Biological Control of Japanese Beetle In Michigan

Final Report
for the
Michigan Department of Agriculture
Horticulture Fund

by
David Smitley
Department of Entomology
Michigan State University
East Lansing, Michigan, 48824

August 1, 2008

Introduction

Significance of Japanese beetle as a pest. The Japanese beetle, *Popillia japonica* Newman is one of the most damaging pests in eastern North America, feeding on roots of turf and ornamentals as a larva, and defoliating flowers, trees, shrubs and fruit crops as an adult (Fleming 1972, Potter 1998). Japanese beetle can be devastating for nursery growers, perennial growers and outdoor cut-flower growers because nurseries cannot ship plants from infested states to non-infested states unless it is certified as free of Japanese beetle (Smitley 1996). The finding of a single Japanese beetle larva can result in restriction of an entire nursery field. Even greenhouse growers must cover their greenhouse vents and doors with screening before they can be certified to ship plants out of the state. In the urban landscape, the Japanese beetle is a serious flower and shade tree pest. It frequently defoliates lindens, sycamores, Japanese maple, birch, chestnut, sassafras, hibiscus, crabapple, ornamental cherries, roses, raspberries, mountain ash, Virginia creeper and many others (Fleming 1972, Johnson and Lyon 1988). In heavily infested areas, insecticide applications must be repeated frequently between June and September to maintain foliage and flowers on these plants. Millions of inexperienced homeowners are purchasing insecticides from local garden centers to spray for Japanese beetle, increasing the pesticide load around homes and gardens and increasing human exposure to pesticides (Ware 1994).

The Japanese beetle is the most damaging pest of golf courses, lawns and sod farms in the eastern United States (Potter 1998, Vittum et al. 1999). Adults are attracted to moist turf where they prefer to lay their eggs. The larvae feed on turf roots, sometimes causing extensive direct damage, and frequently causing indirect damage by attracting skunks and raccoons that tear-up the turf to find grubs. On golf courses the problem extends beyond turf loss: golfers often complain about Japanese beetles landing on them and on the greens where they interfere with putting. Most golf courses in infested areas spray tees, greens and fairways at least once per year to prevent turf injury from Japanese beetle. Recreational turf, roadsides, school yards, industrial turf, and sod farms also may be damaged from Japanese beetle larvae (Vittum et al. 1999).

The Japanese beetle also causes substantial economic losses for many different specialty crop fruit growers. One example is blueberries grown for processing. Adult Japanese beetles have the unfortunate behavior of clinging to berries even after they die, which results in some beetles making it all the way through mechanical sorting procedures. Even one beetle in processed food can jeopardize an entire crop. In the late 1990's in Michigan, blueberry growers lost a contract with the largest processor in the region (a loss of $10 million per year in sales) because a few Japanese beetles were found in the final product (see Trinka letter, Appendix I). Grapes and raspberries are also highly attractive to adult Japanese beetles. Feeding damage to grape leaves may be so severe that yields are reduced, and an entire crop of raspberries can be lost if Japanese beetles are not sprayed. Although turfgrass, nurseries, blueberries, grapes and raspberries have been hit the hardest by Japanese beetle, many other crops are affected, including roses, apple, cherry, peach(fruit damage), and sweet corn (Hadley and Hawley 1934, Metcalf et al. 1962, Fleming 1972, Davidson and Lyon 1987).

Research on *Ovavesicula popilliae* since 1999. Based on the promising work of Hanula and Adreadis (1988) in Connecticut we began to investigate the potential of pathogens for long-term biological control of Japanese beetle in Michigan in 1999. We started by comparing the abundance of Japanese beetle pathogens in Connecticut with the same in Michigan (Hanula and Andreadis 1988, Cappaert and Smitley 2002). We sampled Japanese beetle populations from 35 locations in 15 counties of southern Michigan in 1999 and 2000, specifically looking for *Paenibacillus popilliae* (Dutky), *Ovavesicula popilliae* Andreadis, *Stictospora villani*, and entomopathogenic nematodes (Fleming 1968, Andreadis and Hanula 1987, Poinar et al. 1987, Kaya and Gaugler 1993, Klein and Georgis 1993, Campbell et al. 1995, 1998, Klein and Moysenko 1997, Hays et al. 2004). Third instars were collected from 11 golf courses and 24 low maintenance sites including golf course roughs (n = 8), blueberry farms (n = 7) and recreational turf (n = 9). *Ovavesicula popilliae*, reported to be widespread and epizootic in some eastern states, was absent at all but 2 locations near Kalamazoo, Michigan (Table 1).

