Questions and Answers about Japanese Beetle in Colorado

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Background Questions

What is the Japanese beetle? The Japanese beetle is an insect that was accidentally introduced into North America about a century ago and has become a serious plant pest. The scientific name for the insect is *Popillia japonica*. It is in the beetle family Scarabaeidae, which includes insects that are variously known as scarab beetles, May/June beetles, dung beetles, and chafers. The young stage of the Japanese beetle, and other scarab beetles, are known as white grubs.

How does Japanese beetle damage plants? Japanese beetle damages plants in both the adult (beetle) stage and in the immature (white grub) stage. However, the injuries that it produces in each of these life stages is completely different.

Adults of the Japanese beetle feed above ground on leaves and flowers. They can be very damaging to many commonly grown plants, including roses, lindens, Virginia creeper, grape and beans. The white grubs chew on roots of grasses, including most popular turfgrasses. When abundant they can seriously damage the roots leading to drought stress and, in severe cases, plant death.

What is the life cycle of the Japanese beetle? Japanese beetle has a life cycle that takes one year to complete. The progressive life stages of the Japanese beetle during that period are egg > larva (white grub) > pupa > adult.

Through winter the Japanese beetle in the larval stage, a white grub found within soil. They will move up and down in the soil during the cold months, staying below frost line. Very little feeding occurs during the coolest periods of the year but with warm soil temperatures in spring they resume feeding on plant roots. The white grubs complete their feeding cycle in later spring and transform to a pupal stage, which also occurs in soil.

After pupation has been completed, the adult beetles emerge from the soil. Usually the first of the beetles are males and emergence begins sometime in the middle of June. Over the

next few weeks the remaining beetles emerge. Peak number of adults usually are present in July.

After female beetles have fed a bit and mated, they begin to lay eggs. Eggs are laid in soil, within the top 3 inches, with females selecting soil sites that are moist and support larval host plants (turfgrasses). A small number of eggs (1-4) are laid at a time after which the female returns to feed on leaves and flowers and mature more eggs. She will then return to the soil, lay eggs and then return to feed, a cycle repeated through her lifetime. A single female will typically lay about 40-60 eggs over the course of a life that extends for about 30-45 days.

Eggs hatch about two weeks after they have been laid. The tiny first stage (Instar I) grubs feed on the fine roots of plants and organic matter in the soil. They will molt to a second, larger stage (Instar II) grub which feeds for about 3-4 weeks before molting to the final (Instar III) grub. These grubs will continue to feed throughout late summer and into autumn, moving deeper into the soils as they cool to about 60^{o}F. It is this last stage larva, partially developed, that survives between growing seasons.

Where did the Japanese beetle come from? The Japanese beetle is native to Japan. The first detection of it in North America occurred in New Jersey in 1916. It is suspected that live stages of the insect were accidentally brought to the area a few years earlier in a shipment of nursery material from Japan. Within a few decades after its discovery, Japanese beetle then spread across most all of the eastern and Midwestern United States. Until recently the insect was found almost entirely east of the High Plains, mostly east of the Mississippi.

How did the Japanese beetle get to Colorado? Humans accidentally carried Japanese beetle into Colorado; on its own, Japanese beetle is unable to cross a significant geographic barrier such as the High Plains provide.

There are many ways that humans can carry Japanese beetle to new areas. Perhaps most common is that larvae are carried in the soil of nursery plants; that is the likely way that the Colorado infestations began. Adult beetles incidentally fly into vehicles or aircraft and can be transported; many new infestations of Japanese beetle in the western United States have developed near major airports.

It should be noted that Japanese beetles have been detected numerous times in Colorado prior to its establishment. However, most detections involve single beetles or only a few beetles and these normally die out without establishing. Indeed, prior around 2003, it was debated whether Japanese beetle was capable of reproducing and establishing in Colorado. (It is.)

Where is the Japanese beetle in Colorado in 2018? Presently there are two main areas where Japanese beetle is established and spreading in eastern Colorado. The largest presently involves much of the Metro Denver area, with high populations extending into Boulder and Douglas Counties. Isolated infestations are also known from areas of Larimer and Weld County. The "Denver Area" infestation developed in the early 2000s, first becoming apparent around some Arapahoe County sites (Littleton, Cherry Hills).

A second, well-established infestation is present in Pueblo. This is likely to be a more recent introduction, with damaging numbers of beetle's first attracting attention in the past five years or so.

Isolated introductions have been reported from Colorado Springs, but established populations do not appear to be present there at this time.

How bad a problem is Japanese beetle compared to other areas of the country? Most states east of the Mississippi have had problems with Japanese beetles for well over half a century. In these areas Japanese beetles can show wide variation in abundance from year to year for reasons that are incompletely understood. Weather, particularly the timing of rainfall during critical periods (when eggs are being laid and young larvae are present), is likely an important contributor to these cycles.

In wide areas of eastern North America 2017 turned out to be year when Japanese beetle numbers exploded and were in above average numbers. In these areas numbers of Japanese beetles and the damage they produced were far greater than has ever been seen anywhere in Colorado.

In Colorado, gardeners have never experienced an insect like the Japanese beetle in their gardens, an insect that is conspicuous and causes conspicuous damage on many common garden and landscape plants. This has contributed to a very high level of concern and anxiety about the insect by people in this state.

Japanese beetle in Colorado may ultimately be as important an insect pest as it is in other areas of the US. Or, perhaps even more likely, it will be an insect of importance to area gardens but have population levels that do not, on average, rise to what one might see in Midwestern and eastern states. We shall see in time.

Is it possible to eradicate Japanese beetle? There are a few examples where small populations of Japanese beetle have been eradicated. One example would be in Salt Lake City where an intensive effort, well-funded by the state, appears to have been successful. Another successful effort was in the small town of Palisade, in western Colorado. There are presently efforts to eradicate small populations that have become established in California and southern Oregon, which may prove successful. A larger effort, with a more established population, is presently taking place in Portland.

