

## **Reduced-risk Pest Management Programs for Eastern Tree Fruits**

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A 4-year research project was initiated during the 2002 growing season to evaluate, on a regional scale, pest management systems based on reduced-risk tactics that previous research and experience had indicated would be effective, sustainable, economically viable, and lead to enhanced biological control. The participating states are: Michigan, New Jersey, New York, North Carolina, Pennsylvania, Virginia and West Virginia. The goal of this project was to design pest management systems that greatly reduced residues and worker exposure to organophosphorous, carbamate, and pyrethroid insecticides. The specific objectives were to: (1) Determine the effectiveness of reduced-risk tactics for managing key tree fruit pests. (2) Measure changes in biological systems resulting from use of reduced-risk tactics. (3) Evaluate the economics of using reduced-risk tactics, and (4) Develop and deliver educational programs to facilitate the implementation of reduced-risk tactics.

**General Methods** - The following pest control tactics are being used in programs designed for apples and peaches throughout the region: (1) selective insecticides and acaricides (insect growth regulators, antibiotics, microbials, nicotinoids, oxadiazines, kaolin, horticultural mineral oil, tetrazines, hexythiazox); (2) mating disruption; (3) conservation of natural enemies; (4) cultural practices. These tactics are being integrated into specific pest management programs designed to be most appropriate for each state and major production region within each state. The range of potential tactics that were to be tested and the development of specific IPM program were based on site-specific sampling protocols, local pest complexes and market destination of the crop. Reduced-risk management programs in apples and peaches are being tested in plots of 5A or larger. A block with similar tree training systems, cultivars, ages of trees, and planting spacing has also been selected adjacent to or nearby each reduced-risk block. This block has been treated with the grower's standard pest management practices so that pest levels, fruit quality, harvest damage, and pest management inputs in the two blocks can be compared.

At least 3 reduced-risk blocks and standard comparison blocks were set up in each major growing region of each participating state during the 2002 growing season. Research sites were selected that represented typical horticultural production systems and levels of potential damage from the insect and mite pest complex in each growing region in each state. Research is being conducted during each of the 4 years of the grant in the same research and comparison plots at each site in order to compare results among different seasons and to monitor the pest and damage levels over multiple seasons. All control sprays in both the reduced-risk and standard comparison plots have been applied by growers. Both the reduced-risk research plots and the standard comparison blocks are being sampled throughout the season so that population levels of selected natural enemies and the infestation levels and damage can be compared. The reduced-risk research plots are being monitored according to pest management protocols established by the various states to determine the need and timing for control tactics against insect and mite pests throughout the season. The growers and private pest management consultants determine which pest management practices are used in the standard comparison blocks, but these practices have included use of organophosphate, pyrethroid, and carbamate insecticides. An economic assessment is being conducted to compare the costs of insecticides and acaricides, pesticide application costs, and percent fruit damage in the reduced-risk vs. grower standard comparison blocks. In order to eliminate variability between yields among blocks that is not related to pest management practices, the profitability of the research plots and standard blocks is being compared by estimating the returns to growers using the average state yield and market value for fresh and processed fruit for each state.

**Results** - The following paragraphs briefly summarize the results from apple programs within the cooperating states during the 2002, 2003, and 2004 growing seasons.

### New York

**2002** - Studies were conducted in 17 apple orchards (155 acres) to determine the effectiveness of reduced-risk tactics in managing key pests. Each site was a split-plot design in which the entire block received a program of selective insecticides, and a 5-A portion of the block additionally received pheromones for mating disruption of internal Lepidoptera. Catch trends from the non-disrupted blocks showed codling moth levels to be fairly moderate throughout the season throughout the state; in the most western sites, LAW levels tended to be modest, but OFM pressure was sometimes severe. In the eastern orchards, the opposite trend was seen, with OFM scarcely present, particularly during the latter half of the season, and LAW at reasonably high levels in most of these blocks, particularly towards the end of the season and beyond harvest. Phytophagous mite populations were relatively low throughout the season: RR, an average of 1.6 motiles per leaf, 6% of samples indicating over-threshold populations; grower standards, 1.1 motiles per leaf, 4% of samples over threshold. Fruit damage at harvest caused by insect feeding or infestation was uniformly low in the RR blocks with (91.5% clean) or without (92.0% clean) pheromones, and the grower standards (93.6% clean). Average per-acre insecticide costs were \$216 (plus an additional \$148 for pheromones) in the RR and \$149 in the grower standard blocks. Some localized damage from internal Lepidoptera was noted in two cases. Other fruit-feeding insects caused nominal damage in a few cases, including rosy apple aphid, leafrollers, San Jose scale and tarnished plant bug.

