Internal Lepidoptera Problems in Apple Orchards: From the World to New York

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Since this introductory talk is heavily focused on recent problems with internal lepidoptera larvae infesting commercial orchards in New York State, I would first like to mention that there are three species of lepidoptera in the northeastern United States that can potentially infest apples—codling moth, *Cydia pomonella*; oriental fruit moth, *Grapholita molesta*; and the lesser appleworm, *Grapholita prunivora*.

The codling moth is the most common lepidoptera species infesting apples in commercial orchards throughout the world. This pest was originally controlled by lead arsenate, which was replaced by DDT in the 1940s. The codling moth had developed widespread resistance to both of these compounds by the early 1950s. Organophosphate insecticides were introduced to control this pest in the early 1960s to replace these earlier compounds, and this class of broad-spectrum insecticides, particularly azinphosmethyl, provided excellent control for almost 30 years. In addition to providing excellent control of the codling moth, the materials were also effective against other species of insects attacking fruit and were relatively inexpensive.

Eventually several species of predaceous mites became resistant to these materials, and organophosphates were widely used as a foundation of integrated pest management programs (IPM) in apple orchards because of their lack of toxicity to these beneficial species.

In the early 1990s outbreaks of codling moth occurred almost simultaneously in commercial apple orchards in countries in Europe and other apple production areas throughout the world. Eventually most of these outbreaks were attributed to the development of relatively low levels of insecticide resistance to commonly used organophosphate insecticides (ca. 3-10X), which were sufficient to cause control failures. Table 1 (slightly modified from a presentation made by Dr. V. Harris, M. Angst, and P. Carudel at a 2001 meeting of the Insecticide Resistance Action Committee) shows the worldwide incidence of codling moth resistance to organophosphates (OP), synthetic pyrethroids (SP), and various types of IGRs.

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Organophosphate resistance is common in most apple producing countries and in several of the European countries, Germany, Italy and France, there is documented resistance to all three classes of chemicals, organophosphates, synthetic pyrethroids and various types of insect growth regulators. Entomologists in South America have done very few formal studies to monitor insecticide resistance, but growers in Chile are having increasing difficulty in maintaining adequate control of codling moth even with five to six sprays of organophosphates and are beginning to use mating disruption integrated with insecticides to manage this pest. This lack of effectiveness of normal chemical control programs suggests that organophosphate resistance may be developing in Chile.

In Argentina, growers switched to synthetic pyrethroids a number of years ago to reduce costs but experienced control failures with codling moth control after several years of continuous use of these materials. Current laboratory studies in Argentina conducted by L. Cichon and D. Guana from INTA have shown that field populations of codling moths are about 2X less susceptible to azinphosmethyl than a susceptible population, and adequate control in the field in some orchards can be obtained only by applying five to seven sprays of this material during the season at maximum rates. This increasing need to increase organophosphate sprays suggests that populations of codling moths in some orchards in Argentina are becoming resistant to these materials.

In the United States, the first outbreaks of codling moth occurred in apple orchards in the Washington and California apple growing regions, and subsequent studies indicated that field populations throughout the western fruit production regions had low levels of resistance (4-7X) to azinphosmethyl. During the last 5 years, outbreaks of internal lepidoptera have been reported in all major apple production regions of the United States and Canada, although resistance has not yet been formally documented in all of these areas.

TABLE 1

Current worldwide status of codling moth insecticide resistance.

	Organophosphates	Synthetic pyrethroids	Insect growth regulators
Australia	X		
Canada	X		
USA	X		
Netherlands			X
South Africa	X	X	
Germany	X	X	X
Italy	X	X	X
France	X	X	X
South America	?	X	

New York State has several different apple production regions: western NY along the shores of Lake Ontario, a small area near Lafayette, NY, the Hudson Valley region, several orchards near the city of Saratoga, and the Champlain Valley area. Currently severe damage from internal lepidoptera has been observed only in commercial apple orchards in the western NY region. For example, during the 2001 growing season, Motts North America, western NY's largest processor, rejected 20 loads of apples because of detection of unacceptable levels of internal lepidoptera larvae, and in 2002 they rejected 80 loads from 42 growers.

During 2002, loads of the following cultivars were rejected: Rhode Island Greening (12 loads), Monroe (12 loads), Cortland (7 loads), Idared (7 loads), Jonagold (6 loads), Rome (4 loads) and a total of 4 loads were rejected of Golden Delicious, Ben Davis, and Empire. Informal surveys conducted in apple cultivars marketed as fresh fruit within the region indicated that damage from internal lepidoptera larvae was also quite severe in Gala and Gingergold. In general, surveys showed that all cultivars were infested except McIntosh apples, which had relatively low levels of damage.

