The New York State Apple Research and Development Program: Ten Years of Successful Research Support for the Apple Industry

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The Apple Research and Development program which began in 1991 is a grower-funded research market order that funds research projects to improve the production, storage and marketing of New York apples. Over the 10 years of its history, it has made a significant impact on the research conducted at Cornell and resulted in significant improvements for apple growers.

Over the last decade, the New York State Apple Research and Development Program (ARDP) has played an essential role in supporting the New York apple industry. Along with the New York Apple Association (NYAA) which promotes New York apples, the Apple Research and Development Program has worked to support apple growers by funding research aimed at improving the production, harvesting, storage and market quality of New York apples.

New York apple growers have been funding research on apples for more than 25 years. In the 1980s, a voluntary program existed in Western New York called the Apple Research Association (ARA). Jim Oakes of Lyndonville, NY, was the primary leader of that effort. In that program, processors matched grower contributions. Combined annual contributions between growers and processors were about $25,000-$30,000 and was used to fund numerous research projects at Cornell. However, that amount of money was not enough as federal and state money for research was limited in the 1980s. Also, the ARA included only a portion of Western New York growers and did not include Eastern New York growers at all.

In 1990, the New York State Horticultural Society, led by Walt Blackler, as president, and Peter TenEyk, as vice-president, appointed a committee to study whether or not a better method of funding research could be implemented. The committee, led by Peter Conklin of Hudson, NY, along with George Lamont of Albion, NY, Tré Green of Chazy, NY, Don Neilsen of the NYS Dept. of Ag. and Markets, and Warren Stiles and Terence Robinson of Cornell University, recommended the formation of a research and development program under the Agricultural Marketing Order Law Section 294 of Article 25. The Hort. Society Board unanimously adopted the idea and began gathering signatures of growers on a petition to the Dept. of Ag. and Markets to hold a vote for all growers to determine if a program of mandatory contributions for research should be started in New York State. The vote was strongly in favor of the research program. Thus, beginning in 1990, growers began to contribute 2 cents per hundred weight of apples toward a fund that sponsors all types of research projects that benefit the growers. The program was named the New York State Apple Research and Development Program (ARDP). A nine-member grower advisory board was nominated by growers and appointed by the commissioner of agriculture to oversee the expenditure of the funds.

Since 1991, the ARDP has collected about $150,000-200,000 annually. The ARDP Board has annually considered proposals from researchers at Cornell and other institutions and funded those they feel will be of the greatest value to the New York apple industry. In addition, the apple processors have continued to voluntarily contribute to the ARA. Money from the ARA is used to fund some research projects independently and to jointly fund others with the ARDP.

Over the last 10 years, the ARDP has funded a variety of projects that have helped growers improve the production, harvesting, storage and marketing of New York apples. The results of these research projects have been published in the *NY Fruit Quarterly* which is sent to all apple growers and is the official publication used by the ARDP to communicate the results of the research they fund to the growers. In addition, results have been presented at numerous extension meetings over the last 10 years.

Growers should be proud of the efforts they have made to work together to fund research that benefits the entire industry. The money the growers have raised has been critical to keeping researchers at Cornell working on apple production, storage and marketing problems. The ARDP Board has worked hard to spend the money wisely in ways that will help the industry.

The ARDP was set up so growers would continue to have control of the program. The program depends on the support of the growers and must be voted on every six years. This summer, growers will again vote on whether or not to continue the ARDP program. To assist growers to understand how their money is spent, this issue of the *NY Fruit Quarterly* is dedicated to the ARDP, with short summaries of each of the projects funded over the last two years. They range from apple production projects to studying the health benefits of eating apples.

DEVELOPMENT of NEW APPLE VARIETIES and PRODUCTS

Assessing the Commercial Potential of Advanced Apple Selections and New Varieties of Interest

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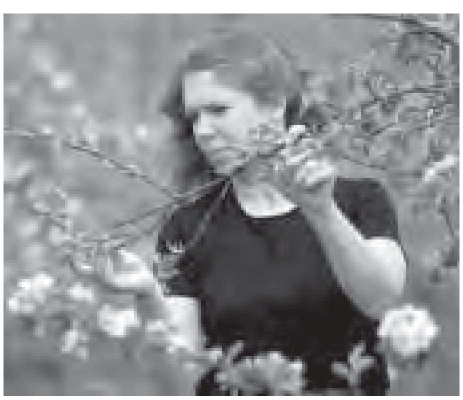
Through this project, we are evaluating the orchard performance, disease susceptibility and storage and shelf life of new apple selections and cultivars. We provide growers with information on varieties they might be interested in for testing. Investing in new cultivars can be risky if faults become apparent after the orchard has been established. Our tests at Geneva indicate potential problems, such as the susceptibility of the popular variety 'Honeycrisp' to soft scald, the russet susceptibility of 'Delblush', and the fire blight susceptibility of 'Zestar'. With this information, growers can assess if their site, management practices, and cold storage regimes place them at high risk for these disorders. Multiple year testing of varieties enables us to provide information on regularity of cropping, tendency for pre-harvest drop, fruit skin russetting, moldy core and other storage disorders. Growers and processors have benefited from having additional information to base their decisions on which varieties to trial. Knowing the varieties' strengths and weaknesses allows the growers to better manage them. New varieties can be very profitable. By providing information on advanced selections from the Cornell program, other programs and nurseries, growers can make better-informed decisions on new plantings.



Dr. Susan Brown pollinating apple blossoms to create new apple varieties.

Improvement of New York Apple Varieties and Rootstocks by Biotechnology Techniques

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The susceptibility of the most popular apple varieties and rootstocks in New York to diseases, especially fire blight, is a continuing problem for the state's growers. Although progress is being made with developing resistant rootstocks by conventional breeding, all new rootstocks must be thoroughly tested, which often reveals unexpected shortcomings. Breeding new scion (fruiting) varieties is much more difficult because of the need to combine resistances with world-class fruit quality. Biotechnology (genetic engineering, or GE) has great potential for producing disease-resistant apples, because it should allow introduction of one or a few genes for resistance without altering the desirable fruit characteristics of the best varieties for New York. We have now refined techniques for doing GE with apple, and have introduced several genes designed to increase resistance to fire blight into Gala apple. Some of these genes have now been shown to cause increased resistance during several years of field testing. Fruit from trees containing the genes has normal size, color, yield, and storage quality. The first genes that were available to us when we started the work, and which we used to show that GE does, in fact, work for apple, are not suitable for commercial use. Therefore, we are now using the efficient methods that we developed to produce resistant apple varieties with new genes that will be acceptable to industry and the public. Fire blight resistant apple varieties and rootstocks will be of great benefit to the New York apple industry by reducing crop and tree loss, and by eliminating the need for sprays to control the disease. They will benefit growers' bottom line, as well as being good for the environment.

