# Twenty Years of Apple Production Under an Ecological Approach to Pest Management

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Since 1978, many apple growers in Massachusetts have been practicing what might be termed a "top down" approach to integrated pest management (IPM). This approach takes as its starting point a conventionally managed orchard that has been under commercial operation for several years or decades and aims, in stepwise fashion, at reducing the amount of pesticide used while gradually advancing the influence of natural ecological processes that promote buildup of natural enemies of pests. Over the past 20 years or so, numerous articles in *Fruit Notes* have reported on progress toward "top-down" IPM in commercial orchards.

An alternative approach to apple IPM that might be termed a "bottom-up" approach takes as its starting point a newly planted orchard and aims, in stepwise fashion, to add external inputs such as pesticide only as needed to augment natural ecological processes in overcoming biological barriers to attaining a high-quality marketable crop.

Since the 1970's, there has been an increasingly intensive effort on most continents where apples are grown to implement a top-down approach to integrated management of apple pests. In its initial stage, this effort usually has involved monitoring weather and/or pest abundance in an orchard and using information from monitoring, in conjunction with threshold values and models, for making decisions as to whether or not to apply a pesticide. Integration at this stage usually has taken the form of overt consideration of natural enemies of the pest in question and explicit attention to choosing pesticides that minimize harm to these and other beneficials. In more advanced stages, top-down approaches to apple IPM have increasingly emphasized integration across disciplines of entomology, pathology, weed science and horticulture and substitution of cultural, biological, genetic and behavioral methods of controlling apple pests for pesticidal methods.

More recently, a bottom-up approach to apple IPM has begun to receive attention. In its purest form, this approach is perhaps best expressed within the philosophy and practices of organic apple production. In a modified form, it may be expressed as ecological apple production that accents, prior to planting orchard trees, ecosystem design, habitat manipulation, cultural management, plant resistance to pests, and biological pest control through natural enemies as the foundational elements of IPM.

In 1977, I planted a small orchard of apple trees in Conway, Massachusetts specifically designed for commercial production using a bottom-up ecological approach to pest management. This approach has been maintained throughout all 20 years (1981-2000) of harvest and sale of fruit. I report here on pest management practices and pest incidence across the entire two decades of commercial sales. Long-term studies can be highly rewarding in elucidating the dynamics of pest populations comprising biological communities. Toward this end, a principal objective of this report is to portray long-term consequences of the ecologically-based pest management approach used in the Conway orchard.

## *Material & Methods*

### *Orchard and Habitat Design*

The orchard (about 1/3 acre) consists of 50 apple trees, all on dwarf (M.26) or semidwarf (M.7) rootstock. Woods border the orchard on the north and east, beginning 6 yards from perimeter apple trees. Open field stretching for 100 yards borders the orchard on the south and west. Ten unmanaged apple trees, some annually bearing fruit, stand 200-250 yards from the orchard. Insofar as possible, the orchard was designed from the outset to maximize genetic-based host plant resistance to pests, minimize influx of pests arising from habitats bordering the orchard, and maximize influx of natural enemies of pests from bordering habitats. Annually, the orchard was pruned in March and received lime and fertilizer based on annual soil pH and leaf nutrient analysis.

The only key apple pest in Massachusetts which can be managed effectively solely through host plant resistance is the fungus that causes apple scab. All 50 trees were scab-resistant cultivars: 'Liberty' (35), 'Prima' (5), 'Priscilla' (5), and 'Freeedom' (5). All four cultivars also were sufficiently tolerant of three other pathogens to obscure, over the entire study, any symptoms of disease caused by them: the fungus that causes powdery mildew, the bacterium that causes fire blight, and the fungus that causes cedar apple rust. The only exception was moderate susceptibility of Prima to cedar apple rust.

