OFFICIAL

Northeast Regional Research Project Statement

PROJECT NUMBER: NE-183
TITLE: Multidisciplinary Evaluation of New Apple Cultivars
DURATION: October 1, 1999, to September 30, 2004

STATEMENT OF THE PROBLEM:

New apple cultivars are continuously being developed around the world. Both the apple industry and scientists working on fruit research can benefit from a unified system for rapid field evaluations of new cultivars. The apple industry in the U.S. needs timely information on the attributes and regional adaptability of new cultivars in order to avoid wasting resources on new cultivars that have serious weaknesses. At the same time, U.S. apple growers must rapidly identify and establish the most promising new cultivars if they are to remain competitive in the world market. Researchers need a unified system for evaluating cultivars to maximize the usefulness of data collected in various locations across the country. Plant pathologists and entomologists need to evaluate new cultivars before they are extensively planted so that cultivar-specific management strategies for common apple pests can be devised and so that growers can be advised to avoid cultivars with intractable pest control problems. Some new cultivars are genetically resistant to one or more of the common apple diseases, and the advantages and limitations of growing these new cultivars should be evaluated throughout apple producing regions in the U.S.

JUSTIFICATION:

Apples are grown on more than 180,000 ha in the United States. The USDA National Agricultural Statistics Service reports apple production statistics for 36 states. Apple production exceeds 25,000 metric tons per year in at least 18 states. Total U.S. production of apples was approximately 4.7 million metric tons during the years 1995-97. The value of the utilized apple crop averaged $1.6 billion over the same three-year period. Significant quantities of apples and apple juice concentrate are also imported each year. U.S. imports of fresh market dessert apples steadily increased and reached 115,842 metric tons for the year 1994 with a market value in excess of $77 million (USDA, 1995).

Increasingly, U. S. apple growers are competing with other apple producers in a worldwide market. Apple production levels in Chile, Brazil, South Africa, New Zealand, the European Economic Community, and eastern Europe all impact apple prices and sales in the United States. In recent years, China has dramatically increase its production to the point that it is now the world's leading apple producing country (USDA, 1997). The future viability of the U.S. apple industry will depend on the ability of U.S. producers to meet changing consumer demands both domestically and in countries that import U.S. apples. O'Rourke (1998a) estimates that world apple production could rise about 30% by 2005, while world population will grow by only 13%.

Most of the apples imported into the U.S. for fresh-market sales are relatively new apple cultivars with distinctive color, flavor, or quality characteristics. These include Granny Smith, Gala, Braeburn, and Fuji. Consumer acceptance of these new cultivars has been demonstrated by their willingness to pay higher prices for the new cultivars than for traditional cultivars grown domestically. In the United States, interest in growing new apple cultivars increased dramatically during the 1990's as apple growers noted both the higher returns received for some new cultivars and the overproduction of standard cultivars such as Delicious. It is predicted that by 2005 production of traditional apple cultivars will drop due to an increase in the production of newer cultivars. The production of the standard cultivars will decline from 42.8% of the total to 38.2%; while the percentage of production from new cultivars will increase from 18.8% to 21.0% in 2005 (O'Rourke, 1998b). Many apple growers are looking for alternatives to their standard regional cultivars such as McIntosh in the Northeast, York Imperial in the MidAtlantic and Delicious in the Pacific Northwest. These cultivars have historical weaknesses such as fruit softening and preharvest drop for McIntosh, biennial bearing for York Imperial and overproduction for Delicious.

New apple cultivars are continually being identified around the world (Chen et al., 1997, Lauri et al., 1997, Braniste 1997). These new cultivars come both from breeding programs and from promising chance seedlings or mutations spotted by nurserymen or fruit growers. In North America, there are active apple breeding programs in British Columbia, New York, Washington, and in the cooperative breeding program operated by Purdue, Rutgers, and Illinois (PRI). Cultivars with resistance to apple scab, and sometimes to other diseases as well, have been released from the PRI program (Korban and Morrisey, 1989), Cornell University's New York State Agricultural Experiment Station (Brown and Terry, 1997; Lamb et al., 1985), and from Canadian programs at Kentville and Smithfield (Crowe, 1988; Warner and Potter, 1988).

Research scientists from at least 25 experiment stations throughout the United States and Canada are already actively involved in some form of apple cultivar evaluations before the NE-183 project was initiated in 1994. Often those evaluations were conducted informally as part of larger projects, and results were rarely published in scientific journals. Probably the largest ongoing cultivar evaluation program is in the Pacific Northwest (Norton, 1993; Norton, 1997; Stebbins and Norton, 1991; Ballard, 1998), but results of that program have limited usefulness for those in other geographic regions. Prior to the NE-183 project, apple cultivar trials were rarely coordinated across broad geographic regions. Data from existing trials usually could not be directly compared because of differences in planting dates, rootstocks used, combinations of cultivars chosen for evaluation, and data collection methods. Independent trials in each state may be beneficial for the apple growers in the state where the trials are performed, but considerable efficiency in total effort and improvement in the quality of information generated has been achieved with a coordinated cultivar evaluation program initiated under NE-183.

Knowing the pest susceptibility spectrum for new apple cultivars is important for several reasons. Some pest problems are not easily controlled (e.g., fire blight and blister spot). Cultivars that are highly susceptible to such pests are unlikely to prove profitable in regions where these pests are endemic. Most other pests can be controlled with appropriate pesticides, but cultivars that require pesticide inputs may become more difficult to produce and market in the future.

