bark moths are attracted by the resinous bark of cankers and their larvae often mine it, especially near the coast.

Cankered stems or branches on susceptible hosts are eventually girdled, causing the death of the part. These dying and dead branches are the symptoms of the disease most noticeable at a distance and are useful in locating it, though branch killing may occur from other causes such as insect or rodent injuries. Stem cankers may reach a length of several feet before the affected tree is girdled by them. Cankers on old or slow-growing trees are much less conspicuous than those on young, vigorous specimens. Bark beetles usually complete the killing of canker-girdled trees in California.

Trees of susceptible species of any size or degree of vigor are subject to the disease but those with open crowns appear to contract it more readily than dense, sheared specimens. Cankers of the stem are most common on young trees and of the branches on old, spreading specimens.

The causal fungus, *Coryneum cardinale,* is characterized by subepidermal acervuli that originate as cavities in a layerlike stroma and later open widely. The spores are oblong-fusoid in shape and 5-septate, with four dark median cells and hyaline end cells. They average 21-26 x 8-10.5 microns on conidiophores 15-55μ long. The fungus has been collected on *Cupressus Abramsiana, C. arizonica, C. Forbesii, C. Goveniana, C. lusitanica, C. Macnabiana, C. macrocarpa, C. pygmaea, C. Sargentii, C. sempervirens stricta, Thuja orientalis, T. plicata, Libocedrus decurrens,* and *Juniperus chinensis femina.* It has also been reported on *Chamaecyparis Lawsoniana* in New Zealand.

Five species of *Coryneum* with 5-septate spores have been reported from conifers, but *Coryneum cardinale* appears to differ from all of them. In addition to the described species of *Coryneum,* at least two others with 5-septate spores occur in California, one as a saprophyte on Monterey Cypress and the other as a canker-forming pathogen on the Coast Redwood. The latter fungus is able to cause cankers on *Cupressus macrocarpa* from inoculation.

In culture, *Coryneum cardinale* develops colonies with a soft, floccose surface, finally becoming deep andover green or grayish-olive in color, especially when exposed to light. Hyphae are variable in size and character. The fungus produces conidia only sparingly in culture.

Spore production from pustules of the organism on cankered bark depends on moisture. Free water or moisture-saturated air is also required for spore germination. Mycelia from different spores anastomose readily.

The optimum temperature for growth of the fungus is about 26° C., the minimum slightly below 5° C., and the maximum about 34° C. The optimum and the limiting temperatures for spore germination are about the same. The saprophytic *Coryneum* from cypress has a considerably lower optimum temperature of approximately 18° C. Because of the generally low prevailing temperatures during moist periods in California, most of the germination of *Coryneum cardinale* spores in nature there will occur at temperatures at which 12 to 24 hours will be required for the process to start.

Dissemination of the fungus by man may occur on pruning tools or on nursery stock. In nature, most local dissemination is by water during rains, though occasional spores may be carried by wind. Up