Most important arthropod pests of apple orchards in Massachusetts are capable of dispersing into orchards from distances of several hundreds of yards, either by flight or passive wind-aided dispersal. However, the majority of females of one key insect pest, codling moth, was known from earlier work in Switzerland to move less than 100 yards within a single generation. Therefore, all unmanaged principal host trees of codling moth (apple, pear, hawthorn and quince) within 200 yards of the orchard perimeter were removed in 1980 to create a host-free zone sufficiently broad to discourage immigration of codling moth females. It was also hoped that such host removal might discourage immigration of lesser appleworm, which is closely related to codling moth, and several species of leafrollers.

Beneficial parasitoids and predators of several different apple orchard pests can provide effective biological pest control when allowed or encouraged to build on plants in habitats bordering orchards or on understory plants within orchards before moving into apple trees. Consequently, a decision was made to encourage the proliferation and growth of rosaceous plants (except the above) adjacent to the orchard. The supposition was that plants in the same family as apple (Rosaceae) would be the most likely to support non-pest species of arthropods that foster buildup of natural enemies of apple pests, particularly of foliar pests such as mites, leafminers, leafhoppers and aphids. No attempt was made to manage orchard understory plants in a way conducive to buildup of beneficial arthropods. Beginning with the first fruit-bearing year (1981), the orchard annually received a variety of practices designed to minimize the impact of pests in as ecologically sensitive a manner as practical.

*Arthropod management*

Several arthropod pests, active early in the growing season and for which no alternative management approaches were known or feasible, were managed through application of pesticide. This was accomplished by spraying orchard trees using a shoulder-mounted, motor-driven mist blower. Horticultural oil was applied annually throughout the 20 years at the tight cluster stage of bud development against overwintering nymphs of San Jose scale and overwintering eggs of European red mite. Phosmet was applied annually throughout the 20 years at or shortly after petal fall and again 10-17 days later, primarily against plum curculio and European apple sawfly. Phosmet was chosen because it afforded a better combination of effectiveness against plum curculio and relative safety to humans and beneficial predators of apple pests than any other insecticide available in 1981. These two annual applications of phosmet also were intended to suppress larvae of green fruitworm and first-generation adults, eggs and/or larvae of codling moth, lesser appleworm and leafrollers arising from immigrants unaffected by removal of unmanaged apple, pear, hawthorn and quince trees within 200 yards of the orchard.

Apple maggot flies were managed behaviorally by capturing females on unbaited red spheres, 3 inches in diameter and coated with Tangletrap™. They were deployed each year for 20 years at the rate of 1-3 per tree (according to fruit load) from early July through harvest. Insects and debris were removed from spheres twice (at monthly intervals) until harvest.

In an attempt to minimize within-orchard buildup of codling moth, lesser appleworm and apple maggot (all of which feed as juveniles inside of fruit), fallen apples (drops) were picked up weekly from early or mid-August until harvest and taken to a distant part of the farm.

Other than the pre-bloom spray of oil against

European red mite eggs, no action was taken against foliar pests such as mites, leafminers, leafhoppers or aphids. Instead, I relied on influx of beneficial natural enemies and their buildup in the absence of insecticide after the second application of phosmet in late May or early June. I did not, however, systematically sample abundance of beneficial natural enemies in or around the orchard to gather evidence that beneficials were in fact providing effective suppression of pest anthropods.

*Disease management*

As indicated above, cultivar resistance to or tolerance of pathogens was the principal approach used in managing apple diseases. This proved insufficient, however, for management of sooty blotch and flyspeck. Symptoms of these diseases do not permanently scar or deface fruit. Instead, symptoms appear as dark blotches or spots on the fruit surface, especially toward harvest. During the first quartile of orchard operation (1981-85), neither was sufficiently abundant to suggest that it should be managed. During the second quartile (1986-90), blotches and spots arising from these diseases became increasingly noticeable and were removed by cleaning each apple with a damp cloth before packing it for sale. This eventually proved so laborious as to be uneconomical. Therefore, during the third quartile (1991-95), certain hosts on which the causal pathogens overwintered, especially blackberry, grape and sumac, were removed if within 100 yards of the orchard in an effort to reduce influx of inoculum. Also, the orchard trees were pruned during summer to reduce relative humidity and hence inoculum establishment within the tree canopy. These measures proved partially but incompletely successful. Hence, during the fourth quartile (1996-2000), a combination of the fungicides captan and benomyl was applied twice annually (July and August) to suppress sooty blotch and flyspeck.