Table 1. Incidence of pathogens of Japanese beetle in Michigan in 1999 compared with the same in Connecticut in 1987 (Hanula and Andreadis 1988, Cappaert and Smitley 2002).

Pathogen	Presence in MI (No. of sites)	Presence in CT (No. of sites)	Infection rate in MI (%)	Infection rate In CT (%)
P. popilliae	6/35	13/49	0.9	3.7
Ovavesicula	2/35	31/49	0.2	24
Stictospora sp.	26/35	39/45	34	50-100

Paenibacillus popilliae also was not as widespread in Michigan (6/35 sites) as it was in Connecticut (13/49 sites). *Stictospora sp*. was found at most locations (25/36) where Japanese beetle infestations have been active for more than 20 yr, but was scarce or absent from areas where Japanese beetle has become established in the last 10 yr. (Cappaert and Smitley 2002).

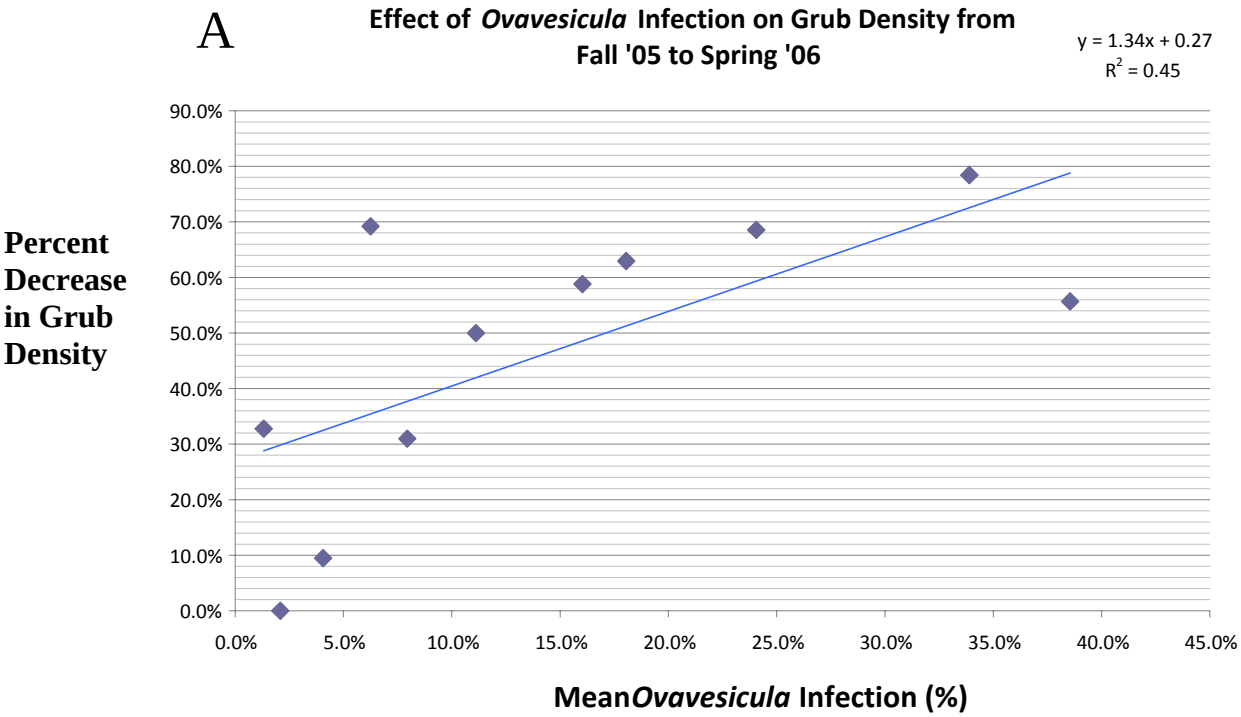
In Hanula's (1990) paper, the density of Japanese beetle larvae declined over a 3-year period at four sites with a high level of *Ovavesicula* infection. However, the impact of Ovavesicula at these sites is still in question because there were no control sites without Ovavesicula for comparison, and there is no way to separate the impact of Ovavesicula from a decrease in Japanese beetle larvae due to the unusually dry soil conditions that were reported for the summer of 1986 (Hanula1990). In order to better determine the impact of *Ovavesicula* on populations of Japanese beetle we collected 2,000 Japanese beetle larvae from a location in Massachusetts where *Ovavesicula* was epizootic for introductions into Michigan. The larvae were sampled to confirm a high level of *Ovavesicula* infection before they were introduced to 4 locations in Michigan in 1999. An additional 2,000 infected larvae were added to the same introduction plots in 2000. Sampling over the next 6 years indicated that *Ovavesicula* can be established through the introduction of infected larvae, and will spread and become epizootic within 300 m of the introduction plots in 6 years (Smitley unpublished, Table 2).