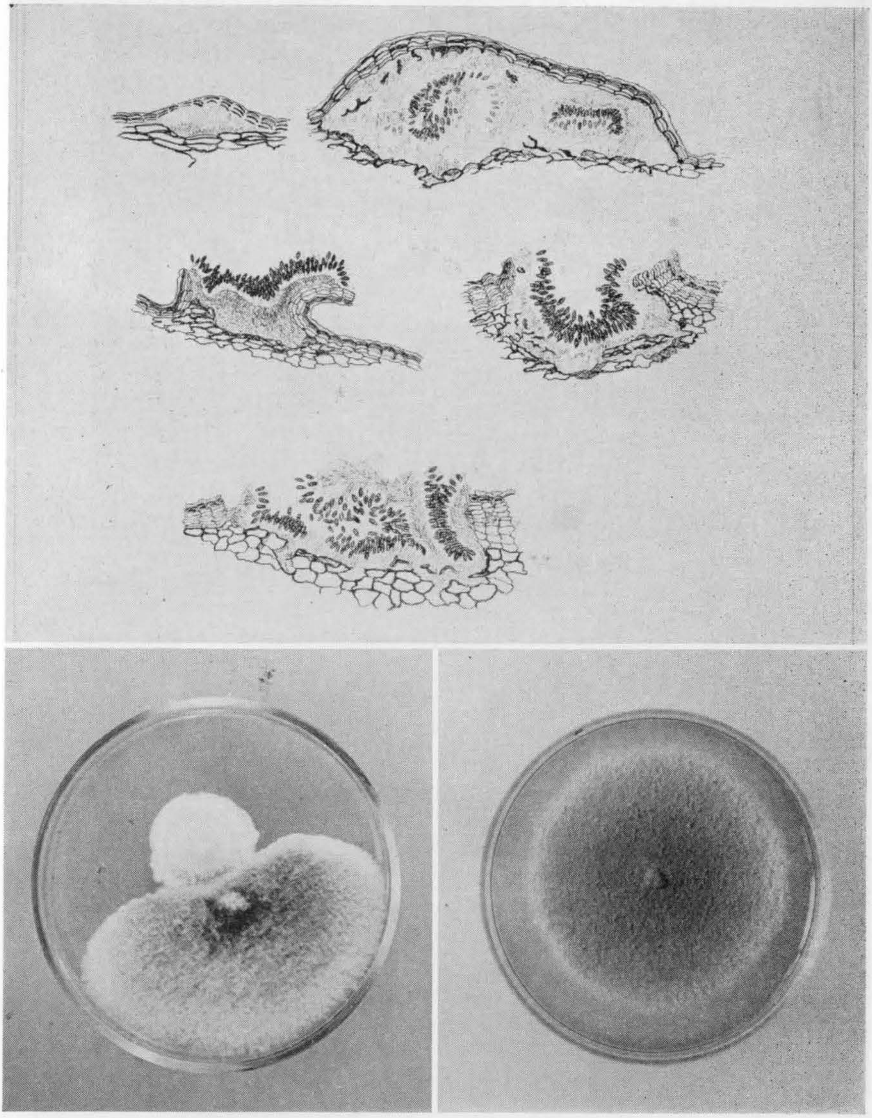

FIGURE 38.

(Upper) Drawings of sections of fruit bodies of *Coryneum cardinale* illustrating stages of development from a subepidermal stromatic pad to an open acervulus and some variations in form of the acervulus.

(Lower right) Fifteen-day-old colony of *C. cardinale* on potato-dextrose agar.

(Lower left) Fifteen-day-old cultures of *C. cardinale* and a saprophytic species of *Corynuem* from *Cupressus macrocrapa* on the same agar plate, illustrating the difference in appearance and rate of growth.

