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Editorial

Stepping Down and Looking Back

By the time you read this, I will have stepped down as director of the New York State Agricultural Experiment Station after 13.5 years in the position. I have seen many changes in the Station, the College of Agriculture and Life Sciences, and the fruit and vegetable industries that the Station serves during my 31 years in Geneva. Perhaps the greatest changes have occurred in the fields of scientific knowledge and agricultural and food technologies.

Because of the relatively strong financial support provided by the state government for the State University of New York (SUNY), which is where the Station receives most of its funds, I think of the 1960s as the "golden years." When I arrived in Geneva, SUNY provided 85 percent of the Station's budget. Ten percent was funded with formula funds provided by the federal government. These percentages have diminished to around 50 and 5 percent, respectively—a significant reduction.

Reductions have also affected personnel. In 1974, there were 68 professors and 200 staff paid on State funds, including those at the Vineyard Laboratory in Fredonia and the Hudson Valley Lab in Highland. Those numbers are currently at 46 and 123, respectively. Thirty years ago, State funds were adequate to pay employees, hire seasonal help, support the operating costs of faculty programs, allow the Station to maintain the physical facilities, and purchase laboratory and field research equipment. Those were the "good old days."

In 1974, the Station and the College were shocked when the SUNY budget was cut. The golden years were over, and the decline in SUNY appropriations has been almost an annual occurrence since then. Faculty must now obtain external funds to help support their technicians, and the percentage of their technician's pay provided by the Station continues to decline each year.

Susan Henry, dean of the College of Agriculture and Life Sciences, is well aware of the situation at the Station, and knows it is exacerbated by the lack of tuition income to offset SUNY cuts at Geneva. Prior to appointing a search committee for the next director, she has appointed a committee to prepare a "white paper" to identify the issues facing the Station. I am also encouraged by the concern for support for the Station expressed by so many members of state government and leaders of the fruit and vegetable industry.

At the same time that economic pressures have led to budget cuts at the Station, changes have occurred in the fruit industry. Most of you are well aware of the challenges of global marketing, increased competition, and shrinking profit margins. Environmental concerns are significant, new pesticides must be carefully managed, pest resistance to some older pesticides is commonplace, and regulatory actions affect us all. The industry has met many challenges and more continue to develop.

Even as the fruit and vegetable industries faced their own budget realities, they continued to contribute funds for research to meet priority needs—and we at the Station appreciate that support. The Apple Research and Development Program, the Grape Production Research, and the Lake Erie Regional Grape Program are prime examples of fruit industries helping themselves and the Station.

At the same time, the Station and the college have done as much as possible to wisely use resources to assist the industry. The Tree Fruit Task Force, started in April 2002, is one recent endeavor. A report from that group appears in this issue.

In closing, I would like to say it has been a pleasure to work with so many of you during my career at Geneva. I have particularly appreciated your help in keeping the Station focused on its mission to the fruit and vegetable industries. Working together will be as important as ever as we strive to overcome the many challenges ahead of us. The future of the Station is an important area of common concern.

James E. Hunter

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FRONT COVER: A booklet profiling 19 New York apple growers (pictured here) was published and sent to all apple growers in November. The booklet is one of the chapters of the "Apple Workbook," a project of the Cornell Tree Fruit Task Force and FarmNet due to be published in January. See related story, p.3.

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TREE FRUIT TASK FORCE
PROGRESS REPORTS

In April 2002, Dean Susan Henry charged then New York State Agricultural Experiment Station Director Dr. Jim Hunter with forming a Cornell Tree Fruit Industry Task Force to help the tree fruit industry adapt successfully to a demanding new market landscape. Her charge was guided by the College of Agriculture's land grant mission and long service to the tree fruit industry.

The mission of the task force is to significantly enhance Cornell's traditional role as an educator and effective developer of promising technologies and marketable products, and to work proactively on behalf of the tree fruit industry, a very important sector of New York's agricultural economy.

The task force is made up of a large group of people involved with the apple industry. Participants include Station and Ithaca campus faculty members, field researchers and extension educators, George Lamont of the NYS Horticultural Society, NY FarmNet Director Cathy Sheils, and New York State Dept. of Agriculture and Markets Deputy Commissioner Rick Zimmerman.

After identifying key problems facing tree fruit farm and marketing operations, the task force decided to focus its activities on four major areas. These committees are co-chaired by task force members. What follows are the progress reports of those committees after a year and a half of activity.

Progress Report on Market Awareness & Decision Making

Co-Chairs: Cathy Sheils, Director, NY FarmNet, and Alison DeMarree, Cornell Cooperative Extension Lake Ontario Fruit Team

Focus

1) Provide educational workshops for growers with an emphasis on industry and marketplace change and the impact of those changes at the farm level.
2) Produce tools and work with growers to assist them with business analysis, decision-making and planning.
3) Share information on how growers are responding to industry changes.
4) Sponsor educational workshops for agricultural service providers to improve understanding of the changes in the industry, the impact at the farm level on both the business and individuals and how to support growers in their adaptation and response to those changes.

Accomplishments

1) A USDA Specialty Crops grant was awarded to NY FarmNet by the New York State Department of Agriculture and Markets to assist with funding these project components.
2) Trainings titled "Working with Apple Growers Responding to the Changing Industry" were held for 88 agricultural service professionals focusing on illustrating the changes taking place in the marketplace and working with growers on business analysis and planning.
3) Workshops were held for 120 growers in the fall of 2002 titled "Responding to the Changing Apple Industry," featuring Dr. Desmond O'Rourke from Washington State. Desmond highlighted the trends in the world and national marketplace and the impact on New York fruit farms.
4) "Harvesting Change: New York Apple Growers Share Their Decision-Making Strategies," a booklet profiling 19 growers, was published and sent to all growers in November, 2003. The booklet shares stories that depict the strategies, difficulties and rewards of making changes.
5) "Harvesting Change: A planning Workbook for Apple Growers," will be released in January 2004. Call 1-800-547-3276 to reserve your copy!
This workbook has been specifically developed for New York apple growers and is a tool designed to help growers create a plan. Every farm can benefit from using this workbook, whether it is a small direct-marketing farm producing fresh fruit, a farm producing value-added products, a large farm growing processing fruit or a combination.

Action Plan for 2004

Workshops for growers are scheduled across the state for January, February and March 2004. At these workshops, growers will be given the opportunity to review and use the planning workbook for their business. Call 1-800-547-3276 for a workshop schedule.

[Team members are Ed Staehr, Steve Hadcock, Marc Smith, George Lamont, Alison DeMarree and Cathy Sheils.]

Progress Report on Market Structure

Co-Chairs: Jerry White, Bruce Anderson, and Wen-fei Uva, Dept. of Applied Economics and Management

Focus

According to the strategic plan for the New York Apple Industry finalized in 2001, "The fragmentation of the New York Apple industry has caused a reduction in market power that results in lower prices and reduced grower returns." The strategic plan led directly to the formation of a cooperative known as Premier Apple which was organized to address this problem of fragmentation. The focus of the Market Structure Team is to help the industry consider, adopt, and implement marketing and organizational alternatives that will lead to greater unity and better economic results.

Accomplishments

1) Our team is represented in an advisory capacity at board meetings of the Premier Apple Cooperative Board of Directors by Bruce Anderson. Premier has a marketing committee that meets (via conference call) every two weeks during the marketing season to discuss supply and demand factors and pricing strategies. The Cooperative can claim partial credit for much stronger prices in 2002 than in other recent years. (The average fresh apple price for the 2002 season was 25 cents per pound according to New York Agricultural Statistics Service—the highest on record. Of course, the 2002 crop was the smallest NY crop in about 50 years.) Participation on the marketing committee now includes representatives from MI, MN, PA, OH, VA, and New England. We will continue to provide an advisory role on this important industry committee.
2) We provided analysis and perspective on the discontinuance of the Washington Apple Commission and what its demise means for the New York industry. We wrote an article, "What Will Happen Without the Washington Apple Commission?" that was published in various extension newsletters. Our analysis was updated and presented recently at the Great Lakes Fruit Workers Conference. We will continue to monitor and update the industry so that appropriate strategic responses to this important new development can occur.
3) We provided input and analysis to a group of investors who developed a business plan for a juice plant (producing not-from-concentrate juice; focusing on apples; $65M investment; 305 employees), projected to open in fall 2004 in LeRoy, NY. This is an example of how the Market Structure Team can have an impact in the future as potential start-up ventures arise that require business planning and economic expertise and guidance.
4) Bruce Anderson serves on a task force on NY market orders organized and appointed by Commissioner Nathan Rudgers of the New York State Department of Agriculture and Markets. The Task Force deals with four commodities, including the apple market order and the tart cherry market order. In this role, we stay involved and provide our expertise in an effort to help the New York tree fruit industry realize and take advantage of cooperative or group action in the difficult market in which an increasing concentration of retailers causes a "buyer dominant" market.
5) The 2003 Cornell Strategic Marketing Professional In-Service Workshop was held on September 16-17, 2003, Ithaca NY. The theme was "Pricing for Success-Selecting an Optimum Pricing Strategy in the Buyer Dominant Market." Organized annually by the Market Structure Team led by Wen-fei Uva, the target audience for this workshop is extension educators and faculty in New York and other eastern states. This workshop helps us build the marketing expertise of extension educators and faculty and improve programming by fostering closer working relationships among the various professionals who are working to improve the marketing skills of growers and marketers.

Plans for the Future

- Build relationships through the Grower Cooperatives Program and the Northeast Cooperative Council (NECC) with other processors in the Northeast. While BirdsEye Foods has exited from the apple industry, Pro-Fac Cooperative continues to source NY apples and fruits for other processors. Our role is to influence and support decisions that will result in better markets for NY and other Northeast fruit producers.
- We will offer support for entrepreneurs with new value-added apple products through the newly funded NY Farm Viability Institute (funded at about $1M for 18 months). Our help will involve, but not be limited to, assistance with business planning and advice and programs on improving market structure.
- We plan to develop a proposal to analyze the potential macroeconomic impact if all state and federal marketing orders were declared unconstitutional.
- We are collaborating with Michigan State University to organize a Marketing Workshop for produce marketers in Spring 2004.

(The Market Structure Team is comprised of Bruce Anderson, Brian Henehan, Wen-fei Uva, and Jerry White, faculty members in the Department of Applied Economics and Management at Cornell.)

Progress Report on Leadership Development

Chair: Marc Smith, Asst. Director, NYS Agricultural Experiment Station

Focus

A few active, well-traveled and often hard-pressed advocates for New York apple growers have been working diligently over many years to recalibrate their farm businesses and their organizations to succeed under dramatically changed world market conditions. This dedicated group understands clearly that realizing economic gains from new export strategies, innovative marketing programs for new tree fruit varieties, the successful adoption of new production technologies, or creative industry alliances requires skilled, knowledgeable, and forceful leaders to show the way.

The Cornell Tree Fruit Industry Task Force is working to broaden and deepen the pool of tree fruit industry leaders committed to sustained prosperity for their production and marketing businesses.

Recognized industry leaders, LEAD-NY, Cornell Cooperative Extension, farm lenders, NY FarmNet, the Johnson School of Management and task force members are designing a series of leadership development programs. Thse programs will send market-savvy tree fruit graduates back into businesses and communities with sharpened skills, renewed motivation, new professional networks based on trust, and innovative ideas to shape a stronger, increasingly competitive tree fruit industry.

Task Force chair Jim Hunter laid out the following framework for program development:

1) The program must be unique, innovative, dynamic and inspirational, providing examples and exposure that will energize participants to successfully tackle challenges and find advantageous opportunities for their businesses and their industry.
2) The overall goals of the three-part program should be stated clearly and up front.
3) The expected outcomes for each of the three sessions should be stated and featured prominently in the agenda.
4) The industry environment that prompted this initiative and within which the program will be offered must be acknowledged clearly and early in the course. Each presentation/tour/exercise should open participants' eyes to possibilities for invigorating the industry and provide lessons that can be taken home and applied to this task.
5) Building skills is important, but the means to do this must be dynamic and relevant to industry needs.