Where eradication has been successful, Japanese beetle was detected, using traps, when it was in very low numbers and in a limited area. This area was then treated intensively with insecticides, most applied to turfgrass sites that might harbor developing larvae. Additionally sprayed insecticides applied to trees/shrubs favored by the insects have often been part of JB-eradication efforts. There is also extensive use of Japanese beetle traps, both for monitoring progress of the eradication effort and to provide some control by trapping out some adults. Eradication efforts are applied continuously over several years, until Japanese beetle is no longer detected in traps.

How was the Japanese beetle eradicated in Palisade, Colorado? A timeline of the Palisade JB eradication project is available through the website of Tri-River Area Extension Japanese beetle was first detected in Palisade by a Master Gardener, in 2002. This

prompted an extensive trapping effort in 2003 to determine how widespread the beetle in Palisade was. A total of 1300 beetles were captured in traps during 2003. No beetles were found then, or ever, outside the city limits.

Because the infestation in Palisade posed a significant threat to regional agriculture, and because the infestation was found to be contained within a small area (central Palisade) eradication efforts were begun in 2004. Initially, this involved treating with the insecticide imidacloprid all areas of irrigated turfgrass within the town, attempting to kill the white grub stage. This was repeated in 2005. After this point, in 2006-2008, annual insecticide applications (imidacloprid, chlothianidan, trichlorfon) were made to a more limited area (200-300 properties) where traps detected the core infestation to be present. Some insecticide sprays of highly favored plants (e.g., Virginia creeper) were also made in these ""hot spots".

Captures of Japanese beetles steadily declined from 2004-2008 and first dropped to zero in 2009. At this point insecticide treatments were discontinued. Since then a monitoring program using traps has been in place. No adult Japanese beetles, except a single adult in 2013, have since been found in Palisade.

Can we eradicate Japanese beetle from Eastern Colorado? Not in areas where it is well established. The insect has spread far too extensively and occurs in far too high population for eradication to be feasible in either the "Denver metro" or Pueblo infestations.

Perhaps eradication could be possible where spot infestations were detected at a very early stage in communities presently isolated from the existing infestations (e.g., Colorado Springs, Fort Morgan, Sterling). However, this would require a very high investment of money to attempt eradication and the possibility of reinfestation – assisted often by humans when the beetles move on vehicles – will increase as more areas of the state are infested.

Are there laws to prevent further spread of Japanese beetle in the United States? There are some federal and state programs designed to limit spread of Japanese beetle from infested areas in the eastern United States to non-infested areas in the western United States.

Activities of the federal agency APHIS (Animal and Plant Health Inspection Service) are regulated by the Japanese Beetle Quarantine and Regulations found in the federal Code of Regulations 7 CFR 301.48. The objective of this is primarily to limit human-assisted spread of the beetle from the eastern U.S. via aircraft.

The regulatory interests of the Colorado Department of Agriculture focus Japanese beetle prevention efforts on an external quarantine and a program of monitoring nursery stock imported into Colorado from the mid- west and eastern US sources where Japanese beetle is present. In addition, in 2017 with the Nursery Industries' support, the first internal (within Colorado) quarantine of a Japanese beetle infested area was adopted. Japanese beetle quarantines put restrictions on the movement of certain nursery materials from areas where Japanese beetle is present to areas where it is not. The Colorado Department of Agriculture maintains a Japanese beetle website that provides information on regulations affecting Japanese beetle in the state.

What traps can be used to capture Japanese beetle? There is a very effective trap for Japanese beetle. The physical trap itself typically involves a yellow, winged vane that intercepts the flying beetles and cause them to trop through a funnel into a collection container below. The lure used, which is highly attractive to both sexes of Japanese beetle, is composed of several floral-derived compounds; the standard lure contains phenyl-ethyl proprionate, eugenol, and geraniol in 3:7:3 ratio.

Sometimes an additional lure is used, based on the mating attractant (sex pheromone) produced by female Japanese beetles, (R,~Z)-5-1 -(1 -Decenyl) dihydro-2(3H)-furanone. Known as Japonilure, this lure captures only males.

Biological control of Japanese beetle

Are there any natural controls of Japanese beetle? Japanese beetles can die from many natural causes. Eggs and early stage grubs of Japanese beetle are very sensitive to drying and will be killed if so soil dry a bit during this critical period. Some adults are killed by birds and grubs will be eaten by skunks and raccoons.

There are also several organisms (biological controls) established in the eastern United States that are specific natural enemies of Japanese beetle. These include some pathogens that produce disease in Japanese beetle and some insects that prey upon and kill Japanese beetle. The most important of these are:

Tiphia vernalis (spring tiphia), a parasitic wasp with a larva that attacks Japanese beetle grubs in the spring;
Tiphia popilliavora (summer/fall tiphia), a parasitic wasp with a larva that attacks Japanese beetle grubs in late summer;
Istocheta aldrichi, a parasitic fly with a larva that develops within and kills adult beetles in midsummer;
Ovavesicula popilliae, a microsporidian disease that infects Japanese beetle larvae and adults; and
Paenibacillus (*Bacillus*) *popillae* (milky spore), a bacterial disease that infects Japanese beetle larvae.

There are also two other, commercially available, biological controls that have been used to control Japanese beetle. Certain nematodes that attack white grubs (*Heterorhabditis bacteriophora*) can be used to kill Japanese beetle larvae in lawns. Recently a bacterium that can kill Japanese beetle has been marketed, *Bacillus thuringiensis* var. *galleriae*. Both of these biological controls are essentially used as a type of biological insecticide to provide control of an existing infestation of white grubs. As they do not persist they do not provide ongoing, long-term control.

Do the biological controls introduced to control Japanese beetle affect any other insects? No.

Beginning in the 1920s, efforts were made by the USDA to find natural enemies that attacked Japanese beetle in its native area (Japan, Korea, parts of China) and try to introduce them into the United States. This was done after it was observed that Japanese beetle is not a seriously damaging pest in its native area, largely due to there being more effective natural enemies attacking it. The organisms that subsequently became established in some area of North America, listed in the preceding section, were brought into the United States between the mid-1920s and the early 1950s.

