SUSTAINABLE AGRICULTURE RESEARCH AND EDUCATION (SARE) PROGRAM AND AGRICULTURE IN CONCERT WITH THE ENVIRONMENT (ACE)
1997 FINAL REPORT - SECTION II

Project Number: LNE88-01/ANE92.16

Project Title: Development of a Sustainable Apple Production System for the Northeast

1. OBJECTIVES

Develop sustainable apple production systems in the Northeast using scab-resistant apple cultivars and integrated pest management techniques. Provide economic analyses of sustainable production systems and forecast impact on the Northeast apple industry. Expedite research and information transfer on sustainable apples production systems for the Northeast. Compare potential impacts of conventional, agrochemical-intensive pest management with alternative Integrated Pest Management practices upon soil, water, wildlife, and beneficial fauna in the orchard agroecosystem and upon human resources.

2. ABSTRACT

Probably the most important accomplishment of the Northeast SARE Apple Production Project was the extensive evaluation of how scab-resistant cultivars (SRC's) could contribute to more sustainable production systems. Based on this evaluation of SRCs over an eight-year period, project participants compiled a list of potential benefits and limitations of using SRCs.

A complex environmental question emerged from our project after several years. We had shown that SRCs enabled 50-100% reductions in fungicide usage. But from a broader perspective, what were the off-site and long-term savings involved when the environmental impacts of pesticides in orchard ecosystems or regional food systems were considered? We conducted a thorough review of current methodologies and databases for assessing environmental impacts of different pest-control practices. Major obstacles to meaningful, holistic impact assessment were identified--especially the lack of comparable or complete databases for pesticide effects on key processes, species, and components of agroecosystems.

Research on IPM strategies applicable to scab-susceptible cultivars provided information that was immediately integrated into state apple IPM programs. For example, in Massachusetts, the SARE Apple Project comprised part of an overall apple program focused on developing and implementing advanced IPM control strategies for sooty blotch and flyspeck, and research on a computer-based predictive model for timing summer fungicides was initiated and is being continued with other funding sources. In New York, fungicide timing studies showed that flyspeck on apple can usually be controlled by fungicides applied on a three-week interval rather than the 14 day interval that was previously recommended for this disease. And in New Jersey, SARE funds enabled Rutgers Cooperative Extension to expand delivery of IPM scouting and information to an increasing number of growers throughout the life of the grant.

The Management Guide for Low-Input Sustainable Apple Production was authored by SARE-project participants and published in 1990. This production guide, targeted for both large and small apple producers, included comprehensive chapters on economics, horticulture, and disease and insect management, with easy-to-understand information on the best reduced-input approaches for managing orchards. The Northeast SARE Apple Production Newsletter was the only publication in the northeastern United States devoted to distributing the latest information on alternative apple production methods. In

1993 the Project organized a comprehensive conference/symposium titled Disease-Resistant Apple Cultivars: An Update on Horticulture, Pests, and Marketing . Attended by 60 interested growers, researchers, and extension/industry personnel, the proceedings were subsequently published in Fruit Varieties Journal . SARE project participants authored hundreds of articles in Extension newsletters and peer-reviewed Journals during the duration of the project. In addition, thousands of contacts were made via mass media and through presentations at grower, industry, and professional meetings. In 1994, outreach efforts were extended to the World Wide Web (WWW) via the 'Virtual Orchard' <http://www.orchard.uvm.edu>, a dedicated WWW site for the dissemination via the Internet of information concerning all aspects of sustainable apple production.

3. SPECIFIC PROJECT RESULTS

3A. Findings and Accomplishments

Because of the breadth and diversity of the Northeast SARE Apple Production Project, it is difficult to succinctly summarize our accomplishments. Some of the project accomplishments are highlighted below. Other results have been published in citations listed at the end of this article under Additional Publications Resulting from the Project . Probably the most important accomplishment of the Northeast SARE Apple Production Project was the extensive evaluation of how scab-resistant cultivars could contribute to more sustainable production systems. By 1992, project participants were working with more than 5,000 trees of SRCs in various commercial and experimental plantings. At least 30 cultivars and numbered selections were evaluated. The greatest disappointment was that most of the cultivars evaluated had serious flaws that limited their usefulness for commercial agriculture. Two of the four SRCs included in the reference planting showed a high incidence of fruit defects and have since been removed from consideration as selections that become named cultivars, thereby reducing the usefulness of the reference planting. Based on extensive evaluation of SRCs over an eight-year period, project participants compiled a list of potential benefits and limitations of using SRCs. Individuals within the project still differ concerning the emphasis they would place on the various benefits and limitations noted below (Rosenberger, 1995), but all agree that the following summary is a fair distillation of what we learned about SRCs.