Apple cultivars with genetic resistance to diseases may become more important as the options for chemical control of apple pests becomes more limited. Cultivars that are resistant to apple scab can be grown with less fungicide sprays and may also require less miticide sprays. Some fungicides affect mite populations by interfering with biological control of mites by predators (Bower et al, 1995). Predators and parasites of other apple pests may also be adversely affected by the broad spectrum fungicides commonly used to control apple scab. New management strategies that are more dependent on biological control of insects and mites may be feasible for cultivars which require less fungicide.

Apple cultivars with genetic resistance to apple scab are still susceptible to other diseases.

Some of the scab-resistant releases from breeding programs have also been selected for resistance to powdery mildew, cedar apple rust and fire blight. However, the results of the necessarily limited evaluations made within breeding programs can be misleading. For example, Liberty was considered resistant to powdery mildew when released but is now considered highly susceptible to mildew in Europe and can become severely infected when planted adjacent to mildew-infected cultivars in New York (Cimanowski et al., 1988; Rosenberger et al., 1994). Liberty is resistant to cedar apple rust but still may develop severe foliage damage attributed to rust-induced leaf spotting (Rosenberger et al., 1994). None of the new apple cultivars are known to be resistant to sooty blotch, flyspeck, bitter rot, and white rot.

For both scab-resistant and scab-susceptible cultivars, better information on cultivar susceptibilities would help apple growers plan new plantings in ways that would reduce the need for pesticides. Cultivars with unique susceptibilities to powdery mildew, rosy apple aphids, leafminers, leafhoppers, leafrollers, or mites might be grouped together in new plantings to facilitate pesticide applications for specific pest problems and to reduce the likelihood that one susceptible cultivar in a planting will become a source of pests for adjacent cultivars (Rosenberger, 1998).

In the past, plant pathologists and entomologists have generally had little impact on cultivar selections and evaluations. Instead, scientists in these disciplines were expected to resolve pest control problems after cultivars had been selected and widely planted. This approach will become less viable in the future as availability, acceptability, and economics of pesticides limits the profitability of cultivars that require extensive pesticide inputs. Concurrent evaluation of both horticultural qualities and pest susceptibilities allows a more rational basis for selecting new cultivars for commercial adoption. Cultivars that are highly susceptible to certain pests may still be promoted by nurseries and planted in commercial orchards if horticultural characteristics and marketability make them appear desirable. However, the data we are generating is making pest managers and growers aware of the kinds of problems likely to occur when these cultivars are planted.

A unified regional (or national) approach to evaluating pest susceptibilities of apple cultivars provides useful new information on the economic importance of various pests across different apple production regions. Scientists already know that some pests may be important in one region but relatively unimportant elsewhere. By evaluating pest populations on the same cultivars over a multistate area and by using the same data collection procedures, cooperating scientists can construct a comprehensive database on variations in apple pest populations across the U.S. This database should prove useful in future risk-benefit analysis which may be required for registrations or re-registrations of pesticides for apples. It may also provide insights on the biological limitations and inter-relationships of pest complexes found in different geographical areas.

Joint evaluation of both horticultural characteristics and pest susceptibilities of new apple cultivars will provide a database which economists can use to predict profitability of the cultivars evaluated. Cultivars and strains with high quality, packout, yield, and good horticultural characteristics will enhance grower profitability. In order for growers to use new cultivars most effectively, characteristics such as mature tree size, hardiness, bloom period, pollination requirements, productivity, adaptability to climate, growth habit, and fruit quality after storage must be determined. The present gap in knowledge of these characteristics has led to a haphazard, and frequently costly, approach for cultivar selection and planting. Growers who plant cultivars not adapted to their region frequently incur six to eight years of costs (usually greater than $24,000/ha) before the deficiencies of their cultivar selections become apparent. Uniform cooperative testing results in more efficient, rapid, and systematic evaluation of cultivar characteristics and will allow the industry to more quickly recognize both the limitations and the advantages of new cultivars.

The uniform plantings currently under study and those proposed will facilitate important complementary studies not specifically included in this project. Other investigators are currently using plantings at multiple sites for detailed studies on the physiology of flowering, fruit set, nutrition, and cold hardiness studies. Food scientists will join this project to assess characteristics of processed products from some of the promising new cultivars. Further, evaluation of the postharvest storage potential of new cultivars in the current planting is one objective in the newly reapproved NE-103 Regional Project.

Coordinating the proposed work across multiple states increases the likelihood that apple grower associations in some of the participating states will contribute toward the costs of the cultivar evaluation work. Successful regional projects, such as NC-140, generate broad industry support and recognition because of their stability and continuity. The wide range of geographic and climatic areas encompassed by both NC-140 and by our proposed NE-183 project ensure that the data generated will be useful to all segments of the industry within the U.S.

RELATED CURRENT AND PREVIOUS WORK:

Apples are a major fruit crop in the United States and there are numerous research projects to support production and storage of this commodity. Currently there are three major regional research projects authorized; NE-183 (this project), NC-140 (Pome and Stone Fruit Rootstocks), and NE-103 (Postharvest Physiology of Fruits). NE-183 and NE-103 are closely linked because fruit produced in the NE-183 plantings is evaluated by participants in NE-103 in several states. Participants in 15 states and provinces (AR, ID, IN, MA, ME, NJ, OH, OR, PA, UT, VT, WA, WI, BC, ONT) are members of both NE-183 and NC-140. Evaluation of new apple varieties on different rootstocks fits within Objective II of this project as well.

