Leaf Rust Caused by *Kuehneola uredinis* on Native and Nonnative *Rubus* Species in Hawaii

DONALD E. GARDNER, Research Plant Pathologist, National Park Service Cooperative Park Studies Unit, University of Hawaii, Honolulu 96822, and CHARLES S. HODGES, Chief Plant Pathologist, Institute of Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service, Honolulu, HI 96813

ABSTRACT

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Kuehneola uredinis is widely distributed in Hawaii, where it primarily attacks *Rubus penetrans*, a noxious exotic species. Other nonnative *Rubus* species are not infected, however. *R. macraei* and *R. hawaiiensis*, both valued endemic species, are mildly and inconsequentially attacked by the rust.

Additional key words: biocontrol, *Rubus ellipticus, R. glaucus, R. rosaefolius*

Although individual residents of Hawaii value exotic *Rubus* species for their fruit, these plants have no economic usefulness as commercial crops and are considered noxious weed pests in forest and pasture lands. The aggressive invasion of such species into native forests of Hawaii's state and national parks and other preserves poses a serious threat to the rare and fragile ecosystems these areas were established to protect. On the other hand, endemic Hawaiian *Rubus* species are highly valued as components of such ecosystems and are strenuously protected by such conservation agencies as the National Park Service (NPS). Control approaches for exotic *Rubus* species must therefore be carefully evaluated for their potential detrimental effects on native as well as undesirable target plants.

The most pervasive noxious *Rubus* species in Hawaii is *R. penetrans* Bailey (prickly Florida blackberry). The taxonomy of *R. penetrans* is somewhat unsettled. St. John (5) acknowledges that this species has been variously placed in synonymy with three other species but refers to it as a cultigen that does not exactly match any of these. Other investigators (D. Hall, *personal communication*) consider *R. penetrans* synonymous with *R. argutus* Link, a native to the southeastern United States. Past attempts to control *R. penetrans* in Hawaii have involved importation and release of various species of phytophagous insects (3). These have been partially effective in some areas, but additional control measures are essential to prevent further spread of this weed.

We are currently investigating the use of plant pathogens, specifically rust fungi, as biocontrol agents for *Rubus* spp. Rust diseases are typically host-specific, often highly destructive, and have been used with success elsewhere in biocontrol programs against other noxious *Rubus* species (4). Cane and leaf rust (*Kuehneola uredinis* (Lk.) Arth.) had been suggested in earlier biocontrol considerations as a potentially effective agent worthy for testing in our program. At that time, however, little information was available concerning the status of this rust in Hawaii.

K. uredinis was first reported in Hawaii by Stevens in 1925 (6) from a single location on the island of Maui, heavily attacking *R. villosus*. This *Rubus* species is not currently recognized as such in Hawaii and was probably used as a synonym of *R. penetrans* (H. St. John, *personal communication*). *R. villosus* was thought by Stevens to have been recently introduced to Hawaii because it was localized in distribution and no published reference to its presence in Hawaii could be found. Stevens (6) further reported that *R. macraei* Gray, a native Hawaiian species, was free of rust infection even though it grew near the infected *R. villosus*.

The status of *K. uredinis* in Hawaii has not been discussed in the literature since Stevens' report. Herbarium specimens (USDA National Fungus Collections, Beltsville, MD) indicate, however, that the uredinial state of the rust was collected on *R. hawaiiensis* Gray, a second native species, on the island of Kauai in 1928 and on *R. penetrans* on Oahu in 1951. A reference to *K. uredinis* on *R. hawaiiensis* in the USDA plant disease index (7) is apparently based on herbarium records or unpublished reports.

This investigation was conducted to document the present distribution of *K. uredinis* in Hawaii and its impact on native and nonnative *Rubus* species.

MATERIALS AND METHODS

R. penetrans is universally distributed throughout Hawaii, occurring commonly on all major islands at elevations above 1,000 m. We have observed light to heavy infection by the uredinial state of *K. uredinis* wherever this host has been found. Infection on *R. penetrans* results in scattered and confluent pale lemon-yellow hypophyllous uredinia with associated yellowing or reddening of corresponding upper leaf surface areas. Necrosis and defoliation may follow moderate to heavy leaf infection. Severely infected thickets frequently appear unthrifty and sparsely foliated, but we have not observed evidence that the disease by itself is capable of significantly limiting the spread of *R. penetrans*. No stem or fruit infection has been noted.

We have observed the telial, spermogonial, and aecial states of *K. uredinis* in the autumn on *R. penetrans*. The telia were hypophyllous, whitish, and waxy in appearance. Teliospores (14–22 × 80–100 μm) with four to seven cells were common. Those observed were often fragmented and incomplete. Teliospore walls were colorless. The aecia were uredinoid, epiphyllous, orange-yellow, and surrounded the prominent spermogonia, which occurred on reddish leaf spots (1). Aeciospores were verrucose and measured 16–19 × 20–23 μm. Urediniospores resembled aeciospores in morphology but were more strongly echinulate and measured 17–21 × 22–28 μm. Dimensions of 18–24 × 85–110 μm for teliospores, 18–19 × 19–23 μm for aeciospores, and 16–19 × 21–27 μm for urediniospores were given for *K. uredinis* by Arthur (1). Although locally common, the spermogonial, aecial, and telial states occur infrequently compared with the uredinial state, which can be found throughout the year.

Irregular white patches of nonviable, apparently hyperparasitized urediniospores similar to those reported by Fischer and Johnson (2) on *Rubus* species in western Washington are commonly seen and can be confused with telial sori on casual observation.

