JAPANESE BEETLE—
LIFE HISTORY AND CONTROL

by John C. Schread

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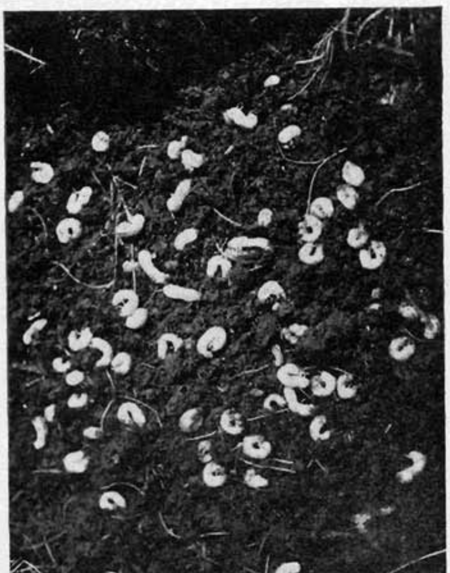

CONNECTICUT AGRICULTURAL
EXPERIMENT STATION
NEW HAVEN, CONNECTICUT

Most insect species have one or more parasites or predators which live at their expense; the Japanese beetle (*Popillia japonica* Newm.) is no exception to the general rule. This insect, during both the larval and adult stages, has a number of natural enemies—certain insects, bacteria, fungi, birds and insectivorus mammals—that prey upon it.

Extermination of the Japanese beetle over any large area by means of any single natural agency cannot be expected. However, insect parasites and predators, as well as other organisms, especially bacteria, may in time reduce Japanese beetle populations to a relatively innocuous level, or at least to the extent that other means of control will become more practical and economical. Hence, it is desirable to utilize all the natural enemies available.

In the following pages parasites and diseases of the Japanese beetle and their practical utilization under Connecticut conditions are discussed, together with information concerning insecticidal controls known to be practical and economical. Several bulletins and short papers on the subject of the Japanese beetle have been published by this Station.[1] This bulletin brings information up to date in both the biological and chemical control fields.

[1] Bulletin 411, "The Japanese Beetle in Connecticut" by W. E. Britton and J. P. Johnson, June, 1938; Circular 157, "Control of the Japanese Beetle" by J. P. Johnson, June, 1943; Bulletin 491, "Studies on the Milky Disease of Japanese Beetle Larvæ" by R. L. Beard, August, 1945, and articles in the Connecticut State Entomologist's Reports for a number of years.

CONTENTS

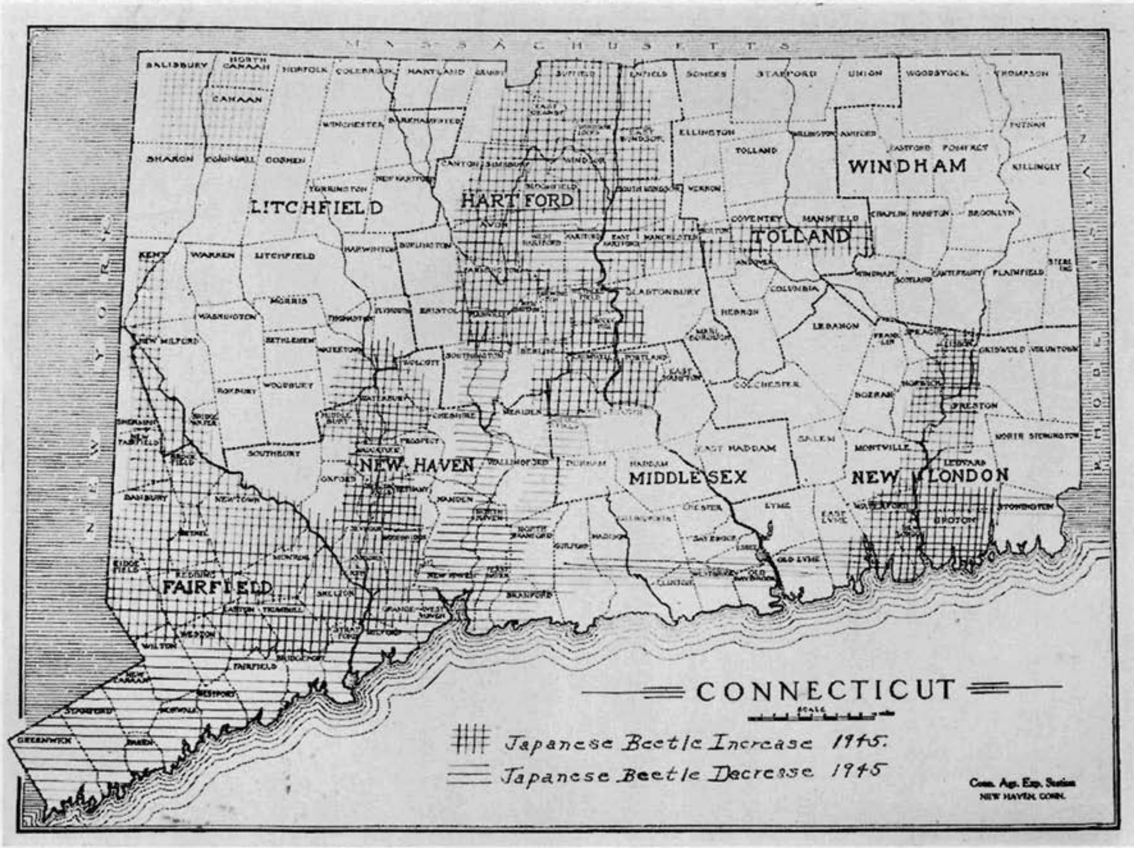

Figure 1. Distribution of the Japanese beetle in Connecticut during 1945.

