Acacia koa: A Review of its Diseases and Associated Fungi

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Abstract

Acacia koa (koa), among the most prominent overstory species of native Hawaiian forests, is affected by a number of diseases, including those caused by rust fungi, wood-rotting fungi, root-infecting fungi, and diseases categorized as seedling blights, foliar infections, and vascular wilts. A number of fungi occurring saprophytically on koa substrates are also known. Symptoms of other apparent diseases and disorders of unknown origin, or whose cause has not been clearly demonstrated, are often manifest as leaf spots or other foliar abnormalities. Endemic pathogens which have evolved with their host may be responsible for many of the heretofore observed disease conditions, and as such usually do not threaten koa populations. However, a condition tentatively referred to as "koa decline" may represent an exception. This condition is characterized by slow to rapid wilt and death of apparently healthy, vigorous trees of all ages, occurring in more or less well defined disease centers. This phenomenon is particularly prominent in upper-elevation koa forests on the slopes of Mauna Loa on the island of Hawai'i. Other apparent decline problems on O'ahu and elsewhere in the Islands have been reported, some associated with insects. The relationship of these observations to the koa decline on the Big Island has yet to be determined, and the question as to whether "koa decline" represents a complex of disease conditions or can be more closely attributed to a single, specific cause requires further study.

Koa (*Acacia koa* Gray), endemic to the Hawaiian Islands, is the second most abundant overstory species in upper-elevation forests. It forms nearly pure stands in montane forests such as those on the slopes of Mauna Loa between approximately 4000 and 7000 ft (1230 and 2150 m) (Whitesell 1990). Koa is distinctive in the formation of crescent-shaped phyllodes which, in older trees, assume the function of the pinnately compound true leaves produced in juvenile stages of development.

As an endemic tree, koa is of critical ecological importance, forming habitat for numerous native birds, insects, and other flora and fauna. As a nitrogen-fixing leguminous species, koa is thought to account significantly for the nitrogen content of otherwise nitrogen-poor volcanic forest soils (Whitesell 1990). Koa is also prominently represented in early Hawaiian legends and culture, and economically is considered the most valuable of the common native timber species. Koa wood, sometimes referred to as "Hawaiian mahogany," can be highly polished to emphasize its deep reddish coloration and wavy grain, and is used for furniture, paneling, and such woodworking crafts as bowls and ukuleles.

St. John (1979) recognized three distinct species as representing the genus *Acacia* in Hawai'i: *A. koa* Gray, *A. koaia* Hbd., and *A. kauaiensis* Hbd. Furthermore, within *A. koa* three varieties were recognized: *A. koa* var. *koa*, found on all major Hawaiian islands; *A. koa* var. *latifolia* (Benth.) St. John (= *A. koa* var. *hawaiiensis* Rock); and *A. koa* var. *waianaiensis* St. John; the latter two restricted to the islands of Hawai'i and O'ahu, respectively. Although the current treatment of *A. koa* (Wagner et al. 1990) combines all of these forms within *A. koa*, the distinction among them is still apparently sufficient to delimit the host ranges of host-specific pathogens, such as the rust fungi. Reference to St. John's classification is therefore useful to this discussion.

Several observations of diseases and pathogenic fungi occurring on koa have been individually reported in the literature as they have been observed over the years (Raabe et al. 1981), or have not been formally published. It was of interest to assemble such published information, together with as yet unpublished observations of fungi and disease conditions of koa, to provide the basis for a discussion of the pathology of this pivotal species.

Diseases caused by rust fungi

Rust fungi, members of the order Uredinales, are so called because of the often brownish to orange appearance of the spore masses. These fungi produce perhaps the most widespread and prominent diseases of koa, collectively referred to as koa rust. Stevens (1925), originally described a single fungus, *Uromyces koae* Arth., as the cause of the disease, but five species of rust fungi,

