NEW YORK
FRUIT QUARTERLY

Editorial

Thank You Bob Andersen

In honor of Bob Andersen's retirement and long and effective efforts with the NY fruit industry, we organized a symposium on Stone Fruit Breeding and Culture in the Northeastern US which was held March 18th and 19th at Geneva. Experts from around the country attended and presented their research. This issue and the next of the NY Fruit Quarterly will feature the papers that were given at the symposium. This issue focuses on cherries while the next issue will focus on peaches and plums. These papers represent the most up-to-date research and the current recommendations from Cornell for growing stone fruits.

Fruit growers in NY State are very interested in diversifying the fruit crops grown on their farms. Sweet cherries are a high value alternative crop. There is a large and lucrative market in the Northeast for high quality sweet cherries; however, cherry production and quality can be inconsistent. The main causes of that inconsistency are rain-induced cracking, bird damage, low yields, high tree mortality and poor postharvest management. If we could solve these problems, NY growers could become consistent suppliers of high quality cherries and expand their acreage of this crop. This issue offers numerous strategies for solving the problems of sweet cherries production in NY State. We hope these papers will assist you in evaluating stone fruits as alternative crops for you farm.

With Bob Andersen's retirement from Cornell University, the Cornell Fruit Team loses a invaluable asset. Bob is known worldwide as an expert on stone fruit breeding, varieties and culture and has been an invited speaker to many fruit growing areas of the world. His worldwide contacts have helped make new varieties and rootstocks available to NY growers. His efforts have helped the NY stone industry develop new vitality.

Bob began his 40-year career in fruit breeding as a graduate student in 1964 at Michigan State University where he earned his Masters degree. He received his PhD degree from the University of Minnesota. The first third of his professional career was spent at Michigan State University where he focused on peach breeding. The second third was spent in department administration first at Clemson University and then at Cornell University. And the last third began in 1990 when he took over the stone fruit breeding and management program at Cornell where he has focused his research and extension efforts in the area of sweet cherry, plum and apricot breeding, cherry, pear, plum, and peach rootstock evaluation, and peach, pear, cherry, plum and apricot variety evaluation.

Through Bob's leadership, stone fruit research and extension has become an important part of the Cornell Fruit Program. Bob always had many ideas about research problems and was very effective in convincing his colleagues to work with him on the problems. He was extremely effective with the stone fruit industry and worked tirelessly to organize the stone fruit growers to help themselves through funding research projects. His vast experience and knowledge of stone fruits made him an invaluable resource to field agents and faculty and growers.

On behalf of the fruit faculty, extension field staff and the fruit industry in New York, we thank you Bob and wish him a successful retirement. You will always be a member of our team Bob.

Terence Robinson and Steve Hoying
Editors

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FRONT COVER: This issue of the Fruit Quarterly celebrates the many facets of the career of Bob Andersen.

BACK COVER: Pictured here are two cherry varieties developed and named by Bob Andersen - Black York on the upper right and Blushing Gold on the lower left. The remaining two photos depict cherry harvest in August 2005 at the Geneva Experiment Station.

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Pollination Research with *Prunus* Species and its Importance to Fruit Growers

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Research over the last 15 years on stone fruit pollination biology has shown that there are many more genetically different pollination compatibility groups than previously thought in both cherry and Japanese plum. This means that there are many more combinations of cultivars that may work effectively in orchard settings to produce regular cropping. Research over the next 15 years may bring answers to other vexing problems with stone fruits.

In a recent editorial by Ms. Margaret Roach, she rephrased an old saying, "Curiosity makes the world go round." I believe curiosity is a driving force for humanity and clearly for scientists. As an example the Cassini-Huygens space mission to land on Saturn's moon, Titan, to explore its elements and atmosphere's composition has just sent back enough data from a few minutes of planned sampling by the Huygens rover to keep earth scientists busy for years in determining its relevance to present knowledge. The methane rains on Titan are thought to have provided some of the building blocks for thonolins which are antecedents of amino acids. Physicists are probably more interested in Titan data to elucidate more about the understanding of the solar system, but most geneticists, theologians and even the person on the street are keen to learn what missing links in human's knowledge about biology are filled. Their curiosity is to explore more about Darwinism versus what is now called by many Intelligent Design (ID). Clearly, curiosity is a driving force for humanity.

Recent Pollination Research and Its Importance To Growers

I will explore here an example from pollination biology research. I think of it as a model for what we should be achieving through our curiosity about fundamental biology questions. Solving some of the 'super questions' can turn our dreams into new cultivars that are truly breakthroughs for human food needs.

Much has been written about pollination. The definitions about this important biological process for all of plant life are important and straightforward for growers to use in their bag of pomological knowledge. Why bother to increase your knowledge of how these pollination phenomena work? My answer, in a just four words, "curiosity can make money!"

How many individuals in the industry know how many genetically different pollen compatibility groups were thought to exist within sweet cherries in 1990? It was fourteen. Collaborative research since 1990 has proven that the actual number is nearly double that. This is important because there are many more combinations of cultivars that may work effectively in orchard settings to produce regular cropping. Also, in the past decade research has demonstrated how the biochemical signals work that control such incompatibility reactions. Similarly, in 1990, no scientist had yet established how many pollen compatibility groups existed that affected cross-pollination in Japanese plums. A recent Japanese publication reports that there are at least twenty-four separate groups with one of them conferring self-compatibility (Beppu et al. 2003).

Again, this means that growers can use scientific knowledge of which cultivars belong to which groups and which ones will pollinate each other. Tart cherries in production in North America were generally thought by American growers to be self-fertile because Montmorency is self fertile. Dr. Iezzoni's collaborative research with Japanese scientists has demonstrated that different classes of tart-cherry pollination groupings exist (Yamani et al. 2002). This is very important because diversification by growers to plant more nutriceutically beneficial cultivars of tart cherry will require high yields of new cultivars, and some of them are known now to be either self-incompatible or only partially self-fertile. Their research demonstrated not only that some tart cherries could be pollenized effectively by some sweet cherries but also demonstrated which sweet cherry cultivars would be effective with which tart cherry cultivars. All of the above sounds to me like precision agriculture instead of hunting in the dark.

I am going to review one of the most recently published pollination research articles. The East Malling research center led the collaborative effort. A graduate student, Dr. Brian Sutherland was the principle. I choose to review this because it presents many important concepts, techniques, definitions; and it's conclusions reach across several *Prunus* crop plants (almonds, apricots, cherries and plums) (Sutherland et al., 2004).

General Definitions About Pollination Biology

Pollination is the movement of pollen among compatible flowering plants (cross pollination) or from anthers to stigmas on the same plant or different plants of the same clone (self-pollination). Note: some plants self-pollinate but set few fruits; they must be considered as self-pollinated and partially self-compatible; they are not, however, self-fruitful. In regards to temperate-zone tree fruits, self-pollination and achieving some fruit set does not necessarily mean that they are self-fertile to the extent that they would have normal seeds. It is beyond the scope of this article to explore the various reasons for low fertility and poor fruit set. For our purposes it should be recognized that self-pollinated, self-compatible, self-fertile and self-fruitful each have separate definitions and causes.

Pollinators - insect vectors that move pollen from stamens to pistilate parts of flowers.

Pollenizers - male plants that provide pollen that is compatible genetically to female plants and that bloom simultaneously to the female.

Fertilization - union of egg cell with gamete from male pollenizer.

Fruit set - in most cases, fruits whose seed have been pollinated, fertilized, and matured through the various developmental processes essential to full fruit development.

Background (taken directly from Sutherland, 2004)

"Self-incompatibility (SI) in flowering plants and cross-incompatibility between cultivars is controlled by the highly polymorphic S-locus. Gametophytic incompatibility occurs when the allele in the pollen matches one of the stylar alleles. *Prunus* S-alleles encode stylar ribonucleases. Most important *Prunus* species are self-incompatible, requiring the planting of suitable pollinator (Note: by our definitions we'd call them pollenizer) cultivars for economic fruit set." (Figure 1).

