USE OF PARASITOIDS FOR CONTROL OF OVERWINTERING INDIANMEAL MOTH POPULATIONS IN POSTHARVEST DRIED FRUITS AND NUTS

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The Indianmeal moth, *Plodia interpunctella*, is a major problem during processing and storage of dried fruit and nuts. Because current control practices rely on fumigation with methyl bromide, the impending loss of this fumigant has created the need for alternative treatment methods. While a single replacement alternative is unlikely, a control program which includes a number of treatment strategies is under investigation. One such strategy is the use of insect parasitoids for control of overwintering pest populations.

Habrobracon hebetor

The Indianmeal moth survives the relatively mild California winter primarily as a last instar diapausing larva, and remains in this stage from early November until late March or mid April. This stage is susceptible to attack by an external parasitoid; *Habrobracon hebetor*. *H. hebetor* females sting and paralyze host larvae before depositing eggs. Observations made at a culled fig warehouse indicated that *H. hebetor* was capable of paralyzing host larvae on warm winter days. Because Indianmeal moth populations remain in a susceptible stage throughout the winter, mass release of *H. hebetor* within dried fruit and nut storages at this time may help reduce the number of moths emerging in the spring.

Materials and Methods: Experimental units were 0.12 m^3 (32 gal) trash cans fitted with clear plastic lids. Each unit contained 22.7 kg (50 lbs) of almonds. About 100 Indianmeal moth eggs were added to each unit on October 17, 1997. Units were then placed within an unheated van cargo container. Timed fluorescent lights provided a 10 hr photoperiod within the container. A datalogger recorded ambient temperatures. *Habrobracon hebetor* reared at about 18°C (65°F) were added on December 30, 1997, after host larvae had entered diapause. Four different infestation levels were used: 0, 3, 9 and 15 female *H. hebetor* per unit. One male *H. hebetor* was added for every three female parasitoids. Three units were used for each infestation level. Beginning in March, 1998, units were examined periodically and any adult moths removed. After no moths were recovered for 10 days, the almonds were placed in 10°C (May 7, 1998), until they could be moved to plastic bags and frozen. Almonds were then examined for Indianmeal moth or *H. hebetor*.

Results: More live adult Indianmeal moth were recovered from controls (0 *H. hebetor*), than from any of the units treated with *H. hebetor* (Table 1). The number of *H. hebetor* added did not seem to have any effect on the number of emerging moths. This may be due to *H. hebetor* cannibalizing the eggs of competing females at the higher treatment levels. Note that an average of 13.7 *H. hebetor* were recovered from the lowest treatment level (3 *H. hebetor*), indicating that successful reproduction had occurred. The numbers of *H.*

hebetor recovered from the other treatments were lower, suggesting that little or no reproduction occurred. Also, more dead Indianmeal moth larvae were recovered from the higher treatments, possibly because greater numbers of developing *H. hebetor* at the lower level consumed their hosts completely.

Venturia canescens

Venturia canescens is an internal parasitoid, depositing a single egg within the larval stage of pyralid moths. The adult *V. canescens* is not as cold tolerant as *Habrobracon hebetor*, and may survive the winter as eggs or larvae within diapausing host larvae. Releasing *V. canescens* in the fall may result in an increase in adult parasite numbers just as Indianmeal moth populations develop in the spring. Studies were done to show that *V. canescens* is capable of surviving subfreezing temperatures within diapausing host larvae.

Materials and Methods: Diapausing Indianmeal moth larvae were obtained by placing 16 oz. rearing units infested with about 100 Indianmeal moth eggs outside in the fall. To obtain parasitized diapausing larvae, five adult *Venturia canescens* were placed in each treatment container and held for 24-48 hours at about 15°C (59°F). Adult parasitoids were removed and treatment containers were returned to 15°C until treatment. Treatment containers were exposed to -10°C (14°F) for various time periods. After treatment, containers were held at 28°C (83°F) and monitored for moth and parasitoid emergence. Additional treatment parameters are given in Tables 2 and 3.

