27 Skunk Vine

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PEST STATUS OF WEED

Skunk vine, *Paederia foetida* L. (Fig. 1), is a recently recognized weedy vine of natural areas in Florida that is spreading into other parts of the southern United States. The weed, which is native to Asia, appears to have the potential to spread well beyond the South to the northeastern states. Control of the plant by chemical or mechanical means damages valued vegetation supporting the vine. Skunk vine is a Category I Florida Exotic Pest Plant Council weed (Langeland and Craddock Burks, 1998), a listing that groups the plant with the most invasive weed species in Florida.

Figure 1. Skunk vine (*Paederdia foetida*), showing its leaves and flowers. (Photograph by K. A. Langeland, University of Florida, Gainesville.)

Nature of Damage

Economic damage. Although *P. foetida* is primarily a weed of natural ecosystems, economic damage does occur in agricultural and urban environments. In Florida, the weed can invade citrus groves located near unmanaged lands (Possley and Brazis, 1998), although the weed is not currently a significant problem in commercial citrus. Skunk vine also invades pasturelands, where cattle have been observed grazing on the weed. Effects on growth and reproduction of livestock, however, are unknown (Gann and Gordon, 1998). In urban landscapes, this vine entwines branches of woody ornamental plants and also spreads horizontally through lawns, rooting at the nodes (Martin, 1995). In westcentral Florida, *P. foetida* is considered the most troublesome weed along roadside right-of-ways (W. Moriaty, pers. comm.), and it also entangles power lines and associated structures (Martin, 1995).

On the island of Hawaii, *P. foetida* is a very serious weed in nurseries producing ornamental foliage plants (Pemberton, pers. obs.). The weed infests field plantings used for propagation. Control of the weed is very difficult because stock plants are easily injured if herbicides are applied. At times, growers have had to abandon or destroy stock plants that have become overgrown by skunk vine. Florida's large ornamental foliage industry also could be affected by skunk vine, as would the container plant industries in other states should the weed spread.

A cursory estimate of economic losses may be determined as the cost of removing or treating the weed. Stocker and Brazis (1999) estimated the cost of manually removing *P. foetida* from a moderately infested area at $1,622/ha. Estimates for herbicidal treatments of light (5.1 vines per m^2) and moderate (33.6 vines per m^2) infestation levels were $430/ha and $645/ha, respectively (B. Nelson, pers. comm.). Complete control was not achieved with a single treatment, regardless of the method.

Ecological damage. While little is known concerning the optimal growing conditions for this weed, it is apparent that skunk vine can tolerate a broad range of climatic, hydrological, and edaphic conditions (Gann and Gordon, 1998). This tolerance is exemplified by the diverse habitats that *P. foetida* has invaded in the southeastern United States, which include xeric uplands (sandhill), rockland hammocks, mesic uplands (hardwood, mixed, and pine forests), and floodplain wetlands (floodplain forest and marsh)

(Dehring, 1998; Gann and Gordon, 1998; Wunderlin, 1998; Pratt and Pemberton, 2001). These habitats are characterized as climax systems that harbor many threatened and endangered species (Anon., 1990).

Ecological damage is widely recognized as a result of invasion by *P. foetida*; specifically the displacement of the native flora (Schmitz *et al.,* 1997; Gann and Gordon, 1998; Langeland and Craddock Burks, 1998). Skunk vine is charged with displacing one of the few remaining populations of the native, federally endangered Cooley's water willow, *Justicia cooleyi* Monach. and Leonard (Langeland and Craddock Burks, 1998). Skunk vine can create dense canopies leading to damage or death of native vegetation (Gann and Gordon, 1998). Prostrate growth can develop into a dense layer of overlapping vines across the soil surface, smothering understory plants (Fig. 2). Climbing vines can scale and cover midlevel and overstory vegetation, eventually resulting in the collapse of trees or their branches. Direct damage to overstory plants increases the probability of gap formation and may alter the impact of fire, which occurs in many of the invaded communities (Gann and Gordon, 1998). Community level impacts have not been assessed.

