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Scab-Resistant Apples for the Northeastern United States: New Prospects and Old Problems

Fruit growers and the produce industry have been under intense public scrutiny during the past decade. Apples (*Malus* × *domestica*) have been especially controversial, cited by some as the epitome of healthy eating and by others as a prime example of pesticide-contaminated food. Commercial orchards in most fruit-growing regions require frequent treatments with a costly array of insecticides, miticides, herbicides, and fungicides. Pesticides compose about 13% of the costs of apple production, or $750/ha in the northeastern United States (7). Seasonal applications of pesticides in apple orchards can include more than 20 different chemicals, in 12–18 separate treatments, in quantities approaching 80 kg/ha annually (8). Apple scab, caused by *Venturia inaequalis* (Cooke) G. Wint., is the most widespread disease and accounts for much of the pesticide usage on apples. Uncontrolled apple scab can have catastrophic consequences—total crop loss, defoliated trees, increased susceptibility to winter cold injury, and decreased bloom or crop in subsequent years (2).

Management programs for apple scab have evolved rapidly in recent years in response to technological, regulatory, and economic developments, and pesticide usage has been substantially reduced where integrated pest management (IPM) tactics have been implemented. In this article, we review the various options and IPM strategies for scab control, describe recent progress in the breeding and evaluation of scab-resistant apple cultivars (SRCs), and evaluate the potential of SRCs to reduce the need for fungicides in apple production. Determining the commercial potential of selected SRCs is the focus of a comprehensive, multidisciplinary project involving researchers and extension specialists at Cornell University, the Rodale Institute Research Center at Kutztown, Pennsylvania, the University of Massachusetts, and the University of Vermont. More than 3,500 scab-resistant apple trees are being evaluated at 50 orchards across five states in this ongoing project, which was initiated in 1988 and is supported in part by the USDA Sustainable Agriculture Research and Education (SARE, formerly LISA) program. The major objectives of the project are to: 1) develop more sustainable apple production systems for the northeastern United States by use of SRCs and IPM techniques, 2) provide economic and environmental impact analyses comparing conventional and alternative apple production systems, and 3) expedite transfer of research information and adoption of more sustainable systems by commercial fruit growers.

Historical Background

Scab has plagued apple growers for many centuries; symptoms of the disease are evident on fruit in still-life paintings dating back to the 14th century. The depiction of scab by artists of past eras implies that its fruit symptoms were once considered acceptable and that consumers of the past must have been less squeamish about eating blemished fruit. Also, most of the apples produced in past centuries were destined for cider or preserves, and fruit with lesions and cracks were still usable. Until the late 1800s, there were no effective chemical controls for apple scab. A few "antique" cultivars—russet types such as Roxbury Russet and Golden Russet, the Russian cultivar Antonovka, and others—were somewhat less susceptible to the disease but were also less productive or marketable than the more susceptible cultivars such as McIntosh and Delicious, which became dominant following the advent of fungicides.

Apple Scab Fungicides

The copper or sulfur-based fungicides of the early 1900s provided only preinfection protection and caused substantial injury to tree foliage. The development of effective, nonphytotoxic chemical protectants and eradicants for scab and other fruit diseases has been considered one of the success stories in modern agriculture (19). By the late 1970s there were at least 17 different fungicides in some 30 brand-name formulations available for controlling apple scab. With the recent availability of sterol biosynthesis inhibiting (SI) fungicides (fenarimol, myclobutanil, and flusilazol), growers are afforded unprecedented postinfection control of apple scab, cedar apple and quince rusts caused by *Gymnosporangium* spp., and powdery mildew caused by *Podosphaera leucotricha* (Ellis & Everh.) E.S. Salmon with fewer applications of fungicides (12,27). The narrow-spectrum SI fungicides are usually combined with broad-spectrum protectant fungicides to increase efficacy and minimize the selection of resistant scab biotypes. However, registrations for most of the key broad-spectrum protectant fungicides—the ethylene-bis-dithiocarbamates (EBDCs), captan, and the benzimidazoles—are now jeopardized because of the zero-risk standard imposed by the Delaney Amendment (22). Further prohibition of the use of broad-spectrum fungicides may severely limit chemical options for scab control and cause the apple industry to resort increasingly to cultivars resistant to scab.

Other factors are also changing management strategies for the apple disease complex. Fewer than one-half of the fungicides available a decade ago are still registered and effective against scab (Table 1). Dodine and the benzimidazoles benomyl and thiophanate-methyl are still available but are no longer effective in many orchards because of resistant strains of *V. inaequalis* and *P. leucotricha*. Resistance to the SI fungicides has also been reported in several loca-

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tions (11,16), but this problem is not yet widespread. As more rigorous testing requirements have been imposed for registering new fungicides and reregistering older ones, corporate and government funds that could have been directed toward developing novel fungicide chemistries have instead been diverted into registration expenses. The future availability of fungicides for managing scab and other tree-fruit diseases has become increasingly uncertain, and there is renewed interest in other disease management strategies.

