Pathogenicity of *Fusarium oxysporum* f. sp. *passiflorae* to Banana Poka and Other *Passiflora* spp. in Hawaii

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ABSTRACT

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Fusarium oxysporum f. sp. *passiflorae*, the cause of vascular wilt of passionfruit (*Passiflora edulis* f. *edulis*), also attacked inoculated banana poka (*P. mollissima*) seedlings. Other noncrop *Passiflora* spp. (*P. ligularis* and *P. foetida*) were susceptible, whereas *P. e.* f. *flavicarpa*, the cultivated passionfruit in Hawaii, and *P. suberosa* were resistant. This work is part of an initial evaluation of possible biocontrol agents for banana poka.

Banana poka, an introduced vine of the Passifloraceae, was first reported in Hawaii in 1921 (5). The common name refers to the oblong-shaped fleshy yellow fruit, superficially somewhat resembling a banana. Banana poka has been usually referred to as *Passiflora mollissima* (Kunth) Bailey (6) (subg. *Tacsonia*), but some workers consider *P. mixta* L. or *P. tripartita* (Juss.) Poir. the proper placement. Close relatives of banana poka (here referred to as *P. mollissima*) are known from cultivated or wild populations in Colombia, Ecuador, and Peru. However, the Hawaiian form may have resulted from inbreeding among a small introduced population and may no longer have an exact native counterpart (6). Aside from this consideration, Hawaii has no native Passifloraceae (10).

Although probably introduced as an ornamental, banana poka has aggressively spread into native forests where it covers hectares of vegetation with draping mats of foliage reminiscent of kudzu in the southeastern United States. Local spread is by birds and feral pigs that are attracted to the succulent fruit and pass the seeds through the digestive tract. Interisland spread is by man. Because of its growth habit and wide distribution, biocontrol may be the only feasible approach. The present study is part of a multiagency research effort to discover and evaluate possible insect and pathogenic agents for banana poka. Only the edible yellow-fruited passionfruit, *P. edulis* Sims (subg. *Passiflora*) f. *flavicarpa* Deg., of the approximately 30 introduced species and forms of *Passiflora* in Hawaii (10) is commercially produced for human consumption. Wild populations of this form are also an important source of the fruit.

Fusarium oxysporum (Schlecht.) emend. Snyd. & Hans. f. sp. *passiflorae* Gordon apud Purss was reported in Australia in the 1950s. It caused severe vascular wilt of purple-fruited passionfruit (*P. e.* f. *edulis* Sims), the form then produced commercially in Australia (7–9). *F. o.* f. sp. *passiflorae* is not known to occur in Hawaii. Investigations to discover sources of resistance among other species of *Passiflora* in Australia demonstrated that *P. e.* f. *flavicarpa* was resistant and offered most promise as a rootstock to which scions of *P. e.* f. *edulis* could be grafted (3,9). The objectives of the present study, conducted in a laboratory environment, were to determine if *F. o.* f. sp. *passiflorae* would attack *P. mollissima*, and to provide information on the host range of this pathogen.

MATERIALS AND METHODS

An isolate of *F. o.* f. sp. *passiflorae* was obtained from the Plant Pathology Branch, Department of Primary Industries, Indooroopilly, Queensland, Australia, under Hawaii Department of Agriculture and USDA-APHIS permits. Pure cultures were grown on potato-dextrose agar (PDA) and other standard media. Cultural and morphological characteristics of the fungus were confirmed as typical of *F. oxysporum* (12). PDA cultures sporulated profusely, producing mostly microconidia, and were used throughout the study as an inoculum source. All culture and inoculation procedures were conducted under secure laboratory conditions at the University of Hawaii. Inoculated plants were maintained in a lighted incubator or in Plexiglass growth chambers, designed to minimize escape of fungal spores, at 20–23 C under continuous Gro-Lux fluorescent lighting.

Seeds were germinated in new vermiculite. Seedlings in the cotyledon or first-leaf stages were removed from

Table 1. Nonpassifloraceous species root-dip inoculated with *Fusarium oxysporum* f. sp. *passiflorae*

Family	Species and common name
Apocynaceae	*Vinca major* L., periwinkle
Bromeliaceae	*Ananas comosus* (L.) Merr., pineapple[a]
Caricaceae	*Carica papaya* L., papaya
Chenopodiaceae	*Beta vulgaris* var. *cicla* L., Swiss chard
Compositae	*Lactuca sativa* L., lettuce
	Tagetes sp., marigold
	Zinnia elegans Jacq., zinnia
Cruciferae	*Lobularia maritima* (L.) Desv., sweet alyssum
Cucurbitaceae	*Cucumis sativus* L., cucumber
Gramineae	*Saccharum officinarum* L., sugarcane[b]
	Zea mays L., corn
Leguminosae	*Acacia koa* Gray, koa
	Crotalaria juncea L., sunn hemp
	Glycine max (L.) Merr., soybean
	Leucaena leucocephala (Lam.) de Wit, koa haole
	Phaseolus vulgaris L., bean
	Pisum sativum L., pea
Liliaceae	*Allium cepa* L., onion
Sapindaceae	*Dodonaea eriocarpa* Sm., 'a'ali'i
Solanaceae	*Capsicum annuum* L., pepper
	Lycopersicon esculentum Mill., tomato
	Solanum melongena L., eggplant
Umbelliferae	*Daucus carota* L., carrot
	Petroselinum crispum (Mill.) Nym., parsley

[a] Rooted ratoons were inoculated.
[b] Rooted stem cuttings were inoculated.