Figure 2. Infestation of skunk vine growing over native forest in central Florida. (Photograph by K. A. Langeland, University of Florida, Gainesville.)

Extent of losses. The extent of losses from *P. foetida* is difficult to ascertain, in part, to a lack of monitoring of impacts of the plant on native communities and unclear valuation of the natural systems it invades.

Geographic Distribution

The geographic distribution of *P. foetida* is currently restricted to the southeastern United States (Fig. 3) and Hawaii. On the mainland, herbaria records show a concentration of *P. foetida* in central and northern Florida, as well as widely separated occurrences in Texas, Louisiana, Georgia, North Carolina, and South Carolina (Brown, 1992; Gann and Gordon, 1998; Diamond, 1999). The probability that skunk vine also has invaded Mississippi and Alabama is high, although no herbaria samples have been collected, and no surveys have been made. Recent discoveries of the weed in North Carolina and in the more tropical regions of southern Florida demonstrate the weed's continued expansion north and south (Diamond, 1999; Pratt and Pemberton, 2001). It is unknown if and how skunk vine spreads over long distances.

While it seems clear that skunk vine can invade much of the southeastern United States, it is difficult to predict the exact area at risk of invasion. It is likely that the northern range limits of this plant in the United States have yet to be realized. In Japan, the northern limit of the plant's range is the Tohoku region, an area with minimum temperatures of -10 to -20°C (Maekawa and Shidei, 1974; Muller, 1982). This distribution suggests that skunk vine can tolerate similar temperatures to those found in the United States Department of Agriculture Plant Hardiness Zone 6 (Cathey, 1990). Using Zone 6 as a northerly limit, the weed can potentially spread to 40° latitude, north of Delaware, Maryland, and the Virginias.

BACKGROUND INFORMATION ON PEST PLANT

Taxonomy

Paederia foetida is one of 30 species in the genus *Paederia* in the family Rubiaceae (Mabberley, 1997). *Paederia* is a genus of subtropical vines and shrubs occurring mainly in southeast Asia (16 spp.) and Africa-Madagascar (12 spp.); two species live in tropical America (Puff, 1991a). Skunk vine is one of two *Paederia* species that have become naturalized in Florida. *Paederia foetida* is naturalized primarily in central Florida, whereas *Paederia cruddasiana* Prain, commonly called sewer vine, is naturalized only in Dade County.

Wunderlin (1998) separates the genus *Paederia* from other members of the Rubiaceae that are either native to or naturalized in Florida by the following suite of characteristics. The plants are woody vines, have flowers and fruits in open solitary inflorescences,