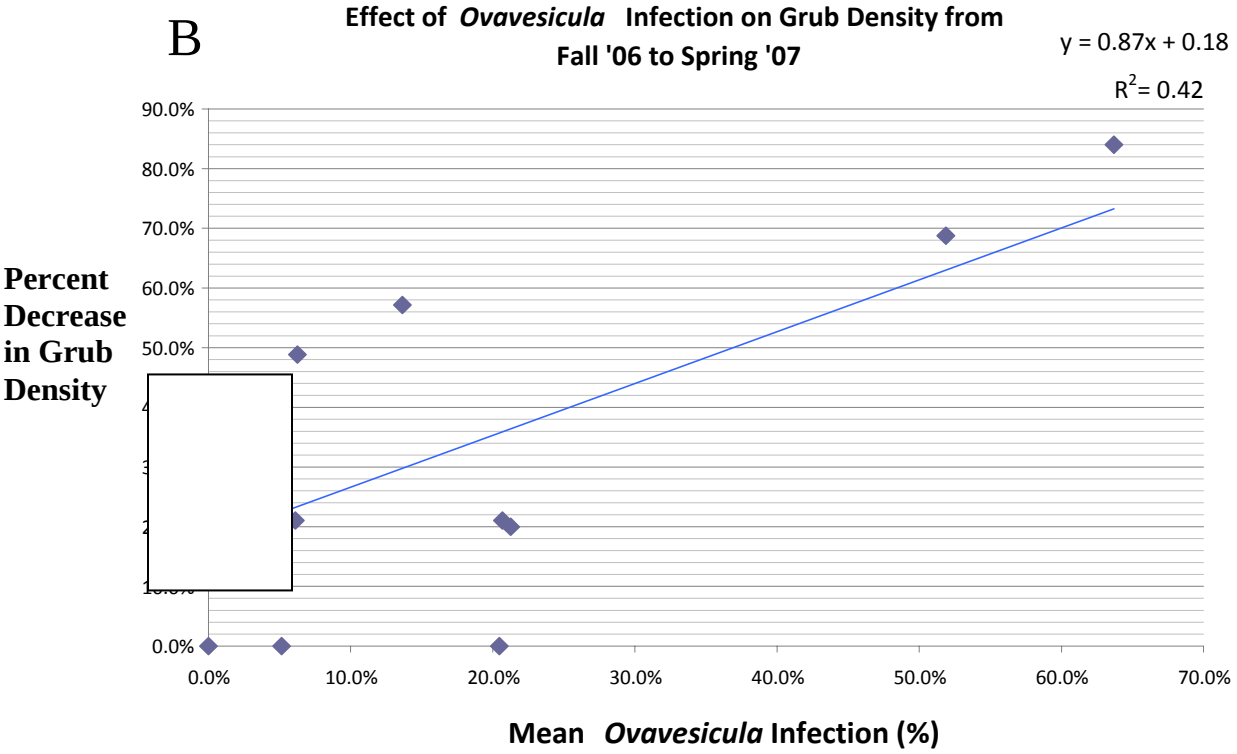
Table 2. Infection of Japanese beetle grubs with *Ovavesisula* from 2000 to 2007 at golf course study sites. *Ovavesicula* apparently spread naturally in south central Michigan (in light turquoise shading) but in Southeast Michigan it was only found where we introduced it ('+') in 1999.

