Rapid Communication

Species Displacements are Common to Two Invasive Species of Leafminer Fly in China, Japan, and the United States

YULIN GAO,1, ZHONGREN LEI,1,2 YOSHIHISA ABE,3, AND STUART R. REITZ4

J. Econ. Entomol. 104(6): 1771–1773 (2011); DOI: http://dx.doi.org/10.1603/EC11206

ABSTRACT Under field conditions, species displacements have occurred in different directions between the same invasive species of leafminers (Diptera: Agromyzidae). Liriomyza sativae (Blanchard) was displaced by L. trifolii (Burgess) in the western United States, with evidence suggesting that lower insecticide susceptibility of L. trifolii is a factor. However, in Japan, the opposite has occurred, as L. trifolii was recently displaced by L. sativae. This displacement is probably because of the higher fecundity of L. sativae and differential effects of parasitoids on the two leafminer species. Here, we carried out long-term surveys of these same two invasive leafminer species during January through March in 1999, 2007, and 2011, as well as June through July in 2011, in eight locations (Sanya, Dongfang, Haikou, Leidong, Lingshui, Wuzhisan, Qionghai, and Danzhou) across Hainan Island of southern China. Our results indicate that, between 2007 and 2011, L. trifolii rapidly replaced L. sativae as the predominant leafminer of vegetables on Hainan Island, similar to the situation in the western United States. Further surveys of growers revealed that avermectins and cyromazine are the two most frequently used insecticides against leafminers on Hainan Island. Dose-mortality tests showed that L. trifolii populations from Hainan Island are less susceptible to avermectins and cyromazine compared with L. sativae populations. This lower insecticide susceptibility of L. trifolii may be associated with the displacement of L. sativae by L. trifolii, although additional ecological or environmental factors cannot be ruled out.

KEY WORDS Liriomyza sativae, Liriomyza trifolii, biological invasion, species displacement, insecticide susceptibility

In addition to the threat that invasive alien species pose to native biodiversity, they may interact with one another, which may lead to the displacement of one species by another and potentially alter agricultural pest management (Reitz and Trumble 2002a, Reitz 2007). Several species of leafmining flies in the genus Liriomyza (Diptera: Agromyzidae) are polyphagous herbivores that are important pests of numerous vegetable and ornamental crops (Parrella 1987). The mining by larvae and the puncturing of foliage by females for feeding and oviposition reduce photosynthesis and increase leaf drop, which lead to lower crop quality and quantity (Johnson et al. 1983, Parrella 1987). Two of the most important of these pest species are Liriomyza sativae Blanchard and L. trifolii (Burgess). Both of these species are endemic to the New World (Spencer 1973), but they have become cosmopolitan pests in recent years through the international trade of agricultural commodities (Parrella 1987; Scheffer and Lewis 2005, 2006). Because these species have been introduced into the same geographic areas, complex interspecific interactions, including species displacements, have been observed (Reitz and Trumble 2002a, Abe and Tokumaru 2005).

In California and other regions of the western United States, L. trifolii rapidly replaced L. sativae as the predominant leafminer pest of vegetables and ornamentals following its introduction, probably from Florida in the 1970s (Trumble and Nakakihara 1983). The displacement of L. sativae by L. trifolii led to a major increase in the pest status of leafminers (Trumble and Nakakihara 1983). The primary reason for the species displacement was thought to be the lower susceptibility of L. trifolii populations to many insecticides (Reitz and Trumble 2002a), but interspecific competition, differential host plant use, and differential effects of natural enemies may have been additional contributing factors (Reitz and Trumble 2002b).

A contrasting situation with these species has occurred in Japan. L. trifolii and L. sativae were first found in Japan in 1990 and 1999, respectively (Abe and Kawahara 2001), and the range of each species rapidly expanded soon after their respective introductions (Tokumaru and Abe 2005). In Kyoto Prefecture, L.
L. trifolii and L. sativae were found coexisting on tomato plants in 1999, but since 2000, L. sativae has become the dominant species, and L. trifolii has become rare (Abe and Kawahara 2001, Tokumaru et al. 2007). Abe and Tokumaru (2008) concluded that the reason for the species displacement is the higher fecundity of L. sativae and differential effects of parasitoids on the two Liriomyza species.

The case of L. sativae and L. trifolii is unusual in that species displacements have occurred in different directions in different locations. To further characterize the relationships between these species, we report results of a long-term study of these two invasive Liriomyza species across Hainan province in the south of China, another region where both species have been introduced. L. sativae was found first on Hainan Island in October 1993, and spread throughout China within a few years (Lei et al. 1997). In 2005, the distribution of L. sativae included >30 provinces, and now it is regarded as an established exotic species in China (Lei and Wang 2005). L. trifolii is a more recent invasive species in China that was first recorded in Guangdong and Hainan Island in 2005 and 2006, respectively. However, L. trifolii has not spread as extensively, to date, as L. sativae in China.

We conducted four surveys across Hainan Island during January through March in 1999, 2007 and 2011, and June through July in 2011. Fully grown larvae and puparia of Liriomyza found in foliage of cowpea (Vigna unguiculata L. Walpers) were collected in eight locations (Sanya, Dongfang, Haikou, Leidong, Ling-shui, Wuzhishan, Qionghai, and Dazhou Cities) across Hainan Island, and these were reared to adulthood. Adult males that emerged were identified based on the morphology of genitalia. In 1999, only L. sativae and Liriomyza huidobrensis (Blanchard), another invasive species, were found, but L. sativae was the predominant species, with very few individuals of L. huidobrensis found.

