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Technical Report 100

RUST AND SMUT FUNGI OF HAWAI`I: AN ANNOTATED HOST INDEX ON ANGIOSPERMS AND FERNS

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March 1996

Cooperative Agreements
1445 CA 09-94-1006 Subag. 2 & 3
NPS CA9016-2-9004

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ABSTRACT

Rust and smut fungi are well-defined groups of plant pathogens. These groups generally are considered to be closely allied with one another and therefore are frequently discussed together. Both groups of fungi are known to cause major crop diseases and are well known throughout the world from the standpoint of their economic significance. These fungi occur on hosts of a variety of plant families in Hawai'i, most introduced from elsewhere, probably arriving with their hosts rather than separately via wind-borne spores. However, some species occur as apparent endemic or indigenous forms on hosts native to the Islands. Members of the grass family (Poaceae) are the most frequent hosts of both the rusts and the smuts. The rust fungi typically infect vegetative plant parts, that is, leaves and stems, where they produce abnormal growths such as witches'-brooms, galls, or raised, sporulating pustules. Because of the virulence and host specificity characteristic of the rusts in general, these fungi have received particular attention in weed biocontrol studies. The smut fungi, with some exceptions, infect reproductive parts, often destroying normal fruit and seeds and replacing these structures with masses of fungal spores. Occurrence of smut infections on economic grain crops can cause complete loss of the crop by destroying the grain kernels, while leaving the vegetative parts of the plant intact. Such severe economic losses associated with rusts and smuts are quite rare in Hawai'i, however. Endemic rusts provide interesting examples of the unusual development well known among other categories of organisms that have evolved in isolated insular systems.

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INTRODUCTION

The rust fungi are referred to as such because of the orange or orange-red color associated with infection by some members of this group, superficially resembling oxidized iron. They comprise a well-defined group with several characteristics in common, including the production of thick-walled, wind-borne spores and occurrence as obligate plant parasites. Rusts have the most complex life cycles of any fungi, often including several different spore types, or states, produced in succession. Even though rusts are generally host-specific, some members of this group require two unrelated host species, for example, one an angiosperm and the other a gymnosperm, or one a monocot and the other a dicot, to complete their life cycles. This requirement for alternate hosts is not known in Hawai'i, however. That is, all of the native and non-native rusts currently known in Hawai'i are able to complete their life cycles on a single host, even though many of the introduced species undergo alternation of generations in their native habitats. In Hawai'i, life cycle completion is accomplished by production of only the uredinial spore state, which is capable of repeated "short cycle" infections, without undergoing the longer cycle characteristic of temperate environments. Therefore, the management practice in temperate climates of controlling certain destructive rust diseases (e.g., white pine blister rust) by eliminating the alternate host, thus breaking the life cycle, would not be applicable in Hawai'i.

The mode through which introduced rusts and smuts arrived in the Islands is open to speculation. Because of their production of resistant, wind-dispersed spores, it is tempting to assume that they arrived in this manner from continental sources. However, Stevens (1925:114) stated: "It appears to me probable that the rusts have not come wind-borne, separate from their hosts, to Hawai'i–if so more rusts would be found there–but rather that rust and host must arrive together, which condition, being subject to greater accident liability, renders successful, natural, rust immigration extremely difficult." Stevens thus accounted for the limited number of rusts and smuts he found in the Islands. He further stated (Stevens 1925:113) "The scant number of rusts as compared with those to be found in the Continental sub-tropics or sub-tropical continental islands is striking." In comparing the rust flora of Hawai'i with that of Puerto Rico, which has reasonably comparable environmental conditions, Stevens concluded: "My collections of the Hawaiian fungi are not exhaustive, but I believe, nevertheless, that the above comparisons are legitimate and that the conclusion is forced that the scarcity of rusts is due solely to the geographic isolation of the Hawaiian Islands which lie more than 1,000 miles from any considerable land body." In fact, Hawai'i is the world's most isolated major island group, situated approximately 2400 miles (4000 km) from North America, the nearest continent. In general, the 1:1 ratio of rusts and smuts to introduced hosts (i.e., crop and horticultural introductions, naturalized plants, weeds) in Hawai'i (Table 1), indicates that these fungi were, in fact, introduced with their hosts rather than arriving separately. A notable exception is found with the rusts considered native which occur on the endemic host koa. The two endemic rusts of the genus *Atelocauda*, and the two members of the obviously closely allied form genus *Endoraecium*, are thought to have originated from *A. digitata* (as *Uromyces digitatus*) from Australia, now considered an indigenous species in Hawai'i, and provide interesting examples of evolutionary development among the fungi (Hodges and Gardner, 1984). Furthermore, examples

of host specificity are found among the native rusts of koa which are specific to particular varieties recognized in the previous classification systems for this species (see St. John, 1979), but which have now been "lumped" together as a single species and variety, as *Acacia koa* (Wagner *et al.*, 1990). An example of such specificity is found in *Atelocauda angustiphylloda*, which appears to be limited to the former *Acacia koa* var. *latifolia* (=*A. koa* var. *hawaiiensis*), the variety endemic to the Island of Hawai'i. In their discussion of *A. koa*, Wagner *et al.* (1990) acknowledge that the classification of *A. koa* remains controversial and subject to reevaluation as new information comes to light. Savile (1979) discussed comprehensively the potential value of the host specificity exhibited by several types of fungi, including the rusts, in establishing taxonomic relationships among higher plants.

The native and non-native rust fungi in Hawai'i range from common to rare in occurrence. Some species are easily found, while others are known only from isolated collections. In the latter case, the inconspicuous nature of some species may account for their infrequent collection. Others may be, in fact, rare in the Islands, either because the host is itself rare or perhaps because environmental conditions are often not favorable for their development. Endemic species are identified by their presence on endemic hosts, together with their absence on related hosts elsewhere. With some exceptions noted below, the rusts in Hawai'i are represented by their uredinial and/or telial spore states (designated II and III, respectively), with the spermogonial and aecial states (0, and I) either known elsewhere but not occurring in Hawai'i, unknown elsewhere as well, or lacking altogether. The latter case is characteristic of most native species in which spore states have been lost through evolutionary reduction. Whereas rust fungi are important pathogens of gymnosperms elsewhere, Hawai'i has no native gymnosperms, and to date no rust fungi have been found on any of the introduced members of this group.

Infections caused by rust fungi may range from obscure to conspicuous, depending on the species and spore state being observed, and may vary in appearance considerably from their "typical" resemblance to iron rust. The rust fungi typically infect vegetative plant parts, that is, leaves and stems, where, depending on the species, they may produce local infections that appear as raised, sporulating pustules, or they may infect systemically, causing abnormal branch or twig growths on woody plants. Such abnormalities may occur in the form of "witches'-brooms," in which a dense cluster of small, sometimes misshapen branches or twigs forms. Witches-brooms may be small and quite inconspicuous or may be large, 1 meter or more in diameter. Stem galls, or abnormal swellings, may also be produced by rust infections. Depending on the species, rust fungi may also be seasonal in appearance, being absent during parts of the year and more readily visible during others. Furthermore, presumably due to climatic variations, some years are obviously favorable for the appearance of rusts and some are not. Thus, some recently reported species may have been overlooked in past records but were found later during times when they were particularly abundant.

Many plant diseases are caused by facultative parasites, that is, pathogens that are favored in their disease-causing ability by a host in a weakened state, such as one predisposed by water stress or occurrence in an unfavorable or marginal habitat. However, this generalization does not apply to rusts, and to a lesser extent to smuts, which usually prefer healthy, vigorous hosts. Thus, the manager should not assume that rust or smut diseases are indications of other, underlying problems causing plant stress. Because they are efficient parasites, rust-caused

diseases often do not kill their hosts outright, but severe, persistent infection leading to defoliation can result in plant death. Smuts destroy the reproductive capability of the host rather than killing it directly. Because they are often host-specific and frequently virulent, rust fungi have been investigated perhaps more than any other group of fungi for their potential in the biocontrol of weeds (Watson, 1991). The disadvantages to the use of rust fungi as biocontrol agents elsewhere include the possible requirement for an alternate host, although if the uredinial, or "repeating" state is present, the fungus may be capable of perpetuating itself indefinitely with this abbreviated life cycle. The other possible drawback is the requirement of the fungus for living host plants, whereas most other types of fungi may be cultured on artificial medium in the laboratory.

In the classification scheme of the fungi, the smuts have much in common with, and are relatively closely allied with the rusts, hence the frequent treatment of these two groups together. Both groups produce wind-borne, resistant teliospores that serve as the basis for their classification and their means of spread. Notwithstanding their similarity, the smuts differ from the rusts in several ways. Whereas, as a group, they are not readily cultured on artificial media, they are not considered strictly obligate parasites, as are the rusts, since researchers have been successful in culturing these fungi apart from the living host. As indicated above, in contrast to rusts, which usually attack vegetative regions (i.e., leaves and stems) of their hosts, smuts usually are associated with the reproductive structures. Most smuts in Hawai'i occur on grasses and sedges and are recognizable as blackened seed heads in which the normal seed production is replaced by powdery or dusty-appearing masses of teliospores. In comparison to the rusts, relatively few smuts have been reported from Hawai'i, perhaps in part because they have received less research attention. Stevens (1925:125) commented on the paucity of smut flora in the Islands, stating: "The smut flora of Hawaii is most remarkable in that, aside from four smuts of cultivated cereals and clearly introduced by white men, there are only three smuts known on the islands." Species known in Hawai'i later were listed by Mäkinen (1969), who in turn referred to Stevens (1925) for most records. These included two species, *Sorosporium paspali* and *Sphacelotheca monilifera*, on native plants, and six additional species on introduced hosts. As mentioned above, Mäkinen remarked on the relatively limited smut flora of Hawai'i, and listed only a few additional species not noted previously by Stevens. Because smuts tend to have broader host ranges than do rusts, they are not limited to the hosts upon which they are found in Hawai'i. Therefore they are not categorized as endemic or indigenous with the same confidence as are the rusts. This does not rule out the possibility that some smuts may be indigenous, however.

Most herbarium specimens cited below are deposited in the Botany Department of Bishop Museum (BISH), but some are at the National Fungus Collection (BPI) at Beltsville, Maryland, the U. S. Department of Agriculture Animal Plant Health Inspection Service collection at Honolulu International Airport (HONQ), the Arthur Herbarium of Rust Fungi at Purdue University (PUR), or are in the collection of Tim Flynn (TF) of the National Tropical Botanical Garden. Host plants of rust and smut fungi are listed alphabetically by genus, with the plant family also included. A general reference is included at the end of each annotation where the authors of the species, reference to the original description, and other references to technical information on the fungus, can be found.

RUSTS

***Abutilon grandifolium* (hairy abutilon; ma'o)** MALVACEAE
***A. incanum* (ma'o)**
***A. menziesii* (ko'oloa 'ula)**

Puccinia heterospora (III, including mesospores) BISH 510512, on *A. grandifolium*)

Like *P. malvacearum*, *P. heterospora* may be found on a number of hosts of the Malvaceae in Hawai'i, including 'ilima and species of *Abutilon*. *Puccinia heterospora* produces conspicuous, sometimes large [3/8 inch (1 cm)] blotch-like dark lesions on both leaf surfaces, but often more prevalent on the undersurface. The lesions appear powdery in texture as a result of the teliospore masses. Teliospores are unusual in morphology, with the two cells delimited by a more or less vertical septum as an extension of the pedicel such that the cells are oriented side by side rather than one distal to the other divided by a horizontal septum as is usually the case. Another unusual feature is the production of mesospores, which are modified, thick-walled one-celled teliospores. In some collections of *P. heterospora*, mesospores are more numerous than are conventional teliospores, or even are present exclusively of the typical two-celled teliospores. The latter situation makes microscopic recognition of the spore state confusing if one is not familiar with mesospores. Infection with *P. heterospora* may resemble that with *P. malvacearum* on hosts such as 'ilima which may be infected with either rust. The rust species on hosts of the Malvaceae are best distinguished from one another by microscopic characteristics. (Gardner and Hodges, 1989)

***Acacia farnesiana* (klu)** FABACEAE

Ravenelia spegazziniana (II) (BISH 510441)

The host is one of several introduced species of *Acacia* in Hawai'i, and the only one of the nonnative species known to be host for a rust. The rust does not appear to occur frequently in Hawai'i, where only the uredinial state is known. Infection is apparent as discrete brown pustules on leaves and the surfaces of seed pods, doing little apparent damage to the host. This rust is notable for the elaborate ornamentation of the surfaces of its spores, visible only with a microscope (Gardner and Hodges, 1985), and for the complex morphology of its teliospores where these are found elsewhere.
(Gardner and Hodges, 1989)

***Acacia koa* (koa)** FABACEAE

Atelocauda angustiphylloda (0, III) (PUR 90229; BISH 511352)

Atelocauda angustiphylloda is a newly described species, recognized previously by Stevens (1925) as *Uromyces koae*. This species is similar to *A. digitata*, also considered *U. koae* in the

original description. Microscopic characteristics of the teliospores suggest that these rusts are closely related to one another, but differ in their life cycles and the forms of the witches'-brooms they produce. *Atelocauda angustiphylloda* is known only on the Big Island, being most readily visible as large witches'-brooms on large, mature koa on the Saddle Road. The brooms differ from those associated with *A. digitata* by the abnormally narrow, small phyllodes, more or less circular in cross section, that comprise the brooms (Gardner, 1991; 1997). Trees may be heavily infected, containing many witches'-brooms.
(Hodges and Gardner, 1984; Gardner, 1991a)

