CIRCULAR No. 332 DECEMBER 1934
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

GENERAL INFORMATION ABOUT THE JAPANESE BEETLE IN THE UNITED STATES[1]

By C. H. Hadley, *principal entomologist*, and I. M. Hawley, *senior entomologist, Division of Japanese and Asiatic Beetles, Bureau of Entomology and Plant Quarantine*

CONTENTS

INTRODUCTION

In 1916 a few conspicuous green and brown beetles were found near Riverton, N. J. They were identified by entomologists as Japanese beetles (*Popillia japonica* Newm.), previously known as occurring only on the main islands of Japan and then found in the United States for the first time. From this small beginning the insect has multiplied and spread until by the end of 1933 it had been found at one or more points in each of 17 States. Observations and experience have shown unmistakably that the beetle has found conditions, in the eastern part of the country at least, ideally suited to its rapid multiplication. There it encounters an abundance of favored food plants, and native parasites to hinder its development are almost totally lacking.

Farmers, fruit growers, and home owners in the area longest infested have not only come to know the beetle but have been forced to learn how to get along with it, even though the association has

[1] This circular summarizes and brings up to date the general information given in Department Circular 363, The Japanese Beetle, which is now out of print. It does not tell how to combat the Japanese beetle. Information on measures for controlling this insect under various conditions may be found in the following publications: Circular 238, Control of Larvae of the Japanese and the Asiatic Beetles in Lawns and Golf Courses, by W. E. Fleming and M. R. Osburn; Miscellaneous Publication 201, Traps for the Japanese Beetle and How to Use Them, by F. W. Metzger, Circular 317, Protection of Orchard and Shade Trees and Ornamental Shrubs from Injury by the Japanese Beetle, by W. E. Fleming, F. W. Metzger, and M. R. Osburn; Circular 326, Protecting Plants in the Home Yard from Injury by the Japanese Beetle, by W. E. Fleming, F. W. Metzger, and M. R. Osburn.

82324°—35——1

been unpleasant at times. As the range of the insect increases each year, new groups of people will meet the invader for the first time; and it is with a desire to acquaint such persons with the appearance, life history, and native and imported enemies, and especially with the destructive feeding habits of this insect, that this circular has been prepared.

WHERE THE JAPANESE BEETLE OCCURS IN THE UNITED STATES

At the close of the 1933 season the area everywhere infested with the Japanese beetle was estimated at approximately 8,800 square miles, of which 6,000 was in New Jersey, 2,120 in Pennsylvania, 560 in Delaware, 50 in Maryland, and 70 in New York. This territory, called the area of continuous infestation, has been covered by the beetles as they have moved outward each summer in an ever-widening circle at a rate of from 5 to 10 miles a year. This continuously infested area is small as compared with the vast territory in the United States still open to invasion, but even within this relatively small area the Japanese beetle is much more abundant in some localities than in others. For several years there have been fewer beetles than formerly in those parts of New Jersey and Pennsylvania where they first occurred, and in certain other places more recently infested the beetles are now at the peak of their abundance. These facts should offer some consolation to persons living in districts now heavily infested, for, if past history is a reliable criterion, the beetle population should soon begin to fall off in such places. The area of continuous infestation and the relative abundance of the beetle are shown in figure 1. The greatest destruction in 1933 was in the almost-black area shown in southern New Jersey.

Outside the area where beetles are everywhere present is a large territory, known as the area of discontinuous infestation, where they are found chiefly in isolated local colonies. The points where beetles have been found up to and including 1933 are shown in figure 2. In some of the places where such local colonies have been found, as in Bridgeport, Conn., Springfield, Mass., and Washington, D.C., Japanese beetles are now present in considerable numbers, but in most places they are still so scarce or locally concentrated that they seldom attract the notice of the average resident. It is not certain that beetles are now (1933) present at all points shown on the map, as many of the places have not been rechecked to determine whether the insect has become established, and in a few places no beetles were found when a recheck was made.

HOW JAPANESE BEETLES SPREAD

Japanese beetles are active fliers, and the natural yearly expansion of the area continuously infested has been due largely to this fact. When in flight, beetles are often aided in their spread by the winds prevailing at the time. Sometimes they can be seen in large numbers flying against the wind, but this is the case only when they are attracted to neighboring vegetation by the odor carried to them by the wind.

In the summer of 1933 many beetles were carried by wind from the heavily infested area in southern New Jersey out over Delaware Bay. After falling into the water, many drifted about until

washed up on the opposite shore in Delaware. Twenty percent of those examined were still alive. From this observation it is apparent that water barriers as wide as Delaware Bay form only a partial obstacle to the spread of the insect. A similar flotation of beetles

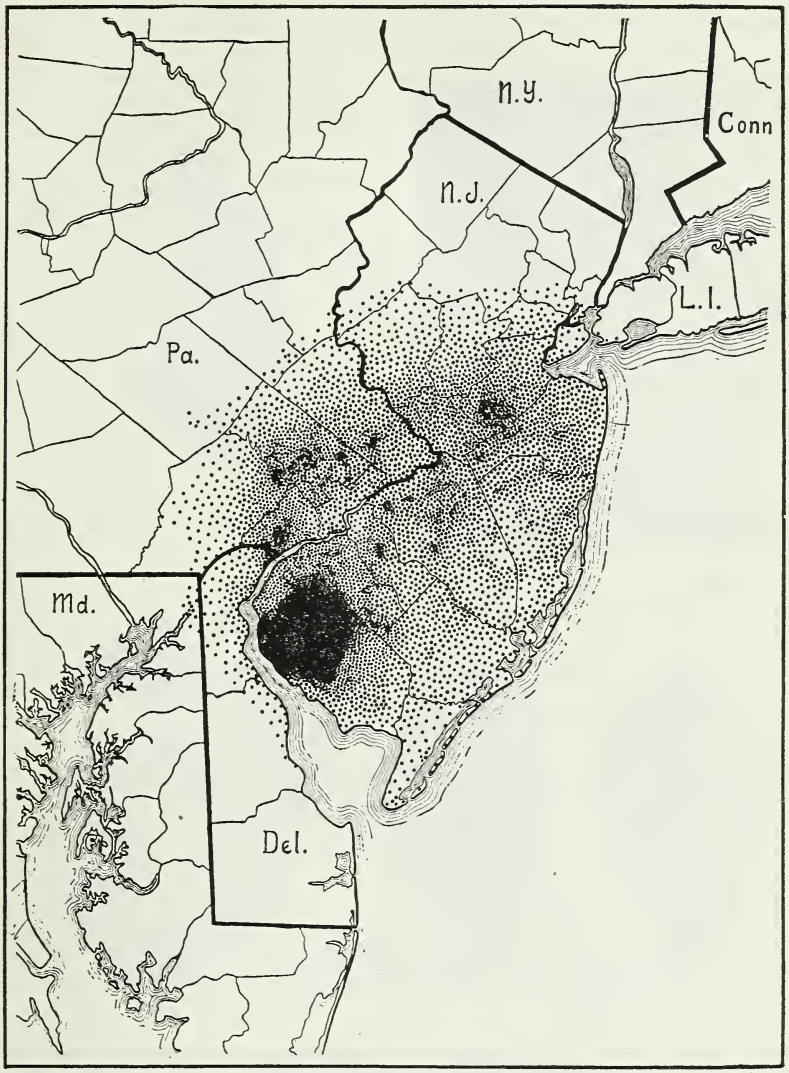


FIGURE 1.—The area of continuous infestation covered in the natural spread of the Japanese beetle by the end of 1933. The density of the stipples indicates the relative abundance of the beetle.

from the New Jersey shore to Staten Island and Long Island has been observed. It would be impossible by any means now known to stop the dispersion of beetles by such agencies as wind and water.