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The Japanese beetle was found in the United States for the first time at Riverton, N. J., in 1916. Since then it has multiplied and spread from New Jersey into other Atlantic seaboard states, as far north as Maine and south to Florida. To date its progress west has not been beyond the states of Iowa and Missouri.

In Connecticut this insect has been found in almost all parts of the State. It occurs in greatest abundance in the more densely populated areas, such as the cities of Hartford, New Haven and Bridgeport and their adjoining towns (Figure 1), but many of the smaller cities and towns are moderately to heavily infested. With the exception of certain towns in Litchfield, Windham and Middlesex counties (Figure 1), our surveys have shown a trace to a fairly heavy beetle population occurring in rural areas. It can be expected that the Japanese beetle will ultimately spread into all parts of Connecticut now uninfested, and its increase in these areas seems certain in view of past performances in the earlier infested towns.

In parts of Fairfield County and in certain areas in the cities of New Haven and Hartford, which number among the earliest Japanese beetle infestations in the State, there has been a noticeable decline in beetle population during the last several years. There is apparently a normal sequence of increase and decline, attributable to natural causes, in Japanese beetle abundance over a period of years.

LIFE HISTORY, HABITS AND INJURIOUSNESS

The first emergence of adult beetles may be expected to occur in Connecticut about June 20, the population becoming more abundant as the season progresses. By late July and early August in a normal season, the adult population will reach its peak. From then until early September its numbers dwindle and, as the days grow cooler, the adults disappear entirely. When warm weather persists into the autumn, an occasional beetle may be seen as late as October 22, our latest record.

As the adults emerge from the ground, they crawl or fly to nearby vegetation and begin to feed. Both foliage and flowers and, in some cases, early ripening fruits are subject to severe damage.

When the weather is warm and clear, the beetles are extremely active. They fly from plant to plant or sometimes congregate in large numbers on one plant, disregarding nearby vegetation of the same species or of other species equally attractive. Mating begins soon after emergence and continues throughout the season. Females prefer to deposit their eggs in thrifty, well kept turf, such as is commonly found on golf courses, parks and lawns. However, eggs are occasionally laid in cultivated ground, especially flower beds. The average female produces about 50 eggs during her life span of four to five weeks.

The eggs hatch into white grubs in ten days to two weeks or longer, depending on soil temperature. The larvae feed on roots of grass and other plants close to the surface of the soil. Each of the first two larval instars (stages) requires a feeding period of about three weeks. The third instar is reached in early fall and the larva remains in this stage until it pupates in June of the following year, although it becomes larger in size as it feeds during the spring months preceding transformation. Occasionally, a larva passes the winter in the second instar, but rarely in the first.

After completing their feeding period in the spring and prior to pupation, the larvae enter a 10-day prepupal condition. From this stage the pupa develops. After a pupal period of one to three weeks, the adult breaks the pupal skin, works its way to the surface of the ground, and crawls or flies away. One year is necessary for the completion of the entire life cycle.

When Japanese beetle grubs are sufficiently abundant in turf (100 or more per square yard), the grass turns brown and dies, owing to the destruction of the root system. Severe damage is especially noticeable during dry periods. Injury is seldom noticeable when there are 50 grubs or less per square yard of turf.

Adult Japanese beetles feed on a wide variety of vegetation. Some 250 to 300 plants are known to be attacked, including herbaceous plants, shrubs and trees. When the beetles are present in abundance, they may completely defoliate them or destroy the flowers or fruit. Between 200 and 250 beetles have been counted on a single peach.

CONTROL

There are two recommended approaches to control of Japanese beetles: destruction of the grubs in the soil before they transform to the adult stage and leave the ground, and destruction of the adult beetles after they have emerged from the soil. This discussion will, for the most part, be confined to the former.

The destruction of the grubs is accomplished by two methods: chemical (the use of insecticides) and biological (the utilization of natural agencies such as diseases and parasites). Lead arsenate and DDT are the most widely recommended insecticides for grub control.

Insecticidal

Lead Arsenate

Lead arsenate is satisfactory for the treatment of turf under most conditions. In 1923 Leach[1] first made use of this insecticide for Japanese beetle control. It has been used constantly since then, a period of virtually 25 years. When

[1] Jour. Agric. Res. Vol. 33, No. 1, 8 pp. 1926.

applied to the soil as a dust or spray, it will not prevent adult beetles from laying their eggs but it will kill the grubs after they hatch. The time required for a grub to acquire a lethal dose of this insecticide depends on its distribution in the soil, the type of soil, soil temperature and the date of application, as well as on the lead arsenate concentration in the soil.

When the material is evenly distributed throughout the upper one or two inches of soil in which grubs are feeding, several weeks may be necessary for them to eat sufficient poison to cause death. Some of the grubs located lower than the first two inches of soil may escape poisoning for the time being and live for some time before coming in contact with the insecticide. Fleming, Baker and Koblitsky[1] studied the effectiveness of acid lead arsenate in 15 types of soil. It was seen that there was a difference in the action of the insecticide in these soils. This was probably due to the reaction of the arsenate with salts in the soil, forming arsenates of varying degrees of toxicity. Acid lead arsenate is generally more effective in acid than in alkaline soils.

The influence of temperature on the feeding activity and on the movement of the grubs both vertically and horizontally in the soil is quite significant and may be a limiting factor in their control by the use of insecticides.