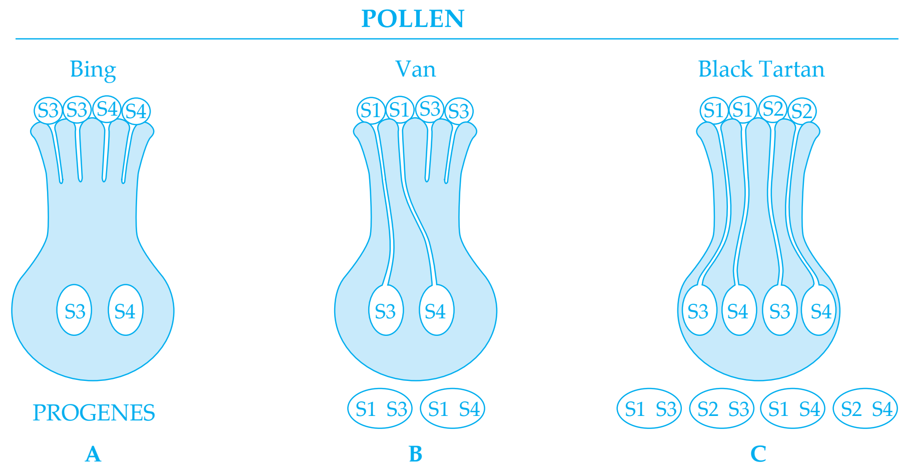
More definitions:

Allele - (from Webster) - any of a group of mutational forms of a gene.

Style & Stylar - that portion of the flower located between the stigmatic surface and the ovary(ies).

Ribonuclease - (from, Albert, et al, 1994) - enzyme that cuts an RNA molecule by hydrolyzing one or more of its phosphodiester bonds.

"Incompatibility genotypes are traditionally identified by controlled pollination, and more recently by stylar ribonuclease analysis (Boskovic and Tobutt 1996, Boskovic et al. 1997, Burgos et al. 1998). Both approaches require plants mature enough to produce blossoms and



A. 'Bing' pistil is self-incompatible with 'Bing' pollen,
B. 'Bing' pistil is partially cross-compatible with 'Van' pollen, and
C. 'Bing' pistil is completely cross-compatible with 'Black Tartan' pollen.

From: Ryugo, K. 1998. Fruit Culture: Its Science and Art. John Wiley & Sons, New York. Used with permission from John Wiley & Sons.

Figure 1. Gametophytic incompatibility in sweet cherry.

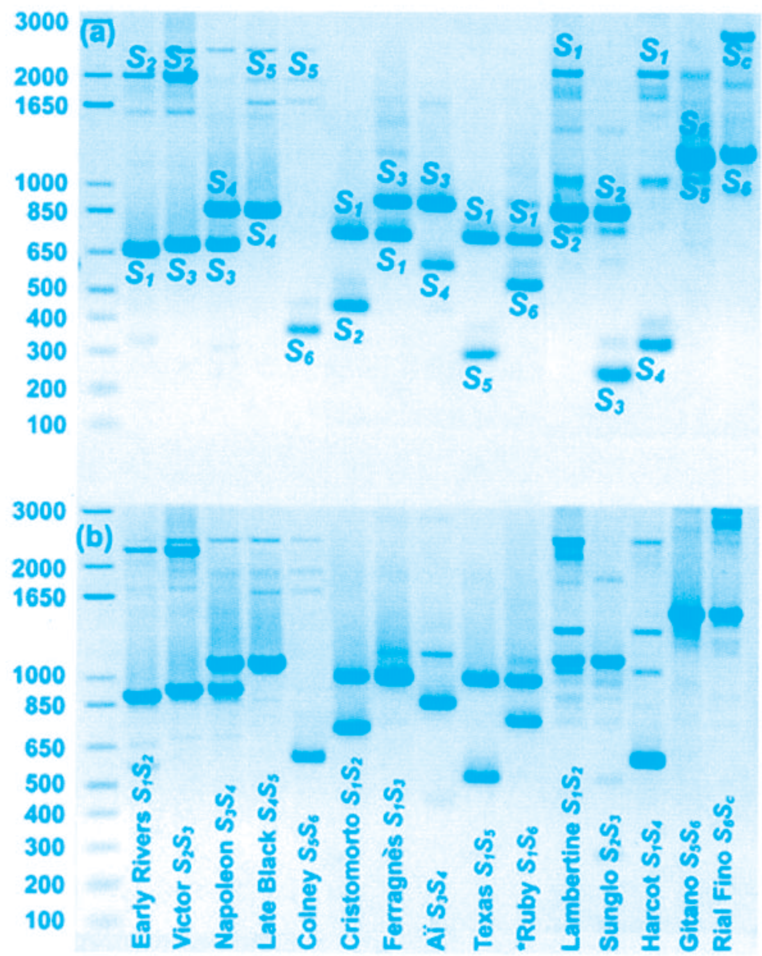


Figure 2 (from Sutherland et al., 2004). S-allele amplification with EM consensus primrers in five genotyped cultivars of cherry, almond and apricot (a) amplified with EM-PC2consFD + EM-PC3consRD (b) amplified with EM-PC2consFD + Em-PC5consRD. One kb Plus Ladder (Invitrogen, Carlsbad, California, USA) in lane 1, cherries in lanes 2-6, almonds in lane 7-11, apriocots in lane 12-16. *'Ruby', previously reported as S6S16, subsequently determined as S1S6 (E. Ortega, pers. Comm.). Some alleles, e.g. cherry S5 and Apricot S1 show additional bands.

the latter technique requires a high degree of technical competence. Numerous *Prunus* S-alleles have been at least partially sequenced. They contain two very polymorphic introns."

More definitions:

Intron - (from Alberts et al, 1994) - noncoding genetic region of a eucaryotic gene that is transcribed into an RNA molecule but is then excised by RNA splicing when mRNA is produced

Polymorphic - an adjective describing a gene that has several forms due to past mutational events.

Sequenced - a verb describing the technical process of identifying the triplets of nucleotides (codons) that are present in linear order within nucleic acids which determine the specific amino acid to be formed.

"Consensus primers based on conserved regions, especially those flanking the polymorphic second intron, have been developed which distinguish S-alleles on the basis of size of polymerase chain reaction (PCR) product, so that S-genotypes can be deduced from ampliphication patterns."

More definitions:

Consensus primers - average or most typical form of a sequence that is produced with minor variations in a group of related DNA, RNA, or protein sequences. The preservation of a consensus implies that the sequence is functionally important.

Conserved regions - parts of genetic information that has been proven to exist amongst, and to regulate the same processes in living organisms.

"PRC" - polymerase chain reaction - technique for amplifying specific regions of DNA by multiple cycles of DNA polymerization, each followed by a brief heat treatment to separate complementary strands.

Sutherland goes on to state the purpose of his experiments: "Previous work with sweet cherry, almonds and sour cherry developed three consensus primers but these primers were developed from a very small set of allele sequences from just one or two species which could limit their use in detecting S-alleles in a wider range of material." The purpose of Sutherland's work was to produce more versatile consensus primers and he reports having created, ".......three new consensus primers that flank the second intron, designed from alleles from five *Prunus* species and incorporating some degeneracy."

TABLE 1 (from Sutherland et al., 2004)

Amplification of S-alleles in sweet cherry, almond and apricot, using consensus primre combinations, two from East Malling and three published previously.

Trait	EM C2 + C3	EM C2 + C5	Tao C2 + C5[1]	Tao C2 + C4[2]	Yamame C2 + C3[3]
Cherry					
S_1	+	+	+	+	+
S_2	+	+	+	–	–
S_3	+	+	+	+	+
S_4	+	+	+	+	+
S_5	+[4]	+[4]	–	–	–
S_6	+	+	+	+	+
Almond					
S_1	+	+	+	+	+
S_2	+	+	+	+	+
S_3	+	+[4]	+	+	+
S_4	+	+	+	–	+
S_5	+	+	–	–	–
S_6	+	+	+	+	+
Apricot					
S_1	+	+	+	+	+
S_2	+	+	–	+	+
S_3	+	+[4]	–	–	–
S_4	+	+	+	+	+
S_5	+	+	+	+	+
S_6	+	+	–	+	+
S_c	+	+	–	–	–

[1]Pru-C2 + Pru-C5 (Tao et al. 1999).
[2]Pru-C2 + Pru-C4R (Tao et al. 1999).
[3]Pru-C2 + PCE-R (Yamane et al. 2001).
[4]Amplification is weak but visible.

Another definition:

Degenerate -an adjective that describes multiple states that amount to the same thing; different triplate combinations of nucleotide bases (codons) that code for the same amino acid, for example.

Sutherland's results are presented in Table 1 and Figure 2.