four of which are considered endemic and one indigenous, are currently recognized on koa (Hodges and Gardner 1984, Gardner 1991), each with distinctive symptoms. These include three species now placed in the genus *Atelocauda*, *A. koae* (Arth.) Cumm. & Y. Hiratsuka, *A. digitata* (Wint.) Cumm. & Y. Hiratsuka, and *A. angustiphylloda* Gardner, and two species of *Endoraecium*, *E. acaciae* Hodges & Gardner and *E. hawaiiense* Hodges & Gardner. *Atelocauda koae* occurs commonly on *Acacia koa* var. *latifolia* on Hawai'i. and on *A. koa* var. *koa* on Kaua'i, O'ahu, and Maui. It has not been reported on Moloka'i, nor has it been found on *A. koaia* anywhere. *Atelocauda koae* is confined to young tissue, occurring most frequently on newly developing true leaves, phyllodes, and shoots of saplings, but also found on new shoots of older trees. It is evident as raised, powdery, brown leaf spots, 1–10 mm diameter, occurring singly or in groups, on both leaf surfaces. Heavy infection, in which spots coalesce to form large, irregular powdery blotches, can cause severe distortion of leaves, shoots, and small branches, leading to stem deformation (Hodges and Gardner 1984, Chen et al. 1996).

Atelocauda digitata is known from all major islands except Lanai, although its presence on this island in upland forests would not be surprising. On *Acacia koa* var. *latifolia*, the conspicuous stages of this fungus cause "witches'-brooms" up to approximately 15 cm tall, comprised of clustered, misshapen, abnormally thickened shoots developing from infected branches. The diseased tissue may be covered by powdery, brown spore masses that are easily rubbed off. Removal of witches' brooms is ineffective in controlling the disease, because the fungus invades branch tissues systemically. From one to many brooms may occur in a tree. Less conspicuous stages of *A. digitata* occur as small, brown, raised sporulating pustules up to approximately 1 mm diameter on the surface of otherwise normal phyllodes. Occasionally such spots are surrounded by larger chlorotic spots, causing them to be more conspicuous. *Atelocauda digitata* kills branch portions distal to the broom, but entire trees are typically not killed by this fungus alone. On *Acacia koa* var. *koa* on Maui and O'ahu *A. digitata* produces hypertrophy of flower and shoot tissue, resulting in malformation, but it does not produce witches' brooms typical of those on *Acacia koa* var. *latifolia* (Hodges and Gardner 1984).

Atelocauda angustiphylloda is confined to *Acacia koa* var. *latifolia* and is limited in distribution on the island of Hawai'i, but visible in large koa trees on the upper Saddle Road. This rust forms large (up to 1 m tall) witches' brooms comprised of hypertrophied but abnormally reduced, much narrowed phyllodes almost circular in cross section, giving a "shoe-string" appearance (Gardner, in press). As with *A. digitata*, brooms are covered with powdery, brown spore masses. Although limited in distribution, large numbers of brooms (100+) may occur in certain mature, presumably susceptible trees. Host trees appear to tolerate infection by *A. angustiphylloda*, but loss of vigor and local tissue death may occur.

Endoraecium acaciae, the most common of koa rusts, has been found on *A. koa* var. *koa* on Maui, Kaua'i, and Hawai'i, and on *A. koaia* on Hawai'i, Kaua'i, and Moloka'i. It has not been found on *A. koa* var. *latifolia*. This fungus produces conspicuous, profusely branched brooms up to 30 cm long comprised of much-reduced, flattened phyllodes covered with spore masses. In apparent contrast to other koa rusts, *E. acaciae* may cause severe damage to the host, and heavy infections producing multiple brooms may kill the entire tree. Brooms of *E. hawaiiense* are similar to those of *E. acaciae* but are smaller, being seldom taller than 12 cm, and relatively inconspicuous. This fungus appears to be limited in distribution, having been found only at certain sites on O'ahu on *A. koa* var. *waianaiensis* and *A. koa* var. *koa*. An insufficient number of trees heavily infected with this fungus has been found to assess its potential for host damage. The two species of *Endoraecium* are further separated from one another by differences in spore morphology.

Wind-distributed spores of the koa rust fungi are thought to be the principal means of long- and short-distance dispersal, although Leeper and Beardsley (1973) noted the possibility that the koa psyllid *Acizzia uncatoides* (Ferris & Klyver) [= *Psylla uncatoides* (Ferris & Klyver)] may at least in part account for short-distance dispersal where populations of these insects are high. Wherever koa rust diseases are observed, evidence can be found of variability in susceptibility to infection among neighboring individual trees. Koa breeding programs directed at selecting such resistance may be the most effective control approach for rust diseases.