The normal distribution of grubs throughout the year is shown in Table 1, which gives soil temperatures at one, three and six-inch levels and the average abundance and depth of Japanese beetle grubs in five separate localities in southern Connecticut at weekly intervals. In the south and southwestern part of the State about 85 per cent of the Japanese beetle grub population hibernates within four inches of the surface. The remaining 15 per cent hibernates at a depth from four to eight inches below the surface. It appears from further examination of Table 1 that a considerable mortality occurs among hibernating grubs, virtually 70 per cent. This is probably not entirely due to winter injury, as 20.1 per cent of the grubs during the fall and spring were infected with types A and B of the "milky disease". The disease is not active, however, when the temperature is below about 60°F. After September 7 Japanese beetle grubs begin to move downward in the soil from the first two-inch level where they have been feeding on grass roots during the summer months. By early November most of the grubs are out of the zone in which susceptibility to poison is greatest and remain at deeper soil levels, where no feeding is done, until the following April (Table 1) when they migrate upward into the upper two inches of soil.

When the larvae hatch in the middle of summer, they are very readily killed by the lead arsenate in the soil. After they have entered the third instar which occurs later in the season when the temperature is lower, a large part of the population may escape poisoning. According to Fleming and Maines[2] in Moores-

[1] Jour. Agr. Res. 53, No. 10: 770-779, 1936.
[2] E-series-624, U.S.D.A., Bul. Ent. Pl. Qu. 1944.

TABLE 1. RELATION OF SOIL TEMPERATURE TO DEPTH OF JAPANESE BEETLE LARVAE IN THE SOIL AT FIVE LOCALITIES IN NEW HAVEN, NORTH HAVEN AND HAMDEN IN 1943 AND 1944

Date	Average soil temperature (°F.)			Average number of larvae per square foot at 2-inch levels				Grub totals per square foot	
	1 inch	3 inches	6 inches	1st level	2nd level	3rd level	4th level		
Aug. 30			71.2	32	3.0	0	0	35	Late summer
Sept. 7			71.4	35	2.3	0	0	37	and early fall feeding.
Sept. 13			64.0	28	3.6	0	0	32	
Sept. 20			62.4	38	3.7	0	0	42	
Sept. 27			59.3	29	2.3	0	0	31	
Oct. 4			55.8	29	3.3	0	0	32	
Oct. 11			54.7	16.8	12.0	2.5	0	31	Downward
Oct. 19			48.8	14.4	12.1	4.8	2.0	33	movement of
Oct. 27			51.0	12.3	16.8	4.4	2.5	36	larvae for
Nov. 4			46.9	10.5	11.9	1.8	0	24	hibernation.
Nov. 10			48.2	7.0	6.2	1.5	1	16	
Nov. 18			37.3	4.6	11.6	2.4	1	20	
Nov. 26			40.4	5.0	11.1	2.2	1	19	
Apr. 3	45.8	40.9	36.9	6.0	12.4	2.0	1	21	Upward move-
Apr. 12	41.0	40.3	39.0	13.0	10.9	3.0	1	28	ment of larvae
Apr. 19	50.0	47.4	42.7	13.8	8.1	1.2	0	23	in the spring to
Apr. 26	51.2	50.4	47.5	16.4	3.8	1.6	0	23	resume feeding.
May 3	64.3	61.0	55.5	16.1	1.3	1.0	0	18	
May 10	72.9	68.5	60.0	19.9	1.2	0	0	21	Spring
May 17	85.1	82.4	74.4	12.8	0	0	0	13	feeding
May 27	66.9	65.9	63.0	14.0	0	0	0	14	of larvae.
June 1	74.7	75.2	72.7	14.5	0	0	0	15	
June 8	85.4	80.0	69.7	9.0	1.7	0	0	11	
June 13	83.8	7.1	70.6	10.6	1.8	0	0	12	Downward
June 21	69.5	68.6	67.5	10.5	2.3	0	0	13	movement of
June 29	84.5	80.1	73.1	9.0	4.0	0	0	13	larvae to
July 7	87.2	80.2	73.4	4.1	1.0	0	0	5	pupate and
July 12	86.5	80.9	76.7	2.3	1.0	0	0	3	emergence
July 18	89.7	85.7	77.6	2.9	2.0	0	0	5	of adults.
July 26	93.4	84.6	77.3	1.2	0	0	0	1	Egg laying
Aug. 1	87.9	83.3	79.4	15.7	0	0	0	16	and first and
Aug. 10	85.5	75.5	71.0	9.3	0	0	0	9	second instar
Aug. 16	83.3	81.0	76.5	14.4	0	0	0	14	of succeeding
Aug. 22	79.2	75.2	71.2	16.3	0	0	0	16	generation.

town, N. J., and Johnson[1] in New Haven, this has been clearly demonstrated between temperatures of 50° and 87°F. It is of interest to note that the approximate temperature threshold of 40°F., for poisoning of larvae by DDT, is similar to that for poisoning by lead arsenate.[2]

For effective control, lead arsenate should be applied at the rate of one pound to 100 square feet of ground area. Although a heavy grub population may not be entirely exterminated, the bulk of the population will be destroyed by this treatment, thus preventing noticeable and permanent damage to the turf. A light infestation may disappear completely. The object is to use only enough lead arsenate to kill the grubs and not enough to damage the plants growing in the soil. The material may be applied at any time, preferably in the spring when temperatures are high and the ground is not frozen, or in the early summer before Japanese beetle eggs hatch. Application of lead arsenate to turf as a

[1] Bul. 501. Conn. Agri. Expt. Sta., pp. 71-74. 1946.
[2] E-series-624, U.S.D.A., Bul. Ent. Pl. Qu. 1944.

spray under pressure or as a dust, watered in with a garden hose, are methods which have proved equally successful.