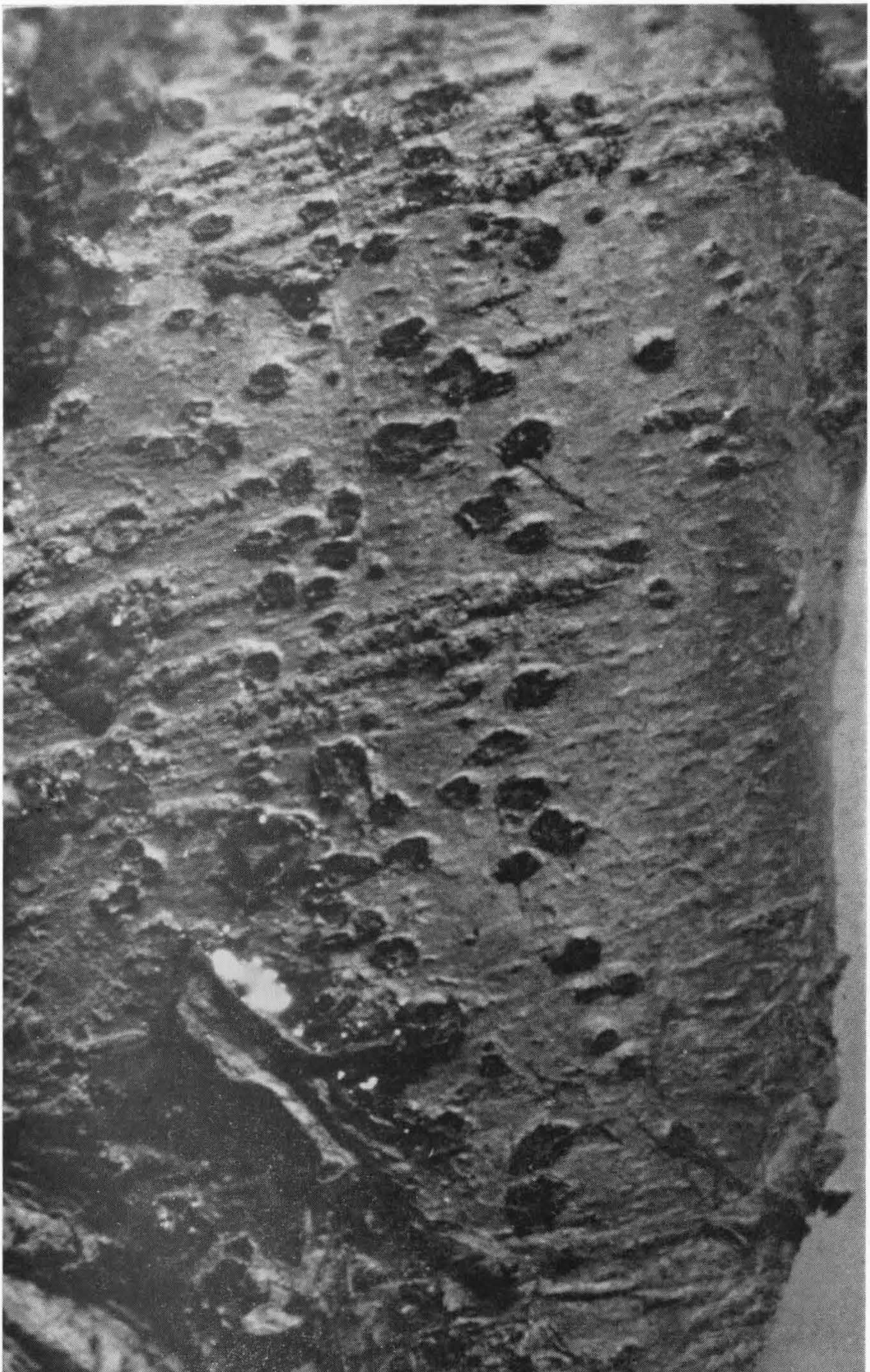

Figure 39.

to 10,000 spores per sq. cm. may be lodged on bark below active cankers. Birds, rodents, and insects may carry these to new locations on feet or bodies. Distance spread to new localities by natural means is probably almost entirely by wind or birds and is very sporadic in occurrence. When protected in a dry situation, spores may retain their viability for many months. In the open they lose it much sooner. However, spores on exposed cypress foliage still showed 29 percent viability after 48 days. There is evidence that they sometimes remain viable for a much longer period when lodged on cypresses.

The fungus is able to enter the host through wounds of almost any size, including very minute ones. Some injury of the epidermis seems to be necessary for infection to occur though incipient lesions can be found where no injury is visible even under magnification. Breaks in the epidermis of cypresses may occur naturally, particularly during rapid flushes of growth. Trees under strong competition seem less subject to the disease than those with ample room and nutrition. Deposits from salt spray carried by winds in locations close to the ocean apparently will not protect trees from the disease.

All species of *Cupressus* show initial susceptibility to *Coryneum cardinale* from inoculation but cankers on the less susceptible species may later become arrested. A few other conifers in the Cupressaceae or Taxodiaceae are slightly susceptible.

To test field susceptibility to the disease, two plots were established at Stanford University, California in which Monterey Cypresses were interplanted in a 6 x 6 foot spacing with test trees, most of which were native races of species of *Cupressus* provided by the Rancho Santa Ana Botanic Garden. To supplement natural cases of the disease in the interplanted trees, all those in the larger plot were inoculated in branches and in the main stems with *Coryneum cardinale*. In the course of the tests 44 percent of the interplanted Monterey Cypresses died from naturally acquired cankers on one plot and 9 percent on the other.

