

**Northeastern IPM Center – IPM Partnership Grants – 2009 – Proposal
Project Description by Ana Legrand, Project Director**

Project Title: Enhancing floral resources for conservation biological control in urban landscapes

1. Project Category: IPM Issues

2. Project Summary:

The most damaging turf insect pests are scarab beetle larvae or white grubs. During 1920's and 1930's USDA entomologists imported *Tiphia vernalis* Rohwer from Korea and *Tiphia popilliavora* Rohwer. (Hymenoptera: Tiphidae) from Japan for Japanese beetle control. Wasp releases were made throughout the northeastern United States. The primary target of these releases was the invasive Japanese beetle. However, *T. vernalis* and *T. popilliavora* can attack the Oriental beetle as well. The goal of the project is to determine if conservation biological control through the addition of floral resources can be used to enhance *Tiphia* spp. parasitism of Oriental and Japanese beetle larvae. The objectives of the project are: 1) to assess the parasitism rates of *T. popilliavora* on Japanese and Oriental beetle larvae; 2) to screen several flowering plant species that could be used to provide nectar resources to *Tiphia vernalis* during May and June; 3) to screen several flowering plant species that could be used to provide resources to *Tiphia popilliavora* during August and September; and 4) to test the hypothesis that the presence of food plants for *Tiphia* wasps will increase parasitism of Japanese beetle and Oriental beetle larvae by these parasitoids. The criteria for selection of floral resource plants will include that they are not attractive to the pest beetles. Results from this project will indicate which plant species the public can use to promote conservation biological control in residences or in public landscapes. The long term impact from this project will be in safeguarding human health and the environment. The proposed approach addresses an important IPM issue of developing more biological control options against the Oriental and Japanese beetles.

3. Background and Justification:

The most damaging turf insect pests are the immature stages of the scarab beetles or white grubs (Tashiro 1987). Among these root-feeding scarab beetles are the Japanese beetle and the Oriental beetle. The Japanese beetle *Popillia japonica* Newman is an exotic pest that has spread gradually and now it is well established in most states east of the Mississippi River (Vittum 1995). This beetle is considered to be the most widespread and destructive insect pest of turf and landscape plants in eastern United States. It is estimated that this invasive insect is responsible for more than \$450 million each year in costs for control and renovation or replacement of damaged turf and ornamental plants (Potter and Held, 2002). Oriental beetle *Exomala orientalis* (Waterhouse) is another exotic turf pest that appears to have arrived a few years after the Japanese beetle. It is reported in most northeastern states. Like Japanese beetles, larvae also feed on roots of turfgrass and are a serious pest. They also cause severe damage to strawberries and nursery stock (Alm et al. 1995). Management actions for white grubs have mainly relied on conventional insecticides, such as imidacloprid, in addition to other cultural control and biological control options. Environmental contamination is a concern with relying mostly on insecticides such as imidacloprid. For example, imidacloprid has the potential to contaminate ground water because of its persistence in the environment and mobility in the soil (EPA 1994,

Bacey 2000). The NY State Department of Environmental Conservation is very concerned about the increasing number of detections in private wells and has notified the EPA about the leaching of imidacloprid to private drinking water (M. Serafini, Director of NY Bureau of Pesticides Management, pers. comm.). Other management options for white grubs are cultural and biological control tactics. Biological control options commercially available include entomopathogenic nematodes and milky spore disease (Koppenhöfer 2002, Boehm et al. 2003). Nematodes used against white grubs are *Heterorhabditis bacteriophora*, *H. megidis* and *Steinernema glaseri*. They all control the Japanese beetle but are not effective against Oriental beetle, Asiatic garden beetle or European chafer larvae (Koppenhöfer 2002). Milky spore disease agent *Paenibacillus popilliae* (Dutky) is effective only against the Japanese beetle larvae and its efficacy in the Northeast has been inconsistent due to environmental factors. Milky spore disease works slower than conventional insecticides and field efficacy is variable in different locations (Vittum 1995). In addition to commercially available biological control agents, other organisms contribute to the mortality of white grubs. For example, *Tiphia* wasps have been the subject of recent studies and their conservation is highly encouraged (Reding and Klein 2001, Rogers and Potter 2004, Ramoutar and Legrand 2007, Legrand 2008).