Benefits of scab-resistant cultivars:

1. SRCs need less fungicide. In northern growing regions where diseases other than apple scab are relatively unimportant, high-quality SRCs can be grown without fungicides in many sites and in most years. However, in the Hudson Valley of New York and other more southerly regions, SRCs may require three to five fungicide applications annually to prevent cedar apple rust, black rot (Botryosphaeria obtusa), quince rust (Gymnosporangium clavipes) , bitter rot (Colletotrichum sp.), flyspeck (Zygophiala jamaicensis), and sooty blotch (a complex involving Peltaster fructicola, Geastrumia polystigmatis, and Leptodontium elatius) . Even with three to five fungicide sprays per year, fungicide use on SRCs would be reduced by at least 50% compared to the minimal program required for scab-susceptible cultivars.

2. SRCs have fewer problems with mites. Fungicides have an adverse impact on mite predators. When SRCs were grown either without fungicides or with only a few summer fungicide sprays in our tests, they generally required no miticides other than the delayed-dormant oil spray each year (Bowers et al., 1995), whereas commercial orchards commonly receive 1-3 miticide sprays per season.

3. SRCs provide new options for niche markets. Certain SRCs have become established as niche cultivars in commercial apple production. For example, in New England, Liberty is being grown on a limited scale and successfully marketed at roadside farm-stands. Redfree has been widely recognized by progressive growers throughout the east as a viable alternative to more common summer apples such as Paulared. The numbered selection NY 75414-1 has been successfully sold at the University of Vermont Horticultural Research Center. In fact, it has become so popular there, that customers now ask for it by the name 'Speckles,' referring to the fruit's conspicuous lenticels. Scab-resistant cultivars may gain market share if there is significant growth in the current niche market for 'ecologically-grown' produce.

4. SRCs provide quality fruit for home gardeners and small-scale farmers, groups that frequently struggle to control apple scab on conventional cultivars. SRCs currently available can provide very good quality fruit with only a few insecticide or insecticide/fungicide sprays each year. A pre-bloom oil and insecticide spray, two or three post bloom sprays targeted for plum curculio (Conotrachelus nenuphar) and codling moth (Cydia pomonella) and the use of baited sticky traps for apple maggot (Rhagoletis pomonella) should enable home gardeners and small-scale farmers to harvest quality fruit. By selecting appropriate cultivars, home gardeners could pick fresh apples from late July through October. Several SRCs (Goldrush and Enterprise) will keep up to six months after harvest with common refrigeration.

5. SRCs may have potential for commercial processing. More than half of the apples grown in eastern US are currently destined for processing, so the use of SRCs for processing could lead to a significant reduction in fungicide use. Until recently, SRCs were evaluated and selected primarily for their potential as fresh-market cultivars. Within the last three years, however, breeders and processors have begun screening advanced selections of SRCs for their potential as processing apples. Processors can clearly define the fruit qualities that they prefer by requesting fruit that fall within certain ranges for size, acidity, soluble solids, firmness, and storage life. Factors such as fruit color, appearance, and minor surface defects are less critical for processing than for fresh-market fruit. Recently, research has been initiated on production systems to produce SRCs for processing (Biggs et al., 1997). A few large processors willing to buy SRCs could provide an immediate outlet for thousands of tons of fruit. By comparison, getting a new cultivar established in fresh market channels requires that thousands of individual produce buyers at both the wholesale and retail levels must be convinced to change cultivars or 'brand loyalty,' and reluctance to change limits introductions of new cultivars.

Limitations of scab-resistant cultivars

1. SRCs are limited by market economics. Apple marketing and microeconomic studies conducted by project participants in MA (Abrahams, 1992) and NY (Murphy and Willett, 1991) revealed a major barrier to grower acceptance of SRCs. They showed that a net yearly savings of $200 per acre could be achieved if no fungicides were needed to produce SRCs. However, the high market value and productivity of orchards (crop values exceeding $10,000 per acre are readily attainable) means that a mere 2% loss in either production or sales price for SRCs relative to proven conventional cultivars would offset the savings in fungicide costs. Thus, SRCs would be profitable only if they are as productive and as marketable as proven varieties like McIntosh, Delicious, or Granny Smith. The higher prices that were anticipated for eco-labeling and reduced pesticide use in the wake of the Alar scare generally failed to materialize except in a few niche markets.

