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Japanese Beetle (*Popillia japonica*)

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Introduction

Japanese beetle (Coleoptera: Scarabaeidae), *Popillia japonica* Newman, is an invasive beetle introduced from Asia to the United States in the early 1900s. It was first detected in New Jersey and later distributed in 28 states in the United States (Fig 1). In Tennessee, the beetle population was first detected in 1936, and about 80 counties in Tennessee have been infested by their establishment. Adult beetles feed on over 300 plant species, including foliage, fruits, and flowers. It is a significant pest of turfgrass, and ornamental and horticultural crops in the eastern United States. Adults and larvae aggregate on the plants and can cause severe injury. Larvae, commonly known as grubs, feed belowground, destroying turfgrass roots in lawns, golf courses, and athletic fields. Adults feed mainly on the leaves of plants, eating between the veins and leaving a characteristic skeletonized appearance.

Once established, Japanese beetles can be a challenging and expensive insect to control. The beetles in the United States are expected to cause damage worth $450 million per year for maintaining and replacing damaged turf and ornamental plants.

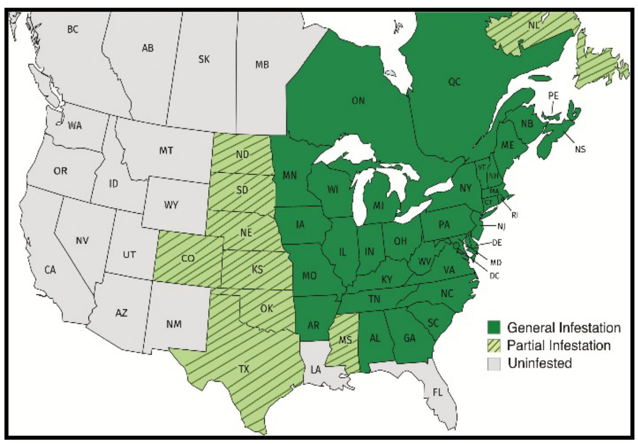

Figure 1. Map of Japanese beetle distribution in the United States as of 2018 and Canada as of 2016.

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Identification

Egg: White appearing as spheroids, ellipses, and cylinders. Eggs are laid 50.8-101.6mm (2-4 inches) below the soil surface, where they can absorb moisture (Fig. 2a).

Larva: White or cream-colored body held in a C-shape; tan-colored head. They have three developmental stages (instars); first instars are 3/32 inch (3 mm) long and third instars are 1 ¼ inch (30 mm) long (Fig. 2b).

Pupa: Cream to reddish brown body; about ½ inch (14 mm) long and ¼ inch (7 mm) wide (Fig. 2c).

Adult: Metallic green head with brown copper forewings (elytra); seven pairs of tufted white hairs along the sides; sharply pointed tibial spurs on males; 7/16 inch (8-11 mm) long and oval shaped (Fig. 2d).

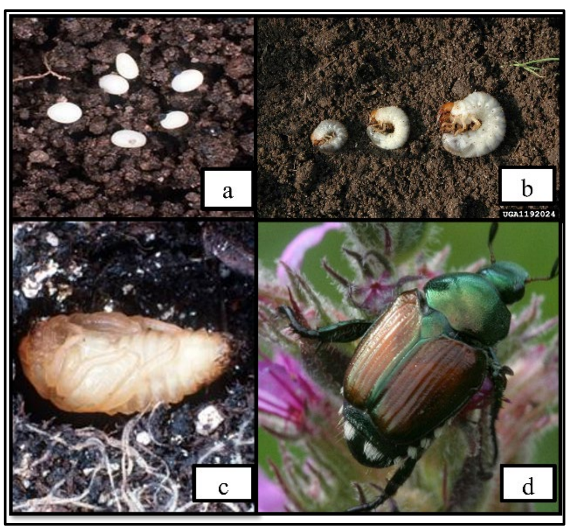

Figure 2. Japanese beetle life stages, including a) eggs, b) larvae (grubs), c) pupa, and d) adult

(b,d)© David Cappaert, Michigan State University

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Life Cycle

Japanese beetle has an annual life cycle with most of its life belowground as a larva. Depending on latitude, adults begin to emerge from the soil from mid-to-late June to early July and live up to 40 days. Adult emergence is based on degree-day accumulation (beginning at 1,030 growing degree days (GDD) and continuing until 2,150 GDD with base 50º F) and is fairly predictable. Every season is a bit different based on the spring temperature. Adults feed on foliage, flowers, and fruit before mating. The ovipositing female burrows into the soil and lays eggs singly at a depth of 2-4 inches (50.8-101.6 mm). Females can lay 40 to 60 eggs during their lifespan.