The influence of modern agencies of transportation and commodity distribution upon the artificial dispersion of an insect is well illus-

trated in the case of the Japanese beetle. There is always danger of the beetles being carried into uninfested territory by such agencies as automobiles, boats, and freight and passenger trains. When beetles are in flight, they frequently fly into such carriers and are transported long distances into hitherto unoccupied territory. Beetles have been found in farm produce grown in infested areas, and this indicates that they might be shipped with it to distant markets. The movement of nursery plants with soil about the roots containing the larvae is another possible means of spread. The possibility of dispersion by these means has been realized for many

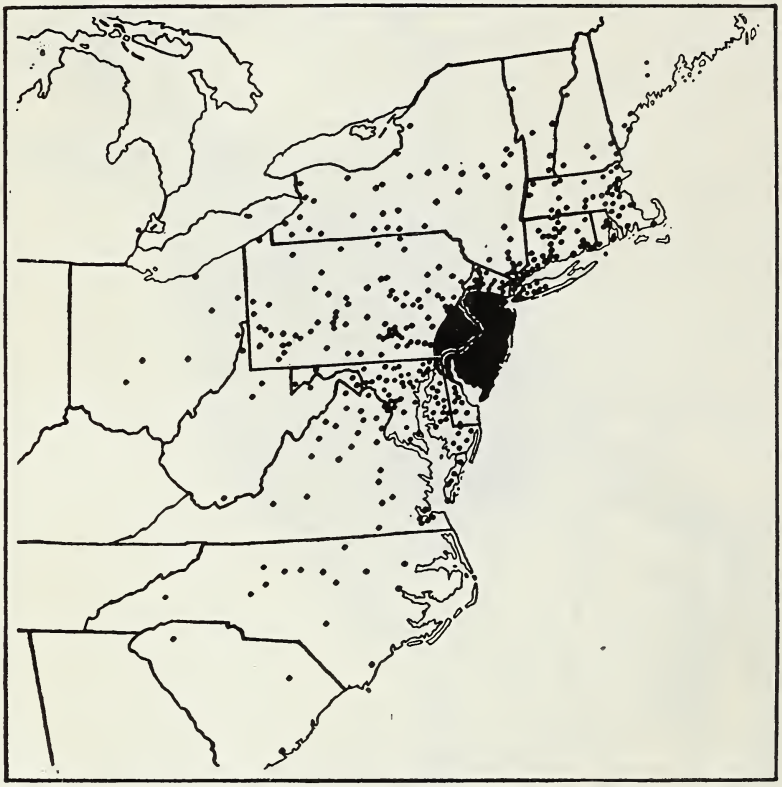


FIGURE 2.—Distribution of the Japanese beetle up to and including 1933. The black area indicates the area of continuous infestation; the dots, places at which local colonies have been found.

years, and strict quarantines have been in force to restrict such spread. That the dispersion of the Japanese beetle in the United States has not been much more wide-spread may be credited to the enforcement of Federal and State quarantine restrictions on the movement of various carriers and products.

HOW TO RECOGNIZE THE JAPANESE BEETLE IN ITS DIFFERENT STAGES OF DEVELOPMENT

The adult, or beetle (fig. 3, *A*), is nearly half an inch long, one-fourth inch wide, broadly oval, and shining metallic green. The

hard wing covers are a coppery brown and extend from the thorax almost, but not quite, to the extreme hind end of the body. There are 2 small tufts of white hairs just behind the wing covers and 5 patches along each side, which enable one to distinguish the Japanese beetle from other beetles that resemble it. The males are usually smaller than the females and may be distinguished from them by

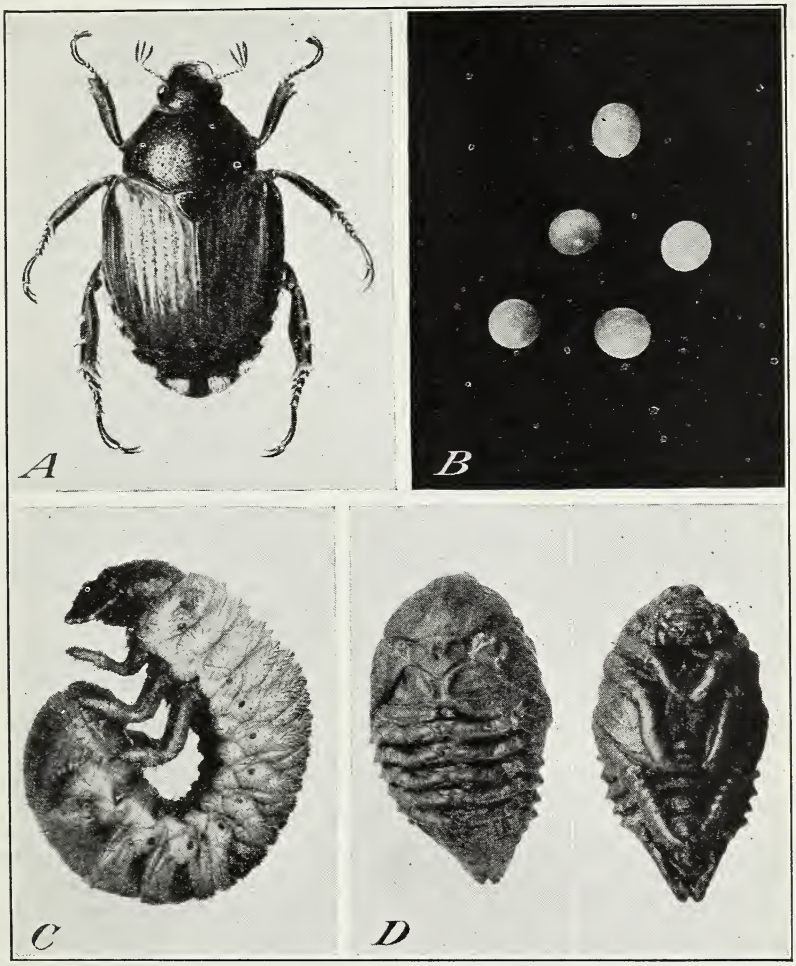


FIGURE 3.—The Japanese beetle in its different stages of development: *A*, Adult, 3½ times natural size; *B*, eggs, 4 times natural size; *C*, full-grown or third-instar larva, about 3 times natural size; *D*, pupa, dorsal (left) and ventral (right) views, about 3 times natural size.

the structure of the first pair of legs. By examining beetles with a magnifying glass or low-power lens, it will be seen that the tibial spur of the male is much more pointed than that of the female, as shown in figure 4.

The eggs (fig. 3, *B*) are elliptical, translucent, and white or cream in color. When first laid, they are about one-sixteenth inch in

diameter, but after being in the ground for about a week they swell to double this size and assume a more nearly spherical shape.

The newly hatched larva, or grub, is about one-sixteenth inch in length, has three pairs of legs, and has the general shape of a blunt-ended crescent. By the time it is full-grown (fig. 3, *C*) it is about 1 inch long and resembles in general appearance the larvae of June beetles, commonly known as "white grubs", from which it may be distinguished by structures shown in figure 15. When mature, the larva gets rid of the accumulated excrement, takes on a pale, shrunken appearance, and changes to an almost inactive condition, in which it is called a prepupa and in which internal changes occur preparatory to transformation to the pupal stage.