Planting new varieties is very risky for eastern apple growers wholesaling their fruit through brokers because fresh-market apples are sold and recognized by their varietal names. Shelf space for apples in supermarket produce sections is limited, so any new apple variety must displace better known varieties to gain shelf space. Most of the new apple varieties introduced in supermarkets over the past 20 years had two characteristics that contributed to their successful introduction. First, the new varieties had distinctive qualities (appearance, flavor, texture) that allowed consumers to easily differentiate between the new varieties and previously-available varieties. Second, the new varieties have been strategically promoted by big-budget agencies such as the Washington State or New Zealand apple marketing associations. Under current conditions, it is very unlikely that any new apple cultivars (SRCs or scab-susceptible) can be introduced in supermarkets and achieve a measurable market share unless the introduction is supported and heavily promoted by large apple marketing agencies such as the one in Washington State.

2. SRCs have fruit quality limitations. None of the SRCs that we evaluated have distinctive and desirable fruit quality attributes such as those found in other recent introductions like Gala (unique flavor and appearance) or Ginger Gold (early-maturing, high-quality summer apple). Some of the more fruit quality problems include a short harvest window and limited long-term storage potential for Liberty (Autio and Costante, 1992); rough appearance and high susceptibility to black rot fruit infections for Freedom; susceptibility to a corky-spot disorder for Enterprise; russetting and small fruit size for Goldrush; susceptibility to 'sunburn' and breakdown of scab resistance for NY 74828-12; severe fruit russet problems with NY 75441-67; undesirable tree growth habit, brittle limb crotches, and conspicuous fruit lenticels for NY 75414-1; uneven ripening and fruit splitting for Priscilla; uneven ripening and short shelf life for Redfree; and objectionably thick and tough skins on many of the SRCs. Several of the SRCs are quite tart at optimum harvest maturity and require several weeks or months in cold storage to attain acceptable sugar/acid balance. Most participants in our SARE project found their personal favorite SRCs, and some SRCs have gained acceptance in local markets, but the perfect fresh-market SRC has yet to be developed.

3. SRCs cannot be grown without fungicides in most locations. Although high quality Liberty apples have been successfully grown without any fungicides near Burlington VT, failure to control flyspeck on Liberty apples grown in the Hudson Valley resulted in an average annual loss of $2,330 per acre, equaling one-third of the potential gross returns for that orchard (Rosenberger et al., 1996). As noted earlier, SRCs need fungicide sprays to prevent cedar apple rust, quince rust, black rot, bitter rot, flyspeck and sooty blotch where these diseases are prevalent. The last three of the diseases mentioned affect fruit during summer and must be controlled with fungicides applied during mid to late summer. As a result, the level of fungicide residues on SRC fruit at harvest will likely remain comparable to fungicide residues found on scab-susceptible cultivars because most residues come late-summer sprays.

Liberty and other SRCs from the Geneva breeding program, though not susceptible to cedar rust, also developed severe leaf spotting when subjected to high levels of cedar rust inoculum and 40% of leaves on Liberty also developed powdery mildew when grown next to Ginger Gold trees that were severely affected by mildew. At other locations in the same region, SRCs that were isolated from inoculum sources developed little rust or mildew (Rosenberger et al., 1994). Thus, proximity to inoculum will affect the number of fungicides needed to control disease on SRCs.

Liberty trees that were not sprayed with fungicide showed early defoliation in the fall and reduced fruit set the following year (Cooley et al., 1995; Rosenberger et al., 1996). This early defoliation was attributed to weakly parasitic fungi or leaf microflora. The improved yields on Liberty trees treated with fungicides suggests that fungicides may contribute to tree health by eliminating fungi that have not heretofore been viewed as apple pathogens.

4. SRCs lose their resistance to apple scab if new scab strains are introduced. Scab-resistance in SRCs has a narrow genetic basis. A race of the scab pathogen discovered in Europe is not controlled by the Vf and Vm genes that confer resistance in SRCs (Parisi et al., 1993). One scab resistant selection with the Vm gene (NY 74828-12) developed scab lesions in two of our Northeast SARE plantings (Brown and Berkett, 1994; Merwin et al, 1994). As of 1996, the incidence of scab on the SRCs remained negligible in the Vermont and Pennsylvania plantings where it was initially observed. However, if the SRCs were widely planted in the Northeast, they might require occasional applications of broad spectrum fungicides to forestall selection of races of Venturia inaequalis able to overcome the Vf and Vm resistance genes.