Development of Extended Shelf-Life Apple Cider w\without Preservatives

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The shelf life of fresh and pasteurized apple cider is very short (2 to 4 weeks, respectively). In an attempt to produce an extended shelf-life apple cider without preservatives, combinations of thermal processing such as pasteurization and hot-fill, ultraviolet light and dimethyl dicarbonate treatments are being investigated. These combinations are also being evaluated for the potential to produce a short shelf-life apple cider without chemical preservatives that will not require refrigeration.

Apple cider shelf life can be increased by special processing without chemical preservatives.

Processing Apple Slices for Long Shelf Life

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Improved consumer convenience of apples may help increase consumption of apples. Fresh sliced apples have been shown to be a convenient and valued enhancement for fresh apples. The problem is the rapid deterioration of cut product. Fresh-cut produce is a $10 billion business of which the apple industry has not captured a significant portion, so we are developing a process to increase the shelf life of cut apples. In our research, we expose apple slices to elevated atmospheric pressures containing 15 - 45% CO_2 for short periods of time (0–20 minutes) to quickly saturate the tissues. Our work suggests that high CO_2 (>15%), 1% O_2 (balance N_2) inhibits softening and the accumulation of off-aromas in fresh-cut apple slices. Saturating the apple tissue with similar atmospheres would further inhibit deterioration by rapidly penetrating the tissue and, when combined with anti-browning treatment, extend the shelf life of cut apples. That work will provide a new procedure for processing cut apples. This would allow the industry to enter the cut product market and provide consumers with apples in a convenient form. It would also allow the development of new products including apple-based fruit salads and cut-apple products for use by consumers as ingredients in salads.

Down Regulation of Ethylene Production in Apples

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Most apples are produced for the fresh market and have to be stored under controlled atmosphere conditions to avoid softening. The softening of fruits is the result of structural changes in the cell walls.These structural changes are caused by the hydrolytic activity of such enzymes as polygalacturonase, cellulase and the diverse hemicellulases that are under the control of the ripening hormone ethylene. Ethylene is synthesized in plants from S-adenosyl-L-methionine by a short pathway that consists of two enzymes: 1-aminocyclopropane-1-carboxylic acid synthase (ACS) and 1-amino-cyclopropane-1-carboxylic acid oxidase (ACO). To interfere with ethylene synthesis in plants, we have cloned two ACS genes from ripening 'McIntosh' apples. The gene showing the closest similarity to the ripening-related ACS gene in other fruits was used to make antisense constructs. 'Royal Gala' plants were transformed with these antisense constructs using an Agrobacterium-mediated transformation system. Transgenic plants were propagated in tissue culture, micrografted to M.9 rootstocks in pots, grown in the greenhouse, and then planted in the field. Transgenic 'Royal Gala' fruits that were produced on these trees by manual pollination (under bee-exclusion netting during flowering) were evaluated for morphological characteristics, ethylene production, ACS activity and ripening parameters in the presence and absence of 1-methylcyclopropene (1-MCP) and ethylene. Our data indicate down regulation of ethylene production and softening was achieved in some transgenic lines. 1-MCP (1 ppm, 24h, 0oC) completely prevented the development of any ethylene formation in transgenic 'Royal Gala' apples. Ethylene treatment (50 ppm, 3h, 21oC) did not affect the eventual onset and magnitude of ethylene formation in transgenic fruits.

CROP PRODUCTION

Orchard Management Systems for Improved Yield and Quality

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The need to improve orchard production efficiency is causing many apple growers to plant high-density orchards. We have planted a series of orchard trials comparing several training systems and a range of tree densities from 150 to 2,200 trees/acre. Data from several of our experiments show that cumulative yields over the development years were largely a function of tree density with systems on dwarfing rootstocks (M.9 and M.26) giving the highest yields. The traditional system of Central leader/M.7 rootstock achieved less than one-third of the high density system. When data from several experiments were placed on the same graph, the relationship of tree density and cumulative yield was curvilinear. Over the range of tree densities from 200 trees/acre to 1,000 trees/acre, the slope of the relationship was about 6.2 packed boxes/tree indicating that as tree density was increased an additional cumulative yield of 6.2 boxes per acre was obtained for each additional tree planted per acre. This would be about six times the cost of the tree. At the higher tree densities, the gain in cumulative yield was very small. This fits the classical law of diminishing returns which states that additional increases in an input factor (tree density) produces a smaller and smaller increase in an output factor (yield). At the high end of this curvilinear relationship, additional increases in trees density would not produce enough extra yield to pay for the additional costs incurred to purchase and plant the extra trees.

Our latest economic analyses show that under New York conditions and fruit pricing, a tree density of about 400-800 trees/acre is more profitable than lower or higher densities. The results of our economic analysis may not be valid for other parts of the world with different fruit, tree and land prices. Nevertheless, from these studies we conclude that planting more trees per acre will result in greater early yields and profitability up to about 1,000 trees/acre. Above this density, it appears, that despite producing greater cumulative yields, profitability is only slightly greater and in some cases less than lower densities. The economic risk is increased significantly with very high density orchards. The relationship of tree density and early cumulative yield can be modified by a number of factors including initial tree quality and pruning severity which would change the optimum economic density.

Robinson, T. and S. Hoying. 2001. Processing apple planting systems trials. New York Fruit Quarterly 9(4): 17-19.

Factors Affecting the Performance of Newly Planted Apple Trees

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One of the pressing needs of the New York apple industry is to replant orchards to new varieties. The large capital investment required to plant a new orchard makes good tree growth and early yields essential to their success. The dwarfing apple rootstocks are more sensitive to environmental stresses and poor management. This project has focused on tree quality, preplant and postplant fertilization, and irrigation. Our experiments have shown that trickle irrigated trees produce more growth than non-irrigated trees which resulted in significant increases in cumulative yield over the first eight years. Trickle irrigation alone increased yield over the first eight years by about 16% but, when trickle irrigation was combined with ground fertilization or fertigation, yield was increased about 25%. Fertigation of young trees has also improved tree growth and early yield, but has been no better than trickle irrigation with ground fertilization. In addition to improving total yield, irrigation and fertigation increased fruit size. The magnitude of the improvement in yields over the first six or seven years from trickle irrigation appears to justify the investment in trickle irrigation for humid climates such as New York's, especially in dwarf apple orchards where significant yields are expected in the second to fifth years.

However, the economic benefit of fertigation versus ground-applied fertilizer with trickle irrigation is less clear and may not be justified based on the cumulative yields from our experiments to date. In the last two years, we have studied the effect of late season nursery urea sprays on the growth of different sizes of maiden apple trees on M.9 rootstock in the first year in the orchard. Total nitrogen amount per tree (g/tree) at time of planting was increased by foliar urea sprays applied to the trees the previous fall in the nursery and was reduced by either root pruning, or canopy pruning. The amount of nitrogen per tree was positively correlated and root:shoot ratio was negatively correlated with total shoot growth, tree dry-weight increment and leaf area. The greatest leaf area development during the first year in the orchard was obtained with the unpruned (root or canopy) trees while trees that received both root and canopy pruning had the least leaf area development. Root pruning had a minimal effect on growth during the first year in the orchard while canopy pruning had a larger effect.