The pupa (fig. 3, *D*) resembles somewhat the mature beetle, except that the legs, antennae, and wings are closely folded to the body. It is pale cream in color, soon becoming a more pronounced tan, and is about one-half inch long and one-fourth inch wide. The change to the adult beetle occurs when the outer skin enclosing the pupa splits, permitting the mature beetle to emerge.

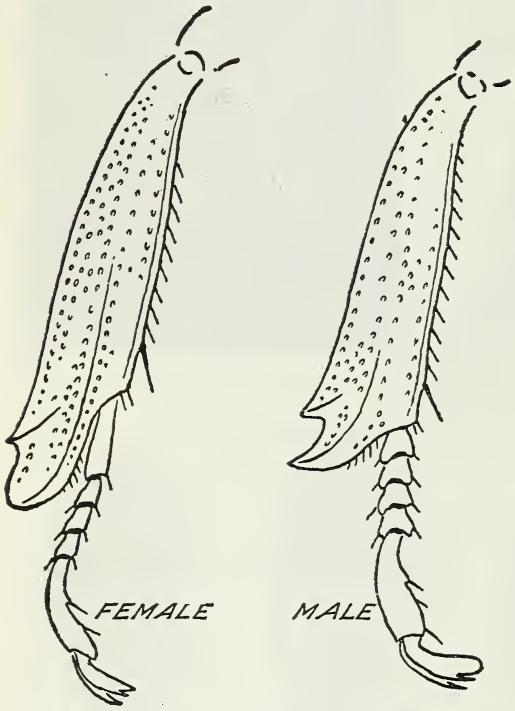


FIGURE 4.—Portions of the first pair of legs of male and female beetles, showing structures by which they may be distinguished.

SEASONAL HISTORY AND HABITS

Between June 10 and 20, in the latitude of Philadelphia, the first Japanese beetles may be expected to emerge from the soil, and in an average season by July 5 they are present in considerable numbers. On reaching the surface of the ground they fly to or crawl upon some plant nearby and proceed to feed upon its foliage or flowers. Mating of the sexes may occur soon after emergence, and is repeated at frequent intervals throughout the summer. Mating usually takes place while the beetles are on the food plants, but it may also occur in other situations, such as, early in the beetle season, on turf, where the conspicuous "balling" of the beetles may be observed. Early in the emergence season the males greatly outnumber the females, and the "balls" result from the efforts of a large number of males to attach themselves to one female.

On warm, sunny days the beetles feed and fly about vigorously, going from one plant to another; and as they are naturally grega-

rious, they tend to collect in groups and to feed on certain plants while leaving other plants, apparently equally attractive, untouched. After feeding, the females enter the ground to lay their eggs. For egg deposition beetles prefer medium-moist loamy soil with closely cropped grass such as would be found in lawns or pastures. Golf greens they find ideal for this purpose, but some eggs are always placed in less favorable situations, such as flower beds and cultivated ground. After burrowing to a depth of 2 to 4 inches, the female beetle deposits from 1 to 3 or 4 eggs at one time (fig. 5), and then after emerging and spending a day or two aboveground feeding, returns to the soil to deposit another complement of eggs. The majority of the eggs are laid at night, although egg laying may also take place during the day. This procedure goes on until about the middle of August, by which time a total of from 40 to 60 eggs have been laid. Both sexes feed voraciously throughout the summer, especially on warm, sunny days; the peak of the feeding season usually occurs the last of July or the early part of August, and thereafter the dead bodies of the beetles may be readily found beneath the plants on which they have been feeding. The normal life of a beetle is from 30 to 45 days, but since some of the beetles emerge later than others, they are found flying in diminishing numbers as late as October.

The eggs hatch about 2 weeks after they are laid. The larvae, or grubs, feed on the finer plant roots, and before reaching maturity pass through three stages, or instars. The change from one instar to the next is accompanied by a shedding or the molting of the skin. The newly hatched, or first-instar, larvae feed for about 3 weeks, reaching a length of about one-fourth inch; the second-instar larvae feed for about the same length of time and attain a length of about one-half inch. The final, or third, instar is generally reached by the latter part of September, by which time the larvae have become from three-fourths inch to an inch in length. For the most part the larvae pass the winter in the third instar, completing their growth in the spring; a small proportion may overwinter in the second instar, and rarely a few in the first instar.

While feeding, the larvae remain mostly in the upper 3 inches of soil, but as winter approaches and the soil temperature falls, they move deeper and go into their winter resting places. When the soil reaches a temperature of about 50° F., movement ceases; at this time the larvae are from 4 to 8 inches below the surface. The greater part of the life of the Japanese beetle is spent in the larval stage, which continues from the time the eggs hatch in July through the fall and winter and until the latter part of May or early in June of the following year. In the spring the larvae move upward in the ground and feed there from April to June; then, after spending about 10 days in the inactive prepupal condition, they change to the quiescent pupal stage. This stage lasts from 8 to 20 days, depending upon the temperature and other conditions. Final transformation to the mature form then takes place, and the adult beetles, emerging from their pupal skins, make their way to the surface of the ground. The entire life cycle of the beetle, which is shown diagrammatically in figure 6, therefore normally requires 1 year.

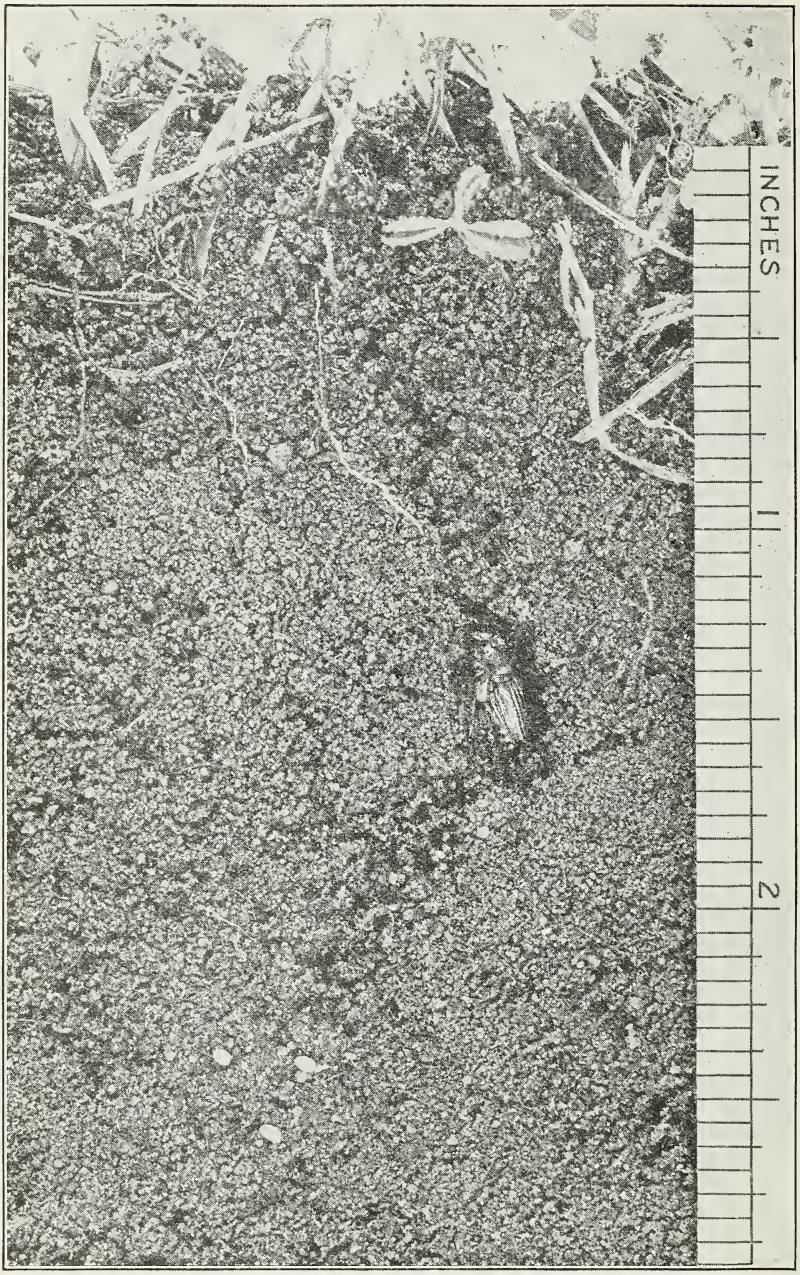


FIGURE 5.—Female Japanese beetle on its way out of the ground after laying eggs.