Wood-rotting fungi

A number of diseases of koa caused by wood rot-

ting, "higher" fungi (i.e., basidiomycetes) have been described. These fungi are characterized by external production of fleshy or woody fruiting bodies which are often conspicuous and indicate the presence of already well-established internal infection. Bega (1979) reported *Phaeolus schweinitzii* (Fr.) Pat., *Laetiporus sulphureus* (Bull. ex Fr.) Bond. & Sing. (= *Polyporus sulphureus* Bull. ex Fr.), and *Pleurotus ostreatus* (Jacq. ex Fr.) Kumm. for the first time in Hawai'i. These species, together with *Armillaria mellea* (Vahl ex Fr.) Quél. and *Ganoderma* sp., were associated with deteriorating old-growth stands of koa on several thousand acres of range land in the Keanakolu, Halepiula, Spring Water Camp areas of Hawai'i Island at an elevation of 5000 to 6000 ft. (1540 to 1840 m).

Wood-rotting fungi produce characteristic types of infection, such as brown cubical rot of heartwood produced by *Phaeolus schweinitzii* and *Polyporus sulphureus*, but positive field identification is usually possible only if the fruiting body is present. An exception, however, is *A. mellea*, which causes a stringy white root and butt rot of a wide range of woody hosts in Hawai'i and elsewhere, including koa (Laemmlen and Bega 1974, Raabe and Trujillo 1963), produces distinctive "shoe-string" rhizomorphs and mycelial fans under infected bark by which it may be identified. Bega (1979) reported that the honey-colored fruiting bodies (mushrooms) of this species were not known in Hawai'i; but fruiting bodies of a fungus agreeing with *A. mellea* in its previously described broad concept have now been found to be common in certain sites (G. Wong, personal communication).

A new species of *Phellinus*, described as *P. kawakamii* Larsen, Lombard, & Hodges, recently was found on *Acacia koa* var. *koa* and *A. koaia* on Kaua'i (Larsen et al. 1985). The same species was also found on *Casuarina equisetifolia* L. on Hawai'i and O'ahu. This heartwood-decaying fungus produces white pocket-rot in its hosts and is characterized by a large fruiting body (to 70 cm wide, 20 cm thick) which is produced near ground level and may be obscured by leaf litter and thus easily overlooked. No fruiting bodies were found on koa during casual observations made in old-growth stands on O'ahu, Maui, and Hawai'i. However, internal decay typical of that produced by *P. kawakamii* was found in a substantial number of stumps of *A. koa* var. *koa* trees salvaged following the 1982 hurricane, indicating that presence of fruiting bodies may not indicate the true incidence of disease in a stand (Larsen et al. 1985). Rather than killing their hosts directly, pathogenic heart and root-rotting fungi destroy timber usefulness and predispose trees to wind-throw and branch or stem breakage. Nelson and Wheeler (1963) reported that more than half of the large koa trees reported in the 1959-1961 forest survey were considered unmerchantable because of excessive wood rot.

Other higher fungi associated with koa, either as saprophytes on dead material or as weak parasites, were reported earlier by Burt (1923). These include *Schizophyllum commune* Fr., a common wood-inhabiting fungus of wide host range and world-wide distribution, where it occurs on dead parts of living trees and on hardwood slash. As an exception to its normal saprophytic activity, *S. commune* was reported to cause wilting of planted three-year-old *Acacia* saplings in South Africa (Ledeboer 1946), but similar virulence on koa has not been documented. *Fomes fasciculatus* Burt was described as a new species on dead koa on Kaua'i, and *F. hawaiensis* Forbes in Lloyd was found on koa on Hawai'i, Kaua'i, Lana'i, and Moloka'i, but its pathogenic ability was not mentioned. Burt (1923) also reported the wood-rotting fungi *F. australis* Fr. on Kaua'i and *F. fullageri* (Berk.) Cke. (location not given) on koa. Although not classified among the higher fungi, wood-inhabiting fungi of the family Xylariaceae: *Hypoxylon annulatum* (Schw.) Mont., *Nummularia guarantica* Speg., and *Xylaria rhopaliodes* Mont. have been reported on koa (Stevens 1925). These genera produce dark, usually conspicuous stromata (fruiting bodies) visible on the bark of infected tissue. The above genera are distinguished by the general morphology of their stromata: flat or cushion-like in *Hypoxylon*, cup-shaped in *Nummularia*, elongate or club-shaped and borne on stalks in *Xylaria*. Most members of the Xylariaceae are saprophytic or weakly parasitic, which is probably true of the species occurring on koa.