He concludes: "The efficacy of the East Malling (EM) primers is attributable to their design from a large set of published sequences drawn from several species and inclusion of degenerate bases where required. " He acknowledges that they may need to be redesigned when new alleles are found that can't be picked out by his new EM primer set. He states, "This EM primer set is effective in a range of species, detecting each allele in all cultivars tested. These primers will be suitable for genotyping seedlings in breeding programs, His final statement: "They should also be useful in population genetics and gene-flow studies based on S-alleles."

So, what does the Eastern US stonefruit growers get out of this (and the collaborative and other preceding experiments about pollen self-incompatibility genetics)? First, they get better and faster knowledge to assist in their planning of new orchard blocks so that they will have pollination plans that work. Second, they get a scientific approach to phylogenetic sleuthing about the origins of different Rosaceae commercial fruit crops. This may help solve regeneration recalcitrance and brown rot susceptibility of *Prunus.*

My Dreams

As I conclude my scientific career I want to ask some questions that have been bugging me and do a little dreaming with the hope that it will inspire future *Prunus* scientists. Dreaming leads to theories which lead to hypothesis which lead to experimentation, and ultimately these dreams produce the basis for business(es) that provide better food and a safer environment.

1. Why are stone fruits so recalcitrant regarding regeneration of whole plants from masses of cells? I assert that we have to get serious about the answer to this question if we want to move breeding of *Prunus* to the next level of genetic progress to meet society's food and environmental expectations. Transformation genetics will be kept locked out in the cold until we can clone most *Prunus* plant material at will at the cellular level. I dream of a project that takes the seed physiologists' knowledge of seed dormancy and geneticists' knowledge of morpho-genetics and then uses this body of knowledge in collaboration with horticultural breeders to solve this dilemma.

2. Why doesn't brown rot in some form attack apples and pears? Or, conversely, why don't stone fruits get fire blight? All of the *Prunus*, *Malus* and *Pyrus* are Rosaceae. Where along their evolutionary paths did the various *Prunus* species diverge from *Malus* and *Pyrus* in such a way that the *Prunus* co-evolved in the same eco-systems with brown rot without developing much of a genetic firewall against this terrible fungal disease? Why were apple and pear ancestors spared? Can we assume that botanical geneticists (phylo-geneticsts) can help us determine which of the living samples of wild accessions of these species are the oldest? Do we have collections in hand that are from geographic sites of intermingled origins of the ancestral homes of apples, pears and stone fruits? If these questions of botanical and pathogen ancestry can't be researched with living accessions, can pollen collections that archeologists use and date for crop plants like maize, wheat and rice also be explored for our most important deciduous tree fruit species? Does the gene-for-gene concept hold potential answers about these questions? I think that we simply have to dream up ways to interest more fundamental sciences to join in exploring our knowledge of food plants and their co-evolution with their pests. I believe that the strong interest in natural foods and their health benefits should be our very best ally in pushing for more science initiatives into the genetics of host-parasite relationships at the molecular level. Who among our scientific community(ies) are working on making these political alliances that will lead to national research initiatives?

3. Are the metabolic pathway(s) in *Prunus* that important fungicides affect in their control of a disease like brown rot known? If so, can't we use this knowledge to direct our research? Do other genera within Rosaeceae use similar anti-fungal metabolites that occur naturally within their tissues? Do they have conserved genes that guard them from brown rot that *Prunus* does not have? Why? Or, why don't mango fruit get attacked by brown rot? A similar question might be asked for cantaloupe. These two kinds of fruit are emerging as major competitors for the market share that stone fruits want. They are juicy and full of sugars that would seem to be substrates for brown rot fungi to attack. Do we have any idea what metabolites protect their tissues from brown rot?

4. Some of my friends from lay backgrounds who love to eat cherries and apricots, and are now seeing 'peento' (flat, doughnut-shaped fruits that are the result of compressed seed shapes in peaches/nectarines). This has made them curious about other seed-related questions. They ask me if we can breed the pit out of stone fruits like they did for seedless grapes? They hardly think of us doing this for them as being a dream. To them it's a readily achievable goal — because they see that clever grape scientists and watermelon scientists have done so. Well, why not get started on this problem? Seeds aren't necessary to the consumer; they're thought of as something to discard. We know about a few cultivars of plums with edible (soft enough to chew) endocarps, which have sweet seeds (nonpoisonous). We know we can breed edible almond seeds and so- called sweet-kernel apricots. So, we are sure that we could breed seeds that would be healthful, but how about changing the structure of the bony endocarp so it is much more palatable as roughage? How seriously has any stone fruit breeder looked into this question? Would it affect propensity for split pits? Most lay people believe it can be done. Do any of you?

5. Dr. Dennis Werner at North Carolina State University recently released the first commercial peach cultivar in the USA that did not have 'Chinese Cling' cultivar as its ancestor. How could we have been so narrow in creating the genetic populations from which the USA's peach/nectarine industry is based? Sweet cherry breeding is still mostly focused on parents that came from Roman Empire sources of old cultivars like Hedelfingen and Napoleon. Dr. Wayne Sherman, Professor Emeritus at University of Florida, dreamed about a low chilling sweet cherry. He used Japanese apricot interspecific hybridization with commercial sweet cherries to get his low chill cherry. These scientists are dreamers and they are my heroes!

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Robert Andersen is a recently retired emeritus professor of Horticulture who specialized in the breeding and culture of stone fruits. He led Cornell's breeding, culture and extension program on stone fruits from 1990 to 2005.

Cherry Breeding: Striving to Make a Difference

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The goals of the cherry breeding programs in the U.S. are to increase grower profitability through the adoption of new cultivars. To reach these goals, it is imperative that breeding teams carefully assess grower needs to identify and rank priorities. In addition, due to the long time required to breed new cultivars, it is critical that the breeding team take risks to include fruit types that have the potential to open up future market opportunities. As the breeder is limited by what is genetically possible, cultivar development begins with an assessment and then accumulation of the genetic diversity needed to achieve these goals.

Access to cherry germplasm for U.S. breeding programs is a very long and cumbersome process for two reasons. The first reason is that USDA-APHIS quarantine regulations prohibit the direct importation of budwood due to virus concerns. Therefore, imported budwood must be sent to the USDA Plant Germplasm Quarantine Office for a minimum of three years for virus indexing. If clean, it will be released. Secondly, the center of diversity for cherry is in the Black Sea and Caspian Sea region, where travel, communication and even express mail access is difficult. Nonetheless, as knowledge of the germplasm and access to superior germplasm is critical for cultivar development, I made at least 10 trips to Eastern Europe from 1984 to 1998 to achieve these goals.

Tart Cherry

Approximately 50 Eastern European tart cherry varieties were imported as budwood between 1985 and 1998. These varieties were tested as part of the MSU tart cherry breeding program and resulted in the release of three varieties developed in Hungary: 'Balaton®', 'Danube™' and''Jubileum®'. These varieties were commercialized because they are uniquely different from 'Montmorency' in fruit quality attributes, and they open up opportunities for new product development. For example, all the varieties have firm fruit with higher sugar levels and natural pigments than 'Montmorency' (Table 1). These attributes have resulted in three new products for''Balaton®', the most widely grown of the selections: cherry port, pitted cherries in a glass pack, and fresh market. More information regarding 'Balaton®' is located at: www.hrt.msu.edu\balaton.html.

In total, the cherry germplasm introduced to the U.S. through the Michigan State University cherry breeding program provided a rich genetic base, which brought forth trait selection and an aggressive sour cherry breeding program. To date, it is through genetic improvement of the traits listed below that I am'"striving to make a difference":

- Cherry leaf spot resistance
- Possibly cherry fruit fly resistance
- Late-bloom time for spring frost avoidance
- Superior fruit quality traits: firm fruit, high soluble solids, freestone, and a range of skin and juice colors.

Approximately 30 MSU selections are in advanced trials on MSU or grower farms, or they are being propagated for advanced trials. We know they have excellent fruit quality from single tree evaluations, but the big questions are yield potential and processing capabilities of the fruit. These on-farm trials are designed to achieve this information by providing a range of environmental conditions and larger quantities of fruit.