As in the case of DDT, lead arsenate cannot be used if the soil is not kept in turf because of the adverse effect on certain plants. Consequently, soil treated with either of these insecticides should not be planted to vegetables or flowers.

DDT (Dichlorodiphenyltrichloroethane)

DDT is now recommended as a soil insecticide to reduce Japanese beetle grub populations (Fleming[1]). A 10 per cent DDT dust used in one of our experiments at the rate of 250 pounds per acre when applied in May resulted in 72 per cent mortality in five weeks (Table 2). At the time of the treatment the

TABLE 2. JAPANESE BEETLE GRUB CONTROL IN PLOT TREATED WITH DDT

No. of digging	Grub population before treatment	Number of grubs per square foot following treatment		
		14 days	25 days	36 days
1	59	36	33	18
2	59	46	23	27
3	77	48	27	16
4	42	41	28	20
5	68	33	37	18
6	86	30	32	6
7	45	38	24	16
8	89	48	24	27
9	73	38	15	19
10	75	38	11	6
11	46	44	19	13
12	25	48	21	29
Average	62.8	48	24.5	17.9

grubs averaged 62.8 per square foot of turf; 14 days later the population was down to 48 per square foot; and on June 26, 36 days after treatment, the population had been reduced to an average of 17.9 grubs and pupae per square foot of turf. In the succeeding Japanese beetle grub generation, hatching during July and August, the residual power of the DDT treatment reduced the grub population from a high of 72-75 average per square foot of turf to two by September 18. Concurrently, an average of 79 grubs per square foot of turf existed in the control blocks.

In smaller areas, DDT (10 per cent dust) may be applied at the rate of 6 pounds per 1,000 square feet for control of grubs.

Three to five pounds of 50 per cent wettable DDT powder in 100 gallons of water or 2 tablespoonsful to one gallon of water when sprayed on vegetation will protect foliage from adult Japanese beetle attack for seven to 10 days. Repeated applications should be made at about weekly

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[1] E-series-716, U.S.D.A., Bul. Ent. Pl. Qu. 1947.

intervals throughout the season. Leafy vegetables and small fruits, such as raspberries and blackberries, should not be sprayed nor dusted with DDT within two weeks of consumption.

"Milky" Disease of Japanese Beetle Grubs

A number of bacterial organisms are responsible for the destruction of Japanese beetle grubs in the soil and have played a major role in reducing grub populations where they have become established. Among the known forms, *Bacillus popilliae* Dutky, commonly known as the organism causing "milky" disease of Japanese beetle grubs, is the most important. Its practical utilization was developed by the United States Department of Agriculture and in the beginning it was distributed by Federal and State agencies only. Since rapid establishment and dispersion of this organism in beetle-infested areas of Connecticut

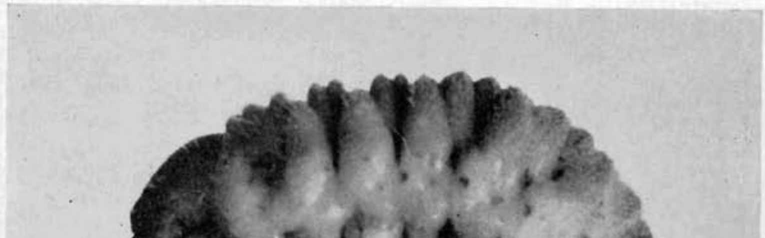

Figure 2. Grub in advanced stage of "milky" disease showing uniform opacity in all parts of body.

has been deemed advisable, this Station has cooperated with the Federal Bureau of Entomology and Plant Quarantine in distributing it throughout the State. In recent years, a number of commercial concerns have been granted permission to manufacture the "milky" disease spore dust and it can now be obtained from retailers in the beetle-infested area.

The spores of the "milky" disease are incorporated in talc to facilitate application. This spore dust mixture contains approximately 100 million spores per gram of material, a standardization set by the U.S. Department of Agriculture.

The customary method of application of the spore dust is to spot the material at five-foot intervals in rows five feet apart, using a level teaspoonful or approximately two grams (two million spores) of the dust to each spot. A supplementary method of application consists of mixing the spore dust with loam, sand, lime, fertilizer or soil insecticide and broadcasting it evenly over the surface of the ground, at the rate of one pound of spore dust to 4,000 square feet of turf. If application is not made preceding rain, the spore dust should be washed into the soil with a garden hose, thus assuring greatest survival of the bacteria. Applications of spore dust may be made at any time of the year when the ground is not frozen. However, for best results, early fall application is preferred.

The bacteria spread in the soil from points of inoculation, principally by the movement of grubs and other soil-inhabiting organisms. Diseased grubs may move around while feeding and before the bacteria render them inactive. Thus, they may die and disintegrate some distance from where they first ingested the spores.

The bacterium is, in the spore stage, strongly resistant to variations in temperature[1,2] and moisture and will, even if Japanese beetle grubs are not present, persist in the soil for long periods of time. White[3] states—"the effect of heat alone on the potency of *Bacillus popillia* is of minor importance under field conditions". After a period of hours following application of spore dust, rays from the sun may cause some mortality of the spores[1,2,3]. White states that—"sunlight does not materially reduce the viability of the spores in the standard "milky" disease spore dust mixture applied for the control of grubs" when the spot method of application is followed. However, when the spore dust is broadcast in a thin film over the surface of the ground, considerable reduction of spore viability may result. When most of the dust is deposited on the turf or soil in layers of sufficient thickness, damage is prevented to any of the spores excepting those composing the thin top-most layer.