Root infections

The ubiquitous "water mold," *Phytophthora cinnamomi* Rands, a root-infecting fungus favored by the oxygen-deficient conditions of waterlogged soil, is known to attack a wide range of plant species. This pathogen was isolated from roots of koa, among those of a number of other forest species, in studies directed at determining its role in the decline syndrome of 'ohi'a (*Metrosideros polymorpha* Gaud.) in Hawai'i

(Kliejunas and Ko 1976). Koa was categorized with species considered "moderately tolerant" to the fungus (Kliejunas 1979), suggesting that *Phytophthora* root rot, while present under conducive soil conditions, usually was not a significant disease of koa. Other ubiquitous root-invading pathogens with wide host ranges, including the fungus *Rhizoctonia* sp. (Raabe et al. 1981) and the root-knot nematode *Meloidogyne incognita* (Kofoid & White) Chitwood (Raabe 1966), have also been found on koa, but the extent of any damage from these agents was not reported and is presumed to be minimal.

Seedling blights

Two species of the fungus *Calonectria* have been reported as causes of koa diseases. *Calonectria crotolariae* (Loos) Bell & Sobers, the pathogen causing collar rot of papaya (*Carica payaya* L.) seedlings, also caused a severe collar rot among a dense cover of koa seedlings reforesting a burned area in Kipapa Gulch in the Ko'olau Mountains of O'ahu (Aragaki et al. 1972). The disease caused a quick decline and collapse associated with signs of fungal growth and production of orange-red fruiting bodies near the soil line. Death occurred two days following onset of symptoms. A slower decline also was observed among some seedlings, in which lower leaves became chlorotic and a progressive wilt led to seedling death in seven days. *Acacia melanoxylon* R. Br. ex Ait. seedlings also were found to be susceptible when inoculated with the fungus from culture. Whereas the incidence of collar rot on koa seedlings was severe, it appears to have been a single event resulting from the coincident occurrence of several predisposing factors. Shoot blights caused by *C. theae* Loos were reported on koa and 'ohi'a on O'ahu (Nishijima and Aragaki 1975). The disease, which also is known to occur on other species of *Acacia*, causes small dark spots on leaves and green twigs. Whereas artificial inoculation of koa seedlings resulted in considerable leaf drop, natural infection has been found only infrequently in Hawaiian forests and was not found to cause significant damage in these environments.

Gardner (1980) reported a severe wilt disease of seedlings of *Acacia koa* var. *hawaiiensis* Rock (=*A. koa* var. *latifolia*) caused by a specific form of the vascular wilt fungus *Fusarium oxysporum* (Schlecht.) Snyd. & Hans., designated *F. oxysporum* f. sp. *koae* Gardner. The disease appeared spontaneously among seedlings grown from seed collected in Hawai'i Volcanoes National Park, and the fungus was shown to be seedborne. Experimentally inoculated seedlings of *A. koaia*, *A. confusa* Merr. (Formosan koa), and *A. simplicifolia* Druce, the latter two being introduced species, were also wilted by the fungus. *Fusarium* wilt diseases have been reported in a wide variety of agricultural and horticultural crops on a world-wide basis, where historically they have been of major economic importance.