To date, the most apparent negative attribute has been a tendency for lower yields in many seedlings. Therefore, intense selection pressure is being applied for high fruit set. Our research has shown that in certain cases, poor fruit set in sour cherry can be caused by the same self-incompatibility system that operates in sweet cherry. Therefore our

The Michigan State University tart cherry breeding program is striving to develop new varieties that are resistant to cherry leaf spot, and cherry fruit fly, that bloom late to avoid spring frost and that have superior fruit quality traits such as firm fruit, high soluble solids, freestone, and a range of skin and juice colors. Approximately 30 MSU selections are in advanced trials on MSU or grower farms.

TABLE 1

Evaluation of flower, fruit and pit traits for 'Montmorency', 'Jubileum™', 'Danube™' and''Balaton®' at the Clarksville Horticultural Experiment Station for 13 years (1988-2000).

Trait	'Montmorency'	'Jubileum™'	'Danube™'	'Balaton®'
Bloom datex	May 6	-1	-3	+1
Harvest datex	July 10	-9	-8	+8
Fruit weight (g)	4.9	5.8	6.2	5.8
Fruit length (mm)	17	19	20	19
Fruit width (mm)	20	23	22	22
Soluble solids (%)	14.2	19	17.3	16
Skin color	Bright red	Dark purple	Dark red	Dark red
Flesh/juice color	Clear	Purple/red	Dark red	Dark red
Pit length	9.6	10.2	11.3	10.4
Pit length/width	1.12	1.11	1.14	1.12
Pit wt./Fruit wt. (%)	6.2	5.7	6.3	6.4

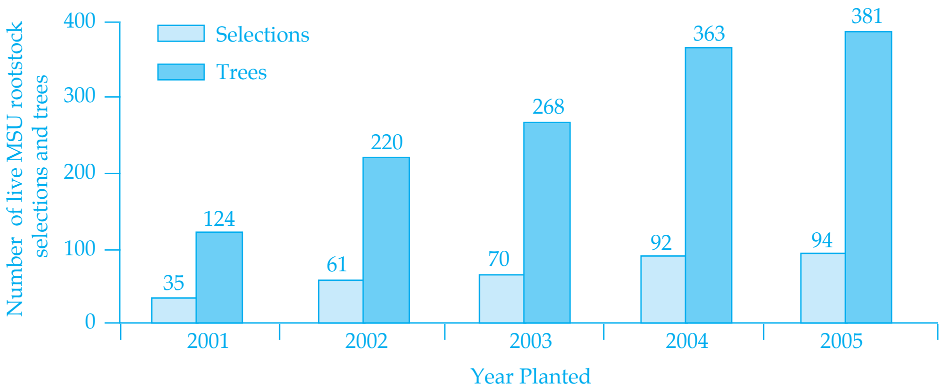

Figure 1. The cumulative number of live MSU rootstock selections and trees currently planted and projected to be planted in Clarksville, MI. The majority of rootstock selections have 'Hedelfingen' scions while some selections have 'Bing' scions.

goal is to develop molecular markers for early detection of highly self-fertile selections. We are currently using this genomics technology to address a production problem. In particular, we are attempting to determine if fruit set in 'Balaton®' would be increased with a pollinator cultivar, and if so, which one.

Cherry Rootstocks

Precocious and dwarfing rootstocks are available from Europe; however, the tendency for cherry cultivars to over-crop on these precocious rootstocks makes it difficult to achieve the large fruit size needed for maximum profitability. For example, 'Gisela 6' induces early and abundant fruiting in the scion. This is a result of an increased number of spurs per tree as well as fruit per spur compared to the standard 'Mazzard'. However, fruiting density (i.e., fruit per spur) on 'Gisela 6', and especially 'Gisela 5', is often excessive. This has created new difficulties in achieving the balanced crop load necessary for maximizing fruit size and quality. This challenge has limited the commercial adoption of these rootstocks.

By the mid-1990's the tart cherry collection at MSU was the largest such collection in the world. At the same time, two of the most successful cherry rootstock breeders in the world, Dr. Hanna Schmidt (Gisela series) and Dr. Brigitta Wolfram (PiKu series), were retiring and their programs were not being continued. According to these breeders, tart cherry and its related species were the most promising species from which to select superior rootstocks. Since dwarfing, precocious, sweet cherry rootstocks would significantly increase the profitability of fresh-market sweet cherry production, a rootstock selection program was begun in 1997 at MSU. The strategy was essentially to 'recycle' the MSU germplasm by selecting rootstock candidates among seedlings that were not suitable cultivar candidates. This effort was designed to sample the diversity within the MSU collection for its rootstock potential prior to its removal.

Due to the susceptibility of some of the international sweet cherry rootstocks to PDV and PNRSV, pre-screening for virus resistance was done. Additionally, for practical reasons, all rootstock candidates were tested for their ability to be propagated from vegetative cutting.

From this five year effort, 92 MSU rootstock selections are identified as having acceptable levels of vegetative propagation capability and virus tolerance (Figure 1). Surprisingly, the vast majority of the MSU rootstocks induced early scion flowering similar to that of a 'GI 6' budded tree. To date, only two rootstock candidates have been eliminated due to graft incompatibility. These results are sufficiently promising, and we propose to re-propagate the superior candidate rootstock selections in 2006 to provide trees for advanced testing in multiple test sites.

Since the initiation of the project, there has been an increased understanding of how a balanced cropping approach can be used to maximize fruit size while maintaining yield. As the rootstock has a direct effect upon fruiting density, our goal is to identify a rootstock that confers a fruiting habit characterized by well-balanced spurs possessing 2-4 fruit. We predict that this will reduce the number of years required to evaluate the rootstocks for yield and fruit size.

Sweet Cherry

The feasibility of sweet cherry breeding to produce commercially successful sweet cherry cultivars is widely accepted. For example,''Ulster' is from the cross 'Schmidt' x 'Lambert', 'Rainier' is from the cross 'Bing' x 'Van', and 'Brooks' is from the cross 'Rainier' x 'Early Burlat'. These three cultivars,''Ulster', 'Rainier', and 'Brooks' developed by Agricultural Experiment Station scientists at Cornell University, Washington State University, and the University of California, Davis, have contributed greatly to the success of the sweet cherry industries in their respective locations.

With the introduction of the self-fertile cultivar 'Stella' in 1968 from the Canadian Breeding program in British Columbia, a whole new series of hybrids were created using 'Stella' as a parent to transmit self-fertility. As in other programs, the Cornell breeders also made crosses with 'Stella' that led to the release of some very promising self-fertile sweet cherry cultivars for the Northeastern U.S. These cultivars have the potential to substantially impact the profitability of sweet cherry production in this region. It is this series of self-fertile cultivars that will represent a successful end to the legacy of the Cornell sweet cherry breeding program.

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Early Twenty-first Century Cherry Varieties for the Great Lakes and Eastern North America

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Performance of cherry varieties across Eastern North America can vary widely due to soil and climatic differences. Nevertheless in this article we give our recommendations on sweet and tart cherry varieties for Eastern North American production during the early twenty-first century – that is, older varieties that we expect to remain important for at least the next decade, as well as new varieties that hold promise for existing and/or new market opportunities, especially for regional fresh markets.

The Great Lakes and Eastern North America cherry-growing regions are characterized by highly variable soils and seasonal climates that can vary widely, day to day, even across short distances. For this reason, cherry-variety performance data from either university research plots or experiences from fellow growers' orchards can constitute neither absolute endorsements of certain success nor guaranteed prophesies of abject failure. In particular, relative bloom sequences among varieties (and thus susceptibilities to cold and flower/fruit diseases) can vary widely from year to year. Successful growers in these regions have come to realize that such cherry variety test reports are usually excellent guidelines, but nothing beats on-site orchard experimentation with varieties that have traits of potential interest for specific markets. That is, the 'perfect' sweet cherry variety clearly has not yet been found; for every positive set of traits (self-fertile, large fruit size, reduced rain-cracking or disease susceptibilities, etc.), there is always an accompanying set of questionable traits (small fruit size, winter cold or spring frost susceptibility, light cropping, etc.). Individual orchard sites, microclimates, and target markets can tend to enhance or minimize certain variety traits and make all the difference between success and marginal returns.

With those caveats plus a few listed at the end of this article, we will provide some key details and comments on sweet and tart cherry varieties for Eastern North American production during the early twenty-first century – that is, older varieties that we expect to remain important for at least the next decade, as well as new varieties that hold promise for existing and/or new market opportunities, especially for regional fresh markets. In general, the varieties discussed below are listed in order of ripening.