Atelocauda digitata (0, I, II, III, IV) (PUR F2890; BISH 510514)

Atelocauda digitata also has been described from Australia, on species of *Acacia* native to that region, and would therefore be indigenous to Hawai'i rather than endemic (Hodges and Gardner, 1984). However, the life cycles of the rusts from the two regions may be different and the relationship between the Hawaiian and Australian rusts is still under study. Like *A. angustiphylloda*, *A. digitata* causes systemic infection, causing abnormal shoots to develop from infected branch tissue. Witches'-brooms produced by *A. digitata* are readily seen wherever koa occurs in Hawai'i Volcanoes National Park. The broom phyllodes are broader and fleshier than are those of *A. angustiphylloda*, but the brooms themselves are not as large. Freshly produced phyllodes of the brooms are light green and bear numerous small (0.1 mm) black pustules (spermogonia), but soon become covered with cinnamon brown, powdery masses of aeciospores which are easily rubbed off. Infected branches may die back, causing conspicuous "flagging" in stands of koa. However, such flagging can be caused by other factors as well, but the presence of the brooms positively indicates the rust-produced disease. Telial and uredinial states of *A. digitata* are produced separately from the spermogonial-aecial brooms in small (0.1–0.2 mm) less conspicuous pustules on otherwise normal-appearing phyllodes.
(Gardner and Hodges, 1989)

Atelocauda koae (0, I, III) (PUR 89864; BISH 560938)

Atelocauda koae is most readily observed in Hawai'i Volcanoes National Park in loose association with *A. digitata*. Stevens (1925) considered this species to represent part of the life cycle of *A. digitata*, and combined the descriptions of the two species together in his original description of the koa rust fungus, as *Uromyces koae*. *Atelocauda koae* is considered endemic to Hawai'i. This rust is confined to young tissue, occurring as conspicuously raised leaf spots (1–10 mm) on either juvenile pinnate leaves or newly developed phyllodes of saplings. The spots become covered with brown, powdery masses of spores that are easily rubbed off. Heavy infection of apical tissue is thought to cause loss of dominance and result in deformed growth (see illustration in Chen *et al.*, 1996). Notwithstanding the similarities of *A. koae* to *A. digitata*, recent studies (Hodges and Gardner, 1984) have shown these as distinct species from one another, although undoubtedly closely related.
(Gardner and Hodges, 1989; Chen *et al.*, 1996)

Endoraecium acaciae (0, III) (PUR 88011; BISH 510444)

Endoraecium acaciae is perhaps the most common rust on koa throughout the Islands, producing a large, dense witches'-broom from systemically infected branches. Infected trees are readily seen on Kaua'i along the highway to Koke'e State Park. Individual trees show apparent variation in susceptibility, with many such brooms occurring in some trees. In such cases, the rust may kill enough branches that the entire tree may be killed. *Endoraecium acaciae* is obviously related to *Atelocauda digitata* and *A. angustiphylloda*, which also produce witches'-brooms resulting from systemic infection. As with the other rusts of koa, the brooms produce masses of powdery brown spores that are easily rubbed off. Phyllodes of *E. acaciae* brooms are narrower in width than are those of *A. digitata*. The rusts are most reliably distinguished by the spore state produced and by the microscopic and germination characteristics of the spores. Both members of the genus *Endoraecium* are rare "endo" forms, in which spores which resemble (uredinoid) aeciospores morphologically germinate as teliospores and have assumed the function of this spore state (Hodges and Gardner, 1984).
(Gardner and Hodges, 1989)

Endoraecium hawaiiense (0, III) (PUR 89866; BISH 494668)

Endoraecium hawaiiense differs from *E. acaciae* in producing a much more reduced, relatively inconspicuous witches'-broom, comprised of only a few phyllodes. This species has been only infrequently found, all collections to date having come from widely separated sites on O'ahu. However, certain individual trees are apparently sensitive to infection and may bear a number of brooms. The species is further distinguished from *E. acaciae* by the morphology of its teliospores (Hodges and Gardner, 1984).
(Gardner and Hodges, 1989)

***Ageratum conyzoides* (maile hohono)** ASTERACEAE

Puccinia conoclinii (II) (BISH 146180)

The host is a short-lived herb with an unpleasant odor. It was introduced to Hawai'i from Central or South America during the 1800s and occurs on all main islands as a common weed. The rust is documented as a single collection at Bishop Museum from 1909, referred to by Stevens (1925) as *Puccinia compositarum*. The rust is probably inconspicuous and may be more common than the single collection would indicate, however.
(Gardner and Hodges, 1989)

***Allium cepa* (onion)** LILIACEAE
***A. ascalonicum* (shallot)**
***A. fistulosum* (green onion)**

Puccinia allii (II) (HONQ 19404, on onion)

Rust of onion and related crops has been reported in Hawai'i (Raabe *et al.*, 1981), but recent reports or collections are not available. Whether the few records suggest onion rust is rarely encountered in the Islands or whether it has been overlooked because it does not cause serious crop losses is not known. The rust, known in Hawai'i in the uredinial state, produces yellow pustules on both surfaces of leaves. It is reportedly common on chives garlic, leek, onion, and other crops in the genus *Allium* in gardens of Europe, Japan, and elsewhere in Asia (Arthur and Cummins, 1962).
(Gardner and Hodges, 1989)

***Alyxia oliviformis* (maile)** APOCYNACEAE

Uromyces alyxiae var. *alyxiae* (III) (BISH 509292)

This rust is limited to maile, an endemic species, so at present is considered endemic itself. However, a related variety, *U. alyxiae* var. *australiensis*, recently has been described on a species of *Alyxia* native to Queensland, Australia (Tierney and Gardner, 1992). *Uromyces alyxiae* was originally described in 1925 by F. L. Stevens, who emphasized its scarcity, but it has been found more recently in several locations where maile occurs. Infection most often occurs as one to several isolated leaf spots, but occasionally heavy infection with numerous spots has been seen. In particular, the rust is found in Kipuka Puaulu and other locations in Hawai'i Volcanoes National Park and Volcano Village. Infection may be quite conspicuous, causing raised spots, or pustules, on the upper leaf surface, accompanied by a corresponding yellow, sunken spot on the lower surface. Spots are well-defined, circular or oblong, and measure 0.5–5 mm in diameter, or up to 20 mm long when occurring on the midvein. Maile stems may also become infected, with gall-like swellings producing spore masses on the surface. Infected stems are frequently distorted (Gardner, 1987a). As infection progresses, masses of light brown teliospores break through the epidermis covering the pustule, giving a brown, textured appearance. The maile rust fungus is not known to produce urediniospores and is considered microcyclic. As rust pustules age, the spots become crusty and wart-like, and turn dark brown. Because both the fungus and host are endemic, they presumably evolved together. Therefore, infection probably does not seriously threaten the health of the host, but may cause an unsightly appearance. This may be a limiting factor in the selection of maile for use for cultural and festive occasions in which aesthetics is important.
(Gardner and Hodges, 1989)

***Anthoxanthum odoratum* (sweet vernal grass)** POACEAE

Puccinia brachypodii var. *poae-nemoralis* (II)

See the annotation for *P. brachypodii* var. *poae-nemoralis* on *Poa annua* and *P. pratensis* below. Raabe *et al.* (1981) reported the occurrence of *P. brachypodii* var. *poae-nemoralis* on sweet vernal grass in Hawai'i, but no voucher specimens are known on this host.

***Artemisia dracunculus* (tarragon)** ASTERACEAE
A. australis

Puccinia tanaceti (II, III) (BPI 042792)

This rust has been collected infrequently in Hawai'i, most recently on tarragon, which is cultivated as a culinary herb. It may be more common than collections would indicate, however. *Puccinia tanaceti* was first reported in Hawai'i (in 1928) as *P. absinthii*, a synonymous name, on *A. australis,* an endemic species. The single collection on this host listed above was deposited in the National Fungus Collection and has not been verified. Further observation is necessary to confirm the occurrence of this species on one or more of the endemic species of *Artemisia* in Hawai'i.
(Gardner and Hodges, 1989)

***Artocarpus altilis* (breadfruit)** MORACEAE

Uredo artocarpi (II) (BISH 614103)

Breadfruit rust had been reported from other localities of the Pacific before its relative recent discovery in Hawai'i (Gardner, 1991b). The rust causes a russeting of leaves, that is, a yellowish speckled appearance that may be mistakenly attributed to other factors, such as mite feeding damage. Upon close examination, the russeting is seen to be associated with small irregularly necrotic leaf spots apparent on both leaf surfaces. The uredinia (the only spore state known for this rust) are minute and easily overlooked. They occur on the undersurfaces of leaves, often in clusters, and their presence is most easily confirmed in the field with a hand lens. The rust has been found on only a few individual trees, on the islands of Kaua'i and Hawai'i, with neighboring trees free of infection. Genetic predisposal to infection by the rust may be a factor in infection. Although heavy infection may cause premature defoliation, this has been observed in only a few isolated cases. Therefore, the rust disease appears to have negligible impact on the health of the tree.
(Gardner, 1997)

***Belamcanda chinensis* (blackberry lily; leopard lily; paradanthus)** IRIDACEAE

Puccinia iridis (II) (TF 5834)

The host is an ornamental introduction from eastern Asia. The uredinial and telial states of the rust occur on a number of hosts of the Iridaceae family throughout North America and Asia (Arthur and Cummins, 1962; Hiratsuka *et al.*, 1992), but only the uredinia have been found in Hawai'i. *Puccinia iridis* is similar to *P. belamcandae*, which occurs on paradanthus in Japan, China, and India, but is distinguished by morphological characteristics such as its slightly smaller spore size. The rust appears as yellow uredinia erupting through ruptured epidermis on both leaf surfaces.

(Gardner, 1997)

***Bidens pilosa* (Spanish needle; beggar tick)** ASTERACEAE

Uromyces bidenticola (II) (BISH 510509)

The host, well known for its barbed seeds that stick to clothing, is a common weed in waste places throughout Hawai'i from sea level to about 4,000 feet elevation in both moist and dry habitats. The rust may be found wherever the host occurs, lower leaves being often so heavily infected that they turn yellow or brown. The rust occurs as numerous, small (0.5 mm) brown pustules mostly on the undersurface accompanied by yellowing on the upper surface. Since Spanish needle is considered a serious weed in cultivated areas and along roadsides, it is unfortunate that the rust does not appear to control the host more efficiently.
(Gardner and Hodges, 1989)

***Bolboschoenus maritimus* (bulrush)** CYPERACEAE

Uromyces lineolatus (II, III) (BISH 146438)

Rust on bulrush has been collected only infrequently, the above specimen being from 1921, but is not as rare as the single specimen would indicate. However, examination of herbarium material of the host itself reveals some specimens that are heavily infected, with both surfaces of older leaves conspicuously covered with brown coalesced spots. Infection appears as linear or elongate pustules that develop parallel to the leaf veins. Immature pustules are covered by the epidermis and eventually expand and break through the epidermis as they mature, leaving a ragged or unevenly torn epidermal margin. Most pustules are uredinial and lighter brown in color. Telial pustules, which are seen less frequently, are similar in appearance but dark brown or black. Occasionally teliospores may appear within predominantly uredinial pustules.
(Gardner and Hodges, 1989)

***Brachiaria mutica* (California grass)** POACEAE

Uromyces setaria-italicae (II) (BISH 510434)

California grass is a large, sprawling perennial grass that usually occurs as a weedy species occurring in dense mats in areas of high soil moisture content or near open water. It occurs throughout the tropics and was introduced to Hawai'i prior to 1924 (Wagner *et al.*, 1990). The rust occurs as more or less linear brown uredinial pustules. As with other rusts occurring on grasses, the pustules are oriented parallel to the leaf veins. They occur on both leaf surfaces and are accompanied by chlorotic (yellow) streaking in cases of heavy infection. At maturity, the spores erupt through the overlying epidermis, resulting in a ragged margin. Although the telial state has not been reported in Hawai'i, California grass rust, like other rusts of grasses, is often heavily parasitized by a hyperparasitic fungus, *Sphaerellopsis filum*. This fungus produces

conspicuous, shiny black fruiting bodies within the uredinial pustules. These dark fruiting bodies can be mistaken for the telial state, which is often dark. To date, *U. setaria-italicae* has not been found to cause heavy infection on its host, and rust pustules are usually found discretely scattered on the leaf surface.
(Gardner and Hodges, 1989)

***Canna indica* (canna)**

Puccinia thaliae (II, III) (BISH 509306) CANNACEAE

Canna is prized and well known as an ornamental and landscaping plant in Hawai'i. Sensitive varieties become infected with a rust fungus evident as numerous small yellow, powdery appearing uredinial pustules primarily on lower leaf surfaces. Masses of urediniospores may be easily rubbed off with the fingers. Telia, usually less frequent, also may be visible among uredinia, appearing as tan-colored pustules containing spores that are not as easily dislodged by rubbing. Heavy uredinial infections may become conspicuous, detracting from the ornamental value of canna. The host may be so severely attacked that cultivation of sensitive varieties becomes impractical (Gardner and Martinez, 1985).
(Gardner and Hodges, 1989)