A search of the CRIS database using 'NE-183', 'NC-140', NE-103 and apple cultivar(s) revealed that there are 111 active projects. Research on cultural problems ranged from work on chemical thinning to improving winter hardiness. There are a number of projects to improve IPM strategies and studying the impact of specific pathogens and insects. There are 12 projects related to breeding, genetic improvement, or genetic preservation of germplasm. This is important since some participants (NY, NJ, IL) in apple breeding projects are currently providing their advanced selections for inclusion in the NE-183 plantings.

Interest in the use of apple scab resistant cultivars has increased in the last five years. Economic analysis of fungicide costs between Liberty, a scab resistant cultivar and McIntosh, a scab susceptible cultivar showed that these costs could be reduced as much as 73% in comparison to standard commercial programs. However in comparing the production of these two cultivars under a traditional organic program, fungicide costs could only be reduced by 57% (Ellis et al., 1998). Schupp and Koller (1997) evaluated Williams's Pride, Redfree and Dayton on three rootstocks for their commercial potential. They concluded that Redfree was the best summer-ripening disease-resistant cultivar for commercial orchards. As part of the Northeast Sustainable Apple Production Project several scab-resistant apple cultivars were evaluated for consumer acceptance in 1988 and 1989. Testers evaluated the fruits for texture, juiciness, aroma, tartness, and sweetness plus overall quality. The cultivar Liberty received the highest overall acceptance in both years, while Prima was also rated high in 1988 and Freedom in 1989 (Durner et al. 1992).

Defining and evaluating fruit quality is difficult and has often been done subjectively. The meaning of quality frequently is determined by the background of the evaluator (Watada, 1980). A general definition of quality put fourth by Kramer and Twigg (1970) is "the composite of those characteristics that differentiate individual items of a product and have significance in determining the degree of acceptability of the item to the buyer." Consumers evaluate quality using five human senses: sight, hearing, smell, taste, and touch. Scientists attempt to quantify and evaluate quality using these same senses; however, quality evaluation studies are frequently misused (Lipton, 1980; Gliha et al., 1981). Early work in the evaluation of taste and flavor of apples was based largely on the personal judgment of the scientist conducting the trials rather than a scientific assessment of sensory characteristics. Hedonic tests have been used in measuring consumer acceptance of color and flavor of Delicious (Crassweller and Hollender, 1989), Gala and McIntosh (Greene and Autio; 1990) and new apple cultivars (Stebbins et al., 1991a).

Less information is available that relates objective measurements to consumer sensory responses (Stevens and Albright, 1980). Blanpied and Blak (1977) measured flesh firmness and acidity levels of five apple cultivars and attempted to relate these measurements to the subjective judgment of ripeness by "six experienced apple panelists." They were unsuccessful. In another study, Liu and King (1978) did establish a positive relationship between penetrometer readings of McIntosh apples and subjective evaluations of the same fruit by over 1000 retail store consumers. They suggested that the subjective judgment made by several experienced apple experts may not agree with the judgment of a large number of consumers.

Consumers are the ultimate judge of cultivar acceptance. Quality and the factors that contribute to the judgement of quality may differ by individual. Alavoine et al. (1990) suggested that sugar content may be the best determinant of consumer acceptance. Acidity was also an element of taste quality that was complimentary to sugar content. However the influence of acidity on taste quality was dependent upon country of residence.

Manalo (1995) surveyed consumers at retail outlets in New Hampshire and determined that they preferred large, totally sweet, crisp apples. It was also determined that crispness was the most important factor determining quality. This study also revealed that consumers who strongly preferred McIntosh were older than 50 years, while those under 20 preferred a sweet apple like Delicious. One of the implications of this information was that growers might want to switch to the type of apple preferred by younger consumers. However, Criner and Nord (1995) suggested that taste preference among younger consumers may be influenced by their past consumption practices. Koster (1990) reported that an individual's preference for a taste was molded in early childhood but that a second period of taste adjustment occurs when individuals reached 18-20 years old.

Color can be a dominant sensory parameter that influences consumer apple purchasing patterns (Smith and Frye, 1964; Crassweller et al., 1984). Subjective color evaluations are hindered by human bias and the inability to compare data from different years and geographical locations. A good relationship has been established between anthocyanin levels (Singha et al., 1991a) or visual rating (Singha et al., 1991b) and chromaticity values. Automation of color determination using calorimeters or other sensing devices may allow color data to be taken in internationally accepted units, overcome lack of uniformity attributed to individual investigators and yearly variation, and provide a useful method to determine harvest index. Few studies have related objective color measurement to consumer subjective evaluations. Hohn (1990) suggested that continued reliance on developing red colored mutants may lead to planting in areas that are unsuitable or ripening at an inappropriate time leading to the production of fruit with inferior eating quality.

Confounding evaluation of fruit quality is ethnic background. Consumers from southern European countries prefer fruits of low acidity with red or yellow coloration, whereas consumers from northern European countries preferred fruits of higher acidity and a greener appearance (Alavoine et al., 1990). Swiss apple consumers were characterized as wanting apples that were crisp, juicy and flavorful (Hohn, 1990). Still others found that texture and taste were more important attributes than aroma and appearance (Daillant-Spinnler et al. 1996). Consumer preferences are also the product of past memories and experiences (Alvensleben and Meier, 1990) and cultivar name recognition (Alavoine et al. 1990).

Fruit quality may be influenced by numerous cultural factors including orchard floor management (Haynes, 1981; Stott, 1976), fertilization (Tami et al., 1986), irrigation (Irving and Drost, 1987; Proebsting et al., 1984), pruning and training (Greene and Lord, 1983; Lord and Greene, 1982; Marini and Barden, 1982; Miller, 1982) and crop load (Hohn, 1990). Pest management and the level of pest control practices may affect fruit red pigmentation, soluble solids, fruit weight and russeting (Ames et al., 1984, Bremer and Bunemann, 1982; Hansen, 1982).