Dark-Fleshed Sweet Cherry Varieties for Fresh Marketing

Early Season

Cavalier™ (Rynbrandt cv.) – Extensively tested. Early ripening, high quality, firm, medium-sized, dark-red fruit. Low productivity on vigorous rootstocks, but a good match for precocious, productive, vigor-controlling clonal rootstocks. Bacterial canker tolerance and winter hardiness are both good, as is resistance to cracking. Self-infertile, in Pollen Group IV (S_2S_3), with an early bloom season; multiple pollenizers are recommended to boost productivity.

Chelan® – Promising, limited test trials. Moderately good quality, dark mahogany red, firm fruit having moderate to large size and early season ripening. For best flavor, fruit must be allowed to ripen fully. Productivity is very good, resistance to cracking is fairly good, and trees are resistant to powdery mildew. Self-infertile, in Pollen Group XVI (S_3S_9), with an early bloom season. May not be large enough under eastern growing conditions.

Tieton® – Promising, limited test trials. Fruit are dark red, firm, very large, with a mild flavor and very attractive appearance, along with an early season ripening time. Very low productivity on vigorous rootstocks, but a good match for precocious, productive, vigor-controlling clonal rootstocks. Very susceptible to rain-induced fruit cracking. Self-infertile, in Pollen Group XVI (S_3S_9), with an early bloom season.

Early Robin® - Promising, limited test trials. Fruit are light yellow-fleshed with an orange red-on-yellow skin blush, firm, with large size, good flavor, and an early-to-mid-season ripening time. Self-infertile (Pollen Group as-yet unknown), with a mid bloom season.

Sam – Extensively tested. Early-to-mid season ripening, moderately large, very dark red to black fruit, with poor flavor until fully ripe and dark. The fruit are borne in relatively tight clusters, which favors brown rot incidence. Winter hardiness and resistance to bacterial canker, as well as fruit resistance to rain-cracking, are among the best. Should only be grown for fresh market if fruit can ripen fully. Self-infertile, in Pollen Group XIII (S_2S_4), with a late bloom season.

Kristin - Extensively tested. Early-to-mid season ripening, moderate sized, firm dark red, flavorful fruit. Winter hardiness is excellent, and fruit have moderate to good resistance to rain-induced fruit cracking. Self-infertile, in Pollen Group III (S_3S_4), with an early-to-mid bloom season.

Mid-Season

Benton® (Columbia) – Promising, limited test trials. Fruit are dark mahogany red, firm, with large size, very good flavor, and a mid-season ripening time. Consumer taste panels in Washington state picked 'Benton' over 'Bing' in three of four years, and performance has been rated consistently high in trials in New York as well as Europe. Resistance to cracking is fairly good. Self-fertile, with a mid-to-late bloom season.

WhiteGold® - Promising, limited test trials. Fruit are light yellow-fleshed with a red-on-yellow skin blush, firm, with moderate-to-large size, good flavor, and an early mid-season ripening time. Trees are very productive, cold hardy and well-adapted to the growing conditions of eastern North America, with a very low susceptibility to cherry leaf spot and bacterial canker. Fruit are moderately tolerant of rain. Self-fertile, with a mid-to-late bloom season.

Glacier® - Promising, limited test trials. Impressively large fruit size, dark mahogany red with very good flavor but less firmness than other fresh market varieties; ripens mid-season. 'Glacier' could be an outstanding fruit for local fresh markets and may be a good candidate for matching with precocious, size-controlling rootstocks. Moderately susceptible to rain-cracking. Self-fertile, with a mid-to-late bloom season.

Ulster - Extensively tested. Fruit are dark red, moderate-to-large, with good quality and a mid-season ripening time. A very productive variety, hence is prone to overproduction on precocious rootstocks if not managed properly. Winter hardiness and wood resistance to bacterial canker are good, though fruit are moderately susceptible to both Pseudomonas infection and rain-cracking. Self-infertile, in Pollen Group III (S_3S_4), with a mid-bloom season.

Rainier – Extensively tested. The excellent quality fruit are light yellow-fleshed with a red-on-yellow skin blush, firm, with large size, very good flavor, and a mid-season ripening time. In the Great Lakes, winter cold damage (particularly in young trees) and its associated disease problems, such as bacterial canker, can be a challenge for maintaining tree health, and in some orchards, 'Rainier' fruits have been noted to be particularly susceptible to *Alternaria* infection. Fruit are also susceptible to rain-induced cracking. Self-infertile, in Pollen Group IX (S_1S_4), with an early-to-mid-bloom season.

Emperor Francis – Extensively tested. The fruit are light yellow-fleshed with a red-on-yellow skin blush, firm, nice quality though of only medium size, and a mid-season ripening time slightly after 'Rainier' and 'WhiteGold'. Productive, with good tree survival of cold winters and endemic diseases, and having better resistance to fruit cracking than `Rainier'. Self-infertile, in Pollen Group III (S_3S_4), with an early-to-mid bloom season.

Sandra Rose® - Promising, limited test trials. Fruit are dark red, moderately firm, large, with very good flavor and appearance, and a mid-season ripening time. Young trees have been productive and healthy thus far in Michigan trials. Self-fertile, with a mid-bloom season.

BlackGold® – Promising, limited test trials. Fruit are moderately large, dark red and heart-shaped, firm, ripen in mid-season, and moderately tolerant of rain. Trees are productive, cold hardy, and well-adapted to the growing conditions of Eastern North America, though resistance to bacterial canker is only mediocre. Self-fertile, with a late bloom season.

Summit - Extensively tested. Impressively large, bright red, heart-shaped fruit size, with good flavor but less firmness than other fresh market varieties. Ripens mid-season, but often is picked earlier, especially by pick-your-own customers due to remarkable size. Moderately susceptible to rain-cracking, and tree winter-hardiness may be marginal in some years, but impressive fruit size is worth a trial. Self-infertile, in Pollen Group I (S_1S_2), with a mid-to-late bloom season.

Schmidt - Extensively tested. Fruit quality is moderately good (in terms of size and firmness) with very good flavor, ripening mid-season with excellent resistance to rain-induced fruit cracking. The traditional drawback with 'Schmidt' is low productivity, but the potential for matching with a new clonal rootstock to impart higher productivity is worthy of further testing. Self-infertile, in Pollen Group XIII (S_2S_4), with a mid-to-slightly late bloom season.

Olympus® - Promising, limited test trials. Fruit are moderate-to-large, firm, with a mahogany red skin and dark red flesh, and a mid-to-late ripening time. A somewhat spreading tree habit, with precocious cropping, very good productivity, and above average resistance to rain-induced fruit cracking. Self-infertile, in Pollen Group II (S_1S_3), with a mid-to-late bloom season.

Attika™ (Kordia) - Extensively tested. Fruit are large, very firm, heart-shaped and mahogany red with a very long stem, have excellent flavor, and a mid-to-late ripening time. Winter hardiness is good, with moderate-to-good tolerance of rain, but the flowers are more frost-sensitive than other varieties. Self-infertile, in Pollen Group VI (S_3S_6), with a mid-to-late bloom season.

Late Season

Sylvia - Promising, limited test trials. Fruit are dark red, large and firm, with good flavor and a mid-to-late season ripening time. Bacterial canker tolerance is good, and the tree has a lower vigor than normal, even on vigorous rootstocks. Tolerance to rain-cracking has varied widely, from excellent tolerance in some locations to excessive cracking on young trees at other locations. Self-infertile, in Pollen Group IX (S_1S_4), with a late bloom season.

Selah® (Liberty Bell) - Promising, limited test trials. A dark red to mahogany, round fruit having impressively large fruit size, excellent flavor, and a mid-to-late season ripening time. Fruit are borne in loose clusters and have average susceptibility to rain-induced cracking. Superior size and cropping habit to 'Lapins' under western conditions, but little performance data yet available in Eastern North America. Self-fertile, with an early-to-mid bloom season.

Skeena® - Promising, limited test trials. A dark red to mahogany, impressively large and attractive high quality fruit, having good flavor and a late ripening time. Superior to 'Lapins' for both fruit traits and tree growth (spreading and precocious) under western conditions, with moderate tolerance to rain, but little performance data in Eastern North America. Self-fertile, with a mid bloom season.

Regina® - Promising, limited test trials. Good quality, mahogany red fruit, having large size, good firmness, a mild flavor, and a late ripening time. Cold hardy and well-adapted to the growing conditions of Eastern North America, with good tolerance of rain and low susceptibility to cherry leaf spot. Productivity is low-to-moderate, making this a good candidate for matching to new clonal rootstocks that impart higher productivity. Self-infertile, in Pollen Group II (S_1S_3), with a very late bloom season; multiple pollenizers are recommended to boost productivity.