Valencia, A. and T. Robinson. 2001. Effect of nitrogen content, root:shoot ratio, trunk caliper, and number of feathers on canopy development of young apple trees after transplanting from the nursery. HortScience 36:462 (Abstr.)

Evaluation of New Apple Rootstocks

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The new series of Cornell-Geneva rootstocks have the potential to replace existing rootstocks because they have resistance to fire blight and phytophthora root rot. Four stocks have now been released (G.16, G.30, G.65 and G.11) and are being commercialized. About a dozen more elite selections are in the pipeline. We have established a series of trials within New York State to further evaluate their commercial potential. We are also gathering promising rootstocks from around the world for trial in New York. Data from these trials will give growers unbiased information about the potential of CG, Supporter, Morioka, Budagovsky, Pillnitz and JTE stocks. From trials planted in 1992-1998 we have identified G. 16, G.11, CG.3041, and CG.4202 as the best elite dwarfing fire blight resistant rootstocks. In two grower trials, almost all trees on M.9 or M.26 were killed by fire blight in 2000, but almost none of the trees on G.16, G.11, CG.3041 or CG.4202 were killed. Other less tested dwarfing CG clones that have exceeded the performance of M.9 or M.26 are CG.3902, CG.3007, CG.4003, CG.4247, CG.5757, CG.6737, CG.3029, CG.50, CG.26, CG.995, CG12.3, and CG.38. Among semi-dwarf stocks, G.30 has been the most productive and far exceeds M.7. Other less tested semi-dwarfing clones that have exceeded the performance of M.7 are CG.5935, CG.5012, CG.5046, CG.5202, CG.5179, CG.6210, CG.6874, CG.756, and CG.7760. Among vigorous stocks, CG.6239, CG.6253, CG.6723, CG.7707, CG.8189 exceeded the performance of MM.111. G.16 trees have generally grown slightly larger than M.9 trees, but are smaller than M.26. Trees on G.16 have been as precocious and productive as M.9 and have shown excellent fire blight resistance. We believe G.16 with its high fire blight resistance may be the best practical alternative to M.9 for successful high density plantings in the East.

The new CG rootstocks—G.16 and G.30—are being sold commercially by most US nurseries. G.11 stoolbeds were planted by commercial nurserymen in 2001 and so should be available in 2003. We have decided to release CG.4202 in New Zealand during May 2002 and in the US in 2004. Nurseries are beginning to bulk up these stocks for commercial sale. We also intend to release CG.3041 and CG.5935 in 2004.

High density orchards are capable of high early and sustained yield.

Improving the Cold Hardiness of Young Bearing Apple Trees

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Cold damage problems in the Northeastern US most often occur in late fall and early winter when hardening of the trees is delayed. The objective of this study was to determine if fall foliar sprays of copper chelate and Apogee induced earlier cold tolerance. In 1999, we tested four concentrations of Cu-EDTA applied by handgun, and evaluated air-blast sprays of 150 and 75 gallons per acre on young McIntosh/M.26 apple trees growing in a commercial orchard in the Champlain Valley. In September 2000, experiments were conducted on a block of late growing three-year-old McIntosh/M.9/ MM.111 trees in a commercial orchard in Burnt Hills, NY. The treatments were: a) Untreated control; b) Apogee; c) Cu-EDTA; and d) Apogee, followed by Cu-EDTA. Shoots were collected in early December, and again in late January, and then were subjected to a range of cold temperatures in a programmable cold chamber at the Hudson Valley Lab. Cold injury resulting from these temperatures was evaluated by determining electrolyte leakage using a conductivity meter. Results of this research showed that while both handgun and air-blast sprays of Cu-EDTA were highly effective defoliants at concentrations of 0.1% copper and up, they did not enhance early winter cold hardiness. Stem tissue on Apogee-treated trees showed less damage from low temperatures in early December. Apogee reduced electrolyte leakage by 17% and 25% at –11°F and –22°F, respectively. These results provide initial evidence that treating actively growing trees in the autumn with Apogee increases early winter cold hardiness. Further study is needed to confirm these results before this method can be put into practice.

Schupp, J. R., L. Cheng, W. C. Stiles, E. Stover, and K. Iungerman. 2001. Mineral nutrition as a factor in cold tolerance of apple trees. NY Fruit Quarterly 9(3): 17-20.

Development of Chemical Thinner Alternatives

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With small-fruited varieties like 'Empire' and 'Gala', the importance of early thinning to attain good fruit size is increasingly recognized. Interest in blossom thinning has increased with the uncertainty surrounding the future market and regulatory status of carbaryl, a carbamate insecticide widely used in chemical thinning strategies. The registration of carbaryl may be threatened by future Food Quality Protection Act actions, and the use of carbamates may limit market access to selective fruit processors or supermarkets in the United Kingdom. Growers will need alternatives to carbaryl should it no longer be an option. This is a new project funded for 2002.

Four studies are planned for 2002 with the following objectives: a) to test lime sulfur as an alternative to carbaryl in conventional thinning programs; b) to determine the application time that produces the best thinning response to fish oil + lime sulfur sprays; c) to test alternatives to fish oil for combination with lime sulfur in thinning sprays; and d) to determine the effect of changing the rates and ratios of fish oil and lime sulfur on thinning efficacy. Our preliminary results have shown that a tank mix of fish oil with lime sulfur (FOLS) is a very effective thinner when applied at 80% bloom. FOLS sprays increased fruit size and return bloom of Delicious apple in 2000. FOLS is organically acceptable, providing organic growers with an alternative to expensive hand thinning for the first time ever. An initial evaluation of post-bloom FOLS in 2001 showed that this timing was more effective for thinning 'Gala' and 'Golden Delicious' apples than treatments applied during bloom. This finding, if confirmed in future trials, will be very important for increasing the ease and usefulness of this strategy for apple growers. The later timing will permit the grower to complete an appraisal of initial fruit set before the treatments need to be applied, largely bypassing the threat of frost. It will also greatly relieve the pressure to apply these materials within a rigid time frame, enabling growers to wait for optimal spray conditions and to cover a greater amount of acreage than possible with a true blossom thinner. This line of research will soon provide New York apple growers with one or more new chemical thinning options for those who wish to address the concerns about carbaryl in export or processing markets, or those who seek organically acceptable thinners that are cost effective.