Not until after the middle of May in Connecticut is the temperature in the upper two inches of soil sufficiently high for rapid "milky" disease development in grubs. Although the bacteria are infective at temperatures as low as 60°F., for best results 80°F. is necessary. With the appearance of grubs of the Japanese beetle and their ingestion of the spore dust, the "milky" disease becomes active and the grub population begins to decline. Because of the fact that some species of native white grubs, the adults of which are June beetles, are susceptible to

[1] Beard, R. L., Conn. Agri. Expt. Sta. Bul. 491, pp. 505-583, 1945.
[2] Dutky, S. R., Jour. Agri. Res. 61, pp. 57-68, 1940.
[3] White, R. T., U.S.D.A., B.E.P.Q., E-703, 1946.

the "milky" disease, an occasional turnover of the Bacillus is reasonably assured even in soils where the Japanese beetle grub population is absent or negligible.

Population density is important in determining the rapidity of establishment and spread of the disease subsequent to soil inoculation. The more intense grub populations result in more rapid increase of infection and ultimately higher disease rate. When the grub population is low, the use of an amount of spore dust equal to that employed where the grub population is high will in all probability necessitate a longer time for the disease to become established. This may be accompanied by a slower build-up in percentage of diseased grubs.

By varying the amount of spore dust, it was found that an application of from one-quarter to one-half pound to 1,000 square feet in the fall resulted in an increase in the incidence of disease from an average of 6 per cent in late May to 100 per cent in early July of the following year. However, the latter figure may not have been an accurate picture of disease incidence, for many healthy grubs had transformed to the adult stage by that time (July 5). Beard[1] has demonstrated the effect of spore dose on incidence of disease and states that the "probability of a grub becoming infected increases with the spore dose". He also states that the three larval instars are equally susceptible.

The bacterium may be a little slow in getting established in certain localities (as long as two to three years). The problem arises whether to use the "milky" disease spore dust to control a Japanese beetle infestation or resort to control by an insecticide. Such a decision will depend on the extent of the grub population and the purpose for which the grass area will be used. When the grub population is high (25 to 100 or more per square foot) and the damage to the grass is extensive, immediate control of the situation necessitates the use of the lead arsenate or DDT. If, however, one is willing to wait and overlook the damage to the grass for a number of months to a year or longer, the "milky" disease should eventually give the desired control. In either case, reseeding of the grass may be necessary.

If an infestation is light (one to five grubs per square foot of turf) it would be advisable to use the "milky" disease organism. This would permit a build-up and spread of the organism in the soil on a rising grub population which would be eventually checked. It is not advisable, however, to use the "milky" disease spore dust when the Japanese beetle first makes its appearance in a locality. There may not be enough grubs in any single lawn area to support or warrant such a precaution. It is better to wait until there is at least one grub per square foot of turf.

As it is known that lead arsenate and DDT treatment are tem-

[1] Beard, R. L., Conn. Agri. Expt. Sta. Bul. 491, pp. 505-583, 1945.

porary controls, their effectiveness lasting three to five years at the doses usually applied, it is advisable to follow up an application of the poison about four years later with a "milky" disease spore dust treatment, thus providing a permanent control agency to supplant the poison as its effectiveness diminishes.

Insect Parasites of the Japanese Beetle

The natural enemies of the Japanese beetle include a number of insect parasites, the importation of which from the native habitats of the beetle in Japan and Korea represents a significant phase of the problem of control in the United States. A few of the more important species are given below. All of them have become established in various parts of the general area of beetle infestation in the United States.

Parasites of the adult beetle:
Centeter cinerea Ald. (Diptera)
Parasites of the larva:
Tiphia vernalis Roh. (Hymenoptera)
Tiphia popilliavora Roh. (Hymenoptera)
Dexia ventralis Ald. (Diptera)
Prosena siberitia Fab. (Diptera)

Prior to their introduction into this country, an exhaustive study of these and other parasites and predators and their relation to the Japanese beetle population in the Orient was made by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. Breeding and colonization of the parasites were necessarily important steps in handling the insects when they reached this country. Subsequent to establishment of the parasites in certain localities in New Jersey and Pennsylvania, collections were made for the purpose of redistribution in advanced areas of general beetle infestation, including Connecticut.

Commencing in 1936, some of the parasite species which attack Japanese beetles were released each year in this State. By the end of 1946, 133 colonizations of *Tiphia vernalis* and 26 of *Tiphia popilliavora,* both wasps, and eight

TABLE 3. PARASITE COLONIZATION IN CONNECTICUT, 200 INDIVIDUALS PER COLONY

Year colonized	No. colonies *Tiphia vernalis*	No. colonies *Tiphia popilliavora*	No. colonies *Centeter cinerea*
1927	0	0	2
1936	4	0	0
1937	5	5	1
1938	15	18	0
1939	25	0	0
1940	14	0	0
1941	16	0	0
1942	4	0	0
1943	10	1	0
1944	12	0	0
1945	14	2	2
1946	14	0	3
Totals	133	26	8

of *Centeter cinerea,* a fly, had been made. Virtually all of the parasites were liberated in Fairfield, New Haven and Hartford counties, the areas of heaviest and oldest Japanese beetle infestation. The number and years of colonizations are given in Table 3.

The progress of the colonies has been followed from year to year and, in certain instances, the establishment and annual increase of the parasites has been sufficiently progressive to assure their survival within reasonable limits. It is expected that ultimately the parasites may account for a large reduction of the beetle population in localities where their presence is of long standing.