*Weed management*

During the first quartile, the orchard floor was mowed 5-6 times each year to enhance air flow, reduce competition of weeds for nutrients and water, and reduce vegetation favorable for establishment of voles. During the second quartile, hay as mulch was spread annually beneath the canopy of each tree to suppress weeds, conserve moisture and provide nutrients. Even though remaining mulch was removed in late August to discourage establishment of voles, eventually voles that fed on tree bark and roots became established in damaging numbers. Hence, during the third and fourth quartiles, mulching was no longer practiced, and I returned to the mowing regime of the first quartile.

*Vertebrate pest management*

Beginning in 1981, voles were managed by placing a roofing shingle beneath each orchard tree after harvest and placing poison bait (as needed) in trails beneath shingles.

Beginning in 1985, deer were repelled from feeding on developing twigs and buds by hanging a bar of scented soap on the trees at greatest risk.

Beginning in 1989, flocking birds (especially crows, bluejays and starlings) were repelled from alighting on trees and pecking fruit by suspending Scare-Eye balloons™about 2 yards above the uppermost foliage at 16-yard intervals. Balloons were employed annually in mid-August and remained through harvest.

*Fruit thinning*

As yields of fruit increased, it became uneconomical to rely solely on thinning of fruit by hand for ensuring acceptable fruit size. Hence, beginning in 1991, carbaryl was included as a chemical thinner with the first application of phosmet.

*Sampling pest incidence*

At harvest, a minimum of 25 randomly selected fruit on each of the 50 trees in the Conway orchard and on each of four unmanaged apple trees 200-250 yards away from the Conway orchard was sampled for pest injury. A fruit was classified as injured by a pest if the degree of injury was sufficient to preclude inclusion of the fruit for sale as “U.S. Fancy” grade.

Foliar populations of spider mites, leafminers, leafhoppers and aphids in the Conway orchard were assessed annually on a presence/absence basis at 3-week intervals from June to harvest by examining 10 leaves or 10 terminal shoots on each of 10 randomly-selected trees.

## *Results*

The annual incidence of each fruit and foliar pest in the Conway orchard across the 20 years of orchard operation is depicted in Figures 1 and 2 in the form of regression lines that express pest incidence as a function of time. If a line shows an upward slope from 1981-2000, it means there was a positive relation between pest incidence and time. That is, the pest tended to increase in incidence over time. If a line shows a downward slope from 1981-2000, it means there was a negative relation between pest incidence and time. That is, the pest tended to decrease in incidence over time.

Among insect pests of fruit in the Conway orchard, only lesser appleworm showed a tendency to increase in incidence from 1981-2000, but the increase was slight and not significantly different from zero. All other insect pests of fruit, including tarnished plant bug, European apple sawfly, plum curculio, green fruitworm, codling moth, leafrollers and apple maggot showed a tendency to remain about the same or decrease in incidence from 1981-2000. Decreases were significantly different from zero only in the cases of tarnished plant bug and green fruitworm. There was no incidence whatsoever of San Jose scale during the entire 20 years.

Among disease pests of fruit in the Conway orchard, both sooty blotch and flyspeck showed a significant tendency to decrease in incidence from 1986-1990 (when incidence of these diseases was first sampled and when no management measures were used) to 1991-1995 (when three types of wild hosts within 100 yards of the orchard were removed) and thence to 1996-2000 (when two summer fungicide sprays were applied annually). There was no incidence of apple scab during any of these years.

Injury by birds in the Conway orchard showed a significant tendency to decrease from 1986-1988 (when no balloons were used as repellents) to 1989-2000, when balloons were employed throughout (data not shown).