Sweetheart - Promising, limited test trials. Very good quality, bright red, firm fruit having moderate to large size, good flavor, and very late ripening. A very grower-friendly tree, with a spreading tree form and precocious, heavy cropping on all rootstocks. Reports on winter hardiness and bacterial canker susceptibility have been variable, and fruit are moderately susceptible to cracking. Self-fertile, with an early-to-mid bloom season (though bloom date has varied widely in Northwest Michigan).

Hudson - Extensively tested. Good quality, mahogany red, firm fruit having moderate to large size, good flavor, and very late ripening. Very good winter hardiness and tolerance to bacterial canker, as well as good resistance to fruit cracking. Productivity is quite delayed, suggesting better potential with a clonal rootstock to impart precocity and productivity. Self-infertile, in Pollen Group IX (S_1S_4), with a late bloom season.

Sweet cherry varieties that are likely to be unsuitable for eastern production for fresh markets due to poor tree (i.e., cold or disease susceptibilities, etc.) or fruit (i.e., soft or small, excessive cracking, etc.) characteristics include: Burlat, Brooks, Cashmere, Index, Van, Bing, Royalton, Somerset, Napoleon (Royal Ann), Gold, Hartland, Sonata, Lambert, Hedelfingen, Lapins.

Tart Cherry Varieties for Fresh Marketing

Recent Great Lakes region marketing research (G. Lang and B. Behe, personal communication) has demonstrated favorable acceptance, by both consumers and retailers, for certain dark-fleshed, high sugar content (Morello-type) tart cherry varieties grown or under test in Michigan. Premium produce retailers handled the fresh tart cherries in protective clamshell packaging, fully ripe with stems off. Most consumers reported eating the fruit fresh, with some limited use for cooking and baking.

Jubileum™ (Érdi jubileum) - Promising, limited test trials. Fruit skin, flesh, and juice are dark mahogany red, relatively large (~5.5 to 6 g) and relatively firm for a tart cherry, with an excellent sweet-tart flavor and an early mid-season (tart cherry) ripening time. The highest sugar levels (18 to 19 °Brix) of the three fresh market sweet-tart cherries. Much less productive than Montmorency, thus is a good candidate for a precocious rootstock. Self-fertile, with a mid-bloom season.

Danube™ ***(Érdi bôtermô)*** - Promising, limited test trials. Fruit skin, flesh, and juice are dark mahogany red, large and firm for a tart cherry, with an excellent sweet-tart flavor and an early mid-season (tart cherry) ripening time. The largest fruit size of the three fresh market sweet-tart cherries. Much less productive than Montmorency, thus is a good candidate for a precocious rootstock. Self-fertile, with an early-mid bloom season.

Balaton™ ***(Ujfehértoi fürtös)*** – Promising, limited test trials. Fruit skin, flesh, and juice are dark mahogany red, relatively large (~ 5.5 to 6 g) and firm for a tart cherry, with an excellent sweet-tart flavor (~16 °Brix) when fully ripe, and a late season (tart cherry) ripening time. Tree has an upright habit and can be less productive than Montmorency in some locations, thus can be a good candidate for a precocious rootstock. Also, not as cold-hardy as Montmorency. Self-fertile, with a mid-bloom season. Excellent potential for not only a fresh market tart cherry, but also desirable for niche processed products such as cherry wine, dried pitted fruit, and its firmness and complex flavor makes it very good for baking, chocolate-covered liquer cherries, etc.

Cherry Varieties for Processing

The sweet cherry industry in Michigan is dominated by production for processing markets. Light-fleshed sweet cherries (primarily 'Gold', 'Emperor Francis', and 'Napoleon') grown for the maraschino market represent 64% of Michigan's 9,000 acres of sweets. The remaining 36% of the acreage are dark-fleshed sweets grown primarily for processing. The overwhelming majority of Michigan's tart cherry acreage is a single variety for processing, 'Montmorency', which will not be discussed here.

Light-Fleshed Sweet Cherry Varieties for Processing

Napoleon – An old variety, no longer recommended.

Emperor Francis – See above. Plantings for processing will likely continue.

Blushing Gold® (NY8182) – Promising, limited test trials. Fruit size is small on heavily-cropped trees, with a red-blushed skin, good firmness and excellent crack resistance. Fruit are readily detached from the stem at maturity for ease of mechanical harvest. Trees are precocious and very productive, with a bit less cold hardiness than–'Gold', 'Emperor Francis', or 'WhiteGold', but adequate for good sites. Self-infertile, in a currently un-named Pollen Group (S_1S_6), with an early-to-mid bloom season.

WhiteGold® - see above.

NY518 (not yet named) – Promising, limited test trials. Fruit is similar to 'Gold', being solid yellow with no red blush, and appears to have better resistance to rain-induced cracking. Self-infertile, in a currently un-named Pollen Group (S_1S_6), with an early bloom season.

Gold – Extensively tested. The dominant sweet cherry variety grown in Michigan, with continued planting. The fruit are solid yellow (no blush), small, and firm. Trees have excellent cold hardiness. Yields are generally disappointing on Mazzard, but better on Mahaleb. Self-infertile, in Pollen Group VI (S_3S_6), with a late bloom season.

Dark-Fleshed Sweet Cherry Varieties for Processing

Ulster – See above.

Sam – See above.

BlackYork® - Promising, limited test trials. Fruit are dark red, firm, moderate to large in size, with good quality, fairly good tolerance of rain, and a mid-season ripening time. The tree is productive, hardy and tolerant to bacterial canker. Self-infertile, in Pollen Group IX (S_1S_4), with a mid-bloom season.

BlackGold® - See above.

Other considerations that can influence variety success include the increasing understanding of when to use (and how to manage) dwarfing and/or highly precocious/ productive rootstocks in the variety picture. Similarly, the potential use of plastic covers or tunnels can change the relative importance of such challenging factors as rain-cracking, bacterial canker or brown rot, spring frost, etc. The use of gibberellic acid (GA_3) early in the season to reduce blind wood and/or pre-harvest to improve fruit firmness can improve the performance of some varieties. Additional information on these and other varieties, as well as other aspects of cherry production, can be found at the websites for Michigan State University (www.hrt.msu.edu/faculty/list_langg.htm) and the MSU Northwest Horticultural Research Station (www.maes.msu.edu/nwmihort/).

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Cherry Rootstocks Trials at Geneva

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Cherry rootstock trials at Geneva since 1986 have shown Gisela 6 (Gi.6) rootstock to be the most reliable semi-dwarfing stock for sweet cherry. Gi.5 has also shown promise as a stock that is about 25% smaller than Gi.6; however, Gi.5 has proven to be unsuccessful if it is not irrigated. Newer trials have shown additional dwarfing stocks that are promising.

Cherry trees on seedling rootstocks are large, slow to bear and do not lend themselves to high-density plantings. As has been done with apple, dwarfing rootstocks are key to successful intensification of cherry orchards. Ever since 1986, when Dr. Jim Cummins planted the first NC-140 sweet-cherry rootstock trial at Geneva, we have continued to have an avid interest in finding better stocks than Mazzard and Mahaleb seedlings.

1986 NC-140 Sweet-Cherry Rootstock Trial

Gisela 6 (Gi.6) emerged from the 1986 trial as the most reliable semi-dwarfing stock. Gi.5 also showed promise as a stock that is about 25% smaller than Gi.6. Both stocks have been planted commercially and gained favor with some growers; Gi.5, however, has proven to be unsuccessful if it is not irrigated. Both stocks suffer from over-setting and small fruit size if horticultural management practices, like strong pruning and irrigation, are not utilized. More recent trials with additional cherry rootstocks have given additional support to Gi.6, and have shown some additional promising rootstocks.