Tiphia vernalis Rohwer

Tiphia vernalis, the spring Tiphia, so called because it occurs in the adult stage in the spring, may be seen on clear warm days from early May through early June. It feeds on honeydew secreted by aphids on maple, oak, chestnut, pine and other trees. It is most active from the middle of the morning until early afternoon and then may be collected by hand for recolonization. It is most abundant for about one week in the latter part of May, at which time there is usually a preponderance of females. The adults seem to be more or less confined to a limited locality in which they had been released, although parasitism of the grubs has been found to occur over a wide area in the vicinity of the colonization. This would indicate a greater distribution of the species than the mere obvious localized presence of the adults reveals.

The parasite lays its eggs on the ventral or lower surface of the Japanese beetle grub. The duration of the egg stage varies with temperature, but a week to 10 days is about the usual length of incubation. The larva of the parasite begins to feed at once, completes its development in about 24 days, and spins a cocoon in which the winter is passed.

The relative abundance of Japanese beetle larvae and *Tiphia vernalis* cocoons has been studied at a number of colonization sites. Between 60 and 70 per cent of all the colony sites in Connecticut were examined in the spring of 1945 for grubs and parasite cocoons. Forty per cent of them contained *Tiphia vernalis* cocoons. Although the ratio of grubs to cocoons varied considerably, the older colony sites showed the presence of the greatest number of parasites. In the 1936 colonization localities, 45.83 per cent of the total grub and parasite individuals removed from the soil were Tiphia cocoons. The 1938 colony sites gave 9.3 per cent cocoons on the same basis. At more recent colonization sites, the percentage of cocoons was less than five. The average number of grubs per square foot of soil was much less at the oldest Tiphia colony sites in comparison with the more recent colonizations. According to White,[1] who has studied the relationship of "milky" disease incidence to Tiphia survival, although some of the Tiphia larvae fail to survive on grubs infected with the "milky" disease, in general, these two biological agencies are compatible.

Adults of *Tiphia vernalis* were present in 1945 and 1946 in several localities in this State in sufficient numbers for collecting and redistribution. A sufficient concentration of adults on trees where they feed on honeydew did not always

[1] White, R. T., J. N.Y. Ent. Soc. 51, pp, 213-218, 1943.

occur at the older colony sites, but frequently at colony sites of but three or four years' standing. This is explained by the presence of a greater Japanese beetle grub population in the vicinity of some of the more recent colonizations and, hence, more host material for the parasites to attack.

Tiphia popilliavora Rohwer

Tiphia popilliavora (Figure 3) closely resembles *Tiphia vernalis* in appearance. However, biologically they differ considerably. This species appears in the adult stage about the middle of August and can be found to a greater or lesser extent from then until the middle of September, reaching maximum abundance the latter part of August. Because of its habits, it is referred to as the fall Tiphia.

The wasps appear on clear days at about the middle of the morning and feed exclusively on wild carrot blossoms, usually until early afternoon. On cool days they may be found until late in the day. When adult females are through feeding for the day, they search for grubs of the Japanese beetle on which to oviposit.

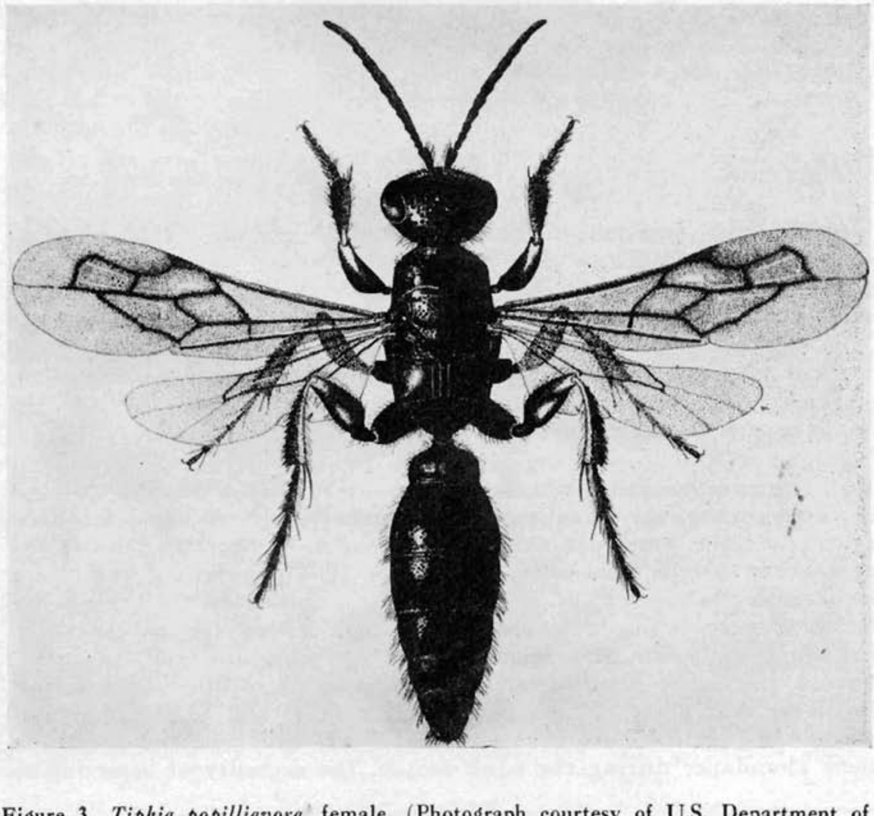

Figure 3. ***Tiphia popilliavora,*** **female. (Photograph courtesy of U.S. Department of Agriculture.)**

Eggs are deposited on the ventral surface of the host and hatch in from a few days to a week, depending on temperature. Feeding begins at once (Figure 4) and continues until after the death of the host. The parasite larval stage is from two to four weeks in length. Immediately after the larva has finished feeding, it forms a cocoon. *Tiphia popillavora* passes the dormant part of its life cycle in the larval stage in the cocoon and does not pupate until shortly before the adults appear in August of the following year.