All of these introduced natural enemies are highly specific in their effects, only attacking Japanese beetle or closely related insects in the same genus. (Note: There are no other scarab beetles in the genus *Popillia* in North America; these beetles are native to Asia.) None of the above organisms, including all those being considered for introduction into Colorado, have ever been found to attack any other kind of insect anywhere in the United States.

There are a couple of other species of white grubs that occur as pests in lawns in Colorado. In the Pueblo area the southwestern masked chafer (*Cyclocephala hirta*) is present. Elsewhere in the United States there are other native *Tiphia* wasps and milky disease that attack related insects (southern masked chafer, northern masked chafer); these species of grubs are not attacked by the natural enemies introduced for Japanese beetle. The kinds of native white grubs found in lawns sometimes in the Denver area, often known as “May” or “June” beetles (various species in the genera *Phyllophaga* and *Polyphylla*) are attacked by several native natural enemies, but they have never been seen anywhere in the US to be attacked by the natural enemies introduced for Japanese beetle.

Are any biological controls of Japanese beetle present in Colorado at this time? It is likely that at this time none of the above biological controls are present in almost all areas where Japanese beetle is present in Colorado.

In some places people have purchased milky spore (*Paenibacillus popilliae*) and applied it to lawn areas. Where this has occurred, this organism may have established. Establishment of milky spore in Colorado has not been confirmed.

In two sites, one in Boulder the other in Pueblo, a pilot attempt to introduce of *Ovavesicula popilliae* was made in July 2015 in coordination with the Colorado Department of Agriculture. This involved collecting beetles infected with this organism from Michigan, then freezing the beetles before they were shipped to Colorado. The dead, frozen beetles that contained the JB-pathogen were applied to soil where Japanese beetle larvae were feeding. Evaluations of both these sites in 2017 indicated that it was present, indicating establishment at the release site.

A proposal is presently (March 2018) under consideration for a comprehensive plan to transfer natural enemies of Japanese beetle from the eastern United States into Colorado. No funding has been identified yet to support this effort, but some progress in this effort should be made during this year.

How effective is milky spore to control Japanese beetle? Not very effective. Milky spore disease, caused by infection with *Paenibacillus popilliae*, may cause a low-grade infection in larvae but typically only kills or seriously harms a small percentage of the Japanese beetle

population - a few percent of the total (at most). Also, when applied to lawns it should not be expected to provide any reduction in grubs in lawns or adults on leaves and flowers in the season when it is applied.

Milky spore is the only biological control commercially available that can be reasonably expected to persist and spread in an area once it has been introduced. (The present supplier of milky spore is St. Gabriel Organics.) When it has spread over a wide area one might expect an ongoing, small reduction (less than 5 percent) in the overall numbers of beetles present.

Japanese beetle larvae (grubs) become exposed to *Paenibacillus popilliae* when they ingest spores of the bacterium, which can remain viable in soil for years. If enough spores are ingested to produce a successful infection, the bacteria multiply in the midgut of the insect. If the disease progresses, the bacteria enter the body cavity and can multiply in the blood. If very high numbers of the bacteria develop so many spores are produced that the insect's blood it turns a milky-white color. Seriously infected insects usually die and, upon death, allow large numbers of the spores to be released in the soil, where they may produce future infections.

How effective is *Ovavesicula popilliae* for control Japanese beetle? *Ovavesicula popilliae* seems to have far greater potential to significantly affect Japanese beetle than does milky spore. In Michigan, where it has been most extensively studied, it typically infects over 30% of the Japanese beetle population. Furthermore, where the disease is present there appears to have been a trend of significant Japanese beetle decline in association with increased infection with this pathogen.

Ovavesicula popilliae is not an organism that is commercially available. Instead, *O. popilliae* - and the various insect predators of Japanese beetle - can only be introduced and distributed in coordination with state and federal agencies. Releases of these non-native organisms require review and permitting before they can be considered for transfer into Colorado.

Like milky spore, *O. popilliae* produces long-lived spores that infect Japanese beetle larvae when they ingest them. The primary tissues in a Japanese beetle that become infected are the Malpighian tubules, organs that are used to excrete waste and maintain water/salt balance. (An imperfect analogy would be the human kidney.) This produces causes a chronic disease that results in a variety of effects in both larvae and adults, including increased susceptibility of larvae to death during winter, shortened adult survival, and reduced reproduction.

What is beetleJUS (or beetleGONE! or grubGONE! or Btg)? A newly developed strain (*galleriae*) of the bacterium *Bacillus thuringiensis* (Bt) has selective effects on beetles in the scarab beetle family (Scarabaeidae) – which includes the Japanese beetle. *Bacillus thuringiensis* var. *galleriae* (**Btg**) is presently only available through mail order and is sold for either control of adult Japanese beetles (under the trade names beetleJUS and beetleGONE!) or for white grubs (under the trade name grubGONE! Other *Bacillus thuringiensis* insecticides that are made of different strains of the bacterium (e.g., *kurstaki*, *aizawi*, *tenebrionis*, *israelensis*) are not effective against Japanese beetle.

Like other *Bacillus thuringiensis* insecticides, Btg works as a stomach poison and must be eaten by the insect to have any effect. If a susceptible insect consumes some of the bacteria then proteins is produces work to damage the cells of the midgut of the Japanese beetle. This will normally cause the insect to soon stop feeding, and cease to cause plant injury. However, it may take several days for the insect to die. The Btg insecticides have fairly short persistence, a few days when applied to leaves or flowers. They do not reproduce and persist at a site (as do milky spore and *Ovavesicula popilliae*) and function to control Japanese beetle more in a manner like a short persisting insecticide.

Can I buy biocontrol organisms of Japanese beetle? A few of the biological control organisms that can attack Japanese beetle are commercially available. These include milky spore (used as a soil application to infect grubs), *Heterorhabditis* species of nematodes (used as a soil application to infect grubs), and the *Bacillus thuringiensis* var. *galleriae* (used as a spray to stop beetle feeding and to kill adults).

Some Colorado nurseries are presently (2018) carrying milky spore, but not many. This can be mail ordered – the product being marketed is St. Gabriel Organics Milky Spore.