Among arthropod pests of foliage in the Conway orchard, three pests (mites, woolly apple aphids and leafminers) showed a tendency to increase in incidence from 1986 (when first sampled) to 2000, but the increase was significantly different from zero only in the case of leafminers. White apple leafhoppers showed a tendency to decrease (but not significantly) from 1986-2000. In no year did populations of any foliar pest exceed levels considered potentially injurious.

Compared with annual pest incidence (across the two decades) on fruit of unmanaged trees 200-250 m from the Conway orchard, annual pest incidence on Conway orchard fruit (across the two decades) was significantly less (at least eight-fold less) for seven of the nine insect pests and apple scab, with especially dramatic reduction in incidence of the four most damaging pests: plum curculio (30-fold), codling moth (150-fold), apple maggot (150-fold) and apple scab (zero injury of orchard fruit) (Table 1). The only exceptions were tarnished plant bug (against which no protective measures were taken in the Conway orchard and injury was not significantly different from that on the unmanaged trees) and San Jose scale (whose level of injury was nil in the Conway orchard and very low on the unmanaged trees).

## *Discussion*

Even though almost all of the elements that comprised the bottom-up, ecological approach to pest management adopted at (or shortly after) the outset remained in place across the entire two decades of Conway orchard operation reported here, there were four exceptions. First, the application of hay mulch beneath orchard trees, instituted for the second quartile (1986-90), had to be abandoned for the third and fourth quartiles (1991-00) because of buildup of damaging voles beneath the cover of mulch. Second, it was necessary to introduce use of Scare–Eye balloons during the second and for succeeding quartiles to deter wounding of fruit by birds. Third, the encouragement of growth and proliferation of all rosaceous plants in areas bordering the orchard (except for unmanaged apple, pear, hawthorn, and quince trees) had to be abandoned at the beginning of the third quartile for blackberry, whose canes supported progressive buildup of summer disease inoculum during the first two quartiles. Many large commercial orchards are equipped to remove or diminish evidence of flyspeck and sooty blotch on fruit by water-dipping and brushing fruit before sorting. Lacking such equipment, I was obliged during the second quartile to remove evidence of these diseases by wiping fruit with a damp cloth, a process that became uneconomical as yields increased with tree maturity. Hence, during the third quartile,