Factors Affecting the Efficacy of Chemical Fruit Thinning

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The decisions concerning chemical thinning (chemical, rate and timing) are the most critical ones a grower makes each season, and the least predictable. Understanding how environmental conditions affect thinner response will improve our ability to predict response and thus improve the results of chemical thinning and the value of the crop. Field studies were conducted in 2000 and 2001 with 6- and 7-year-old Gala and McIntosh trees on M.9 rootstock, and Delicious apple trees on M.26 rootstock where single application sprays of a tank mix of 75 ppm of 6-benzlyadenine (BA) plus 1 pt. of Carbaryl (Sevin XLR Plus) per 100 gal water, or 7.5 ppm of Naphthaleneacetic Acid (NAA) (Fruitone N) plus 1 pt. of Carbaryl per 100 gal of water were applied at 3- or 4-day intervals beginning at petal fall until 28 days after petal fall. Trees were sprayed with an airblast sprayer at 100 gal per acre using a 2X concentration of chemicals. In both years, a prolonged cool post-petal fall period resulted in slow fruit growth rate and poor thinning during the traditional thinning window. Thinning effectiveness was poor when fruits were smaller than 15mm and improved when fruits were relatively large between 15 and 20 mm. In 2000, this later period coincided with a warm period, but, in 2001, this coincided with one of the coolest periods during the experiment. It appears that in cool years, the applications of fruit thinning chemicals should be delayed until fruits are relatively large. These results are in contrast to our longstanding theories about fruit thinning and temperature and our general recommendation that NAA or BA be applied between 7 and 12 mm king fruit size. A possible explanation is that in cool years when fruit growth after petal fall is slow, carbohydrate reserves used to supply fruit growth are not reduced to a low level, where the mild stress from chemical thinners applied under cool conditions would cause some fruits to abscise. In such years, a relatively large fruit size is required before reserves are at a low point where they are most susceptible to chemical thinners. These results indicate that, in cool years, it is better to wait for relatively large fruit sizes before fruit thinners are applied.

Comparing Foliar Nitrogen with Soil Applied Nitrogen on Apple Yield, Fruit Quality, and Tree Cold Hardiness

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The objective of this project is to compare fall foliar urea application with traditional spring soil N fertilization to determine the best nitrogen management regime for optimizing apple yield and quality in commercial apple orchards under New York soil and climate conditions. Mature Marshall McIntosh/M.9 and Empire/M.7 trees received one of the following four N treatments at the same rate of 46 lbs/acre: (1) soil applied N in the spring (control); (2) foliar urea sprayed twice at weekly intervals after harvesting; (3) 50/50 split between fall foliar and spring soil application; and (4) 36/64 split between spring foliar and soil application. Fall foliar urea application to Marshall McIntosh increased reserve nitrogen levels in spurs and shoots. However, nitrogen content of leaf samples taken in late July the following year, was slightly lower in fall foliar N treatment than in the control and the split application treatments. There was no significant difference in fruit number, fruit size, soluble solids, firmness, and yield among the four treatments, although spring foliar and soil split application tended to give the highest fruit number and yield. No difference in leaf N content, yield, and fruit size was observed in Empire trees among the four N treatments. There was no difference in cold hardiness in either Marshall McIntosh or Empire trees among the four treatments. Whole tree excavation after fall foliar 15N-urea application indicated that nitrogen derived from fall foliar urea contributed 15% of the total tree nitrogen and increased tree N concentration by 16.3%. These results indicated that fall foliar urea application did improve tree reserve N status in the fall, but it appears that, when applied at the same rate, fall foliar urea application does not have any advantage over soil application in supporting tree growth and yield.

Seasonal Patterns of Root Growth and Lifespan in M9, M26 and B9 Rootstocks in New York

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Although the roots of apples are a critical component of trees, we know very little about them, especially in our climate. For two years, we have studied the patterns of when new roots are produced and how long they live in the field with three dwarfing rootstocks (M9, M26, B9) under Gala trees. The results so far have shown that the three rootstocks displayed the same general patterns as to when they grow and how long the new roots live over the two years examined. However, the seasonal patterns of root production varied tremendously from year to year. In 2000, most new roots were produced in June and July. In contrast, in 2001, a flush of new roots occurred between budbreak and bloom, few new roots were produced between bloom and harvest, but a large flush of root production occurred immediately after harvest in late September/early October. Previous studies in New York with M.9 and other stocks suggest that the June-July flush of roots is more normal, but clearly root growth can vary dramatically from year to year. We feel that the warm spring period in 2001 combined with very heavy crop loads and drought, limited root growth to the early flush until harvest, and a heavy rain relieved the limitations. Then a fall flush could occur. In general, new apple roots remain white (the most physiologically active stage) for about 3-4 weeks, then turn pink or brown for some weeks to months before dying. Full root lifespan analyses are not yet completed as they require several years to be sorted out.

CROP PROTECTION and INTEGRATED FRUIT PRODUCTION

Development of an Integrated Fruit Production (IFP) Protocol for New York Apples

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The recently adopted strategic plan (2001) for the New York apple industry calls for Cornell to develop a market oriented integrated fruit production (IFP) program for apples in New York. Industry leaders have indicated that an IFP program is necessary to keep the industry competitive both from a production perspective and also from a marketing perspective to maintain and expand market access. New York marketers report that apple buyers from Europe are beginning to require greater and greater environmental and food safety characteristics for the fruit they purchase. At the moment, these are largely aimed at the packing plant,but, recently, they have indicated they will likely proscribe specific production and pest management practices beginning in 2002. The New York apple industry can act in a proactive manner to keep these markets and make inroads in other European markets by developing an IFP protocol. We are developing a New York Integrated Fruit Production protocol which would detail eco-friendly pest management, disease control, weed control, fertilization and fruit thinning, packing and storage practices to assure apple buyers that New York apples are safe and are produced in an environmentally sound manner. Such programs are common in European countries where IFP has been in place for 10 years. The New Zealand apple industry instituted such a program three years ago. We are working collaboratively with the New York apple industry to develop and test a New York IFP protocol on growers farms. If this project is successful, a workable and respected IFP program for New York growers and marketers will result. This will help the New York apple industry assure foreign and domestic buyers that New York apples are safe and are grown in an environmentally sound manner. This would help the New York apple industry keep current markets and make inroads in other European markets.