These are ambitious goals, and, as LEAD-NY director Larry Van De Valk points out, expectations must be realistic.

Action Plan

The Task Force had hoped to announce three, three-day leadership workshops to be held in the Lake Ontario, Hudson Valley and Lake Champlain production regions of New York this winter. There is, however, more planning work to be done in order to strike the balance between realistic expectations and the need to have a significant impact on industry conditions. Funding and recruitment issues will also require attention. Cornell task force members, together with tree fruit growers committed to the success of this initiative expect to hammer out the final elements of a promising, workable plan over the next few months.

[Team members are Larry Van De Valk, Mike Fargione, marc Smith, Jim Preston, Clint Sidle, Cathy Sheils, Jim Bittner, and Jim Hunter.]

Progress Report on Production Technology and Fruit Quality

Co-Chairs: Terence L. Robinson, Dept of Horticultural Sciences, NYSAES, and Christopher B. Watkins, Dept. of Horticulture, Ithaca

Focus

The initiative to improve production technology and fruit quality arose from the NY Apple Industry Strategic Plan developed in 2001. That document called upon Cornell to focus research and extension efforts on several important problems for the NY apple industry. For the last several years, members of Cornell's fruit work team have been carrying out significant research and extension on the production and fruit quality problems which the industry identified as priorities.

Accomplishments

Goal 1. Develop guidelines for the safe and effective use of SmartFresh® (1-methylcyclopropene or 1-MCP).

The Cornell Post Harvest Team led by Chris Watkins has carried out extensive and ongoing studies on 1-MCP in all three growing regions of the state since 2000. Through that effort, initial guidelines were developed for use on many of the varieties grown in New York. In 2001, semi-commercial trials were conducted which provided confidence for the widespread use of Smartfresh in 2002 when it first became available to the New York industry. About 25 CA rooms were treated with MCP in that year and were largely successful. Fruit quality of apples sold in the late winter, spring and summer of 2003 was vastly better from 1-MCP treated rooms than conventional CA. This led to broadscale use of Smartfresh in the fall of 2003 with more than 100 CA rooms being treated. As these apples are sold this winter and coming spring and summer, consumers should notice a significant improvement in crispness and keeping quality that should translate into greater demand for New York apples. Initial results of the research and extension efforts with 1-MCP were published in an article on 1-MCP in the *NY Fruit Quarterly* in the Winter of 2001.This was followed by a second article on 1-MCP in the Spring of 2003. Additionally, training on the use of MCP was given at the biannual storage workshop held at Ithaca on July 30, 2003.

Goal 2. Develop a research and educational program on the internal worm problem in Western New York.

Beginning in 2001, loads of fruit delivered to processing plants in Western New York began to show significant infestations with fruit feeding worms which were identified as Oriental Fruit Moth, Codling Moth and green apple worm. The problem increased in 2002. The Cornell Entomology team led by Art Agnello and Harvey Reissig developed a regional research/extension project to understand the problem and develop solutions in 2003. The Lake Ontario Fruit Team also responded by organizing several fruit schools and workshops where Cornell experts as well as experts from PA where the problem has been in existence since the mid-1990s presented their research on how to control Oriental Fruit Moth and Codling Moth. In 2003, the internal worm problem was minimal due to improved control practices and probably favorable weather. Based upon the experience of other fruit growing areas it is likely that internal worms will continue to be a problem for New York growers in future years. The entomology team at Cornell is aggressively studying insect resistance and alternative control strategies.

Goal 3. Develop an Integrated Fruit Production (IFP) program for the New York apple industry.

New York export marketers report that apple buyers from Europe are increasingly requiring environmental and food safety assurances for the fruit they purchase. Beginning in 2002 they have attempted to proscribe specific production and pest management practices based upon IFP protocols from other areas and to introduce third party audits. Beginning in 2004 they will require growers to be in compliance with European Good Agricultural Practices (Eurepgap).

In response to such increasing demands, the New York Apple Industry's Strategic Plan called upon Cornell to develop an Integrated Fruit Production program that could be used with export fruit to allow the fruit industry to act in a proactive manner to keep access to UK and European markets.

The term "integrated fruit production," or IFP, was coined in Europe in the late 1980s. It differs from IPM (integrated pest management) which has been the dominant term in the USA because it includes orchard management practices other than those based on pest control alone. IFP includes recommendations on integrated pest, nutrient, weed and cropload management, best management practices for spraying, packing and storage. In some cases, it requires certification of sprayers and training of spray applicators. European programs are not directly transferable to New York due to vastly different climate and pest and disease complexes.

Over the last two years, the Cornell Fruit research and extension team led by Terence Robinson and Juliet Carroll have developed a draft of New York IFP guidelines that detail eco-friendly pest, disease, and weed management; fertilization and fruit thinning; best spray, packing and storage practices. A draft document has begun a thorough review within all segments of the New York apple industry to assure that it is realistic and helpful. In addition, the Cornell Fruit Team conducted field trials around the state to test the IFP protocol in 2003. It is expected that the New York IFP program will help assure apple buyers that our apples are safe and are produced in an environmentally sound manner.

Goal 4. Develop an educational program for growers that addresses yield.

Average yields in New York apple orchards are far below those achieved in experimental orchards at Geneva and on some growers' farms. Higher yields are possible and are required to stay in business. New York apple growers need to continue to replant with high density orchards using precocious, efficient rootstocks to improve yields. The Cornell Fruit Team led by Terence Robinson continues to address improved yields with an array of extension activities including systems trials, field days and summer tours. In February 2003, the Cornell Fruit Team conducted a two-day orchard planting systems school held in conjunction with the IDFTA meeting in Syracuse. During the summer of 2003, field days were held in the Hudson Valley and in Western New York where high density concepts were demonstrated. The Fruit team is planning a series of one-day workshops on orchard planting systems over the winter of 2003 and 2004. Articles on the value of high density orchards were published in *The New York Fruit Quarterly* in the winter of 2001 and the spring of 2003.

Goal 5. Developing new varieties for New York apple growers.

Cornell's apple breeding and variety evaluation team led by Susan Brown has accelerated efforts to develop new high quality apple varieties and to test varieties from around the world that the fruit industry can capitalize on.

New selections have been identified and are being prepared for trials on growers farms. An extensive variety showcase was organized at the Fruit Quality Forum held in Syracuse in Jan. 2002 and again at the Eastern New York Fruit School in Feb. 2003. An article on new varieties was published in *The NY Fruit Quarterly* in the summer of 2002. An entire issue focused on Honeycrisp production and storage in the fall of 2003.

Goal 6. Develop a Total Quality Improvement program for New York apples.

The Cornell Tree Fruit Team focused on fruit quality throughout the year at many educational events, including four winter fruit schools where many presentations are aimed at improving fruit quality, pruning demonstrations to improve light distribution in the canopy, thinning meetings to improve final fruit size, and a nutrition in-depth school to improve fruit nutrient balance. Latest storage advances were addressed at the Cornell storage conference in August 2003. Topics included: Diphenylamine (Watkins); diphenylamine fogging technology and new fungicides (Peter Sanderson, Washington apple commission); Postharvest fungicides – the New York perspective (Rosenberger); 1-Methylcyclopropene - New York update and recommendations (Watkins and Nock); CA room testing (Bartsch); Status of SmartFresh: the first commercial year (Reed and Wargo, AgroFresh); Effects of 1-MCP treatment on development of blue mold decay in Empire apples (Rosenberger, Wargo and Watkins); and Honeycrisp maturity and storage recommendations (Watkins, Nock). Dave Rosenberger and Alison DeMarree presented the results of a survey of bagged fruit from supermarkets in both Eastern and Western New York. These extension efforts to improve fruit quality culminated with the harvest maturity program to aid growers in proper harvest timing for both eastern and western NY.

Goal 7. Develop diversification options for New York apple growers.

Tree fruit growers in New York are very interested in growing other crops besides apples. Sweet cherries, peaches, pears, and plums are all high value alternative crops. The Cornell Stone Fruit Team led by Bob Andersen has established grower demonstration plantings of new varieties in both eastern and Western New York and assisted many growers in making initial plantings of alternative fruit crops. The Cornell Fruit Team assisted the NYS Hort Society in obtaining two grants from the NYS Dept. of Ag and Markets to study high density cherry production. Two large systems trials were planted at Geneva in 1999 and in 2002. Two peach systems trials were planted on growers farms in 1999. With a grant from the New York Pear Growers Association, a high density pear systems trial was planted in April 2003 at Geneva. A series of hard cider apple demonstration plantings were also planted in April 2003. These field demonstrations and research projects have been accompanied by an article on plums in the Summer 2001 issue of *The NY Fruit Quarterly*, and by two articles on Sweet Cherry production in the Summer 2003 issue of *The Fruit Quarterly*.

Action Plan

The production technology and fruit quality initiative of the Cornell Tree Fruit Task Force has resulted in significant research and extension efforts that are helping equip the New York tree fruit industry with better production practices and technologies to improve yields and fruit quality. This, coupled with a rigorous emphasis on quality by the industry, will help the New York apple industry meet changing market conditions.

[Team members are Terence Robinson, Chris Watkins, James Schupp, Steve Hoying, Alison DeMarree, Kevin Iungerman, Dena Fiachino, Jim Wargo, Bob Andersen, Lailiang Cheng, Art Agnello, Harvey Reissig, Susan Brown, Ian Merwin, Alan Lakso, Debby Breth, Mike Fargione, Richard Straub, William Turechek, and Dave Rosenberger.]

Antioxidants of Apples

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> Apples are a significant source of antioxidants in people's diets in the US and Europe. In the US, 22 percent of the phenolics consumed from fruits come from apples, which makes apples the largest source. Since apples are so high in a variety of antioxidants, it is no surprise that apples, specifically, have been associated with a decreased risk of chronic disease.

In the United States and most industrialized countries, cardiovascular disease and cancer are ranked as the leading causes of death. These diseases have been linked to lifestyle choices, one of the most important of which is diet. It has been estimated that eating a healthy diet could prevent 30 percent of all cancers. Many of us as children were told to "eat your vegetables because they are good for you," and the adage, "an apple a day keeps the doctor away" is still quite popular. Recently, many studies have been providing scientific backing for both of these common phrases.

Hundreds of epidemiological studies have been performed examining the effects of diet on health. Although not all studies show a link between fruits and vegetables and health, a majority of studies show a positive correlation between fruit and vegetable consumption and a reduced risk of chronic diseases, such as cardiovascular disease and cancer.

Diet and Chronic Disease

In the early 1990s, researchers examined well over a hundred epidemiological studies related to diet and cancer. In 128 of 156 dietary studies, fruits and vegetables were shown to have significant protective effect against a variety of different cancers (1). Researchers found that individuals who consumed small quantities of fruits and vegetables were twice as likely to get cancer compared to those who ate larger quantities of fruits and vegetables. Very recently, a study showed that high consumption of fruits and vegetables was also associated with a reduced risk of breast cancer in woman in China (2). Fruit and vegetable consumption also appears to have a protective effect against coronary heart disease (3). In this study, approximately 84,000 women were followed for 14 years and 42,000 men were followed for eight years. Researchers found that those who ate the greatest quantities of fruits and vegetables had a 20 percent lower risk for coronary heart disease. The lowest risk was seen in people who consumed more green leafy vegetables and fruits rich in vitamin C. Not only could a diet high in fruits and vegetables help prevent heart disease and cancer, but it might also help protect against a variety of other illnesses. For example, a diet high in fruits and vegetables may help protect against cataracts, diabetes, Alzheimer disease, and even asthma (4-6).