Carex wahuensis CYPERACEAE

Uredo hawaiiensis (II) (BISH 509295)

The host is a large endemic sedge which occurs in a variety of native habitats, ranging from dry to mesic shrubland, coastal forest, on ridges, slopes, or in gulches, often on rocky substrate. It occurs on all main islands of Hawai'i except Ni'ihau and Kaho'olawe. *Uredo hawaiiensis* is not now known to occur on any other host and is therefore considered endemic. The rust occurs only in the uredinial state, and appears as scattered, linear medium brown pustules following the leaf veins. Heavy infection has not been observed and the rust appears to cause little damage to the host.
(Gardner and Hodges, 1989)

***Carex* sp.** CYPERACEAE

Puccinia molokaiensis (II, III) (PUR F5559; BPI 086600)

Puccinia molokaiensis is known from only a single collection made by O. Degener and H. Wiebke "Half mile along road east of Hanaliioliio" on Molokai, according to the notation accompanying the collected specimens. It was collected on an unidentified species of *Carex*. All known material from this collection was used as the holotype and isotypes of the newly described rust and sent to herbaria on the mainland. All of the specimens are now meager and teliospores are difficult to find. Other collections of this rust are needed, but it is probable that it

no longer exists in nature. The *Carex* host has been assumed to be a native species, thus suggesting that the rust itself is native also, but lack of knowledge of the specific identity of the host make attempts to find this rust even more difficult.
(Gardner and Hodges, 1989)

***Cenchrus echinatus* (sandbur)** POACEAE

Puccinia cenchri (II) (BISH 510443)

Sandbur has been declared a noxious weed in Hawai'i, where it occurs in dry to moist regions, thriving in sandy soils (Haselwood and Motter, 1976). It is best known for its production of barbed burs that stick to clothing, hair, etc. and are difficult to remove. Sandbur rust is usually inconspicuous, occurring as individual light brown uredinial pustules on both leaf surfaces, but often mainly on the upper surface. Unfortunately, the fungus seems to be of little or no value as a biocontrol agent for this weed.
(Gardner and Hodges, 1989)

***Chamaesyce celastroides* ('akoko)** EUPHORBIACEAE
***C. degeneri* ('akoko)**
***C. multiformis* ('akoko)**
***C. olowaluana* ('akoko)**

Puccinia levata (II, III) (BISH 494677, on *C. celastroides*; PUR F19671, on *C. multiformis*; BISH 509299, on *C. olowaulana*)

Puccinia levata occurs widely in Hawai'i on a number of endemic *Chamaesyce* hosts, having been collected most frequently on *C. celastroides* and *C. olowaluana* in the open dry forests of Pohakuloa on the Big Island. The rust occurs as more or less conspicuous uredinial pustules, 0.25–1.5 mm in diameter, on both leaf surfaces, but usually more frequently on the undersurface. Pustules themselves are brown due to the coloration of the urediniospores, which emerge through the ruptured epidermis, the ragged edges of which are prominent. Pustules are frequently associated with purplish or yellowish coloration of the leaf tissue, enhancing the visibility of infection. Spots may occur singly, or two to several may be found on a single leaf, but infection is not known to be so heavy that pustules coalesce as with other rusts. Telia are less common and appear similar to uredinial pustules but are darker in color. Teliospores also may occur in small numbers intermixed within uredinial pustules. Stevens (1925) listed *P. levata* (as *P. velata*) as endemic, but in his discussion he also referred to Mexican material of this species. A more recent treatment (Hennen and Hodges, 1981) suggests that *P. levata* represents the same species as one found on euphorbiaceous hosts in Mexico, Guatemala and the West Indies, indicating that it occurs in Hawai'i as an indigenous rather than an endemic species. On *C. olowaluana* at Pohakuloa, *P. levata* is closely associated with another rust, *P. vitata,* which causes witches'-brooms as described below.
(Gardner and Hodges, 1989; Hennen and Hodges, 1981)

Puccinia vitata (0, III) **(on *C. olowaluana*)** (BISH 509303)

At Pohakuloa, as mentioned above, *P. vitata* occurs in close association with *P. levata* on *C. olowaluana.* Unlike *P. levata* which has a broader host range among *Chamaesyce* spp., *P. vitata* is limited to this host. The rusts may be distinguished from one another by their different developmental manifestations. Infection by *P. vitata* is systemic in the branches and twigs and causes the host to produce a "witches'-broom," an abnormally dense, often more or less spherical, cluster of branches and twigs superficially resembling a broom. The witches'-brooms are conspicuous and may reach 45 cm (18 inches) in diameter. Brooms may sometimes hang down from normal-appearing branches in a pendulous fashion. Infected branch tissue may be swollen, with powdery-appearing chestnut brown telia visible in cracks in the bark. *Puccinia vitata* also produces a spermogonial state, but the spermogonia are less conspicuous than telia and are not always evident (Hennen and Hodges, 1981; Gardner, 1988a). They are small dark bodies scattered on the surface of bark of infected branches and twigs. Unlike the situation with *P. levata*, no other spore states of *P. vitata*, are thought to exist elsewhere; therefore, *P. vitata* is considered endemic to Hawai'i
(Gardner and Hodges, 1989; Hennen and Hodges, 1981)

***Chamaesyce clusiifolia* ('akoko)** EUPHORBIACEAE

Uredo stevensii (II) (BISH 500005; BPI 155868; PUR F8939)

As with all species of *Uredo*, this rust exists only in the uredinial state. Like *Puccinia molokaiensis*, *U. stevensii* is a rare rust that has not been seen in recent years. It is currently known only from now meager herbarium specimens, all collected by Stevens in the 1920s. According to the Stevens' original description in (1925), the uredinia are dark cinnamon brown, occurring on both upper and lower leaf surfaces in circular or spiraling groups on discolored areas 0.3–0.8 mm in diameter. Microscopic characteristics of the urediniospores have been used to further define this species. While *U. stevensii* was reported only on *C. clusiifolia* (as *Euphobia clusiaefolia*) and *Chamaesyce* sp. (as *Euphorbia* sp.), too little information exits for these reports to indicate conclusively the extent of the host range of this rust, although it probably is (or was) limited to *Chamaesyce*.
(Gardner and Hodges, 1989; Hennen and Hodges, 1981).

***Chamaesyce hirta* (hairy spurge; garden spurge)** EUPHORBIACEAE
***C. prostrata* (prostrate spurge)**

Uromyces euphorbiae (0, I, II, III) (BISH 146426, on hairy spurge; BISH 510518, on prostrate spurge)

Hairy spurge and prostrate spurge are a low-growing annual weeds common throughout the Islands and throughout the warmer regions of the United States south to Argentina. In Hawai'i, it occurs in disturbed and waste places in moist and dry regions. It also occurs as a weed in

cultivated areas, lawns, and along roadsides. *Uromyces euphorbiae* is unusual in Hawai'i in that it produces four spore states, all of which can be readily found on the host. Aecia, uredinia, and telia occur as more or less conspicuous pustules with ruptured epidermal margins. Spermogonia typically are smaller, dark blister-like eruptions associated with aecia.
(Gardner and Hodges, 1989)

***Christella dentata* (downy wood fern, pai'i'iha)** THELYPTERIDACEAE

Desmella aneimiae (II) (BISH 644615, BPI 737878, TF 5982)

The host occurs throughout warmer and temperate regions of the world and is one of the most common ferns in Hawai'i, where it was introduced about 1887 (Valier, 1995). The rust, unlike the other fern rust known to occur in Hawai'i, *Uredinopsis hashiokai* (see *Pteridium aquilinum* below), is not white-spored, but produces yellow-pigmented urediniospores on the undersurface of the frond. *Desmella aneimiae* was discovered relatively recently in the Ku'ia Natural Area Reserve, Mahanaloa Valley, Kaua'i. It was recognized by its discoverer, Tim Flynn, by the general orange-yellow coloration imparted to stands of the host by the abundance of this rust (T. Flynn, personal communication). A third genus of fern rusts, not known to occur in Hawai'i, produces urediniospores with a yellow, sometimes very faintly yellow-pigmented spore content, whereas the spore wall itself remains colorless. *Desmella aneimiae* is distinguished from these rusts microscopically by having obviously pigmented urediniospores in which the spore wall, as well as the spore contents, are colored. Another unusual microscopic feature of *D. aneimiae* is its "substomatal" development, in which the vegetative parts of the fungus do not radiate throughout the tissue surrounding infection, as with other fungi, but fungal development is limited to the cellular chambers beneath the stomates. The rust produces clusters of urediniospores and teliospores (when these are present, they have not been found in Hawai'i) that emerge directly through the stomatal openings. As noted above, other rusts, including those on ferns, typically produce uredinial pustules beneath the leaf epidermis, which rupture at maturity to release the urediniospores.
(Gardner, 1997)

***Chrysanthemum indicum* (chrysanthemum)** ASTERACEAE
***C. morifolium* (chrysanthemum)**

Puccinia chrysanthemi (II) (BISH 146176; on *C. indicum*)
(HONQ 49342; on *C. morifolium*)

The rust is limited to cultivated chrysanthemums, where it occurs as individual dark brown powdery-appearing pustules on the undersurfaces of leaves and on stems. Infection usually is not heavy and does little damage to plants, but its presence may be considered undesirable and possibly affect the market value of cut flowers. With this, and other important horticultural species, development and use of varieties less sensitive or resistant to infection is considered the most practical long-term approach to control of the disease.
(Gardner and Hodges, 1989)

***Cirsium vulgare* (bull thistle)** ASTERACEAE

Puccinia cnici (II, III) (BISH 590221)

Bull thistle is a common weed in pastures and disturbed places throughout Hawai'i, where, notwithstanding its attractive flowers, its sharp spines make it an especially undesirable introduction. The rust may be found wherever the host occurs, usually appearing as brown uredinial pustules. When occurring individually, the pustules measure 1–3 mm in diameter, but infection is often so heavy that the pustules coalesce into irregular spore masses. The spores are powdery and readily rubbed off, appearing as brown powder on the fingers. Lighter infection is usually confined to the undersurfaces of lower leaves, but heavily infected plants bear rust pustules on both surfaces, accompanied by leaf necrosis (i.e., dead tissue). Darker brown, or black, telial pustules may be interspersed among the lighter brown uredinial pustules. Telia do not appear powdery, but the spores can be seen as relatively large, dark, shiny spherical structures when viewed with a hand lens.
(Gardner, 1997)

***Commelina diffusa* (honohono "grass"; day flower)** COMMELINACEAE

Physopella tecta (II) (BISH 510521)

The host is native to the Old World tropics but is widely naturalized in Hawai'i, often forming a conspicuous part of the ground cover in disturbed mesic and wet forests and other disturbed sites. The rust is consistently present wherever the host occurs, such that at any given site finding a non-infected honohono plant is often not possible. The rust, which occurs only as the uredinial state in Hawai'i, produces clusters of minute yellow pustules on the undersurfaces of the leaves, and also may occur on the stems. The pustules are so small they are best viewed with a hand lens. The upper leaf surfaces take on a "bronzed" appearance. The rust occurs with such frequency that the casual observer could mistake the bronzed appearance for the normal color, rather than the uniformly bright green color of uninfected leaves (Gardner, 1981).
(Gardner and Hodges, 1989)

***Coprosma rhynchocarpa* (pilo)** RUBIACEAE
***C. waimeae* ('olena)**

Uredo vulcani (II) (BISH 509308, on pilo; TF 4669, on 'olena)

Rust on pilo, a small tree endemic to the island of Hawai'i, was found by accident while searching for a possible spermogonial-aecial host of the rust on maile, *Uromyces alyxiae* (see above). Rust pustules found on leaves of pilo in the vicinity of infected maile in Kipuka Puaulu, Hawai'i Volcanoes National Park, were at first thought to represent this aecial state. Only later, upon careful examination were the pustules recognized as representing the uredinial state of a

separate, as yet undescribed, rust whose discovery was unexpected (Gardner, 1988b). Despite further searching, the rust was known from the leaves of only a few trees in Kipuka Puaulu until its discovery by Tim Flynn, National Tropical Botanical Garden, some years later on the island of Kaua'i on 'olena (Gardner, 1997). Its discovery on widely separated islands indicates that the range of the rust is greater than at first thought, but has remained undiscovered until recently probably because of its inconspicuous nature. Although its uredinial pustules are bright yellow when fresh, they are minute and often occur sparsely on the leaf undersurface. In heavier infections, uredinia may occur in clusters and correspond with necrotic spots on the upper surfaces, although infections have not yet been found so severe that the leaf is covered with uredinia. Because of its occurrence on endemic hosts, and lack of reference to a similar rust on other members of the Rubiaceae elsewhere, the rust on *Coprosma* spp. is considered an endemic species.
(Gardner and Hodges, 1989)

***Crassocephalum crepidioides* (fireweed)** ASTERACEAE

Puccinia senecionicola (II) (BISH 590219)

Fireweed is an annual weed commonly encountered throughout Hawai'i in moist cultivated areas, disturbed sites, and waste places. Only one collection of *Puccinia senecionicola* from this host is available, but the rust is undoubtedly more widely distributed than this collection would indicate. Only the uredinial state has been found in Hawai'i at present, which occurred as minute brown pustules moderately to heavily infecting the undersurfaces of the lower leaves. This rust also has been reported from Mexico and tropical America on species of *Cacalia* and *Senecio*, other genera of the Asteraceae.
(Gardner, 1997)