The *Bacillus thuringiensis* var. *galleriae* products may be in some retail stores in 2018, but may not. The formulation beetleJUS is being sold mail order through Gardens Alive! For acquiring the beetleGONE or grubGONE formulations you likely will have to contact the manufacturer, Phyllom BioProducts.

The *Heterorhabditis* species of nematodes that can be used for control of the grubs are sold by many suppliers, all mail order. You can find these when searching the publication Biological Control Organisms for Insects and Mites.

Some of the biological controls *cannot be purchased*. These include all the insect parasitoids and predators (*Istocheta aldrichii*, *Tiphia vernalis*, *Tiphia popilliavora*) and the pathogen *Ovavesicula popilliae* that attack Japanese beetle elsewhere in the United States. These are all organisms that can only be introduced into Colorado through government programs and all require special permitting before they are allowed to be brought to the state. (These types of restrictions are used for almost any organism not presently in the state that is being considering for introduction and permanent establishment.) However, as indicated above, pilot programs are being develop by Colorado State University, in coordination with the Colorado Department of Agriculture, to attempt introduction of some of these in selected test sites during 2018.

Control of Japanese beetle white grubs in turfgrass

What kind of damage do Japanese beetle larvae cause to lawns? Japanese beetle larvae, a type of white grub, develop by feeding on the roots of grasses. Most damage occurs when the insects are in their last, largest stage and feeding most heavily - usually in late August and September.

The most obvious effect produced by white grub root pruning is drought stress, due to the inability of root-damaged plants to pick up enough water. This is well indicated in heavily

damaged turfgrass, which can often be easily rolled back, like newly laid sod. If plant damage is extensive and plants drought stress becomes severe, plants may be killed.

An indirect kind of injury and symptom of a white grub infestation in turfgrass is the appearance of night active predators - skunks and raccoons - that dig up lawn areas in search of grubs for food. Such digging may be extensive and can cause more harm to lawns than the grubs.

There are several other kinds of white grubs, native to Colorado, that also damage lawns in some parts of the state. Most common is the southwestern masked chafer, *Cyclocephala hirta*, which is present in both western and eastern Colorado. Certain May/June beetles (*Phyllophaga* species) can cause problems in lawns and pastures in eastern Colorado. These other white grubs, and their management, are discussed in Fact Sheet 5.516, Billbugs and White Grubs

What can be used to control Japanese beetle white grubs in lawns? There are several types of controls that can be used to control damage by Japanese beetle larvae (white grubs) in lawns, including cultural, biological and chemical controls. Often a mixture of two or more approaches works best.

What are cultural controls that can help control Japanese beetle damage to lawns? Mowing can affect the susceptibility of lawns to grub damage. This is because the size of the root mass increases along with mowing height. Therefore, turfgrass that is mowed higher and has a larger amount of roots can better tolerate root damage that does occur. Conversely, lawns mowed shorter will have a smaller mass of roots and plants become more susceptible to grub damage.

Watering can have several effects. Japanese beetle eggs and the tiny early stage larvae are very susceptible to drying. If the top couple of inches of soil in a lawn can be allowed to dry a bit during the time eggs are being laid and hatching - July and early August - then many may be killed. Since higher temperatures during this period tend to make plants be more susceptible to water stress, growing lawns in a manner that promotes deep root growth can allow the lawn to be more tolerant of some soil drying. One way that this can be achieved is through deep, but less frequent, irrigation during spring.

If grubs have already caused some root injury, usually in late August and September, then watering may need to be increased a bit to keep soils moist enough to promote regrowth of roots.

Japanese beetle larvae can develop on the roots of all cool-season turfgrasses (e.g., Kentucky bluegrass, tall fescue, perennial ryegrass), which constitute most all lawn grasses grown in Colorado. However, some warm season turfgrasses (e.g., bermudagrasses) are poor hosts for Japanese beetles.

Anything that can improve growing conditions - watering, fertilization, core aeration, mowing - can allow turfgrass plants to better tolerate root damage white grubs produce.

What are biological controls that can help control Japanese beetle larvae in lawns? Insect parasitic nematodes that can control white grubs have long been commercially reared

and made available by several suppliers. Insect parasitic nematodes, sometimes called "predator nematodes" or "beneficial nematodes", are minute (near microscopic) round worms that develop within various kinds of insects. They are generally provided on some moist media, such as a sponge, that may contain tens of millions of nematodes. These are then washed into a sprayer or large watering can and then applied to the lawn area. The insect parasitic nematodes then seek out and try to enter white grubs or other susceptible insects (e.g., cutworms, billbugs). If successful the nematode reproduces within the insect, killing it within a few days after infection.

There are several kinds of insect parasitic nematodes that are available; these occur in two genera, *Steinernema* and *Heterorhabditis*. *For control of white grubs, such as Japanese beetle, only nematodes in the genus Heterorhabditis are effective!* (*Heterorhabditis bacteriophora* is the most commonly sold species.) Nematodes in the genus *Steinernema* (e.g., *S. carpocapsae*, *S. feltiae*) cannot consistently penetrate white grubs and are not useful for their control.

Insect parasitic nematodes are applied somewhat like any spray product used for white grub control. However, they are living organisms and require some care for them to be used effectively. Most important is that they cannot tolerate drying. Applications should be made in as much water as is feasible to water them into the thatch/soil. It would be desirable to make sure the soil is moist before application but it is critical that the area be irrigated as soon as possible - within a few hours after application. During storage and application the nematodes also should not be exposed for long to direct sunlight or high heat. Insect parasitic nematodes are effectively used when grubs are present and soil temperatures are warm (e.g., mid-July to September).

A new biological control product that should be able to provide some control of white grubs is the *galleriae* strain of the bacterium *Bacillus thuringiensis*. The present formulation sold for control of white grubs in lawns is marketed as grubGONE! *B. thuringiensis* var. *galleriae* is appropriately applied around the time when peak egg hatch is expected to occur and young larvae are present, normally sometime in July. (Note: Other formulations of *Bacillus thuringiensis* var. *galleriae* are used to control adult Japanese beetles and discussed below. Trade names include beetleJUS! and beetleGONE!)