Evaluating reduced environmental impacts of SRC production

A complex environmental question emerged from our project after several years. We had shown that SRCs enabled 50-100% reductions in fungicide usage. Additional reductions in herbicides and insecticides were possible when advanced IPM methods where implemented in SRC orchards. Although an immediate savings of $200 per acre in pesticide costs was possible, this economic assessment did not include the indirect benefits that accrued from reduced environmental impacts of pesticides in orchard ecosystems or improved regional food systems. We wondered if it would be possible to develop an environmental impact assessment for different apple production systems that would include more than just pesticide inputs.

The flexibility of our project management system made it possible for us discuss, adapt and divert some funds to explore this question in 1992. Starting with the prototype pesticide impact model of Kovach et al. (1992), we conducted a thorough review of current methodologies and databases for assessing environmental impacts of different pest-control practices (Levitan et al, 1995). Major obstacles to meaningful, holistic impact assessment were identified. These included the lack of comparable or complete databases for pesticide effects on key processes, species, and components of agroecosystems. Research linkages were developed with EPA and USDA. Although this work was later continued under separate federal funding, research initiated as part of our apple project is now influencing regional, national and international discussions about pesticide policy, farmer decision tools and eco-labeling systems based on environmental impact criteria (Levitan, 1997). Conclusions and recommendations drawn from the work include the following:

1. There is no single definitive set of appropriate environmental and social parameters to consider in evaluating pesticide risk. Pesticide use (by weight or volume) is a is a commonly used but inadequate proxy for pesticide risk. The choice of risk indicators depends upon available data, how system developers and users value different components of the environment, and the scale, objectives, and proposed application of the assessment tool. In part, the choice and weighting of risk indicators reflect value judgments, but such judgments do not necessarily imply bias or illogic. Rather, they will ideally reflect the considered (expert) opinions of stakeholders. The assumptions and structure of assessment systems should be transparent and flexible to enable (a) evaluation of the underlying value judgments, (b) modifications of the system, and (c) sensitivity analysis of the results.

2. Pesticide risk indicators and assessment systems should, as much as possible, incorporate complex ecological realities into tools that are simple-to-use and understand. The validity and utility of pesticide decision tools will improve as the structure and scoring methods of prototype systems are critiqued and improved and as data become more accessible and are generated for a broader array of environmental indicators. Currently, most pest control impact data reflect the toxicity of single doses of single active ingredients to single species of test organisms. Data gaps exist for interactive and secondary effects, impacts of chemical mixtures, impacts at higher levels of ecological organization, and sub lethal effects on long term health and biodiversity.

3. Assessments of the economic costs of pesticide use (or non-use) should include costs borne by society, such as costs for remediation of environmental problems as well as costs borne by the agricultural producer. Production costs should be labeled as such, rather than referring to this subset of costs by the broader term "economic costs." Costs of production should be assessed separately from human health and ecological effects because the magnitude of production costs does not alter the magnitude and importance of environmental effects. However, farm-level decision tools must be able to evaluate both production costs and environmental impacts within an integrated framework so that tradeoffs can be visualized, calculated and considered.

4. Pest control is just one dimension of sustainable agriculture, and pesticidal products are just one type of pest control. Both must be considered within the broader context of sustainability criteria, including the consumption and degradation of energy and natural resources; social stability and vitality of farms and communities; and landscape protection for wildlife habitat, ecological processes, and human renewal.

Advances in apple IPM

Research on IPM strategies applicable to scab-susceptible cultivars provided information that was immediately integrated into state apple IPM programs. Control strategies for sooty blotch and flyspeck were evaluated, and research on a computer-based predictive model for timing summer fungicides was initiated and is being continued with other funding sources. A two-year trial in MA where no summer fungicides were applied demonstrated that summer-pruning alone reduced flyspeck by 50%. In commercial orchard blocks using fungicides, summer pruning also significantly reduced disease incidence and improved fruit quality (Cooley et al., 1992, 1997). Pruning was believed to reduce flyspeck by increasing evaporative potential within the trees and by improving spray deposition in the middle and upper portions of the trees when applications were made with an airblast sprayer. Fungicide timing studies in New York showed that flyspeck on apple can usually be controlled by fungicides applied on a three-week interval rather than the 14 day interval that was previously recommended for this disease (Rosenberger, 1994).