Much of the protective qualities of fruits and vegetables has been attributed to phytochemicals, which are the non-nutrient plant compounds such as caretenoids, flavonoids, isoflavonoids, and phenolic acids. Thousands of phytochemicals have been identified in foods, and many have not. Different phytochemicals have many different activities which may help protect against chronic disease. For example, phytochemicals have been found to inhibit cell proliferation, regulate inflammatory and immune response, and protect against lipid oxidation (7, 8).

Phytochemicals' major role is to protect against oxidation. We live in a highly oxidative environment, and many processes involved in metabolism may result in the production of more oxidants. Like all animals, humans have many antioxidant defense systems, but they are not perfect and oxidative damage can occur. Oxidative damage plays a role in cancer and heart disease. As oxidative damage accumulates, it plays a role in the aging process in general. Therefore, it is important to protect against oxidative damage as best as we can. It is estimated that there are 10,000 oxidative hits to DNA per cell, per day, in humans (6). Oxidants may also target lipids and proteins, and lipid oxidation is associated with heart disease. Since fruits and vegetables are high in antioxidants, a diet high in these foods should help prevent oxidative stress, and therefore may slow aging and help prevent chronic disease. These findings have led the National Research Council to recommend five or more servings of fruits and vegetables a day.

Health Benefits of Apples

A major class of phytochemicals found commonly in fruits and vegetables are the flavonoids. The most common flavonoids found in fruits and vegetables are quercetin and its conjugates (9). Apples are a significant source of flavonoids in diets in the US and in Europe. In the US, 22 percent of the phenolics consumed from fruits are from apples, which makes apples the largest source. In Finland, apples and onions are the primary sources of dietary flavonoids. In the Netherlands, apples rank third behind tea and onions as the top sources of flavonoids.

Apples are commonly enjoyed by many cultures, and our lab has determined that they are a good source of antioxidants. When compared to other commonly consumed fruits in the US, apples had the second highest level of antioxidant activity (Figure 1). Apples ranked second for total concentration of phenolic compounds. Perhaps more importantly, apples had the highest proportion of free phenolics when compared to other fruits (10). This means these compounds are not bound to other compounds in the fruits, and the phenolics may be more available for eventual absorption into the bloodstream.

Since apples are so high in antioxidants, it is no surprise that apples, specifically, are associated with a decreased risk of chronic disease.

Three studies have specifically linked apple consumption with a decreased risk for cancer. Women who consumed at least one serving a day of apples and pears had a reduced risk of lung cancer (11). In another study, it was found that apples and onions, both good sources of quercetin, were associated with a reduced risk of lung cancer, and that those who consumed the least amount of apples and onions had the greatest risk of getting the disease (12). In Finland, yet another study associated high apple consumption with decreased risk of lung cancer (13).

A recent study has shown that apple and pear consumption has been associated with a decreased risk of asthma (4). Apple consumption has also been associated with a decreased risk of coronary heart disease in women (14). In the Netherlands, apple and pear consumption was associated with a decreased risk of obstructive pulmonary disease (15). In a Finnish study, death from heart disease in women was reduced in groups of women with the highest consumption of apples (16). Apple, tea, and onion consumption was also associated with a reduced risk of death from coronary heart disease in men in the Netherlands (17). A reduced risk of Type II diabetes was associated with apple and berry consumption in another major Finnish study (18).

In the laboratory, apples and the compounds in them have properties that may explain their effects in protecting against disease. Our lab has found that apples, and especially apple peels, have powerful antioxidant activity and can greatly inhibit the growth of liver cancer and colon cancer cells (19, 20). Based on results from all of these studies, it appears that apples may play a significant role in reducing the risk of a wide variety of diseases.

Phytochemicals in Apples

Apples contain a large concentration of flavonoids, as well as a variety of other phytochemicals. The concentration of these phytochemicals may depend on many factors, such as cultivar, harvest and storage, and processing. The variety and concentration of phytochemicals also varies greatly between apple peel and apple flesh.

Some of the most well-studied antioxidant compounds in apples include quercetin-3-galactoside, quercetin-3-glucoside, quercetin-3-rhamnoside, catechin, epicatechin, procyanidin, cyanidin-3-galactoside, coumaric acid, chlorogenic acid, gallic acid, and phloridzin.

The levels of all compounds vary greatly among different varieties of apples, and between the peel and the flesh. The compounds commonly found in apple peels are the procyanidins, catechin, epicatechin, chlorogenic acid, ploridizin, and the quercetin conjugates. In the apple flesh, there is some catechin, procyanidin, epicatechin, and phloridzin, but these compounds are found in much lower concentrations in the flesh than in the peel. Quercetin conjugates are found exclusively in the peel of the apples. The only compound found in higher concentrations in the flesh is chlorogenic acid (21). In general, it can be concluded that apple peels contain a higher concentration of antioxidant compounds.

Because the apple peel contains more antioxidant compounds, it can be inferred that the apple peel may have higher antioxidant activity and higher bioactivity than the apple flesh. Early research from our lab showed that peeled apples had less antioxidant activity than apples with the peel. Apples with the peel were also better able to inhibit cell proliferation when compared to apples without the peel (20).The cell proliferation assay is a measure of the ability of a compound or fruit extract to inhibit the growth of tumor cells. Therefore, the greater the ability of a compound to inhibit cell growth, the greater the potential it has for anticancer activity. More recent work from our lab has shown that apple peels contain anywhere from two to six times (depending on the variety) more phenolic compounds than in the flesh, and two to three times more flavonoids. The antioxidant activity of the peel was also much greater, ranging from two to six times greater when compared to the flesh, depending on the variety of the apple (19).

Effects of Variety and Ripening on Phytochemical Content

Researchers in our lab have found quite a range in total phenolic and total flavonoid content among different varieties of apples. Of four common varieties used for applesauce (Rome Beauty, Idared, Cortland, and Golden Delicious), Rome Beauty had the highest phenolic content and Cortland had the lowest. Rome Beauty also had the highest flavonoid content while Cortland had the lowest. However, Idared contained much higher anthocyanins than any of the other varieties (19). Anthocyanins are the antioxidant compounds that give fruit a

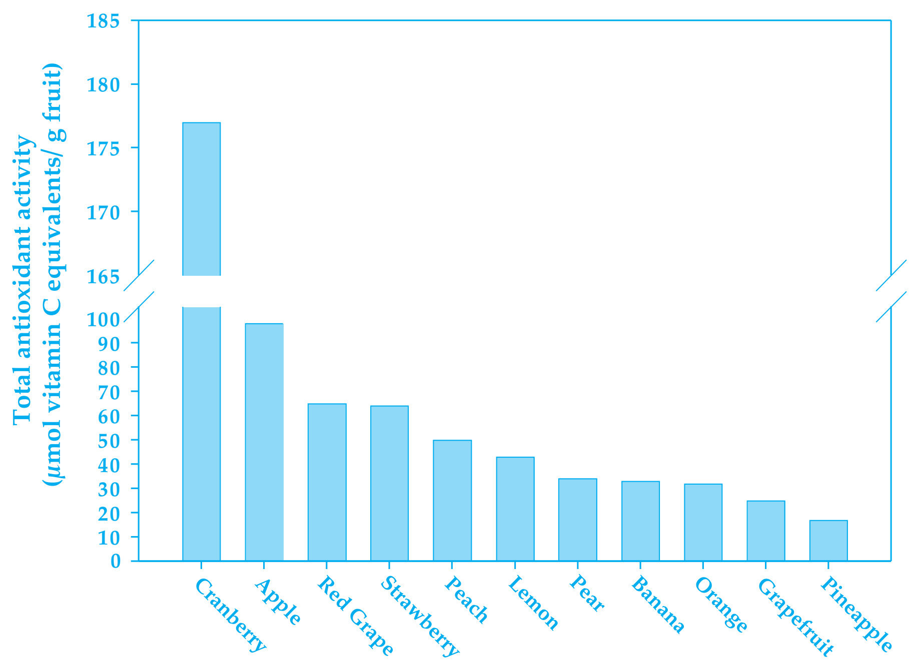

Figure 1. Antioxidant activity of various fruit extracts.

red or blue color. Out of 10 varieties commonly consumed in the US, Fuji apples had the highest total phenolic and total flavonoid compounds (Figures 2 and 3). Red Delicious were also quite high. The apples containing the lowest amounts of phenolics and flavonoids were the NY647 and Empire, respectively .

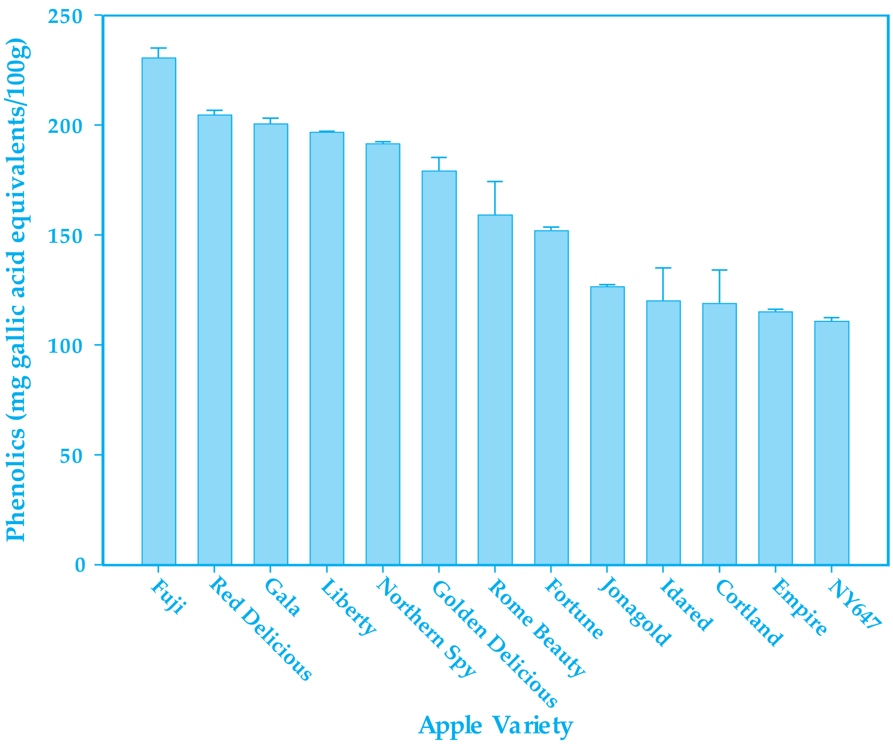

Figure 2. Total phenolic content of apples (mean ± SD, n=3).

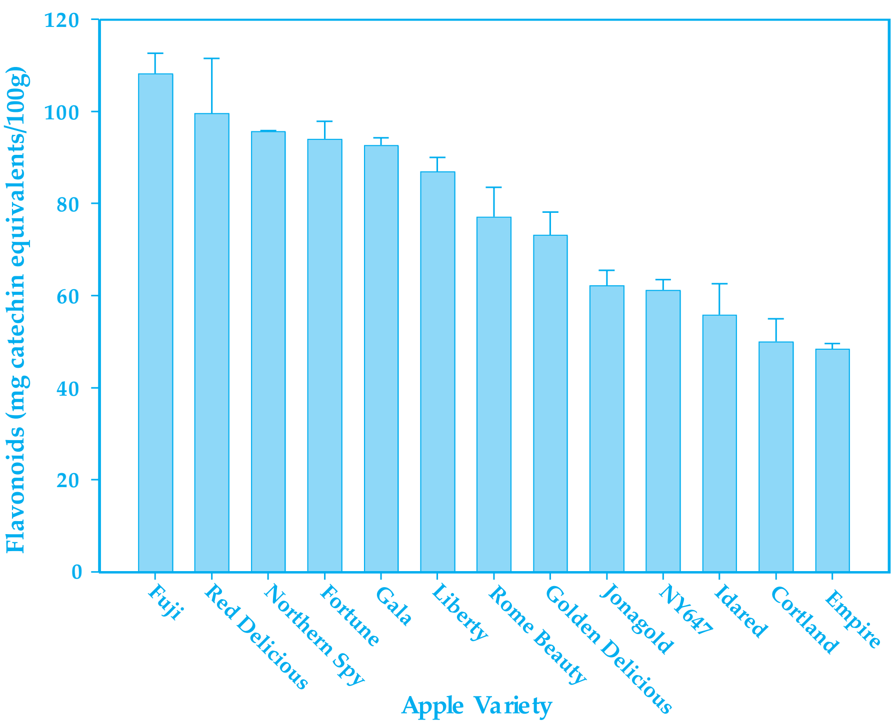

Figure 3. Total flavonoid content of apples (mean ± SD, n=3).