Management of Obliquebanded Leafroller Damage and Insecticide Resistance with a Biorational Insecticide Program

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This study was conducted on growers' farms (Cooperators: Richard Endres, Todd Furber, Ed and Seth Burnap, Lynoaken Farms, Glendale Farms) and showed that resistance to organophosphates remained relatively stable in the field populations of OBLR during the three years of the study, despite the absence of sprays of these materials. The control of OBLR in the soft pesticide programs was generally better than that obtained by growers in their standard pesticide treatments. However, adequate control of plum curculio was not obtained in most of the blocks, and, at the end of the study, damage was observed even in blocks that were completely free of this pest during the first season. These results showed that adequate control of the curculio cannot be maintained for multiple seasons without using special control sprays even in blocks that would not be considered to be at risk from this pest. This soft insecticide program did not provide adequate control of internal lepidoptera in some of the blocks for multiple seasons, although control of apple maggots was acceptable. Foliar pests such as tentiform leafminers, green apple aphids, white apple leafhoppers, and mites were not serious problems in the soft pesticide blocks. Tarnished plant bug damage was generally similar in growers' standard programs and the soft pesticide blocks. Secondary pests, such as rosy apple aphids and the San Jose Scale were problems in some of the soft pesticide blocks. However, the overall insect damage in the standard and soft pesticide was fairly similar during all seasons of the three-year study, except in one orchard, which suffered severe damage from curculio and internal lepidoptera. The costs of insecticides applied in the standard and soft pesticide programs were fairly similar.


Adult obliquebanded leafroller.

Leafminer Damage and the Leaf/Fruit Ratio of Size-Controlled Apple Cultivars

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Through experiments with both natural infestations and simulations of leafminer damage, it was determined that infestation greater than 2 mines/leaf caused significant reductions in fruit size of 'Empire' apple, but premature fruit drop was not affected.

Determination of the Damage Potential of the Leafhopper Complex on Apple

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This project provided support for assessing biological and occurrence characteristics of leafhoppers. Major impact was the determination that damage to apple was also being done by the previously unreported rose leafhopper, and current management protocols consider this an important finding.

Status of Borers Infesting Apple Burrknots and Their Management in New York Orchards

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Prompted by the regulatory loss of Lorsban for postbloom use on apple, we performed field trials during two seasons and determined that petal applications of this material provided control of dogwood borer almost equal to the previously recommended timing.

Biological Mite Control in Hudson and Champlain Valley Apple Orchards Through The Distribution and Conservation of *Typhlodromus Pyri*

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[2]Cornell Cooperative Extension

In contrast to Western New York where the mite predator *Typhlodromus pyri* is widespread and conserved to provide biological mite control, biological mite control has not been actively pursued in eastern New York orchards, at least in part because of the real or assumed absence of *T. pyri*. Previous research has shown that *T. pyri* can provide complete biological mite control in Eastern New York orchards. During 2001, we began a project to demonstrate this on a large scale. We found that:

- Of 11 Hudson valley (HV) and 8 Champlain valley (CV) orchards where *T. pyri* were released, the predator was also present in approximately 80% of the plots in these orchards where it was not released.
- Release of *T. pyri* increased densities of the predator two- to three-fold compared to densities in plots where no releases were made.
- Densities of European red mite (*Panonychus ulm*i) remained low in release plots even though miticides were not used.

These results indicate the strong potential for using *T. pyri* in HV and CV orchards to control European red mite. This will benefit the apple industry by providing a stable, effective, and nearly cost free mite management program.

Fire Blight of Apple Interstems and Rootstocks

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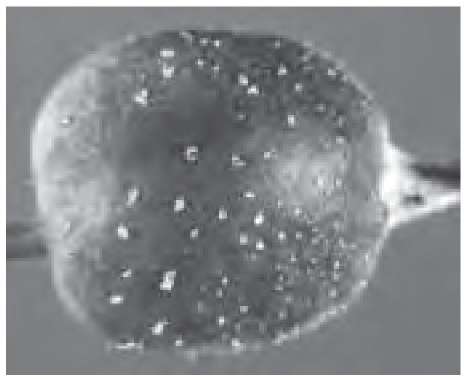
Fire blight usually first infects apple blossoms, damaging the crop, and later apple shoots, damaging the tree. In recent years, an even more devastating infection of the rootstock has occurred in New York orchards planted on M.9 and M.26 dwarfing rootstocks. We have



Fruit infected with fire blight showing droplets of ooze containing high concentrations of FB bacteria.

shown that rootstocks can become infected from infections of root suckers and through burrknots damaged by borers. But a third avenue of infection may be the most serious—the movement of fire blight bacteria downward inside healthy-appearing branches and trunks, from infected blossoms and shoot-tips into susceptible M.9 and M.26 rootstocks. We now have evidence that such movement can happen very quickly when blossom infections occur in trees, particularly those in their 3rd or 4th leaf. Pruning out infections to prevent spread into the rootstock has given varied results in different years. Thus, control of blossom infections (and of suckers and burrknots) is critical in young dwarf orchards. The dwarfing rootstock, B.9, and the new Geneva rootstocks, especially the dwarfing stock G.16, show great promise for reducing the problem because of their high resistance to fire blight, which has held up in two severe orchard trials. Apple trees grafted on B.9 and G.16 are available from several nurseries. Other fire blight resistant rootstocks will be released by the Geneva breeding program in the near future. Understanding how rootstock infection occurs and the development of strategies and resistant rootstocks to prevent it will greatly reduce tree losses in New York dwarf apple orchards.

Biology and Control of Fungi that Cause Apple Fruit Russet

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Russet occurs on many important apple cultivars in New York and results in reduction of fresh market quality of the fruit and therefore to grower profits. We have discovered that a common fungus, *Aureobasidium pullulans*, is prevalent on apple and is able to cause russet of fruit in New York orchards. Russet caused by the fungus often has characteristic black corky spots within the russeted region that is comprised of spores of the fungus. Although Golden Delicious is most prone to russet, other important cultivars were identified by growers as having significant russet in some years. Fungicides such as Captan, Polyram and, to some extent, Sovran are inhibitory to A. pullulans, and provide a significant level of control in orchard experiments. However, it was determined that some isolates of the fungus are reduced in their susceptibility to these fungicides. It is interesting that isolates recovered from plants that are not sprayed with fungicides were found to be the most sensitive to captan and Polyram suggesting that long term use of the fungicides has led to tolerance. Tolerance of some isolates may explain why complete control of russet has not been achieved in the orchard even following weekly sprays. *A. pullulans* is not sensitive to some fungicides, such as dodine and the sterol-inhibitor group. It has been possible to observe the effects *A. pullulans* has on fruit surfaces using microscopy. Fruit inoculated with the fungus show changes in surface cells within seven days. It was first observed that the fungus erodes the surface (wax and cuticle) and induces cell divisions in outer apple tissues that are associated with the classical wound response. Our evidence suggests that the fungus induces russet rapidly after reaching a certain population threshold. Identifying how the fungus causes russet may lead to the discovery of novel ways to control russet.