**2003** - Again, pheromone ties suppressed trap catches of the target species at levels near zero. Phytophagous ERM populations surpassed economic threshold levels in 3 each of the RR and grower standard plots during the summer; average foliar numbers were 3.4 and 1.0 motiles per leaf, respectively. Predator mite numbers were low (~0.14 per leaf) throughout. Fruit insect damage at harvest was again uniformly low across all blocks and treatments, with no statistically significant differences between the RR blocks with (95.5% clean) or without (95.7% clean) pheromones, and the grower standards (96.0% clean). Overall damage was somewhat reduced from 2002, however, with only six farms exhibiting any internal Lepidoptera feeding damage, compared with eight farms in 2002. Insecticide costs averaged \$262 and \$202 per acre for RR (8.2 total applications) and grower standard (8.7 total applications) programs, plus a \$141 per acre pheromone cost in the RR sites. Other fruit-feeding insects causing nominal damage in isolated cases included leafrollers, tarnished plant bug, and plum curculio.

**2004** - The pheromone ties continued to suppress trap catches of all three species at levels near zero. Phytophagous ERM populations surpassed economic threshold levels in 2 RR plots during the summer. Fruit insect damage at harvest showed no significant differences between the RR blocks with (95.5% clean) or without (94.7% clean) pheromones, and the grower standards (94.6% clean), similar to the previous 2 years. Overall damage from internal Lepidoptera was considerably reduced from 2003, with only seven farms exhibiting any internal worm damage, and a maximum value of 1.1%. Other fruit-feeding insects causing damage in isolated cases included tarnished plant bug, plum curculio, and apple maggot.

### Pennsylvania

**2002** - Studies were conducted in 7 orchards (41 acres) of both fresh and processing apples. Codling moth pressure was moderate to heavy in 4 of the RR blocks, while OFM populations

ranged from low to moderate in most cases. Foliar aphids were numerous in two sites, and phytophagous mite populations were generally low during this growing season, with average foliar samples of just over 2 motile forms per leaf, and predators averaging 0.6 mites per leaf; just over 20% of the foliar samples returned an over-threshold result. A total of 5 acaricide applications were made in the grower standard blocks, compared with one in the RR blocks. Fruit insect damage at harvest was very low (<5%) and equivalent in the two treatments, with a low incidence of damage in a few cases caused by European apple sawfly, tufted apple bud moth, and apple maggot. Per-acre insecticide costs averaged \$190 in the RR blocks (6.0 sprays) vs. \$143 in the grower standards (6.7 sprays); pheromone costs in the RR blocks averaged \$49 per acre.

**2003** - The biggest challenge in the RR blocks was a buildup of apple maggot in several sites, one of which had had unacceptable injury at harvest. A lure failure resulted in one instance of high obliquebanded leafroller fruit injury in the RR treatment. Phytophagous mites were very scarce during the summer, averaging less than one per leaf overall; conversely, some unexpectedly high predator mite numbers were seen in a few cases, including the first PA detection of *Typhlodromus pyri*. An over-threshold mite count was determined in less than 5% of the samples taken. Fruit quality in the RR orchards (3% damage) was comparable to that from the grower standard sites (2% damage). Average insecticide costs dropped slightly to \$166 per acre in the RR blocks (5.6 sprays average), and rose to \$150 per acre in the grower standards (7.3 sprays average); however, pheromone costs were higher at \$57 per acre in the RR sites.

**2004** - Pest pressure was higher in almost all blocks than in previous years, with the exception of spirea and rosy apple aphids, leafminers, and leafhoppers, which were unusually low. Because of an abnormally wet summer, the residual activity of many of the RR and some of the conventional insecticides was reduced, hence efficacy was not as good as expected in either case. In particular, performance with sprayable pheromones and pheromone ties was reduced and the residual activity of Avaunt was shortened to a maximum of 7 days. One problematic pest with few good RR options is the stinkbug complex; the only effective conventional control is Lannate. Assail and Calypso were found to be effective in controlling the 17-year periodical cicada, but cost over 10 times as much as pyrethroids. However, as pyrethroid sprays eliminate predatory mites (including the newly discovered *Typhlodromus pyri* in PA apple orchards), the more expensive options were used in order to preserve long-term mite control. Although no RR apple orchards had loads rejected at harvest because of the presence of internal worms, the injury levels were higher than in previous years. Reduced-risk programs continue to give equivalent or better fruit protection than conventional insecticide programs, but at a significantly higher cost/acre.