Distress about the use of pesticides in urban areas, particularly where children are likely to come into contact with pesticide materials has energized the demand for pest management programs that rely less on chemical insecticides. Connecticut residents have expressed such concerns through several pieces of legislation that have been enacted. For example, Public Act No. 05-252 prohibits the use of lawn care pesticides on the grounds of any child day care center or group day care home except for emergency situations. It also bans the use of lawn care pesticides on the grounds of any public or private preschool and public or private school with students in grade 8th or lower. Thus, cultural tactics and biological control options should be in more demand for the management of lawn pests. However, an important problem in white grub management is the paucity of non-chemical alternatives. Effective biological control options are nematodes and milky spore disease. However, as mentioned above, they are effective only against the Japanese beetle and, at least for the milky spore disease, environmental factors as influenced by geographical location can impact effectiveness. Thus, the proposed project seeks to advance the use of biologically-based alternatives against white grubs that will be easy to implement by homeowners, groundskeepers or managers of public settings where turf is a principal component of the landscape. The management alternative to be explored will be a conservation biological control approach for *Tiphia* wasps that parasitize Oriental and Japanese beetle larvae.

During 1920's and early 1930's USDA entomologists imported *Tiphia vernalis* Rohwer from Korea and *Tiphia popilliavora* Rohwer. (Hymenoptera: Tiphidae) from Japan for Japanese beetle control. Several wasp releases were made throughout the northeastern United States. Releases of *T. vernalis* were made between 1936 and 1949 in six of Connecticut's eight counties and *T. popilliavora* was released in 5 counties between 1921-1940 (King et al. 1951). The primary target of these releases was the Japanese beetle. However, *T. vernalis* and *T. popilliavora* can attack the Oriental beetle as well (King and Holloway 1930). *T. vernalis* is not known to parasitize any native scarab beetle species (Ladd and McCabe 1966) These parasitoids feed on the larvae with *T. vernalis* attacking the 3rd instars during spring and *T. popilliavora* attacking 2nd or 3rd instars during late summer. Since 1950 the occurrence of *T. vernalis* and *T.*

popilliavora in Connecticut had not been monitored and they had been considered to be rare in occurrence. A recent survey by Ramoutar and Legrand (2007) indicated that *T. vernalis* wasps were widely distributed in the state with a peak occurrence around the last week of May. Moreover, data collected by the PD indicates that *T. popilliavora* is likely to also be found around the state (Legrand 2008). *T. vernalis*, also referred to as the Spring *Tiphia*, has been documented to attack on average 60% of Japanese beetle larvae (King and Parker 1950, King et al. 1951). Recent field surveys by the PD indicate that parasitism rates in Connecticut, on average 61% of grubs samples, are comparable to previous records. In addition, the Spring *Tiphia* is also inflicting mortality on Oriental beetle populations with a parasitism rate ranging from 7% to 33% in low-density Oriental beetle populations (Legrand 2008). Reding and Klein (2001) found that in a nursery setting the rate of *T. vernalis* parasitism ranged from 6.4% to 23.1% on Oriental beetles.

The main objective of the project is to determine if conservation biological control through the addition of floral resources can be used to enhance *Tiphia* spp. parasitism of Oriental and Japanese beetle larvae. Conservation biological control involves manipulation of the environment to enhance the survival, fecundity, longevity and behavior of natural enemies to increase their effectiveness (Landis et al. 2000). One approach in conservation biological control is to provide food resources to natural enemies either through food sprays or by incorporating flowering plants habitats that could provide food resources over a period of time. Many parasitoid wasps species visit flowers to obtain nectar and/or pollen that provide essential nutrients. This in turn improves fecundity, longevity and increases rates of parasitism (Landis et al. 2000, Rogers and Potter 2004). Most research on this approach of conservation biological control has addressed pests in agroecosystems. Nevertheless, studies such as Rebek et al. (2005) and Ellis et al. (2005) have documented success in using this approach for pest management in urban landscapes. The *Tiphia* species described in this proposal have been observed using nectar resources to supplement their diet. *T. vernalis* adults emerge in the spring and they have been observed feeding on honeydew deposits from soft scales or aphids and on nectar (Balock 1934, King and Parker 1950). Currently, attention is still being given to the importance of adult food plants for *T. vernalis* success. Potential plants that harbor aphids for honeydew or produce nectar have been suggested in an effort to enhance populations of this parasitoid (R.C. McDonald, http://www.oardc.ohio-state.edu/biocontrol/j_beetle.htm). Moreover, it has been noted that researchers in China have used their knowledge of *T. vernalis* food plants to increase parasitism rates of white grubs to an average of 85% (R.C. McDonald, referenced above). Research by Rogers and Potter (2004) in Kentucky examined the potential to recruit more *T. vernalis* and *T. pygidialis* using sugar water sprays and flowering plants. Out the 15 plants examined peonies in their 3rd year of planting significantly attracted more *T. vernalis* and parasitism was increased from 1- 3% in areas without flowering plants to about 24% in areas with the peonies. It is hypothesized that the earlier plantings of peonies were not attractive enough perhaps due to a reduced number of blooms. It is suggested that some of the plants examined but that did not attract *T. vernalis* might still be useful depending on growing conditions (Rogers and Potter 2004). This same study showed that provision of sugar water in the laboratory to *T. vernalis* and *T. pygidialis* increased their longevity from an average of 6 days to 30 days. As seen above, there is interest and background information on the use of flowering plants to supplement the diet of adult *T. vernalis*. On the other hand, little information exists for *T. popilliavora* even though early records show that flowering plants are important for this species as well. *T. popilliavora*