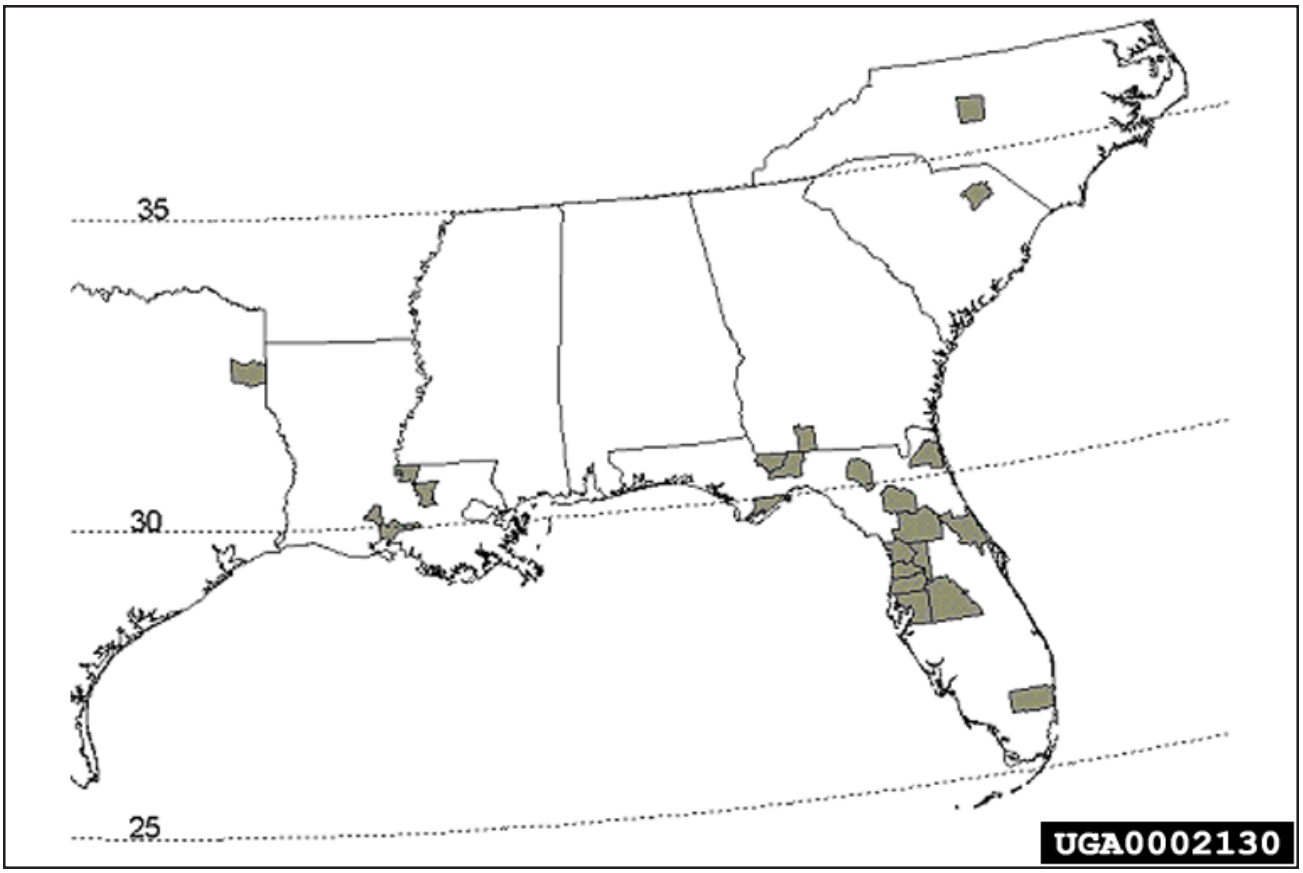

Figure 3. Known distribution of skunk vine by county in the eastern United States.

lack thorns, have similarly sized flowers within the inflorescence, have flowers and fruits with stalks, have corollas that are pale lilac in color with pubescent outer surfaces, and bear yellow-orange fruits. Skunk vine and sewer vine are easily separated from one another by their fruits. Skunk vine has spherical fruits and the seed (diaspores) lack wings, whereas sewer vine has fruits that are laterally compressed and seeds that are conspicuously winged. The leaves of sewer vine are typically larger than those of skunk vine. The common English names of these plants relates to the odor of the leaves, which is due to the presence of sulfur compounds (Mabberley, 1997). The odor is another helpful character to identify these vines and separate them from other plants.

Recent work (Puff, 1991a) has confirmed skunk vine and sewer vine from Florida as *P. foetida* and *P. cruddasina*. The large native range in both temperate and tropical Asia and considerable variation in leaf morphology, pubescence, and floral tube length resulted in taxonomic confusion. The most common but invalid names of skunk vine are *Paederia scandens* (Lour.) Merrill, *P. chinensis* Hance, *P. tomentosa* Blume, and *P. crudassiana.*

Biology

The biology of skunk vine is virtually unstudied. *Paederia foetida* is evergreen in southern Florida and deciduous from central Florida north, probably because frost is rare in southern Florida but usual from central Florida north. The weed occurs in a great diversity of habitats in its native range. The following habitats were recorded on herbarium specimens of skunk vine or observed for the plant in Japan and Taiwan: grassy hillsides, secondary forests, open places in primary forests, forest shade, river banks, canal banks, waste ground, hedges and thickets, roadsides, and fences, even in large cities. The large native range and the diversity of climatic zones and habitats occupied indicate that skunk vine has exceptionally broad environmental tolerances. It appears not only to be the most widespread *Paederia* species but also the most common *Paederia* species in most of its range.

