

Japanese beetle, *Popillia japonica* (Newman)

Introduction

The Japanese beetle (JB), *Popillia japonica*, is native to Japan and the Russian Far East. It was accidentally introduced to eastern USA in the early 20th century, then into the Azores in the 1970s and, in 2014, it was found in Northern Italy, from where it is presently spreading (EPPO 2022). In eastern North America, it causes considerable damage to golf courses, lawns, pastures and herbaceous and woody landscape plants, and similar damage are now being observed in Italy, where JB population levels have become very high. The host range includes more than 300 different ornamental and agricultural plant hosts. Adults feed on foliage, flowers, and fruits, and larvae on grass roots (Potter and Held, 2002). Infestations of JB also have an indirect economic impact on nurseries because of the cost of applying the phytosanitary measures adopted to prevent the movement of plants with soil containing beetle larvae.

History of classical biological control against *Popillia japonica*

During 1920-1933, the USDA imported dozens of parasitoids of *P. japonica* and related scarabs from the orient and Oceania and released 14 species into infested areas in the USA (Fleming, 1968; Clausen 1978). Only five parasitoids became established. The most widely distributed are *Tiphia vernalis*, a wasp that parasitizes overwintering grubs in spring and *Istocheta aldrichi*, a tachinid fly that parasitizes adults. *Tiphia vernalis* is well established throughout the beetle-inhabiting areas in the USA but has not yet reached Canada. *Istocheta aldrichi* has long been restricted to the New England states, but has recently become established in North Carolina, Michigan, Minnesota and Missouri, USA (Jackson and Klein, 2006) and in Quebec, Canada (Gagnon and Giroux, 2019). In the USA, it is often considered that these parasitoids do not provide sufficient control (Potter and Held, 2002). However, parasitism by *I. aldrichi* seems to increase since the beetle has spread further north. Furthermore, in its area of origin in Japan, parasitism is much higher and the beetle is considered a minor pest. Therefore, classical biological control should still be considered in newly invaded areas.

Most promising natural enemies for classical biological control

Tiphia vernalis Rohwer (Hymenoptera: Tiphidae): the adult wasp locates third instar larvae by kairomones in spring. The wasp uncovers the subterranean larva, paralyzes it, and lays an egg on the exterior of the larva. The egg will later hatch and burrow into the host to feed (Rogers and Potter 2003). *Tiphia vernalis* is not abundant in Japan and was originally collected from other *Popillia* spp. in China and Korea (Fleming, 1968; Clausen 1978). It is known to attack at least one native species in the USA, *Anomala orientalis* (Reding and Klein 2001). *Tiphia vernalis* can parasitize up to 60% of JB larvae, but further studies show that preventative applications of imidacloprid insecticides during their flight period inhibit the wasps' ability to parasitize (Clausen, 1979; Rogers and Potter 2003).

Tiphia popilliavora Rohwer (Hymenoptera: Tiphidae): this species was collected from JB in Japan and the other known hosts are other *Popillia* spp. in Asia. In contrast to *T. vernalis*, *T. popilliavora* attacks larvae in autumn and, in the USA, adults often fly too early to parasitize the last instar

Preparedness in biological control of priority biosecurity threats

larvae of JB, which is their preferred stage. *Tiphia popilliavora* was first considered widely established in the USA but has become rarer, for unknown reasons.

Istocheta aldrichi Mesnil (Hymenoptera: Tachinidae): the adult fly lays eggs on the pronotum of the adult beetle, mostly on females. When the eggs hatch, the larvae burrow into the flight muscles and then into the abdomen of the adult beetle, where the fly pupae will overwinter. Death of the adult beetle usually occurs within six days (Clausen 1978). This parasitoid is native to Japan, where it is the dominant parasitoid of JB. In northern Japan, it parasitised up to 100% of females in years of low JB abundance and 30-35% in years of high beetle abundance (Clausen 1978). In North America, where it has been introduced, *I. aldrichi* has not completely synchronized with its host's life cycle and often emerges prior to the beetle. This lack of synchronization is most likely due to climatic differences between the area of origin and the area of introduction. Interestingly, while the beetle and its parasitoid migrate to colder areas in northern USA and Canada, which are climatically more similar to northern Japan, parasitism is increasing, reaching an average of 39% in Canada in 2019 (Vincent and Lasnier 2020).

Other natural enemies for classical biological control

During the extensive surveys by USDA in Japan in the early 20th century, many other parasitoids were found on JB. However, from the information provided by Fleming (1968), Clausen (1978) and references therein, no other parasitoid seems abundant and specific enough to be considered as suitable biological control agent for Europe.

Several entomopathogens can infect JB and are occasionally used or tested as biopesticides in invaded areas. A strain of the bacterium *Paenibacillus popilliae* not present in Europe which is apparently specific to JB could potentially be used for classical biological control.

The entomopathogenic bacterium *Paenibacillus popilliae*, which causes milky disease in insects, potentially could be used for classical biological control in countries where it is currently absent (CABI, 2022). A strain that infects JB is apparently specific (Potter and Held, 2002).

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Preparedness in biological control of priority biosecurity threats

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