adults emerge in August and early September and they are said to feed on nectar from umbelliferous plants particularly wild carrot. In fact, it was noted that the potential for the success of introducing this wasp for Japanese beetle control would be enhanced by the presence of food plants such as wild carrot (King and Holloway 1930). More plant options need to be investigated for our geographical region in an effort to promote parasitism on Japanese and Oriental beetle larvae.

The need of the proposed work has been identified by the following groups. The New England Regional Turfgrass Foundation identified research needs in IPM and control of the Oriental beetle (Robert Ruszala, pers. comm.). The Northeast working group on golf turf IPM listed as a research priority the development of alternatives to current pesticides including new (non-pesticide) IPM techniques (Turf IPM Working Group 2001). Similarly, in 2003 the northeastern Community IPM Working Group stated as a priority the importance of addressing priorities identified by the Turf IPM Work Group and to research and develop methods for low-input landscape and turf maintenance (Community IPM work group 2003, www.nepmc.org/work_commpriority2003.cfm). This same group listed as a priority in 2005 the need for general research on residential IPM (www.nepmc.org/work_commpriority2005.cfm) and in 2007 the group noted that the most important focus for the group was IPM in residential settings (www.nepmc.org/work_commpriority2007.cfm). The proposed project also addresses priorities listed by NEREAP-IPM in 2006 which included the need for IPM research and extension for residential settings to reduce impacts on water quality. Another priority listed is to conduct research on biological control of diseases, arthropods and weeds (northeastipm.org/priority/2006/generalpriorities.htm). In relationship to this priority, the northeast nursery and landscape IPM research and information transfer needs assessment lists as a research need the development of more/better microbial control alternatives for Japanese beetle grubs (Landscape IPM 2002). Finally, Community and Urban IPM priorities collected at the 2005 Community and Urban IPM Conference held in New Hampshire include the need to develop IPM for turf including low-impact, low-risk pesticide options and to develop cost-effective biological controls for landscape pests (www.nepmc.org/priority/2005_urban_conf.htm). The results from this project will provide another option for homeowners or landscape managers who seek to use biological control methods in dealing with invasive pests such as the Japanese or Oriental beetles. This is an important issue for IPM given our need to reduce risks from pest management actions. Moreover, the development of environmentally-sound pest management tactics and diversification of IPM plans for turf and landscape systems is of high priority. The use of turfgrass in the United States has increased dramatically during the last four decades due to increases in urban development. As urban and suburban development encroaches into rural landscapes, turf is replacing cropland as the principal managed land cover in the region. For instance, GIS land use data give a conservative estimate of approximately 208,000 acres under turf and turf related land use in Connecticut (Project NAUTILUS 2001). This would place turf acreage as the largest amount of land devoted to a single type of intensively managed system. This is compared to the total amount of farmland acreage in Connecticut which is approximately 360,000 acres (NEASS 2002).

4. Objectives and Anticipated Impacts:

The objectives of the project are: 1) to assess the parasitism rates of *T. popilliavora* on Japanese and Oriental beetle larvae; 2) to screen several flowering plant species that could be used to provide nectar resources to *Tiphia vernalis* during May and June; 3) to screen several flowering plant species that could be used to provide resources to *Tiphia popilliavora* during August and September; and 4) to test the hypothesis that the presence of food plants for *Tiphia* wasps will increase parasitism of Japanese beetle and Oriental beetle larvae by these parasitoids. The criteria for selection of floral resource plants will include that they are not attractive to the pest beetles. Results from this project will indicate which plant species the public can select to promote conservation biological control in their residences or in public landscapes. Conservation biological control of *Tiphia* wasps using floral resources will be a different tool promoted in our area that could be implemented in a short time leading to less insecticide use in urban landscapes. The long term impact from this project will be in safeguarding human health and the environment. The pests and setting addressed in this proposal are found throughout the Northeastern region and the proposed approach will address an important IPM issue of developing more biological control options against the Oriental and Japanese beetles.