Results: Dissections of parasitized host larvae showed that *V. canescens* is slow to develop at 15°C. Even after 10 days, most dissected host larvae contained only parasitoid eggs. Survival of *Venturia* seem most correlated with survival of host larvae (Table 2 and 3.) Parasitoid age or host source had little consistent effect. Some *V. canescens* survived exposure to -10°C for as long as 5 days. Given that the Central Valley rarely sees such low temperatures, *V. canescens* is likely to survive the winter months within diapausing host larvae.

Discussion

Initial results with small scale release of *Habrobracon hebetor* against diapausing Indianmeal moth larvae indicate that relatively small numbers of *H. hebetor* may be effective in reducing pest populations in storage. The demonstrated ability of *Venturia canescens* to survive sub-freezing temperatures within diapausing host larvae suggests that release of these parasites in the fall may yield a ready source in the spring. While use of these parasitoids alone would be unlikely to provide adequate control, they show promise as part of an integrated management system, by reducing the number of overwintering Indianmeal moths.

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Table 1. Efficacy of *Habrobracon hebetor* in reducing overwintering Indianmeal moth (IMM) populations in stored almonds.

Treatment	Live	Insects recovered from frozen almonds			
(E *H. hebetor)*	Adult IMM	*H. hebetor*	IMM larvae	IMM pupae	IMM adults
0	32.0	0.0	0.7	0.0	0.7
3	6.0	13.7	11.7	0.0	0.0
9	3.0	10.3	18.7	0.0	0.7
15	6.3	12.7	22.3	0.3	0.3

Figures are averages of 3 replicates

Table 2. Emergence of Indianmeal moth (IMM) and *Venturia canescens* after exposure to sub-freezing temperatures: 1996 studies.

Exposure	1 day old *V. canescens*			3 day old *V. canescens*		
to -10°C	Control	*V. canescens* added		Control	*V. canescens* added	
(days)	IMM	IMM	*V. canescens*	IMM	IMM	*V. canescens*
0	37.7	22.0	32.3	56.0	7.7	13.7
1	44.0	25.3	23.7	22.7	6.7	15.0
2	62.7	16.0	26.0	16.0	3.3	11.0
3	41.3	12.7	22.7	4.0	3.3	6.0
5	6.3	6.7	8.7	0.0	0.7	2.0

Indianmeal moth exposed to adult *V. canescens* for 24 hours; parasitized hosts exposed to sub-freezing temperatures 1 and 3 days after exposure to adult parasitoids. Figures are averages of 3 replicates

Table 3. Emergence of Indianmeal moth (IMM) and *Venturia canescens* after exposure to sub-freezing temperatures: 1998 studies.

Exposure	Host HCRL			Host Wildtype		
to -10°C	Control	*V. canescens* added		Control	*V. canescens* added	
(days)	IMM	IMM	*V. canescens*	IMM	IMM	*V. canescens*
			2 day old *V. canescens*			
0	45.3	27.0	14.7	67.3	45.0	26.0
1	39.0	24.3	12.0	43.0	44.0	32.7
1.5	29.0	40.0	1.3	36.7	21.0	6.7
2	16.0	19.7	5.0	30.0	11.3	19.7
			10 day old *V. canescens*			
0	39.0	27.3	1.7	58.7	15.3	24.7
1	7.3	8.7	12.7	10.0	11.7	15.0
1.5	10.3	8.7	3.3	10.0	7.7	20.7
2	1.3	6.3	3.3	15.0	6.7	8.7

Indianmeal moth exposed to adult *V. canescens* for 48 hours; parasitized hosts exposed to sub-freezing temperatures 2 and 10 days after exposure to adult parasitoids. 'HCRL' refers to long-term HCRL laboratory IMM culture; 'wildtype' refers to IMM recently isolated from a culled fig warehouse. Figures are averages of 3 replicates