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the growth medium and the roots were immersed and agitated in conidial suspensions (approximately 10^6/ml) in water. The seedlings were replanted in new vermiculite. Equal numbers of control seedlings were root-dipped in water and replanted. Symptom development was observed and recorded 4–6 wk following inoculation. In other tests, seeds were germinated in commercial potting soil amended with *F. o.* f. sp. *passiflorae* cultured on a moist oatmeal-sand mixture (1:5, v/v). Controls were grown in either unamended soil or soil amended with a sterile oatmeal-sand medium. Alternately, 3-wk-old postemergent seedlings of *P. ligularis* Juss. (subg. *Tacsonia*) were treated by pouring an *F. o.* f. sp. *passiflorae* PDA culture slurry into the soil.

In addition to *P. mollissima*, seedlings of *P. e.* f. *edulis*, *P. e.* f. *flavicarpa*, *P. ligularis*, *P. foetida* L. (subg. *Passiflora*), and *P. suberosa* L. (subg. *Passiflora*), all from seed from local wild populations, were similarly inoculated. Seedlings of a variety of nonpassifloraceous crop, ornamental, and native species were root-dip inoculated with *F. o.* f. sp. *passiflorae* to confirm specificity of the pathogen to the genus *Passiflora* (Table 1). At least 10 plants, representing at least two replications of each of the species and an equal number of controls, were tested.

Wilted seedlings were surface-disinfested by shaking in a 10% commercial sodium hypochlorite solution for 30 sec. The stems were then cut into 0.5-cm serial sections and placed on 2% water agar. Fungal growth from cut ends was examined for sporulation and eventual chlamydospore production. The recovered fungus was recultured on PDA and its characteristics were compared with those of the original cultures.

RESULTS AND DISCUSSION

F. o. f. sp. *passiflorae* caused significant wilting and death of inoculated *P. mollissima* seedlings, such that the Hawaiian population of this species may be considered susceptible to Fusarium wilt disease. Recovery of the pathogen from successive stem sections indicated systemic distribution, an important characteristic of vascular wilt diseases, distinct from localized root diseases associated with other pathogens. Mortality among root-dip inoculated younger seedlings (i.e., those in the cotyledon stage, 5 days or less after emergence at inoculation) sometimes exceeded 90% (Fig. 1A). Mortality decreased to below 50% among older plants (i.e., those with 2–3 developing leaves, 10 days or more after emergence at inoculation). Although only one isolate of *F. o.* f. sp. *passiflorae* was available for this study, it is possible that more virulent isolates exist or could be selected through host passage manipulation. *P. e.* f. *edulis*, *P. ligularis*, and *P. foetida* were also attacked by the fungus, whereas *P. e.* f. *flavicarpa* and *P. suberosa* were resistant (Table 2). None of the nonpassifloraceous plants inoculated showed any reaction to the fungus, providing evidence of the specificity of *F. o.* f. sp. *passiflorae* to the genus *Passiflora*.

The forma specialis concept of *F. oxysporum* is based on narrow host specificity (11), often apparently restricted to a single species. However, exceptions are known in which two or more intrageneric hosts occur (2), or hosts may even represent different