5. Approach and Procedures:

Objective 1: Assessment of parasitism rates of *T. popilliavora* on Japanese and Oriental beetle larvae. (Year 1)

The work for this objective will be carried out in September and early October of 2009. The PD has collected preliminary observations about the timing for sampling *T. popilliavora* eggs or larvae found on white grubs. Twelve to fifteen sites around the state will be selected and these will include parks and golf courses. At each site, soil core samples will be taken using a standard golf cup cutter and samples will be obtained every 5 feet along three 60 foot transects. Grubs found in each soil core will be collected and taken back to the laboratory for identification and scoring of parasitism. White grub densities and average percents of parasitism found will be calculated for the Oriental and for the Japanese beetle.

Objective 2: Screening of flowering plant species that could be used to provide nectar resources to *Tiphia vernalis* during May and June (Year 1)

A screening of flowering plants will be done to determine which species are most attractive to *T. vernalis* in terms of observing it take nectar from the plants. The plant selection will be based on the following criteria: 1) The plants need to be in bloom from May to beginning of June which is when adult *T. vernalis* are found; 2) The floral morphology and flower color for some of the plants selected will mimic that of Autumn olive which is a plant that flowers when adult *T. vernalis* are active. This plant could be a good selection because many *T. vernalis* adults have been observed on it and it is found in residential and public landscapes. However, it is considered an invasive plant so it would not be the best species to promote; 3) Some plants included in the selection will have extrafloral nectaries. Peonies will be one plant selected because of this and also because Roger and Potter (2004) showed it to be attractive to *T. vernalis*. Nevertheless, this plant is considered secondarily susceptible to Japanese beetle feeding; and 4) Plants selected should not be attractive to Japanese or Oriental beetles. The USDA has produced a list of plants that are attractive to the Japanese beetles and these plants will be avoided.

Plants will be selected with the help of local nurseries to ensure that plant material is readily available to the public. Plant material will be purchased from the nurseries and the most vigorous plants available and ready to bloom will be selected. Selected plants for screening will be transplanted into turf field plots established at the Plant Science Education and Research Facility, University of Connecticut. A randomized block design will be utilized with each plant species replicated 3 times. Each treatment plots will be 6x6 feet and will contain 5 plants of each species. This design is similar to that used by Roger and Potter (2004) in their work with *T. vernalis*. Plants already in bloom will be transplanted as soon as it is feasible. The presence of *T. vernalis* has been documented at the research facility where the trials will be established. Timed observations will be taken from each treatment plot and the number of wasps observed will be recorded. In addition, around the beginning of July, numbers of Oriental or Japanese beetles observed on the plants will be recorded to avoid selecting a plant that might be attractive to these insects. Similarly, in September, soil core samples will be taken from treatment plots to quantify any grub species present.

Objective 3: Screening of flowering plant species that could be used to provide resources to *Tiphia popilliavora* during August and September (Year 1)

A screening of flowering plants will be done to determine which species are most attractive to *T. popilliavora* in terms of observing it take nectar from the plants. The screening procedures will be the same as described for Objective 2. The presence of *T. popilliavora* has been documented at the research facility where the trials will be established. The plant selection will be based on the following criteria: 1) The plants need to be in bloom from August to September which is when adult *T. popilliavora* are found; 2) The floral morphology and flower color for some of the plants selected will mimic that of wild carrot *Daucus carota* which is a plant that flowers when adult *T. popilliavora* are active and it has been recorded to be a preferred food plant for this wasp (King and Holloway 1930). This plant will be included in the screening but it might not be the most practical plant to suggest to for public use due to its biennial cycle; 3) Some plants included in selection will have extrafloral nectaries. In addition, at least one selection will be a goldenrod species because the PD has observed *T. popilliavora* near sites where goldenrods are present; and 4) Plants selected should not be attractive to Japanese or Oriental beetles. The USDA has produced a list of plants that are attractive to the Japanese beetles and these plants will be avoided.