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Table 1. Infectivity of *Kuehneola uredinis* on native and noxious exotic *Rubus* species in Hawaii

Species	Field infection[a]	Greenhouse infection[b]	Detached leaf infection[c]
Native			
R. hawaiiensis	+(1)[d]	−[e]	+(1)
R. macraei	−	+(1)	−
Nonnative			
R. ellipticus	−	−	−
R. glaucus	−	−	−
R. penetrans	+[f]	+	+
R. rosaefolius	−	−	−

[a] Natural infection observed on the islands of Hawaii, Maui, and Kauai.
[b] Plants were inoculated by spraying with aqueous urediniospore suspensions of approximately 4×10^5 spores per milliliter to presaturation and maintained under high (90–100%) relative humidity. Results were observed after about 3 wk.
[c] Leaves were inoculated as in the greenhouse and maintained in moist petri dishes at room temperature or incubated at 17–19 C. Results were observed after about 3 wk.
[d] +(1) Indicates light leaf infections (ie, one to several 1.0-mm-diameter discrete uredinial sori without epiphyllous symptoms).
[e] − Indicates no infection.
[f] + Indicates a range of infection severity including heavy infection (ie, extensive colonization of leaf undersurfaces by convergent uredinia and corresponding epiphyllous symptoms).

R. hawaiiensis, the more common of the two native species, is also attacked by *K. uredinis* in the field, although to a significantly lesser extent than is *R. penetrans*. Infection of *R. hawaiiensis* results only in one to several small (1 mm diam.) individual, hypophyllous uredinial sori per leaf that remain discrete. Aside from the uredinia themselves, no symptoms or other detrimental results of infection are manifest on *R. hawaiiensis*. In agreement with Stevens' report (6), we have not observed *K. uredinis* on *R. macraei* in the field. This species is rare, however, and only infrequently encountered.

Likewise, we have observed no infection on *R. ellipticus* Sm. (yellow Himalayan raspberry), *R. rosaefolius* Sm. (roseleaf raspberry), or *R. glaucus* Benth. (wild raspberry) in Hawaii, even in areas where infection on nearby *R. penetrans* plants is heavy. We have found no conclusive published report of *K. uredinis* attacking any of these three *Rubus* species elsewhere, although *R. ellipticus* and *R. rosaefolius* are implied as hosts of this rust in the USDA plant disease index (7). Like *R. penetrans*, these are undesirable exotic species occurring within or near Hawaii's NPS and other natural areas.

To assess the infectivity of *K. uredinis* on each of the mentioned native and nonnative *Rubus* species under uniform conditions, rooted cuttings of each species were established in pots in the greenhouse on a mist bench or were covered with plastic bags for 48 hr after inoculation to ensure high (90–100%) relative humidity. The plants were sprayed to presaturation with freshly collected urediniospores in water suspensions at concentrations of about 4×10^5 spores per milliliter. Inoculum was collected from various *R. penetrans*-infested sites on the islands of Hawaii and Maui. Detached leaves of each species were also tested by placing leaves of comparable age and developmental state in moist petri dishes and spraying them with spore suspensions of similar concentrations. The leaves were maintained at room temperature in the laboratory or at 17–19 C in a lighted incubator.

RESULTS AND DISCUSSION

R. penetrans became readily infected under greenhouse conditions, with uredinia developing about 3 wk after inoculation. Expanding or mature leaves appeared most susceptible, whereas newly formed unexpanded leaves were not infected. The disease was perpetuated in the greenhouse only under conditions of high humidity. As in the field, infection was limited to undersurfaces of the leaves and yellowing, reddening, and necrosis occurred on corresponding upper areas. No stem or fruit infection occurred in the greenhouse. Detached leaves of this species also became infected (Table 1), with uredinia likewise appearing about 3 wk after inoculation. Light and temperature conditions of incubation did not appear critical to this development.

R. macraei became lightly infected in the greenhouse even though natural infection in the field had not been found in our limited observation. Individual, scattered uredinial sori were produced on several leaves without apparent negative impact on the plants. Detached leaves of *R. macraei* did not become infected. Conversely, detached leaves of *R. hawaiiensis* became lightly infected but no infection was obtained on this species in the greenhouse (Table 1). We consider it likely that both native *Rubus* species are only slightly susceptible to *K. uredinis*, with infectivity determined by subtle factors of the environment or of host or pathogen physiology. Thus, it is probable that *R. macraei* may also be attacked in the field under suitable conditions.

Aside from *R. penetrans*, our inoculations produced no infection on any of the other nonnative species tested. These results are consistent with our field observations of these plants (Table 1).

Our observations indicate that although *K. uredinis* exerts some impact on *R. penetrans*, the rust is not capable of severely curtailing this host in Hawaii under normal conditions. The pathogen, however, has become well established on *R. penetrans* and is distributed throughout the islands. It may act in conjunction with other purposely introduced biocontrol agents in impairing the growth and vigor of this species. The aggressiveness and competitive advantage of *R. penetrans* in favor of native plants may thereby be lessened. Although the two endemic *Rubus* species show some susceptibility to *K. uredinis*, the minimal effect on these species indicates a genetic differential between these and *R. penetrans* that is regarded positively. The possibility that various races of *K. uredinis*, such as those known among other rusts, exist in Hawaii was not considered in this study. Attention may be directed toward the determination of such races if future observations indicate that they occur. Further work toward the biocontrol of undesirable *Rubus* species in Hawaii with other rusts, introduced for this purpose, is planned for the future.

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