Some of the new scab-resistant cultivars are now receiving recognition for quality as well as disease resistance (Acuff, 1990; Crosby et al., 1992; Greene, 1998; Greene and Autio, 1993). Observations (Berkett and Cooley, 1989) and informal taste tests (Schupp et al, 1990; Stebbins, 1989) confirm that recent disease resistant cultivars have consumer acceptance. Stebbins et at. (1991b) found that taste panelists rated Liberty higher than McIntosh, and on another date panelists ranked Liberty higher than Delicious and equal to Empire. Durner et al. (1992) reported that panelists preferred disease resistant cultivars Liberty and Freedom over Spur Red Delicious.

Fruit maturity studies are essential for new cultivars. In order to evaluate the attributes of an apple properly, it must be harvested at the appropriate stage of maturity. Stebbins et al. (1991b) harvested fruit at 7-day intervals for 3 or more weeks to assure evaluation of each cultivar at the optimum stage of maturity. The most precise method to establish the time of ripening is to determine the initiation of the ethylene climacteric (Autio, 1991; Blanpied, 1989). However, ripening of some cultivars including one of the most successful new cultivars, Gala, cannot be assessed using ethylene because the time of ripening is not marked by a rapid rise in ethylene (Greene and Autio, 1990). The starch-iodine test, which determines the extent of starch hydrolysis, is one of the best field methods to determine the proper time of harvest (Blanpied, 1974; Smith et al., 1979). It can be used to predict the appropriate time of harvest. As fruit ripen, ground color changes from green to yellow. Visual changes in ground color were shown to be a valuable method to determine ripening of Gala, Fuji and Braeburn (Plotto et al, 1995). Ground color charts should also be developed to provide another very useful simple method to determine the proper time to harvest some new apple cultivars (Streif, 1983).

Storage potential of new apple cultivars may be determined in part by the ability of stored fruit to compete in the marketplace with fresh fruit being imported from the southern hemisphere. Stebbins et al. (1991b) conducted taste panel evaluations on a number of new apple cultivars. Cultivars that received very high ratings at harvest frequently received significantly lower ratings following storage. Therefore, quality following storage may be a dominant factor in determining the ultimate success of a new cultivar. Fuji and Braeburn, currently two of the most heavily planted apples in the world, are noted for their long-term storage potential (Norton, 1997; Stebbins, 1988). These cultivars have consistently received high ratings following storage (Stebbins et al., 199lb). The most common storage disorders of apples include senescent breakdown, brown core, bitter pit, scald, and decay. Cultivars that consistently show a high incidence of any of these disorders will not become important commercial cultivars.

Establishment costs for orchards are very high. Apples come into full production from 4 to 12 years after planting, depending upon the cultivar and rootstock (Castaldi, 1988). Because of the high initial capital investment and long time required for trees to come into full production, growers can not afford to take the risk of investing in substantial acreage of new apple cultivars without knowing production, quality, and storage characteristics of the cultivar. In addition, growers must have estimates of cost and returns similar to those published by Prokopy (1991), for growing disease resistant apples. These data can then be used in an orchard spread sheet (Castaldi, 1988; Sciabarrasi and Lord, 1997) so that responsible financial decisions can be made about planting new, cultivars. Regional testing and cooperative evaluation are the only logical ways to generate appropriate data so that growers can make sound business decisions.

Differential susceptibility of cultivars to various diseases has been reported for many older cultivars. Aldwinckle (1974a-c) summarized the consensus of fruit pathologists concerning susceptibilities of common commercial cultivars to apple scab, powdery mildew, cedar apple rust, quince rust, and fire blight. Thomas and Jones (1992) reported the susceptibility of numerous cultivars and strains to fire blight under field conditions during a severe epidemic in Southwestern Michigan. Sutton and Pope (1989) reported on susceptibilities of some scab-resistant cultivars to fire blight and cedar apple rust. Several other groups have published a similar report on cultivar susceptibility to cedar apple rust, mildew, and sooty blotch and flyspeck (Seem et al., 1987; Yoder et al., 1994). Camilo (1989) evaluated cultivars and clones for resistance to bitter rot. Disease susceptibility rankings for cultivars grown in southeastern United States are included in a recent Southeastern Regional Publication, but the table has many blanks for rankings of cultivar susceptibilities to summer diseases (McVay et al., 1994). The work proposed in this project represents the first coordinated effort to assess susceptibilities of new cultivars to diseases using a uniform protocol with multiple observers and planting locations.