Foliar infections

Sutton and Hodges (1983) described a new leaf-spotting fungus, *Gloeocoryneum hawaiiense* Sutton & Hodges, on *A. koa* var. *koa* at Makaha Ridge on Kaua'i. Although *G. hawaiiense* originally was found on only two trees, both trees were heavily infected. Leaves infected with this fungus have since been found on Maui (Gardner, unpublished). The fungus appears as small, dark, spore-producing leaf spots (conidiomata), often arranged in short, more or less linear rows 30–120 mm long. Following maturity of the conidiomata, the immediately surrounding area becomes necrotic. Notwithstanding the severe leaf infection, the disease was reported to cause little apparent damage to the host itself. A leaf spot disease in which numerous (i.e., > 30 per cm^2) dark, circular to oblong spots, 0.8–1.5 mm in diameter, on both phyllode surfaces was observed among koa trees planted in plots near Kahului, Maui (J. Tavares and D. Ogata, unpublished). The spots, which sometimes coalesced to produce larger blotches, were associated with *Alternaria alternata* (Fr. ex Fr.) Keissl., although the role of this fungus as the primary cause of the disease is questionable and remains to be experimentally demonstrated. This fungus most often occurs as a saprophyte or a weak parasite on a broad range of plant hosts. The dry conditions of the koa plots outside of their natural elevational range may have placed the trees under unnatural stress, predisposing them to infection. *Alternaria alternata* also was reported on koa leaves in Hawai'i Volcanoes National Park, but a description of symptoms of infection was not included (P.H. Dunn and G. Baker, unpublished). Stevens (1925) reported *Lophodermium intermissum* Starb. on presumably live koa at Wahiawa, O'ahu, and Pogue's Ditch Trail on Maui. Species of *Lophodermium* may occur either saprophytically or parasitically, causing leaf spots containing dark, erumpent fruiting bodies.

The Meliolales, or "dark mildews," are found primarily in tropical regions and are well represented in

Hawai'i, occurring on a wide range of native species. The members of this well-defined group are closely allied with one another and have other characteristics in common with the powdery mildews (order Erysiphales) and the rust fungi. Like the rusts, they are highly specialized, usually host-specific, obligate parasites (that is, they cannot be cultured on artificial medium but require living host tissue for survival). Most of the species of dark mildews occurring in Hawaii are known only from endemic host species, and are themselves considered endemic (Stevens 1925, Goos and Anderson 1972). The dark mildews are conspicuous as black, more or less circular spots or blotches on leaf surfaces. The fungal colony, which may appear somewhat thick and velvety in texture, may occur as an isolated spot, or several colonies may coalesce to cover much of the photosynthetic area. The dark mildews are sometimes confused with another group of black fungi, the sooty molds, which occur superficially on plant or other surfaces and are not considered parasites. *Meliola koae* Stev. is recognized as the species occurring on koa (Stevens 1925, Goos and Anderson 1972). A second species, *M. bidentata* Cke., also was reported on koa by Raabe et al. (1981) based on previously unpublished data from the files of the Department of Plant Pathology, University of Hawai'i at Manoa. The identity of this fungus appears questionable and should be confirmed through further collection.

Petrak (1953), in his "Contributions to the Fungal Flora of Hawai'i," listed a number of fungi associated with native plants, including the leaf-spotting fungus *Mycosphaerella koae* Petr., which he found on dry seed pods of koa at Kona (Hawai'i Island) and described as a new species. Although the original collection was associated with dead tissue, members of the genus *Mycosphaerella* are often parasitic and are known to cause serious leaf diseases of other hosts (Hanlin 1990). Other than the initial report by Petrak, no information apparently is available concerning occurrence of *M. koae* on koa, however.

A number of apparent phyllode infections occur, some commonly, for which a cause has not been found. Although leaf-spotting fungi in such cases are usually suspected, sporulation or fruiting, which is necessary to identify such agents, has not been observed. Of particular note among these symptoms is a prominent chlorotic (yellow) speckling which is frequently observed on *A. koa* var. *latifolia*. Until fungal agents of known pathogenicity are isolated as the probable causes, the possibility that such symptoms may also result from abiotic factors, such as physiological stresses or imbalances, must also be considered.