### West Virginia

**2002** - Studies were conducted in 7 blocks (67 acres) of both fresh market and processing apples. The RR programs provided control of direct pests (87% clean fruit average) that was comparable to or better than grower standard programs (85% clean fruit average) in all but one orchard, in which mating disruption of codling moth was less effective than insecticides. Levels of indirect pests were lower, and parasitism of spotted tentiform leafminer was higher in RR than in grower standard programs. Mite numbers reached high levels in a few cases, giving a mean sample value of 7.7 per leaf in the RR sites (3 total acaricide applications), compared with 2.0 per leaf in the grower standards (1 acaricide application); however, only 15-20% of the samples were classified as over threshold in both treatments. Predator mites averaged approximately 0.2 per leaf in both cases. RR programs required \$175 per acre average in insecticide cost (average of 6.9 total applications) compared with \$118 per acre in the grower standard programs (6.4 total applications). Additionally, RR programs used an average of \$106 per acre for pheromones, making them twice as expensive as the grower standards.

**2003** - Apple fruit injury was lower in the case of codling moth, oriental fruit moth, and leafrollers, higher for tarnished plant bug and San Jose scale, and similar for plum curculio, European apple sawfly and apple maggot in the RR blocks compared with grower standard management programs. Clean fruit averaged 95 and 91%, respectively, for RR and grower standard programs. Incidence of spirea aphid, white apple leafhopper, and spotted tentiform leafminer was lower; rosy apple aphid was higher; and European red mite was similar in RR (2.3 average motiles per leaf; 29% of samples over threshold, two total acaricide sprays) and grower standard (2.6 motiles per leaf; 20% of samples over threshold, one total acaricide spray) blocks. In addition, levels of aphid natural enemies and leafminer parasitism were generally higher in the RR programs. The RR insecticide costs per acre averaged \$160 for the RR blocks (5.6 average applications) and \$137 for the grower standards (7.5 average applications); the RR sites, which used sprayable pheromones and pheromone dispensers, cost an additional \$58 per acre.

**2004** - Studies continued in 7 blocks (61 acres) of both fresh market and processing apples. Average injury to apple fruit was about 4% higher in RR than in grower standard blocks; however, the difference was less than 1% when one grower with high codling moth injury was removed from the average. Average injury in the RR program was higher for codling moth, oriental fruit moth, leafrollers, plum curculio, San Jose scale and stink bugs, but lower for tarnished plant bug, European apple sawfly and green fruitworms, with no injury from apple maggot. Clean fruit averaged 88 and 92%, respectively, for RR and grower standard programs. Overall incidence of foliar pests, predators and leafminer parasitism was low in both management programs, except for a high level of European red mites in RR plots at one site. RR programs averaged \$40/acre more than conventional programs, which is a decrease in the cost difference from \$160 and \$72/acre in 2002 and 2003, respectively.

### New Jersey

**2002** - Studies were conducted in a 5A block of fresh market apples. Most indirect pests remained at low levels during the season, but European red mite required an acaricide treatment in both the RR (11.3 motiles per leaf average) and grower standard (17.1 motiles per leaf average) sites; predator mites, however, were high at an average maximum level of 1.7 and 2.3 per leaf respectively, in the two treatments. Fruit damage at harvest was highest in both treatments from tarnished plant bug (RR, 16%; grower standard, 12%). Insecticide costs per acre averaged \$184 in the RR block (6.5 total applications) and \$78 in the grower standard (8 total applications), plus an additional \$59 per acre cost in the RR orchard for sprayable pheromone.