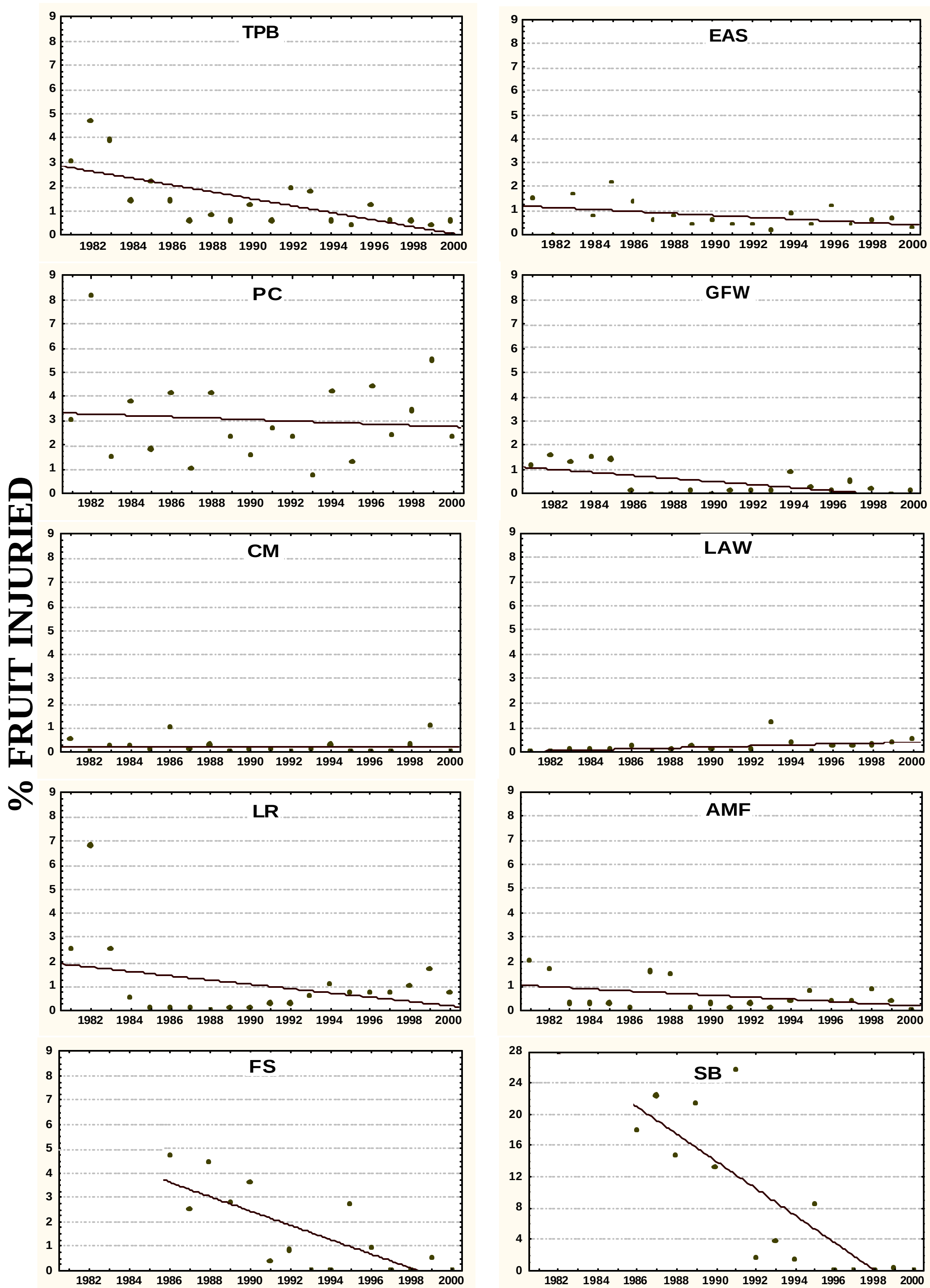


Figure 1. For each principal insect pest of fruit in the Conway orchard, the relationship between annual pest incidence and time (from 1981-2000).