Differential susceptibility of cultivars to insects and mites has been carefully evaluated for only a few pest species. Alm et al. (1985), showed that the apple blotch leafminer insect could survive on all apple cultivars tested, but that it favored some cultivars over others when given a choice. In a comparison of 74 scab-resistant apple selections, all apple selections had similar counts of plum curculio feeding scars, but 22.9% of the selections had fewer larval exit holes than did Jonathan (Goonewardene et al., 1975). Three crabapple cultivars were found resistant to both plum curculio and to three common apple diseases (Alm and Hall, 1986; Crassweller et al., 1980). Floral, vegetative, and fruit characters may all be important in host susceptibility to plum curculio. Plum curculio damages early maturing apple cultivars more than a later cultivar (McIntosh), but McIntosh also has different foliar characteristics (Petch, 1927; Whitcomb, 1929; Lafleur and Hill, 1987). Numerous researchers have reported observations on differences between cultivars in their tolerance and susceptibility to attack by European red mite (Ravi, 1996; Ravi et al., 1998). In commercial orchards, however, cultivar susceptibility factors may be confounded by affects of orchard fungicides on mites and mite predators (Bower et al., 1993; Hall, 1979; Kreiter et al., 1998; Walker et al., 1989). Moreover, better understanding of cultivar susceptibility to European red mite would be extremely useful, because the introduction of predator Typhlodromus pyri can provide biological control of this pest on cultivars having low to medium susceptibility, provided that orchard chemicals detrimental to the predator are withheld (Breth et al., 1998). Most reports on differential susceptibility of apple cultivars to insects and mites are derived from observations within very limited geographic areas. There have been no attempts to study differential susceptibility of apple cultivars across multiple production areas as we are proposing to do in this study. Because of recent implementation of the Food Quality Protection Act, some of the fungicides and insecticide classes currently so vital to IPM programs may be lost to commercial producers, resulting in potential management problems on cultivars that are susceptible to key pests. Elucidation of these cultivars prior to planting could greatly aid producers in areas where these pests are of critical concern.

OBJECTIVES:

I. Evaluate horticultural qualities and pest susceptibility of new apple cultivars, strains, and advanced selections at numerous locations throughout the United States to determine both the limitations and positive attributes of these cultivars.

II. Develop horticultural and pest management strategies for new cultivars or cultivar strains that are emerging as commercially-acceptable cultivars.

III. Compare the cost of production and profitability of new apple cultivars.

PROCEDURES:

Objective I. Planting #1. Cooperators from 18 states and two Canadian provinces established 28 uniform plantings of promising apple cultivars and advanced selections in the spring of 1995 (AR, CT, GA, MA, ME, MI, MO, NC, NJ, NY-I, NY-G, OH, OR, PA, VA, VT, WA, WI, WV-USDA, ONT, BC). Project participants are detailed in Attachment 1. More than one planting was established in several states (MI, NC, NY, PA, WV-USDA) to allow evaluation under different climatic conditions within the state or to allow more complete collection of both horticultural and pest susceptibility data.

The Objective I plantings have a primary designation of either horticultural or pest susceptibility studies. Plantings for horticultural studies are located in AR, MA, ME, MI, NC, NJ, NY-I, NY,-G(two Locations), OH, OR, PA (two locations), VT, WA, WI, AND WV-USDA. Plantings for pest susceptibility studies are located in CT, GA, MI, NC, NY-G, VA, and WV-USDA. Collecting both horticultural and pest susceptibility data from the same planting will not be done because of the likelihood of confounding. For example, evaluations of mildew susceptibility requires that trees remain unsprayed, but severely affected trees will produce no useful information on yield.

In the 20 plantings designated for horticultural studies, trees receive conventional pesticide applications consistent with the best pest management strategies for the region. In addition, plantings will also be used for observations on susceptibility of the cultivars to pest such as aphids, mites, leafhoppers, sooty blotch, flyspeck, Brooks fruit spot, and Alternaria leaf blotch under conditions encountered in commercial orchards. Plantings designated for pest susceptibility studies (CT, GA, NC, NY-G, VA, WV-USDA) have been protected with appropriate amounts of pesticides during the early life of the trees to ensure establishment of the trees. Pesticide applications in these plots are now being modified to allow assessment of susceptibility to one or more of the following groups each year:

1. Early season diseases: apple scab, cedar apple rust, powdery mildew, fire blight, black rot.

2. Summer diseases: sooty blotch, flyspeck, Brooks spot, Alternaria leaf blotch, black rot, white rot, bitter rot.
3. Insect pests: plum curculio, aphid complex, leafhopper complex, leafminer complex, leafroller complex, scale insects and incidental foliar feeding insects (e.g., Japanese beetles).
4. Mites; including European red mite, two-spotted spider mite, apple rust mite, and predatory mites.

Details of strategies for evaluating pest susceptibility are determined by the Pest Susceptibility Subcommittee. The subcommittee develops common protocols to ensure uniform sampling and data recording. Separate protocols will be devised for collecting pest incidence data in sprayed horticultural plantings where cooperators are available to collect such data. Concurrent collection of both insect and disease data in pest susceptibility plantings proved to be confounding. Therefore, insect and disease data will be collected in these plantings in different years.

Cultivars included in the first planting were selected by the Cultivar Selection Subcommittee. The Subcommittee solicited suggestions from apple breeders, apple cultivar experts, and members of the technical project. The list of cultivars in the first planting includes:

1. Arlet
2. Creston
3. Braeburn
4. Cameo
5. Enterprise
6. Fuji (BC Type II)
7. Gala Supreme
8. Ginger Gold
9. Golden Delicious (Gibson strain)
10. Golden Supreme
11. GoldRush
12. Honeycrisp
13. Fortune
14. NY 75414-1
15. Orin
16. Pristine
17. Sansa
18. Senshu
19. Shizuka
20. Suncrisp
21. Sunrise
22. Yataka

All trees were propagated by Adams County Nursery, Aspers, PA on M. 9 NAKB 337 in 1993. Golden Delicious 'Gibson' strain, Braeburn and Yataka were also budded on MARK. Having three cultivars propagated on both M.9 and Mark rootstock provides an internal control for detecting situations where tree performance may be adversely affected by our choice of M.9 as the primary rootstock. Golden Delicious was included as a universal standard since it performs well across a wide variety of climates. Further, it is considered a high quality fresh market apple and it processes into high quality processed products. In addition, Pioneer McIntosh/M.9 was included in the pest management plantings to serve as additional standard cultivar control with known susceptibility to apple scab. Trees were budded with the intention of planting 5 replications of each cultivar for each location. Unfavorable weather following budding resulted in incomplete numbers of trees. Pest management plantings received 5 replications of all cultivars. Horticultural plantings received between 2 and 5 replications of all cultivars. Senshu was not included in the Horticultural plantings because of limited numbers.