The eggs hatch in about 10 to 14 days, the first instars take 2 to 3 weeks to develop, and the second instars take about 3 to 4 weeks to develop, depending on temperature. Temperature has a different effect on Japanese beetle development during different stages of its life cycle. Each stage has a different threshold, optimal, and maximum temperature. The temperature range for their development is 55.4 to 95°F (13 to 35ºC) from the egg to the adult stage. The optimum temperature for egg development is 86°F (30 ºC), for larvae (first to third instars) is 81°F (27ºC) and pupa is between 86-90°F (30 to 32ºC). In late fall, larvae stop feeding and overwinter about 2 to 8 inches (50.8-203.2 mm) below the soil surface. Larvae move closer to the soil surface as soil temperatures rise in the spring (50°F [10ºC]). Larvae continue feeding for 4-8 weeks during the spring. The prepupal stage lasts for 10 days during May. Pupation occurs usually in mid-to-late spring, and adults emerge in about 1 to 3 weeks.

Host Plants

Rose, grape, linden, apple, crabapple, cherry, blueberry, plum, and related trees, as well as birch, elm, raspberry, currant, basil, Virginia creeper, hollyhock, marigold, corn silks, and soybean, are susceptible cultivated hosts.

Larva Injury

Japanese beetle larvae develop in the soil and feed on plant roots (Fig. 3). They reduce the ability of plants to absorb water and nutrients, affecting plant survival during hot and dry conditions. Initial larva injury in turf appears as drought stress damage. More severe damage causes the turf to die in large, irregular patches.

Figure 3. Larva feeding on tree roots.
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Adult Injury

Adults are more active during the daytime and feed on the soft tissues between the veins on the upper surfaces of plant leaves, leaving behind skeletonized leaves and large, irregular holes (Figs. 4, 5). They frequently start by feeding in the upper canopy. They prefer sunny leaves over shaded ones. Trees that have sustained severe damage sometimes lose their leaves and turn brown.

Figure 4. Adult Japanese beetles feeding on rose.
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Figure 5. Skeletonized maple leaves by Japanese beetle.
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Integrated Pest Management

Management of Japanese beetle is very challenging. The adult and larva attack different parts of plants, which can affect management options. An integrated pest management approach will improve adult or larval control efforts.

Cultural Control

It is crucial to keep trees and plants healthy by supplying the required water and fertilizers to reduce plant stress. Trees and shrubs that are mature and healthy can tolerate heavy feeding without significant long-term impacts, whereas young plants may become stunted, injured, or even die with persistent feeding. Beetles in production systems can be reduced through tillage, intercropping, non-preferred groundcovers, and to some extent, irrigation management. Geranium is toxic to Japanese beetle. When adult beetles consume geranium petals, they become paralyzed and vulnerable to predation and desiccation. Females prefer to lay their eggs in moist soil; therefore, reduced irrigation during the peak egg-laying season can reduce larva populations. Also, tilling soil to a depth of at least 4-5 inches during fall has been found effective in reducing larval survival. Application of nitrogen fertilizer at an early stage (May, June) is generally not recommended. However, fall nitrogen fertilization helps in root regeneration and repair of damage caused by the larva.

Physical Control

Hand-picking

Beetles in a small area can be physically removed from plants, especially on cool mornings when they are less active. Beetles can be collected and drowned by shaking host plants over buckets with soapy water. However, physical control methods can be labor-intensive and time-consuming.

Trapping

Japanese beetle traps, which are commercially available, can help to control small, newly established, or isolated populations (Fig. 6). Trap lures containing a blend of beetle pheromones and plant volatiles are available. These beetles were found to be attracted to different trap colors like white, yellow, and solid green. In a recent study, solid green color traps baited with a lure made of eugenol and phenethyl propionate and female-generated sex pheromone was found effective in reducing pollinator captures and effectively increased Japanese beetle traps (Sipolski et al. 2019). These traps also are used to monitor and detect populations of Japanese beetle in new areas. High tunnels that block ultraviolet light can be used in small fruit crops to keep the beetle away from the plants. The proper placement of traps is essential, as lures and traps placed near host plants often attract adult beetles to the vicinity of hosts, causing more damage on adjacent crops.