***Cymbopogon citratus* (lemon grass)** POACEAE

Puccinia nakanishikii (II, III) (BISH 509305)

Lemon grass is a perennial grass widely cultivated in Hawai'i by homeowners for its ornamental value and for the lemon-scented oil that it produces (Neal, 1965). It is also used as a culinary ingredient in the cuisines of the Oriental cultures represented in Hawai'i. Depending apparently on favorable climatic conditions, lemon grass can become severely and conspicuously infected with rust. The rust occurs in both the uredinial and telial states, the former producing lighter brown and the latter producing darker pustules on both leaf surfaces. Heavily infected tissue becomes obviously discolored and necrotic in a streaked pattern corresponding to the leaf venation (Gardner, 1985). Whereas lemon grass is of little commercial importance in Hawai'i, the rust may damage plants so severely that economic loss would undoubtedly result if lemon grass were to be cultivated as a commercial crop.
(Gardner and Hodges, 1989)

***Cynodon dactylon* (Bermuda grass)** POACEAE

Puccinia cynodontis (II, III) (BISH 510436)

Bermuda grass rust may be found wherever Bermuda grass is grown in Hawai'i, and where it has escaped cultivation. The rust is most often inconspicuous, with heavy infections thus far appearing to be uncommon. This is perhaps due to the resistant grass varieties most often planted. Uredinia occur as individual lighter brown pustules on the leaf undersurfaces, whereas telia, which are less frequently found, occur as darker pustules. The rust appears to do little damage to the host.
(Gardner and Hodges, 1989)

***Cyperus rotundus* (purple nutsedge)** CYPERACEAE

Puccinia canaliculata (II, III) (BISH 511589)

Both purple nutsedge and the closely related species yellow nutsedge (*Cyperus esculentus*) are widespread weeds in Hawai'i, where both spread rapidly by underground tubers and have been declared noxious. It is interesting that *P. canaliculata* has been found only on purple nutsedge in Hawai'i to date, because this rust occurs also on yellow nutsedge on the U. S. mainland where it has been under study as a potential biocontrol agent (Phatak *et al.*, 1983). The reason yellow nutsedge is not attacked in Hawai'i is not known and should be further investigated. On purple nutsedge, the rust produces conspicuous yellow-orange to cinnamon brown uredinial pustules primarily on the undersurfaces of leaves. Telial pustules, also on leaf undersurfaces, are less common, and appear darker brown or black. Uredinial and telial pustules develop beneath the leaf epidermis and break through at maturity, leaving conspicuous, irregularly torn epidermal margins around the exposed spores.
(Gardner and Hodges, 1989)

Puccinia philippinensis (II, III) (BISH 511590)

This rust, also occurring on, and limited to purple nutsedge, has been identified as such from only one collection in Hawai'i (in 1986), and is therefore by far the less common of the two species attacking this host. It is possible that this species occurs more frequently, but has been misidentified as *P. canaliculata.* The diseases caused by these rusts resemble one another, and are distinguished only by microscopic spore characteristics.
(Gardner and Hodges, 1989)

***Dactylis glomerata* (orchard grass)** POACEAE

Puccinia striiformis var. *dactylidis* (II, III) (BISH 511586)

The rust on orchard grass was reported previously as *P. graminis* (Raabe *et al.*, 1981) but has been distinguished from this species by microscopic morphological characteristics, including the presence of paraphyses (sterile hairs) (Cummins, 1971). Orchard grass is a well-known naturalized perennial grass occurring throughout the Islands in pastures and along roadsides. Rust has been only infrequently found on orchard grass where it appears to do little or no damage to its host, although heavy infection can produce linear chlorotic streaks in the leaves. It occurs as bright orange-yellow pustules (uredinia) associated with the veins in linear clusters on both leaf surfaces but often more prevalent on the upper surface (Cummins, 1971). The telial state also has been found, but less frequently. It occurs as darker leaf pustules.
(Gardner and Hodges, 1989)

***Dianthus caryophyllus* (carnation)** CARYOPHYLLACEAE

Uromyces dianthi (II) (BISH 146401)

Rust on carnation has been infrequently reported. It occurs as uredinial pustules on leaves and stems, usually not causing major damage to the host but possibly causing the flower to be less marketable. Carnation rust in Hawai'i has been also referred to *Puccinia arenariae*, but since the uredinial state of the latter species is described as wanting, the species observed is considered *U. dianthi*. As with infection of other ornamental species, the most effective long-term approach to control is through the development and use of resistant varieties.
(Gardner and Hodges, 1989)

***Digitaria pentzii* (=*decumbens*) (pangola grass)** POACEAE
***D. ciliaris* (=*henryi*) (crabgrass)**
***D. setigera* (=*pruriens*) (itchy crabgrass)**
***D. violascens* (smooth crabgrass)**

Puccinia oahuensis (II, III) (BISH 510510, on *D. ciliaris*)

Several species of *Digitaria* are known commonly as crabgrass and occur as common lawn and garden weeds. Rust-infected crabgrass is common and recognized by the yellowing of the grass blades. Examination with a hand lens reveals minute pustules on the leaf undersurfaces, typically associated with scattered spores. Both uredinial and telial pustules are common, the latter being darker in color. Notwithstanding its common occurrence, the persistence of crabgrass indicates that the effectiveness of this fungus as a biocontrol agent is minimal. *Puccinia oahuensis* is of interest from a taxonomic standpoint in that it was originally described as an endemic species to Hawai'i, (hence the name *P. oahuensis*) (Stevens, 1925). However, its occurrence on introduced hosts presented a contradiction with this concept. Cummins (1943) later brought species of *Digitaria* rusts from other localities into synonymy with *P. oahuensis*, creating a species concept that extended beyond the range of the originally-described rust from Hawai'i. Therefore, in its current concept, *P. oahuensis* is found throughout the warmer regions of the world. The original name was retained according the rules of nomenclature, but is now somewhat misleading.

(Gardner and Hodges, 1989)

***Euphorbia peplus* (petty spurge)** EUPHORBIACEAE

Melampsora monticola (II, III) (TF 3917)

The host is an annual herbaceous pasture weed that has become naturalized in Hawai'i. The collection cited above was found in the 'Ola'a Tract of Hawai'i Volcanoes National Park. When fresh, the uredinial state is visible as conspicuous bright orange pustules on both leaf surfaces. The telia are inconspicuous, being produced under the leaf epidermis and remaining nonemergent. They are visible on the leaf surface only as a darkened spots in the vicinity of the uredinia (Gardner, 1997). Although *M. monticola* has been only infrequently collected in Hawai'i, the occurrence of its host as a common weed suggests that the rust itself may occur more commonly than has been recognized.
(Gardner, 1997)

***Ficus carica* (common fig)** MORACEAE

Cerotelium fici (II) (BISH 560938)

Fig rust is known from New Zealand and other localities in the Pacific, and had probably occurred in Hawai'i long before it was formally reported (Gardner, 1997). The rust appears to be widespread in Hawai'i, present wherever fig is cultivated on all major Islands. It produces clusters of minute, pale yellow uredinia on lower leaf surfaces. Infection causes irregular, necrotic spots in upper leaf surfaces corresponding to pustules on lower surfaces. Infection may lead to necrosis (death) of leaf margins, which tend to curl inward. Heavily infected leaves fall prematurely. During winter months in Hawai'i, rust-infected fig trees have been observed with complete defoliation. Uredinia may also occur on the surface of fruit, where they produce necrotic spots 1 to 3 mm (1/8 inch) in diameter.
(Gardner, 1997)

***Fuchsia hybrida* (hybrid fuchsia)** ONAGRACEAE
***F. magellanica* (fuchsia)**

Pucciniastrum epilobii [*Uredo fuchsiae* (?) (II)] (BISH 510522)

Fuchsia rust occurs as clusters of minute yellow uredinial pustules on the undersurfaces of leaves. Because the pustules are small and inconspicuous, lightly infected leaves appear normal and the disease becomes obvious only in cases of heavy infection. Upper surfaces of heavily infected leaves become discolored in areas corresponding to uredinial clusters on the undersurfaces, and leaf contortion and premature defoliation may occur (Gardner, 1979). Telia of this rust species have been only infrequently reported and have not been found in Hawai'i. Because telia are not available, the rust should not be referred to as *Pucciniastrum* in a technical

sense, but the name *Uredo* is preferred as more accurate by some authors. Although fuchsia is usually considered a desired ornamental shrub, *F. magellanica* has escaped cultivation and has become somewhat invasive in Hawai'i Volcanoes National Park. For this reason, this species has been the subject of weed control efforts by resource managers. Because of this, the occurrence of the rust on fuchsia in the Park, together with attack by a leaf-deforming eriophyid mite, was welcomed as biocontrol against this species (Gardner, 1987b).
(Gardner and Hodges, 1989)

***Geranium cuneatum* (nohoanu)** GERANIACEAE

Puccinia leveillei (III) (BISH 509296)

The host, nohoanu, is considered endemic to Hawai'i. The rust, previously referred to as *Puccinia geranii-silvatici* in the literature, is known also from *Geranium* hosts in North and South America and is probably indigenous to Hawai'i (Gardner, 1994). The host in Hawai'i is covered with short, silver hairs. Rust infection, in the form of telia (uredinia are lacking in this species) is visible as dark, often conspicuous, eruptions of teliospores among the silver hairs. Telia are embedded in the underlying leaf and stem tissue and open by means of irregular slits, through which teliospores are expelled. Hypertrophy (swelling) of the stem tissue may accompany production of telia. Infected leaves produce telia mostly on the undersurfaces. Microscopically, the teliospores are dark brown in color and are readily identified by their short, compact appearance with no constriction at the septum, and a verrucose (bumpy) ornamentation of the spore wall, especially on the upper cell.
(Gardner and Hodges, 1989)

***Glycine max* (soybean)** FABACEAE

Phakopsora (*pachyrhizi*?) (II) (BISH 641410)

Soybean rust was discovered recently in soybean fields on O'ahu and subsequently has been found in plantings of this crop elsewhere in the Islands (Killgore *et al.*, 1994). Two species of rusts are known that attack soybean, *Phakopsora pachyrhizi* and *P. meibomiae*. The former species, which occurs in Asia and is not yet known in North America, causes a much more virulent disease of major importance on soybean. Infection in Hawai'i was found to cause 100% crop destruction (Killgore *et al.*, 1994). *Phakopsora meibomiae*, thought to have originated in the Western Hemisphere, is of less economic importance at present. Based on the severity of attack in Hawai'i, the rust has been unofficially identified as *P. pachyrhizi*. Positive identification of these two species depends on the availability of the telial state, which has not been found in Hawai'i. The discovery of soybean rust in Hawai'i has alarmed the U. S. Department of Agriculture Animal and Plant Health Inspection Service, because of the possibility that Hawai'i may serve as a stepping stone for the fungus, enabling its eventual accidental introduction to the soybean growing regions of North America. Soybean rust causes small brown pustules mainly on the undersurfaces of leaves, but in severe infections, all portions of plants may be covered with coalesced pustules.

(Gardner, 1997)

***Heteropogon contortus* (pili grass)** POACEAE

Puccinia versicolor (II) (BISH 146246)

Pili grass is a widely distributed tropical perennial grass. It is indigenous to the Islands or possibly introduced by early Polynesians. No recent collections of rust are available, although this may be more a result of the rust having been overlooked rather than being rare. In any case, heavy infections on pili grass have not been reported. The rust occurs as yellow uredinial pustules mostly on the lower surfaces of the leaves (Cummins, 1971). Although seen only in microscopic observation, this rust is somewhat distinctive in having urediniospores with irregularly thickened walls and a colorless interior spore cavity (lumen), giving a white stellate, or star-like, appearance to the spore lumen.
(Gardner and Hodges, 1989)

***Holcus lanatus* (common velvet grass; Yorkshire fog)** POACEAE

Puccinia coronata (II, III) (BISH 510513)
P. recondita (II, III) (BISH 494667)

Two rusts are known on velvet grass, a species native to Europe and now widely naturalized in Hawai'i in mid to upper elevations on the major islands. When fresh, both rusts produce a conspicuously bright orange, or yellow-orange infection on the leaves caused by urediniospores. Whereas the rusts are difficult to distinguish on the basis of their uredinial states, microscopic differences in their teliospores make distinction possible. Teliospores of *P. coronata* are characterized by prominent digitate (finger-like) processes at the apex, giving the spore a crown-like appearance, hence the name *coronata*. Teliospores of *P. recondita* are without conspicuous ornamentation and are rounded at the apex. Aside from their occurrence on velvet grass, both rusts have host ranges that include a number of other grasses elsewhere. Both *P. coronata* and *P. recondita* have been considered by some authors to represent a complex of rusts, each member of the complex given a subspecific name depending on the particular host grass species on which it occurs. The hosts include a number of grain crop species of economic importance elsewhere.
(Gardner and Hodges, 1989)

***Hordeum vulgare* (barley)** POACEAE

Puccinia coronata (II, III) (BISH 146183)

See the annotation for *P. coronata* under *Holcus lanatus* above. No recent collections of the rust on barley are available from Hawai'i. Inclusion here is based on a collection from the early 1900s.
(Gardner and Hodges, 1989)

***Hydrocotyle verticillata* (marsh pennywort)** APIACEAE

Puccinia hydrocotyles (II) (BISH 146214; TF 5328)

Marsh pennywort is a small creeping water-loving herb. The leaves are circular in outline with the petiole attached at the center. This species is native to North America and may be indigenous to Hawai'i. It became naturalized prior to 1871 (Wagner *et al.*, 1990). Rust occurs on both sides of the leaf, but may be more prevalent on the upper surface. Individual uredinial pustules are minute and darkly colored, but they often occur in groups or clusters which are more conspicuous than individual uredinia would be. The clusters are surrounded by a lighter green or yellow halo, giving the appearance of a larger leaf spot.
(Gardner and Hodges, 1989)

Lotus subbiflorus FABACEAE

Uromyces striatus medicaginis (II)

See the annotation for *U. striatus medicaginis* under ***Medicago sativa*** and ***M. polymorpha*** below.