In Massachusetts, the SARE Apple Project comprised part of an overall apple program focused on developing and implementing advanced IPM methods. Substantial funding from the state, the federal government, the USDA Northeast IPM program and the Massachusetts Society for the Promotion of Agriculture enabled scientists in MA to make substantial progress towards what has been called second-level IPM (Prokopy et al., 1994; Prokopy et al, 1996; Cooley and Autio, 1997). Because pooled funding sources were used to advance IPM practices within the state, it is difficult to pinpoint impacts specifically attributable to the SARE apple project. Rather, advances in the state IPM program must be considered as a whole with some of the credit devolving to SARE funding.

SARE resources were used in Massachusetts to investigate methods for decreasing fungicides targeted against flyspeck and sooty blotch. Arthropod pests targeted during the summer were apple maggot, codling moth, lesser appleworm (Grapholitha prunivora), leafrollers (Choristoneura rosaceana and Argyrotaenia velutinana), mites (Panonychus ulmi), aphids (Aphis pomi and A. spiraecola), leafminers (Phylonorycter), and leafhoppers (Typhlocyba pomaria and Edwardsiana rosae). Of these, apple maggot and mites were particularly important.

Development and testing of second-level IPM strategies were done over four years, largely in blocks of 2 to 4 ha in commercial orchards in cooperation with growers. As would be expected, arthropod and disease damage prior to mid-June (about two weeks after petal fall) were similar in both standard and second-level IPM blocks. Total fruit injury from insects active after mid-June was similar in both block types in the first two years of the study (0.5%). However, in the second two years, fruit injury was greater in the second-level blocks (4.8% vs. 1.9%). This difference could be attributed largely to lesser apple worm, leaf rollers, codling moth and maggot fly. Growers used 37% less insecticide against fruit-damaging pests in the second-level blocks, though there was no difference between block types in pesticide use against foliar arthropod pests. Similarly, growers used significantly less fungicide in the second-level blocks (34% less). Results showed that pesticide-use after mid-June may be significantly reduced, but at a significant cost in terms of increased management and, over three to four years, increased insect damage.

In New Jersey, SARE funds enabled Rutgers Cooperative Extension to expand delivery of IPM scouting and information to an increasing number of growers throughout the life of the grant. The NJ program reached 50 growers in 1988, but grew to 61 growers in 1991, and 76 growers by 1996 when over 75% of NJ apple acreage was managed under IPM practices. Some growers managed part of their farms under organic protocols (Polk, 1991). Like MA, SARE funds were pooled with other federal and state support. Because of information exchange within the project, second-level IPM techniques developed in MA were extended to a limited number of growers in PA and NJ. The techniques introduced including minimizing the use of summer insecticides in order to maximize parasitism of pest populations and replacing some insecticide sprays with red sticky balls used to trap and control apple maggot flies.

3B. Dissemination of Findings

A publication titled Management Guide for Low-Input Sustainable Apple Production was authored by SARE-project participants and published in 1990. This production guide, targeted for both large and small apple producers, included comprehensive chapters on economics, horticulture, and disease and insect management, with easy-to-understand information on the best reduced-input approaches for managing orchards. The guide contained useful descriptions of scab-resistant apple cultivars, including color plates of fruit. More than 3,000 copies of the production guide were distributed, and additional copies are still requested. During the time it was published, the Northeast SARE Apple Production Newsletter was the only publication in northeastern United States committed to distributing the latest information on alternative apple production methods. Alternative was defined as methods which had potential to contribute to more ecologically-stable apple production systems. The newsletter was positioned as a non-refereed outlet for researchers, cooperative extension specialists, and growers. An average of two issues were produced annually, ranging from 8 to 28 pages per issue. The Newsletter had over 1,000 subscribers. While most subscribers were on mailing lists in the states of project participants, there were subscribers in a total of 35 states, five Canadian provinces, and five other countries. In 1993 the project organized a comprehensive workshop titled Disease-Resistant Apple Cultivars: An Update on Horticulture, Pests, and Marketing . Attended by 60 interested growers, researchers, and extension/industry personnel, the proceedings were subsequently published in Fruit Varieties Journal (Schettini and Berkett, 1994). The workshop provided the first multi-disciplinary forum (including commercial apple growers) for discussing the current status of SRCs, how to grow them, and perspectives on how SRCs would fit into future production systems. SARE project participants several hundred articles in Extension newsletters and peer-reviewed Journals during the duration of the project (Table 2). In addition, thousands of contacts were made via mass media and through presentations at grower, industry, and professional meetings. In 1994, outreach efforts were extended to the World Wide Web (WWW) by Cowgill and Clements (VanVranken and Cowgill, 1996). The Virtual Orchard (http://www.orchard.uvm.edu) is a dedicated WWW site for the dissemination via the Internet of information concerning all aspects of sustainable apple production. The Virtual Orchard has been visited many thousand times by people as far away as New Zealand and Chile, and has been cited as a valuable Internet resource for apple production in trade magazines (Malone, 1996). Several special extension education efforts sponsored by project participants are worthy of note. Taste-testing of SRCs was conducted at Terhune Orchards, Princeton, NJ, at their annual Apple Day. This event, which attracts over 13,000 attendees, provided valuable marketing information on New Jersey grown scab-resistant apples. In another cooperative effort, the University of Vermont and Vermont Apple Orchards successfully test marketed 200 boxes of Liberty fruit via a large retail farm-market in Colts Neck, NJ. Consumer acceptance of Liberty was demonstrated via taste-testing and test marketing organized during the Fall of 1992 and 1993 at Martin's Grocery, a large retail super-market chain in northern Vermont and New York (Clements et al., 1994.) Taste-testing in NJ also demonstrated consumer acceptance of several SRCs (Durner, et al., 1992).