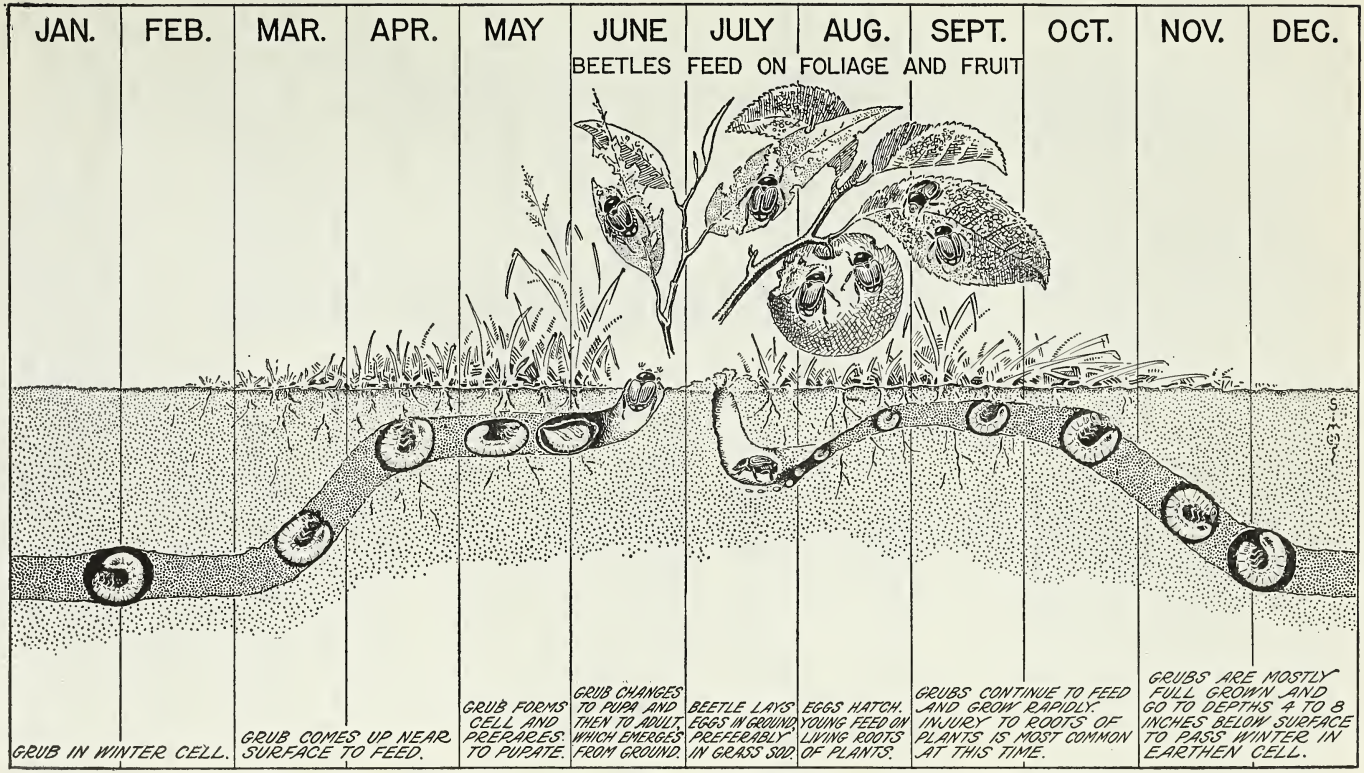


FIGURE 6.—Diagrammatic representation of the seasonal life cycle of the Japanese beetle.

82324°—35——2

FOOD PLANTS OF THE JAPANESE BEETLE

The Japanese beetle has been found to feed on approximately 260 different plants, but it does not relish all of these to the same extent. In addition to a large number of deciduous trees, shrubs, and flowers especially preferred by the insect, there are many that may be attacked to a lesser extent, the degree of feeding depending on the relative abundance of the beetle in the particular locality. In the absence of preferred food, the more tender foliage of plants normally untouched may be eaten. A case of this kind was found in 1933, when several varieties of evergreens, plants normally ignored by the beetle, were heavily attacked. The more attractive food plants are listed below, those marked with an asterisk (*) being those preferred. The foliage alone is eaten unless otherwise noted.

Plants Often Attacked by the Japanese Beetle

Small fruits:
- Blackberry, foliage and fruit
- Blueberry and huckleberry, foliage and fruit
- Currant, red varieties
- *Grape
- *Raspberry, foliage and fruit

Orchard fruits:
- *Apple, foliage (fig. 7, *A*) and especially fruit of early ripening varieties
- *Cherry
- Peach; injury severe on fruit of early ripening varieties (fig. 8), and occasionally severe on foliage
- Plum, foliage and fruit
- Quince

Truck and garden crops:
- Asparagus
- Beans
- Rhubarb
- *Sweet corn, foliage, silk (fig. 9), and ear

Field crops:
- Alfalfa
- Clover, foliage and flowers
- *Field corn, foliage, silk, and ear
- *Soybean

Ornamental shrubs and vines:
- Barberry
- Butterflybush, flowers only
- Crapemyrtle, foliage and flowers
- Lespedeza
- Oriental flowering cherry
- *Rose, foliage, buds, and flowers
- *Shrub-althea, flowers (fig. 10)
- *Virginia creeper

Flowering garden plants:
- Canna, foliage and flowers
- *Dahlia, foliage and flowers
- *Hollyhock, foliage and flowers
- *Marshmallow, foliage and flowers
- Rosemallow, foliage and flowers
- Snapdragon, especially flowers of dark-colored varieties
- *Zinnia

Shade trees:
- *Elm
- *Horsechestnut
- *Linden (fig. 7, *B*)
- *Lombardy poplar
- Norway maple
- Pin oak
- Planetree or buttonwood
- White birch
- *Willow

Weeds and other noneconomic plants:
- Alder
- *Bracken
- Dock
- *Elder
- *Evening primrose, foliage and flowers
- *Indian mallow or velvetleaf
- *Sassafras
- *Sensitive fern
- *Smartweed, foliage and flowers
- Tear thumb
- *Wild fox grape
- *Wild summer grape

Many plants are never or seldom fed on by the Japanese beetle. Some are attacked only when the beetles are unusually abundant or preferred food plants scarce or absent. Some of the plants that are immune or nearly so are given in the following list:

PLANTS RARELY OR NEVER ATTACKED BY THE JAPANESE BEETLE

Small fruits:
- Dewberry
- Gooseberry

Orchard fruits, pear

Truck and garden crops:
- Cabbage
- Carrot
- Cauliflower
- Eggplant
- Lettuce
- Onion
- Parsley
- Pea
- Potato
- Radish
- Spinach
- Squash
- Sweetpotato
- Tomato
- Turnip