***Malva parviflora* (cheese weed)** MALVACEAE

Puccinia malvacearum (III) (HONQ 8550; on *M. parviflora*)

The rust is known only in its telial state (i.e., microcyclic) and is commonly found on hosts of the Malvaceae (Raabe *et al.*, 1981), including cheese weed, a common along roadsides and in waste places. Elsewhere, *P. malvacearum* is known as hollyhock rust, because of the frequent, conspicuous infection of this rust on this host. Infections are apparent as dark gray pustules, sometimes numerous, on the undersurfaces of leaves. Sunken, chlorotic spots also may be visible on the corresponding upper surfaces.
(Gardner and Hodges, 1989)

***Medicago sativa* (alfalfa)** FABACEAE
***M. polymorpha* (bur clover)**

Uromyces striatus medicaginis (II, III) (BISH 146420, on alfalfa)

Alfalfa rust is visible as small (0.5–1.5 mm) pustules, mainly on the undersurfaces of leaves of this crop. Uredinial pustules are lighter brown whereas telia are dark, appearing almost black when observed with the unaided eye. Teliospores appear as shiny spheres when viewed under the magnification of a hand lens. Sporulating uredinia have a more powdery appearance, with a

visibly ragged epidermal margin caused by the erupting spores. Depending on the collection, more telia may be present than uredinia, an opposite situation from most rusts in Hawai'i. Severe infection may cause defoliation and destruction of the alfalfa crop.
(Gardner and Hodges, 1989)

***Melicope anisata* (mokihana)** RUTACEAE
M. ovata
M. peduncularis

Puccinia rutainsularа (III) (BISH 612837; TF 5562, on mokihana)

Previous unpublished reports of a rust on mokihana are included in the files of the Plant Disease Clinic at the University of Hawai'i and a rust reported from a *Pelea* (=*Melicope*) host was deposited at the National Fungus Collection (BPI) under the tentative name "*Xenostele*". However, the rust on *Melicope* spp. was not rediscovered and formally described until relatively recently (Gardner, 1990, 1994; Marr and Gardner, 1989). The rust occurs as clusters of telia (no other spore states are known) which are borne in conspicuous "wart-like" growths, or galls, on the undersurfaces of the leaves. Columns of teliospores are forcibly exuded from the deep-seated telia on the surface of the gall, giving it a "hairy" appearance. A possible explanation for the lack of attention given to this rust previously is the resemblance of the rust galls to galls more commonly found on mokihana leaves that are associated with eriophyid mites. The two types of galls resemble each other rather closely and would not readily be distinguished by the casual observer. Rust galls are usually sparse, with one or two occurring on a leaf, but occasionally leaves are found with many galls, making the rust quite conspicuous. Aside from the specimen at BPI, the rust is thus far known from the Koke'e region of Kaua'i.
(Gardner, 1997)

***Mentha spicata* (spearmint)** LAMIACEAE

Puccinia menthae (II, III) (BISH 612839)

Spearmint is a widely cultivated aromatic herb that has become naturalized in Hawai'i. Only the uredinial and telial states have been found in Hawai'i, which appear as somewhat inconspicuous pustules on the undersurfaces of the leaves (Gardner, 1997). Uredinia, which are more common, are lighter brown while telia are darker. Although spearmint rust has been found only infrequently, it is probably not rare in Hawai'i but has been overlooked by earlier collectors.
(Gardner, 1997)

***Myoporum sandwicense* (naio, false sandalwood)** MYOPORACEAE

Uredo myopori (II) (BISH 548135, PUR F14529)

Rust on naio was first discovered in the 1940s at Parker Ranch on the island of Hawai'i. Specimens were sent directly to the Arthur Herbarium at Purdue University (PUR). The rust was later described as a new species, *U. myopori*, by a researcher at PUR, together with a number of other miscellaneous specimens from other regions, and published in a nondescript manner. No other record of the rust from Hawai'i was known locally until its rediscovery in 1989, at which time it was thought to be a new species (Gardner, 1989). Later confirmation of this collection with the curator of PUR indicated the rust to be a rediscovery of the species. To date, the rust has been found only on the island of Hawai'i, in Hawai'i Volcanoes National Park and in dry, upland naio-mamane forests on the slopes of Mauna Kea. Most collections of the rust are of sparsely-infected leaves, with uredinial pustules approximately 1 mm in diameter, the margins of the uredinia conspicuously torn. Red leaf spots surround uredinia, increasing the visibility of sites of infection. One collection from a tree on the Mauna Loa Strip Road of Hawai'i Volcanoes National Park was made of unusually heavily infected leaves, bearing numerous uredinia and with extensive leaf discoloration. It is not known whether in this case the rust was collected during the proper season for its development, or had developed under unusually favorable conditions.
(Gardner, 1997)

***Oxalis martiana* (pink wood sorrel)** OXALIDACEAE
***O. regnellii* (white wood sorrel)**

Puccinia oxalidis (II, III) (BISH 509304; BISH 510446; on white wood sorrel)

While oxalis rust usually appears quite rare in Hawai'i, its appearance may depend on specific favorable environmental conditions. Under these conditions, it produces prominent infection and is readily found as conspicuous, powdery-appearing yellow pustules on the undersurfaces of leaves. Occasionally it becomes an economic problem on white wood sorrel, which, because of its leaves that resemble four "leaf" clover, is sold as a substitute for shamrock for St. Patrick's Day. Rust infection causes the foliage to be unsightly and unsaleable. *Puccinia oxalidis* has been misidentified in Hawai'i as the aecial state of *P. sorghi* (Raabe *et al.*, 1981) and possibly that of *P. purpurea*, both of which are known to occur on species of *Oxalis* elsewhere (Cummins, 1971). However, the rust on *Oxalis* is a uredinial, rather than an aecial state, and teliospores, although rare, have been observed associated with the urediniospores (Gardner, 1986). Therefore, the aecial states of neither *P. sorghi* nor *P. purpurea* are known to occur in Hawai'i.
(Gardner and Hodges, 1989)

***Paederia scandens* (=*P. foetida*) (maile pilau)** RUBIACEAE

Coleosporium paederiae (II) (BISH 510516)

Maile pilau is a thin-stemmed twining vine known for its unpleasant scent. It is native to eastern Asia and is now widely naturalized in Hawai'i, occurring in a variety of habitats. The rust is commonly seen on this host, the leaves of which are conspicuously infected with bright yellow or yellowish-orange uredinial pustules, mostly on the under surfaces of the leaves. The habit of

maile pilau to twine tightly around neighboring vegetation and to mingle its leaves closely with those of its supporting plant has resulted in mistaken reports of rust on other, previously unreported hosts in Hawai'i. Examination of these hosts for confirmation has revealed that the rust reported was actually *C. paederiae* on maile pilau.
(Gardner and Hodges, 1989)

***Panicum maximum* (Guinea grass)** POACEAE
***P. nephelophilum* (konakona)**

Uromyces graminicola (II, III) (BISH 146193, on konakona)

Only a single specimen, collected in 1921, is available of this rust on konakona. Raabe *et al.* (1981) also reported Guinea grass as a host, but no specimens are known of the rust on this species. The *Panicum* rust was originally identified as *Puccinia esclavensis*, and this specimen served as the voucher for Stevens' report of *P. esclavensis* from Hawai'i. Stevens noted that the host had been found only once, on the island of Kaua'i, but was heavily infected. The identification of the rust was updated by Y. Mäkinen in about 1967 (unpublished), who noted on the herbarium specimen the presence of "very scarce" teliospores that had been apparently overlooked by Stevens. Mäkinen's identification was based on the characteristics of the teliospores. More collections and information on this rust are obviously necessary to properly characterize this rust in Hawai'i. Cummins (1971) described *U. graminicola* with brown uredinia on both leaf surfaces, or mostly on the lower surface, and telia blackish-brown, soon erupting through the host epidermis, and powdery appearing.
(Gardner and Hodges, 1989)

***Paspalum conjugatum* (Hilo grass)** POACEAE

Puccinia chaetochloae (II, III) (BPI 055574)

A single specimen is available of *P. chaetochloae* on Hilo grass, suggesting that the rust is relatively rare, or more likely, has been overlooked by potential collectors. Cummins (1971) describes the rust with brown uredinia occurring on both leaf surfaces and remaining covered by the epidermis for an extended period before they erupt. Telia also occur on both leaf surfaces and are blackish. Like the uredinia, they are covered by the epidermis during an extended period during development. No information is available concerning the frequency or severity of infection in Hawai'i, and more observations and collections are necessary. Microscopic characteristics, that is, the presence of sterile hairs (paraphyses) distinguishes this rust from *P. paspalina*, which also occurs on *Paspasum* hosts in Hawai'i. Color differences of teliospore walls are also a useful distinguishing characteristic.
(Gardner and Hodges, 1989)

***Paspalum scrobiculatum* (=*P. orbiculare*) (ricegrass)** POACEAE

Puccinia paspalina (II) (BISH 146208)

Early collections of this rust on ricegrass in Hawai'i were labeled *Puccinia huberi*. Arthur and Cummins (1962) placed *P. huberi* in synonymy with *P. levis*, but Cummins (1971) later recognized both *P. huberi* and *P. paspalina* as valid species, with *P. paspalina* occurring on *Paspalum* hosts and *P. huberi* on *Panicum* hosts. At present, *P. huberi* is not known to occur in Hawai'i according to Cummins' concept of this species. Recent observations and collections of *P. paspalina* on ricegrass are lacking. Cummins (1971) described the uredinia as cinnamon-brown or paler, and occurring on both leaf surfaces, but mostly on the lower surface. Telia were described as grayish black and covered by the epidermis for an extensive period during development. They occur on both leaf surfaces or mostly on leaf sheaths.
(Gardner and Hodges, 1989)

***Pelargonium hortorum* (garden geranium)** GERANIACEAE

Puccinia pelargonii-zonalis (II) (BISH 510507)

Geranium rust is known from many localities and was first reported in Hawai'i in 1967, where it is known in only the uredinial state. At present, it probably occurs widely throughout the Islands. Infection may consist of individual, scattered sporulating pustules. On heavily infected leaves, pustules may be arranged in conspicuous zonate (i.e., target board) patterns which appear as concentric rings 0.25 inch or more in diameter on the leaf undersurfaces. The pustules are medium to dark brown and powdery, with spores that are easily rubbed off on the fingers. Corresponding tissue on the upper surface may be discolored.
(Gardner and Hodges, 1989)

***Pennisetum clandestinum* (Kikuyu grass)** POACEAE

Phakopsora apoda (II) (BISH 509307)

Kikuyu grass rust is widespread in Hawai'i, probably occurring wherever its host, a popular introduced pasture grass, is grown (Gardner, 1984). Kikuyu grass is typically more heavily infected lower on the grass leaves (i.e., nearer the ground) and where this host occurs in shady areas rather than in full sun. Infection is usually light to moderate, but under favorable environmental conditions, numerous uredinial pustules are conspicuous on grass leaves, where they occur on both leaf surfaces. The pustules are circular and small (about 1 mm in diameter) but are easily seen because of their dark gray color against the light green color of the host tissue. Telia have not been found in Hawai'i. Notwithstanding its usefulness as a pasture grass, the invasive nature of Kikuyu grass makes it an undesirable weed in protected native habitats, such as national parks. Unfortunately, the rust does not appear to control Kikuyu grass significantly in these situations.
(Gardner and Hodges, 1989)

***Phyllostachys* sp. (bamboo)** POACEAE

Puccinia phyllostachydis (II) (BISH 590220)
Stereostratum corticioides (II) (BISH 510517)

Several rusts are known to occur on bamboo (Kenney, 1997), but only two have been reported from Hawai'i, both represented by their uredinial states. *Puccinia phyllostachydis*, the more common of these, occurs as minute brown pustules, often in clusters, on both leaf surfaces. Infection may be so severe that the pustules appear to coalesce into larger russeted (yellowish-brown textured) areas. Recent collections were made in the area of Koke'e, Kaua'i, and the Manoa Cliffs Trail on O'ahu. This rust can probably be found wherever bamboo occurs and environmental conditions are favorable for its appearance. Although heavily infected leaves may die, the rust does not appear to cause significant damage in bamboo stands themselves. The second rust on bamboo in Hawai'i, *S. corticioides*, is distinguished from *P. phyllostachydis* microscopically by its lack of paraphyses (sterile hairs) which are abundant and elaborately developed in *P. phyllostachydis*. At present, *S. corticioides* is known in Hawai'i by only a single collection from an ornamental planting on bamboo in Waikiki, suggesting that it was recently introduced.
(Gardner and Hodges, 1989)