3C Site Information

Not Applicable

3D. Economic Analysis

Economic studies of the profitability of instituting sustainable practices on apple orchards in the Northeast have focused on micro level analyses and an industry wide analysis. The industry-level analysis centered on using econometric models to evaluate the impacts of changes in the apple industry and to determine the transmission of prices between the grower, shipping point, wholesale, and retail market levels. A dynamic model of the US apple industry, including relationships for bearing acres, production, utilization, and allocation to the fresh, canned, frozen, juice, dried and other markets, was developed and results from the model were published. Micro-economic studies showed that growers can significantly reduce pesticide costs without compromising fruit quality by growing SRCs and using size-controlling rootstocks. For SRCs on M. 7 rootstock (mid-size trees), total pesticide use, including fungicides applied for summer diseases, was 40 lb. of product costing $113/Ac. This represents a 50% reduction in pesticide use compared to commercial practices with standard cultivars. On dwarf trees, the total cost was only $55/A. Growing SRCs with no fungicides, or with inadequate fungicide protection, can result in costly losses because summer diseases can reduce fruit quality. In a four-year study with Liberty apple trees in southeastern New York, the estimated gross return (in dollars per acre) was 50% greater for fungicide-treated than for untreated plots. The mean value of fruit per tree for 13 tests was $2.93 for trees receiving no fungicides during summer compared to $7.76 for trees receiving summer fungicides.

The summer fungicides applied in the sprayed plots failed to provide complete control of sooty blotch and flyspeck. If fungicides had provided complete control of these diseases, the mean value per tree would have been $9.93. For some cultivars, the increased crop value from mulched trees may justify the greater costs for the mulches. Natural and synthetic mulches were compared with mechanical tillage and herbicides as orchard ground cover management systems (GMS). Substantial differences in fruit size, color, blemishes, and pre-harvest drop among the eight apple genotypes and 10 GMS treatments resulted in a broad range of fruit packout values, from $3.48 to $7.45 per 42 pound bushel. Cumulative crop market-value estimates based on yields and proportional packouts from 1992 to 1994 also varied greatly, from $3,323 to $7,386/Ac, assuming a planting density of 270 trees/Ac. Some of the most expensive treatments were the least profitable, while trees in several low-cost mulches (white polypropylene, polyester fabric, and hay mulches) produced the most profitable crops. Voles caused more serious damage to trees under synthetic and hay mulches, despite the use of mesh trunk guards and rodenticide baits. Participating growers and retail sales reports confirm that the best immediate market potential for SRCs may exist in the low-volume direct marketing niche that constitutes an important and profitable sales outlet for many fruit growers in the Northeast.

4. POTENTIAL CONTRIBUTIONS AND PRACTICAL APPLICATIONS

Using SRCs is simply one kind of pest management tactic (genetic resistance), and therefore might be expected to have limited value if used exclusively as a disease management strategy. Used in conjunction with other IPM tactics, SRCs have the potential for reducing, but not eliminating, the need for fungicides. Several impediments to fungicide reduction exist in SRC-based systems, including potential for damage from important diseases other than scab, marginal cost savings relative to increased costs for alternative management methods, and increased risks for some alternative methods (Penrose, 1995). Project participants have also shown that the current production methods are largely defined by the free-market system that forces growers to compete on a world market to supply consumers with a blemish-free product. SRCs that are currently available should be promoted for home garden use and for niche-market sales. Fruit quality and storage life of named SRCs are not yet good enough to warrant large commercial plantings for fresh market sales. Like any other new cultivar of apples, SRCs face formidable barriers in gaining recognition and market acceptance in fresh-market channels. SRCs may gain more rapid acceptance in the processing market if acceptable selections can be identified.