Objective 4: Test the hypothesis that the presence of food plants for *Tiphia* wasps will increase parasitism of Japanese beetle and Oriental beetle larvae by these parasitoids. (Year 2)

Experiment 1. Influence of wasp food plants on parasitism of Japanese and Oriental beetle larvae by *Tiphia vernalis*. The best plants derived from the Objective 2 screening will be utilized. A complete randomized block design will be utilized with 2 or 3 selected food plant species included as treatments. Plants will be transplanted into a turfgrass field and for each treatment 5 plants will be placed as a group in the center of a 15 x15 feet plot. Each treatment will be replicated 5 times. Around the food plant area, there will be four equidistant stations that will be seeded with 20 grubs each: 2 stations with Oriental beetle larvae and 2 with Japanese beetle larvae. The beetle species will be randomly assigned to each station location. The stations will be constructed as to prevent grub escape by encircling the area with a metal sheeting or plastic

material. The stations will be located 3.2 feet from the food plant area. The control plots will consist of turfgrass areas without any food plants present at the center and areas with a plastic plant mimic. Grub stations will be located using the same pattern described above. Grubs will be seeded to coincide with the peak activity of *T. vernalis* adults. In mid-June, grubs will be examined to determine levels of parasitism. Analysis of variance will be used to determine treatment effects. This experiment will be repeated during a second year. However, this second year repetition falls outside the proposed project dates. Other sources of funding will be sought to carry out this repetition of the experiment.

Experiment 2. Influence of wasp food plants on parasitism of Japanese and Oriental beetle larvae by *Tiphia popilliavora*. The best plants derived from the Objective 3 screening will be utilized. The experimental procedures will be the same as described for experiment 1. Grubs will be seeded to coincide with the peak activity of *T. popilliavora* adults. In early October, grubs will be examined to determine levels of parasitism.

6. Evaluation Plans:

Success of the approach will be measured in the 2nd year of the project when it will be determined if adding certain floral resources to the landscape indeed increases the numbers of *Tiphia* wasps and parasitism on Oriental and Japanese beetles. Subsequently, the results of the research will be communicated to several groups that are involved in turf/landscape maintenance and to homeowners. Step-by-step procedures will be developed in order to increase adoption by the public. Information will be distributed through the IPM Program website under the section of 'Biological Control of White Grubs' which is already available (<http://www.hort.uconn.edu/ipm/>). Fact sheets (such as the one submitted as a relevant reprint) will also be distributed and results will also be communicated at public events. In the short-term, interest in the developed approach could be measured by monitoring webpage downloads and post-presentation surveys. Evaluation of adoption and impacts could be addressed in the future within a larger extension effort dealing with turfgrass/landscape IPM.

7. Key Personnel Involved:

Dr. Ana Legrand, Assistant Extension Professor & IPM Program Coordinator is the project director. Dr. Legrand is an entomologist and is currently studying *T. vernalis* and *T. popilliavora* in Connecticut. In addition, Dr. Legrand is also involved in investigating the use of *Metarhizium anisopliae* for white grub management.

8. References:

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The spring *Tiphia*: a natural enemy of the Japanese beetle

The Japanese beetle, *Popillia japonica*, was first detected in Riverton, NJ in 1916. Since then it has expanded its range continuing to be an important pest of ornamentals and turf. During 1920's and early 1930's USDA entomologists imported *Tiphia vernalis* Rohwer (Hymenoptera Tiphidae) from Korea to aid in Japanese beetle control. This wasp also known as the spring *Tiphia* is a small parasitic wasp that attacks the older larvae or grubs of the Japanese beetle. With their help, populations of Japanese beetles are reduced in number from what potentially could be more severe infestations. Numerous wasp releases were made by the USDA throughout the Northeast. In six of Connecticut's eight counties, releases of *T. vernalis* were made between 1936 and 1949. Surveys done in 2004 and 2005 confirmed that this wasp is present in every Connecticut county and it is found attacking Japanese beetle grubs. At one location, 61% of grubs sampled in mid-June had been attacked by *T. vernalis*. During spring look out for this wasp as one more beneficial that can aid you in dealing with the Japanese beetle.

Spring *Tiphia* females are about half an inch long and the males are about three-eighths of an inch long (Fig. 1). These shiny black wasps are solitary. They do not live in nests or swarms and they have only one generation per year. Male wasps emerge first and 3 to 4 days later females emerge. In Connecticut, *T. vernalis* adults are active from the first week of May to the beginning of June with a peak in adult numbers observed around the last week of May. Adult wasps feed on honeydew produced by insects like aphids and they are seen on the foliage of maple and cherry. Tulip trees are reported as being one of their preferred plants for seeking honeydew. After mating, female wasps burrow into the soil and search for grubs. When a host is found, the wasp stings it and paralyzes it momentarily while the wasp attaches one egg on the ventral groove between the third thoracic and first abdominal segments (Figs. 2 and 3).