Antioxidant activity also varies among the different varieties of apples, and this is a reflection of the phytochemical differences between varieties. There is a correlation between phenolic content of apples and antioxidant activity. The apple varieties with higher phenolics tended to have higher antioxidant activity.

Other researchers have found similar variations in phytochemical content between different cultivars of apples. Van der Sluis et al (2001) analyzed Jonagold, Golden Delicious, Cox's Orange, and Elstar, and found that Jonagold contained the highest concentration of quercetin glycosides, catechins, and chlorogenic acid when compared to the other varieties. Golden Delicious had the second highest concentration, while Cox's Orange and Elstar had the lowest concentrations. Escarpa and Gonzalez (1998) measured compounds in Golden Delicious, Reinata, Red Delicious, and Granny Smith, and found that, of these four varieties, Golden Delicious had the lowest concentration of many different flavonoids. Reinata had the highest level of flavonoids, but Granny Smith and Red Delicious were also very high. Another group looked solely at procyanidin content of four varieties of apples and found that Granny Smith and Red Delicious had the highest procyanidins while McIntosh and Golden Delicious had the lowest (22).

In addition to apple variety, there are a number of other factors that can affect the phytochemical profile of apples. Development and ripening of the fruits may impact phytochemicals in apples. In Jonagold and Elstar, quercetin glycosides, phloridzin, catechins, and chlorogenic acid concentrations were highest early in the season, and decreased to a steady level during maturation and ripening (23). Anthocyanins in Elstar and Jonagold started high and decreased in mid-season, but, before maturation, the concentrations rose rapidly. Interestingly, this increase in anthocyanin content occurred only in fruit grown in the outer part of the canopy, not in the inner canopy. The amounts of quercetin glycosides in both Jonagold and Elstar were also greater in fruit grown in the outer canopy (24). Awad (2000) also found that sun-exposed fruits (both Jonagold and Elstar) had greater levels of anthocyanins and quercetin glycosides when compared to shaded fruits, giving more evidence that exposure to sunlight affects production of these two compounds (24). In general, it can be concluded that improving light exposure for apples may help increase the production of certain phytochemicals. There was no sunlight effect on phloridzen, catechin, and chlorogenic acid.

The effect of different nutrients on flavonoids and chlorogenic acid in apples has also been examined. Awad (2002) found that fertilizing with nitrogen was associated with decreases in anthocyanins, catechins and total flavonoids, and also with decreased percentage of blush in the fruit peels. Also in Elstar, fertilizing with calcium was associated with an increase in anthocyanins and total flavonoids.

Researchers examined the effect of applying different chemicals that may enhance ripening on the formation of various phytochemicals. Ethephon increased anthocyanin production, but did not increase chlorogenic acid or any of the other phytochemicals studied. Gibberellins and (s)-trans-2-amino-4-(2-aminoethoxy)-3-butenoic acid hydrochloride (ABG-3168) both decreased anthocyanin production, but did not have an effect on other compounds studied. The application of other chemicals, such as alar, cycocel, seniphos, shikimic acid, plantacur-E and galactose did not have an effect on any of the phytochemicals examined (25, 26).

Effects of Storage and Processing on Phytochemical Content

Phytochemical content in apples is not significantly affected by storage. Quercetin glycosides, phloridzin, and anthocyanin content of Jonagold, Golden Delicious, Red Delicious, Elstar, and Cox's Orange were not affected by 52 weeks of storage in controlled atmospheric conditions. Chlorogenic acid and total catechins decreased slightly in Jonagold. Total catechin concentration decreased slightly in Golden Delicious, but chlorogenic acid concentrations remained stable (27). After 25 weeks of cold storage, there was no decrease in chlorogenic acid in any variety of apple, but catechin content decreased slightly in Golden Delicious, Elstar, and Cox's Orange. Both types of storage had no effect on antioxidant activity in any variety of apple examined. Another group looked specifically at the effects of storage on apple peel phenolics and found that storage at 0°C for 9 months had little effect on phenolic content (28).

Processing can also affect phytochemical content. Apple juice obtained from Jonagold apples by pulping and straight pressing had only 10 percent the antioxidant activity of fresh apples. Juice obtained after pulp enzyming resulted in juice that had only 3 percent antioxidant activity. After pulp enzyming, the juice contained 31 percent less phloridzin, 44 percent less chlorogenic acid, and 58 percent less catechin. Most of the compounds remained in the apple pomace (29). Millions of pounds of waste apple peels are generated in the production of applesauce and canned apples in New York each year. Since apple peels contain the majority of the antioxidants when compared to the flesh (19), our lab has looked into the possibility of using apple peels as a value-added ingredient. Apple peels were blanched and then dried under a variety of conditions (oven-dried at a range of temperatures between 40°C and 80°C, air-dried, or freeze-dried). The freeze-dried samples had the greatest total phenolic and flavonoid content, and the total phenolic and flavonoid content was actually greater than in the fresh peels. Apple peel powder had strong antioxidant activity and also greatly inhibited cell proliferation (30). Apple peel powder may be used in various food products to increase their phytochemical content and antioxidant activity.

Summary

As researchers find more and more evidence to support the role of phytochemicals in decreasing the risk of chronic disease, some have hoped to find a magic bullet that prevents chronic disease. However, when researchers attempt to link specific chemicals with health benefits, they are often less successful than when comparing health benefits and total food consumption. This is because apples, as well as other fruits and vegetables, contain a complex mixture of thousands of phytochemicals.

After years of research, it is still impossible to identify all the compounds let alone thoroughly understand how all of these compounds interact. For example, we know that the antioxidant activity in 100 g of apples is equivalent to about 1500 mg of vitamin C, and the amount of vitamin C in 100 g of apples is only about 5.7 mg (20). Vitamin C is a powerful antioxidant, but this research shows that nearly all of the antioxidant activity from apples comes from a variety of other compounds. Vitamin C in apples contributed less than 0.4 percent of total antioxidant activity. A dose of 500 mg of vitamin C has actually increased oxidative damage to DNA in humans. In addition, intervention studies with vitamin C supplements have shown no health benefits in the prevention of cancer and cardiovascular disease. Since the effects of high levels of other single antioxidants are unknown, it is not recommended that pure supplements be ingested, until further research is completed (8). In the meantime, we continue to support the recommendation that people eat at least five servings of fruits and vegetables a day. Evidence supports that apples are especially beneficial to consume.

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Reduced Application Rates of Provado for Management of Leafhoppers and Aphids on Apple

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Provado insecticide is generally recognized for its high degree of efficacy against sucking insects, particularly leafhoppers and aphids but it is costly relative to older standards. This research shows that with this highly effective insecticide, reduced rate application strategies can be employed to economically maintain these two pest complexes at non-damaging levels.

Two leafhopper species, the white apple leafhopper (WALH), *Typhlocyba pomaria* McAtee and the potato leafhopper (PLH) *Empoasca fabae* Harris, comprise a complex that annually damages apple foliage in New York State. In the Hudson Valley region, moreover, the rose leafhopper (RLH), *Edwardsiana rosae* (L.) is an annual pest, due in large measure to the widespread occurrence of its alternate host, multiflora rose. Damage to apple foliage by the mesophyll-feeding hoppers (WALH and RLH) appears as stippling or leaf chlorosis. The migratory PLH is a terminal-feeder that injects a salivary toxin while feeding, producing symptoms ranging from chlorosis to the typical "hopper burn," resulting in reduced growth rate of terminals. Accumulated excrement from the leafhopper complex reduces the marketability of fresh market fruit, while moderate to high adult presence at harvest causes considerable annoyance to harvesters.

Although three species of terminal-feeding aphids attack New York apple, the green apple aphid (GAA), *Aphis pomi* De Geer, is generally considered as the pest of greatest significance. Feeding on new growth by GAA nymphs causes stunted and misshapen leaves. Because aphids produce honeydew, high populations feeding in proximity to fruit clusters can cause cosmetic damage due to development of the sooty mold fungus on this sugary exudate. Less commonly, they cause blemishes by feeding directly on developing fruit.

The current treatment threshold for combined WALH and RLH is >1.0 nymph per leaf for the first and subsequent generations. Because PLH nymphs and adults affect only new-growth foliage, management in established bearing orchards is generally not recommended. In new plantings, however, where rapid growth is essential, insecticide treatment is often advisable. A treatment threshold for GAA has not been established. This pest generally has a narrow window of occurrence during spring. Populations will often be dramatically affected by a duo of natural enemies (larvae of *Cecidomyiidae* and *Coccinellidae*) if detrimental insecticides are withheld. Nonetheless, if populations remain excessive for an extended time period, many growers will apply pesticidal control measures.

Provado 1.6F insecticide is generally recognized for its high degree of efficacy against sucking insects, particularly leafhoppers and aphids. Because this insecticide is costly relative to older standards, we performed field trials using applications of reduced rates and various application timings to examine efficacy against leafhoppers and aphids, and to assess the effects on aphid natural enemies.

Leafhopper Nymphs and Adults, 2000

During September, treatments comprising full-label rate (8.0 oz/acre) and one-quarter label rate (2.0 oz/acre) of Provado were compared to full-label rate (48.0 oz/acre) and one-quarter label rate (12.0 oz/acre) of Sevin XLR. Efficacy against WALH and RLH nymphs (number/leaf) and adults (numbers/3 min. collected by a vacuum sampler, Figure 1) was determined at 2d, 4d and 10d post treatment, respectively. Results showed very good efficacy against nymphs from reduced rates of both insecticides (Table 1). At 4d post treatment, significant reductions in adult numbers were obtained by one-quarter label rates of both insecticides; at 10d post treatment, however, all Provado treatments were superior to Sevin XLR. The enhanced persistence of Provado is logical, given that the neonicotinoid active ingredient penetrates, and is stored in, the leaf (translaminar), whereas Sevin XLR has no similar properties. Prior to the registration of Provado, various formulations of Sevin were used extensively in New York to manage leafhoppers.

Our results show that reduced rates of Provado are effective against both

Figure 1. Vacuum apparatus used to collect leafhopper adults from apple trees.

Figure 2. Damage from nymphs of white apple and rose leafhopper.

TABLE 1

Efficacy of reduced rates of Provado and Sevin XLR against leafhopper nymphs and adults[1], 2000.

Treatment	Amt./ acre	No. nymphs/25 leaves *2d post treat.*	No. adults/3 min. (percent reduction)[2] *4d post treat.*	*10d post treat.*
Provado 1.6F	8.0 oz	0.0 a	6.1 ab(93.7)	2.9 a (97.5)
Provado 1.6F	4.0 oz	0.0 a	7.3 ab (95.0)	2.9 a (97.6)
Sevin XLR plus	48.0 oz	0.6 a	3.8 a (96.1)	12.5 b (87.1)
Sevin XLR plus	12.0 oz	0.8 a	9.9 b (87.8)	23.5 bc (71.2)
Untreated	-	28.6 b	78.6 c (4.3)	77.2 c (6.1)

Means followed by the same letter are not significantly different (P=0.05; Fisher's protected LSD).
[1]White apple and rose leafhopper (>95 percent rose leafhopper).
[2]Adults collected by vacuum sampler. Reduction based on precounts taken 17 Sept.

motile stages of leafhoppers, significantly more so than the older standard.