Figure 4. Japanese beetle larva with young *Tiphia popilliavora* larva attached and feeding. Enlarged three times. (Photograph courtesy of U.S. Department of Agriculture.)

Less work has been done in Connecticut with this parasite than with *T. vernalis,* but it is potentially a valuable contribution to our Japanese beetle parasites. Large colonies have developed in several towns in Fairfield County from which considerable material has been collected for redistribution.

All of the colony sites of *T. popilliavora* have been visited at one time or another since their inception. Parasites were observed at 35 per cent of them, and of this number 27 per cent were the 1938 colonizations.

The question arises whether to use insecticides or "milky" disease in an area where the larval parasites have been released.[1] In a localized grass plot where adult parasites can be found in numbers and the cocoon population exceeds or balances that of the grub population, it may not be necessary to resort to other methods of control unless the grub population is very high. It would appear that where the parasites are abundant the grub population is rapidly diminishing and, in consequence, this factor would obviate the necessity of additional treatment. In larger turf areas such as parks, golf courses and adjoining estates where the parasites have been established for some time and appear in some abundance during the adult season, the necessity of resorting to

[1] White, R. T., J.N.Y. Ent. Soc. 51, pp. 213-218, 1943.

supplementary control measures would again depend on the grub population and whether or not there is existing turf injury. In the event localized or widespread turf injury unexpectedly appears the use of insecticides or "milky" disease may be resorted to without permanent injury to the parasite colony.

White[1] believes there may be some adverse effect of the "milky" disease on larvae of *T. popillavora* because, at the time of the year this parasite is active, soil temperature is more favorable for the disease.

Centeter cinerea Ald.

Centeter cinerea, a tachinid fly parasitic on adult Japanese beetles was brought to the United States from an area about 300 miles north of Tokyo, Japan, by the Federal Department of Agriculture.

Centeter deposits its eggs on the upper surface of the Japanese beetle (Figure 5), in most cases on the thorax. The adult parasites live for about two weeks and may deposit upwards of 100 eggs each. Eggs hatch in about two days. The parasite larva chews directly through the shell of the egg into the thoracic cavity of the host, later migrating to the abdomen. The parasite breathes by attaching itself to the air sacs of the beetle. About nine days are necessary from the time of oviposition to the pupation of the parasite. A parasitized beetle buries itself in the soil shortly before death and the parasite in the pupal stage passes the dormant period of 10 to 11 months in the body of its victim.

Since only one larva of this fly can mature in a single adult beetle, the fly's habit of frequently laying more than one egg on a host results in a potential waste. This is due to a lack of synchronization of the life cycles of the two insects. Should the parasite become more adjusted to its host, greater and more widespread parasitism of adult beetles may be expected.

In 1937 one colony of Centeter was released at Riverside Park in Hartford where it became established and soon spread into nearby areas. This colony has been under observation every summer since. During the construction of a dike in the park and along the river front to prevent overflow of the Connecticut River, all low vegetation, with the exception of certain trees, was uprooted and destroyed. This presumably reduced the beetle population and, hence, deleteriously affected the parasite. With re-establishment of turf in the park at the completion of the dike, the beetle increased in abundance, as did the parasite.

In 1944, because of extended spring and summer drought, the emergence of the bulk of the beetles was delayed for 10 days to two weeks. The parasite was likewise slower in initial appearance. In previous years, Centeter had emerged during the latter part of June and early July and, as the survival of the adult is of relatively short duration, the parasites died before Japanese beetles were present in any numbers. This, of course, was not conducive to high parasitism. In 1945 the situation was much the same as in 1944, so far as delay in beetle and parasite emergence was concerned. However, the delay in 1945 resulted

[1] White, R. T., J.N.Y. Ent. Soc. 51, pp. 213-218, 1943.

from cold weather during spring and early summer. Centeter was present much later in July in 1945 in comparison with former years, and beetles became sufficiently abundant later in July to minimize superparasitism.

Parasitized beetles were collected in July, 1945, for the purpose of establishing the parasite in other localities as shown in Table 4. Of the total number of beetles collected July 9, 31.8 per cent were superparasitized. The July 19 collection, 10 days later than the first collection, showed a superparasitism of only 10.5 per cent, virtually three times less than existed in the early part of the month.