The Role of Epiphytic Bacteria in the Shoot Blight Phase of Fire Blight

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The purpose of the project is to determine if fire blight bacteria can multiply on the surface of apple leaves without causing disease (epiphytic). The long-term goal of the research is to identify the sources of fire blight bacteria that initiate the shoot blight phase of the disease. If fire blight bacteria are capable of growing epiphytically on apple shoots, these bacteria could serve as a source of bacteria for subsequent shoot infections and explain how shoot infection can sometimes seem to "appear from nowhere". Results indicate that fire blight bacteria do not multiply or survive on apple shoots without causing disease. Although bacteria can be detected on apple shoots after inoculation, it appears that the bacteria detected are associated with the direct infection of shoots and not with epiphytic survival. These results indicate that shoot blight infection should be associated with rain events and close proximity to infected material. They also support previous recommendations stressing the importance of pruning out fire blight cankers during dormant pruning and the importance of controlling blossom blight, since both active cankers and blossom infections would be obvious sources of bacteria for shoot inoculation.

Integrated Diagnosis and Management of Apple Replant Disease in New York Orchards

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As growers renovate old orchards, apple replant disease (ARD) often becomes a serious problem. Chemical soil fumigation sometimes controls ARD, but fumigation responses have been variable and may be linked with environmental problems. Other possible control tactics for ARD include disease-suppressive preplant cover crops, correction of soil compaction, nutrient and pH problems, and disease resistant rootstocks. Six years ago, we began a project to test and develop comprehensive strategies for diagnosing and controlling orchard replant problems. With funding support from New York apple growers, we tested methods for predicting the severity of ARD and biological or chemical strategies for controlling ARD at selected commercial apple orchards in the state's major fruit-growing regions. Soils from 17 orchards were sampled during 1996 to 1998 for nematode populations and nutrient status, and growth of apple seedlings or grafted rootstocks was compared in fumigated, pasteurized, and untreated field soil. At the same time, six or seven preplant soil treatments were evaluated at each orchard: 1) No treatment (Control); 2) Brassica/Sudan grass cover crops (B/S); 3) Lime and fertilizer amendments (L/F); 4) Lime and fertilizer plus Brassica/Sudan grass (LFB/S); 5) Lime and fertilizer plus Vapam fumigation (LFV); 6) Vapam soil drench; and 7) Telone C-17 soil fumigation. The following year, apple trees were planted into each preplant treatment, and, since then, we have measured tree growth, fruit yields, and nutrient uptake each year. The preplant bioassays indicated ARD problems at two-thirds of these orchards-seedlings or grafted trees grew much better in pasteurized or fumigated soil. Nematode populations were below damage thresholds at most sites.

In subsequent years, tree responses to the preplant treatments were inconsistent from farm to farm. Fruit yields varied up to five-fold among the orchards. At a few sites, trees responded positively to fumigation, while, at others, the best growth and yields occurred in fertilizer/cover crop treatments, or there was no significant benefit from any preplant treatment. The initial diagnostic bioassays over-predicted substantially the subsequent tree growth responses to soil fumigation in most orchards. These results indicate that preplant soil treatments can not guarantee good growth and early yields of apple trees. The many other factors that can limit replant success must also be managed correctly. Fruit growers can benefit from this research by considering preplant soil treatments as just one of many management practices essential for successful establishment of orchard replants.

Pesticide Application Technology

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Correct pesticide application continues to be a major concern to all growers. Research activities have been based upon the area of improving deposition and reducing drift. Often reducing drift by larger droplets doesn't necessarily improve deposition due to leaf run-off. Air induction nozzles fitted into air blast sprayers have been evaluated in a number of orchards and we have had great success at applying growth regulators and controlling disease. Insect control has been less successful. The nozzles are an inexpensive way of reducing drift and are extremely useful if growers are near watercourses or have close neighbors. Other work of interest to apple growers is the development of deflectors to target spray towards the canopy. This on-going project is funded by other outside bodies, but the results to date look most promising.

HARVEST and STORAGE QUALITY

Use of 1-Methylcyclopropene (1-MCP) for Control of Softening and Other Ripening Processes of New York-Grown Apples

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1-Methylcyclopropene (1-MCP) is an exciting postharvest chemical that will soon become available to fruit industries. Federal registration is expected in June 2002. 1-MCP, or SmartFreshTM, as it will be known commercially, represents a potential revolution in our ability to store fruit and produce a better quality product in the marketplace.The chemical, which is released as a gas in storage rooms, inhibits the action of ethylene, the plant growth regulator that controls ripening of fruit such as the apple. The consequences of inhibiting ethylene action are to prevent or slow down softening, color change and other ripening related events. The New York industry relies on varieties that are particularly prone to softening, and we must exploit the effectiveness of 1-MCP.

The first two years of this project have involved a major undertaking to examine a range of variety, harvest maturity and postharvest handling operations that will affect the efficacy of the chemical for the New York industry. It is essential that we gain the knowledge that will allow initial use of 1-MCP with minimum risk. The experiments that have been completed or are still in storage include:

• A survey of the responses of most important varieties to our industry.

- Effects of fruit maturity, especially for McIntosh and Empire.
- Comparison of air and controlled atmosphere (CA) storage regimes.
- Investigation of regional effects.
- Comparison of warm versus cold treatment with 1-MCP.
- Effect of storage temperature, e.g. can we store 1-MCP treated fruit at 38°F and eliminate chilling injury as a major storage risk for the New York industry.
- The effect of delays after harvest before treatment with 1-MCP.

We have found, or are finding, answers to these questions. Initial results have been described at fruit schools, the Postharvest Handling Newsletter, and the Storage Workshop. It is now clear that responses of fruit to 1-MCP can vary greatly both in terms of varieties and where they are grown, that 1-MCP is not a substitute for long term CA storage for many varieties, and that varieties grown in some regions may be more responsive to 1-MCP than those grown on other regions. Fruit treated warm are often more responsive to 1-MCP than those treated cold, the latter method being the presumed commercial method of application. Such treatments raise handling issues that need to be resolved. Also, there is a failure rate with the chemical that is not always explained by internal ethylene concentrations. We need to develop a strategy to determine when fruit have not responded to the chemical.

Watkins, C.B., Nock, J.F. 2000. MCP: Facts, speculation, and how could it affect the NY apple industry? New York Fruit Quarterly 8 (3): 5-9.

Watkins, C.B., Nock, J.F. 2001. What do New York results tell us about the future of MCP. p79-96. In: Storage Workshop 2001: Apple handling and Storage. NRAES-153.

Several presentations have also been made at Statewide fruit schools.

Understanding the Soft Scald Problem in Honeycrisp

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Honeycrisp is an exiting new variety that has generated enthusiasm among many New York growers. However, two types of physiological disorders, bitter pit and soft scald, have occurred in the marketplace and have the potential to destroy this promising apple. In this project, our focus has been on soft scald. The most serious aspects of soft scald to date have been its sporadic nature, sometimes occurring after fruit has left the shipper, and that it can develop internally without any external symptoms. We have concluded from this two-year project, completed this year, that the following factors are important for soft scald control in Honeycrisp.