Fig. 1. *Tiphia vernalis* adults



Fig. 2. *Tiphia vernalis* egg attached to Japanese beetle grub.



Fig. 3. *Tiphia vernalis* egg attached to Japanese beetle grub.

The egg stage lasts for 9-10 days and the larval stage lasts about 20 days. The parasitic larva after hatching is found outside the host, securely attached and feeding on it until the host dies (Figs. 4 - 6). The parasitic larva grows rapidly and the full-grown larva spins a papery, water resistant, silken cocoon (Fig.7). Within the cocoon it completes its development and transforms into an adult wasp. It passes the winter in this stage within the cocoon until the next spring

when adults emerge to start the cycle all over again. *Tiphia* females live for about a month and may lay 40-50 eggs on as many different grub hosts. The female wasps seek out the fully grown Japanese beetle grubs in the period of time when the grubs are feeding before pupation. The spring *Tiphia* wasp will also attack Oriental beetle grubs.



Fig. 4. Early *Tiphia vernalis* larva feeding on Japanese beetle grub.



Fig. 5. *Tiphia vernalis* larva feeding on Japanese beetle grub.



Fig. 6. Mature *Tiphia vernalis* larva completing its feeding on Japanese beetle grub.

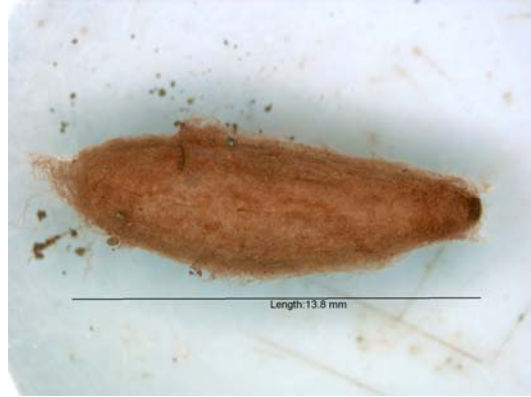


Fig. 7. *Tiphia vernalis* cocoon

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SURVEY OF *TIPHIA VERNALIS* (HYMENOPTERA: TIPHIIDAE),
A PARASITOID WASP OF *POPILLIA JAPONICA*
(COLEOPTERA: SCARABAEIDAE), IN CONNECTICUTDARRYL RAMOUTAR¹ AND ANA LEGRAND²¹University of Rhode Island, Department of Plant Science and Entomology, Woodward Hall,
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The Japanese beetle, *Popillia japonica* (Newman) (Coleoptera: Scarabaeidae), was first encountered in the United States (US) in Riverton, New Jersey in 1916 (Clausen et al. 1927) and has since become the most economically damaging pest of turf and landscape plantings in the eastern United States (Potter & Held 2002). In response to the expansion of *P. japonica*, during the late 1920s and early 1930s, entomologists from the United States Department of Agriculture (USDA) imported several parasitoid wasp species that were natural enemies of *Popillia* in their native habitat (Clausen et al. 1927; King et al. 1951). Of these, *Tiphia vernalis* (Rohwer) (Hymenoptera: Tiphiidae) successfully established and widely distributed itself in the northeastern US, confirmed by surveys in the years subsequent to their release (King & Parker 1950; Ladd & McCabe 1965). In addition to being found in the northeast, today *T. vernalis* occurs in North Carolina, Ohio, Tennessee, Michigan, and Kentucky (Rogers & Potter 2004b; Reding & Klein 2001; Oliver et al. 2005).

In its native habitat (Korea, Japan, and China), *T. vernalis* has been reported to parasitize *P. quadriguttata* (Fabricius), *P. chinensis* (Frivaldsky), *P. formosana* (Arrow), and *P. japonica* (Clausen et al. 1927; Clausen et al. 1932; Clausen et al. 1933; Balock 1934; Fleming 1968; Reding & Klein 2001). *Tiphia vernalis* is univoltine and adults are active from mid-Apr through mid-Jun (Roger & Potter 2004a; King & Parker 1950). Adult female wasps locate soil dwelling larval hosts by using kairomones found in body odor trails and frass (Rogers & Potter 2002). Once a suitable host is found, it is stung ventrally in the mid-thoracic region paralyzing it temporarily (Rogers & Potter 2004a). An egg is then laid externally on the larva in the suture between the third thoracic and first abdominal segments on either side of the median ventral line with the anterior pole directed toward the lateral margin; the placement of the egg in this position is specific to *T. vernalis* (Clausen et al. 1927; Gardner & Parker 1940). *Tiphia vernalis* is an ectoparasitoid and by the fall the parasitoid becomes an adult and overwinters in this stage within the cocoon. Adult wasps emerge in the spring and have a short window of about 6 to 8 weeks in which to

mate and parasitize a third instar Japanese beetle (Clausen et al. 1927). The availability of nearby food plants directly affects the efficacy of this wasp in realizing high parasitization rates (Clausen et al. 1932; Clausen 1956).