Analysis of Related Plants in the Eastern United States (Florida)

Native species. The Rubiaceae, to which skunk vine belongs, is a large, mostly tropical family with more than 10,000 described species in 630 genera (Mabberley, 1997). Florida has 44 native species belonging to 20 genera (Wunderlin, 1998). These native plants are diverse in life form, and include herbs, woody vines, shrubs, and trees. Thirty-two native plants, in 10 genera, belong to the same subfamily (Rubioideae) as *Paederia* (Robbrecht, 1988; Wunderlin, 1998).

Five native species in four genera in the Rubiaceae are rare in Florida and are legally protected endangered or threatened plants (Coile, 1996). Three are endangered (*Catesbaea parviflora* Sw., *Ernodea cokeri* Britton ex Coker, and *Strumpfia maritima* Jacq.), and two are threatened (*Ernodea littoralis* Sw. and *Pinckneya bracteata* [W. Bartram] Raf.). Two of these rare species are *Ernodea* species that belong to the same subfamily Rubioideae as skunk vine. One of the others, the small shrub *S. maritima*, has uncertain affinities within the Rubiaceae, and so its relative relatedness to skunk vine is unknown. Although there are many native species in the Rubiaceae in Florida, none are very closely related to skunk vine because none are in either the genus *Paederia* or tribe Paederieae to which skunk vine belongs. The tribe Paederieae has no native members in the continental United States.

Economically important species. The checklist of the woody cultivated plants of Florida (Burch *et al*., 1994) lists 24 genera of plants in the family Rubiaceae. Eight of these (*Catesbaea*, *Cephalanthus*, *Chiococca*, *Genipa*, *Hamelia*, *Mitchella*, *Pinckneya*, and *Psychotria*) are native groups dealt with above. Most of the other genera (12 of 16) could be placed with available literature, and only one genus (*Serissa*) belongs to the same subfamily and tribe as skunk vine (Burch *et al.,* 1994; Robbrecht, 1988). The genus *Serissa* has one cultivated species (*S. foetida* Lam.), a tiny shrub commonly used in planters and edge plantings in Florida (Watkins and Sheehan, 1975). There are important Rubiaceous cultivated shrubs that are distantly related to skunk vine (they belong to other subfamilies). For instance, *Gardenia* species (particularly *Gardenia jasminoides* Ellis = *Gardenia augusta* [L.] Merr.) are grown as fragrance plants and produced commercially for use as cut flowers. *Ixora* species (*Ixora coccinea* L. and others) are grown for their showy red, orange, and yellow flowers, and are one of the most common hedge plants in South Florida. *Mussaenda* species are shrubs that increasingly are being cultivated because of their colorful flower-like bracts. Coffee (*Coffea arabica* L.) is grown at times as an ornamental curiosity.

Only a few herbaceous members of the Rubiaceae are cultivated in Florida. *Pentas lanceolata* (Forssk.) Deflers, a subfamily Rubioideae member, is very commonly cultivated for its showy flowers, which attract butterflies. For more detailed analysis of economic and native members of the Rubiaceae and their subfamilial and tribal placements in Florida, see Pemberton and Pratt (1999).