What are chemical controls used to control Japanese beetle larvae in lawns? There are four active ingredients found among the insecticides that are presently sold to control white grubs in lawns: imidacloprid, chlothianidan, chlorantraniliprole, and trichlorfon. The features of these four products, and their use, is summarized below:

imidacloprid

Trade name(s) commercial formulations: Merit, Mallet, Zenith, others
Trade name(s) retail formulations: Hi-Yield Grub Free Zone II, Bayer Advanced Complete Insect Killer for Soil & Turf (with beta-cyfluthrin), Bayer Advanced Season-Long Grub Control, Bonide Grub Beater
Insecticide class: neonicotinoid
Comments: Has moderate-long persistence but can provide season long control when applied as early as June when eggs are starting to hatch. Fairly fast (a couple of weeks) in

providing control of grubs following application. Moves systemically in plants. Hazardous to bees if applied when flowering plants in lawns are present during application. (Mowing before application greatly reduces this hazard.)

chlothianidan

Trade name(s) commercial formulations: Arena
Trade name(s) retail formulations: None at present for turfgrass use.
Insecticide class: neonicotinoid
Comments: Has long persistence. Can provide control if applied from May into August. Fairly fast (a couple of weeks) in providing control of grubs following application. Moves systemically in plants. Hazardous to bees if applied when flowering plants in lawns are present during application. (Mowing before application greatly reduces this hazard.)

chlorantraniliprole

Trade name(s) commercial formulations: Acelepryn
Trade name(s) retail formulations: Scott's GrubEx
Insecticide class: diamide
Comments: Has very long persistence but moves relatively slowly into soil. Best applied in May/June; some control possible with applications made in April or early August. Fairly slow (weeks) in providing control after application. Has some ability to move systemically in plants. Very low hazard to bees. Very low hazard to humans, pets.

trichlorfon

Trade name(s) commercial formulations: Dylox
Trade name(s) retail formulations: Bayer Advanced 24 Hour Grub Killer Plus Granules
Insecticide class: organophosphate
Comments: Trichlorfon has very short persistence but is fast acting. It is appropriately used to control existing problems with white grubs and must be watered in immediately after application. Breakdown is very rapid (days), particularly in high pH soils. Trichlorfon has fairly low hazard to bees; where flowering weeds are present mowing before application greatly reduces risk to pollinators.

When is the best time to apply treatments to control Japanese beetle larvae? It depends on the treatments being considered.

Chlorantraniliprole (GrubEx, Acelepryn) is slow-acting but quite persistent. It can be applied from early April through July to control Japanese beetle grubs that start feeding in mid-July to late July.

Products containing clothianidin (Arena) are somewhat less persistent but faster acting than chlorantraniliprole. These can be effective for control of Japanese beetle grubs when applied from May through August.

Products containing imidacloprid (Merit, Bayer Advanced Season-Long Grub Control, Hi-Yield Grub Killer II, others) are somewhat less persistent than chlothianidan and about as fast

acting. These can be effective for control of Japanese beetle grubs when applied from May through August.

Products containing trichlorfon (Dylox, Bayer Advanced 24 Hour Grub Killer) will persist for only a short period but it is extremely fast acting. It is used when larvae are present; it does not provide any residual control.

Insect parasitic nematodes (*Heterorhabditis bacteriophora*) have fair persistence and can be fast acting. They are effectively applied when larvae are present and soil temperature remain warm, typically late July through midSeptember.

Bacillus thuringiensis var. *galleriae* (grubGONE!) has short persistence. It is effectively applied around the time when peak egg hatch is occurring, typically late July and early August.

Does it help to try and control grubs in spring? There is no benefit to treating grubs in lawns in spring. The grubs present in spring, which survived through winter and are in their final phase of development, can rarely produce any significant damage to lawns in spring, which are rapidly growing at the time and can well tolerate the root feeding that does occur.

Furthermore, most insecticides applied in spring do not remain effective long enough to be able to control white grubs that hatch from summer-laid eggs and which are more likely, in late summer, to cause turf damage.

Another consideration with spring applications is that there is greater risk to pollinators if the lawn area supports flowering plants such as dandelions, violets and clovers. These can be highly attractive to many kinds of bees, and are usually past bloom by late spring. Certain insecticides used for grub control that move systemically in plants (imidacloprid, chlothianidan) have highest potential to appear in nectar and pollen if applied at or shortly before plants are in flower.

The only insecticide applied in spring that can be expected to kill Japanese beetle grubs present in spring is trichlorfon.

Can insecticides used for Japanese beetle grubs affect pollinators? In turfgrass sites that are pure grass, flowers are not present that would attract pollinators. In these situation there is essentially no hazard to pollinators no matter what insecticide is used for grub control. However, potential problems can occur if there are flowering plants (dandelions, white clover, etc.) that are attractive to and visited by bees.

In lawn areas where pollinator attractive flowering plants are present, the risk from an insecticide application *can be greatly reduced* if the lawn is mowed before application, removing the blossoms. No insecticides should ever be applied to any plants that are flowering and attracting pollinating insects.

The type of insecticide being applied also greatly affects the potential hazard to pollinators. Imidacloprid and chlothianidan are quite toxic to bees and have fairly long residual effects. These would produce the greatest potential for risk to pollinators. Chlorantraniliprole*, Bacillus thuringiensis* var. *galleriae* and insect parasitic nematodes are grub treatments that have very little, if any, hazard to pollinators when applied to turfgrass.

How much does control of Japanese beetle white grubs on one's property affect later problems with adult Japanese beetles on the property? *There will be very little, if any, association between the number of white grubs that successfully develop on a property and the number of adults one will subsequently see on plants during summer.* That is because Japanese beetle is an extremely mobile insect that regularly flies considerable distances, causing them to thoroughly remix over a large area. As a result it can be expected that most Japanese beetles present in a yard originated some distance away.