On Plot 1 the disease appeared in only three test species, *Cupressus lusitanica, C. Macnabiana,* and *C. sempervirens,* and only the first and third of these were present in the plot in sufficient numbers to make the results significant. Of the two, the Mexican Cypress, *C. lusitanica,* had the greatest percentage, 23.8 percent, of trees affected. There were several additional doubtful cases of the disease in this species. Species well to fairly well represented on the plot, and remaining free of the disease were *C. arizonica, C. glabra, C. guadalupensis, Chamaecyparis Lawsoniana, Cryptomeria japonica, Juniperus virginiana, Thuja orientalis,* and *T. plicata.*

Test species chiefly affected in Plot 2 were the rather closely

FIGURE 39.
Acervuli of *Coryneum cardinale* on bark of *Cupressus macrocarpa.* x9.6

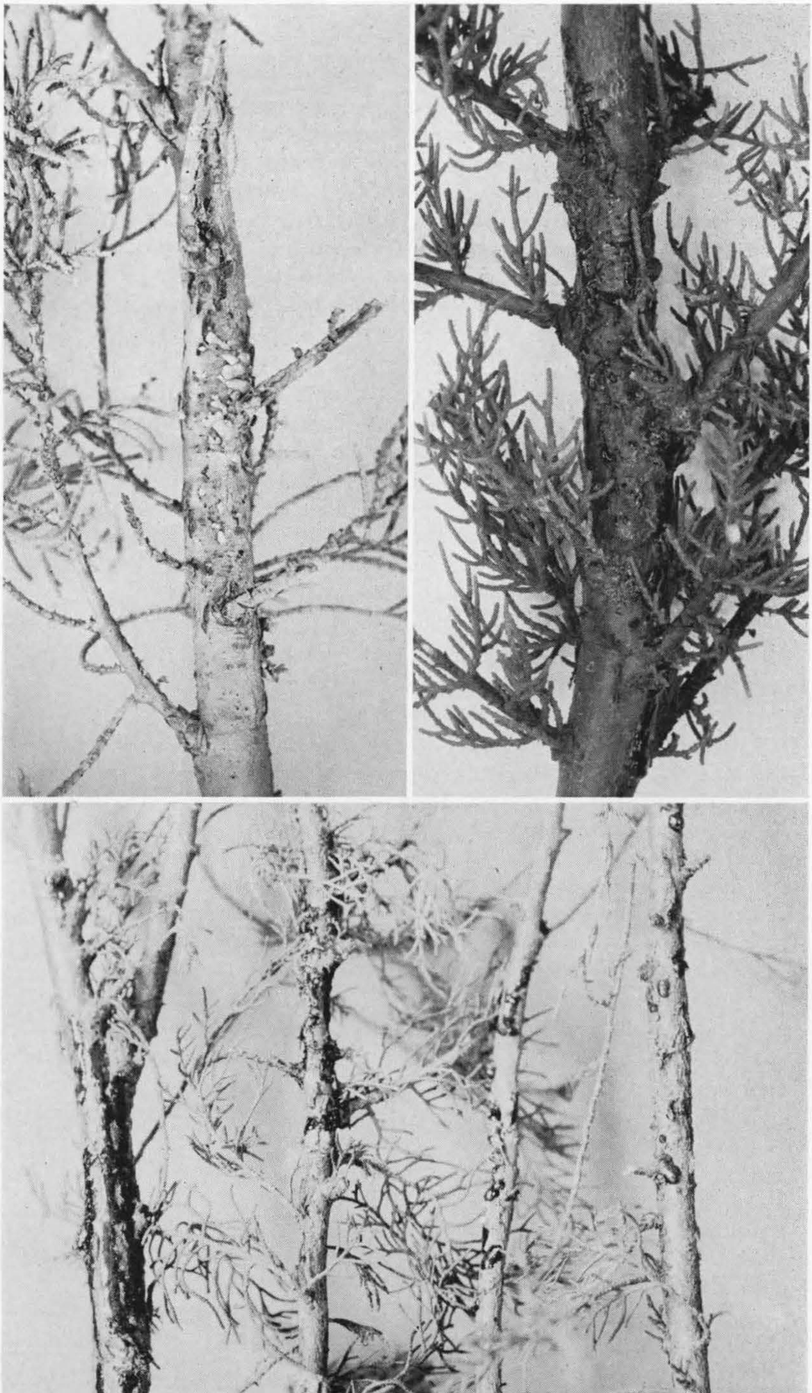

FIGURE 40.

related *Cupressus macrocarpa, C. pygmaea, C. Abramsiana,* and *C. Goveniana* with the percentages of infected trees from 90 to 30 percent in the order given. *C. lusitanica* and *C. Sargentii* were moderately affected, with 18 and 13 percent respectively developing the disease, while *C. Macnabiana* and *C. Forbesii* showed light infection, or about 5 and 4 percent respectively. All other species of *Cupressus* in the plot and a few trees each of *Juniperus chinensis femina, J. chinensis torulosa,* and *J. virginiana glauca* remained free of the disease.