Field crops:
- Barley
- Oats
- Rye
- Wheat

Ornamental shrubs and vines:
- All evergreens
- Azalea (except deciduous varieties)
- Beautyberry
- Box
- Clematis
- Deutzia
- English ivy
- Euonymus
- Forsythia
- Honeysuckle
- Hydrangea
- Lilac
- Mockorange
- Privet
- Rhododendron
- Snowberry
- Spirea
- Weigela
- Wisteria

Ornamental garden plants:
- Aquilegia or columbine
- Calendula
- Carnation
- Chrysanthemum
- Coreopsis
- Cosmos
- Four-o'clock
- Gladiolus
- Goldenglow
- Iris
- Larkspur
- Lily
- Marigold
- Nasturtium
- Pachysandra
- Pansy
- Peony
- Petunia
- Phlox
- Poppy
- Snapdragon (light-colored varieties)
- Sweet pea
- Tulip
- Violet

Shade trees:
- All evergreens (except cypress)
- Ash
- Beech
- Carolina poplar
- Catalpa
- Dogwood
- Locust
- Maples (except Norway and Japanese)
- Oaks (except pin and chestnut)
- Redbud
- Sweetgum
- Tupelo or sourgum
- White poplar

HOW THE JAPANESE BEETLE FEEDS

The Japanese beetle is most conspicuous and injurious in the adult form. Feeding is confined chiefly to the foliage on the upper and outer parts of plants exposed to the bright sunlight, and occurs during the warmer part of the day, generally between 9 or 10 in the morning and 3 in the afternoon. On cloudy or cool days there is almost no feeding. Since beetles are most active when the temperature is high, they tend to feed on the higher trees in the middle of the day and on lower plants early in the morning and late in the afternoon. The injured leaves have a characteristic skeletonized appearance (fig. 7) because the beetle eats out the fleshy part of the leaf and avoids the veins. These leaves soon turn brown and drop, and as a result it is not uncommon to find preferred food

FIGURE 7.—*A*, Japanese beetles feeding on apple leaves; *B*, linden leaves showing characteristic feeding of the Japanese beetle.

FIGURE 8.—Japanese beetles feeding on peach foliage and fruit.

plants in the heavily infested areas entirely stripped of their foliage. These plants often develop a new crop of leaves late in the summer.

The Japanese beetle is a pest of great importance on early-ripening fruit, especially apples, peaches (fig. 8), and plums. The feeding on

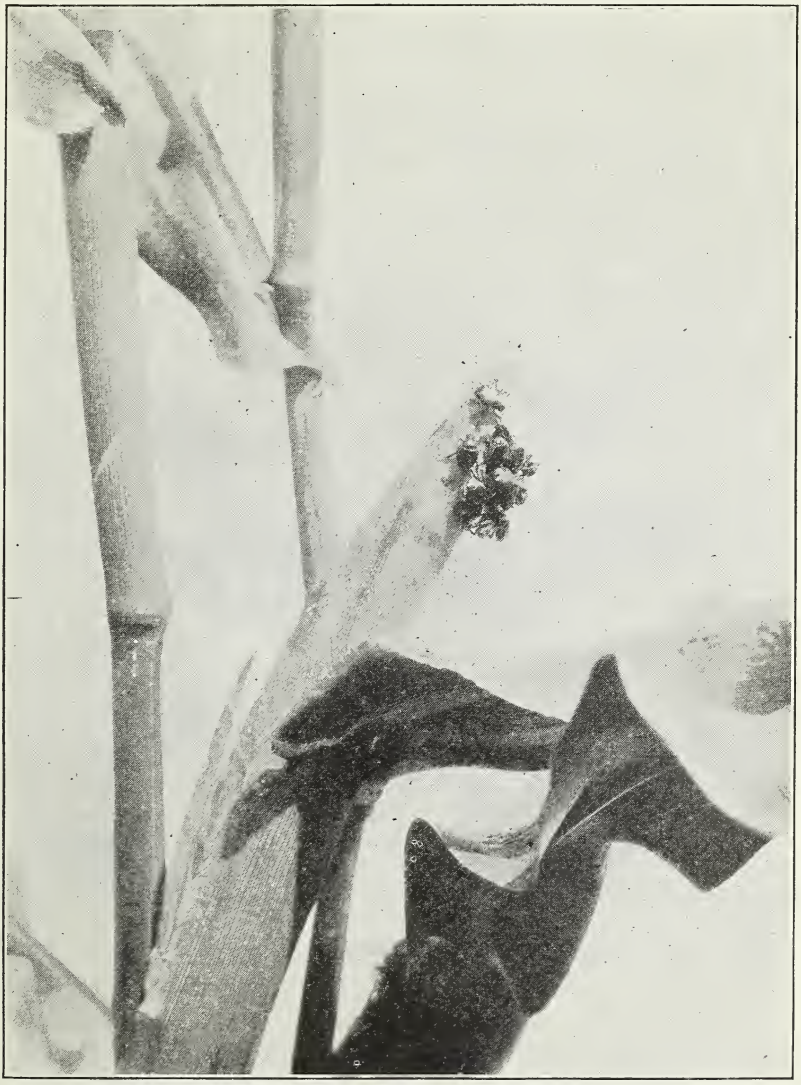


FIGURE 9.—Japanese beetles feeding on silk at tip of ear of corn.

such fruits is often very severe, as the beetles concentrate in masses on the fruit and eat into the juicy interior until only the core, stone, or pit is left. Prematurely ripened or imperfect fruits are preferred, but in heavily infested areas nearly all the fruit may be injured. As many as 296 beetles have been found clustered on a

single apple. Late-maturing varieties of fruit usually escape attack. Commercial varieties of pears are not injured.

The beetle is also destructive to both sweet and field corn. The chief injury results from the feeding of adult beetles on the silk as it grows out from the husk, before actual pollination takes place (fig. 9). The destruction of the green immature silk prevents pollination, and the ears therefore lack the full quota of kernels.

Soybeans and blossoms of red clover are injured most among field crops other than corn; and asparagus and rhubarb among truck crops but to a lesser extent; beans also may be attacked.

A traveler driving through a heavily infested section in midsummer can hardly fail to note the brown appearance of many shade and orchard trees resulting from the feeding of beetles on the foliage. A more careful inspection will show that the upper leaves of berry bushes and grapevines are also turning brown, and if per-

FIGURE 10.—Feeding of the Japanese beetle on flowers of shrub-althea. Uninjured plant at the left.

chance the common smartweed is allowed to grow in a garden or along the edge of a field, beetles will be found feeding there in great numbers. This weed is so attractive to the beetle that scouts, looking for the insect in places where its presence is uncertain, will seek it first of all in patches of smartweed. A traveler in the heavily infested area is also made aware of the presence of beetles by the large numbers that fly against the windshield of his car.

In cities and villages where beetles are numerous in yards and gardens, they are found most often on the foliage and within blossoms of rose, hollyhock, and shrub-althea (fig. 10), and on leaves

of Virginia creeper. If an elm, horsechestnut, linden (fig. 7, *B*), white birch, or willow tree serves as shade, the lawn beneath is likely to be littered with the brown skeletonized leaves.

Beetles are by nature so restless that they shift from one food plant to another throughout the season. In general, however, they seem to prefer weeds, sassafras, sweet cherries, and grapes early in the season; by midsummer fruit and shade trees tend to be most heavily infested; while in August and September they may usually be found in greater numbers on flowers then in bloom or on plants which continually put out new foliage that is more tender than the older foliage of their former food plants.

FOOD HABITS OF THE LARVA

The feeding activities of larvae of the Japanese beetle, though less spectacular than those of the adult, are often equally important. Larval feeding on the roots of grass and field, garden, and nursery plants has resulted in a type of damage unsuspected by many people.