Leafhopper Nymphs, 2001

Having demonstrated that greatly reduced rates were effective, we sought to examine the cost effectiveness of various programs. Treatment scenarios using full, one-quarter and a combination of full and one-quarter label rates of Provado were compared during mid-season (3rd to 5th cover). During this period, indigenous WALH and RLH, and migratory PLH are usually present in Hudson Valley apple orchards. In general, 3rd cover applications impact immigrating adult PLH, 4th cover applications coincide with nymphal emergence of all three species, while 5th cover applications affect early instar nymphs of all species. Efficacy was assessed, one day after the final application, by counting numbers of nymphs/leaf, and by observing foliar symptoms of PLH damage. The cost of each spray program was estimated based on a local distributor quote ($4.00 per oz. of formulation). All rates and application timings provided very good control of WALH and RLH (Table 2). Against high populations of PLH nymphs, multiple applications generally provided superior control regardless of rate - PLH continually reinfest new leaves not exposed to residues from previous applications. Assessment of foliar damage (chlorosis and curled leaves) by PLH revealed that multiple applications of reduced rates were generally effective in the reduction of both symptoms, particularly curled leaves. By comparisons of each program's economics, it is apparent that effective management of leafhoppers can be achieved at significantly reduced costs. Because established apple trees can tolerate a good deal of damage from the indirect feeding of leafhoppers, multiple applications of Provado at one-quarter label rate is a logical program.

Green Apple Aphid and Predators, 2002

Because Provado is often used during early season to manage GAA infestations, an experiment was designed to examine the effects of reduced rates against this pest and two of its most important natural enemies. Similar to leafhopper studies, full, one-half, one-quarter, and one-eighth label rates of Provado were applied once during mid-summer. Thirty aphid-infested terminals/replicate were tagged for pre treatment counts and subsequent evaluation. Post-treatment aphid counts were made at 3d, 7d and 23d. Aphid numbers per terminal

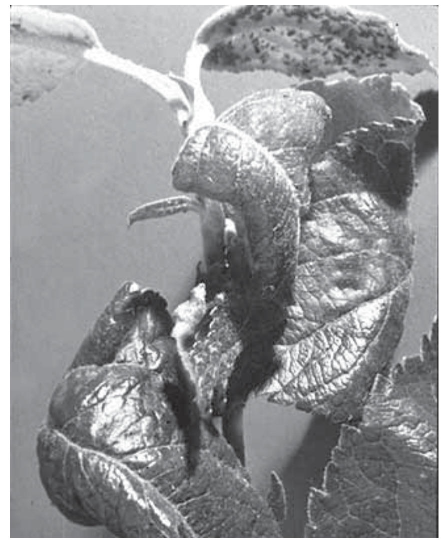

Figure 3. Apple terminal infested by green apple aphids.

TABLE 2

Efficacy and approximate costs of reduced rates of Provado against leafhopper nymphs and damage, 2001.

Treatment	Amt./ acre	Timing[1] (no. apps.)	No./leaf WALH, RLH[2]	No./leaf PLH[2]	Percentage shoot lvs. chlorosis by PLH[2]	Percentage shoot lvs. curled by PLH[2]	Cost/ acre[3]
Provado 1.6F	8.0 oz	3C (1)	<0.1	13.0	66.0	43.0	$32.00
Provado 1.6F	8.0 oz	3, 4C (2)	0.0	1.6	19.0	4.0	$64.00
Provado 1.6F	8.0 oz	3C (1)					
Provado 1.6F	2.0 oz	4,5C (2)	0.0	0.2	56.0	1.0	$48.00
Provado 1.6F	2.0 oz	3-5C (3)	0.0	0.7	37.0	6.0	$24.00
Untreated	**-**	**-**	**5.1**	**11.0**	**97.0**	**77.5**	

[1]Third cover, fourth cover, etc.
[2]White apple leafhopper(WALH), rose leafhopper(RLH) and potato leafhopper(PLH).
[3]Based on estimated cost of $4.00 per ounce of formulation and 400 gal./acre.

TABLE 3

Efficacy of reduced rates of Provado against green apple aphid, 2002.

		3d post treat. 27 June		7d post treat. 1 July		23d post treat. 17 July	
Treat.	Amt./ acre	Aphid rating[1]	Percent redn.[2]	Aphid rating	Percent redn.	Aphid rating	Percent redn.
Provado 1.6F	8.0 oz	0.70 a	76.7	0.14 a	95.3	0.06 a	97.9
Provado 1.6F	4.0 oz	1.05 b	65.0	0.37 b	87.7	0.05 a	98.4
Provado 1.6F	2.0 oz	1.38 c	54.0	0.53 b	82.3	0.20 a	93.3
Provado 1.6F	1.0 oz	1.49 c	50.3	0.89 c	70.3	0.08 a	97.5
Untreated	-	2.85 c	5.0	2.71 d	9.7	0.15 a	95.0

Means followed by the same letter are not significantly different (P=0.05; Fisher's protected LSD).
[1]Rating (0 – 3) of aphid numbers/terminal; see text for details.
[2]Based on precounts taken 24 June.

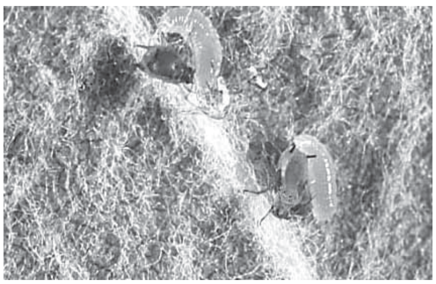

Figure 4. Natural enemies of apple aphids.

TABLE 4

Efficacy of reduced rates of Provado against two key aphid predators, 2002.

		7d post treat. (1 July)[1]		Percent reduction[2]	
Treatment	**Amt/ acre**	**Cocc.[3] larvae**	**Cecid.[3] larvae**	**Cocc.[3] larvae**	**Cecid.[3] larvae**
Provado	8.0 oz	0.01 a	0.03 a	95.7	87.8
Provado	4.0 oz	0.02 a	0.04 a	84.3	93.8
Provado	2.0 oz	0.07 ab	0.04 a	87.8	93.2
Provado	1.0 oz	0.20 b	0.19 b	⇑ 329.2	⇑ 53.6
Untreated	-	1.19 c	0.21 b	⇑ 487.2	⇑ 22.0

Means followed by the same letter are not significantly different (P=0.05; Fisher's protected LSD).
[1]Average number of larvae/aphid infested terminal.
[2]Based on precounts taken 24 June.
[3]Cocc. = Coccinellidae (Coleoptera); Cecid. = Cecidomyiidae(Diptera); ⇑ = population increase.

were estimated by a rating where: 0 = no aphids; 1 = 1-10 aphids/leaf; 2 = 11-100 aphids/leaf; and 3 = >100 aphids/leaf. Treatment effects on predators were assessed 7d post treatment by counting the number of larvae/5 apical terminal leaves.

At the 3d and 7d assessment dates, GAA reductions followed a dose-response relationship (i.e., full rate > one-half rate, etc.) (Table 4). At 7d, all treatment rates reduced GAA numbers by at least 70 percent. Aphid numbers in all treatments, including untreated, decreased >90 percent 27d after application. In most years, as July wanes, aphid populations naturally decline due to lack of succulent tissue as terminal buds set, and/or because of natural enemies. The results indicate that decreasing rates of Provado provided decreasing efficacy against GAA; however, all but the one-eighth label rate provided considerable, and probably acceptable, efficacy.

A single application of Provado was generally detrimental to larvae of *Coccinellidae* and *Cecidomyiidae* (aphid predators) (Table 4). All treatments between full and one-quarter label rates significantly reduced numbers of both predators. The one-eighth label rate however, allowed both predator species to increase dramatically at 7d after application. Such increases may have contributed to the 70 percent reduction in GAA populations provided by this treatment (Table 3). These results suggest that the one-eighth label rate provides adequate suppression of aphids, while not affecting predators.

Producers would need to decide the degree of control desired for a particular situation. If management or suppression below some marginal level of damage is desired, reduced rates of Provado could provide a cost effective program against leafhoppers and aphids. Expenditures could be reduced to an even greater degree if reduced rates of Provado were tank mixed with other pest control treatments during regular cover spray periods.

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Water Conditioners and Surfactants Enhance Growth Control, But Have Little Effect on Fruit Cracking of Empire Apple Caused by Apogee

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The growth regulator prohexadione calcium (trade name Apogee) can cause fruit corking and cracking when applied to the variety Empire. The fruit injury is directly caused by the formulated product, Apogee itself, under certain environmental conditions. The potential economic consequences are so severe that this product should not be used on Empire. Empire is the only variety thus far identified as being susceptible to damage by Apogee.

The growth regulator prohexadione calcium (trade name "Apogee") can cause fruit corking and cracking when applied to the variety Empire. This injury is sporadic, and has occurred across several years in New York, Michigan, Ohio and Pennsylvania. Empire is the only variety thus far identified as being susceptible to damage by Apogee. The sporadic nature of the Apogee damage to Empire suggests that one or more environmental or application factors may be contributing to this problem. Since Apogee is applied as a foliar spray, the presence of other agricultural chemicals applied to fruit may be involved in Empire corking and cracking.

Apogee efficacy is reduced if the source of spray water is high in calcium carbonate ("hard water"), or if calcium-containing fertilizers are added to the spray solution. Apogee contains ammonium sulfate (AMS) as a water conditioner, and growers are advised to add additional AMS or other water conditioners when mixing spray solutions from a hard water source. One possible explanation for the damage is that it may be caused by AMS. Foliar applications of nitrogen fertilizer salts can cause phytotoxicity when applied at excessive concentrations, under poor drying conditions, or when applied with pesticides (Stiles and Reid, 1991). In earlier trials, Empire cracking was worse when AMS was added to the spray mixture than when it was omitted (Butch Palmer, ACDS Research, Williamson, N.Y., unpublished data). A similar Empire fruit injury was attributed to a tank mix of captan fungicide with $CaCl_2$ or surfactants under slow drying conditions (Rosenberger, 1999).

Empire is widely planted throughout eastern North America, and there are many instances when it would be desirable to manage tree vigor using Apogee. The objectives of this study were: 1) to evaluate the effect of hard water, with and without water conditioners, on the efficacy of vegetative growth reduction and incidence of Empire fruit cracking caused by Apogee; and 2) to evaluate the effect of surfactants, captan, and $CaCl_2$ on the efficacy of growth reduction and incidence of Empire fruit cracking caused by Apogee.

Materials and Methods

Experiment 1. Hard Water and Water Conditioners, Highland, NY

This experiment was conducted on nine-year-old Empire/ M.26 apple trees that were trained to a central leader and spaced 10 x 20 feet. Water for the soft water treatments was obtained from a

Figure 1: Fruit cracked caused by Apogee.

surface-fed pond, and averaged 58 ppm calcium carbonate ($CaCO_3$) equivalents. Hard water was obtained from a drilled well and averaged 222 ppm $CaCO_3$ equivalents.

The treatments were: 1) untreated control; 2) AMS in soft water; 3) Apogee in soft water; 4) Apogee in hard water; 5) Apogee in hard water and AMS; and 6) Apogee in hard water and Choice water conditioner. Chemical rates were: Apogee 3 oz. per 100 gal. (62.5 ppm), AMS 1 lb per 100 gal., and Choice 2 qt. per 100 gal. All treatments included Regulaid at 1 pt. per 100 gal. The first application was made on 7 May 2001, when terminal shoot growth averaged 1-2 inches. The second application was made on 24 May.