1998 NC-140 Sweet-Cherry Rootstock Trial

From our sweet-cherry trial planted in1998, there are three groups of rootstocks to discuss with respect to tree vigor. The two seedling stocks (Mazzard and Mahaleb) continue as the most vigorous with Gi.6, Weiroot 10, and Weiroot 13 remaining close in size. Weiroot 158, Gi.195-20, and Edabriz continue to comprise the mid-vigor group. The low-vigor group includes Gi.7, Weiroot 72, Gi.5, Weiroot 53, and Gi.3 (formerly Gi.209/1). Relative propensity to sucker (most to none) were: Weiroot 10, Weiroot 158, Weiroot 13, Gi.7, Mazzard, Weiroot 72, Weiroot 53, Edabriz, Gi.195/20, Gi.6, Gi.3, Mahaleb, Gi.5. Some low-vigor stocks have shown early cessation of terminal growth, minimal extension growth, and unhealthy, pale green-yellow leaves which prematurely cupped and drooped in late August through September and October. These symptoms resembled drought stress but no prolonged period had passed without rains. This trial is not irrigated and the lack of irrigation may be the cause of the poor performance of the most dwarfing stocks. An analysis of trunk cross-sectional area increase for the last few years indicates that the low vigor stocks have shown a depressed growth rate despite a light to zero crop during the last three growing seasons at Geneva. In another trial of cherry orchard systems with both Hedelfingen/Gi.5 and Hedelfingen/Gi.6, this one irrigated, both stocks showed adequate growth and no leaf cupping and poor leaf coloration.

Winter injury to flower buds in January 2004 caused major loses of fruiting for the second year in a row. With Hedelfingen, trees on Gi.3 had the lowest live flower count followed by Gi.5, Weiroot 53 and 72, Gi.7 and Gi.195/20 (Table 1). The greatest number of live flowers was with trees on Mazzard, Mahaleb, Weiroot 10, and 13 followed by Weiroot 158, Edabriz and Gi.6. During the 2003/2004 winter, a mid-season warm spell caused an early loss of hardiness by some stocks. Temperatures dropped from 60°F on January 2 to minus 18.5°F on January 9.

Some of the less vigorous stocks failed to be more yield efficient than more vigorous stocks. This was due in part to severe bud damage in the winter but may also have been due to poor compatibility between the scion and the rootstock. The exception to this was Weiroot 72, which in 2004 had one of the best yield efficiency ratings.

After four cropping seasons, Gi.6 appears to be the best overall rootstock in the trial. Weiroot 72 would be a close second choice because of high yield efficiency and good winter survival if suckering propensity weren't considered of importance; however it had six times as many suckers as Gi.6. Gi.5 can only be recommended if trees are irrigated and under high levels of commercial horticultural management.

2002 PiKu1 and PiKu3 Rootstock Trial

The PiKu series of cherry rootstocks were bred in Pillnitz (Dresden), Germany. The plant material was provided for trials in the United States via International Plant Management Inc. in the spring of 2002. The trial compares eight scions varieties (Attika, BlackGold, Hedelfingen, Lapins, Regina, Summit, Ulster, WhiteGold) and 2 PiKu rootstocks. At the end of three seasons, trees on PiKu1 were significantly smaller than trees on PiKu3. Three cultivars (Hedelfingen, WhiteGold and Regina) were significantly lower in vigor than the other five more vigorous scions. PiKu1 shows some aerial roots, which are attractive to borers.

1998 NC-140 Tart-Cherry

TABLE 1

Live flower ratings for thirteen sweet-cherry rootstocks with Hedelfingen as the scion in the 1998 NC-140 sweet cherry rootstock trial at Geneva, NY taken on May 5, 2004 following a severe January freeze event.

Rootstock	Live Flower Rating*
Mahaleb	4.0
Mazzard	4.0
Weiroot 10	4.0
Weiroot 13	4.0
Edabriz	3.6
Weiroot 158	3.6
Gi.6	3.4
Gisela 195/20	2.9
Gi.7	2.7
Weiroot 72	2.6
Weiroot 53	2.0
Gi.5	1.5
Gi.3	1.1

0 = no live flowers, 1 = fewer than 50 live flowers, 2= 50 to 100 live flowers, 3= 100 to 250 live flowers, 4 = over 250 live flowers per tree.

Rootstock Trial

In our 1998 NC-140 Montmorency Sour-Cherry Trial, Mahaleb, Gi.6 and MXM60 are the most productive rootstocks. Maheleb performs well except in sites prone to phytophthora root rot. Where this disease is prevalent on heavier soils, Gi.6 and MxM 60 have shown greater promise.

After three years, there were three groups of vigor classification for Montmorency. The most vigorous group includes: Weiroot 13, Weiroot 10, Mahaleb, and Gi.6. 'Weiroot 53' has a malady just above the graft unions on all trees. Emanations in the bark just above the union take the form of three-quarter-inch bark lumps with deep vertical grooves about every 5cm apart and some horizontal grooves in the erupted bard. These eruptions were about 30cm in height and were thicker and longer if the graft union was fully exposed above the soil line. Weiroot 53 had a very marked decline in yield efficiency in 2004 compared to earlier seasons when it had been the most yield-efficient stock under Montmorency.

Although results of this trial are showing greater production for Montmorency with some of the newer stocks, New York growers are unlikely to adopt dwarfing stocks, especially Gisela stocks since they are too expensive for their use to be justified.

2002 Balaton Tart Cherry on PiKu1 and PiKu3 Rootstock Trial

With Balaton tart cherry there were no significant differences in trunk circumference between PiKu 1 and PiKu 3 at the end of three growing seasons. This was surprising, since with sweet cherry, trees on PiKu1 were significantly less vigorous than trees on PiKu3.

Conclusions

Cherry rootstock trials at Geneva since 1986 have shown Gi.6 rootstock to be the most reliable semi-dwarfing stock for sweet cherry. For commercial plantings we recommend Gi.6 be planted at densities from 300-600 trees/acre. Precocious and productive varieties such as Sweetheart will require more aggressive pruning and irrigation to avoid small fruit size. The greatest drawback with Gi.6 is that it is a semi-dwarfing rootstock and will not be suitable for planting densities above 500 trees/acre. Gi.5 has also shown promise as a stock that is about 25% smaller than Gi.6 and can be planted in densities up to 800 trees/acre. However, it can only be recommended if trees are irrigated and under high levels of horticultural management. Newer trials have resulted in additional dwarfing stocks that are promising. Weiroot 72 is dwarfing and could be a good choice because of high yield efficiency and good winter hardiness; however, propensity to suckering is high. The newer stocks PiKu 1, 3 and 4 show promise but it is too early for any definitive conclusions.

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Performance of High-Density Sweet Cherry Training Systems in New York

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The introduction of dwarfing cherry rootstocks has allowed new possibilities for developing high-density cherry orchards with smaller trees that are more precocious and productive. Our results show that high-density cherry orchards with ~ 450 trees/acre can result in substantial yields in the first six years and return four times the gross return of the traditional Central-leader system which has only 130 trees/acre.

Sweet cherries are a high-value crop of increasing interest in the Northeastern U.S. The introduction of dwarfing cherry rootstocks (Lang, 2000; Perry et al., 1996, Robinson, et al., 2005) and newer varieties (Kappel, 2002) has allowed new possibilities for developing high-density cherry orchards with smaller trees that will be more precocious and productive that can either be covered with rain exclusion shelters or treated with $CaCl_2$ to prevent rain cracking (Andersen et al., 1999; Balmer, 2001; Lang, 2001; Lang and Ophardt, 2000; Lang and Perry, 2002; Weber, 2001). Several high-density training systems have been developed for sweet cherries (Long, 2001a; Long, 2001b; Perry, 1998) giving fruit growers many options for planting density, rootstock, and training protocol. The objective of this project was to compare high-density production systems on both standard and dwarfing rootstocks for sweet cherries. A second objective was to determine the effect of training system and rootstock on fruit size.

Materials and Methods

In April of 1999 a replicated field trial was planted at Geneva, New York with Hedelfingen on three rootstocks (Gi.5, Gi.6 and MxM.2), Lapins and Sweetheart on two rootstocks (Gi.5 and Gi.6) and Tehranivee and Regina on one rootstock (Mahaleb). Each variety/rootstock combination was planted into each of six training systems: Central leader, Spanish bush, Slender spindle, V system, Marchant inclined tree system, and Vertical axis. Tree densities and spacings are given in Table 1. Each training system plot consisted of three 32m long rows and was replicated three times. Each row was planted on a broad 30cm-high berm to control winter damage associated with excessive soil moisture. In addition, a subsurface drainage line was installed in the center of each tractor alley to remove excess moisture in the spring and during heavy rainfalls before harvest.