As the grub burrows through the soil, it eats off the rootlets of turf, killing the grass, and lawns present the spotted appearance shown in figure 11. Such turf may readily be rolled back with the fingers and the larvae beneath disclosed (fig. 12). At the present time the greens, and in many cases the fairways, of most of the golf courses in the heavily infested area have been treated with lead arsenate to protect them from larval attack, and many lawns have received the same treatment. Larvae are most abundant in thrifty, well-kept lawns, the tender grasses of which are preferred to the tougher varieties. As many as 1,531 larvae have been found in 1 square yard of golf green; 100 per square yard are ordinarily enough to ruin the turf, especially in periods of deficient rainfall.

In addition to injuring lawns, grubs may destroy the grass in pastures and damage corn, bean, tomato, strawberry, and other field and garden plants by feeding on the roots. In some cases larvae feed on the large main roots of plants until these are severed. Some varieties of nursery stock have also been severely injured by the girdling of the main roots by larvae at depths of from one-half to 1½ inches below the surface of the ground.

The injury resulting from larval feeding is most severe when the larvae are making their greatest growth, as they eat more ravenously then than at other times. This is the case in September and October before the larvae enter their winter resting period, though in some cases the destructive effect on the plants may not be noticed until the following spring.

For some time it was believed that beetle larvae fed largely on decaying vegetable material in the soil. It now appears that, though larvae feed to some extent on such material, they develop more slowly than when reared on the living plant material. The stomach contents of a large number of larvae taken from sod showed 64.3 percent of living plant matter.

If larvae are in soil with a limited food supply, they will often move about in search of food. In tests to determine this point some larvae were found to move 7 feet in 37 days. Larvae often collect around the roots of plants growing in cultivated ground and are scarce or lacking in the surrounding soil.

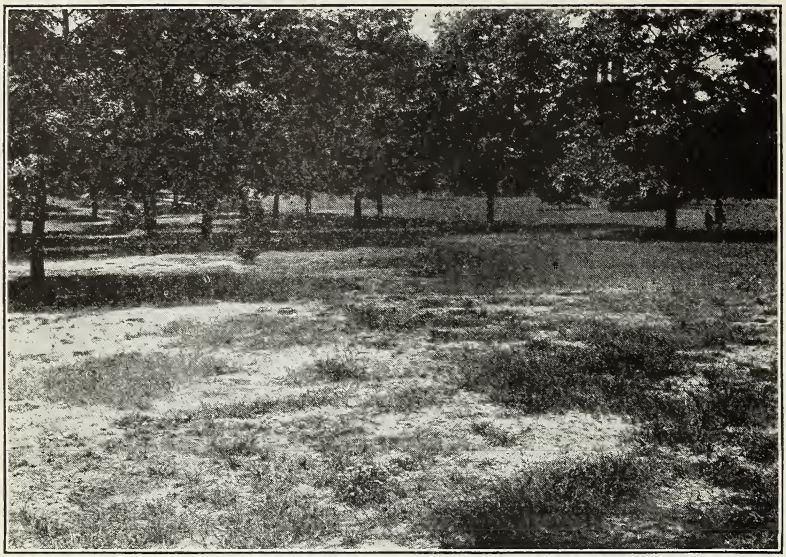


FIGURE 11.—A lawn injured by the feeding of Japanese-beetle larvae on the roots of the grass.

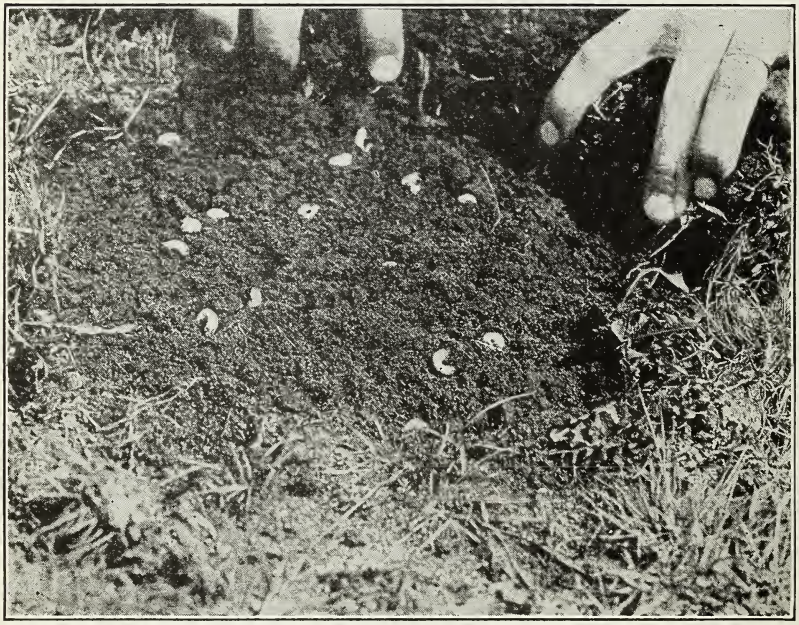


FIGURE 12.—Japanese-beetle larvae exposed by rolling back an area of dead turf.

NATURAL FACTORS LIMITING BEETLE ABUNDANCE

The Japanese beetle, as its name implies, is a native of Japan, where it is found in varying numbers in the main islands of that country. It is not considered a serious pest in its original home, as it has never become so abundant there as in the United States. This may be explained in part by the fact that favorable host plants of the beetles and breeding places for the larvae are more limited in Japan than in this country. Then, too, in Japan there are many insects that prey on the beetle and thus hold it in check. As is usual with insects of foreign origin, the Japanese beetle gained entry into the United States unaccompanied by these parasitic and predatory enemies, and as a result has been able to develop without this natural check on its increase.

INFLUENCE OF CLIMATIC CONDITIONS

In the Philadelphia area the Japanese beetle shows only minor variations in its life cycle from year to year. The abundance of beetles, however, may vary according to seasonal conditions. If the combined rainfall of June, July, and August amounts to less than 10 inches, so many eggs and small larvae perish that beetles are much less abundant the following year. In such dry summers beetles have a greater tendency to deposit their eggs in low moist spots than to scatter them evenly over a field. As a result larval feeding is concentrated in such places and injury resulting therefrom is more localized than in years of normal rainfall.

The Japanese beetle is at present abundant only in places where the climate differs but little from that of the Philadelphia area; consequently it is only possible to surmise how the insect will develop in places with markedly higher or lower temperatures or with a widely different rainfall. From a study of the weather records of Japan, the native home of the insect, and a comparison with weather data taken in the United States, it is believed that the insect will be able to develop in most of this country east of western Kansas. In the more northern parts of New England and in the interior north of Illinois, Missouri, and Nebraska, it is possible that winter temperatures may be low enough at times to prove fatal to the larvae, especially when there is an absence or scarcity of snow. In much of the more arid western part of the United States it is believed that the insect will not develop because of the general dryness of the region and the deficient summer rainfall, though it may be possible for it to maintain itself where irrigation is practiced extensively.

Where the insect becomes established farther north, 2 years will, in all probability, be required for many larvae to complete their life cycle. Studies of colonies in southern New England have given evidence that a few of the grubs do not reach maturity the first year, but remain in the soil until the second year, when they transform into beetles, thus requiring 2 years to complete their cycle. There is some indication that this holdover of grubs also occurs occasionally in the cold soils of poorly drained areas as far south as New Jersey.