IPM Tactics for Scab Control

Contemporary IPM strategies for scab control are based primarily on precise timing and application of fungicides to reduce disease inoculum or eradicate incipient infections. Various models have been proposed for predicting key developments in the epidemiological cycle of scab, but most growers continue to rely on refined versions of the venerable Mills system (20) to determine the occurrence of infection periods and the optimal timing of fungicide applications. Plant pathologists in the northeastern United States monitor weather and crop data with electronic devices and sample pseudothecia in overwintering leaves to predict the release of primary ascosporic inoculum (13). Simulation models such as the one described by James and Sutton (17) have been proposed for predicting ascospore maturity, but none is currently used by commercial growers because the predictive confidence intervals are too wide to provide a sufficient margin of crop safety. Also, the recent report (4) that viable conidia of *V. inaequalis* can overwinter within apple buds indicates that suppression of ascosporic inoculum may not adequately control scab in orchards with high carryover disease pressure.

Table 1. Fungicides available for controlling apple scab over the past two decades

1973	1983	1993
Benomyl	Benomyl	Benomyl[a,b]
Captafol	Captafol	
Captan	Captan	Captan[b]
Dichlone	Dichlone	
Dodine	Dodine	Dodine[a]
Ferbam	Ferbam	Ferbam
Folpet	Folpet	
Glyodin	Glyodin	
Maneb + zinc	Maneb + zinc	
Metiram	Metiram	Metiram[b]
Sulfur	Sulfur	Sulfur
Thiram	Thiram	Thiram
Zineb	Zineb	
Ziram	Ziram	Ziram
	Thiophanate-methyl	Thiophante-methyl[a,b]
	Triforine	Triforine
		Fenarimol
		Myclobutanil

[a] Of limited usefulness because resistant strains have developed in many orchards.

[b] Future registration status uncertain because currently listed by EPA as potential Class B or Class C human carcinogen.

The risk of scab epidemics can be greatly reduced by cultural practices that minimize inoculum from the previous year. Removing or destroying infested leaves on the orchard floor can substantially reduce overwintering inoculum. Natural degradation of leaves has been enhanced by applying urea sprays in the fall, by tilling leaves into the orchard soil, and by chopping leaves with flail mowers. Establishing fungal saprophytes such as *Athelia bombacina* Pers. on apple leaves and applying such compounds as dinitro-*o*-cresol (Elgetol), benzimidazoles, and some SI fungicides after harvest have also been shown to reduce development of pseudothecia in overwintering scabby leaves (12).

Several novel tactics for inoculum reduction are being evaluated by growers and researchers in the Northeast. One strategy is to induce noninfective spore release by applying water to orchards with a sprayer when ascopores are ready for release but the weather is not conducive to germination and infection. Another strategy, being evaluated by Burr et al (6) in New York, involves isolating hyperparasitic bacteria and fungi from orchard soils, scab lesions, and pseudothecia on fallen leaves. They report (6) finding several promising antagonistic microorganisms, including one strain of *Pseudomonas syringae* van Hall that appeared to control scab as effectively as captan under greenhouse conditions. At present, these inoculum reduction methods are not widely used in commercial orchards because they are perceived as unproven or uneconomical. Growers find it inconvenient to reactivate sprayers after harvest to apply fungicides, urea, or biocontrol agents. Also, overwintering inoculum is never completely suppressed within an orchard, and commercial orchards in the Northeast are usually close to abandoned orchards, wild apple trees, and other sources of scab inoculum.

The integration of improved models for predicting scab infection periods, cultural practices and biological control agents that reduce scab inoculum, and narrow-spectrum fungicides with greatly improved postinfection activity into coherent disease management programs has enabled apple growers to effectively reduce crop losses to scab in most years. However, even the most advanced IPM strategies are based on the continuing availability and affordability of effective fungicides. Given the possibility of drastically reduced fungicide options in the future, there is much interest in apple cultivars with field resistance to scab and other major fungal diseases.

Disease-Resistance Breeding Programs in North America

Table 2. North American disease-resistant apple breeding programs, selected cultivars introduced (with year of formal release), and advanced selections undergoing final evaluations

Purdue/Rutgers/Illinois	Cornell/Geneva	Nova Scotia	Ontario/Quebec
Prima (1970)	Liberty (1979)	Nova Easygro (1971)	Macfree (1974)
Priscilla (1972)	Freedom (1985)	Nova Mac (1978)	Moira (1978)
Priam (1974)	NY74828-12	Nova Spy (1986)	Trent (1978)
Sir Prize (1975)	NY75414-1		Britegold (1978)
Jonafree (1979)	NY7541330		Murray (1978)
Redfree (1981)	NY73334-35		Richelieu (1983)
Dayton (1988)			Rouville (1983)
McShay (1988)			
William's Pride (1988)			
Enterprise (1992)			
Goldrush (1992)			
Co-op 27-29 and 31			