5. FARMER ADOPTION AND DIRECT IMPACT

Apple production systems are very complex and change slowly. Because of the complexity of the cropping system, the value of the crop, and the high pesticide use rates, apple growers in the Northeast have traditionally benefited from a close working relationship with academic scientists and cooperative extension agents. Those familiar with the apple industry recognize that apple growers are very quick to adopt new practices that are profitable. Virtually no gap exists between advances in knowledge and technology and application of that knowledge and technology except when economic constraints limit the application. Since the introduction of IPM in the early 1970's apple growers have significantly reduced their use of pesticides both in terms of pounds and dosage equivalents applied per acre (Kovach and Tette, 1988; Prokopy et al, 1996; Cooley and Autio, 1997). This has occurred in spite of the observation that the benefits of pesticide reduction are presumably public, while the risks of loss are private (Penrose, 1995). Nevertheless, because of their continued reliance on pesticides, apple growers are sometimes considered regressive by those who believe pesticide use could be further reduced or eliminated if growers were only better educated.

6. PRODUCER INVOLVEMENT

See Table

Year	No. of meetings with growers/ consumers	Individual contacts at meetings	Estimated contacts via mass media	Extension newsletter articles/fact sheets	Citable publications
1988-1990	24	21,000	2,850,000	32	12
1991	74	21,000	1,270,000	31	29
1992	76	18,000	300,000	27	24
1993	60	12,350	---	26	12
1994	135	18,350	1,200,000	32	10
1995	45	6,000	235,000	30	14

7. AREAS NEEDING ADDITIONAL STUDY

Several areas of further research were identified in the Project's Annual Reports. These include: Breeding new scab-resistant cultivars Screening for arthropod resistance to new cultivars Building a predictive model for summer disease management that includes measurements of ambient temperature and accumulated hours of surface (apple) wetness Effects of pesticides on non-target pests Fruit thinning recommendation for new cultivars Mechanisms of soil conservation and sustainable fertility enhancement in perennial crop systems such as orchards Determine why Ziram-sulfur combination sprays provide such exceptional control of sooty blotch and flyspeck, and determine if Ziram-sulfur will also control bitter rot and black rot Effects of specific horticultural management practices (i.e. nutrition, pruning, rootstock selection, and thinning) on commercial fruit quality of SRC's.

8. PHOTOGRAPHS

Attached

LITERATURE CITED

Abrahams, N. A. 1992. Economics of low-input apple production in the northeast. M.S. Thesis, Department of Resource Economics, University of Massachusetts. 69 p.

Autio, W. R. and Costante, J. F. 1992. Ripening and storage of the 'Liberty' apple. Fruit Varieties Journal 46(4):235-244.

Biggs, A. R., Baugher, T. A. , Kotcon, J. B., Glenn, D. M., Collins, A. R., Sexstone, A. J., Hogmire, H. W., Byers, R. E., and Lightner, G. W. 1997. Growth, establishment and nitrogen utilization of four apple cultivars following rotation with corn or killed sod. Amer. J. Alt. Agric. 7:(in press).

Bower, K. N., Berkett, L. P., and Costante, J. F. 1995. Nontarget effect of a fungicide spray program on phytophagous and predacious mite populations in a scab-resistant apple orchard. Environ. Entomol. 24: 423-430.

Brown, S.K. and Berkett, L.P. 1994. An explanation of reports of apple infection on fruit of NY74828-12. Fruit Varieties Journal 48: 34.

Clements, J. M., Costante, J. F, and Berkett., L. P. 1994. Super-marketing and tasting Liberty apples in Vermont. Fruit Varieties Journal 48(1): 35-36.

Cooley, D. R., Autio, W. A., and Gamble, J. W. 1992. Second-level apple integrated pest management: The effects of summer pruning and a single fungicide application on flyspeck and sooty blotch. Fruit Notes 57 (1)16-17.

Cooley, D. R., Gamble, J. W., and Autio, W. R. 1997. Summer pruning as a method for reducing flyspeck disease on apple fruit. Plant Dis. 81 (accepted).