The Horticulture Subcommittee made cultural and management decisions the first two year that were applied universally over all plantings. Trees were planted in 1995 at an in row spacing of 2 meters. Trees were headed at planting time, individually staked, with the intention of providing support for the life of the tree. Minimal pruning and training was done to allow assessment of natural tree structure, and to allow natural flowering and fruit set tendencies to express themselves. Trees were not allowed to crop the first two years. All flowers were counted and then flowers or young fruit were removed the first year by hand or by chemical means followed by hand thinning. Trees initially were allowed to set fruit in the second year. The persisting fruit were counted and then all fruit was removed by hand to assure good return bloom for the third year. Fertilizer application, pest management, and orchard floor management have been done according to recommended local standards. Leaf samples have been taken annually on Golden Delicious/M.9 and Braeburn/M.9 and standard leaf nutrient analysis done at the Agricultural Analytical Services laboratory at Pennsylvania State University. Trunk circumference 50 cm above the soil line have been measured each year at leaf fall. Height and spread of trees and the terminal growth of ten terminal shoots per tree will be taken after five years. Weather data are taken including daily maximum and minimum and precipitation during the growing season. Where available, solar radiation will be recorded.

Trees were allowed to fruit in their third leaf, 1997, and this will continue in subsequent years. The horticulture subcommittee established revised guidelines for management of young cropping trees, and provided a horticulture protocol to be used for evaluating tree performance in horticultural plantings. Protocols will follow standard and accepted methods. The date of full bloom and petal fall will be recorded. Bloom will be determined either by rating bloom or counting all flowers on three tagged and measure limbs per tree. Initial set will be determined and then the crop load will be adjusted by hand or chemically. All fruit on 1-year-old wood will be removed and the remaining fruit will be spaced 15-20 cm apart on older wood. Details of horticultural management and data collection for the uniform plantings will be reviewed regularly by this subcommittee and the revisions, if appropriate, will be distributed to NE-183 participants before 1 April of each year. Field horticulture data will be collected by all cooperators with plantings designed for horticulture studies (AR, MA, ME, MI, NC, NJ, NY-I, NY-G [two locations], OH, OR, PA [two locations], VT, WA, WI, and WV-USDA).

The Fruit Quality Subcommittee established a fruit evaluation protocol that is to be used by all cooperators with horticultural plantings. All horticulture locations will randomly harvest 10 fruit per tree and record total weight, soluble solids length:diameter ratio, and starch index reading according to Blanpied and Silsby, 1992. Optional data that can be collected on the 10-apple samples include: weight of 10 individual fruit, flesh firmness, titratable acidity of juice collected during the pressure test, color rating, color space reading (L*a*b* values) and fruit russet. All apples on each tree will be harvested, counted, and weighed. Yield efficiency will be calculated from trunk cross sectional measurements and the total tree yield data. Protocols established by the committee will be reviewed at the annual meeting.

The Fruit Quality Subcommittee established a protocol for evaluating sensory and organoleptic assessment of fruit in 1998. A system was devised to rate the fruit from each tree for attractiveness, crispness, juiciness, sweetness, acidity, flavor, and overall desirability. Optional evaluations were also suggested for color, sunburn, fruit shape, skin tenderness, flesh firmness, astringency, flesh color, and the incidence of cork spot, bitter pit, and watercore. The Fruit Quality Subcommittee will review the protocol yearly, and make suggestions for changes before the harvest season.

Storage potential is a major factor that may ultimately determine the success or failure of a new cultivar. Assessment of fruit quality must include not only harvest evaluations but also evaluations after a period of storage. One of the objectives of the recently approved NE-103 Regional Projects is to establish a collaborative and interdependent working relationship with members of NE-183. Five stations participating in NE-103 will evaluate fruit from the first NE-183 planting (MA, MI, NC, NY-I PA). The fruit evaluation protocol currently used by NE-183 will also adopted by participating members of NE-103. This will be complemented by fruit internal ethylene. Because there are so many selections in the NE-183 project, evaluations will be limited to assure that a manageable number of fruit are evaluated each year. At least four selections will be evaluated each year. As numbers of fruit per tree increase, CA storage trials maturity at time of harvest, storage atmospheres and storage duration will be evaluated.

Data management for the entire project is coordinated by project statistician, Dr. Ron McNew from the Agricultural Statistics Laboratory at the University of Arkansas. The project statistician will review planting plans to ensure designs are appropriate to achieve the stated goals of the project. The project statistician will work with the Horticulture and Fruit Quality and Pest Susceptibility Subcommittees to assure that the growth measurements, fruit and pest sampling procedures and measurements are consistent with good and appropriate methods of statistical analysis. The experimental design for our uniform plantings will allow analysis of variance that includes as sources Location, replication nested in Location, cultivars, and Location X cultivars. The Residual will be used as the error term for the interaction of Location and Cultivar, one of the interesting components of the analysis. Assuming that the analysis indicates a significant Location X cultivar interaction, various models will be fitted to the data in an attempt to account for the interaction. Where appropriate, data on successive years will be included in the analysis using repeated measures to determine the main effects of year and interactions involving year.