There are currently three major programs to develop disease-resistant apples in the United States and Canada (Table 2). A cooperative breeding program involving Purdue, Rutgers, and Illinois universities (PRI) was initiated in 1948 to develop scab-resistant apples. By 1992, the PRI program had named and released 11 cultivars (9). The program is now in transition, formulating plans concerning future collaborations and continuing to stress disease resistance, using both traditional and molecular plant breeding techniques. Cornell University's disease-resistant apple breeding program was initiated at the New York State Agricultural Experiment Station in Geneva in the late 1940s. From the outset it has emphasized disease resistance to apple scab, cedar apple rust, powdery mildew, and fire blight. Two cultivars have been named, and many advanced selections are available for testing. The Cornell/Geneva program emphasizes integration of traditional and molecular methods to genetically improve apples. Many researchers are involved cooperatively in projects on developing regeneration, transformation, and genetic mapping systems; on targeting resistance to virus, fungal, and bacterial diseases; on enhancing quality; and on genetically regulating tree form.

Several apple breeding programs in Canada have concentrated on disease resistance. The breeding and evaluation of cultivars resistant to apple scab began at two Department of Agriculture facilities in Ontario in 1949. Five SRCs were released from 1974 to 1980 by breeding programs in Ottawa and Trenton, Ontario (15). The Ontario programs have since been discontinued, and the remaining advanced selections are being evaluated and released at the Agriculture Canada Research Station in Saint-Jean-sur-Richelieu in Quebec. The breeding program at the research station in Kentville, Nova Scotia, has released three SRCs, and plans are under way to license this material for distribution in the United States. The Nova Scotia program is emphasizing resistance to scab and other major diseases, with an interest in pyramiding sources of resistance from diverse apple types. SRC apple breeding programs are also under way in France, England, Russia, the Netherlands, Poland, Romania, and Brazil (9).

Genetic Sources of Resistance

Quantitative and qualitative sources of resistance to scab are available, with the latter behaving as single dominant genes or a block of closely linked genes (29). Both types of resistance may confer field immunity to scab with either no macroscopic evidence of infection or fewer and smaller sporulating lesions. Resistance to scab was first noted in progenies of *Malus floribunda* 821 (25). A program was initiated in 1955 to study sources of resistance and to determine the relationship of the scab resistance genes, and symbols were designated to identify the different gene loci. Ten of the qualitative genes were identified as being located at the V_f (*M. floribunda* 821) locus and two at the V_m (*M. micromalus* pit) locus. The later discovery of pathogen race 5 and the finding that both *M. micromalus* and *M. atrosanguinea* 804 were susceptible to this race provided evidence that both loci have the same gene (28). Three other loci—V_b (Hansen's baccata No. 2), V_{bj} (*M. baccata jackii*), and V_r (*M. pumila* R12740-7A)—were identified, with a single gene pair at each.

Controlled inoculations under greenhouse conditions established definite reaction classes for each source of resistance (25): class 1 = pinpoint pits and no sporulation; class 2 = irregular chlorotic or necrotic lesions and no sporulation; class 3 = few restricted sporulating lesions; class M = mixture of necrotic, nonsporulating, and sparsely sporulating lesions; and class 4 = extensive, abundantly sporulating lesions. The class 1 (pinpoint) reaction is considered a hypersensitive response in which host epidermal cells below the infection peg collapse within 40–72 hours and the fungus is killed soon after. The other classes of host reactions are not expressed until 3–12 days after inoculation, and the fungus remains viable for as long as 21 days. Breeding programs vary in classification of scab-resistant plants. The PRI program considers classes 2, 3, and M as resistant and only class 4 as susceptible, which has resulted in nearly 1:1 ratios of resistant to susceptible progeny in their crosses. The Cornell/Geneva program defines resistance more stringently, with any sporulation classified as a susceptible host response. This conservative rating system has produced a much lower proportion of resistant progeny, but the justification is that any sporulation in the greenhouse might indicate susceptibility under field conditions.

There has always been a concern that new races of the pathogen might arise and overcome existing sources of scab resistance. For this reason, most breeding programs inoculate young seedlings with a mixture of the known scab races and provide optimum conditions for disease development. Because of a close correlation between leaf and fruit infection, progeny can be rated and eliminated at the seedling stage, greatly reducing expense and time involved. Five different virulent races were initially identified on apple, four of which can overcome certain genes for resistance (28). The recent report of a new sixth race of *V. inaequalis* capable of overcoming the resistance of some SRCs with V_f resistance, but not the resistance of *M. floribunda* 821 itself, is of great concern (23). At two of our Northeast SARE apple plantings, variants of scab have appeared in the advanced selection NY74828-12, which relies solely on the V_m resistance gene. These observations emphasize the need to diversify sources of resistance, to combine at least two independent genes in new cultivars, and to develop new breeding strategies. The situation also illustrates the importance of developing integrated strategies for deploying disease-resistant fruit cultivars in commercial production. For example, it may be that one or two applications of a broad-spectrum fungicide in SRC orchards early each summer—as is often recommended for SI fungicide programs—would be beneficial in delaying or averting the selection of pathogen biotypes resistant to the V_f genes.