A few species, such as *Cupressus sempervirens, Thuja orientalis,* and the junipers, suffered more than the others from competition and the results obtained with them may not be fully representative. Guadalupe Cypress remained entirely free of canker and appeared promising for horticultural use from other standpoints. Tecate Cypress also did well and the two trees contracting the disease were only slightly affected.

Comparison of results on the Stanford plots with disease development in the plantings of *Cupressus* and other native genera at the Rancho Santa Ana Botanic Garden, as well as in the experimental cypress plantings made by the Garden at various locations in southern California, indicated that *Cupressus Macnabiana* is considerably more susceptible on the average than it appeared to be at Stanford; the percentage of affected trees of this species exceeding that for *C. Sargentii* at several locations. A single tree of *C. Bakeri Matthewsii* developed a small canker at Riverside and two small cankers were found on *C. arizonica* in the Wardman planting at Anaheim, where the tree was quite evidently not suited to the environment. Several cankered specimens of *C. nevadensis* were found in all and a number of trees of *Thuja plicata* had developed the disease in a planting of this species in the Rancho Santa Ana Botanic Garden.

The inadequacy of inoculation results as a guide to probable field susceptibility is illustrated by the freedom of *Cupressus glabra* from Coryneum canker in the open as compared with its apparent susceptibility under inoculation. Inoculation tests with species such as this are more indicative of field behavior if run long enough to determine whether the lesions later become arrested.

On the basis of all field evidence, the New World cypresses and other conifers on which there are sufficient observations to make judgments are arranged in five groups according to probable susceptibility in the open, with *Cupressus macrocarpa* listed as the most susceptible and the inland species of *C. arizonica, C. Bakeri, C. glabra,* and *C.*

FIGURE 40.

(Upper) Branch cankers of *Coryneum cardinale* on *Cupressus macrocarpa.* (Left) Canker on a thrifty, young branch. Note copious exudation of resin. (Right) Canker from a more slowly growing branch. The exuded resin is less abundant and has dried in place rather than flowing down the branch.

(Lower) Cankers of *Coryneum cardinale* on small branches of *Cupressus sempervirens.*

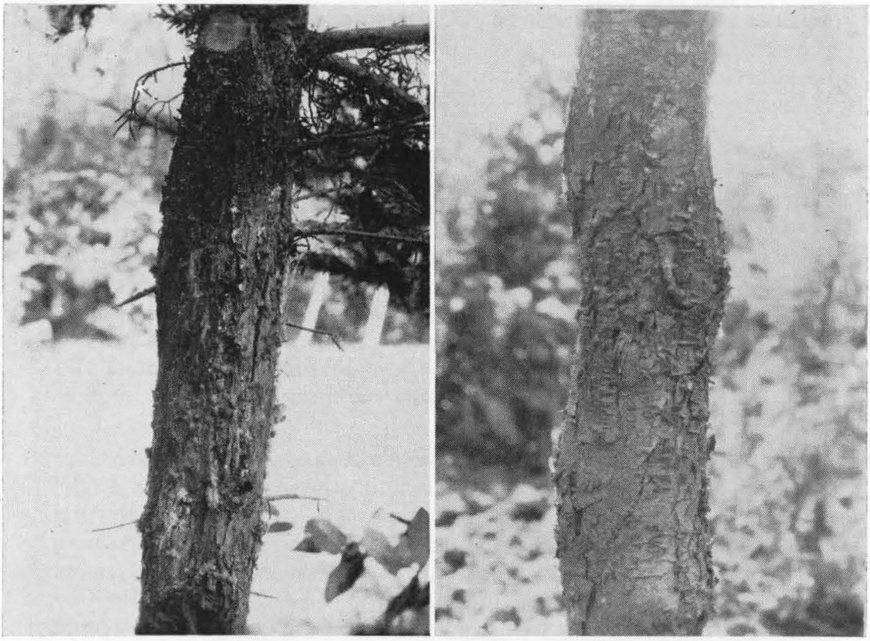

FIGURE 41

FIGURE 42

Stephensonii as not susceptible, among others, including the insular species, *C. guadalupensis.*

There is still no definite evidence on the origin of the disease in California.