***Plumeria obtusa* (Singapore plumeria)** APOCYNACEAE
***P. rubra* (red plumeria)**

Coleosporium plumeriae (II, III) (BISH 641407)

The plumeria rust fungus was introduced to Hawai'i relatively recently, presumably from other regions where plumeria is grown, such as Florida or southern Texas. It was first found on O'ahu in January, 1991, and has since spread to all islands and may be found wherever plumeria is grown (Ogata and Gardner, 1992). Red plumeria is sensitive to infection, and can become defoliated by heavy infection. Singapore plumeria is relatively resistant to infection. Infection, which is limited to the leaves, is conspicuous as masses of bright yellow-orange, powdery uredinial spore masses may cover undersurfaces, with smaller spore pustules sometimes appearing on the upper surface. The spores are easily rubbed from the leaves. Darker orange-brown, waxy-appearing telia, which are not removed by rubbing, are later produced among the uredinia.
(Gardner, 1997)

***Poa annua* (annual bluegrass)** POACEAE
***P. pratensis* (Kentucky bluegrass)**

Puccinia brachypodii var. *poae-nemoralis* (II) (BISH 146191, on annual bluegrass; BISH 146225, on Kentucky bluegrass)

Collections from Hawai'i of rust on both species of bluegrass are older (1921, 1940) and no recent information on rust on these hosts is available. Another species of rust, *Puccinia poarum*, which also may attack *Poa* spp., has been recorded in Hawai'i (G. Baker, unpublished files). However, microscopic examination of herbarium specimens showed that numerous paraphyses were present, indicating the collections to be *P. brachypodii* var. *poae-nemoralis*. Therefore, the presence of *P. poarum*, in which paraphyses are scarce or lacking (Cummins, 1971), has not yet been confirmed in Hawai'i. Symptoms of infection include yellowish or yellowish-brown uredinia that are mostly on the upper leaf surface. Telia, which have not been reported for Hawai'i, occur mostly on the lower leaf surface and are blackish and covered during an extensive period of development by the host epidermis (Cummins, 1971).
(Gardner and Hodges, 1989)

***Polygonum punctatum* (water smartweed)** POLYGONACEAE

Puccinia polygoni-amphibii (II, III) (BISH 511350)

Water smartweed is a perennial herb capable of rooting at the nodes. It is native to North and South America and the West Indies and is now widely naturalized in Hawai'i, where it occurs in disturbed sites in wet forests, in standing or running water and along streambeds (Wagner *et al.*, 1990). The rust commonly occurs as minute (0.1 mm) tan or brown uredinial pustules on both leaf surfaces. Pustules may occur individually, or, on heavily infected leaves (usually those lower on the plant), they may coalesce or occur in groups, making them more conspicuous. Also, death of leaf tissue may be associated with clusters of uredinia, resulting in rather conspicuous leaf spots. Telia are less common, but when present they resemble the uredinia but are darker in color. Species of *Geranium* are reported as the spermogonial-aecial hosts of *P. polygoni-amphibii* (Arthur and Cummins, 1962), but there are no records of these spore states occurring on *Geranium* spp. in Hawai'i.
(Gardner and Hodges, 1989)

***Prunus persica* (peach)** ROSACEAE
***P. cerasifera* X *P. salicinia* (plum)**

Tranzschelia discolor (II) (BISH 494629, on peach; TF 4658, on plum)

This rust is common on stone fruits on the U. S. mainland and elsewhere where these crops are grown. On peach, the uredinial pustules are minute, brown, and occur in clusters on the lower surface of the leaf. Despite the small size of individual uredinia, necrotic spots develop around groups of uredinial pustules, making infection more conspicuous. The spots are limited by the surrounding leaf veins, giving them an angular appearance. Yellow spots also develop on upper leaf surfaces corresponding with uredinial clusters below, which also may be conspicuous when viewed against the surrounding green tissue of the leaf. Heavy infection may lead to premature defoliation. On plum, the rust also occurs as minute uredinia on the leaf undersurface with uredinia surrounded by a conspicuous dark reddish-brown leaf spot. Corresponding small (0.5–1.0 mm diameter) dark red or reddish-brown leaf spots occur on the upper surface which cause

infection to be readily recognized. With heavy infections, leaf spots on the upper surface coalesce to form distinct red blotches.
(Gardner and Hodges, 1989)

***Pteridium aquilinum* (bracken fern)** HYPOLEPIDACEAE

Uredinopsis hashiokai (II) (BISH 580246)

Rust on bracken fern represents one of two species of fern rusts in Hawai'i (Gardner and Flynn, 1996). Whereas the host, *Pteridium aquilinum*, is regarded as one of the most common of any plant species worldwide, some fern experts now consider the form of this species occurring in Hawai'i to be an endemic variety (H. Wagner, personal communication; Gardner and Flynn, 1996). The fungus is unusual in that it lacks any pigment, producing white urediniospores. The colorless condition is thought by some investigators to indicate the early phylogenic origin of this rust, which is consistent with its occurrence on fern, itself an ancestral derived vascular plant. The rust was earlier thought to be rare in Hawai'i, but it may instead be seasonal, with heavy infections sometimes occurring in which undersurfaces of fronds are covered with masses of urediniospores released from ruptured subepidermal uredinia. The white spore masses are less conspicuous than similar masses of pigmented spores would be, however. Telia are not known to occur in Hawai'i. Rust spores should not be confused with the sori or spores of the fern itself, which are larger and brown in color.
(Gardner and Hodges, 1989)

***Rhynchelytrum repens* (natal redtop grass)** POACEAE

Puccinia levis var. *tricholaenae* (II, III) (BISH 510508)

Like *Puccinia coronata* and *P. recondita*, *P. levis* is often considered a species complex of several varieties or subspecies, each occurring on a specific host. Microscopically, *P. levis* is characterized by production of two-celled teliospores, the cells being separated by a vertical septum as described for *P. heterospora* above. The uredinia occur on both leaf surfaces and are dark brown in color. Telia are blackish-brown and may occur on both leaf surfaces, but are often more abundant on the under surface. This rust has not been observed frequently enough to assess the degree of severity with which it may infect its host. More observations and collections are needed.
(Gardner and Hodges, 1989)

***Rhynchospora rugosa* (pu'uko'a)** CYPERACEAE

Uromyces rhynchosporae (II) (BISH 146433)

Pu'uko'a is a rush of a genus commonly referred to as beak-rushes (Wagner *et al.*, 1990). This host was listed as endemic by St. John (1973) but as indigenous by Wagner *et al.* (1990). Like

most rushes, this host occurs in wet areas but occasionally is found in mesic forests on the major Islands. No recent collections of this rust are available, the report here based on a collection from 1921. The lack of recent specimens is possibly more a result of the rust being overlooked by potential collectors rather than its rarity in Hawai'i. The uredinia occur as linear, brown pustules on the stem. As indicated above, the potential severity of infection is not known at present. More collections are needed for a better understanding of the characteristics of this rust in Hawai'i.
(Gardner and Hodges, 1989)

***Rosa odorata* (cultivated rose)** ROSACEAE

Phragmidium mucronatum (II)	(BISH 486119)
P. rosae-pimpinellifoliae (II)	(BPI 126634)
P. speciosum (?)	(no specimen available)

The lack of available telial states, whereby the species of *Phragmidium* on rose may be positively identified, contributes to the ambiguity in classification. The rust occurs as individually small yellow uredinia on the leaf undersurfaces. Heavy infection is apparent as powdery masses of uredinia develop giving the leaf undersurface a yellow color. Severe infection can cause premature defoliation and detract from the aesthetics and vigor of ornamental rose bushes.
(Gardner and Hodges, 1989)

***Rubus argutus* (prickly Florida blackberry)** ROSACEAE
***R. hawaiensis* ('akala)**
***R. macraei* ('akala)**

Kuehneola uredinis (0, I, II, III)	(BISH 510438, BISH 510520)

Several rusts are known to infect blackberry and related species of *Rubus*, but only *K. uredinis* is known to occur in Hawai'i at present. The rust first reported by Stevens (1925) on *R. villosus* (a host probably synonymous with *R. argutus*), and was probably introduced with the host, which was first collected in the Islands in 1904 (Wagner *et al.*, 1990). More recent observation has shown that the rust also is capable of attacking the two endemic species in Hawai'i, *R. hawaiensis* and *R. macraei*, both of which are commonly referred to as 'akala (Gardner and Hodges, 1983). In a manner similar to *Pucciniastrum vaccinii* on 'ohelo (see above), occurrence of *K. uredinis* on the endemic species of *Rubus* therefore is an example of an introduced plant pathogen being capable of attacking native species. Fortunately, the rust does not appear to be fully adapted to the endemic hosts, and is found as discrete yellow or orange-yellow pustules on the undersurfaces of the leaves. Infection appears to cause little or no damage to the hosts. While *K. uredinis* attacks the introduced blackberry more severely, occurring as bright yellow uredinial pustules (when fresh) on the leaf undersurfaces, it appears to be incapable of exerting significant biological control for this host, which usually is considered an invasive pest. The pustules may occur discretely and scattered, or may be clustered and conspicuous. Although the

spermogonial, aecial ,and telial states of *K. uredinis* are also known in Hawai'i (Gardner and Hodges, 1983), these are more rare and less frequently encountered. Stem infection of prickly Florida blackberry is also evident in newly developing canes in the spring, in which conspicuous, powdery-appearing bright yellow-orange pustules emerge at intervals along the cane. Even this systemic infection, unfortunately, does not appear to limit significantly development of the introduced blackberry.
(Gardner and Hodges, 1989)

***Saccharum officinarum* (sugar cane)** POACEAE

Puccinia melanocephala (II, III) (BISH 510506)

Although two rust fungi capable of attacking sugar cane are known (*Puccinia kuehnii* and *P. melanocephala*), only *P. melanocephala* is known to occur on this crop in Hawai'i, where it was first discovered in 1982. This rust is now widely distributed on susceptible sugar cane varieties throughout the islands, necessitating the development of resistant varieties. The rust is capable of causing considerable economic losses, although its overall effect in Hawai'i may be of decreasing significance because of the declining sugar cane industry. The brown uredinial pustules occur on the lower leaf surface. Lesions coalesce in severely infected leaves, which become necrotic. At present, telia, which are similar to the uredinia but dark colored, are known from only a single collection from sugar cane growing in a Hawai'i Sugar Planters' Association greenhouse. The presence of telia in the field would not be unexpected.
(Gardner and Hodges, 1989)

***Setaria verticillata* (bristly foxtail)** POACEAE

Puccinia substriata (II) (BISH 511587)

Bristly foxtail is a weedy annual grass native to Europe and now widely naturalized in Hawai'i, where it occurs in dry, disturbed areas. *Puccinia substriata* occurs on this host as brown uredinial pustules on both leaf surfaces, but usually more abundant on the lower surface. The rust may be somewhat obscure, as severe infections have not been reported in Hawai'i. McCain and Trujillo (1967) reported a species of *Uredo* on a *Setaria* host in addition to *P. substriata*, but no specimen appears to be available. It is Assumed that the *Uredo* sp. represents a rust distinct from the uredinial state of *P. substriata* as suggested by its separate report, but no further collections or information on this rust are known at present.
(Gardner and Hodges, 1989)

***Sida fallax* ('ilima)** MALVACEAE

Puccinia heterospora (III, including mesospores) (BISH 146195)

See the annotation for *P. heterospora* under *Abutilon* spp. above.