The possible vulnerability of our apple scab-resistant material needs to be stressed. Of the approximately 50 scab-resistant cultivars that have been released worldwide, 39 are reported to carry the V_f gene from *M. floribunda* 821. Freedom carries additional polygenic resistance from Antonovka, Rouville has the V_m gene from *M. atrosanguinea* 804, Nova Easygro and Nova Spy have the V_r gene from a Russian seedling, and Murray has the V_m or V_f gene from *M. micromalus* (9). The extensive reliance on V_f as a source of resistance needs to be curtailed, and pyramiding of genes should be a high priority in breeding programs. Breeders also need to ensure that minor genes for resistance are not ignored. Rousselle et al (24) suggested that the expression of V_f may be modified by minor genes, transmitted by resistant or susceptible parents, with additive effect. A loss in quantitative factors fortifying the resistance may also be occurring within some breeding protocols. The work on finding molecular markers for sources of scab resistance will greatly increase the efficiency by which multiple sources of resistance may be pyramided.

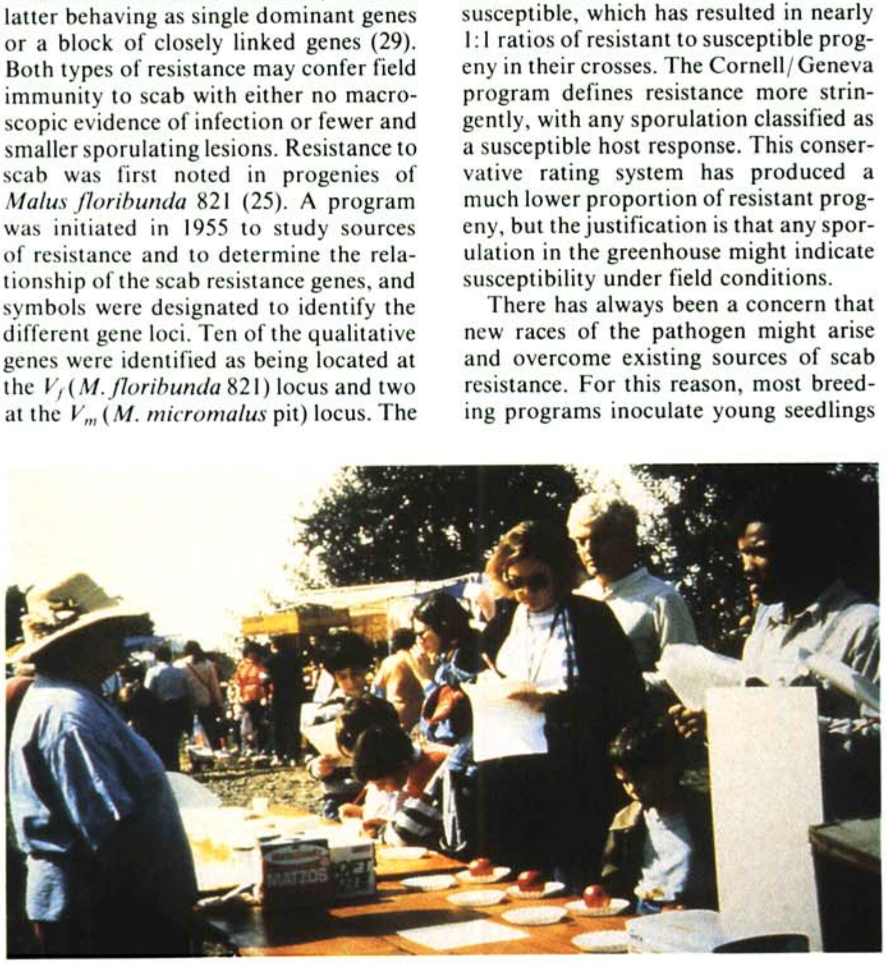


Fig. 1. Taste panels conducted by participants in the USDA Sustainable Agriculture Research and Education (SARE) project in the northeastern United States indicate consumers may prefer several of the scab-resistant apple cultivars to conventional cultivars.

Breeding Strategies

The original *M. floribunda* 821 that provided the V_f resistance gene has very small fruit (<2 cm in diameter) and unpalatable crabapple fruit characteristics. An examination of the pedigrees of most scab-resistant material reveals identical first- and second-generation crosses. In the first generation, *M. floribunda* 821 was crossed with Rome Beauty. Two sister seedlings selected from this cross for their scab resistance and fruit characteristics were intercrossed to produce an F_2 seedling designated 26829-2-2. These two generations from the original crosses are the common progenitors of many of today's named cultivars, with subsequent generations reflecting the particular priorities of each breeding program (9). To improve size and quality in these early generations, and still maintain scab resistance, a modified backcrossing procedure was necessary. Apple suffers from inbreeding depression, so repeated backcrossing to the same parent is not desirable. In a modified backcrossing strategy, the seedling with the best size and commercial quality that possesses resistance to scab is selected in each generation and crossed to a different high-quality recurrent parent. This process is continued for as many generations as are required to produce the qualities desired. Most scab-resistant cultivars currently being tested represent four or five generations from the original *M. floribunda* × Rome Beauty cross.