Although only informal surveys were conducted in 2002 to assess damage from internal lepidoptera species within the western NY region, preliminary observations suggested that about three to four orchards had 20 to 30% infested fruit at harvest; approximately 40 to 50 growers had 1-10% damage, and there were many other growers who had traces of damage below 1%. Generally fruit was marketed normally either for fresh markets or sold for processing in these orchards that had relatively low damage levels. Since the processors rejected fruit loads whenever just one live larva was observed during their normal fruit sampling procedure, it was difficult to quantify actual fruit infestation levels from their observations.

Therefore, fruit was sampled to estimate the percentages of internal lepidoptera damage in orchards from which fruit had been rejected for processing. At least two samples of 100 fruits were examined either from lots of bins that had been rejected by the processor or on trees within orchards where damage was observed prior to harvest. These samples revealed that damage levels from rejected loads and among trees were somewhat variable, ranging from 1-19% but generally averaged >5% infested apples. Samples collected from either bins or trees showed that there was substantial variability in infestation levels between bins or trees from each site, but damage in different samples from the same bin or tree were relatively consistent.

In order to identify which species of internally feeding lepidoptera were present in infested apples collected from problem orchards in western NY, samples of infested fruit were collected both from processors and from growers' individual orchards. A total of 677 larvae were recovered from 20 different orchards. However, adequate samples (>10 larvae) were recovered from only about 10 commercial orchards. Table 2 presents a comparison of different species of larvae recovered from samples taken in the monitored orchards. About 72% of the total larvae dissected from infested apples in NY at the end of the 2002 growing season had anal combs, which indicated that they were either oriental fruit moths or lesser appleworm. Almost one-half of the 10 sampled orchards had almost no codling moth larvae, and codling moth populations were low in most of the other block (Table 2). Only one of the sampled blocks had a high percentage of codling moth larvae (L-1) and another site (V-1) had an estimated 58% of codling moth larvae.

It is very difficult to separate oriental fruit moth larvae and lesser appleworm larvae using taxonomic keys. A sample of larvae from six of the orchards that had larvae with anal combs was sent to Pennsylvania State University to be examined by Dr. Greg Krawczyk, who is one of the most experienced entomologists in the United States in identification of lesser appleworm larvae.

The results of his examinations of the larvae from these sites are shown in Table 3. Although larvae in all of the sites were predominantly identified as oriental fruit moths, a small percentage of larvae from all orchards were identified as lesser appleworms, with percentages ranging from 6-33% of the total larvae. Additional studies will have to be done to confirm the presence of lesser appleworm larvae in severely infested apple orchards in western NY. Generally this species has not been considered a serious pest in commercial apple orchards, although it can commonly be found infesting apple and hawthorn fruit throughout northeastern North America in unsprayed habitats.

These studies conducted during the 2002 growing season clearly show that outbreaks of internal lepidoptera occurred in multiple commercial apple orchards throughout the western NY apple growing region. This problem was definitely more serious in 2002 than it has been in previous years. Although the majority of larvae collected from infested apples were identified as oriental fruit moths, multiple species including codling moths and even lesser appleworms were apparently present in some orchards. Future studies will have to be done to monitor the susceptibility of populations of internal lepidoptera in some of these problem orchards to organophosphate insecticides and other types of chemicals, and different control programs will have to be tested. If this problem is not solved relatively quickly, apple growers in NY, particularly in the western production region, could suffer major losses from infestations of internal lepidoptera larvae in the future.

TABLE 2

Preliminary classification of internal lepidoptera larvae in fruit from severely infested New York apple orchards, 2002.

Orchard	Percentage of larvae	
	Oriental fruit moth or lesser appleworm	Codling moth
B-1	84	16
D-1	97	3
E-1	90	10
L-1	5	95
V-1	58	42
D-2	100	0
M-1	100	0
P-1	100	0
S-1	100	0
S-2	100	0

TABLE 3

Preliminary identification of non-codling moth larvae collected from severely infested orchards during 2002 in NY.

Site	# larvae	Oriental fruit moth (% of larvae)	Lesser appleworm (% of larvae)
#1	15	94	6
#2	33	94	6
#3	49	94	6
#11	24	83	17
#35	42	67	33
#40	25	84	16
#46	12	83	17