PARASITIC INSECTS THAT ARE ENEMIES OF THE JAPANESE BEETLE

Studies of our native parasites and predators of white grubs have shown that none of these as yet have brought about any marked control of the introduced Japanese beetle. Efforts have been under way to import from Japan some of the more important parasites of the Japanese beetle occurring in its native habitat. Five species of imported parasites, 3 from Japan and 2 from Chosen (Korea), are now established in this country within the area heavily infested by the Japanese beetle. Three of these introduced parasitic insects in their new environment have met adverse conditions, which have retarded their spread and rapid increase. On the other hand, the other two species, the Japanese *Tiphia* (*T. popilliavora* Rohwer) (fig. 13) and the Korean *Tiphia* (*T. vernalis* Rohwer), have shown ability to establish themselves in the areas inhabited by the Japanese beetle, and they promise to be of value in its control.

The habits of the Japanese *Tiphia* and the Korean *Tiphia* are generally similar. The Korean *Tiphia* is active in the adult stage during May and early in June, whereas the Japanese *Tiphia* is on the wing during August and early in September. In appearance the adult females of *Tiphia* resemble winged black ants and are about three-fourths of an inch in length. The males are similar to the females, but are usually somewhat smaller. Both the males and the females are most active during the warmth of midday, and they are most frequently seen at this time, feeding on flowers such as wild carrot or on honeydew that has fallen from aphids and scale insects onto the leaves of plants.

FIGURE 13.—Female of the Japanese *Tiphia*. Enlarged 4 times.

After feeding, the female *Tiphia* spends much time in the soil in search of Japanese-beetle larvae. Upon contact with a larva the *Tiphia* attacks and stings it, thereby causing a temporary paralysis. While the larva is inactive a single egg is deposited on its under surface. This egg is firmly attached so that subsequent movements of the larva cannot dislodge it. After recovering from paralysis the larva starts feeding normally, and continues to do so for some time after the *Tiphia* egg has hatched. Meanwhile the *Tiphia* larva feeds by sucking the body fluids of the host larva (fig. 14), and in the course of 15 to 20 days not only sucks out all the fluids but also consumes the body. By this time the *Tiphia* larva is fully grown. It then spins a silken cocoon within the earthen cell formerly occupied by the host larvae, and in this stage passes the winter, finally emerging as an adult in May or August, according to the species.

The Japanese *Tiphia* is now well established in New Jersey and Pennsylvania within the area heavily infested by the beetle, where

at the present time there are 185 colony centers. As rapidly as conditions permit, additional colonies are being placed in the outlying areas of beetle infestation; for example, there are now five colony centers on Long Island, N.Y. In the areas observed in Japan where this *Tiphia* is abundant, it may cause a 20-percent parasitization of the host grubs.

The Korean *Tiphia*, which is active during May, was successfully established in this country in 1926. It has been liberated in 197 colony centers, most of which are also located within the area of heavy infestation. Surveys have shown that at least 69 percent of these colonies are well established, and in a few areas where checks have been made the percentage of parasitization has been observed to range from 7 to 38.

BIRDS AS DESTROYERS OF ADULTS AND LARVAE OF THE JAPANESE BEETLE

Certain birds feed readily on Japanese beetles. Some of the more important of these are the purple grackle, European starling, cardinal, meadow lark, catbird, English sparrow, and robin. When the stomach contents of 29 grackles were examined, it was found that all had fed on Japanese beetles and that 66.3 percent of the total contents of their stomachs consisted of beetle remains. Chickens, turkeys, and ducks readily feed on beetles and derive considerable nourishment from them, as the beetles have been found to contain 22.1 percent protein, presumably capable of being assimilated.

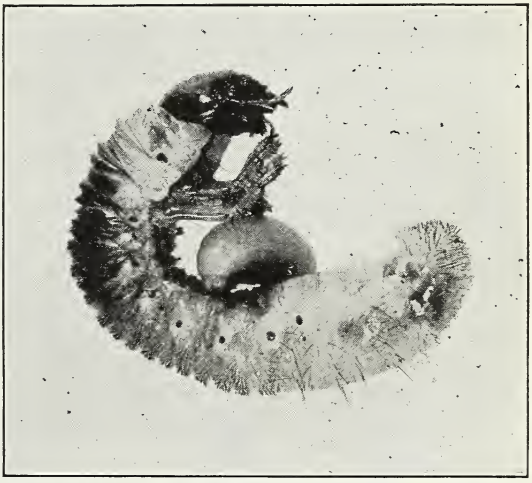


FIGURE 14.—Japanese-beetle larva with a young Japanese *Tiphia* larva attached and feeding. Enlarged 3 times.

Birds also dig up and devour large numbers of larvae each year in the heavily infested area. The most important of these is the European starling, which in recent years has increased in numbers and extended its range widely in the Eastern States. Wherever larvae are feeding near the surface of the ground, flocks of starlings may be seen on lawns and in fields digging up the grubs with their long, pointed bills. In lawns the small circular holes made by the birds are sometimes not more than 2 inches apart, and in one case investigated there was evidence that the larval population had been reduced from about 100 per square foot to 5 or 6. During the nesting season the birds feed many of the juicy larvae to their young.

Other birds that relish the larvae of the Japanese beetle are the purple grackle and the crow. The latter, instead of extracting the larvae through small round holes, frequently pulls up small pieces

of turf and scatters them here and there over a lawn. In farming sections chickens destroy many of the grubs, especially when fields are being plowed or cultivated.

SMALL MAMMALS AS PREDATORS OF BEETLE LARVAE

It has been found recently that certain mammals with more or less subterranean habits feed on larvae of the Japanese beetle. The more useful of these are the common mole, the large short-tailed shrew, the skunk, and the pine mouse.

DISEASE AS A DESTROYER OF BEETLE LARVAE

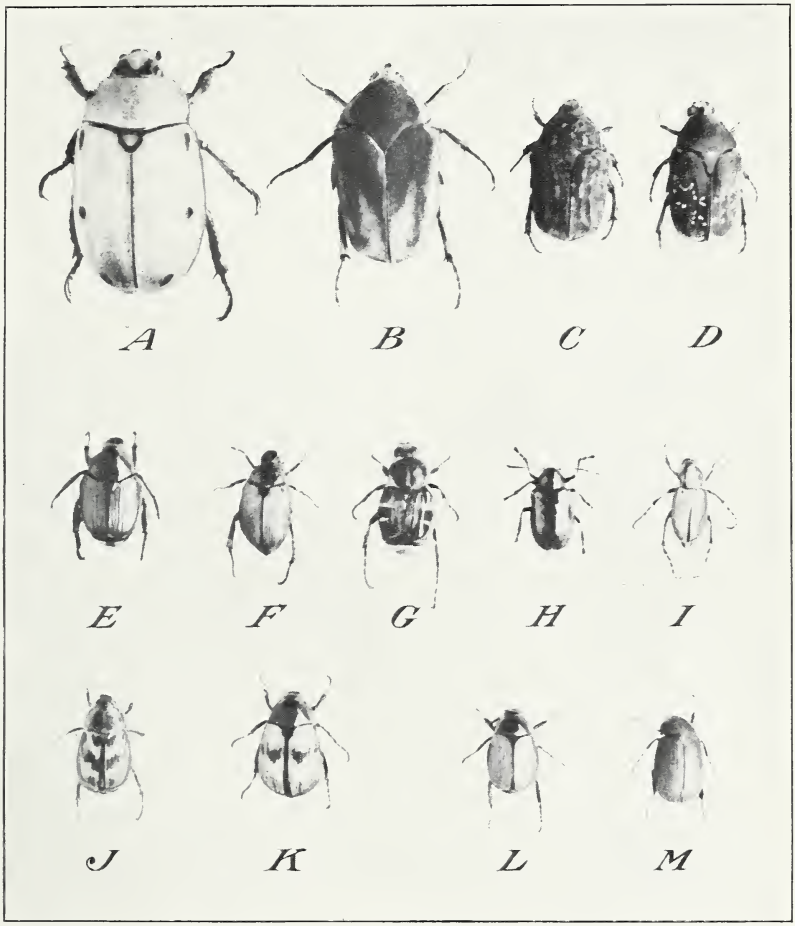
It has been known for a long time that Japanese-beetle larvae are subject to the attack of disease organisms. The external appearance of diseased larvae indicates that several kinds of organisms are at work, although their identity is still in doubt. In the most commonly observed condition the larvae have black swollen bodies and soon die. In an extensive series of larval diggings made in June 1933, 11.8 percent of all the larvae found were diseased, while in examinations made in the early fall of the new brood of larvae less than 1 percent were found to be diseased; the presence of diseased larvae increased thereafter, until by the last of October 3.7 percent of the larvae examined were diseased.