Figure 6. Trap for Japanese beetle.
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Biological Control

Several biological control agents, such as nematodes, parasitoid wasps, and microbial organisms, provide natural or commercial Japanese beetle control.

Nematodes

Heterohabditis bacteriophora Poinar and *Steinernema glaseri* Steiner, are two commercially available nematodes reported to be effective against Japanese beetle larvae in turfgrass. Products are formulated to be applied by dilution in water like chemical pesticides. Within a year, some entomopathogenic nematodes were found to reduce the larval population by 90% without any adverse effects on non-targeted organisms. Nematodes also are often compatible with some insecticides and may even be enhanced with insecticides, like imidacloprid, which slow the larval defensive response to nematodes.

Parasitoids

Tiphia vernalis Rohwer and *Tiphia popilliavora* Rohwer (Hymenoptera: Tiphiidae), two species of tiphiid wasps, were introduced as biocontrol agents against Japanese beetle larvae in the early 1900's. The wasp larvae develop as ectoparasitoids on the beetle larvae (Fig. 7b). The winsome fly, *Istocheta aldrichi* (Mesnil) (Diptera: Tachinidae), is another introduced tachinid fly that parasitizes adult Japanese beetles. Female flies lay eggs on the thorax of Japanese beetle adults, usually preferring the larger female beetles (Fig. 7a). Other tachinid fly species also are known to parasitize adult beetles. Tiphia wasps and winsome flies are not commercially available currently.

Figure 7. Japanese beetle with a) Istocheta fly eggs on the thorax of adult, b) Tiphiid wasp larva on the beetle larva.

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Bacteria

Two bacterial species, *Paenibacillus popilliae* Dutky and *Paenibacillus lentimorbus* Dutky (Bacillales: Paenibacillaceae), are responsible for causing milky spore diseases in Japanese beetle larval populations. Furthermore, an active strain of *Bacillus thuringiensis* subspecies *japonensis,* strain Buibui

(Btj), and *Bacillus thuringiensis galleriae,* strain SDS-502 (Btg), were found effective in reducing the beetle population. The Btj bacterium, isolated from Japanese soils, is particularly toxic to Japanese beetle larvae when applied to first and second instars. The Btg formulations reduced the adult population when applied to foliage.

Fungus

Application of *Metarhizium brunneum* (Petch) (Hypocreales: Clavicipitacea) F52 was found effective for the reduction of larval density by 50% in turfgrass plots targeting second and third instars (Behle et al 2015). However, the efficiency of this biopesticide application could be affected by temperature and soil moisture.

Microspordians

Ovavesicula popilliae Andreadis (Dissociodihaplophasida: Ovavesiculdae) is a microsporidian pathogen found in the soil that can infect adult and larval Japanese beetles. Larval ingestion of *Ovavesicula* while feeding on roots may reduce the fecundity in adults by 50% and increase the mortality rate of infected larvae by 76.5% (Piombino et al. 2020). *Ovavesicula* is not commercially available currently.

Chemical Control

Chemical management approaches may be required in cases of severe larval or adult infestations to mitigate damage. Several chemicals are effective for controlling Japanese beetle larvae or adults. Pyrethroids, organophosphates, carbamates, neonicotinoids, and anthranilic diamides pesticides are currently used to manage Japanese beetles. Common adult insecticides include: bifenthrin, carbaryl, cyfluthrin, deltamethrin, permethrin, azadirachtin, and pyrethrins. For larvae, common insecticides include: imidacloprid, bifenthrin, trichlorfon, anthranilic diamides (e.g., chlorantraniliprole). It is essential to follow all product label instructions to achieve proper treatment of Japanese beetle adults and larvae. Some insecticides also have label restrictions on timing and plant type to protect pollinators.

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Precautionary Statement

To protect people and the environment, pesticides should be used safely. This is everyone's responsibility, especially the user. Read and follow label directions carefully before you buy, mix, apply, store or dispose of a pesticide. According to laws regulating pesticides, they must be used only as directed by the label.

Disclaimer

This publication contains microbial pesticide recommendations that are subject to change at any time. The recommendations in this publication are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific microbial pesticide being used. The label always takes precedence over the recommendations found in this publication. Use of trade, brand, or active ingredient names in this publication is for clarity and information; it does not imply approval of the product to the exclusion of others that may be of similar and suitable composition, nor does it guarantee or warrant the standard of the product. The author(s) and Tennessee State University assume no liability resulting from the use of these recommendations.

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