IPM in Washington Tree Fruits: Overview and Prehistory

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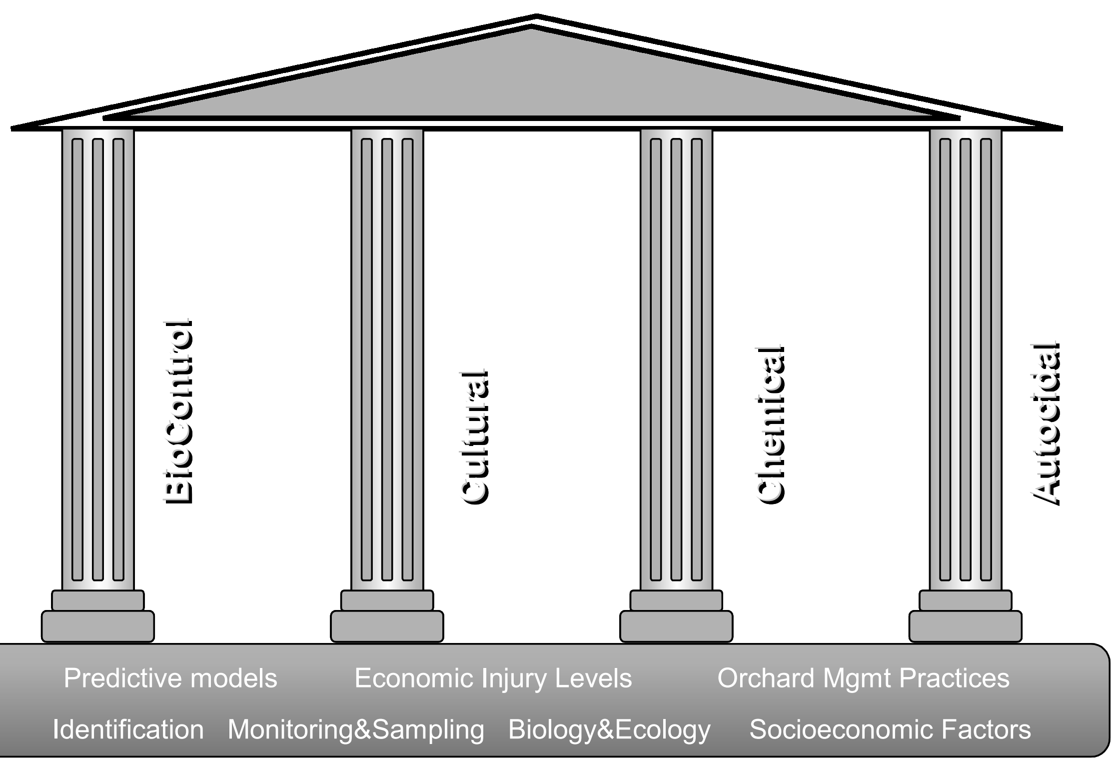
IPM defined (more or less): several classic definitions of IPM are worth noting; none are recipes, but describe the general aim and approach.
Metcalf and Luckmann (1975) (after Rabb 1972):

> [IPM]…is the intelligent selection and use of pest-control actions that will ensure favorable economic, ecological, and sociological consequences"

and Geier 1966:

> 1) determining how the life system of the pest needs to be modified to reduce its number to tolerable levels, that is, *below the economic threshold*
> 2) applying biological knowledge and current technology to achieve the desired modification, that is, *applied ecology*; and
> 3) devising procedures for pest control suited to current technology and compatible with economic and environmental quality aspects, that is, *economic and social acceptance.*

The structure of an IPM is often visualized in the following manner:



Historical Narrative: Fruit trees were planted in Washington as early as 1826 (usually adjacent to forts and missions), but a commercial industry was not organized until the mid-1880s, when irrigation water and railroad transportation became available.. Planting apples in Washington's semi-arid interior valleys was a novel concept at the time, but trees thrived as long as sufficient water was provided. In some cases, moving a plant to a new region and climate, where it is isolated from established plantings (east coast, Midwestern US; humid temperate climate) could conceivably be a considerable advantage, if many of the pests (arthropod and disease) are left behind, with thousands of miles of mountain and prairie in between. Unfortunately, many of the apple's pests were transported along with it, and established by human agency long before strict quarantine regulations existed. The ability of the pest to establish itself depended to some extent on how well it adapted to the new climate, and whether it spent its entire life cycle on apple, or needed an alternate host/habitat to complete its life cycle. Two illustrative examples are diseases: cedar apple rust didn't thrive because no cedars occurred to complete the life cycle (absence of an alternative host); and scab did not thrive because of the drier environment (unsuitable climate).

A second consideration when a crop plant is moved to a new region is what resident pests may decide it is a suitable host, and add it to their host range. Certain lepidoptera (e.g., western tent caterpillar) that feed on deciduous trees had no problem using apple as a host. Broadly polyphagous species like twospotted spider mite would similarly have no problem using apple as a host, even if they were originally introduced to the region on another crop.

By the turn of the last century, (1900s) codling moth was already well established in the region, and the pest of key importance, a position it has not lost since that time. It dominated the entomological research on PNW tree fruits for the first half of the century. Paris Green (copper acetoarsenate) was one of the first control measures used, but it was displaced by lead arsenate because the latter's lower phytotoxicity and greater "sticking" power. Originally, only a single "calyx" spray (3/4 petal fall, when the calyx cup was still open) was necessary to provide season-long control. By the mid-1920s, the arsenic residues on apples in retail outlets was an issue, and by the late 1920s it was a crisis. By the early 1930s, up to 6 sprays of lead arsenate were used on apples, with up to 20% damage in some orchards, although generally <5%. By 1944, up to 8 sprays was mentioned, with still no certainty of control. Although lead arsenate was still the primary means of control throughout the first half of the century, as control diminished, nearly every other available product, or combinations thereof, were tried: oils and soaps as spreader-stickers, or oil as an ovicide; nicotine, pyrethrum, cryolite and ryania. Oil became the dominant adjuvant during this period; ironically, the research during the latter part of the lead arsenate era was evenly divided between how better to stick it on the fruit in season, and then how best to wash it off after harvest. Occasionally, biological control agents were investigated, but with little hope or enthusiasm. Orchard sanitation (thinning, banding) was promoted as supplements to a spray program, and bait traps became popular as an aid to determining spray dates (as early as 1926).

Although codling moth dominated the pest problems in apples, there were a number of other pests, including San Jose Scale, Aphids, Spider mites, Rust mites, Lygus, Buffalo Treehopper, Leafhoppers, Thrips, Leafrollers, Fruitworms, and Ants. There were a number of detailed biological studies made during these years, but the approach to control of the pests was still primarily chemical, despite the limited arsenal (lead arsenate, nicotine sulphate, and oil).

Mites were a serious intermittent problem, and were blamed for fruit size reduction, but compared to the ongoing codling moth crisis, were not uppermost in the grower's mind.

Tree fruit pest management limped along with a lead arsenate program until DDT became widely available after World War II; in Washington, this was apparently the 1947 or 1948 season. The transition was almost instantaneous because of the problems with lead arsenate (resistance, residues) but first and foremost, because DDT was so highly effective and long lasting. It worked on almost all pests, and a spray or two lasted all season. The list of pests controlled dropped steadily over the succeeding years of use, with mites one of the first to drop off; conversely, mite problems grew steadily worse during this period due to some combination of stimulation and predator toxicity. Interestingly, the problem with mite outbreaks was known from experimental tests before the introduction in 1947, and the warning was placed prominently in the contemporary version of the spray guide; but the codling problem was so pressing that DDT was used regardless. Resistance played a major role in the demise of this compound also; by the time it was forcibly removed from the market, it was not considered very useful, and had since been supplanted by a whole new group of compounds: The Organophosphates.