If everyone over a large area were able to well control all the Japanese beetle larvae developing in their lawns, how much difference would that make in later problems with adult Japanese beetles? If there were intensive efforts to control all Japanese beetle grubs in all properties over a large area (e.g., many square blocks) then it is reasonable to expect that properties in the center of this area would likely see fewer adult beetles in the year following treatment. Properties closer to the edges of the treated area would likely see very little, if any, effect since they would be readily colonized by adult beetles originating outside the treated area. Any suppression that did occur would only be able to be maintained with annual treatments.

Will Japanese beetle grubs develop on roots other than turfgrass? David Shetlar of the Ohio State University provided some comments on this subject:

"It has been my experience that JB adult females are able to discern green and they will prefer to lay their eggs under green surfaces…. When nurseries keep the weeds and grasses out of their tree rows, they rarely have JB grubs. However, the eggs can be laid in the grass strips between the trees and an occasional grub will crawl into the no-grass zone.

"In the case of potted nursery stock, some of these holdings are packed tightly and, to the beetle, the area looks like it is covered with green. When they land on the plants, they can drop to the soil, which is often not really soil, but a high-organic potting mix. This appears to be acceptable to the female beetles for egg laying.

"Remember that most of our turf scarabs are eating and digesting organic matter and thatch is a great source. It just so happens that turf roots and crowns are also in that zone. So, when potting mixes have undigested organic matter as part of the mix, this can support grub growth."

Can Japanese beetle grubs develop in compost piles? Theoretically yes, but realistically this is not likely to occur and would be insignificant. The question above this indicates the kinds of conditions that could theoretically allow Japanese beetles to get into compost – 1) thickly growing plants attractive to the adults growing above the compost, which 2) allows some adults to drop to the surface of the compost where 3) they may then lay some eggs which 4) could result in some larvae that were successfully surviving by feeding on the decaying organic matter.

However, there is a native species of white grub that is very commonly associated with compost, particularly compost that has some animal manure in it. This is the larva of the **bumble flower beetle**, *Euphoria inda.* The adults of this insect are fairly commonly seen

visiting ooze from wounded or bacterial infected plants or at flowers that produce large amounts of pollen (e.g., lilies, some thistles) that collect and decay.

Control of Japanese beetle adult damage to leaves and flowers

What kind of damage do adult Japanese beetles cause to garden and landscape plants? The adult beetles chew leaves and flowers. Leaves are typically damaged in a manner that is quite distinctive, known as skeletonizing, where feeding occurs between the main leaf veins, producing a damage that makes the leaves look lacy. Flower feeding by beetles is largely restricted to the petals. Injury typically is concentrated on upper parts of plants that are sun-exposed.

What kinds of plants are most often damaged by Japanese beetle in Colorado? A partial list of the plants that Japanese beetle most seriously damage would include:

Virginia creeper*	Grape
Rose (most)**	Linden*
Silver lace (*Polygonum aubertii*)**	Gaura**
Rose of Sharon**	Hollyhock*
Raspberry*	Crabapples (some)
Japanese maple	Peking cotoneaster
Beans (green, edamame)	Basil

Japanese beetle will feed on the flowers of several of these plants, notably rose, silver lace, gaura, Rose of Sharon, and hollyhock. Furthermore, many of these plants produce flowers that are attractive to and visited often by some pollinator insects, notably bees. Plants that are in flower during part of the time when Japanese beetle adult are present are indicated by a single asterisk *. Plants that may be blooming the entire time when Japanese beetles are present on the plant are indicated by two asterisks **.

What can be used to control damage by adult Japanese beetles? There are several things that are used to limit damage by adult Japanese beetles including hand picking, trapping, use of plants that Japanese beetle avoid, and insecticides.

How useful are traps to control Japanese beetle? The Japanese beetle trap is extremely effective in capturing Japanese beetles. Because of this it has been an invaluable tool to quickly detect Japanese beetle when it has moved into a new area and to monitor its spread following establishment.

However, it has been repeatedly demonstrated that traps are not effective *for controlling damage by Japanese beetle* once it has become well established and is present over a wide area. This is because the traps capture only a fraction of the adults in an area. Furthermore, the lures used in the traps are highly attractive to the beetles and will have the effect of drawing beetles to the area from long distances. The net effect of this is that plants growing in the near vicinity of a Japanese beetle trap will usually be more damaged than if a trap was not present.

Where Japanese beetle occurs in low numbers in a small, isolated area - such as occurred in Palisade in 2003 - then using a large number of traps spread through the area can help suppress Japanese beetle. That is not the situation that occurs in eastern Colorado at this time.

If I crush a Japanese beetle, does it attract more Japanese beetles? No it does not.

Japanese beetles will often be seen massed on a plant when feeding, which indicates that there is some kind of signal involved in bringing them together. However, the attractant that causes masses of Japanese beetles are compounds produced by the plant in response to the wounds the beetles make when they are feeding (along with the attractants plants normally produce even when not wounded).

The only chemicals that Japanese beetles produce that are attractive to other Japanese beetles are the sex pheromones produced by virgin females shortly after they emerge from the soil in early summer. Females only produce this pheromone for a brief period, ceasing production after they mate, which happens very soon after they emerge from the soil.

Can Japanese beetle eggs still hatch if the adult beetle is killed? No they cannot. Any eggs remaining in the adult beetle when it is killed will not be able to hatch nor would they occur in a place where they could survive if they did hatch (in moist soil within the root zone of a host plant or amidst suitable decaying plant matter).

How effective is handpicking to manage Japanese beetle? Handpicking can be effective for control of Japanese beetle in some situations and may be the most effective and most appropriate treatment in small plantings.

There are two benefits from handpicking. One is that there is an immediate reduction in the number of beetles on plants when they are collected. Also, by removing the beetles, that stops further plant injuries caused by feeding - and thus reduces the amount of attractants the plants produce in response to feeding injuries. As a result it can be expected that there will be fewer new beetles drawn to the plants.

Japanese beetles are perhaps the easiest of all insects to hand pick from plants. They will usually drop readily from plants when disturbed and can easily be collected in a can placed under the insects. A collecting can usually contains water; a small amount of soap/detergent in the water is advisable to break the surface tension of the water causing the collected beetles to readily drown.