Harvest maturity and storage temperature: Soft scald development is clearly increased by exposure to storage temperatures of 33°F, especially in fruit from later harvest dates. In the first year, at the last harvest dates, even a higher storage temperature of 37°F did not control the disorder. In the second year, storage temperatures of 33, 38 and 42°F were tested. The highest temperature did reduce soft scald development in highly susceptible fruit, but a high decay incidence and less favorable sensory profiles make this temperature unacceptable for storage. Although advanced fruit maturity in some orchard blocks in mid-September was sometimes associated with soft scald development, no association with IEC was found for fruit harvest late. This study has not identified any single factor that is related to fruit susceptibility to soft scald, and a project to be initiated this harvest season aims to develop harvest indices for the variety.

Postharvest treatments: A holding period at 50°F of a week prior to cold storage markedly reduces soft scald development. Informal tasting of fruit does not suggest that Honeycrisp quality is deleteriously affected by this treatment, and we are aware of two growers who have applied this method with good results. However, both warmer storage temperatures, as well as delay treatments, enhance bitter pit incidence. Therefore, bitter pit susceptibility is the major issue that needs to be resolved for the Honeycrisp variety if soft scald is to be controlled satisfactorily. The major recommendations from this work are that fruit should be harvested as soon as appropriate color and flavor have been obtained and that a storage temperature of 38°F is recommended. Storage operators need to find a way to ensure that a dedicated room is available, especially as crop volume increases.

Rosenberger, D., J. Schupp, C. Watkins, K Iungerman, S. Hoying, D. Straub, and L. Cheng. 2001. Honeycrisp: promising profit maker or just another problem child? NY Fruit Quarterly 9(3):9-13.

Watkins, C.B., Nock, J.F., and Iungerman, K., 2001. Understanding the soft scald problem in Honeycrisp. Pages 9-20. In: Apple Handling and Storage: Proc. Storage Workshop 2001, Cornell University, Ithaca. Natural Resource, Agriculture, and Engineering Service (NRAES) Publication 153, Cornell University, Ithaca, NY. 130 p.

Effects of Foliar Applications of Calcium, Boron, and Flint Fungicide on Incidence of Bitter Pit

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[4]Cornell Cooperative Extension

Objectives of this project were to compare effectiveness of foliar sprays of calcium, boron, and Flint fungicide for reducing bitter pit and to evaluate interactions among the three products. Replicated plots were established in Honeycrisp apple orchards in the Hudson Valley and in Western New York. In five trials conducted over two years, Flint fungicide significantly reduced the incidence of bitter pit at harvest in only one trial, and the bitter pit suppression provided by Flint disappeared when apples were evaluated after several months of cold storage. Calcium chloride (CaCl2) sprays also failed to control bitter pit in 2000 when they were applied only three times during summer using low rates (equivalent to a total of 0.9-lb actual calcium per 100 gal of dilute spray). In 2001, however, CaCl2 sprays provided good control of bitter pit in the Hudson Valley trial when six applications were made during summer (June through August) with rates adjusted to provide a seasonal total of 3 lb of actual calcium per 100 gal of dilute spray. At harvest, Honeycrisp from Ulster County trees that were treated with CaCl2 had only 2% of fruit with bitter pit compared to 9% in fruit from non-treated trees. After 47 days of cold storage at 37°F, the percentage of fruit downgraded because of bitter pit had increased to 25% for fruit sprayed with CaCl2 compared to 67% for control fruit. Even the best treatments in this trial had a high incidence of bitter pit because trees in the test orchard had a light crop, the fruit were harvested slightly immature, and the 37°F. storage temperature favored continued development of bitter pit after harvest. Combining Flint fungicide, Solubor sprays, or Messenger (harpin protein) with CaCl2 did not enhance the effectiveness of the CaCl2 sprays. In Western New York, commercial formulations of calcium that, when applied according to the label, totaled 3 lb of actual calcium per 100 gal of dilute spray, provided 80-90% control of bitter pit in fruit that were rated after 90 days of cold storage plus 7 days at room temperature. In treatments where total calcium applied during the season ranged from 1.8-2.2 lb or actual calcium, control of bitter pit ranged from 36-63%. Results of this trial showed that bitter pit in Honeycrisp is best controlled by applying high rates of CaCl2 throughout summer. However, CaCl2 sprays alone will not completely control bitter pit if other factors predispose fruit to severe bitter pit. Therefore, controlling bitter pit on a highly-susceptible apple cultivar such as Honeycrisp will require an integrated program of CaCl2 sprays, crop load and fertility management, and attention to harvesting fruit at optimum maturity and storing them at temperatures that minimize both bitter pit and other storage disorders such as soft scald.

Rosenberger, D., Schupp, J., Watkins, C., Iungerman, K, Hoying, S., Straub, D., and Cheng. L. 2001. Honeycrisp: promising profit maker or just another problem child? NY Fruit Quarterly 9(3):9-13.

Schupp, J., Straub, R., Rosenberger, D., and Watkins, C. 2001. Managing Honeycrisp for production and quality. Compact Fruit Tree 34:107-109.

Schupp, J. R., Rosenberger, D. A., Watkins, C. B., Cheng, L., and Hoying, S.A. 2001. Understanding the bitter pit problem in Honeycrisp. Pages 1-8 in: Apple Handling and Storage: Proc. Storage Workshop 2001, Cornell University, Ithaca. Natural Resource, Agriculture, and Engineering Service (NRAES) Publication 153, Cornell University, Ithaca, NY. 130 p.

ARDP Funded Projects - 2002

RESEARCHER	TITLE	ARDP AWARD	ARA AWARD
Aldwinckle, Robinson, Fazio	Fire Blight of Interstems and Rootstocks	8,580	
Aldwinckle	Improvement of NY Apple Varieties & Rootstocks by Biotechnology Techniques	15,000	
Amissah, Hotchkiss, Watkins	Processing Apple Slices for Long Shelf Life	3,000	
Brown, Maloney	Assessing the Commercial Potential of Advanced Apple Selections & New Varieties of Interest	8,900	8,000
Burr, Goffinet	Biology & Control of Fungi That Cause Apple Fruit Russet	4,000	
Cheng, Schupp, Merwin, Watkins	Comparing Foliar Nitgrogen with Soil Applied Nitrogen on Apple Yield, Fruit Quality, & Tree Cold Hardiness	8,000	
Koeller, Turechek	Simplified Testing of Fungicide Resistance in Commercial Apple Orchards	7,700	
Lakso, Robinson, Cheng, Eissenstat, Fazio	Seasonal Patterns of Root Growth & Lifespan in Dwarfing Rootstocks in NY	10,830	
Landers, Barber	Development of a Method for Measuring Pesticide Deposits in Apple Trees	12,000	
Liu	Role of New York Apples in the Prevention of Cancer	10,000	
Norelli	The Shoot Blight Phase of Fire Blight	5,000	
Nyrop, Iungerman, Jentsch, Straub	Biological Mite Control in Hudson and Champlain Valley Apple Orchards Through the Distribution and Conservation of *T. Pyri*	3,920	
Reissig, Nyrop	Monitoring the Effects of Newer "Soft Insecticides" Against Parasites of the Oblique-Banded Leafroller	4,590	
Robinson, Agnello, Carroll, et al	Development of an Integrated Fruit Production (IFP) Protocol for NY Apples	6,000	
Robinson, Lakso, Cheng, Valencia	Maximizing the Performance of Young Apple Trees	11,500	
Robinson, Hoying, Fargione, Iungerman	Orchard Management Systems for Improved Yield & Fruit Quality	20,000	8,000
Schupp, Robinson	Development of Chemical Thinner Alternatives	8,000	
Watkins, Wargo	Maturity & Quality of Honeycrisp	7,500	
Watkins, Nock, Hoying, et al	Use of 1-methylcyclopropene (1-MCP) for Control of Softening & Other Ripening Processes of New York-Grown Apples	19,550	
Total		**174,070**	**16,000**