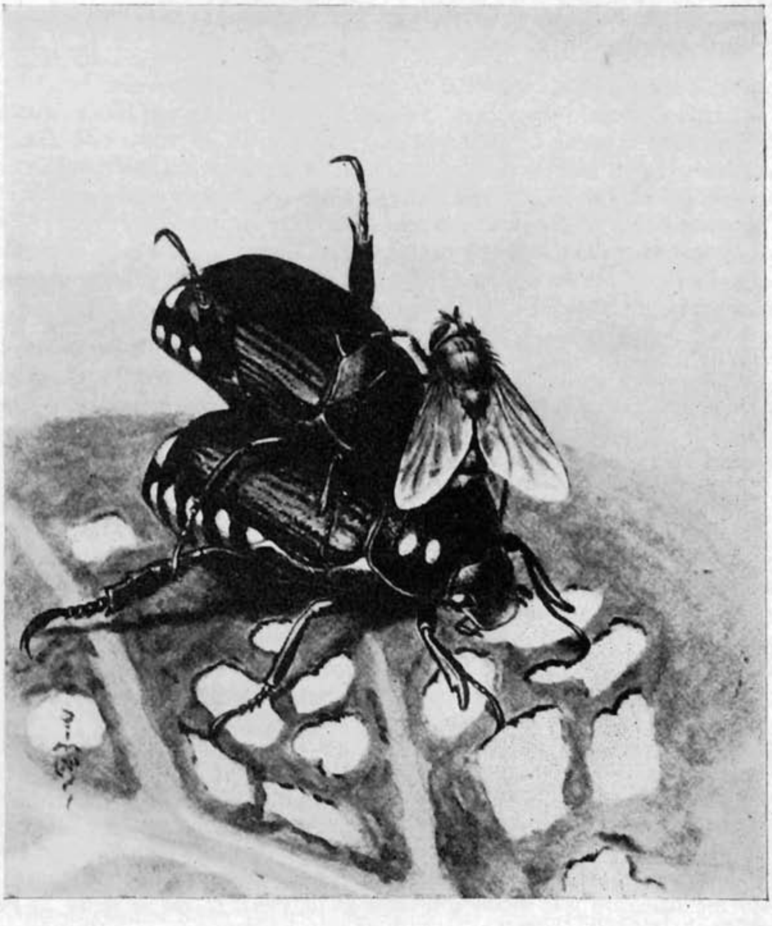

Figure 5. A female *Centeter cinerea* in the act of ovipositing upon Japanese beetle female. (Photograph courtesy of U.S. Department of Agriculture.)

The parasitized beetles were released at two different localities on the Farmington River, one in the town of Farmington and the other in the town of Windsor, where environmental conditions are similar to Riverside Park and vicinity. On July 17, 1946, 4 per cent of the beetles collected at the site in Windsor were parasitized.

TABLE 4. CENTETER PARASITISM OF ADULT JAPANESE BEETLES, 1945

Date collected	Number of beetles collected	Number of beetles with one egg	Number of beetles with two eggs	Number of beetles with three eggs	Number of beetles with four eggs
July 9	207	141	45	18	3
July 19	152	136	16	0	0

Adverse weather conditions in 1946, extreme dryness following a cold wet spring, resulted in 10 days to two weeks delay in quantity emergence of the beetle in Riverside Park. The first beetles found were seen on June 29, none of them parasitized. On July 5, 84 adult beetles were observed in the Park, 60 of which were parasitized by Centeter. Of this number, 36 were parasitized by one egg each; 21 by two eggs; two by three eggs, and one by four eggs.

On July 11, 362 parasitized beetles and on July 18, 217 were taken from the park for redistribution. The individuals of both collections were released at two separate localities for establishment of the parasite, one at Orange Hills Country Club, Orange, and the other at Rolling Mill Athletic Field in Waterbury. Table 5 gives detailed information concerning the parasitized beetles.

TABLE 5. CENTETER PARASITISM OF ADULT JAPANESE BEETLES, 1946

Date collected	Number of beetles collected	Number of beetles with one egg	Number of beetles with two eggs	Number of beetles with three eggs	Number of beetles with four eggs	Number of beetles with five eggs
July 11	362	266	80	12	2	2
July 18	217	202	14	1	0	0

Twenty-six and five-tenths per cent of the beetles collected July 11 were superparasitized. Of the July 18 collection 6.9 per cent were in this condition, virtually 20 per cent less than earlier in the month. Superparasitism was about 5 per cent less in 1946 than in 1945.

Scouting in 1946 in the vicinity of the original colonization site at Riverside Park showed that the parasite had spread three miles north along the shore of the river on both sides, and for some distance back from the shore.

SUMMARY AND CONCLUSION

The Japanese beetle, although continuing to increase in some sections of Connecticut, has noticeably declined in parts of Fairfield County and in the cities of Hartford and New Haven, all of which number among the earliest and heaviest infestations in the State.

The two approaches to control of Japanese beetle are (1) destruction of the grubs in the soil, and (2) destruction of the adults following their emergence during the summer. Grubs may be destroyed by the use of chemicals or by the employment of natural agencies. Lead arsenate and DDT are the best chemicals for control known at the present time; insect parasites and diseases are the usable biological agencies. Lead arsenate and DDT are satisfactory for the treatment of turf under most conditions. They may be applied as a dust or a spray during any season of the year that the ground is not frozen. When applied to frozen turf, the material may wash from the surface of the ground and be lost.

When lead arsenate is used, the standard application is one pound to 100 square feet or 450 pounds to the acre. DDT, when applied as a 10 per cent dust, should be used at the rate of six pounds to 1,000 square feet or 250 pounds to the acre. Residual power of both chemicals will last for from three to five years. When used as a spray to control adults, apply five pounds of 50 per cent wettable DDT powder in 100 gallons of water.

"Milky" disease spore-forming bacterium has played and will continue to play a major part in reducing Japanese beetle grub infestations in Connecticut. Over 3,000 separate colonizations of the spore dust have been made by this Station and many private property owners have also used the bacterium. The "milky" disease, although somewhat slow in effectiveness, is a permanent control measure. Once the soil is inoculated the bacterium persists indefinitely and in time may, of itself, hold Japanese beetle grub populations to a minimum.

Insect parasites of both the grub and adult stages of the Japanese beetle have been released annually in Connecticut for a number of years. Two species of grub parasites, one known as the spring Tiphia and the second as the fall Tiphia, commonly referred to as solitary wasps, are the most important and best known at the present time. Each has but one generation a year and both are increasing in abundance in many places where early releases were made. A fly parasite is taking a toll of adult Japanese beetle populations in several localized sections of the State. All three parasites show considerable promise in aiding in effectual control of the beetle in the future.