In 6 of Connecticut's 8 counties, from 1936-1949, the USDA released female wasps in groups of 100 (referred to by the USDA as a colony) at 151 separate locations. The number of colonies released in each county was as follows, 79 in Fairfield County, 33 in Hartford County, 2 in Middlesex County, 28 in New Haven County, 8 in New London County and 1 Windham County. Releases were not made in Tolland and Litchfield counties. A USDA study done in 1950, surveyed 5 sites near the original release points in 2 counties, Fairfield and New Haven, and confirmed the establishment of *T. vernalis* at these sites (King et al. 1951). The 1950 survey did not examine all counties where releases were made. The distribution of *T. vernalis* in Connecticut had not been monitored since the 1950 USDA survey and tiphiid wasp parasitoids of white grubs had been considered rare in Connecticut (Abbey 2001). Tashiro (1987) suggested that in the past 20-25 years *T. vernalis* has been scarce or unseen in many areas.

In 2004, a survey was conducted on 10 golf course fairways, at least 1 in each county, to determine if *T. vernalis* was established in all of Connecticut's 8 counties. In 2005, populations of adult wasps were monitored to determine seasonal activity in the south, central, and northern regions of the state. In 2005, activity was monitored on 1 golf course in the south region, 1 in the central region and 2 in northern region. The technique described by Rogers & Potter (2004b) for attracting the species was utilized during both years. These methods required the application of 20% sugar water to leaves paralleling golf course fairways on sunny mornings from a height of 0-2 m. In 2004, sugar water was applied to the foliage of plants along golf course fairways for a length of 25 m and this was repeated every 30 min for 2 h. All the wasps attracted to this area, during the time interval, were counted. In 2005 this procedure was repeated for 60 m, reapplying sugar water every 60 min for 2 h. In 2004 and 2005 wasp voucher specimens were collected and these are currently

stored in the laboratory of Dr. Ana Legrand at University of Connecticut. Authentication of *T. vernalis* was determined morphologically by Dr. Ken Ahlstrom of the North Carolina Department of Agriculture and Consumer Services.

The survey indicated that *T. vernalis* wasps are presently distributed throughout all of Connecticut's 8 counties, even in counties where they were not released (Fig. 1). The 2005 survey results indicate that *T. vernalis* adults are active from the first week in May to the beginning of Jun. Peak numbers were observed during the fourth week of May (Table 1). In Kentucky, where extensive sampling of *T. vernalis* has been conducted, adults were found to be active from mid-Apr to mid-Jun (Roger & Potter 2004a). There was substantial variation in the numbers of wasps observed at each site. For example, at Hunter Memorial Park (New Haven County) the peak number observed was 563 adults, while only 28 were seen at Skunk-gamaug Golf Course (Tolland County). The results of this survey show that the wasps are not rare in Connecticut and that they should be integrated

with other measures for Japanese beetle management. For example, the public is generally unaware of these wasps and integrated pest management guidelines could suggest methods to conserve and enhance their population; e.g., planting floral nectar sources to attract and sustain the wasps (Rogers & Potter 2004b) and avoiding insecticide treatments to turf during the adult flight period (Rogers & Potter 2003; Oliver et al. 2005). While adult wasps were readily observed in this study, parasitized larvae were not found in the limited search conducted. Additional work needs to address the current rates of parasitism by *T. vernalis*. In Kentucky, *Tiphia* spp. have been found to parasitize up to 58% of potential host grubs (Rogers & Potter 2004a) and King & Parker (1950) found an average of 57% of Japanese beetle grubs parasitized over a 13-year study.