Puccinia malvacearum (III)

Infection by *P. malvacearum* on 'ilima has been observed on Maui, although no herbarium specimens have been kept. Infection observed on 'ilima was conspicuously visible on both lower and upper surfaces of the leaves. On the upper surface, dark sporulating pustules were surrounded by sharply defined light green halos that contrasted with the normal darker green color of the leaf tissue. Corresponding numerous large (to 5 mm diameter) dark pustules without halos occurred on the lower surface.
(Gardner and Hodges, 1989)

***Sorghum halepense* (Johnson grass)** POACEAE
***S. vulgare* (sorghum)**

Puccinia purpurea (II, III) (BISH 146229, on Johnson grass; BISH 510523, on sorghum)

Puccinia purpurea is common throughout Hawai'i causing conspicuous infection on Johnson grass, a roadside weed. Both uredinia (brown) and telia (blackish) are readily produced and occur mainly on the under surfaces of the leaves. However, in the severely infected plants usually seen, rust pustules may occur on both surfaces and leaf spots coalesce to cause general necrosis of the leaf. A characteristic of infection with *P. purpurea*, as suggested by the name, is the purplish leaf spot surrounding rust pustules, best noted in mild infections where discrete leaf spots may be observed. This rust also occurs on sorghum, although the extent of economic impact on this crop in Hawai'i is not known. Cummins (1971) reported production elsewhere of the spermogonial and aecial states of *P. purpurea* on *Oxalis* spp., but this rust is not known to occur on *Oxalis* in Hawai'i, where the only rust known on *Oxalis* is *Puccinia oxalidis* (see above).
(Gardner and Hodges, 1989)

***Stenotaphrum secundatum* (St. Augustine grass)** POACEAE

Puccinia stenotaphri (II, III) (BISH 510442)

St. Augustine grass is a coarse, commonly planted lawn grass in Hawai'i. In some areas it has also escaped cultivation and become established in natural areas. Only light to moderate infections have been observed to date in Hawai'i. The rust appears somewhat inconspicuous in these situations, although heavy infections could cause lawn grass to be unsightly. The rust specimen represented in the above collection, from escaped St. Augustine grass in Hawai'i Volcanoes National Park, did not appear to be controlling the host in that area. Both uredinial and telial pustules occur on both leaf surfaces. Uredinia are yellowish to cinnamon-brown. Telia are blackish and long covered by the epidermis prior to emergence (Cummins, 1971). McCain and Trujillo (1967) reported a rust on St. Augustine grass as *Uromyces ignobilis*. These

authors did not state whether telia were observed, and no herbarium specimen apparently was kept. It is therefore unclear whether only the uredinial state was observed and misidentified as *U. ignobilis*, or whether both rusts are present in Hawai'i.
(Gardner and Hodges, 1989)

***Taraxacum officinale* (dandelion)** ASTERACEAE

Puccinia hieracii (II) (BISH 511588)

Dandelion rust occurs as small brown uredinial pustules of the undersurfaces of leaves. Infection is usually not severe, and little evidence of infection is usually visible on the plant other than the uredinia themselves. Under favorable environmental conditions, however, heavy infections can cause leaf yellowing. Since dandelion is usually considered a weed, the lack of control of this species resulting from rust infection is unfortunate.
(Gardner and Hodges, 1989)

***Tournefortia (=Messerschmidia) argentea* (tree heliotrope)** BORAGINACEAE

Uredo wakensis (II) (BISH 649055)

The host is a small tree native to tropical Asia and Polynesia which has become naturalized in Hawai'i. It is common in coastal areas of all islands except Kaho'olawe. Recently a rust has been found causing moderate to heavy infection on leaf undersurfaces in several localities. Only the uredinial state is known thus far in Hawai'i, and pustules occur as individual dark, raised leaf spots 1–3 mm in diameter. Spore masses are dark brown, contrasting in color with the lighter green color of the leaf. Heavy infections, in which spots coalesce, are quite conspicuous. Heavily infected leaves may turn yellow prematurely and fall. It is not known why this rust has not been reported from the inhabited islands of Hawai'i until recently, but it is known from Wake and Midway islands. At present, there is some disagreement as to whether the rust should be placed in the genus *Uredo* or in *Uromyces*, and proper taxonomic placement is currently under consideration.
(Cummins, 1940)

***Triticum aestivum* (=*T. vulgare*) (wheat)** POACEAE

Puccinia recondita (II, III) (BISH 146177)

Recent collections of *P. recondita* on wheat in Hawai'i are lacking, the above specimen having been collected in 1910. Raabe *et al.* (1981) indicate that Stevens (1925) recorded this rust, possibly as *P. rubigo-vera*, on wheat, but this record appears to be in error. Recent collections are needed to confirm the identification according to the present concept of *P. recondita.* See the annotation under *Holcus lanatus* above.
(Gardner and Hodges, 1989)

***Vaccinium reticulatum* ('ohelo)** ERICACEAE
***V. calycinum* (tree 'ohelo)**

Pucciniastrum vaccinii (II) (BISH 509294; BISH 612838)

Pucciniastrum vaccinii is known to occur on other species of *Vaccinium* elsewhere, and occurrence of this rust on 'ohelo and tree 'ohelo, both endemic Hawaiian species, is an example of attack of native hosts by a fungus thought to have been introduced to Hawai'i. Notwithstanding this assumption, given the probability that rust fungi were introduced to the Islands with their hosts rather than arriving wind-borne separately, the host on which *P. vaccinii* was introduced is not known. Raabe *et al.* (1981) did not record any rusts on introduced hosts of the Ericaceae family, such as rhododendron or azalea. Only the uredinial state is known to occur in Hawai'i, thus the rust cannot be technically identified as a member of the genus *Pucciniastrum.* However, for practical purposes the rust is identified by its uredinial characteristics. The rust has been found in Hawai'i Volcanoes and Haleakala national parks, but appears not to be widespread within populations of the host, showing preference for certain individual plants, which appear particularly sensitive. The rust has been collected on only a single plant of tree 'ohelo to date. Infection appears as small, yellow, usually discrete pustules on the undersurfaces of leaves. When viewed with a hand lens, each pustule can be seen to have a well-developed pore, as opposed to an irregularly ruptured epidermis characteristic of other rusts, from which spores are expelled.
(Gardner and Hodges, 1989)

***Vigna catjang* (cow pea)** FABACEAE

Uromyces phaseoli (II, III) (BISH 146425)

The rust on cow pea is a member of a complex of closely related rusts sometimes considered as separate varieties depending on their host. Under this system, cow pea rust is designated *U. phaseoli* var. *vignae*. Rust of common bean has also been reported under an earlier name (*U. appendiculatus*) in Hawai'i, but herbarium specimens appear to be lacking. Rust appears as brown pustules mainly on lower leaf surfaces. Infection may be heavy, with coalesced pustules, leading to defoliation.
(Gardner and Hodges, 1989)

***Vulpia* sp. (annual fescue)** POACEAE

Puccinia striiformis var. *striiformis* (II, III) (TF 4560)

This rust is known to be widely distributed throughout the world on a large number of grass genera (Cummins, 1971). It produces a conspicuous infection by its formation of masses of bright orange-yellow uredinia in linear patterns corresponding with the leaf venation on both leaf

surfaces. Its occurrence in Hawai'i, and on grass hosts other than annual fescue, is probably not uncommon. Telia are dark and covered by the epidermis for an extended period during development. They occur mostly on the under surface of the leaves and leaf sheaths arranged in linear patterns. *Puccinia striiformis* var. *striiformis* is distinguished from *P. striiformis* var. *dactylidis* on orchard grass (see above) by its production of larger spores and preference for lower environmental temperatures. Furthermore, *P. striiformis* var. *dactylidis* is limited physiologically in host range to *Dactylis glomerata* whereas, as noted above, *P. striiformis* var. *striiformis* has a wide host range (Cummins, 1971).
(Gardner, 1997)

***Wikstroemia oahuensis* (akia)** THYMELAEACEAE
***W. uva-ursi* (akia)**

Melampsora yoshinagai (II) (BISH 509293, on *W. oahuensis*; BISH 500327, on *W. uva-ursi*)

Rust on *Wikstroemia* hosts in Hawai'i is rather obscure, causing its early report by Stevens (1925) to be somewhat surprising. Stevens considered this species endemic to Hawai'i and described it as *Pucciniastrum wikstroemiae*. Since the telial state has not been found in Hawai'i, the rust was later placed in the form genus *Uredo*, as *U. wikstroemiae*. Rediscovery of akia rust more recently led to reexamination of this species and to the determination, even in the absence of teliospores, that the rust was not affiliated with the genus *Pucciniastrum* (Gardner, 1988b). The rust was placed in the genus *Melampsora* as *M. yoshinagai*, a species already known on other species of *Wikstroemia* East Asia. Thus, although the species of *Wikstroemia* occurring in Hawai'i are endemic to the Islands, the rust itself is now considered probably indigenous rather than endemic (Gardner, 1994). As mentioned above, akia rust has been found only infrequently, where it occurs as light-colored, becoming tan with age, inconspicuous pustules on the undersurfaces of leaves (Gardner, 1992). By far the majority of potential akia hosts examined have no rust infection. Where the rust has been found, it usually occurs as individual, or few scattered pustules, although certain closely associated individuals of *W. uva-ursi* in Hawai'i Volcanoes National Park have been found with leaves that become quite heavily rusted. The uredinia, with prominently ruptured epidermal margins, occur in clusters. The upper surfaces of heavily infected leaves become yellow. The reason for the abundance of rust at this site is not known, whether the plants are unusually susceptible to infection or whether the environment is particularly favorable to rust development in that microhabitat.
(Gardner and Hodges, 1989)

***Xanthium strumarium* (=*X. italicum*) (cocklebur)** ASTERACEAE

Puccinia xanthii (III) (BISH 146249)

Cocklebur is a well-known annual weed in cultivated areas, pastures, rangelands, and waste places. It is recognized by the burs, which stick to clothing and animal fur. *Puccinia xanthii* is currently known in Hawai'i from earlier collections (1915) on O'ahu and Kaua'i. This rust is

known in only the telial state, which occurs as leaf pustules. Notwithstanding the lack of recent documentation in the Islands, there is no reason to assume that the rust does not occur more frequently but has been overlooked by collectors.
(Gardner and Hodges, 1989)

***Xylosma hawaiiense* (maua)** FLACOURTIACEAE

Uredo sp. (II) (BISH 649010)

Xylosma rust was discovered only recently (January, 1997) by Tim Flynn (National Tropical Botanical Garden) in the South Kona District of the island of Hawai'i. It has not yet been formally described. Although the genus *Xylosma* is widely represented in tropical regions elsewhere, as its name implies, both species occurring in Hawai'i, including *X. hawaiiense*, are considered endemic to the Islands. Infection is in the form of minute yellow (when fresh) uredinial pustules on the undersurfaces of leaves. Infection is inconspicuous and thus far has been found on only a few accessible leaves. Since most leaves of the host trees are out of reach, more exhaustive efforts at collection are necessary to increase the collection. If telia are not found, as is the case with other Hawaiian rusts, the *Xylosma* rust will probably be classified in the form genus *Uredo* as indicated above. Occurrence of the new rust on an endemic host, with literature searches thus far failing to find evidence of a similar rust on other species of *Xylosma* elsewhere, suggests that the new rust is itself endemic and would be an addition to the list of native rusts (Gardner, 1994).
(Description not yet published)

***Youngia japonica* (Oriental hawksbeard)** ASTERACEAE

Puccinia crepidis-montanae (II) (BISH 614102)

The host is a low-growing, annual herb native to southeastern Asia. It has become a naturalized weed in moist, shaded habitats in disturbed areas throughout the Islands. The rust appears to occur seasonally, or in response to favorable climatic conditions, and may produce moderate to heavy infections on the undersurfaces of the leaves nearest the soil. Only the uredinial pustules have been found in Hawai'i, and are visible as minute, bright yellow, raised leaf spots. The pustules are usually discrete, but may tend to coalesce in particularly heavy infections. Corresponding small sunken, discolored spots are evident on the upper leaf surfaces.
(Gardner, 1997)

***Zanthoxylum dipetalum* (kawa'u)** RUTACEAE

Puccinia rugispora (III) (BISH 612841)

Members of the genus *Zanthoxylum* are found in tropical and even temperate areas of North America and Asia. Representatives in Hawai'i, including kawa'u, are considered endemic to the

Islands (Wagner *et al.*, 1990). *Zanthoxylum dipetalum*, including two varieties: *dipetalum* and *tomentosum*, is a tree growing up to 15 m (48 ft.) tall usually found infrequently scattered in mid to upper elevation native forests. The rust was discovered in 1988 (Marr and Gardner, 1989) and, like *Puccinia rutainsularа*, also on a member of the Rutaceae (see above); to date it is known from only the region of Koke'e State Park on Kaua'i (Gardner, 1990, 1996). Relatively few individual trees have been found to be infected with *P. rugispora*. Only the telial state is produced, with the dark telia occurring in clusters up to 5 mm in diameter, giving the leaf a dark, blotched appearance and causing infection to be conspicuous. Telia produce bumps on the leaf surface, which produce slit-like openings at maturity through which the dark teliospores are expelled. These are visible with a hand lens scattered on the leaf surface around the telial clusters. Notwithstanding its limited distribution, the rust may infect particular individual trees heavily, whereas other trees bear only a few telial clusters per leaf, and most kawa'u trees examined have no rust, suggesting that variation in resistance to the disease exists within the kawa'u population. Even on trees that become heavily infected, the rust appears to cause little damage to the tree itself. Excessive premature defoliation has not been observed from these trees, suggesting a close balance between the endemic host and the apparently endemic rust which evolved with the host.
(Gardner, 1997)

***Zea mays* (corn)** POACEAE

Puccinia polysora (II, III) (BISH 510511)
P. sorghi (II, III) (BISH 510505)

Two species of rust occur on corn in Hawai'i, both of which may cause severe infections, leading to economic losses. Resistant varieties are being developed as the best defense against these diseases. Both the small brown uredinia and blackish-brown telia of *P. polysora* occur on both leaf surfaces. The telia are long covered by the epidermis. Heavily infected leaves become yellow and die, eventually even leading to the death of the corn stalk. Like *P. polysora,* both uredinia and telia of *P. sorghi* are produced on both leaf surfaces, with uredinia cinnamon-brown and telia blackish-brown and erupting through the epidermis early in development. The two rust species are distinguished by microscope characteristics of the teliospores, which are irregular and angular in shape in *P. polysora*, and regularly (i.e., symmetrically) shaped in *P. sorghi.* No aecial state is known for *P. polysora*, but the aecial state of *P. sorghi* is reported to occur on species of *Oxalis* (Cummins, 1971). The rust found on *Oxalis* in Hawai'i has been reported as the aecial state of *P. sorghi* (Raabe *et al.*, 1981); however, this rust is now known to be the uredinial state of *P. oxalidis* as reported above.
(Gardner and Hodges, 1989)

***Zoysia matrella* (Manila grass)** POACEAE
***Z. japonica* (Japanese lawn grass)**
***Z. tenuifolia* (mascarene grass)**