### North Carolina

**2002** - Studies were conducted in 9 orchards (71 acres) of both fresh and processing apples. Although a RR program was compared with a conventionally managed (organophosphate-based) grower standard comparison, 3 of the 9 RR sites received one OP spray due to the grower's decision. European red mite was the most abundant indirect pest (average foliar populations of 5.2 motiles per leaf, vs. 3.0 in the grower standard); acaricidal treatment was required in 2 RR and 3 standard blocks. Rosy apple aphid and green apple aphid were present between mid-May to the first week of July, but densities did not differ between treatments. However, generalist predator populations, primarily cecidomyiids and syrphids, were more abundant in RR (3.28 predators per 10 shoots) compared with grower standard (1.88) blocks. Overall, direct insect damage (mean across all nine sites) was slightly higher in RR (5.1% damage) compared with grower standard blocks (4.4%). Plum curculio damage was the most abundant insect damage (1.8 vs. 3.0 in RR and grower standard blocks), while small levels (<1%) of damage were caused in all blocks by plant bugs and internal leps (codling moth and oriental fruit moth). Apple maggot infestations exceeded 1% in two orchards, with damage in RR greater than grower standard blocks at both locations. The higher cost of new reduced-risk insecticides compared

with older insecticides used in conventional blocks was reflected in insecticide programs of \$212 (8.4 total applications average) and \$170 per acre (9.3 total applications), respectively. RR blocks also incurred per-acre average pheromone costs of \$105.

**2003** - The program continued in 8 blocks (66 acres) in 2003. Two different reduced-risk programs were evaluated; 1) use of mating disruption for oriental fruit moth and RR insecticides for other pests, and 2) use of mating disruption for both oriental fruit moth and codling moth and RR insecticides for other pests. Indirect pests were adequately controlled at all locations, and their abundance was similar in RR and grower standard treatments. Phytophagous mites, however, reached an average of 22.3 and 27.2 motiles per leaf (33% of samples taken were over threshold, with one total acaricide spray, in each case) in the two treatments, respectively, owing to an early summer buildup that later subsided. Fruit damage caused by direct pests was slightly higher in RR (5.4%) versus grower standard (2.7%) orchards. This was due to relatively high infestations of Comstock mealybug (10.5%) at one location, apple maggot (4%) at one location, and internal-feeding Lepidoptera at two locations (2.0 and 3.4%). This damage slightly increased the difference in the percent clean fruit at harvest between the conventional (97.6%) and RR (95.3%) treatments. The insecticide cost per acre of the RR program averaged \$184 (8.6 total applications), compared with the grower standard, \$178 (10.0 total applications). Pheromone cost averaged across all RR blocks was \$63 per acre.

**2004** - During the third year, there were fewer mite and insect problems in both RR and grower standard orchards compared with previous years. There was an apparent shift to considerably higher generalist predator and predacious mite populations in RR orchards; there had been little difference in predator populations between the two treatments in previous years. Averaged across all orchards, there was a higher percentage of fruit free of insect damage observed in the RR (94.4%) vs. grower standard (92.3%) orchards at harvest. Comstock mealybug was the only pest that inflicted high levels of damage, and this was present at only one site, where the percent infested fruit in the RR and grower standard blocks was 11.1% and 25.6%, respectively. The cost per acre for insect control, including pheromones, in RR and standard orchards averaged \$237 and \$188, respectively. Compared with 2003, this represents a reduction in cost in the RR blocks of about 7% and an increase in conventional blocks of about 1.1%.

## Michigan

**2002** - Studies were conducted in 6 orchards (77 acres) of both fresh and processing apples. Incomplete trap shutdown of codling moth was noted in half of the RR blocks, owing to lower than optimal pheromone treatments; these instances were generally associated with higher fruit damage at harvest (3.3% average) than in the grower standard blocks (0.9%). Foliar injury from leafrollers was also seen in 2 RR sites, and one case of slight plum curculio damage was also recorded. Indirect pests were not often problematic, other than woolly apple aphid in two sites. Phytophagous mite levels were low and comparable in both treatments (average population sample of ~2 per leaf), and predator mites were somewhat higher (average of 0.2 per leaf) in the RR blocks than in the grower standards (average of <0.1 per leaf). Overall fruit quality at harvest was similar in the RR (95.4% clean) and grower standard (96.4% clean) blocks. Average insecticide costs were substantially higher in the RR (\$336 per acre, 8.4 total applications) than the grower standard (\$145 per acre, 7.6 total applications) blocks, added to which was an average of \$138 per acre in pheromone costs for the RR orchards.