A Data Management Subcommittee will work with the project statistician to standardize data collection formats, and to coordinate data transmission from the individual investigators to the statistician. This subcommittee will take responsibility for making initial assessment of the data collected. It will segment the data into appropriate parcels and coordinate the initial write-ups. For example, data may be parceled into tree growth and productivity, fruit quality and harvest maturity, or specific comparisons of pest susceptibility.

Objective I Planting #2. Cooperators from 20 states and three Canadian provinces will establish 29 uniform plantings of promising apple cultivars and advanced selections in the spring of 1999. The planting participants are detailed in Attachment 1. This second planting will also have a primary designation of either horticultural or pest susceptibility studies. Plantings for horticulture are located in AL, ID, IN, MA, MI (two locations), NH, NJ, NY-G, NC, OH, OR, PA (two locations), UT, VT, WA, WI, WV, Nova Scotia, Ontario, and British Columbia. Plantings for pest susceptibility studies will be located in CT, ID, MA, MI, NY-G, and VA. Locations where both horticulture and pest susceptibility studies will be established include ID, MA, MI, and NY. Collecting of both horticulture and pest susceptibility data from the same planting will not be done because of the likelihood of confounding.

The Cultivar Selection Committee solicited suggestions from apple breeders, apple cultivar experts, and members of the technical projects. Golden Delicious 'Gibson' strain will be the standard control to be included in all plantings. 'Rogers' McIntosh will also serve as a control in pest management plants. All trees were propagated by Wafler Nursery, Wolcott, NY in August of 1997 on M.9 NAKB 337. Trees were budded with the intention of planting 5 replications of each cultivar at each location. Nine of the cultivar selections come from breeding programs where resistance to apple scab is a component in the selection process. Pest susceptibility of the remaining selections is unknown. The following list of cultivars will be included in the second planting.

1. Golden Delicious (Gibson strain)   9. Coop 39*   17. NJ 90

2. McIntosh (Rogers strain)	10. CRQ10T17*	18. NJ 109
3. Ambrosia	11. CQR 12-750*	19. NY 75907-72*
4. BC 8S-25-33	12. Delblush	20. NY 75907-49*
5. BC 8S-27-51	13. Hampshire	21. NY 65707-19*
6. BC 8S-26-50	14. Jubilee Fuji	22. Pink Lady
7. Coop 25*	15. Pinova*	23. Runkel
8. Coop 29*	16. MN 1824 (Zesta)	24. Autumn Gold

*Reported resistance to apple scab

Participants in the project have developed planting, maintenance, data collection, and evaluation procedures for the first planting. Appropriate changes have been made where warranted. The Pest Susceptibility, Horticulture, Fruit Quality, and Data Management Subcommittees will adopt or slightly modify these protocols for the second planting. Most of the work has been done, so we anticipate few changes from what we are already doing in the first planting.

Objective II: Existing plantings of emerging cultivars will be used by some cooperators to develop more detailed horticultural and pest management information. Cooperators within this objective will formulate common protocols to collect data from multiple sites and thereby gain understanding in how management strategies will need to be modified to fit regional ecosystems. By using existing plantings, data collection can begin sooner than is possible for the Objective-I plantings. In addition, more detailed information will be collected in the first NE-183 planting. Cooperative efforts will be focused in the following areas of investigation.

Chemical thinning: Chemical thinning continues to be the most important management activity that a grower is required to do. Thinning strategies are cultivar-dependent and frequently differ between geographic locations. Specific thinning chemicals and strategies will be tested on Fuji, Gala, Braeburn, and later on Ginger Gold, Honeycrisp, Suncrisp, and Goldrush when blocks approach maturity. Cooperative thinning projects will be carried out between and among interested states and provinces (ID, MA, OH, PA, VA, WV, ONT).

Flowering: Biennial bearing and return bloom are indicators of flowering potential. Cultivars that do not flower regularly may be commercial liabilities. Flower development, spur quality, and the viability of flowers will be evaluated in several locations (OH, IN, MA, VA)

Nutrition: Cultivars differ in their leaf nutrient content and nutrient content required to mature high yielding, high quality fruit, with good storage potential. Leaf nutrient content will be determined in all cultivars in the NE-183 first planting and the nutrient content will be related to growth, yield, and fruit quality (ID, NY, NJ, WI).

Postharvest: Evaluation of the postharvest requirements of new and existing cultivars is Objective 1 in the recently-approved NE-103 Postharvest Physiology of Fruits Regional Project. The postharvest storage potential of fruit in the first NE-183 planting will be evaluated cooperatively by postharvest physiologists and participants in NE-183 in five states (MA, MI, NC, NY-I, PA). Standard protocols adopted by NE-183 for evaluating maturity and quality at harvest will be used. In addition, internal ethylene at harvest will be determined. At least four selections will be studied in detail each year. As fruit numbers allow, CA storage trials will be initiated.

Pruning: Cultivars differ considerably in growth and fruiting habit. Pruning techniques will be evaluated to determine the most appropriate way to prune and train Enterprise, Suncrisp, and Goldrush (PA, WV).

Cold Hardiness: The ability of new cultivars to withstand extremely low temperatures, and survive cold periods following widely fluctuating temperatures is a factor that will limit introduction of new cultivars into some areas. Evaluation of the cold hardiness of cultivars in the first NE-183 planting are planned (VT, ONT). The frost tolerance of new cultivars will be studied in two locations (VT, ONT) and detailed damage to flowers and spurs will be evaluated if frost occurs (OH, MA).