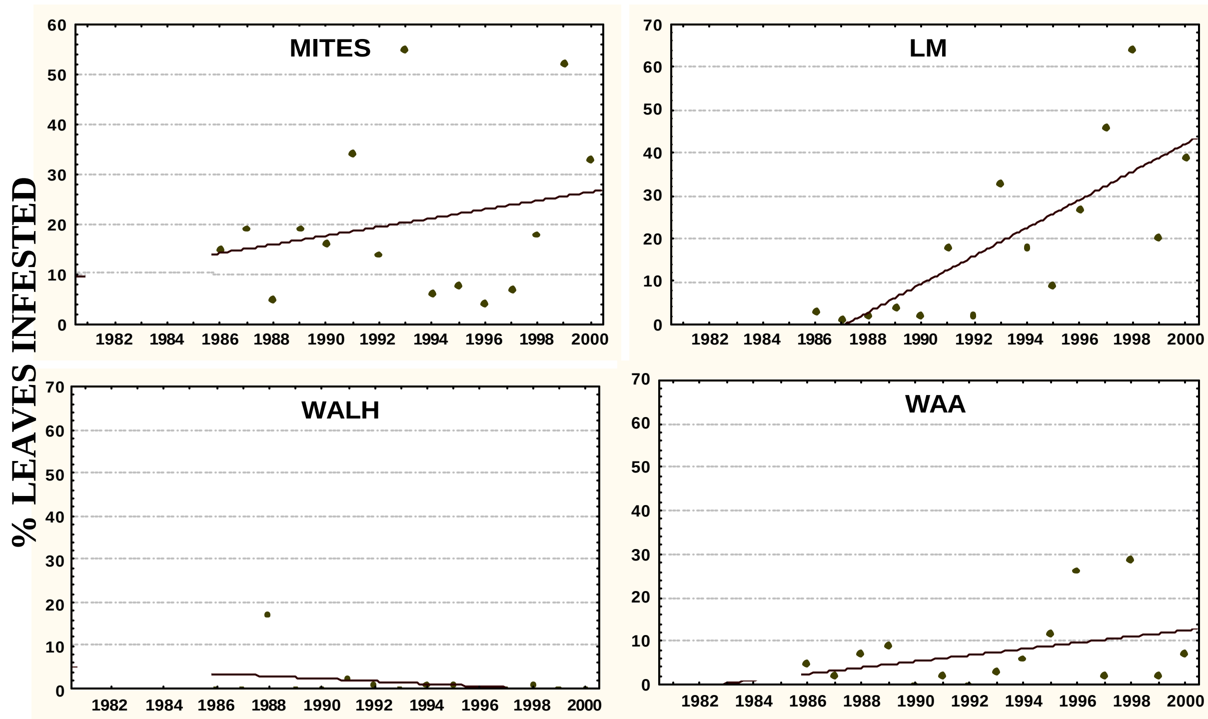


Figure 2. For each principal arthropod pest of foliage in the Conway orchard, the relationship between annual pest incidence and time (from 1986-2000).

blackberry plants (as well as grape and sumac) within 100 yards of the orchard perimeter were removed. This alone proved insufficient to reduce incidence of summer diseases to an acceptable level and was followed by application of two fungicide sprays for the fourth quartile. Finally, increasing yields associated with orchard maturity necessitated less reliance on hand removal of excess fruit as the sole approach to thinning and use, during the third and fourth quartiles, of the chemical thinner carbaryl as an amendment to phosmet in the first insecticide spray.

The only Conway orchard pest that increased significantly across the two decades of orchard operation was leafminers. The increase coincided with a shift from 100% apple blotch leafminer to 98% spotted tentiform leafminer as the dominant leafminer species in the orchard. Such a shift in leafminer composition occurred during this same time period in several large New England apple orchards, for yet uncertain reasons. The potential impact of this shift on leafminer management remains to be determined.

In another article in this issue of *Fruit Notes*, we present information on incidence across eight years (1991-1998) of codling moth, lesser appleworm and leafrollers in small blocks (about 1/2 acre) of apple trees in six large commercial orchards, wherein each block was surrounded by odor-baited spheres to control apple maggot and no insecticide was applied after mid-June. Results showed a slight but insignificant tendency toward increase of codling moth and lesser appleworm and a moderate and significant tendency toward increase of leafrollers across the eight years. The slight but insignificant trend toward increasing incidence of lesser appleworm over time in the small blocks of apple trees in commercial orchards matches a similar trend found for lesser appleworm in the Conway orchard. On the other hand, there were slight long-term trends toward decreasing numbers of codling moth and leafrollers in the Conway orchard that were inconsistent with the long-term trends toward increasing numbers of these pests in the small blocks of apple trees in the commercial orchards. Reasons for this inconsistency are unknown but could involve natural ecological processes having a greater influence

Table 1. Percent harvested fruit injured by pests in the Conway orchard and on unmanaged apple trees 200-250 yards from the Conway orchard. Data represent mean values of annual samples taken from 1981-2000[z].

| | Injured fruit (%) | |
|---|---|---|
| Pest | Conway orchard | Unmanaged apple trees |
| Tarnished plant bug | 1.5 | 2.1 |
| European apple sawfly | 0.8 | 7.4* |
| Plum curculio | 3.0 | 94.6* |
| Green fruitworm | 0.5 | 7.1* |
| Codling moth | 0.3 | 45.7* |
| Lesser appleworm | 0.2 | 1.7* |
| Leafrollers | 0.6 | 5.7* |
| Apple maggot | 0.6 | 90.8* |
| San Jose scale | 0.0 | 0.5 |
| Apple scab | 0.0 | 40.4* |

[z] Values followed by an asterisk indicate a significant difference from the corresponding value for the Conway orchard at odds of 19:1.

in the Conway orchard.