Although Japanese beetles can be hand collected at any time, it is probably most efficient when done late in the day or early in the day. Temperatures are cooler and it is darker at these times, causing the beetles to remain still on plants, which allows them to be more easily collected. When temperatures have warmed and it is sunny beetles more often escape from collection by flying away.

However, hand picking may not be adequately effective in some situations, particularly those that involve JB infestations on highly attractive flowers. That is because these flowers may produce significant chemical attractants and have colors that are strongly attractive to Japanese beetle adults. This can cause continued recruitment to the plant even if hand

picking has removed all the beetles (and stopped new injuries with the attractants produced by wounding).

What should I do with the collected Japanese beetles? Anything you want. They can be discarded in the trash, composted, buried in the garden or dumped on the ground. Since the dead beetles are not attractive to live beetles it makes no difference.

Can Japanese beetles be safely fed to animals? Japanese beetles are not toxic to animals and many insect-eating birds and mammals will readily feed on them.

One fairly extensive livestock use of Japanese beetles is to feed chickens. Often this is done by using a Japanese beetle trap to attract the insects, which are then funneled to an area where the chickens will eat them.

Can insecticides used to control adult Japanese beetles affect pollinators? If Japanese beetles are only feeding on the leaves and the plant does not produce flowers that attract pollinators, there is essentially no hazard to pollinators no matter what insecticide is used. However, very real problems can occur if Japanese beetles are feeding on flowers or visiting plants that have flowers that are attractive to and being visited by bees.

The type of insecticide being applied also greatly affects the potential hazard to these pollinators. Some of the most effective insecticides for controlling Japanese beetle have fairly long persistence on the plant and can kill Japanese beetles – and bees – for several days after being sprayed.

Insecticides that are highly toxic to bees and have effects that persist for days include all of the pyrethroids (bifenthrin, beta-cyfluthrin, gamma-cyhalothrin, permethrin), carbaryl (Sevin), and imidicloprid. *None of these insecticides can be applied to plants that are in flower and are being visited by bees.* They can be used after all blossoming has passed.

Some insecticides have lower toxicity to bees or have such short persistence (hours) that they can be used safely on plants if they are applied at times of the day when bees are not visiting – very early in the morning or at dusk. Pyrethrins, azadirachtin, and acetamiprid are insecticides that can be safely used in this manner.

Two insecticides used for Japanese beetle control that pose minimal risk to pollinators are *Bacillus thuringiensis* var. *galleriae* and chlorantraniliprole. The former is a biological control recently marketed as beetleJUS or beetleGONE!, both of which are presently available only through mail order. The insecticide chlorantraniliprole, marketed as Acelepryn, also provides very low hazard to bees, but is only marketed to commercial applicators. Both of these insecticides allow use on plants that are flowering.

What are chemical controls used to control adult Japanese beetle larvae feeding on leaves and flowers? There are quite a few active ingredients among the insecticides used to control adult stages of Japanese beetle. These vary considerably in their ability to control Japanese beetle, their hazard to desirable insects (e.g., pollinators), plants on which they can be legally used, and other features, as summarized below:

acetamiprid

Trade name(s) commercial formulations: Tristar
Trade name(s) retail formulations: Ortho Flower, Fruit, and Vegetable Insect Killer
Insecticide class: neonicotinoid
Labeled for use on food crops: Label allows use on some fruits and vegetables.
Hazard to bees: Acetamiprid has much lower toxicity to bees than do other neonicotinoid insecticides but is hazardous to bees if directly sprayed. Can be used on plants that are in blossom but cannot be applied at times when bees are visiting (e.g., dusk, dawn).
Comments: Applied as a spray and provides moderate persistence (days-week) of control of Japanese beetle damage. Moves systemically within plants.

azadirachtin

Trade name(s) commercial formulations: Azasol, Azamax, others
Trade name(s) retail formulations: Bioneem
Insecticide class: unclassified, natural product (derived from neem seed)
Labeled for use on food crops: Yes.
Hazard to bees: Hazardous to bees if directly sprayed. Has residual effect of about a day. Can be used on plants that are in blossom but cannot be applied at times when bees are visiting (e.g., dusk, dawn).
Comments: Applied as a spray and provides short persistence (couple days) of control of Japanese beetle damage.

Bacillus thuringiensis var. *galleriae*

Trade name(s) commercial formulations: beetleGONE!
Trade name(s) retail formulations: beetleJUS!
Insecticide class: microbial
Labeled for use on food crops: Yes.
Hazard to bees: Very low hazard. Can be applied to plants that are in flower and are being visited by pollinators.
Comments: *Bacillus thuringiensis* (Bt) var. *galleriae* is a newly commercialized strain (*galleriae*) of Bt that works on certain kinds of beetles, including scarab beetles/white grubs such as the Japanese beetle. It is a stomach poison, which must be eaten by the susceptible insect for it to be effective. The most immediate effect from this insecticide is that the insect stops feeding, due to disruption of its digestive system. It is a slow acting insecticide and may take a few days to kill a Japanese beetle; during much of this time the still alive - but no longer feeding - beetle will remain on the plant. Persistence of effect seems to be several days.

bifenthrin

Trade name(s) commercial formulations: Talstar, Onyx, others
Trade name(s) retail formulations: Ortho Max Insect Killer for Lawns and Gardens (also contains cypermethrin)
Insecticide class: pyrethroid
Labeled for use on food crops: No

Hazard to bees: Extremely hazardous to bees and has residual effect of several days. Cannot be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides moderate-long persistence (week+) of control of Japanese beetle damage.

carbaryl

Trade name(s) commercial formulations: Sevin, Carbaryl
Trade name(s) retail formulations: Sevin
Insecticide class: carbamate
Labeled for use on food crops: Label uses include many vegetables and some fruit crops.
Hazard to bees: Extremely hazardous to bees and has residual effect of several days. Cannot be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides moderate persistence (several days - week) of control of Japanese beetle damage.

chlorantraniliprole

Trade name(s) commercial formulations: Acelepryn
Trade name(s) retail formulations: None
Insecticide class: diamide
Labeled for use on food crops: No
Hazard to bees: Very low hazard to honey bees and there is no label restriction for use on flowering plants. Can be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides moderate-long persistence (week+) of control of Japanese beetle damage.