In the 2007 survey, we selected 34 sample sites in cowpea crops in the same eight locations, and collected a minimum of 30 leafminer individuals per sample. Ten samples contained only L. trifolii, and 11 samples contained only L. sativae. Ten samples contained both species of leafminers, and neither species was found in the remaining three samples. Overall, the relative abundance of L. sativae (n = 714) was 52.5% of the total Liriomyza population (n = 1360), with the remaining 47.5% all being L. trifolii.

From January through March of 2011, 24 samples (>30 individuals per sample) were collected from cowpea crops in the same eight locations of Hainan Island. In contrast to the earlier surveys in 1999 and 2007, almost all of the leafminers (n = 804) were L. trifolii (99.5%). No L. sativae individuals were found, and only two L. huidobrensis individuals were found. From June through July of 2011, eight samples (>100 individuals per sample) were collected from cowpea crops in the same eight locations of Hainan Island. During this sampling period, we also found that all of the leafminers (n = 1005) were L. trifolii. No L. sativae individuals were found. These results show clearly that L. trifolii has replaced L. sativae as the dominant Liriomyza species on Hainan Island.

We first speculated that chemical insecticide selection and differences in the insecticide susceptibility were the major reason for the displacement of L. sativae by L. trifolii on Hainan Island. Hainan Island is a major supplier of vegetables to inland areas of China, and Liriomyza species have been important pests in cowpea, cucumber, celery, and other vegetables, since their initial introductions. In particular, cowpea is the most important vegetable crop in Hainan, and because of its importance, farmers have attempted to control leafminer populations through intensive insecticide use. This intensive insecticide use led to the Hainan “toxic cowpea” case in 2009–2010, which was a major food safety crisis (http://english.peopledaily.com.cn/90001/90776/90882) because most cowpea from Hainan Island tested positive for significant residues of pesticides.

To determine which insecticides were being used specifically against leafminers, we conducted surveys of growers in 2009, 2010, and 2011. These surveys showed that >50 insecticides were used by local growers to control leafminers. However, avermectins and cyromazine accounted for >95% of the total insecticides used against leafminers.

Therefore in 2011, we evaluated the susceptibility of L. sativae and L. trifolii to these two major insecticides used for controlling leafminers on Hainan Island. We tested the mortality response of second instars of L. trifolii and L. sativae to labeled field rates of avermectin (4.5 ppm) and cyromazine (46.8 ppm). Populations of both leafminer species were obtained in June 2007 from cowpea crops grown in Sanya, and were subsequently reared on cowpea in the absence of insecticides at the Sanya experiment station. Leaves containing second instars were dipped in insecticide solutions, and larval mortality was based on the proportion of larvae that successfully pupariated. For avermectin, the mean mortality for L. trifolii was 13.3 ± 1.7% compared with 94.4 ± 3.7% for L. sativae. For cyromazine, the mean mortality for L. trifolii was 53.9 ± 5.8% compared with 90 ± 3.4% for L. sativae. There were significant differences in mortality between the species for each insecticide. Student’s t-test: Avermectin: t = 41.03, df = 4, P = 0.0001; Cyromazine: t = 7.274, df = 4, P = 0.002), with L. trifolii being significantly more tolerant than L. sativae to both insecticides.

We cannot be certain if there was a sudden collapse of L. sativae populations in 2011 or if there was a continual decline after 2007. However, as growers continued to experience problems with leafminers throughout 2008–2010, it is not likely that L. trifolii simply filled an empty niche left by an unrelated collapse in L. sativae populations. Rather, the change in Liriomyza demographics in Hainan appears to be related to interspecific differences and interactions between L. sativae and L. trifolii.

The rapid displacement of L. sativae by L. trifolii on Hainan Island can be associated with lower insecticide susceptibility of L. trifolii. Historically, L. trifolii has
been considered more tolerant to other chemicals than *L. sativae* (e.g., Mason et al. 1987). The findings of our study are similar to the conclusions of Reitz and Trumble (2002a) that the lower susceptibility of *L. trifolii* to many commonly used insecticides contributed to its displacement of *L. sativae* in California and other regions of the western United States. However, the contrasting displacement of *L. trifolii* by *L. sativae* in Japan shows that these species interactions are complex and the outcomes are likely influenced by additional factors, such as fecundity, effect of natural enemies, and interspecific hybridization, some of which may be unique to specific geographic regions where these highly invasive species interact.

**Acknowledgments**

We thank Prof J. Wen (IPP-CAAS) for identifying the leafminer species. We are grateful to Y. Leng (NATESC) and S. Xie (HNASS) for providing important informations, as well as J. Xiang, W. Yu, Q. Wei, and Y. Zhang for collecting the data in this study. We also thank Marshall Johnson (UC Riverside) for valuable comments on the manuscript revision. This research project was supported by the National Key Basic Research Program (973 Projects Grant 2009 CB119004) and the earmarked fund for Modern Agro-industry Technology Research System (Nycytx-35-gw27).

**References Cited**