Genetic engineering techniques hold promise for future possibilities of cloning resistance genes for apple. Molecular markers are being found for scab resistance and are also being sought for other disease resistance genes. Closer linkage between the markers and genes for resistance is needed before gene cloning becomes a possibility. The polyploid nature of apple may make this approach difficult, because genes for scab resistance may behave like single genes but actually be much more complex. Recently determined markers and those now being sought should facilitate the pyramiding of resistance genes and avoid the need for extensive progeny testing. Genes outside of *Malus* with broad-spectrum activity against fungal pathogens are also being examined. Recent advances in developing transformation and regeneration systems in apple make future prospects for improvement excellent. In fact, some growers are hesitant to plant SRCs at this time because they anticipate that scab-resistance traits may soon be available in transgenic lines of familiar cultivars such as Delicious and McIntosh.

Availability and Acceptance of Scab-Resistant Cultivars

Scab-resistant cultivars introduced by Cornell, Nova Scotia, and the PRI program are now available from several commercial nurseries in the United States. Advanced selections undergoing final evaluations are available from Cornell's program under a nondistribution agreement, and selections from the other programs may also be available for field testing with certain restrictions. Although SRCs have been available for several decades, almost all of the major commercial cultivars today are older, scab-susceptible types that originated as chance seedlings in the late 1800s. This situation contrasts sharply with agronomic crops, where producers quickly adopt the latest disease-resistant cultivars of maize, rice, wheat, and soybeans as these become available. Unique consumer attitudes about apples are partly responsible for this anomaly. Few market patrons inquire or care about particular cultivars of wheat or maize, but most have definite favorites when it comes to apples for fresh consumption. Buyer loyalty to old-time favorites has made growers and commercial outlets reluctant to commit precious retail shelf space to the new scab-resistant apples.

Despite these limitations, there is increasing interest in SRCs from growers and processors. For example, although Liberty accounted for only 0.6% of the apple acreage planted in New England during 1985–1989, an increase to 5% of new plantings has been projected for 1990–1994 (3). Mounting concerns about pesticide applications may be fueling some of this interest, but the higher quality of recent disease-resistant releases is also a factor. Taste panel evaluations conducted by SARE project participants around the Northeast indicate excellent consumer acceptance of several SRCs (Fig. 1). Two new introductions from the

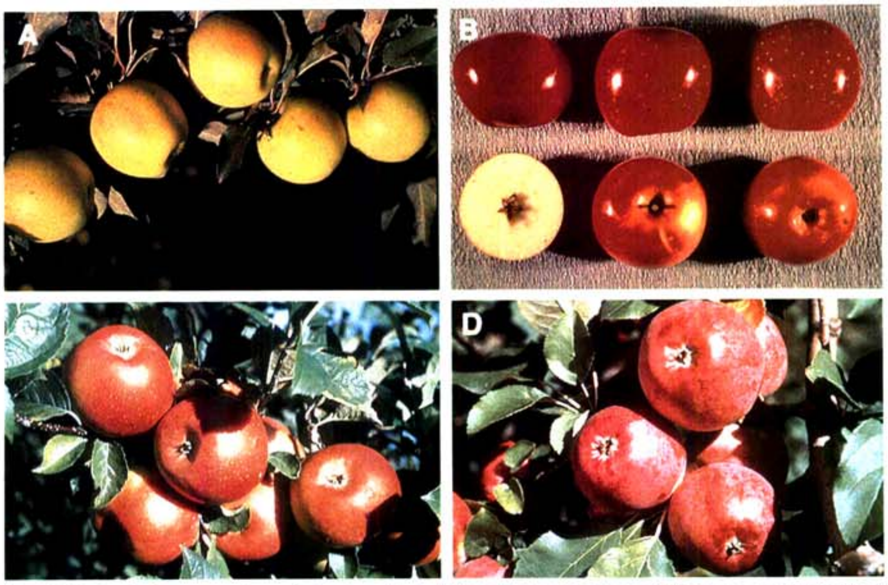


Fig. 2. Selected new scab-resistant apple cultivars from the Cornell/Geneva and Purdue/Rutgers/Illinois breeding programs: (A) Goldrush, (B) Enterprise, (C) Freedom, and (D) Liberty.