beta-cyfluthrin

Trade name(s) commercial formulations: Tempo
Trade name(s) retail formulations: Bayer Advanced Rose and Flower Insect Killer (with imidacloprid), Bayer Advanced Vegetable and Garden Insect Spray
Insecticide class: pyrethroid
Labeled for use on food crops: Vegetable and Garden Insect Spray and Tempo formulations allow use on many commonly grown vegetables. Bayer Advanced Rose and Flower Insect Killer is not labeled for use on any food crops.
Hazard to bees: Extremely hazardous to bees and has residual effect of several days. Cannot be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides moderate persistence (several days - week) of control of Japanese beetle damage.

gamma-cyhalothrin

Trade name(s) commercial formulations: None
Trade name(s) retail formulations: Triazicide Insect Killer for Lawns and Landscapes
Insecticide class: pyrethroid
Labeled for use on food crops: Labeled for use on many vegetable and most fruit crops.

Hazard to bees: Extremely hazardous to bees and has residual effect of several days. Cannot be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides moderate-long persistence (week+) of control of Japanese beetle damage.

imidacloprid

Trade name(s) commercial formulations (foliar and soil application): Merit, Mallet, Zenith, others
Trade name(s) retail formulations (soil application): Bonide Annual Tree & Shrub Control, Bayer Advanced Rose & Flower Insect Killer (with beta-cyfluthrin), Bayer Advanced 3-in-1 Insect, Disease and Mite Control (with tau-fluvalinate, tebuconazole)
Trade name(s) retail formulations (foliar application): Bonide Systemic Insect Spray, Bayer Advanced 2-in-1 Systemic Rose & Flower Care, Bayer Advanced Tree & Shrub Protect & Feed (with chlothianidan), Bayer Advanced Fruit, Citrus and Vegetable Insect Killer Hi-Yield Systemic Insect Granules, Ortho Bug B Gon Year-Long Tree & Shrub Insect Control, ferti-lome Tree & Shrub Systemic Insect Drench
Insecticide class: neonicotinoid
Labeled for use on food crops: Variable, depending on formulation. Many products that have imidacloprid as the sole active ingredient also allow use on some fruits and vegetables. Products that are combine with a fungicide (tebuconazole) or another insecticide (tau-fluvalinate, chlothianidan, beta-cyfluthin) cannot be applied to fruits, vegetables or other food crops.
Hazard to bees: High hazard to bees. Can move systemically into nectar and pollen. Label directions often include the following statement:

> "Do not apply when bees are foraging. Do not apply this product to plants that are flowering. Only apply after all petals have fallen off."

Comments: Imidacloprid can be applied both as a spray or soil treatment, which is picked up by roots. When used as a spray it degrades fairly quickly in sunlight, but likely could provide control for several days, perhaps a week. When used as a soil treatment it is applied to the roots and the area is then soaked. Movement of the insecticide into the soil and uptake by from roots is fairly slow; effects of treatment may not begin to be noticeable for 2-3 weeks. Once within plants it can persist and control Japanese beetle feeding on leaves for a few weeks. *Soil applications of imidacloprid cannot prevent damage to rose flower petals*.

permethrin

Trade name(s) commercial formulations: Astro, Permethrin, others
Trade name(s) retail formulations: Bonide Eight Insect Control Vegetable, Fruit & Flower; Bayer Advanced Complete Insect Dust for Gardens; Ace House & Garden Bug Killer2
Insecticide class: pyrethroid
Labeled for use on food crops: Label uses include most vegetable and many fruit crops.
Hazard to bees: Highly hazardous to bees and has residual effects capable of harming bees that can last a few days. Cannot be used on plants that are in blossom and bees are visiting.
Comments: Applied as a spray and provides short persistence (days) of control of Japanese beetle damage.

pyrethrins

Trade name(s) commercial formulations: Pyrenone, Pyganic, others
Trade name(s) retail formulations: Many retail formulations for garden use exist
Insecticide class: pyrethrins, natural product (derived from flowers pyrethrum daisy)
Labeled for use on food crops: Yes.
Hazard to bees: Hazardous to bees if directly sprayed. Has residual effect of hours. Can be used on plants that are in blossom but cannot be applied at times when bees are visiting (e.g., dusk, dawn).
Comments: Applied as a spray and provides very short persistence (day) of control of Japanese beetle damage.

Can systemic insecticides be used to control of adult Japanese beetle adults? Two of the insecticides used to control Japanese beetle can move systemically in plants, imidacloprid and acetamiprid.

Imidacloprid is normally used as a soil treatment, with the insecticide being picked up by the roots and moved through much of the plant, particularly to the new foliage. When applied to the soil it may begin to control Japanese beetle in about a week or two if the soil is moist and may provide control of beetles feeding on leaves for a few weeks. It is not very effective for control of adult beetles that are feeding on flowers. Imidacloprid can also be applied as a spray, and is found in some retail formulations mixed with the pyrethroid insecticide beta-cyfluthrin.

However, imidacloprid is highly toxic to bees and with its ability to persist can be quite hazardous to these pollinators. Because of this hazard, imidacloprid cannot be applied to plants that are in flower that are visited by bees. It can be used on plants that do not produce flowers that are attractive or after blossoming has passed for the year.

Acetamiprid is a systemic insecticide that is used as a spray and can control adult beetles for several days. It is much less toxic to bees than is imidacloprid and can be used on plants with flowers if the application is made at a time of day when bees are not visiting the plant – very early in the morning or at dusk.

Insecticides containing azadirachtin or chlorantraniliprole have a some limited ability to move systemically in plants, much less than acetamiprid or imidacloprid.

What kinds of commonly used sprays are not effective for control of Japanese beetle damage to leaves and flowers? A partial list of products that have failed to control Japanese beetle in CSU trials would include the following active ingredients:

capsaicin
canola oil
cottonseed oil
garlic oil
horticultural oils (mineral oils)
insecticidal soap
neem oil
rosemary oil
spinosad
thyme oil

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