Experiment 2. Hard Water and Water Conditioners, Pittstown, N J

This experiment was conducted on 11-year-old Empire/ M.26 apple trees that were trained to a central leader and spaced 12 x 20 feet. Water for the soft water treatments was obtained from a drilled well, and averaged 42 ppm $CaCO_3$ equivalents. The addition of $CaCl_2$ to the tank mix was used to simulate hard water and raised the water hardness to 1000 ppm $CaCO_3$ equivalents.

The treatments were: 1) untreated control; 2) AMS in soft water; 3) Apogee in soft water; 4) Apogee in hard water; and 5) Apogee in hard water and AMS. The chemical rates were the same as in experiment 1. Applications were made on 10 May and 24 May 2001 and included Regulaid spreader-activator at 1 pt. per 100 gal.

Experiment 3. Surfactants, $CaCl_2$ and Captan, Geneva, NY

This experiment was conducted on 9-year-old Empire / M.9 and M.7 apple trees that were trained to a vertical axis system and spaced 8 x 16 feet. Spray water was from the town of Seneca water supply that came from Seneca Lake and had a water hardness of 260 ppm $CaCO_3$ equivalents.

The treatments were: 1) untreated control; 2) Apogee + Quest water conditioner; 3) Apogee + Quest + Regulaid; 4) Apogee + Quest + Regulaid + AMS; 5) Apogee + Quest + Regulaid + AMS + Silwet L77; 6) Apogee + Quest + Regulaid + AMS + captan fungicide (Captec 4L) ; 7) Apogee + Quest + Regulaid + AMS + $CaCl_2$ (Stopit); 8) Apogee + Quest + Regulaid + AMS + captan + $CaCl_2$; and 9) Apogee + Quest + Regulaid + AMS + Silwet L77 + captan + $CaCl_2$.

Chemical rates were: Apogee 12 oz. per 100 gal. (250 ppm), Quest 1 qt. per 100 gal., AMS 12 oz. per 100 gal., $CaCl_2$ (Stopit 51 fl. oz. per 100 gal.) , 1.3 lb Ca per acre, Regulaid 1 pt. per 100 gal., Silwet L77 1 qt. per 100 gal. and captan 1 lb a.i. per 100 gal. The first application was made on 14 May 2001, when terminal shoot growth averaged two inches. The second application was made on 5 June.

Results

Experiment 1. Hard Water and Water Conditioners, Highland, NY

All Apogee treatments caused an initial reduction in shoot growth on 31 May (Table 1). From 26 June to 24 July, bi-weekly shoot measurements showed Apogee combined with either water conditioner had the least growth, followed by Apogee in soft water, which had less growth than Apogee in hard water, and control trees had the greatest shoot growth. Curiously, AMS applied with Regulaid in soft water also provided some shoot growth control. At the end of the growing season (13 Oct.), Apogee combined with either water conditioner still provided more growth control than

TABLE 1

Effect of Apogee, water hardness, and water conditioners on shoot length and fruit injury of Empire apple in Highland, NY

Treatment			Shoot length (cm)						Water sprout length (cm)	Fruit injury rating	Damaged fruit (%)
Apogee (ppm)	Water hardness (ppm)	Water conditioner[z]	31 May	13 Jun	26 Jun	10 Jul	24 Jul	13 Oct			
Control	—	—	20 a	29 a	37 a	38 a	38 a	39 a	107 a	2.5 d	49 b
0	58	AMS	17 b	24 b	31 b	31 b	31 b	31 b	102 a	2.7 c	50 b
63	58	0	17 b	21 cd	26 c	28 c	28 c	29 b	92 a	2.8 bc	60 b
63	222	0	17 b	22 bc	29 b	31 b	31 b	31 b	85 a	2.9 abc	57 b
63	222	AMS	16 b	19 de	24 d	25 d	25 d	25 c	104 a	3.0 ab	77 a
63	222	Choice	15 b	18 e	23 d	24 d	24 d	25 c	104 a	3.1 a	79 a

[z] AMS is ammonium sulfate applied at 1 lb per 100 gal. Choice water conditioner applied at 2 qt. per 100 gal.
[y] Total fruit damage includes damage caused by hail.

TABLE 2

Effect of Apogee, water hardness, and water conditioners on shoot length of Empire apple in NJ

Treatment			Shoot length (cm)							Water sprout length (cm)
Apogee (ppm)	Water hardness (ppm)	Water conditioner[z]	25 May	11 Jun	25 Jun	09 Jul	20 Jul	3 Aug	14 Nov	
Control	—	—	17 b	23 b	26 b	27 b	27 b	28 b	28 b	83 a
0	42	AMS	20 a	27 a	31 a	33 a	33 a	34 a	34 a	111 a
63	42	0	15 c	16 d	17 d	18 d	18 d	19 d	20 d	92 a
63	1000	0	17 b	19 c	21 c	22 c	22 c	23 c	24 c	125 a
63	1000	AMS	15 c	17 d	19 cd	19 d	9 d	20 d	21 d	109 a

[z] AMS is ammonium sulfate applied at 1 lb per 100 gal.

when Apogee was applied without a conditioner, even when a soft water source was used. Apogee had no effect on the growth of water sprouts.

Apogee had no effect on fruit set, yield, yield efficiency, fruit number per tree, crop load, fruit size or fruit drop (data not presented). All Apogee treatments increased the extent of fruit injury compared to the untreated controls (Table 1). AMS without Apogee also caused a small but significant increase in injury rating of fruit samples. Fruit damage was high for all treatments in this experiment, due to early hail, that damaged nearly half the fruit on all trees. Apogee combined with either water conditioner increased the amount of fruit damage. However, Apogee without a conditioner or AMS without Apogee had no effect on the amount of fruit damage.

Experiment 2. Hard Water and Water Conditioners, Pittstown, NJ

All Apogee treatments reduced shoot growth in this study, but to different degrees (Table 2). Growth of terminal shoots of trees treated with Apogee in soft water or with Apogee in hard water plus AMS was least, followed by that of Apogee in hard water. Shoot growth for trees treated with AMS without Apogee was greater than that of untreated controls, the opposite result of the previous study. Apogee did not affect water sprout length.

Apogee had no effect on total number of fruit per tree (data not presented). Apogee in hard water reduced crop load, with and without AMS (Table 3). Pre-harvest fruit drop was severe on Apogee-treated trees, and those treated with Apogee in soft water had the most drop. The number and yield of harvested fruit on Apogee treated trees was reduced markedly by the amount of pre-harvest drop. Apogee had no effect on fruit size distribution of the harvested fruit (data not presented).

Trees treated with Apogee in soft water had smaller average fruit size, otherwise fruit size was unaffected by Apogee (Table 4). Fruit from trees treated with Apogee had more severe corking and cracking than fruit from trees treated with AMS without Apogee or untreated trees. The severity of fruit corking and cracking was greatest for Apogee in soft water. All fruit that dropped prior to harvest showed fruit cracking, and when these were added to the number of hand-harvested fruit with cracking, Apogee-treated trees had more damaged fruit than untreated trees. The total amount of damaged fruit was greatest with Apogee in soft water, while AMS without Apogee did not increase fruit cracking.

Experiment 3. Surfactants, $CaCl_2$ and Captan, Geneva, NY

Rootstock did not affect shoot growth, yield, fruit size, fruit drop, fruit color or fruit injury rating (Table 5). Trees on M.9 rootstock had greater crop load and yield efficiency than trees on M.7 rootstock.

All of the Apogee plus Quest (A/Q) treatments with the exception of the A/Q and Regulaid treatment caused a significant reduction in shoot length in the lower half of the tree canopy, while all of the treatments reduced shoot length in the top of the tree (Table 5). Shoot length in the tops of untreated trees was much longer than shoot length in the bottoms of untreated trees. On A/Q treated trees, shoot length in the bottom and tops of the trees were similar. The addition of Regulaid, AMS, Silwet, $CaCl_2$ or Captan did not affect the growth control obtained from A/Q used alone.

None of the A/Q treatments affected fruit number per tree, yield or crop load relative to the control (Table 5). However, the A/Q plus Regulaid treatment increased fruit number, yield and crop load compared to several other A/Q treatments. The addition of AMS to the A/Q treatments resulted in lower crop load where A/Q plus Regulaid was used.

A/Q did reduce fruit size and yield efficiency. The addition of either Silwet

TABLE 3

Effect of Apogee, water hardness, and water conditioners on fruit size and yield of Empire apple in NJ

Treatment							Percent fruit with fruit diameter (cm):			
Apogee (ppm)	Water hardness (ppm)	Water conditioner[z]	Crop load (no./cm² TCSA)	Harvested Fruit/tree (no.)	Harvested Fruit/tree (kg)	Preharvest drop (%)	>7.6	7.0-7.6	6.4-6.9	<6.4
Control	—	—	12.1 a	1522 a	209 a	7 c	12 a	21 a	38 a	22 a
0	42	AMS	11.1ab	1419 ab	190 a	13 bc	9 a	22 a	40 a	19 a
63	42	0	10.5 abc	999 c	94 d	45 a	4 a	7 b	23 b	21 a
63	1000	0	9.6 bc	1326 abc	163 bc	21 b	4 a	18 a	36 a	25 a
63	1000	AMS	8.5 c	1157 bc	134 cd	22 b	4 a	15 a	36 a	19 a

[z] AMS is ammonium sulfate applied at 1 lb per 100 gal.

TABLE 4

Effect of Apogee, water hardness, and water conditioners on fruit quality of Empire apple in NJ

Treatment							
Apogee (ppm)	Water hardness (ppm)	Water conditioner[z]	Fruit weight (g)	Fruit diameter (mm)	Fruit L/D ratio	Fruit injury rating	Total fruit damage (%)
Control	—	—	142 a	6.9 a	.87 a	1.5 c	12 c
0	42	AMS	141 a	6.9 a	.86 a	1.8 c	20 c
63	42	0	130 b	6.6 b	.87 a	4.3 a	69 a
63	1000	0	137 ab	6.8 a	.86 a	3.1 b	33 b
63	1000	AMS	140 a	6.9 a	.86 a	3.2 b	41 b

[z]AMS is ammonium sulfate applied at 1 lb per 100 gal.