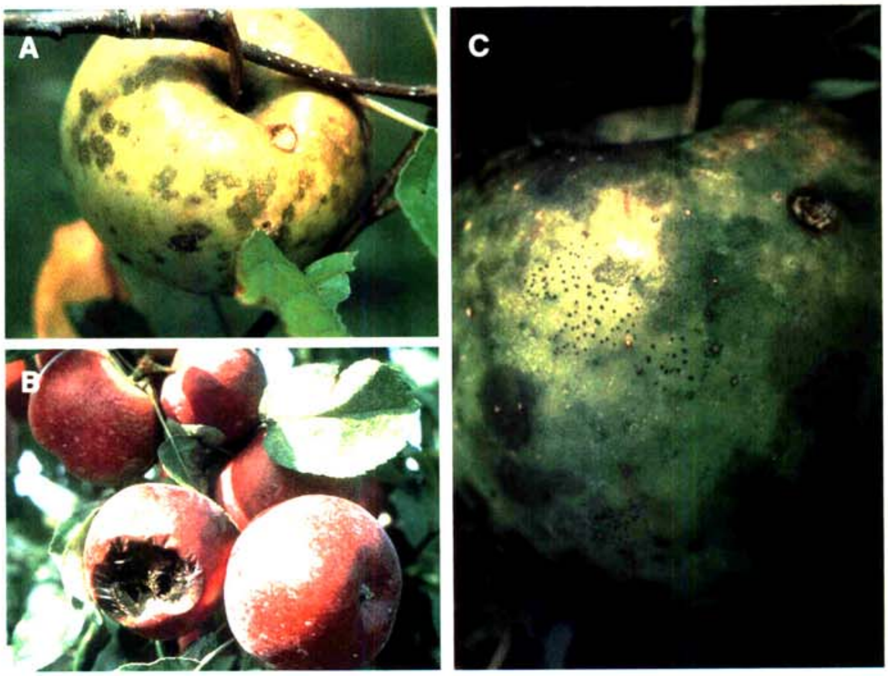


Fig. 3. So-called summer diseases on scab-resistant apple cultivars not receiving any fungicides: (A) Sooty blotch on Sir Prize, (B) black rot on Liberty, and (C) sooty blotch and flyspeck on Freedom.

PRI program, Goldrush (Fig. 2A) and Enterprise (Fig. 2B), were recently rated better than standard cultivars and other SRCs after 5 months in cold storage (T. M. Schettini, *unpublished*). Durner et al (10) reported that tasters in New Jersey consistently rated four SRCs—Freedom (Fig. 2C), Liberty (Fig. 2D), Prima, and Priscilla—better than the standard cultivar Delicious. Similar results were reported by J. M. Clements et al (*unpublished*) in a Vermont market. It thus appears that consumers might accept many of the SRCs if they were aggressively marketed in commercial channels.

The SRCs now available represent a wide range of fruit types, maturity dates, and postharvest storage potential. Like other apple cultivars, they are likely to vary substantially in adaptability to different growing conditions. A priority in our SARE projects has been the establishment of SRC plantings in diverse commercial orchards to evaluate cultivar performance in the different pest complexes, soil types, mesoclimates, and markets of the Northeast. Providing reliable information on the quality and performance of these new cultivars and establishing test plantings in commercial orchards may actually be necessary to attain grower acceptance. Establishing a modern high-density apple orchard and bringing it into production usually costs more than $20,000/ha, and the financial risk is high even for plantings of standard cultivars. Most fruit growers are highly specialized and produce only a few cultivars for a specific market outlet. The present apple marketing system is based on the mass production of some 10 cultivars (all scab-susceptible) and demands consistent year-round deliveries of fruit uniform in size, appearance, taste, texture, and shelf life. These factors all work against the adoption of new cultivars by commercial growers.

On the other hand, consumers today are much more interested in trying new foods and fruit cultivars than in past years. In recent years, a few growers have profited greatly by anticipating the next "hot" new apple cultivars, because these often command substantially more than the conventional types in wholesale markets. Following the recent successes of Braeburn, Fuji, and Gala (all introductions from scientific breeding programs), growers are much more interested in new cultivars. A market structure and feasibility study of SRCs in the Northeast (21) indicated that cultivar novelty could provide an important marketing advantage for SRCs, because a pesticide-conscious public and produce industry might be receptive to new apple cultivars that require few or no fungicides and taste as good as or better than the conventional favorites. However, this market analysis also suggested that because of the intense competition for produce shelf space in most markets, sales promotions and commitments by growers will be essential to provide adequate fruit for specific retail outlets.

Significant savings in fungicide application costs may result from production of disease-resistant cultivars. A microeconomic analysis by Abrahams (1) indicated that growers in the Northeast might save $475/ha annually by producing SRCs instead of McIntosh or Empire apples. However, the estimated market value of a typical 35 Mg/ha (725 bu/acre at $8/bu) apple crop is more than $14,300. The saving in fungicide costs for SRCs therefore represents only 3% of the crop value and could easily be offset by equivalent differences in the market value or productivity of a particular cultivar. To provide meaningful economic advantages over the standard cultivars, therefore, the SRCs must excel in every other important attribute. A central component in our SARE apple projects has involved replicated plantings of selected SRCs in five northeastern states, along with Empire, a productive, high-quality apple well adapted to the region, as a standard control for comparing tree vigor, hardiness, productivity, and other essential attributes. To date, it appears that yield and tree establishment of several of the SRCs compare favorably with those of Empire.