Parathion was introduced shortly after DDT, and although it found a number of uses in tree fruits, it lacked the broad spectrum of activity and excellent residual activity. Guthion came into widespread use in the late 1950s, and has been the Washington's primary codling moth material ever since. While modest levels of resistance were detected in the 1990s, this material still constitutes the definitive "big hammer" for this pest. Lorsban and Penncap were inserted into specific places in the program, not because they were stronger codling moth materials, but the slightly different spectrum of activity helped pick up San Jose scale and leafrollers. Zolone and Imidan became available about 1970, and were alternative choices for codling moth control, but never displaced Guthion. Mites, aphids, leafhoppers, and leafminers were at one time all susceptible to OPs; currently they are only suppressed by most of these compounds. From "one-stop shopping" with the OPs, our programs had to gradually "diversify" chemically to better cover the array of pests.

The basic concepts of IPM were being formulated during the late 1950s through the 1960s, although early entomologists (1920s and 30s) were certainly aware of the nature of problems arising from heavy reliance on pesticides. Although the concept of biological and cultural control was understood and partially implemented, the basic framework and tools were lacking to attack the problem in a different way. To a large extent, the imminent threat of codling moth infestation forced growers into a "control at any cost" type of program.

IPM highlights: Selected important events for Washington Apples

Biological control of the woolly apple aphid: although IPM per se had not been articulated, the concept of classical biological control (importation of natural enemy from the place of origin of the pest) was known, and successfully implemented in the first half of the 20^{th} century. This was the deliberate introduction and dispersal of *Aphelinus mali*, a hymenopterous parasitoid of woolly apple aphid. It was first introduced in the eastern half of the US, and released in Hood River in 1928, BC in 1929, and Wenatchee in July 1931. Woolly apple aphid has been generally held in check by this parasitoid, although it is likely that some mortality occurs due to broadspectrum sprays currently used.

Integrated Mite Control: Like many seminal discoveries, this started as an observation, and ended up as the "poster boy" of integrated biological control programs. This occurred during the DDT era in the late 1950s, and started with a bad frost year, when growers backed off on sprays because they couldn't waste money on such a poor crop. Stan Hoyt observed that mite problems were much less severe in badly frosted (minimally sprayed) orchards, and found a predatory mite suppressing populations of the predominant mite species at the time, McDaniel mite. At the time, the acaricides themselves (Fenson, Genite, Mitox) were some of the worst offenders in perpetuating mite flareups. Growers that stopped using disruptive materials were able to establish fairly rapidly an integrated mite control program in which miticides were rarely, if ever needed. This program has been remarkably robust, in that mite treatments only occurred on a small fraction (ca. 10%) of the orchards in the late 1980s, although there has been some erosion since then. However, the principle, once firmly established, got many devoted adherents. This program is maintained by screening new compounds for effects on predatory mites (*Typhlodromus occidentalis*) and their alternate prey, apple rust mite, and is the primary reason the pyrethroids were never widely used on Washington apples.

Mating Disruption: The introduction and implementation of mating disruption in 1990 constitutes the first major qualitative change in codling moth control in over a century. Although regulated as a pesticide, it is the first widely adopted technology that had no direct toxic effect, and thus put it in a wholly different category in terms of worker and environmental safety. The possibility of reduction in broadspectrum sprays for codling moth opened the window of opportunity for enhanced biological control of other pests.

Future Trends/Goals: Today's session will cover the trends of the future in more detail, but some of the major features will include: mating disruption as a primary tactic for codling moth control, supplemented by more selective chemicals (IGRs, possibly chloronicotinyls); greater reliance on biological control for indirect pests (mites, aphids, leafhoppers, leafminers), with a small percentage of the acreage needing chemical intervention; bringing more cultural techniques online, such as habitat management for mitigation of some orchard invaders (true bugs, thrips); ground cover or hedgerow management techniques for conserving and promoting natural enemies. This style of pest management requires greater knowledge, skill and time inputs than chemically based programs, but should provide greater ecological stability, and experience fewer problems with resistance.