Coryneum canker is not well adapted to control by surgery or sprays as the causal fungus permeates diseased bark and extends into the wood for as much as 10 mm. Sprays are useful, however, for prolonging the life of Monterey Cypress windbreaks by reducing the number of new infections. A low-lime bordeaux of 4-2-50 formula proved to be the most effective of the sprays tested but some of the newer spray materials may be equally effective. A spreader-adhesive should be used with the bordeaux.

Where new plantings are to be made the most practical solution of the disease problem presented by the Coryneum canker will be by the substitution of resistant species for the susceptible ones formerly used. The choice of species for planting will depend somewhat on site conditions and the purpose of the planting.

Certain Monterey Cypresses have shown indications of resistance to the disease and may provide a future source of acceptable planting stock, either through vegetative propagation or by breeding.

FIGURE 41.

Stem cankers of *Coryneum cardinale* on trees of *Cupressus macrocarpa* of sapling size, illustrating the less conspicuous character, often encountered, of cankers on older wood. A canker about 18 inches (45 cm.) in length extends down from the sawn branch of the trunk on the left. A two-year-old stem infection in the trunk on the right has produced a definite crook. The disease was transferred to this tree on a handaxe used in trimming off lower branches.

FIGURE 42.

(Left) Branch and top killing by *Coryneum cardinale* on a 12-year-old forked tree of *Cupressus macrocarpa.*

(Right) Killing by *C. cardinale* on Italian Cypress, *Cupressus sempervirens.* The upper part of the main stem was killed earlier and removed.