Comparison of the average level of clean (pest-free) fruit produced in the Conway orchard during 1997-2000 with that in eight large Massachusetts commercial apple orchards that practiced basic IPM and were sampled during 1997-2000 showed values of 92.8 and 92.6% clean fruit, respectively. These high levels of pest-free fruit stand in stark contrast to 0% clean fruit on Conway unmanaged trees during this same period. They were achieved with annual application of one pre-bloom horticultural oil spray, two insecticide sprays and two fungicide sprays in the Conway orchard compared with an annual average of two pre-bloom horticultural oil sprays, one acaricide spray, seven sprays containing insecticide and nine sprays containing fungicide in the large commercial orchards. Thus, the Conway orchard received pesticide sprays only about one-fourth as often as did large Massachusetts commercial apple orchards operated according to first-level IPM guidelines.

An analysis of input of purchased materials and labor for operation of the Conway orchard from 1985-89 compared with that for typical large commercial orchards of a neighboring region (eastern New York) during a similar time period revealed substantially lower input of materials and higher input of labor for operation of the Conway orchard. A similar relationship characterized operation of the Conway orchard relative to large Massachusetts commercial orchards from 1991-00. One advance that would reduce considerably the cost of labor for the Conway orchard would be substitution of reusable pesticide treated wooden spheres for sticky spheres in controlling apple maggot flies. Refined versions of the former are nearly ready for commercial use, as reported in the 2000 issue of *Fruit Notes*.

Ideally, a bottom-up ecologically based approach to management of apple orchard pests would involve no use whatsoever of any pesticide that might harm beneficial relationships among organisms inhabiting the orchard and its environs. Such may be the case (or nearly so) in apple orchards designed and maintained using practices of organic agriculture. Until very recently, it was impractical to implement sustainable commercial apple production in northeastern North America owing largely to inability to suppress plum curculio to a commercially acceptable level without use of a synthetic pesticide (such as phosmet). The recent labeling (in 1999) of kaolin clay as an organically approved material for control of plum curculio and other apple insect pests in the United States now opens the way to a potentially less disruptive ecologically-rooted bottom-up approach to growing apples than the form used here. Because kaolin clay costs about three times more per application than phosmet and requires at least four rather than two applications to achieve plum curculio control, it remains to be seen whether the considerably greater monetary outlay associated with substituting kaolin clay for phosmet can be sustained economically. Further, kaolin clay may not be as friendly to survival of natural enemies of orchard pests as believed initially.

### *Conclusion*

The findings of this long-term assessment of the effectiveness of a bottom-up, ecologically-based approach to apple pest management, as practiced in a small commercial apple orchard in Conway, demonstrate clearly that such a minimum-intervention approach can be conducive to sustained production of high quality apples even under high pest pressure common to orchards of Massachusetts and other New England states. Indeed, when pest incidence during the most recent four years of Conway orchard operation (1997-2000) was compared with that in large commercial orchards in Massachusetts during this same period, the amount of pest injury to fruit at harvest was essentially identical (7%) even though the Conway orchard received about 75% less insecticide and fungicide.

The question arises as to whether the bottom-up, ecological-based approach to pest management used for the past two decades in the small Conway orchard can be adopted for use when planting and maintaining larger commercial orchards. Conceivably yes. But a principal constraint lies in selling fruit of scab-resistant cultivars whose names have little or no recognition in the global marketplace. Of necessity, such apples would need to be niche-marketed in pick-your-own, roadside stand, and other similar direct-market outlets. It is among those growers whose local clientele (however limited) may have a long-term interest in purchasing apples grown under a bottom-up, ecological-based pest management approach that such an approach will have the greatest appeal.

### *Acknowledgements*

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