Problems and Benefits

Several other important diseases of apple may limit the widespread adoption of scab-resistant cultivars. Some SRCs have also been bred and selected for resistance or field tolerance to other prevalent diseases, such as powdery mildew, cedar apple and quince rusts, and fire blight. The cultivars with this multiple disease-resistance should provide the greatest opportunities for reducing fungicide use in northeastern orchards, because those resistant only to apple scab will still need several fungicide applications each season to protect trees and fruit from rusts and powdery mildew in areas where these are perennial problems (26). Morever, certain other "minor" or "summer" fruit diseases may also become significant problems in SRC orchards where fungicide treatments are substantially reduced (Fig. 3). These include black rot and white rot caused by *Botryosphaeria* spp., bitter rot caused by *Colletotrichum* spp., sooty blotch caused by *Gloeodes pomigena* (Schwein.) Colby, and flyspeck caused by *Schizothyrium pomi* (Mont. & Fr.) Arx. Prior to the development of broad-spectrum fungicides, these now "minor" diseases were often major problems. In recent decades, they have been coincidentally suppressed by fungicides targeted at scab and the other major apple diseases.

A priority of the Northeast SARE projects has been to evaluate the extent to which minor fruit diseases might become a problem in SRC orchards. Several experiments in New York and Massachusetts have evaluated cultural practices—e.g., summer pruning, planting densities, and training systems that increase air circulation and reduce humidity in the tree canopy—as methods to reduce the incidence of summer diseases. Observations to date indicate that in certain regions and summers, sooty blotch and flyspeck are likely to cause serious problems in SRC orchards. Dur-

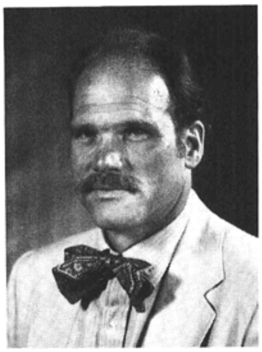
Table 3. Percentage of fruit with flyspeck and sooty blotch and mean yields of cv. Liberty apples (planted on M.9 rootstock in 1987) in relation to tree planting density, ground cover management, fungicide treatments, and fruit position in dry (1991) and wet (1992) years in Hudson Valley, New York

		Flyspeck (%)		Sooty blotch (%)		Mean yield (t/ha)	
Treatment	**Comparison**	**1991**	**1992**	**1991**	**1992**	**1991**	**1992**
Tree density	1,400/ha	11.1	62.2	0.8	18.8	11.9	27.9
	2,300/ha	11.7	64.1	2.0	20.3	20.3*[a]	42.2*
Ground cover	Mowed	9.8	62.4	0.7	17.6	14.5	35.1
	Unmowed	13.2	64.0	2.1	21.5	17.8	35.0
Fungicide	Sprayed[b]	1.6	45.2	0.0	4.3	17.4	36.3
	Unsprayed	28.6*	79.4*	5.3*	42.2*	14.9	33.8
Fruit position	Upper limbs	...[c]	48.3	...	8.8	...	...
	Lower limbs	...	67.7*	...	33.2*	...	...

[a] Significantly different at $P < 0.05$.

[b] Benzimidazole + captan fungicides in mid-June, mid-July, and mid-August.

[c] Not evaluated.



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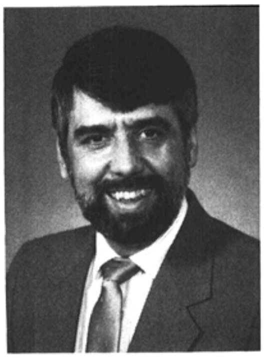
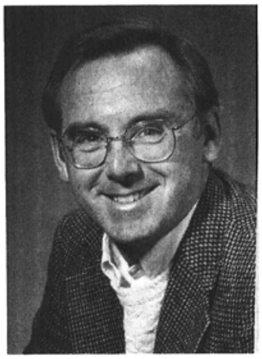


D. A. Rosenberger



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Dr. Merwin was raised on a farm in New York's Hudson Valley and received his B.A. (1969) from Reed College in Portland, Oregon. After a year traveling in South America on a Watson Fellowship, he worked as a gardener and operating engineer in Golden Gate Park, San Francisco, California, for 12 years. He then completed a Ph.D. (1990) in pomology, plant pathology, and ecology at Cornell University and shortly thereafter was appointed assistant professor with research and teaching responsibilities in the Department of Fruit and Vegetable Science at Cornell. His research interests include orchard agroecology, IPM, environmental impacts of fruit production, biological control of plant-parasitic nematodes, orchard floor management, and international agriculture. His primary role in the Northeast LISA-SARE projects has been the horticultural evaluation and management of scab-resistant apples.

Dr. Brown received her B.S. (1978) at the University of Connecticut, M.S. (1980) at Rutgers University, and Ph.D. (1984) in genetics at the University of California at Davis. In 1985, she joined the tree fruit breeding program at the New York State Agricultural Experiment Station in Geneva, where she is currently an associate professor in the Department of Horticultural Sciences. Her research program involves quantitative and qualitative genetic studies aimed at understanding and improving apple germ plasm, utilizing traditional and molecular approaches. Her role in the Northeast SARE apple projects has involved the breeding, selection, and field evaluation of disease-resistant apples.