Vascular wilt diseases

As was indicated by the seedling disease caused by *Fusarium oxysporum* discussed above, pathogenicity and host range of the suspected causal agents of these diseases is most easily demonstrated experimentally on seedlings. However, vascular wilt diseases are typically virulent on all developmental stages of the host, where they cause rapid, irreversible wilting and decline. On older plants, the fungus systemically invades the vascular system and is contained within internal tissues during most stages of disease progression and is therefore not directly visible. In agricultural systems, development of resistant varieties has been relied on as the only practical control approach to a number of economically important vascular wilt diseases of crops caused by *Fusarium* and *Verticillium*. Genetic resistance is probably present in population of forest species as well, including koa, but has not yet been as well investigated or exploited.

Centers of decline among koa stands in the Mauna Loa Strip region of Hawai'i Volcanoes National Park have been observed for a number of years (Gardner, unpublished). Some such centers are apparently no longer active or are progressing slowly within mature stands in which a number of older trees have died. On the other hand, well-defined centers of decline are obviously active among otherwise vigorous stands of koa in the Mauna Loa Strip, in which pre-senescent trees of all ages, including saplings, are rapidly dying. Symptoms of the decline point to *Fusarium* wilt as a possible cause (Gardner 1980). *Fusarium* agreeing with the description of *F. oxysporum* f. sp. *koae* has been isolated from diseased trees at these sites, cultured and shown to be virulent to inoculated healthy seedlings (Gardner 1980; unpublished). However, lack of consistent recovery from older trees to date suggests the need for more thorough investigation before definite conclusions can be drawn. In 1994 a *Fusarium* isolate associated with wood discoloration was recovered from branch sections of a mature, dying koa tree, marked by progressive thinning of the crown, at a homestead on Mt. Tantalus, O'ahu. Pathogenicity of the isolate was subsequently demonstrated in inoculation tests of koa seedlings

(Gardner and E. Yoshino, unpublished data). Because decline caused by vascular wilt organisms may be rather nondescript, without overt evidence of the causal agent, death of isolated, individual trees such as this possibly occurs more commonly than is currently recognized.

Koa decline

Addressing the subject of koa decline, Laemmlen and Bega (1972) reported that according to aerial surveys in 1954, 67,000 acres of koa and ohia forests occupying approximately 600,000 acres on the island of Hawaii were in slight (<20% dead trees) to severe (60% dead trees or more) decline. In 1965, the affected areas had increased by 10,000 acres, and the severely affected portions had increased from 5000 acres in 1954 to 14,000 acres, with more recent ground surveys indicating a steadily deteriorating situation. The decline was characterized as a rapid wilt and death of trees and/or a slow progressive decline causing a thinning of foliage with many dead twigs, followed eventually by complete defoliation and death. The most severely affected forest was on the slopes of Mauna Kea at an elevation of 750–1700 m. Laemmlen and Bega (1972) mentioned several possible causal or contributing biotic agents, including the fungi *Armillaria mellea, Phytophthora cinnamomi,* and *Diatrype princeps* Penz. & Sacc.; the insects *Xylosandrus compactus* Eichoff (black twig borer) and *Plagithmysus bilineatus* Sh., a native wood-boring beetle; together with the activities of wild pigs and other mammals (presumably rats). Damage to young koa by stripping of bark from limbs and trunks has been documented as an apparently common phenomenon, with up to 54 percent of trees sampled in four- to six-year-old stands in the Laupahoehoe and Waiakea areas on the island of Hawaii affected (Scowcroft and Sakai 1984). Whereas in this study complete girdling by such bark removal was rare, injury has been observed in the Mauna Loa Strip region of Hawai'i Volcanoes National Park in which girdling, presumably caused by rats, resulted in the death of branches of older trees. Such effects result in conspicuous browning and wilting of foliage and may be confused with disease symptoms, such as those generally attributed to koa dieback (Gardner, unpublished). Abiotic factors such as changes in soil drainage were also suggested as possible contributing factors. Although Laemmlen and Bega (1972) indicated that quantitative and qualitative studies of the decline were to be initiated, the original scope of the work became separately focused on the prominent ohia decline phenomenon (c.f. Hodges et al. 1986), with little emphasis on koa. The extent to which a vascular wilt disease may be operative in the forest decline syndrome described by Laemmlen and Bega is not known, but the high degree of host-specificity characteristic of the wilt *Fusaria* suggests that such a disease would not fully account for a general decline of forests including both koa and 'ohi'a and possibly other species.