Cooley, D. R., and Autio, W. A. 1997. Disease-management components of advanced integrated pest management in apple orchards. Agric. Ecosyst. Environ. 58 (accepted).

Cooley, D. R., Prokopy, R. J., Mason, J., and Wright, S. 1995. Effects of pesticides on pest ecology in blocks of scab-resistant apple cultivars. Fruit Notes 60(1): 16-19.

Durner, E. F., Polk, D. F., and Goffreda, J. C. 1992. Low-input apple production systems: Consumer acceptance of disease-resistant cultivars. HortScience 27:177-179.

Kovach, J. and Tette, J. P. 1988. A survey of the use of IPM by New York apple producers. Agric., Ecosys. and Env. 20:101-108.

Kovach, J., Petzoldt, C., Degni, J., and Tette, J. 1992. A method to measure the environmental impact of pesticides. N. Y. Food and Life Sciences Bull. No. 139. 8 p.

Levitan, L. , Merwin, I. and Kovach, J. 1995. Assessing the relative environmental impacts of agricultural pesticides: The quest for a holistic method. Agriculture, Ecosystems Environ. 55:153-168.

Levitan, L. 1997. An overview of pesticide impact assessment systems (a.k.a. "pesticide risk indicators") based on indexing or ranking pesticides by environmental impact. Background Paper prepared for the Organisation of Economic Cooperation and Development (OECD) Workshop on Pesticide Risk Indicators 21-23 April, 1997, Copenhagen, Denmark (revised May 19, 1997). 135 pages. Available at <http://www.pmac.net>.

Malone, L. 1996. 'Growing on the Web.' American Fruit Grower, October 1996: 14-15.

Merwin, I. A., Brown, S. K., Rosenberger, D. A., Cooley, D. R., and Berkett, L. P. 1994. Scab-resistant apples for the northeastern United States: New prospects and old problems. Plant Dis. 78:4-10.

Murphy, C., and Willett, L. S. 1991. Issues in the Development and marketing of reduced chemical agricultural products: a look at disease-resistant apple cultivars. Agricultural Economics Extension Report No. A. E. Ext. 91-34, Cornell University Dept. of Ag. Econ., Ithaca, NY.

Parisi, L., Lespinasse, Y., Guillaumes, J., and Kruger, J. 1993. A new race of Venturia inaequalis virulant to apples with resistance due to the Vf gene. Phytopathology 83:533-537.

Penrose, L. J. 1995. Fungicide use reduction in apple production -- potentials or pipe dreams? Agriculture Ecosystems and Environment 53:231-242.

Polk, D. F. 1991. Pest incidence in disease resistant cultivars grown under organic methods compared to standard cultivars grown under a traditional IPM Program. Pennsylvania Fruit News, Vol. 71(4):48-52.

Prokopy, R. J., Cooley, D. R., Autio, W. R. and Coli, W. M., 1994. Second-level integrated pest management in commercial apple orchards. Amer. J. Alt. Agric., 9: 148-156.

Prokopy, R. J., Mason, J. L., Christie, M. M. and Wright, S. E., 1996. Arthropod pest and natural enemy abundance under second-level versus first-level integrated pest management practices in apple orchards: a four year study. Agric. Ecosyst. and Environ. 57: 35-47.

Rosenberger, D. A. 1994. Summer disease control on apples. Pages 80-86 in: 124th Ann. Rpt. State Hortic. Soc. of Michigan. 250 p.

Rosenberger, D. A. 1995. A summary of five years of field research with scab-resistant apple cultivars. N.Y. Fruit Quarterly 3(3): 2-6.

Rosenberger, D. A., Engle, C.A., and Meyer, F. W. 1994. Early-season diseases occurring on scab-resistant apple cultivars and advanced selections grown in southeastern New York State. Fruit Var. Jour. 48:52-53.

Rosenberger, D. A., Engle, C.A., and Meyer, F. W. 1996. Effects of management practices and summer fungicides on productivity, incidence of sooty blotch and flyspeck, and economic value of Liberty apples. Plant Dis. 80: 798-803.

Schettini, T. M, and Berkett, L. P. 1994. Introduction to the Workshop Scab-Resistant Apple Cultivars: An Update on Horticulture, Pests, and Markets. Fruit Varieties Journal 48(1): 33-34.

VanVranken, R. W., and Cowgill, W. P. Jr. 1996. Utilizing Electronic Mail List Discussion Groups on the Internet to Enhance Communication in Specific Commodity Groups. HortTechnology 6:318-324.