Natural Enemy Host Specificity Level Needed

Herbivores suitable for use as natural enemies of skunk vine would be those whose feeding and development are restricted to the tribe Paederieae. If skunk vine natural enemies are limited to Rubiaceous plant species belonging to the genus *Paederia* or, more broadly, to the tribe Paederieae, no native plants would be used as hosts because none of Florida's native plants belong to this tribe. However, the introduced ornamental plant *S. foetida* might be used by such an agent (with tribe level specificity), because this plant also belongs to the Paederieae. This cultivated plant should be included in host range tests, and its horticultural worth more carefully evaluated if it appears to be an acceptable host of any candidate biological control agents. No other rubiaceous plants cultivated in Florida would be hosts of natural enemies with this tribe level specificity. We expect that many insects with this tribe or genus level of host specificity should be associated with *P. foetida* and other *Paederia* species in their native ranges.

HISTORY OF BIOLOGICAL CONTROL EFFORTS IN THE EASTERN UNITED STATES

Area of Origin of the Weed

The native range of skunk vine was determined by Puff (1991b) and by Pemberton, who examined ca. 400 skunk vine specimens in the herbaria of the National Museum of France (Paris), the Royal Botanical Garden at Kew (UK), the British Museum of Natural History (London), and the Makino Herbarium at Tokyo Metropolitan University (Japan).

The plant reaches north as far as 42° at the tip of the island of Honshu in Japan. Its southern limits are Christmas Island (south of Java) and Timor in Indonesia – both at about 10° S. To the east the plant reaches Honshu and Japan's Bonin Islands at about 143° E, to the west skunk vine reaches Nepal at about 85° E.

Paederia foetida was reportedly introduced as a potential fiber plant to an unknown location in Florida by the U.S. Department of Agriculture prior to 1867 (Morton, 1976). The geographic origin of the introduced material is unknown. This plant was identified as a problematic weed as early as 1916, when it was found to have entangled ornamental plants near the city of Brooksville (Hernando County) in central western Florida (USDA, 1918). Early references to skunk vine in the region, coupled with its current geographic distribution (Fig. 2), suggest the site of original introduction and epicenter for subsequent dispersal was westcentral Florida (USDA, 1918; Small, 1933; Morton, 1976). Subsequent introductions from Darjeeling, India were made to the USDA Miami Plant Introduction Station in 1932 but the fate of these plants is unknown, as is the rationale for the introduction.

In addition to the United States, skunk vine has naturalized in Mauritius, Reunion, Sri Lanka (probably), New Guinea (probably), and Hawaii (Puff, 1991b). In Hawaii, the plant is known from the islands of Hawaii, Oahu and Kauai (Puff, 1991b), and also Maui (D. O'Dowd, pers. comm.).

Table 1. Natural Enemy Types Observed in a Preliminary Survey of Skunk Vine (*Paederia foetida*) in Central Japan and at One Site in Taiwan during October, 1997

Natural enemy (Order: Family)	Type Feeder/feeding	Places Recorded	Comments
Acyrthosiphon nipponicus (Essig et Kuwana) (Homoptera: Aphididae)	aphid	Mie Pref., Japan	at several sites, probably a specialist
Hornworm larvae either *Macroglossum* spp. or *Asplendon himachala* (Lepidoptera: Sphingidae)	leaf-feeding hawk moths (1 or 2 spp.)	Tokyo and Mie Pref., Japan	specificity unknown
Serpentine leafminer (Lepidoptera: unidentified family)	leaf-mining moth	Tokyo and Mie Pref., Japan	common, may be a specialist
Blotch leafminer (Lepidoptera: unidentified family)	leaf-mining moth	Tokyo and Mie Pref., Japan	at several sites, probably a specialist
Nokona pernix (Leech) (Lepidoptera: Sesiidae)	stem-galling moth	Nagoya, Japan	specialist
Fruit-boring moth (Lepidoptera: unidentified family)	feeds within fruit	Tokyo and Mie Pref., Japan	interesting because of damage, unknown specificity
Web-making moth (Lepidoptera: unidentified family)	feeds on and within fruit from a web	Mie Pref., Japan	interesting because of damage, unknown specificity
Spider mite (Acari: Tetranychidae)	distorted leaves	Tokyo, Japan	unknown specificity, probably a generalist
Blotch leaf disease (Cercosporia-like)	fungus? causing dead leaf blotches	N. of Taipei, Taiwan	not very damaging, could be a specialist