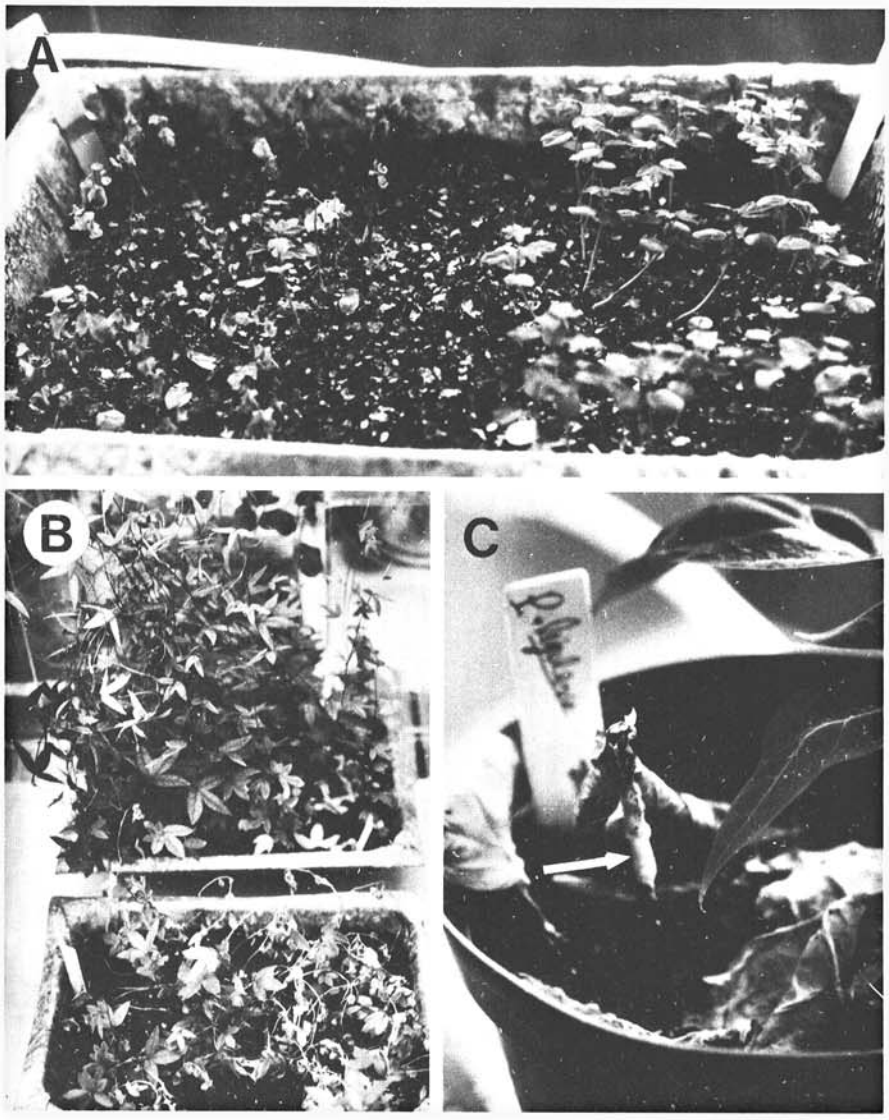

Fig. 1. Fusarium wilt of *Passiflora* spp. **(A)** (Left) Wilted seedlings of *P. mollissima* root-dip inoculated in the cotyledon stage and (right) healthy controls approximately 5 wk following inoculation. **(B)** (Front) *P. mollissima* grown from seed in soil infested with *F. oxysporum* f. sp. *passiflorae* and (behind) the control 10 wk following planting. **(C)** Defoliated *P. ligularis* 6 wk following postemergence soil amendment. Note external fungal growth on the stem (arrow).

Table 2. Mortality of *Passiflora* spp. seedlings root-dip inoculated with *Fusarium oxysporum* f. sp. *passiflorae*

Species	Inoculated/control[a]		
	No. of plants	No. diseased	% Mortality
P. edulis f. *edulis*	331/308	111/0	34/0
P. e. f. *flavicarpa*	487/424	1/0	0.2/0
P. foetida	322/292	85/1	26/0.3
P. ligularis	74/74	22/0	30/0
P. mollissima	531/489	247/21	47/4[b]
P. suberosa	224/186	0/0	0/0

[a] Data were recorded approximately 6 wk after inoculation.
[b] An unidentified *Fusarium* sp. producing predominently macroconidia was recovered from diseased controls.

families (1). Therefore, pathogenicity of *F. o.* f. sp. *passiflorae* within different subgenera, although perhaps exceptional, is not without precedent. It is possible that the known host ranges of other formae speciales of *F. oxysporum*, although still remaining relatively narrow, could be expanded by inoculation surveys of allied noneconomic species, as was indicated by this study.

Australian studies (8,9) showing *P. e.* f. *flavicarpa* to be resistant to Fusarium wilt are supported by the resistance reported here of *P. e.* f. *flavicarpa* from Hawaiian populations. Resistant cultivars (e.g., Redlands Triangular) developed in Australia to replace *P. e.* f. *edulis* are currently available to the passionfruit industry (4).

Disease expression among susceptible plants grown in both preemergence- and postemergence-infested soil was less uniform than among root-dip inoculated seedlings. Nevertheless, both amendment methods were effective, resulting in 66% mortality among preemergence-inoculated *P. mollissima* plants 10–15 wk following emergence (Fig. 1B). In postemergence tests, 84% mortality among *P. ligularis* plants was obtained 6–15 wk following addition of inoculum to the soil (Fig. 1C).

Whereas the susceptibility of banana poka seedlings and other Hawaiian *Passiflora* spp. to *F. o.* f. sp. *passiflorae* was determined under controlled laboratory conditions, the potential of this pathogen as a biocontrol agent under natural field conditions depends on many additional factors. *F. o.* f. sp. *passiflorae* is capable of dissemination and disease production among mature purple-fruited passionfruit under cultivation in Australia (7,8). However, the pathogenicity and dissemination effectiveness of the fungus in mature banana poka infestations of higher elevation (≥1,210 m) wet forests in Hawaii remains to be determined. Field resistance of the edible passionfruit forms and of families related to Passifloraceae (e.g., Flacourtiaceae, Violaceae), represented in Hawaii by native or introduced species, should also be evaluated.

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