**2003** - Nine apple farms (107 acres) were evaluated this season. RR apple maggot management practices protected fruit as well as the standard management materials. Average phytophagous mite levels were somewhat higher in the RR sites (3.3 motiles per leaf) than in the grower standards (1.6 motiles per leaf), but 8 total acaricide applications were made in each treatment group. Predator mite counts continued to be higher in the RR blocks (average counts

of 0.5 per leaf vs. 0.3 per leaf). Fruit damage levels at harvest were comparable (2-3%) in each treatment. Insecticide cost continues to be the major difference between the RR and the grower standard programs, with the RR program costing \$389 per acre, 8.4 total applications (plus \$130 for pheromones) as opposed to \$197 per acre, 9.1 total applications, for the grower standards.

**2004** - Codling moth, oriental fruit moth, obliquebanded leafroller, apple maggot, and plum curculio management in RR programs performed as well as grower standard programs, with harvest injury at 3% and 2.7%, respectively. European red mite populations were 2x greater in RR than in grower standard orchards. Reduced-risk insecticide programs cost 2x as much as standard programs, with pheromone mating disruption accounting for nearly one-third of the overall cost in RR programs.

### Virginia

**2002** - Studies were conducted in 2 orchards (10 acres) of both fresh and processing apples. The RR schedule was based on DD timings through the early part of the season, but was not particularly dependent upon trap thresholds. High phytophagous mite levels were seen in both programs (average levels of 9.2 and 10.5 motiles per leaf in RR and grower standard blocks), resulting in one acaricide application in each case; predator mite levels averaged ~0.4 per leaf in all blocks. The RR program performed as well as or better than the grower standard program in terms of percent clean fruit at harvest (96.5% vs. 91.8%, respectively), but the cost was much higher — \$319 vs. \$180 per acre for insecticides, plus \$41 additional per acre for pheromones in the RR sites. Tarnished plant bug was the only pest that appeared to be controlled less effectively by the RR program than the standard.

**2003** - The RR program was based on DD timings and trap thresholds, and fewer sprays were applied (6.0 vs 6.8) than in grower standard programs, based on below-threshold counts. This was especially true for CM, which was the main reason for the reduced number of sprays. The unfavorable weather this season may have contributed to reduced internal Lepidoptera and mite populations in comparison to normal seasons. Heavy rosy apple aphid pressure was addressed in the RR blocks by using oil at delayed-dormant stage plus Provado at petal fall. Fruit quality at harvest was high (98% clean) in the RR blocks compared with the grower standards (91% clean). Insecticide costs in the RR blocks averaged \$177 per acre (plus \$29 per acre for pheromones), compared with \$105 per acre in the grower standards. The main pest concern remains the effective control of oriental fruit moth and codling moth.

**2004** - An average total of 6.5 insecticide applications were made in the RR blocks, compared with 8.3 in the grower standards. The RR programs provided good control of internal Lepidoptera in both participating orchards, as opposed to higher damage in one of the grower standard blocks. Both grower standard blocks had more leafroller damage than did the RR blocks. Late season damage from stink bugs was a major problem in all blocks, particularly in the case of one grower's RR (35.5%) and standard (15.8%) orchards. The 2004 RR programs cost an average of 66% more than the corresponding grower standard programs.

### All States - Economics

**2003** - The economics of the RR system was evaluated in 2003 for both apples and peaches. A total of 36 apple comparisons were made for insect management costs; standard spray programs averaged \$178.82/A, while the RR blocks averaged \$228.53/A and the RR blocks with pheromones averaged \$379.33/A. Partial budgets were prepared for 30 apple comparisons that had the same cultivars for both the grower standard and RR blocks. In general, the RR blocks had slightly higher quality than the standard blocks, but the difference was not great enough to overcome the difference in insect management costs. Overall, 4 of the apple RR blocks were more profitable than the standard blocks, 2 were as profitable, and 24 were less profitable.

**Summary & Conclusions**-Although the results from three years of testing reduced-risk pest management program have shown that the complex of major arthropod pests can be controlled using reduced-risk insecticides, these new programs have consistently been substantially more expensive (1.5–2.5X) than growers' standard programs that use conventional insecticides. The high costs of current programs using these materials will likely retard or even obviate the widespread adoption of these programs by growers in the Eastern US. This will short-circuit the intended outcome of the RAMP project: to test and foster adoption of pest management programs that do not use organophosphates, carbamates, or pyrethroids.