Puccinia zoysiae (II, III) (HONQ 018623)

Species of *Zoysia* grass are small, fine-leaved grasses popular for putting greens of golf courses and for home lawns. Possibly due to the resistant varieties now in use, few specimens of this rust have been collected in Hawai'i, although the rust is probably more common than the collections would indicate. Corresponding with the leaf size itself, uredinia are small, discrete, and occur on the upper leaf surface. They are bright yellow when fresh but turn colorless when dry. Telia are blackish-brown and occur on both leaf surfaces. They do not remain long covered by the epidermis upon formation (Cummins, 1971).
(Gardner and Hodges, 1989)

SMUTS

***Avena sativa* (common oats)** POACEAE

Ustilago avenae (Lyon 327)

Stevens (1925) reported oat smut at the Honolulu Agricultural Experiment Station in 1913, a specimen of which is represented in Lyon's collection. Oat smut, which is apparent on the seed heads as black powdery spore masses is common and well-known throughout temperate regions of the world wherever oat crops are grown. It is of considerable economic significance in these regions.
(Mäkinen, 1969)

***Bromus willdenowii* (=*B. catharticus*) (rescue grass)** POACEAE
***B. breviaristatus* (short-awned bromegrass)**

Ustilago bullata (Mäkinen 66-1106)

The smut was recorded at Waihee and along the Saddle road on the island of Hawai'i (1966) and earlier (1938) at Kapapala (Mäkinen, 1969). It is probably more common and widespread on *Bromus* hosts than is indicated by these few, older collections. The smut is recognized by its production of black, powdery spore masses in place of normal fruit (seed) tissue.
(Mäkinen, 1969)

Carex wahuensis CYPERACEAE

Farysia caricis-filicinae (Mäkinen 66-1255)

This host, a large sedge, is endemic to Hawai'i. It is listed above as host to an endemic rust fungus, *Uredo hawaiiensis*. Whereas the rust occurs on the leaves, the smut affects the flowers,

replacing normal tissue with masses, or "spore balls" of black, powdery-appearing teliospores. The specimens reported by Mäkinen (1969) were collected along the Mauna Loa Strip road in Hawai'i Volcanoes National Park. He stated that about 20 specimens of the host occurred in the locality, but that only two of these were heavily infected, the others showing no sign of infection. *Carex macloviana* var. *subfusca*, growing near the infected specimens, appeared to be healthy. In spite of careful search, no smut was found elsewhere. Mäkinen (1969) listed *F. caricis-filicinae* as one of four smut species he considered native to Hawai'i, although the taxonomy of the genus *Farysia* was confused and required revision.
(Mäkinen, 1969)

***Cynodon dactylon* (Bermuda grass)** POACEAE

Ustilago cynodontis (Mäkinen 66-2110; HONQ 37782)

As noted above, Bermuda grass, a popular lawn grass in warmer regions, is also host of a rust fungus, which is identified by its infection on leaves of this host. In contrast, the smut produces infection in the seed heads, replacing normal tissue with black, powdery masses of spores. The smut was first confirmed to occur in Hawai'i in 1954 (although it was probably present much earlier), and occurs commonly wherever Bermuda grass is grown in the Islands.
(Mäkinen, 1969)

***Fimbristylis cymosa* (mau'u)** CYPERACEAE

Thecaphora mauritiana [Rock 14021 (BISH Vasc.); Mäkinen 66-1315]

This smut attacks the flower heads of the host, replacing the normal tissue with black, powdery masses of teliospores. It is represented in Hawai'i by two specimens, one from the south coast of the island of Hawai'i, Punalu'u Beach Park in 1966, and the other from Molokai at Kahaeokailio in 1918 (Mäkinen, 1969). Mäkinen (1969) noted that this species is known also on *Fimbristylis monostachya* from Mauritius, and Mysore, India, and that it probably has a wide distribution in tropical areas but escapes notice because it is inconspicuous. He included this smut as one of four that he considered native to Hawai'i, presumably as an indigenous species.
(Mäkinen, 1969)

***Heteropogon contortus* (pili grass)** POACEAE

Ustilago monilifera [Mäkinen 65-201; Mäkinen, 66-103; J. F. G. Stokes (BISH Vasc.)]

As noted above, pili grass is also host to a rust fungus, *Puccinia versicolor*, which causes leaf infection. This smut has long been present in the Islands, having been reported by Stevens (1925) under the name *Sphacelotheca monilifera*. As with other smuts, it attacks the seed heads of its host, producing black, powdery spore masses in place of normal flower tissue. Pili grass is considered possibly indigenous to Hawai'i, or to be a Polynesian introduction (Wagner *et al.*,

1990), and Mäkinen (1969) listed *U. monilifera* among the four species of smut he considered native. He undoubtedly intended this smut to be considered indigenous, since it was probably introduced with its host, widespread species throughout the tropics (Wagner *et al.*, 1990). (Mäkinen, 1969)

***Holcus lanatus* (common velvet grass; Yorkshire fog)** POACEAE

Entyloma dactylidis (Mäkinen 66-1725a)
Ustilago striiformis (Mäkinen 66-1235)

Two species of smut have been reported on velvet grass in Hawai'i, a widely naturalized species which is also host to two rust fungi, *Puccinia coronata* and *P. recondita*, (see above). *Ustilago striiformis* was collected at the end of the Mauna Loa Strip road in Hawai'i Volcanoes National Park, 1966. *Entyloma dactylidis* is known from collections at Kilauea on the island of Hawai'i, and from Koolau Gap region of Haleakala Crater, Maui, 1966 (Mäkinen, 1969). Both smuts were probably introduced to Hawai'i with their host.
(Mäkinen, 1969)

***Hordeum vulgare* (barley)** POACEAE

Ustilago jensenii (Lyon 324)

Barley is a well-known grain crop grown in temperate regions throughout the world, although it is not considered a major crop in Hawai'i. The smut was recorded at Koke'e, Kaua'i, in 1935 Mäkinen, 1969). It also was reported on O'ahu by Stevens (1925) under its former name, *Ustilago hordei. Ustilago jensenii* has been the subject of much research directed toward development of varieties of barley resistant to this economically important pathogen.
(Mäkinen, 1969)

***Paspalum scrobiculatum* (=*P. orbiculare*) (ricegrass; mau'u laiki)** POACEAE
***P. conjugatum* (Hilo grass; mau'u) (Lyon 79)**
***P. dilatatum* (dallis grass)**

Ustilago paspali-thunbergii [BISH 690 (numerous other collections, as *Sorosporium paspali*, on rice grass cited by Stevens, 1925:125–126)]

Of the three above-listed hosts of *Ustilago paspali-thunbergii*, rice grass is possibly indigenous but may be an early introduction to Hawai'i. Hilo grass and dallis grass are both considered naturalized introductions (Wagner *et al.*, 1990). The smut has been found frequently in Hawai'i, and, in addition to those listed by Stevens (see above), numerous collections were cited by Mäkinen (1969). Stevens (1925) devoted considerable space to the discussion of this smut, including a thorough description of its occurrence on the inflorescence of its host. *Ustilago paspali-thunbergii* also presented earlier taxonomic difficulties. Stevens (1925) recounted

deliberations relative to the proper classification of this smut, including variations on different *Paspalum* hosts, and its occurrence in the Philippines, Australia, and Hawai'i. *Ustilago paspali-thunbergii* is one of four smuts considered by Mäkinen (1969) to be native to Hawai'i, presumably as an indigenous species.
(Mäkinen, 1969)

***Phoenix dactylifera* (date palm)** ARECACEAE

Graphiola phoenicis (Mäkinen 65-38A; Lyon 263; Stevens 275)

Smut of date palm was first reported in Hawai'i by F. Petrak (1953), who stated that the fungus, was observed on living leaves of a palm tree, "probably *Phoenix* sp." on 6 December, 1927 on the University (of Hawai'i?) campus. The collection was designated "C. L. Shear and N. E. Stevens, No. 1106." Mäkinen (1969) listed other collections of this fungus from several locations in Honolulu, from Kaua'i, and from the island of Hawai'i. No recent collections of smut on date palm are known; however, as stated by Mäkinen (1969), this fungus is probably much more common than the relatively few observations indicate. It is interesting to note that, as observed by Petrak, the smut occurred on leaves of the host, whereas as stated in the introduction above, smuts are most often associated with the reproductive parts of their hosts. Although the appearance of the smut fungus on the host was not described, the growth may be expected to appear as gray or black fungal colonies on the leaf surface, resembling mildew.
(Mäkinen, 1969)

***Polygonum glabrum* (kamole)** POLYGONACEAE

Ustilago reticulata (no specimen available)

Kamole is an annual or perennial herb native to tropical and subtropical areas of Asia and Africa and perhaps to tropical America. It is naturalized in Hawai'i and may be quite common in mid elevations on most major islands along stream beds, taro paddies, and in moving water (Wagner *et al.*, 1990). The smut was reported apparently from a single specimen (now destroyed) collected by K. Parris in 1937 (Mäkinen, 1969). The specimen was from Waimea on the island of Hawai'i. Although a description of infection on kamole itself is lacking, *U. reticulata* probably affected the reproductive tissues of this host, producing black, powdery masses of teliospores in place of normal floral tissue.
(Mäkinen, 1969)

***Sorghum vulgare* (sorghum)** POACEAE

Ustilago reiliana (C. W. Carpenter 125, 1917)
U. sorghi (Lyon 341)

Commercial sorghum, *Sorghum vulgare* and Johnson grass, *S. halepense*, were listed above as hosts of the rust fungus *Puccinia purpurea*, which occurs on and may severely affect the leaves of these species. Stevens (1925:127) listed the two smuts on *Sorghum*, by former names *Sphacelotheca reiliana* and *S. sorghi*, that affect the flowering structures of these hosts. These smuts are known of *Sorghum* hosts elsewhere and are probably not uncommon in Hawai'i. (Mäkinen, 1969)

***Zea mays* (corn)** POACEAE

Ustilago maydis (no specimen available)

Stevens (1925:125) commented on the absence of corn smut in the Islands: "Corn has long been grown on the islands,...yet careful search has as yet failed to show the presence of corn smut there. The absence of this and other grass smuts presents an argument of some weight against theories postulating wind-carriage of fungi to the islands." Later, however, Mäkinen (1969) confirmed that corn smut had arrived in Hawai'i. He referred to it as *Ustilago zeae* as well as *U. maydis*. Because of its conspicuous appearance and its occurrence on one of the most widely distributed and best known grain crops, corn smut itself is well known. Like other smuts, it occurs as a large blue-black tumor or gall-like growth on an otherwise normal corn cob. The gall is covered by a membrane, and contains masses of teliospores that are released to the wind for dispersal when the membrane is ruptured. Crop breeding programs have produced corn varieties that are resistant to smut, causing infection to be less prevalent than it previously has been. (Mäkinen, 1969)

Note: Species of *Sporobolus* (Poaceae), especially *S. africanus* and *S. indicus*, have the common names "smutgrass" and "West Indian smutgrass", respectively, in Hawai'i (Wagner *et al.*, 1990). This is due to the almost universal presence of a conspicuous disease of seed heads known as "sooty spike." This disease bears close resemblance in outward appearance to a smut-caused disease, hence the common name "smutgrass." However, the disease is actually caused by a fungus not classified as a smut, *Bipolaris ravenelii*, referred to in older literature as *Helminthosporium ravenelii* (Raabe *et al.*, 1981).

ACKNOWLEDGEMENTS

I appreciate the assistance of Tim Flynn of the National Tropical Botanical Garden who found and collected several of the above rust species. Also, I am grateful for my long associations with Dr. Charles Hodges, now retired from the Institute of Pacific Islands Forestry, USDA Forest Service, and Dr. Joe Hennen, now retired as curator of the Arthur Herbarium of rust fungi, Purdue University. Both have participated enthusiastically in the study of Hawaiian rusts over the years.

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TABLE 1. Hosts, listed by order, of rust and smut fungi in Hawai'i.

Host Order	No. of Host Genera	No. of Rusts/Smuts	Host Status
RUSTS			
Apiales	1	1	naturalized
Asterales	1	1	horticultural
	1	1	crop
	7	7	weed
Caryophyllales	1	1	horticultural
Commelinales	1	1	naturalized
Cyperales	11	11	crop
	14	14	weed
	1	1	naturalized
	4	4	native
Ericales	1	1	native
Euphorbiales	3	3	weed
	4	3	native
Fabales	1	1	naturalized
	1	5	native
	3	3	crop
Gentianales	1	1	horticultural
	1	1	native
Geraniales	1	1	horticultural
	1	1	weed
	1	1	native
Lamiales	2	2	naturalized
Liliales	1	1	crop
Malvales	2	1	native
	1	1	weed
Myrtales	1	1	horticultural
	1	1	native
Polygonales	1	1	naturalized

Polypodiales	1	1	naturalized
	1	1	native variety (?)
Rosales	2	2	horticultural
	1	1	naturalized (1 species) & native (2 species)
Rubiales	1	1	naturalized
Sapindales	2	2	native
Scrophulariales	1	1	native
Urticales	1	1	horticultural
	1	1	crop
Violales	1	1	native
Zingiberales	1	1	horticultural
SMUTS			
Arecales	1	1	horticultural
Cyperales	5	5	crop
	3	3	native
	3	3	naturalized weed
Polygonales	1	1	naturalized