Preventing Postharvest Decays of Apple Fruit

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Objectives of this project were to determine: 1) if boron concentrations in apple fruit affect fruit susceptibility to decay during storage; and 2) how inoculum of *Penicillium expansum*, the fungus that causes most postharvest decays, cycles from one year to the next. Different boron fertilizer regimes were applied to replicate plots in orchards at Geneva and Highland. Fruit from these plots were harvested at normal maturity and were inoculated by placing a drop of a spore suspension of *P. expansum* on the ends of the fruit stems. The inoculated fruit were then moved to long-term controlled atmosphere (CA) storage and were evaluated for decay after nine months of CA storage. Results from the first year confirmed that high boron concentrations increase susceptibility of fruit to invasion by P. expansum through stems. The incidence of decay in Empire fruit from untreated trees (no added boron) in the Highland experiment was 20%, and fruit had 24 and 11 ppm boron in leaves and fruit, respectively. For trees given moderate boron treatments, the comparable numbers were 38% decay for fruit with 31 and 24 ppm boron. Trees with high boron fertilization (including soil-applied boron) also had 38% decay, but leaf and fruit concentrations of boron were 39 and 38 ppm, respectively. Similar results occurred with Delicious fruit taken from the same treated plots. Under the second objective, spore trapping in three packinghouses over a two-year period showed that spore density in packinghouse air often exceeded 150 spores per liter during late winter. At the high spore densities measured in packinghouse air, spores can settle onto bins in the packinghouse at a rate of more than 1 million spores per bin per hour, thereby contaminating bins with inoculum that will remain viable until bins are reused the following year. The airborne spores also contaminate fruit on the packing line and contribute to the high incidence of decays noted in retail apple displays during two years of store surveys. Results from these trials show that growers can reduce fruit susceptibility to decay by avoiding excessive boron fertilization. However, better sanitation is needed in packinghouses to reduce airborne inoculum that contaminates fruit being packed and that contributes to inoculum recycling on bins.

Rosenberger, D. A. 2001. Decay and quality problems at the retail level. Pages 21-23 in: Apple Handling and Storage: Proc. Storage Workshop 2001, Cornell University, Ithaca. Natural Resource, Agriculture, and Engineering Service (NRAES) Publication 153, Cornell University, Ithaca, NY. 130 p.

Rosenberger, D. A. 2001 Postharvest decay control without fungicides. Pages 21-23 in: Apple Handling and Storage: Proc. Storage Workshop 2001, Cornell University, Ithaca. Natural Resource, Agriculture, and Engineering Service (NRAES) Publication 153, Cornell University, Ithaca, NY. 130 p.

Rosenberger, D. 2001. Postharvest pathogens create problems for storage. The Fruit Grower News 40(6):40-41.

Rosenberger, D. 2001. Sanitation methods for apple packinghouses explored. The Fruit Grower News 40(6):42-43.

Rosenberger, D., Meyer, F., and Ahlers, C. 2000. Progress in understanding and controlling postharvest decays of apples. N.Y. Fruit Quarterly 8(3):24-28.

HEALTH BENEFITS of APPLES

Antioxidant and Antiproliferative Activities of Selected New York Apple Cultivars

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Diets rich in fruits and vegetables have been associated with lower incidences in cancer and lower mortality from coronary heart disease. Antioxidants in fruits and vegetables are thought to reduce cancer rates by counteracting the prooxidant load of the body. In addition to the presence of vitamins C and E, fruits and vegetables are a rich source of other antioxidants such as phenolic acids and flavonoids. We measured the total antioxidant activity of several apples varieties by Total Oxyradical Scavenging Capacity (TOSC) expressed as mmol vitamin C equivalents per gram. We found that all varieties of apples that we tested exhibited great antioxidant activity. Apples with the skin had higher antioxidant activity than apples without skin. Apple skins are known to contain higher amounts of phenolic compounds than the flesh. Others have reported that the amount of phenolics in the skin of apples is several times higher than that of the flesh and that the quercetin glycosides (the most predominate flavonoid in apples) are only found in the skin. Although apples have a relatively low Vitamin C content (which is one of the better known antioxidants), they do contain relatively high amounts of other antioxidants. The Vitamin C in apples accounts for only 0.4% of total antioxidant activity. Therefore, the majority of antioxidant activity of apple is not from Vitamin C, but from other phytochemicals in apples. The combination of different phytochemicals in apples may function additively or synergistically to be responsible for this potent antioxidant activity.

Apples are high in antioxidants which help prevent cancer.

Apple extracts from selected apple varieties were added to human liver cancer HepG2 cells to determine if the extracts could inhibit tumor cell proliferation. There was a large variation in the effects of the different apple varieties on the inhibition of cell proliferation, but all apple varieties inhibited liver cancer cell proliferation. Apples without skin were less potent in inhibiting HepG2 cell proliferation whereas apples with skins exerted greater inhibitions of cell proliferation. Our results show that the combination of phytochemicals in apples is critical to its potent antioxidant activity and antiproliferative activity. Apple with the skin displayed higher antioxidant and antiproliferative activities than apple without skin. The total phenolic and flavonoid content was positively related to antioxidant activity and inhibition of cell proliferation. Additionally, the minimal contribution of Vitamin C to the antioxidant activity of apples further supports the proposal that other phytochemicals, such as phenolic acids and flavonoids, significantly contribute to the in vitro antioxidant activity of apples. This data provides direct supportive evidence for the Five-a-Day program, and suggests that apples are a good way for consumers to obtain their antioxidants for health improvement and disease prevention.

Terence Robinson is an Associate Professor of Pomology in the Horticultural Sciences Department.