Pest Management: Cultivars will differ markedly in relative susceptibility to disease and arthropod pests. Data from pest susceptibility plantings (CT, MA, MI, NY-G, NC and VA) will be formatted into tables of Cultivar Diseases and Arthropod Susceptibility. Similar tables for pesticide efficacy are presented in crop production guides published by most states (Smith et al., 1998; Stiles et al., 1998).

The collection of promising apple cultivars in the NE-183 plantings is not duplicated in any state or province. Thus, these provide a unique opportunity to do other replicated experiments. For example, the processing quality of processed products such as chips, slices, and juice will be evaluated in New York (NY-G). The relationship between flower and spur quality and final fruit set will be studied (OH).

Objective III: Data collected in Objective I and II will be used to establish to what extent and under what conditions establishing new orchards with new cultivars will be sound financial ventures. Data on fruit production and quality will be summarized into categories representing market grades based on fruit size and color. This color/size/grade data along with cultivar specific variable production costs identified in Objectives I and II will be entered into the Apple Orchard Budgeting Excel spreadsheet (Sciabarrasi and Lord, 1997). This spreadsheet allows development of cultivar-specific budgets including production, storage, and marketing costs and returns form wholesale and retail markets as well as the development of cash flow projections for each. Data gathering and analysis will be done by William Lord (NH) with contributing data collected from participating states (ID, MA, NH, NY-G, NY-I, NC, PA, VT).

EXPECTED OUTCOMES:

Results. New apple cultivars were planted in multiple site test orchards. These cultivars/rootstock combinations were and continue to be evaluated for horticultural characteristics, fruit quality attributes, and resistance to pests and diseases. A cultivar database was developed and in available on the WWW (http:www.VIRTUAL ORCHARD.NET). Harvest and pest management strategies have been developed for these cultivars.

Outcomes. New apple cultivars have been identified that have less dependency on pesticides. Growers can now easily access the latest information on new apple cultivars on the WWW. Armed with this information growers can then select with much greater certainty cultivars that will be successful in the global economy.

ORGANIZATION:

The regional committee is composed of all participating cooperators (See Attachments 1 and 2), and administrative advisor (Dr. Robert C. Seem) appointed by the Northeast Agricultural Experiment Station Directors, and a CSRS representative. The technical committee meets at least once each year to discuss progress of the research, coordinate ongoing research, review procedures, and plan future research activities. Voting privileges are restricted to one member from each participating unit. Participation by Agriculture Canada, Canadian Provinces, and industry representatives is at the invitation of the Technical committee with approval of the Administrative Advisor.

The regional technical committee will elect an executive committee composed of a chair, vice-chair, and secretary. A succession of officers will be maintained so that the vice-chair becomes chair, the secretary becomes vice-chair, and a new secretary is elected each year. The responsibilities of the executive committee members are as outlined in the *Manual for Cooperative Regional Research.* The chair will preside at all meetings of the technical committee, organize the agenda of the annual meeting, and coordinate establishment of the various subcommittees. The vice-chair will prepare the annual report for the project. The secretary will prepare the minutes of the annual meeting and any special meetings. The administrative advisor is responsible for distributing the minutes and submitting the annual report and minutes to the CSRS representative and other interested parties.

The technical committee will utilize subcommittees to manage many aspects of the project. The chair will appoint subcommittees as the need arises. These subcommittees include:

The Cultivars Selection Subcommittee determines which cultivars and advanced selections should be included in future plantings. This Subcommittee will canvas the members to determine participation in the planting, arrange propagation, and facilitate distribution of the trees needed for the new planting.

The Horticulture Management Subcommittee devises minimum horticultural management strategies to be used in all plantings, including details of pruning and training methods, fruit thinning strategies, fertilizer regimes, protocols for collecting soil and leaf samples for nutrient analysis.

The Fruit Quality Evaluation Subcommittee is charged with two responsibilities. First, it establishes the fruit quality evaluation protocol to be used on all cultivars at harvest. These include standardization of sample size and method to determine fruit size, color, firmness, soluble solids, and shape. Second, it establishes the sensory and organoleptic protocols to be used to evaluate cultivars. Among the evaluations are cosmetic appeal, fruit disorders and blemishes as well taste perception of sweetness, acidity, astringency, texture and flavor.

The Pest Management Subcommittee will determine methodology and yearly priorities for evaluating pest incidence.

The Economics Subcommittee will determine methodology for economic studies and will solicit cost and production information as needed from other project participants.

The Data Management Subcommittee will coordinate will coordinate collection of data and ensure that all participants enter data in compatible spread-sheet formats. This subcommittee will be responsible for identifying individuals or small groups within the project who will take responsibility for working with the statistician to summarize data on specific aspects of the project.

At the end of the third fruiting season, project participants will begin publishing an annual project summary which will consist primarily of data tables presenting results of the project. The annual project summaries will be published by the N. Y. Agricultural Experiment Station at Geneva and will be distributed to all interested researchers, cooperative extension staff, and growers. The annual project summary will ensure that data are compiled and distributed to all interested parties in a timely manner. Various subsets of data from the project will be compiled and published in refereed journals after data sets are deemed worthy of wider publication.

SIGNATURES:

Regional Project Title: **Multidisciplinary Evaluation of New Apple Cultivars**

D R Mackenzie for AA — Aug 16, 1999

Administrative Advisor — **Date**

AA- Robert Seem (NYG)

D R Mackenzie for NERA — Aug 16, 1999

Chairman, Regional Association of Directors — **Date**

George Cooper — 8/26/99

Administrator, Cooperative State Research, Education and Extension Service — **Date**

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