BEETLES SOMETIMES MISTAKEN FOR THE JAPANESE BEETLE

Each year residents in areas in which the Japanese beetle is not sufficiently numerous to be generally recognized find beetles that are new to them that they mistake for the Japanese beetle. Some of those most often found are shown in plate 1. All the beetles illustrated are native to this country, except the Japanese beetle (*Popillia japonica* Newm.), the Asiatic garden beetle (*Autoserica castanea* Arrow), and the oriental beetle (*Anomala orientalis* Waterh.). These three beetles are all of Asiatic origin. Most of the beetles illustrated are diurnal or day fliers, and all but the milkweed beetle (*Chrysochus auratus* (Fab.)) are lamellicorn beetles of the family Scarabaeidae. As has been noted, the larvae of beetles of this family are commonly known as white grubs, and all superficially resemble the larva of the Japanese beetle (fig. 3, *C*) in form, though they often differ greatly from it in size. The most convenient way of separating larvae of this family from one another is by observing with a magnifying glass the arrangement of certain hairs and spines on the underside of the tip of the body. On the larvae of the Japanese beetle two rows of prominent spines are arranged like a V, as shown in figure 15. Most of these larvae are found in soil, but those of the spotted *Pelidnota* and *Trichiotinus piger* are found in stumps or dead logs and those of the bumble flower beetle in manure piles.

SUMMARY

The Japanese beetle was first found in the United States in 1916, and it has spread by natural means at a rate of 5 to 10 miles a year until by 1933 infestations were known to occur in 17 States. The infestation is not continuous throughout this entire territory, but



The Japanese beetle and 12 beetles sometimes mistaken for it: *A*, Spotted Pelidnota (*P. punctata* (L.)); *B*, green June beetle (*Cotinis nitida* (L.)); *C*, bumble-flower beetle (*Euphoria inda* (L.)); *D*, *E. herbacea* (Oliv.); *E*, Japanese beetle (*Popillia japonica* Newm.); *F*, *Strigoderma arboricola* (Fab.); *G*, *Trichiotinus piger* (Fab.); *H*, milkweed beetle (*Chrysochus auratus* (Fab.)); *I*, rose chafer (*Macrodactylus subspinosus* (Fab.)); *J*, oriental beetle (*Anomala orientalis* Waterh.); *K*, *A. binotata* Gyll.; *L*, *Pachystethus lucicola* (Fab.); *M*, Asiatic garden beetle (*Autoserica castanea* Arr.).

only in a small portion, covering approximately 8,800 square miles, whereas in the remainder of this area there are more or less scattered colonies.

The first beetles appear between June 10 and 20 in the heavily infested area, and they are present until October, but in greatly reduced numbers after the middle of August. After mating, the female beetle digs into the soil and deposits a few eggs from time to time until a total of 40 to 60 have been laid. The small larvae feed near the surface on the roots of grass and other plants and grow larger, until by fall most of them are full grown. They pass the winter at depths of 4 to 8 inches and in the spring return to near the surface, feed for a while and, after spending about 10 days as prepupae and 8 to 20 days as pupae, transform to beetles. These leave the soil, having passed through a complete life cycle in 1 year.

Japanese beetles have been recorded as feeding on the foliage of 260 plants, but they prefer some plants to others. Some of those most attractive are apple, cherry, and grape and such shade trees as elm, horsechestnut, and linden. The fruit of early-ripening apples and peaches is usually eaten, as well as the silk of field and sweet corn. The flowers of rose and hollyhock and the leaves of Virginia creeper are also highly esteemed, and beetles are often found in numbers on the common smartweed when they are scarce on other plants.

Some plants are rarely or never fed on. Of these, the evergreens, common grains, most truck and field crops, and many of our common ornamental flowers deserve mention. The pear is the only common fruit that is not attacked.

Japanese beetles feed most extensively in the bright sunlight during the warmer part of the day. The tissue between the veins is eaten, giving the leaves a skeletonized appearance. These leaves turn brown and fall, with the result that preferred food plants in the heavily infested area are often stripped of their leaves.

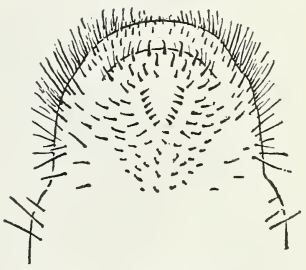


FIGURE 15.—Arrangement of hairs and spines on the underside of the last body segment of the larva of the Japanese beetle. The V-shaped arrangement of the last two rows of spines is characteristic of the larva of this beetle.

The larvae, or grubs, of the Japanese beetle feed on the roots of tender grasses in lawns, golf courses, and pastures, and to a lesser extent on the roots of field, truck, and nursery plants. Injury from feeding is most evident in September and October.

The future spread of the beetle may be influenced by climatic factors. In years in which the combined summer rainfall of June, July, and August is less than 10 inches, there is such a high mortality of eggs and small larvae that beetles are less abundant the following year. A comparison of the climatic conditions in Japan, the original home of the beetle, with those in the United States indicates that the Japanese beetle will be able to develop in most of the States east of western Kansas. In northern New England and in the interior north of Illinois, Missouri, and Nebraska, the winter temperatures may be low enough to prove fatal to larvae, especially in the absence of snow.

Two parasitic wasps of the genus *Tiphia*, introduced into the United States from Japan and Chosen (Korea), respectively, and now well established in many local colonies throughout the heavily infested area, should in future years serve as a check on beetle abundance. These small wasps deposit eggs on beetle larvae, and the parasite larvae hatching from these eggs suck the body fluids from beetle larvae and eventually entirely consume them.

The purple grackle, starling, and other birds feed readily on adult Japanese beetles. These two birds, as well as others, are also known to dig up and destroy many beetle larvae. Chickens will feed on both larvae and adults. Certain small mammals also feed to some extent on beetle grubs.

Larvae of the Japanese beetle are subject to the attack of one or more disease organisms that tend to reduce the larval population.

The distinctions between Japanese beetles and some beetles often mistaken for them are illustrated.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Under Secretary	REXFORD G. TUGWELL.
Assistant Secretary	M. L. WILSON.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Director of Finance	W. A. JUMP.
Solicitor	SETH THOMAS.
Agricultural Adjustment Administration	CHESTER C. DAVIS, *Administrator.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	J. N. DARLING, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	FREDERICK D. RICHEY, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

This circular is a contribution from

Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Division of Japanese and Asiatic Beetles	C. H. HADLEY, *Principal Entomologist, in charge.*

23

U. S. GOVERNMENT PRINTING OFFICE: 1935

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 5 cents