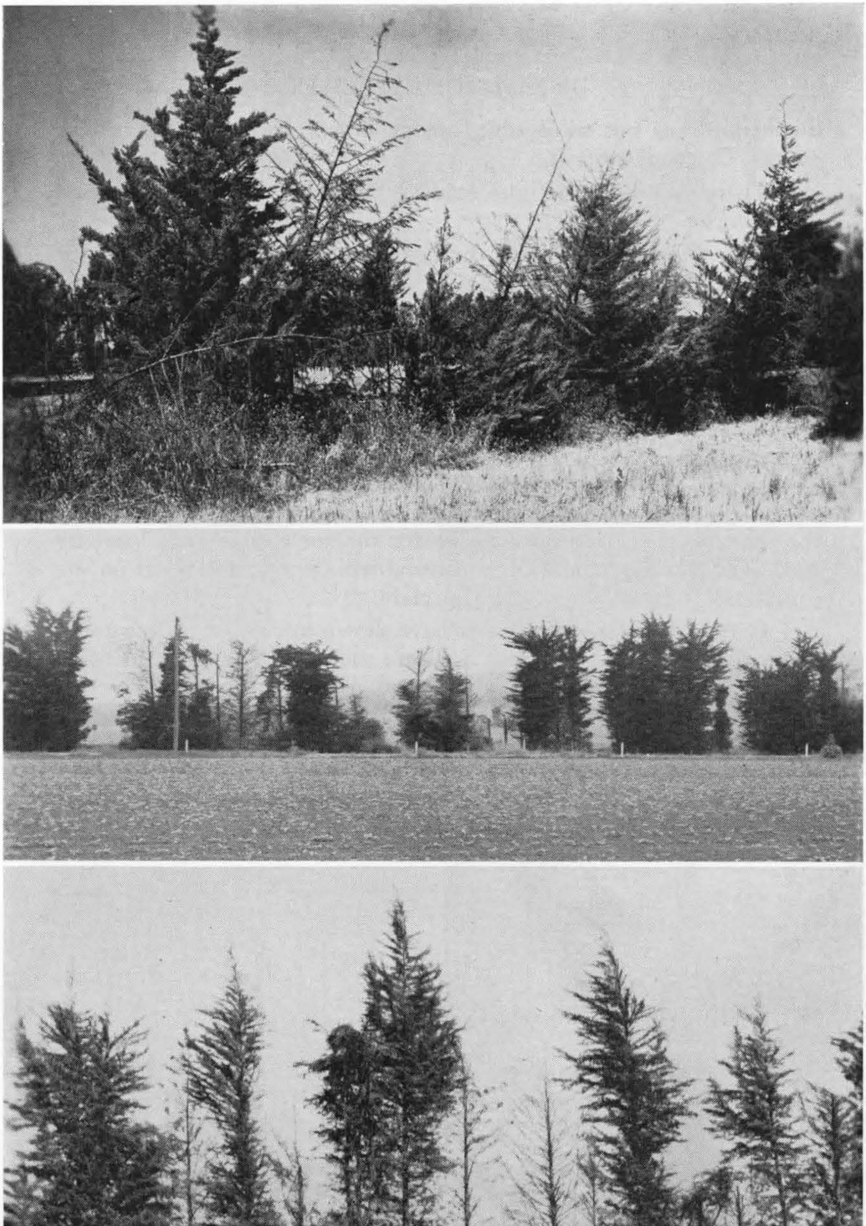

FIGURE 43.—For explanation see page 321.

FIGURE 44.—For explanation see page 321.