Dr. Rosenberger received his B.A. degree (1969) from Goshen College, Goshen, Indiana, spent 2 years doing rural development work in Algeria, then completed his Ph.D. (1977) at Michigan State University, East Lansing. In 1977, he joined the faculty in the Department of Plant Pathology at Cornell's Agricultural Experiment Station in Geneva and became the research and extension tree fruit pathologist at Cornell's Hudson Valley Laboratory in Highland, New York. He was appointed superintendent of the Hudson Valley Laboratory in 1990. Dr. Rosenberger conducts applied research on the biology and chemical control of fungal pathogens of tree fruits. In 1988, he helped organize the five-state Northeast Sustainable Apple Production Project, which has been funded by the USDA through its programs for Low-Input Sustainable Agriculture (LISA) and Sustainable Agriculture Research and Education (SARE). Within this project, Dr. Rosenberger has concentrated on developing disease management strategies for scab-resistant apple cultivars.

Dr. Cooley received his A.B. degree (1974) at Harvard College, M.S. (1978) at the University of Vermont, and Ph.D. (1986) in plant pathology at the University of Massachusetts. He is currently assistant professor of plant pathology at the University of Massachusetts. His research specialty is management of fruit diseases, and he has worked in a number of areas, including interactions between air pollutants and fungal pathogens, computer applications for decision support in disease management, and chemical management of plant diseases. His present research involves disease ecology and biointensive IPM of strawberry and apple pathosystems, and his major role in the Northeast SARE apple projects has been alternative management strategies for the so-called summer diseases.

Dr. Berkett received a B.A. degree in biology from Gettysburg (PA) College, a M.S. degree in entomology from the University of Maine at Orono, and a Ph.D. in plant pathology from The Pennsylvania State University. During all three degrees, she was involved in IPM in apple production, gaining experience in commercial orchards and at PSU's Fruit Research Laboratory, Biglerville, where she worked with Dean Asquith, entomologist, and, more recently, with Kenneth D. Hickey, plant pathologist. For the past 5 years, Dr. Berkett has been the overall project coordinator for the USDA SARE Project on the Development of Sustainable Apple Production Systems for the Northeast. Recently, she was appointed chairperson of the Department of Plant and Soil Science at the University of Vermont, Burlington, where she has been a faculty member for 10 years, with primary responsibilities for IPM research and extension on apples.

ing two summers in New York's Hudson Valley, much of the fruit from unsprayed Liberty trees was unmarketable because of sooty blotch or flyspeck blemishes (Table 3). Reducing tree planting density or close mowing of the orchard ground cover to increase air circulation in the tree canopy did not significantly reduce the incidence of these diseases; there was more diseased fruit in the wet summer of 1992 and on lower branches within the trees. In another study, summer pruning did significantly reduce the incidence of flyspeck in a Massachusetts orchard with less disease pressure (D. R. Cooley, *unpublished*). We have also observed severe black rot, sooty blotch, and flyspeck infections on some of the other SRCs in our SARE plantings not receiving fungicides. There may be fewer problems in cooler, drier regions or summers, but it appears that the SRCs will require broad-spectrum fungicide sprays to control these fruit diseases in certain regions or during unusually humid summers.

On the positive side, there may be arthropod pest management benefits associated with reduced fungicide use in scab-resistant apple orchards. Researchers in many regions have noted that some of the fungicides used for scab control adversely affect predators of insect and mite pests. Eliminating early-season fungicides has in some cases reduced the need for miticide sprays later in the season (14) and increased the populations of predatory stigmaeid and phytoseiid mites (5). From a more holistic perspective, project participants are also adapting the "environmental impact quotient" computer model of Kovach et al (18), integrating toxicological, edaphic, economic, and non-point source pollution databases to assess subtle or long-term impacts on the farm or regional agroecosystem that may accrue from the shift to low- or zero-fungicide apple production.

Growing cultivars genetically resistant to diseases is a widely utilized and effective management practice in many crops. Given the environmental, health, and economic concerns related to fungicide use, the important question is whether SRCs are a viable alternative option for commercial apple production. To find the answer we must determine the climatic and edaphic adaptability of the SRCs, their relative productivity under commercial orchard conditions, and their optimal harvest dates, storage conditions, and market niches. We should also develop low chemical input systems for insect and weed management that complement the SRC's reduced fungicide input requirements. Providing such multifaceted information for a five-state region has required innovative organizational and research tactics. The Northeast SARE apple projects involve 22 principal investigators spanning the disciplines of economics, entomology, horticulture, plant pathology, plant breeding, and soil science. The logistical demands of integrating projects in these different disciplines have been formidable, but we believe the effort is essential for developing a database to enable rapid deployment of SRCs. Coordinated extension efforts must also be mounted to transfer on-farm research information quickly to other growers and regions. If successful, our projects will determine the relative strengths and weaknesses of the SRCs and may facilitate their acceptance by growers, the produce industry, and the general public. This could help reduce fungicide usage by northeastern fruit growers and provide alternative fruit cultivars and production systems for the future.

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