Table 2. Natural Enemies of Skunk Vine (*Paederia foetida*) Recorded in the Japanese Literature

Natural Enemy (Order: Family)	Type of Feeder	Country	Estimated Specificity	Reference
Acyrthosiphon nipponicus (Essig et Kuwana) (Homoptera: Aphidae)	aphid	Japan	high	Moritsu, 1983
Lygaeus fimbriatus Dallus (Hemiptera: Miridae)	plant feeding true bug	Japan	high	Tomokuni, 1993
Dulinius conchatus Distant (Hemiptera: Tingidae)	lace bug leaf feeder	Japan	high	Tomokiuni and Saito, 1998
Phygasia fulvipennis (Baly) (Coleoptera: Chrysomelidae)	leaf beetle	China, Japan	low-multifamily	Chujo and Kimono, 1961
Trachyaphthona sordida (Baly) (Coleoptera: Chrysomelidae)	leaf beetle	Japan	high	Chujo and Kimono, 1961
Asphondylia sp. (Diptera: Cecidomyidae)	flower-galling fly	Japan	very high	Yukawa and Masuda, 1996
Asphondylini tribe member-new species (Diptera: Cecidomyidae)	flower-galling fly	Japan	very high	Yukawa and Masuda, 1996
Nokona chrysoidea (Zukowsky) (Lepidoptera: Sesiidae)	stem-galling moth	Taiwan	very high	Kallies and Arita, pers. com.
Nokona pernix (Leech) (Lepidoptera: Sesiidae)	stem-galling moth	China, Japan	very high	Arita, 1994
Nokona rubra Tosevski and Arita (Lepidoptera: Sesiidae)	stem-galling moth	Ryukyu Is. (Japan)	very high	Arita, 1994
Goniorhynchus exemplaris Hampson (Lepidoptera: Geometridae)	moth	Japan, Korea	unknown	Ko, 1969
Asplendon himachala Butler (Lepidoptera: Sphingidae)	moth	China, Japan, Korea, Taiwan	unknown	Sugi, 1987; Ko, 1969
Macroglossum pyrrhostica Butler (Lepidoptera: Sphingidae)	moth	China, Japan, Korea, Taiwan, India,	high?	Ko, 1969; Miyata, 1983; Sugi,1987
Macroglossum bombylans Boisduva (Lepidoptera: Sphingidae)	moth	Japan	medium-other family	Miyata, 1983
Macroglossum stellatarum L. (Lepidoptera: Sphingidae)	moth	Africa, China, Europe, Japan, Korea	medium-other family	Ko, 1969
Trichohysetis rufoterminalis (Christoph.) (Lepidoptera: Pyralidae)	moth	Japan	unknown	Miyata, 1983

Areas Surveyed for Natural Enemies

Paederia foetida has not yet been a formal target of a biological control program. A feasibility study to determine the plant's suitability for biological control was conducted by the authors. Part of this study was to gather information to indicate whether promising natural enemies appear to be associated with the plant in its native range.

Searches of English language literature revealed few insects or diseases associated with skunk vine. A preliminary survey to obtain an indication of the occurrence of natural enemies associated with skunk vine was made in Japan and Taiwan during October 1997 by R. Pemberton. In addition, the published literature, particularly from Japan, was examined to identify the natural enemies that have been recorded on the plant.

Natural Enemies Found

Nine natural enemies – seven insects, one mite, and one fungal pathogen – were encountered during field surveys (Table 1). Most were unidentified Lepidoptera, including foliage feeders, leafminers, and fruit feeders. The leafminers and stem gallers are probably specialist herbivores of the plant. The fungal disease found in Taiwan may be *Pseudocercospora paederiae* (Swada ex.) Goh and Hsieh recorded recently in Florida (Walker *et al.,* 2001). It does not appear to cause significant harm to skunk vine in either Japan or Florida.