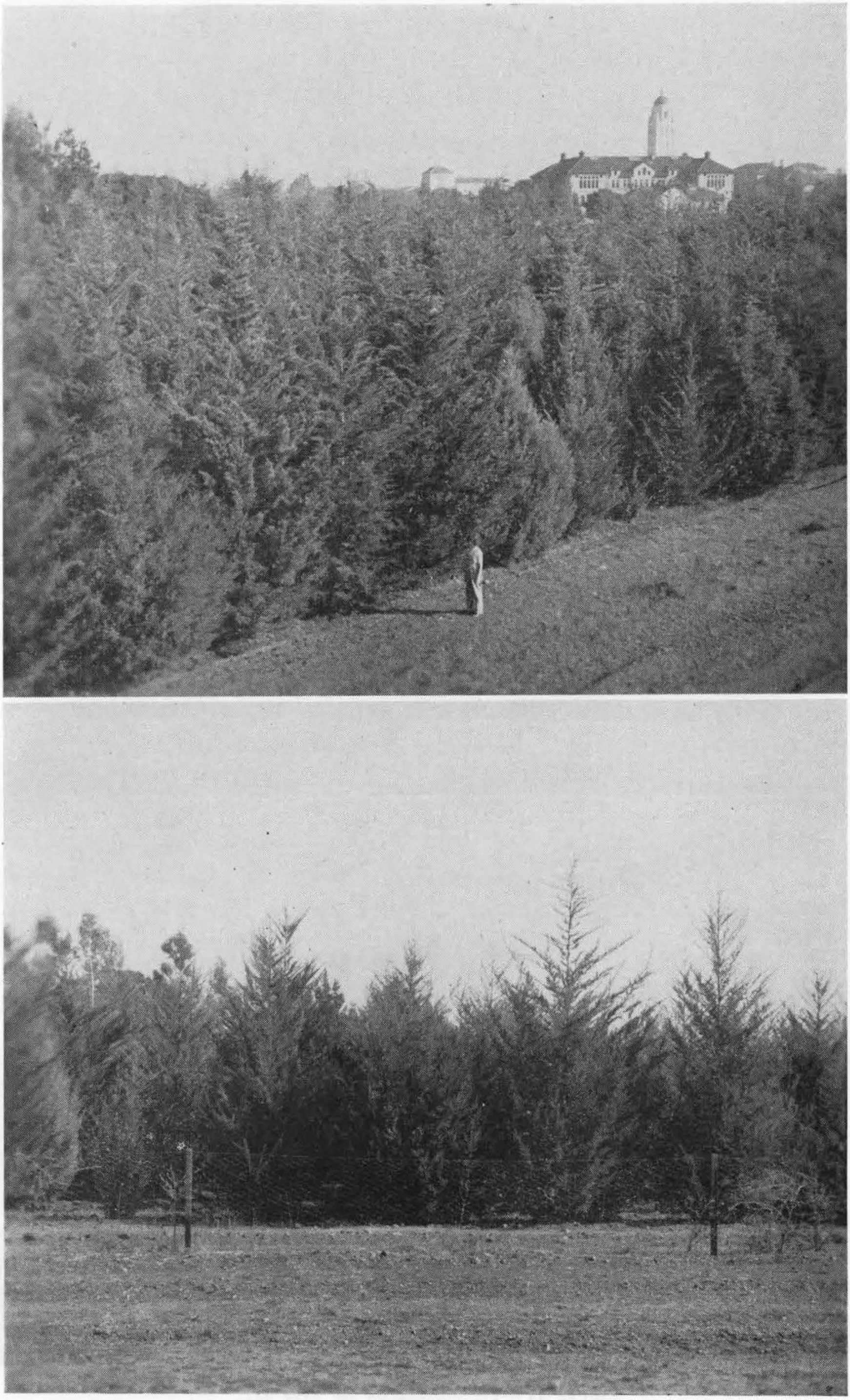

FIGURE 45.—For explanation see page 321.

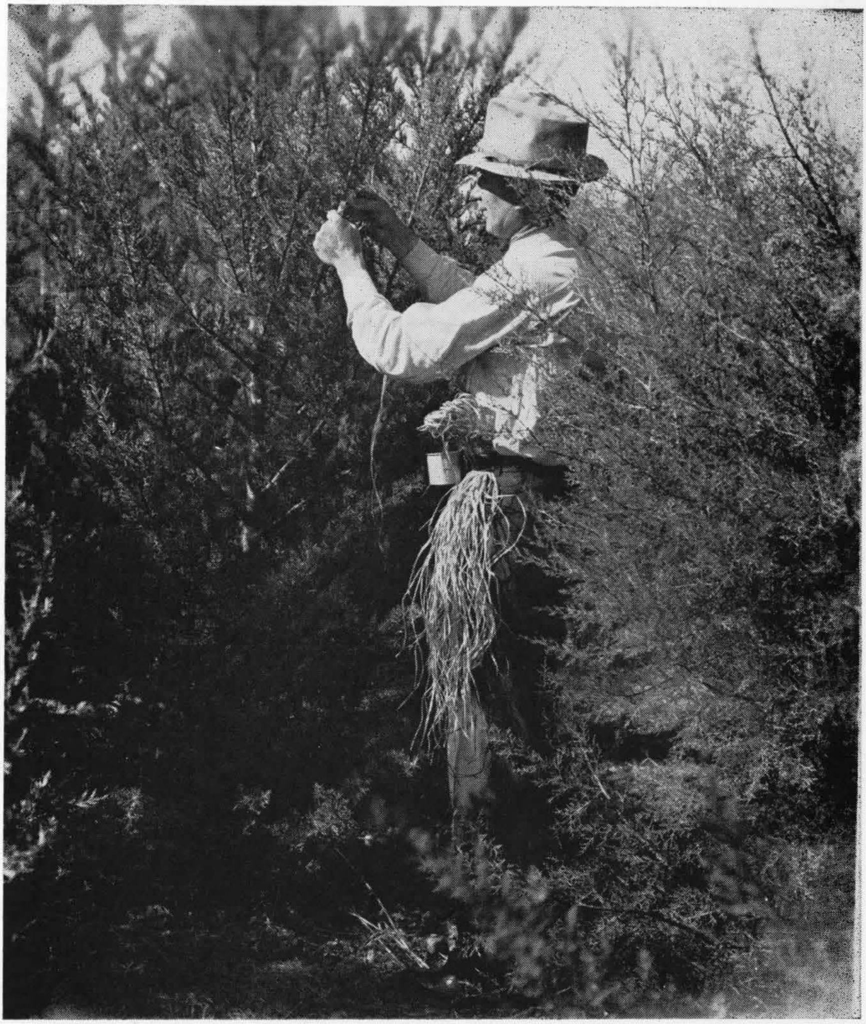

FIGURE 46.
Inoculating branches of Monterey Cypress interplants with *Coryneum cardinale*, susceptibility test plot No. 2, Stanford University.

FIGURE 43.
Monterey Cypress windbreaks ruined by Coryneum canker.
Upper photo, Santa Clara County, California; middle and lower photos, Ventura County, California.

FIGURE 44.
Field susceptibility test plots, Stanford University, summer of 1936.

FIGURE 45.
Field susceptibility test plot No. 2, Standard University, with native cypresses propagated at the Rancho Santa Ana Botanic Garden.
(Upper) The plot from the west, November 1939.
(Lower) View across the plot from the northwest, August 1941.