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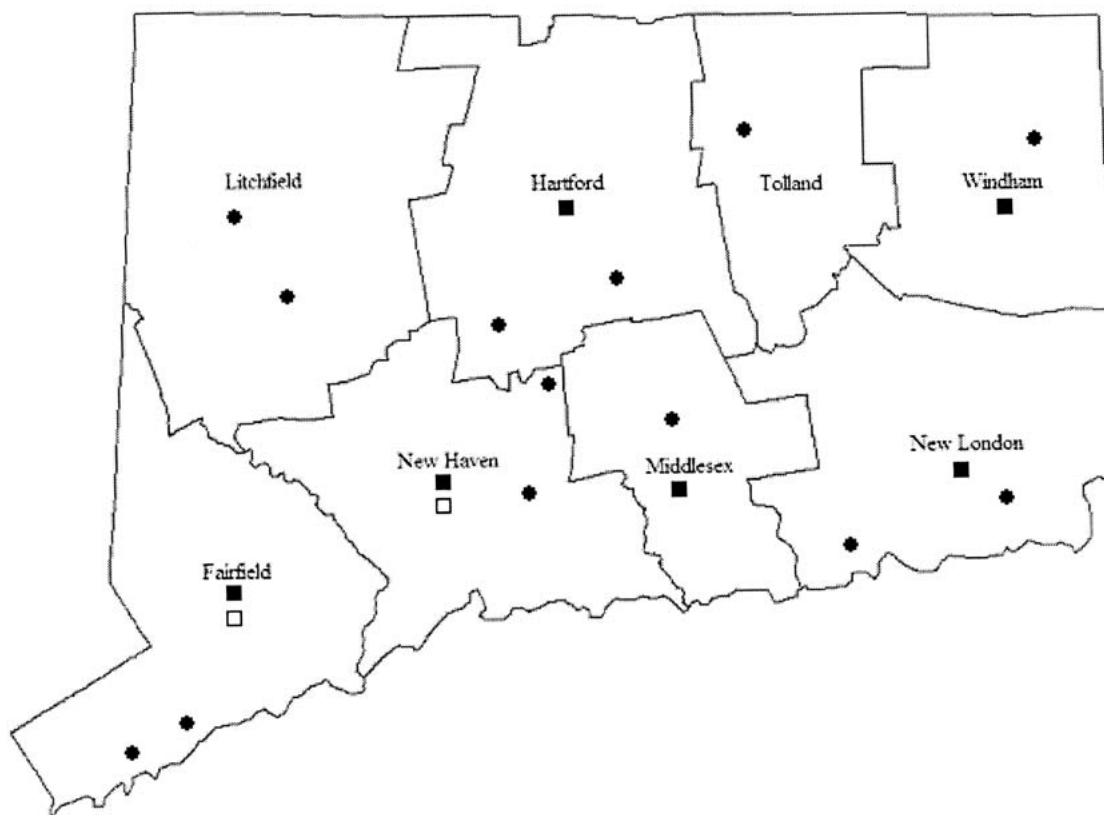


Fig. 1. Specific locations in Connecticut counties where *T. vernalis* wasps were released and where they were found by subsequent surveys. ■ Counties where the USDA released *Tiphia vernalis* adults during 1936-1949. □ Counties where the USDA reported viable *Tiphia vernalis* colonies as a result of releases made during 1936-1949 (from USDA surveys conducted in the 1950s). ● Locations within each county in Connecticut where *Tiphia vernalis* wasps were found during 2004 study.

TABLE 1. THE SEASONAL TIMING OF *TIPHIA VERNALIS* COLLECTIONS IN CONNECTICUT DURING 2005 DETERMINED BY THE NUMBER FOUND AT EACH LOCATION FOR EACH WEEK.

Date sampled	BA	HMP	WCC	SCG
May 2	2	9	0	0
May 9	28	15	4	0
May 17	28	430	6	52
May 23	35	563	28	84
May 30	10	387	4	27
Jun 6	0	60	0	0
Jun 11	0	0	0	0

BA—Bartlett Arboretum, Fairfield County, southern location; HMP—Hunter Memorial Park, New Haven County, central location; WCC—Willimantic County Club, Windham County, northern location; SCG—Skungamaug Golf Course, Tolland County, northern location.

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SUMMARY

This study determined the distribution and seasonal timing of *Tiphia vernalis* (Rohwer) (Hymenoptera, Tiphidae) in Connecticut. *Tiphia vernalis*, an imported parasitoid of the Japanese beetle, was considered rare in the state before this study. The survey results indicated that *T. vernalis* is present in every county of the state including Tolland and Litchfield counties, where the wasps were not originally released. The widespread existence of the species in the state is significant because it aids in the control of the Japanese beetle, a serious pest of turf and landscape plantings.

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