The 16 insect natural enemies recorded in the literature that attack skunk vine (Table 2) include an aphid and a mirid bug that bear the red-and-yellow warning coloration often seen in specialist herbivores. An Indian lace bug has recently invaded the Osaka area of Japan, where is causes considerable damage to skunk vine (Tomokiuni and Saito, 1998). Two gall flies in the genus *Asphondylia* have been recorded to gall the flowers of the plant and may reduce the reproductive potential. Three sesiid moths gall the stems of skunk vine in different parts of Asia. The impact of these galls on the plant is unknown. Two chrysomelid beetles have been recorded to use skunk vine as host and one of these, *Trachyaphthona sordida* (Baly), is believed to be a specialist on the plant (Chujo and Kimono, 1961). Because chrysomelid beetles have successfully controlled many weeds including alligator weed, leafy spurge, tansy ragwort, and purple loosestrife (Julien and Griffiths, 1998), *T. sordida* will be of special interest. The remaining six insects are Lepidoptera, four of which are leaf feeding sphingid moths with broad or unknown host ranges. The remaining two Lepidoptera include two little known pyralid and geometrid moths. These herbivores occupy diverse niches on the plant. Nine of these 16 insects are thought to have high degrees of host specificity suggesting biological control of skunk vine using insects has considerable promise.

RECOMMENDATIONS FOR FUTURE WORK

An essential first step in forming a biological control project against skunk vine will be to obtain funding for the work. The feasibility study of Pemberton and Pratt (2000) on the suitability for biological control of skunk vine provides a solid basis for a project. Potential conflicts with native and economic plants are well defined and some promising natural enemies are known. During the first phases of the project we recommend the actions listed below.

(1) Conduct surveys for natural enemies in the native region of the plant. Because skunk vine's distribution is in subtropical to warm temperate areas of Florida and the southern United States, surveys should focus on northeast Asia and parts of the Himalayan Mountains. Surveys in northeast Asia should include the parts of Japan, South Korea, and China that are climatically similar to the infested regions in the United States and that are known to have promising natural enemies. The chrysomelid, *T. sordida,* is of particular interest, as are the flower-galling flies. The plant is common in northeast Asia and easily surveyed. The second area that should be investigated is the western end of the plant's native distribution, in northern India and Nepal. Although the source of the skunk vine introduction(s) that became a problem in Florida is unknown, USDA introductions from northern India in 1932 suggest that the region might also have been the original source of the weed. Northern India and Nepal also have areas with climatic similarity to the infested areas in Florida. This region is home to many *Paederia* species, which may have co-evolved specialist herbivores. Because there are no native plants in the same genus or tribe as skunk vine in Florida, natural enemies of other species in the genus *Paederia* also could be safely employed against the weed. Surveys should include searches for plant pathogens of skunk vine.

(2) Design host specificity testing schemes based on the analysis of economic and native Rubiaceae in Florida and the American South. Acquisition of test plants will be aided by the fact that many Florida members of the Rubiaceae are in cultivation.

(3) Conduct surveys of existing natural enemies of skunk vine in Florida and other southern states. One specialized pathogen, *Pseudocercospora paederiae* [Swada ex.] Goh and Hsieh, native to Asia, has been found in Florida. Other natural enemies of *Paederia* spp. may have been introduced to Florida as well. Pathogens occurring in Florida, that might have moved to skunk vine from native members of the Rubiaceae, could have promise as mycoherbicides.

(4) Study the ecology of skunk vine in problem areas in the United States. Because almost nothing is

known about the ecology of the weed, studies to identify the susceptible stages of the plant (adult, juvenile, and seed bank), as well as the phenology and population dynamics, should assist in natural enemy selection.

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