TABLE 5

Effect of Apogee on shoot growth, crop load, yield and fruit size of Empire apple trees on two rootstocks at Geneva, NY

Stock	Treatment Number	Apogee Treatment	Avg. shoot length (lower half of tree) (cm)	Avg. shoot length (upper half of tree) (cm)	Fruit no. per tree	Yield per tree (kg)	Av. fruit size (g)	Cropload (no. fruit/ cm^2 TCSA)	Yield efficiency (kg fruit/ cm^2 TCSA)	% Fruit drop
M.7			**32.6 a**	**31.8 a**	**333 a**	**49.9 a**	**151 a**	**3.34 b**	**0.50 b**	**23 a**
M.9EMLA			**31.4 a**	**34.9 a**	**367 a**	**57.5 a**	**158 a**	**8.24 a**	**1.28 a**	**21 a**
	1	Untreated Control	35.7 a	50.5 a	352 abc	59.7 a	170 a	5.88 abcd	1.01 a	17.7 c
	2	Apogee + Quest	31.0 b	31.0 b	375 ab	55.5 ab	149 cde	5.90 abcd	0.88 abc	22.2 ab
	3	Apogee + Quest + Regulaid	33.3 ab	32.3 b	410 a	59.9 a	147 de	6.74 a	0.99 ab	25.5 a
	4	Apogee + Quest + Regulaid + AMS	31.0 b	31.8 b	350 bc	51.4 b	146 de	5.74 abcd	0.84 c	24.8 a
	5	Apogee + Quest + Regulaid + AMS + Silwet	32.1 b	31.8 b	307 c	47.4 b	156 bcd	5.15 cd	0.80 c	19.6 bc
	6	Apogee + Quest + Regulaid + AMS + Captan	30.0 b	29.9 b	367 abc	52.2 ab	142 e	6.19 ab	0.87 bc	25.5 a
	7	Apogee + Quest + Regulaid + AMS + $CaCl_2$	31.6 b	31.9 b	327 bc	51.4 b	159 bc	5.44 bcd	0.86 bc	19.6 bc
	8	Apogee + Quest + Regulaid + AMS + Captan + $CaCl_2$	32.1 b	29.8 b	349 bc	55.4 ab	159 bc	6.14 abc	0.98 ab	19.7 bc
	9	Apogee + Quest + Regulaid + AMS + Silwet + Captan + $CaCl_2$	31.1 b	31.3 b	315 bc	50.7 b	162 ab	4.99 d	0.81 c	20.9 bc
Contrasts for Apogee Treatments ($p \leq 0.05$)										
	(1 vs 2)	Apogee + Quest Effect	***	*	NS	NS	***	NS	*	*
	(2 vs 3)	Regulaid Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(3 vs 4)	Ammonium Sulfate Effect	NS	NS	*	*	NS	*	*	NS
	(4 vs 5)	Silwet Effect	NS	NS	NS	NS	*	NS	NS	**
	(4 vs 6)	Captan Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(4 vs 7)	$CaCl_2$ Effect	NS	NS	NS	NS	**	NS	NS	**
	(4 vs 8)	$CaCl_2$ + Captan Effect	NS	NS	NS	NS	**	NS	*	**
	(4 vs 9)	$CaCl_2$ + Captan+Silwet Effect	NS	NS	NS	NS	***	NS	NS	*
	(4 vs 5)	Silwet Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(4 vs 6)	Captan Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(4 vs 7)	$CaCl_2$ Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(4 vs 8)	$CaCl_2$ + Captan Effect	NS	NS	NS	NS	NS	NS	NS	NS
	(4 vs 9)	$CaCl_2$ + Captan+Silwet Effect	NS	NS	NS	NS	NS	NS	NS	NS

or $CaCl_2$ to A/Q treatments partially reversed the negative effect of A/Q on fruit size. A/Q increased pre-harvest fruit drop. The addition of either Silwet or $CaCl_2$ to the A/Q treatments partially reversed the undesirable effect of A/Q on fruit drop.

A/Q sprays had no effect on fruit red color or percentage of fruit in the Extra Fancy grade (Table 6). Fruit injury was greatest in treatments that included captan, while the untreated control had the least injury. The other A/Q treatments were intermediate in the extent of fruit injury, but many were not different from the control. The primary cause of fruit damage was Apogee plus Quest and that the effects of the other chemicals were non-significant. Several Apogee treatments increased fruit rots following storage, due to the cracking on the fruit. Fruit treated with Apogee plus Quest had the greatest amount of rot, while the untreated control had the least.

A packout analysis of fruit samples showed that all Apogee treatments with the exception of A/Q plus Regulaid reduced the yield of undamaged fruit and all Apogee treatments reduced the yield of large fruit. The gross crop value was reduced by all Apogee treatments. None of the spray additives affected gross crop value.

Discussion

In the Hudson Valley trial, adding a water conditioner increased the ability of Apogee to reduce shoot growth compared to Apogee with either hard or soft water (Table 1), suggesting that a water conditioner is beneficial when low rates of Apogee are used, even when the initial hardness of the spray water source is low. AMS and Choice were equally effective water conditioners when used as described.

Apogee provided no growth control of water sprouts (Tables 1 and 2). Apogee must be applied prior to the first flush of terminal shoot growth in order to be effective, so our timings of Apogee spray were too early to reduce the growth of water sprouts, which start growing later. To limit the number of water sprouts in the canopy, the use of heading or stubbing back cuts (i.e. bench cuts) should be avoided when pruning.

Apogee had no effect on fruit set or yield, but it did reduce fruit size at Geneva and in one of the Apogee treatments in NJ (Tables 3 and 5). Apogee increased set in some previous studies while in others it had no effect. Greene (1999) showed that fruit set increased linearly with increasing Apogee concentrations between 125-375 ppm (6 to 18 oz per 100 gal.). The concentration of 63 ppm (3 oz. per 100 gal.) Apogee used in the Hudson Valley and NJ may have been too low to affect set.

Apogee has been studied on a number of commercially important apple cultivars over the past decade, including Delicious; Fuji, Gala, Golden Delicious, Rome, Granny Smith, Macoun, McIntosh, Stayman, Spartan and York Imperial. There were no reports of fruit injury in any of these studies, including most notably with Stayman which is prone to skin cracking. Fruit injury caused by Apogee has been reported only for Empire. The pre-harvest fruit drop from Apogee -treated trees documented in NJ

TABLE 6

Effect of Apogee on fruit quality of 'Empire' apple trees on two rootstocks at Geneva, N.Y.

Stock	Treatment Number	Apogee Treatment	Fruit surface with red color (%)	% fruit with XF grade	% Damaged fruit	Av. fruit injury rating	% Rotte fruit	Yield undam-aged nfruit (T/ha)	Yield large fruit (>7.6cm) (T/ha)	Gross return ($/ha)
M.7			**72.2 a**	**69.6 a**	**33.1 a**	**1.9 a**	**13.9 a**	**28.0 a**	**13.1 a**	**7,641 a**
M.9EMLA			**73.8 a**	**73.6 a**	**33.8 a**	**1.9 a**	**13.9 a**	**32.0 a**	**17.2 a**	**9,571 a**
	1	Untreated Control	73.9 a	73.1 a	26.0 b	1.7 b	7.8 b	37.8 a	25.2 a	14,189 a
	2	Apogee + Quest	74.5 a	74.8 a	36.8 ab	2.0 ab	21.1 a	29.6 b	13.3 bc	7,500 bc
	3	Apogee + Quest + Regulaid	74.0 a	74.6 a	26.8 b	1.7 b	12.1 ab	36.5 a	16.2 b	10,035 b
	4	Apogee + Quest + Regulaid + AMS	73.7 a	73.0 a	33.1 ab	1.9 ab	13.7 ab	28.3 b	12.3 bc	7,060 bc
	5	Apogee + Quest + Regulaid + AMS + Silwet	72.6 a	71.7 a	33.8 ab	1.9 ab	12.6 ab	26.2 b	13.4 bc	7,584 bc
	6	Apogee + Quest + Regulaid + AMS + Captan	72.9 a	70.9 a	39.6 a	2.1 a	14.8 ab	26.5 b	10.1 c	5,614 c
	7	Apogee + Quest + Regulaid + AMS + $CaCl_2$	70.0 a	64.8 a	30.1 ab	1.8 ab	18.2 a	30.0 b	15.9 b	9,474 b
	8	Apogee + Quest + Regulaid + AMS + Captan + $CaCl_2$	73.2 a	72.7 a	39.8 a	2.1 a	8.2 b	27.6 b	14.9 bc	7,732 bc
	9	Apogee + Quest + Regulaid + AMS + Silwet + Captan + $CaCl_2$	71.9 a	69.0 a	35.2 ab	1.9 ab	16.4 ab	27.5 b	15.1 bc	8,276 bc
	Contrasts for Apogee Treatments ($p \leq 0.05$)									
	(1 vs 2)	Apogee + Quest Effect	NS	NS	*	*	**	**	***	***
	(2 vs 3)	Regulaid Effect	NS	NS	NS	NS	*	*	NS	NS
	(3 vs 4)	Ammonium Sulfate Effect	NS	NS	NS	NS	NS	*	NS	NS

(Table 3) and Geneva (Table 5) was attributed to premature ripening caused by the severe fruit cracking at these sites.

Fruit damage to Empire was severe in all three of our trials, despite the use of the lowest labeled concentration of Apogee in two of the trials (Tables 1 and 4). Damage was exacerbated in one of the trials by the addition of a water conditioner (Table 1), however AMS applied with Regulaid, but without Apogee, had no effect on either the severity or extent of fruit injury. The addition of surfactants, $CaCl_2$ or captan to the Apogee treatments had no effect on the severity of the fruit damage. During previous trials by the authors, the use of Apogee on Empire has not always resulted in fruit injury. The potential for Apogee injury on 'Empire' may be related to certain weather conditions, which we do not yet understand. Fruit cracking caused by Apogee increased preharvest drop in two of three experiments (Tables 3 and 5), and increased post-harvest rot in the Geneva experiment where fruit were stored prior to grading (Table 5). From these results we conclude that the fruit injury is directly caused by the formulated product, Apogee itself, under certain environmental conditions, and that the potential economic consequences are so severe that this product should not be used on Empire.

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Effects of Spotted Tentiform Leafminer and European Red Mite on Apple Leaf Function and Crop Development

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Several individual leaf feeding pests affect apple trees by reducing leaf photosynthesis which results in reduced carbohydrate supply to developing fruits. While pest level tolerances have been developed or estimated for single pests, several pest stresses often occur concurrently. We found that leaf injury by STLM at relatively high levels does not greatly affect leaf and canopy photosynthesis, fruit growth, or fruit quality but does increase pre-harvest drop of McIntosh. In contrast, mite damage does significantly reduce leaf photosynthesis.

Apples are subject to attack by several foliage feeders. While pest level tolerances have been developed or estimated for single pests, several pest stresses often occur concurrently. Of the different types of apple pest effects commonly seen, injury from European red mite (ERM) (*Panonychus ulmi* Koch) has been the most extensively studied. Several studies have shown a decline in leaf photosynthesis with ERM injury, which, in turn, can lead to reductions in yield and fruit quality (Lakso et al., 1996). Much less work has been done on the impact of other pests such as spotted tentiform leafminer (STLM) (*Phyllonorycter blancardella* Fabricius), or on the combined effects of two or more pests.

The principal integrating mechanism of foliar pest damage appears to be reductions in the carbohydrate supply for fruit development caused by the reduction of leaf photosynthesis. Many studies of fruit carbohydrate supply and demand have shown that several other internal and external factors, in addition to leaf health, also play a role in tree physiology. Flowering, fruit set fruit growth and sustained cropping depend on an adequate carbohydrate supply in relation to the demand for carbohydrates for growing fruits, shoots, leaves, wood and roots. Consequently, foliar pest thresholds will depend on how the tree integrates the influences of all pest injuries as well as other factors that affect the carbohydrate balance such as cloudiness, drought stress, etc.

If individual pests affect the apple tree by reducing leaf photosynthesis, it is possible that the effect of multiple pests is additive by way of reductions in leaf photosynthesis. This concept was the basis for the research described here.

Methods

We conducted experiments to assess the effect of STLM feeding damage on leaf and whole-tree photosynthesis and the impacts on fruit yield and quality. In some experiments we measured the influence of STLM and ERM feeding damage on the same leaves. Measurements were taken from mature McIntosh and Red Delicious apple trees at the New York State Agricultural Experiment Station in Geneva. We measured the amount of leaf area injured by STLM mines; photosynthesis of leaves having STLM mines and photosynthesis by leaf tissue within and immediately adjacent to mines; photosynthesis of leaves with both STLM and ERM injury; and whole-tree photosynthesis of trees having simulated STLM infestations. On trees with varying levels of STLM and ERM infestations, we recorded fruit growth, yield, and maturity as indicated by starch staining, sugar concentration and firmness.