Nonpathogenic fungi associated with koa

In addition to the diseases and disease conditions of koa described above, and to the fungi that under favorable conditions may cause or contribute to koa disease, a number of fungi have been reported associated with koa tissue as saprophytes. Petrak (1952) described as new species two stromatic fungi found on dead koa branches on Mt. Tantalus: *Diaporthe shearianа* Petr. and *Thyridaria koae* Petr.

Fungi also have been found existing on leaf surfaces but causing no apparent harm to the plant. Members of the genus *Pestalotia* are frequently isolated from diseased tissue, but their role as pathogens is questionable. *Humicola brevis* (Gilman & Abbott) Gilm. and species of *Pestalotia*, including *P. angusiana* M.B. Ellis, *P. breviseta* Sacc., and *P. stevensonii* Peck have been found on apparently healthy koa phyllodes in Hawaii Volcanoes National Park (G. Baker, unpubl.). A number of other more or less common fungi, including *Cylindrocephalum* (= *Chalara*) sp., *Cylindrocarpon* sp., *Cylindrosporium* sp., *Epicoccum purpurascens* Ehrenberg, *Papulospora* sp., *Sporotrichum laxum* Nees, *Stachybotrys atra* Corda, and *Triscelophorus monosporus* Ingold also have been reported on koa leaves (phyllodes) or leaf litter (Goos 1978; G. Baker and P.H. Dunn, unpublished records in the University of Hawai'i Department of Botany). Whereas some saprophytic or epiphytic species are more or less generalists, capable of subsistence on a wide variety of substrates, others show some degree of specificity. In a study to determine the association of fungi with leaf surfaces of three endemic trees, koa, 'ohi'a, and olapa (*Cheirodendron trigynum* (Gaud.) Heller.), Baker et al. (1979) found a large number of fungi on leaves of 'ohi'a but significantly fewer on koa phyllodes and leaves of 'olapa, which were not as widely sampled. They concluded that the smooth phyllode surfaces of koa retained spores poorly. Stoner et al. (1975), listed a large number

of fungal species in surveys of soil of root zones of native vegetation types, including *A. koa* var. *hawaiiensis*, of the Mauna Loa region of Hawai'i Volcanoes National Park.

Conclusions

Whereas a considerable number of fungi and other possible disease agents (i.e., nematodes) are associated with koa, relatively few of these currently cause diseases of significance to the general well being of native *Acacia* in Hawai'i. Outbreaks such as the above-described seedling collar rot caused by *Calonectria crotolariae* are locally devastating but, because they depend on a coincidental occurrence of several conditions favorable to disease development, are observed only rarely. Many wood-rotting fungi, while probably more prevalent than published reports indicate, are most prevalent in older, senescent or presenescent trees, often hastening but not causing their decline. Among the exceptional diseases which may impact otherwise vigorous, actively growing trees are those caused by rust fungi and agents responsible for the koa dieback observed in the Mauna Loa Strip area of Hawai'i Volcanoes National Park. The rust fungi attacking koa are relatively well understood and all are thought to be native species, closely related to one another, having evolved in close association with their hosts (Hodges and Gardner 1984). While infection causes branch flagging, with heavy infection by *Endoraecium acaciae* resulting in some apparent death of koa, and timber quality may be affected by distortion of the terminal development of young trees infected with *Atelocauda koae,* rust diseases are not considered threatening to koa populations.

Perhaps the most ominous threat to koa, from the standpoint of disease, is the koa decline syndrome, currently prevalent and well defined in the Mauna Loa Strip region of Hawaii Volcanoes National Park. As stated above, although the presence of *Fusarium oxysporum* f. sp. *koae* has implications, the extent to which this fungus contributes to the decline is not known. Likewise, the relation of decline in this location to other, more incidental death of koa trees elsewhere throughout the islands, is not known. Perceived increases in frequency of such deaths may be a result either of increased awareness of koa itself or reflect an actual disease situation. Research directed at elucidating these problems is anticipated.

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