Golf course site	*O. popilliae* Introduction site (+)	*O. popilliae* % infection fall 2000	*O. popilliae* % infection fall 2005	*O. popilliae* % infection fall 2006	*O. popilliae* % infection 2007 Spring	Fall
Medalist #5			11	0	6.7	0.0
Medalist #4	+	0	0	0	27.3	12.5
Binder Park #18			51	52	75.0	11.1
Binder Park #6		0	31	44	60.0	13.3
Eastern Hills #7			43	13	0.0	0.0
Eastern Hills #5	+	20	17	24	13.3	33.3
Kalamazoo #15			17	64	16.0	ND
Kalamazoo #1		6	20	41	0.0	0.0
Willow #10			0	8	0.0	2.1
Willow #9	+	0	7	43	0.0	45.0
Orchard Lk #10			0	0	0.0	8.3
Orchard Lk #15	+	0	13	30	10.9	27.8
Pine Valley SM			0	5	10.7	50.0
Pine Valley #4		0	0	3	0.0	0.0

Golf course sites where *Ovavesicula* was introduced and control sites with no or little *Ovavesicula* were sampled again in 2005 and 2006 to determine the incidence of *Ovavesicula* infection along the fairways where it was introduced, adjacent fairways, and control fairways. Survival of Japanese beetle larvae from October to May was determined at all the same locations by sampling grubs from 16 plots along each fairway. The impact of *Ovavesicula* on Japanese beetle was then determined by comparing larval survival at locations with various levels of infection by *Ovavesicula* (Figure 1A, 1B). Percent infection of grubs by *Ovavesicula* was inversely related to grub survival in both years. At sites where there was no or very little *Ovavesicula*, Japanese beetle larvae survived at a rate of 70 to 80%, while at sites with the highest incidence of infection larval survival was only at a rate of 25 to 40%. In addition we found that about 20% of the adult female beetles were also infected, and egg production in infected females was reduced by 60%. The combined impact of larval mortality and reduced egg production gives an average population reduction of 57% per year due to *Ovavesicula*. This level of sustained natural biological control is expected to significantly reduce the density of Japanese beetles and therefore the amount of damage to turfgrass, blueberries, raspberries, nursery crops and landscape ornamentals.

Figure 1. Decrease in Japanese beetle grub density from fall 2005 to spring 2006 (A) and from fall 2006 to spring 2007 (B) at study sites with various levels of *Ovavesicula* activity.





Accomplishments in 2007:

At each of the 10 golf course study sites Japanese beetle grubs were collected in the spring and fall from 16 locations along the edge of the original fairway (inoculated or control, depending on the golf course), and from 16 locations along a different fairway located from 50 to 150 m away. Forty grubs from each fairway were dissected to determine percent infection by *Ovavesicula popilliae* and milky disease. Japanese beetle adults were collected from each golf course in late July and early August using a standard Japanese beetle trap baited with eugenol. At least 60 adults from each fairway were dissected and examined for infection by *O. popilliae*. In addition, the ovaries were removed and developing eggs counted to determine effects of infection on the reproductive ability of females.

Results in 2007: *O. popilliae* infection of Japanese beetle grubs continued to increase at sites where it was introduced in 1999 and 2000 (Table 2). At Orchard Lake and Willow golf courses, where *O. popilliae* appears to have originated as a result of our introductions into a 100 m^2 plot area in 1999 and 2000, the infection of grubs has spread up and down the entire length of a fairway and infected grubs are now being found in adjacent fairways. Infection levels at those sites have now increased to >30%, a level expected to have a significant impact on the density of grubs in that population. In 2007, adults were dissected and examined for *O. popilliae* infection for the first time. At sites where *O. popilliae* was previously found in grubs, the infection level of adults ranged from 5 to 30%. This rate of infection of adults will allow *O. popilliae* to spread at least a ¼ mile per year, because adults frequently fly that far. Also, infected females only

produced 40% as many eggs as healthy females. The impact of *O. popilliae* infection on Japanese beetle populations was measured by determining the survival of grubs from fall of 2005 to spring of 2006. At golf courses where more than 25% of the grubs were found to be infected, the decrease in grub density from fall to spring was 57.4% compared with 28.2% at sites where no *O. popilliae* was found. When the observed reduction of egg production in infected females is added to grub survival rates, at sites where *O. popilliae* is active, Japanese beetle populations could decline 67% or more per year when compared with sites without *O. popilliae*.

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