Results

Over three years a somewhat surprising, yet very consistent, result was that up to five STLM mines per leaf caused very little reduction in leaf-level photosynthesis, and even a very high density of 10 mines per leaf resulted in only about a 10-15 percent reduction in photosynthesis (Fig. 1). The mine of a mature STLM larva occupies approximately 0.5 cm^2 of leaf area, which corresponds to 2 percent to 3 percent of the area of a normal apple leaf. Therefore, at a density of 10 mines per leaf, leaf area is reduced 20 to 30 percent. Visually, this damage appears to be much more severe than the actual 20-30 percent reduction in leaf surface area. Even at 10 mines per leaf, the reduction in photosynthesis is less than the proportional leaf area consumed by the STLM larvae. Apparently, leaves compensate for some of the leaf area lost by increasing the photosynthesis of the remaining leaf tissue.

The initial mines produced by young STLM larvae are visible only from the

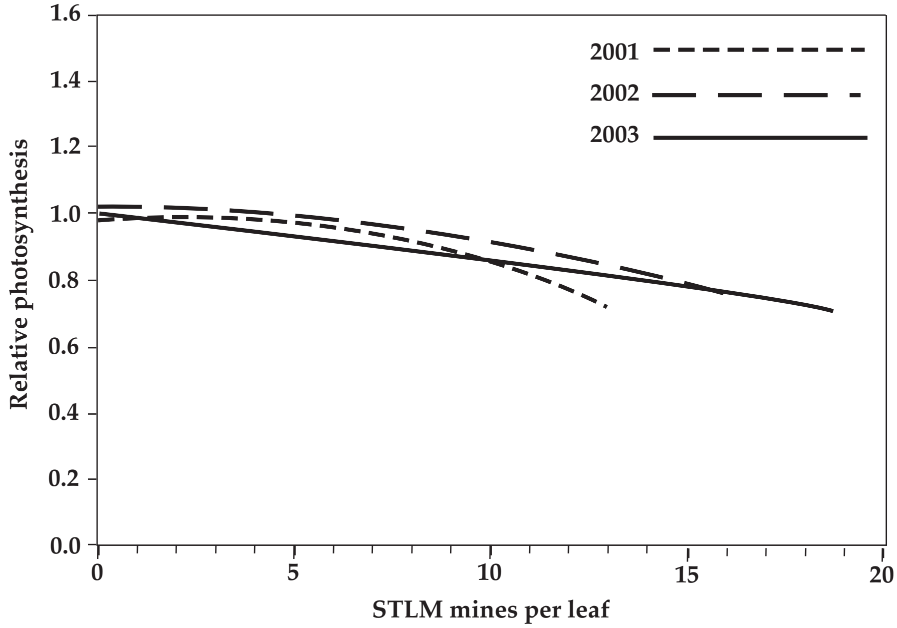

Figure 1. Influence of mature second generation spotted tentiform leafminer mines on photosynthesis by apple leaves. Readings are relative to the photosynthesis of leaves with no mines on the days of measurement. The three lines describe the relationships found in many measurements in 2001, 2002 and 2003.

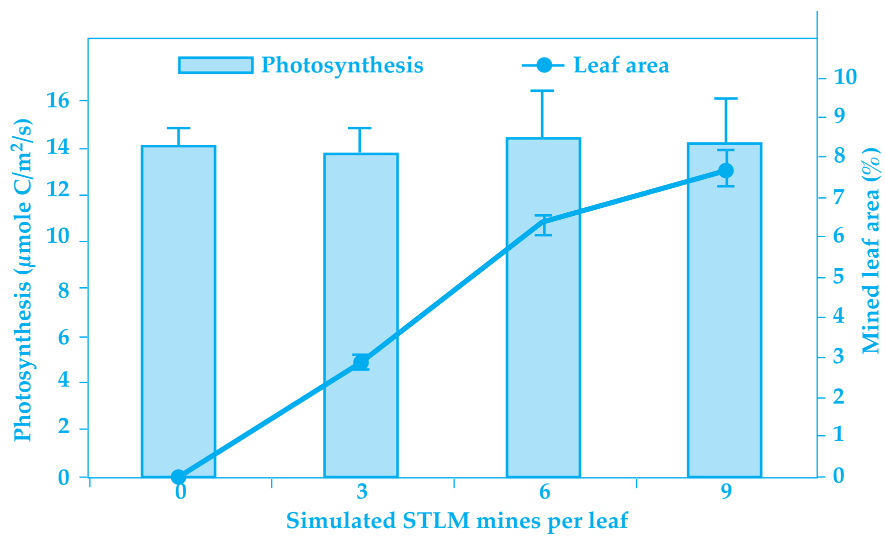

Figure 2. Influence of simulated spotted tentiform leafminer mines on average percent leaf area mined and on whole-tree photosynthesis of Red Delicious apple trees. Error bars indicate the variation in results of each treatment.

bottom of leaves. Mines produced by these young larvae did not have any measurable effect on leaf photosynthesis. Mines produced by mature STLM larvae show feeding damage on both the upper and lower leaf surfaces. However, there remains some green tissue within mines that continues to photosynthesize. We measured photosynthesis by the tissue occupied by the mine before and after masking the mined area. When we covered the mined area on a leaf with opaque material, it further reduced the photosynthetic capacity of the mined leaf tissue showing that the green tissue remaining in STLM mines contributes some photosynthesis. Combined with some degree of compensation by the remaining healthy leaf tissue, leaf photosynthesis was only slightly affected by STLM mines unless the number of mines was very large.

Considering the modest influence of STLM mines on leaf photosynthesis, we did not expect to observe an effect of STLM mines on whole-tree photosynthesis. Because we were unable to really control STLM numbers on our test trees, we mimicked STLM damage by punching holes in the leaves with the same distribution as the natural pattern of STLM infestation. Although the trees were subjected to as many as nine simulated mines per leaf in the most severely damaged leaves, or up to 8 percent total leaf area "attacked," we found no measurable reduction in whole-tree photosynthesis (Fig. 2). Therefore, the results of our leaf and whole-tree studies suggest that surprisingly the levels of STLM injury commonly found in the field do not cause much effect by reducing photosynthesis.

Our previous research has shown that ERM feeding and resulting damage can greatly reduce photosynthesis (Lakso et al., 1996). Compared to the ERM results, our results with STLM are surprising because damage by STLM is visually more dramatic. To evaluate the combined effects of ERM and STLM on photosynthesis, we measured photosynthesis on leaves injured by both these pests. ERM damage was visually scored on a scale that related to a range of approximately 0 to 1250 mite days[1] (current IPM thresholds for ERM are about 500-700 mite days). We found that the reductions in photosynthesis from STLM and ERM seem to be simply additive and independent of each other (Fig. 3). Furthermore, the influence of ERM feeding damage on photosynthesis was greater than that for STLM even though the apparent visual effect of STLM on the leaf was greater. For example, 750 mite days reduces leaf photosynthesis about 15 percent. Mite damage corresponding to 750 mite days is not uncommon, while heavy bronzing that can occur relates to mite days in excess of 2000. In comparison, 10 STLM mines per leaf reduced photosynthesis about only 10-12 percent. Ten STLM mines per leaf appears visually to be a much more severe injury than 750 mite days. So with these two pests, what you see, is not what you get!

As the previous studies have shown, leaf damage from ERM feeding can impair leaf and canopy photosynthetic function. In moderately to heavily cropped trees a shortage of carbohydrate supply can result in smaller fruit size and inferior fruit quality. In contrast, STLM does not greatly affect leaf and canopy photosynthesis. The carbohydrate

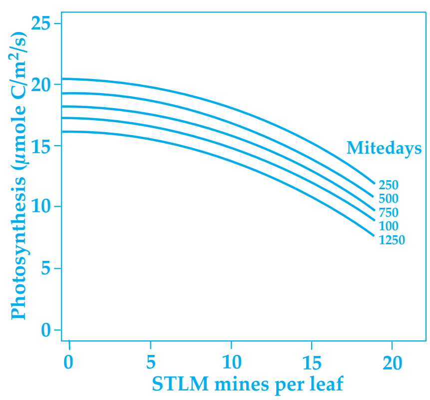

Figure 3. Influence of spotted tentiform leafminer mines on leaf photosynthesis of McIntosh apple leaves when the leaves also had 250, 500, 750, 1000 and 1250 mite days of European red mite injury.

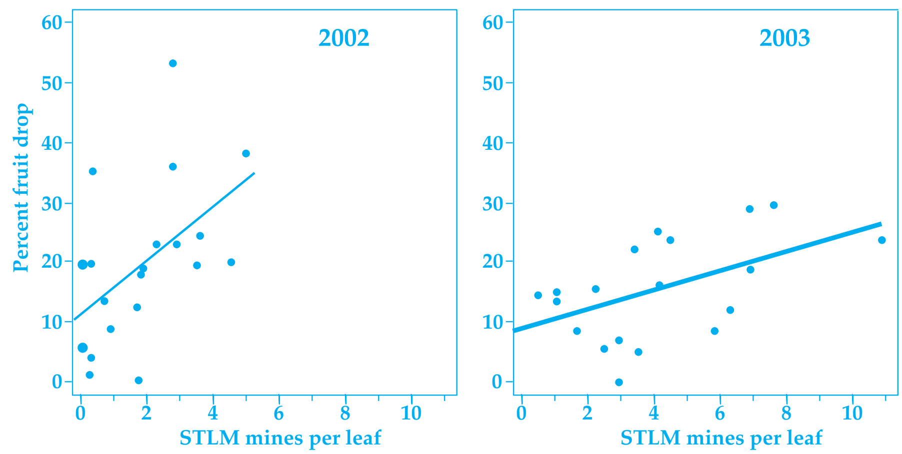

Figure 4. Influence of spotted tentiform leafminer mines on pre-harvest drop of McIntosh fruit. Fruit drop was adjusted to account for natural variation across the orchard. STLM mine density was the average number of mines counted on mid-aged leaves of vegetative terminals.

supply vs. demand would suggest fruit growth, fruit size, and fruit quality would not be affected much by STLM. We tested these predictions by measuring fruit yield and quality from McIntosh and Red Delicious trees with varying levels of STLM infestation.

We found that STLM infestations of nearly 10 mines per leaf did not influence fruit quality as measured by sugar content and firmness. However, pre-harvest fruit drop from McIntosh trees was significantly increased by damage from STLM (Fig. 4), but this did not occur on Red Delicious trees. In 2003, the test trees were damaged by both STLM and ERM, with mite levels reaching approximately 1500 mite days. Mite injury did not alter pre-harvest drop on the McIntosh trees. These results indicate that the effect of STLM damage on pre-harvest fruit drop in McIntosh is caused by factors other than by reducing carbohydrate supply. In general, McIntosh trees are very prone to pre-harvest drop, although the mechanism is unknown.

Summary

Our studies have shown that leaf injury by STLM at relatively high levels does not greatly affect leaf and canopy photosynthesis, fruit growth, or fruit quality. Reductions in photosynthesis caused by STLM and ERM feeding injury are additive, indicating that the carbohydrate supply vs. demand is an integrator of their effects on photosynthesis. However, STLM damage elicits significant pre-harvest drop of McIntosh but not Red Delicious. From the perspective of carbohydrate supply and demand balance, current thresholds for STLM of 1-2 mines/leaf are conservative except for McIntosh trees or perhaps other varieties known to be susceptible to pre-harvest fruit drop.

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Kuo-Tan Li is a post doctoral research fellow in the department of horticultural sciences working with Alan Lakso, a research professor who specializes in stress physiology of fruit crops. Jan Nyrop is a professor in the department of entomology who specializes in multiple pest effects on fruit crops and biological control of fruit insect pests.

[1] Mite days is a measure of cumulative mite density. Ten mites for 10 days results in 100 mitedays as does 20 mites for 5 days.

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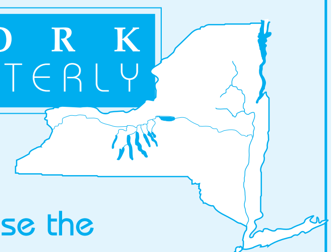

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