The Central-leader system was developed by heading the leader at 90cm at planting, removing large diameter feathers, removing buds below the new leader bud along 20cm of the leader and attaching clothespins to lateral branches when 10cm long to improve crotch angle. In the second through fourth year, the leader was headed annually removing one third of last year's growth, large diameter upright shoots were removed and five buds below the new leader bud on the leader were removed at bud swell. Later as the shoots developed in the spring, clothespins were attached to lateral branches when 10cm long to improve crotch angle. In the third year, four primary scaffold branches were tied down to 15° above horizontal in early June.

The Spanish-bush system was developed by heading the leader at 40cm at planting, attaching clothespins to lateral branches when 10cm long to improve crotch angle, and by reheading each lateral shoots in early July to multiply number of shoots. In the second through fourth years, all shoots on the tree were headed at bud swell removing one half of last year's growth and then reheading by about one half in early July to multiply number of shoots.

The Slender-spindle system was developed by heading the leader at 90cm at planting, removing all feathers, removing buds below the new leader bud along 20cm of the leader and attaching clothespins to lateral branches when

TABLE 1

Tree densities, spacings and initial heading heights of six orchard-planting systems in the NY sweet cherry systems trial.

Planting System	Tree density (trees/ha)	Tree Spacing (m)	Initial heading height (cm)
Modified Central Leader	336	4.9 X 6.1	80
Spanish Bush	673	3.1 X 4.9	40
Slender Spindle	897	2.4 X 4.6	90
V-Slender Spindle	997	1.8 X 5.5	90
Marchant Trellis	1035	2.4 X 4.9	100
Vertical Axis	1196	1.8 X 4.6	120

10cm long to improve crotch angle. As lateral branches grew longer than 25cm, the clothespins were relocated to hang from young developing leaves near the apical end of the shoot to weigh the shoot down to maintain horizontal branch angle. Clothespins were moved further out on the shoot every two weeks to maintain a horizontal branch angle. In the second through the fourth year the leader was headed at bud swell removing one third of last year's growth and the next five buds below the new leader bud were removed. Lateral branching along 'V' scaffold arms was induced in years two - four by removing 67% of lateral buds along the one-year-old section of the scaffold at bud swell (Robinson et al., 2004). New lateral shoots on the leader were weighted with clothespins as in year one.

The 'V' system was developed by heading the leader at 30cm at planting and allowing only two strong buds to develop. Clothespins were attached to the two lateral branches that were oriented toward the tractor alleys when 10cm long to improve crotch angle. At the beginning of the second year, the two primary scaffold branches were tied to training stake at 60° above horizontal at bud swell. In years two - four, the two primary scaffolds were not headed. Lateral branching along the 'V' scaffold arms was induced by annually removing 67% of lateral buds along the one-year-old section of the scaffold at bud swell (Robinson et al., 2004).

The Marchant inclined tree system was developed by planting the trees at 45° angle down the row. The leader was headed at 100cm at planting. All of the feathers were removed and all of the buds on underside of the leader were removed. The remaining buds thinned to a 20cm spacing. The leader was trained to a 60° angle along the row utilizing a four- wire trellis and an inclined bamboo pole at each tree. In the second-fourth year, the vertical lateral branches arising off the inclined leader were tied in the opposite direction down the row by tying to trellis at 45° above horizontal at bud swell. Large-diameter vigorous shoots were removed at bud swell.

The Vertical-axis system was developed by heading the leader at 120cm (Zahn, 1994). Large diameter feathers (larger than two thirds the diameter of the leader) were removed. Lateral branching along leader was induced by removing 67% of buds along branch at bud swell (Robinson et

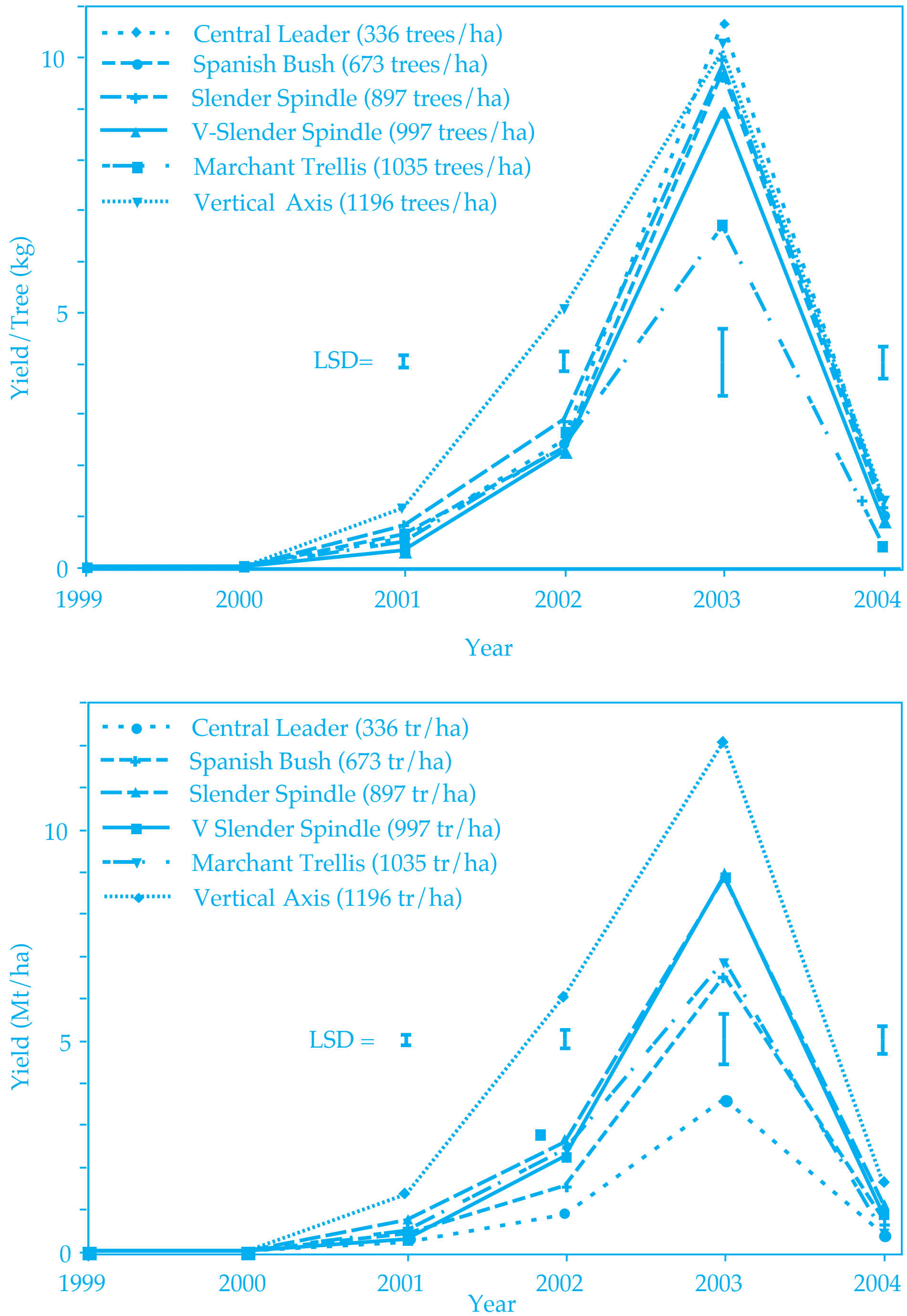

Figure 1. Annual yield/tree and yield/ha of five sweet cherry varieties (Hedelfingen, Lapins, Sweetheart, Regina and Tehranivee) on MXM.2, Gisela 5, Gisela 6 and Mahaleb rootstocks at Geneva NY. Vertical bars represent LSD for significant difference within each year.

al., 2004). Clothespins were attached to lateral branches when 10cm long to improve crotch angle. During the second through the fourth year, the leader was not headed. Large diameter branches were stubbed back to 20cm at bud swell if they were larger than 2/3 diameter of leader. On an annual basis, lateral branching along leader was induced by removing 67% of buds along the branch at bud swell. Cement weights were attached to the ends of second year lateral branches to maintain horizontal branch angle.

The trees fruited for the first time in the third year, and yield and fruit size data were recorded in the third-fifth years. A 25-cherry sample was collected each year from each tree and analyzed for proportion of cracked fruit and fruit soluble solids. Economic gross returns were calculated as: Gross Return ($/ha) = [Cumulative yield (kg/ha) – yield of cracked fruit (kg/ha)] * $2.20/kg. Data

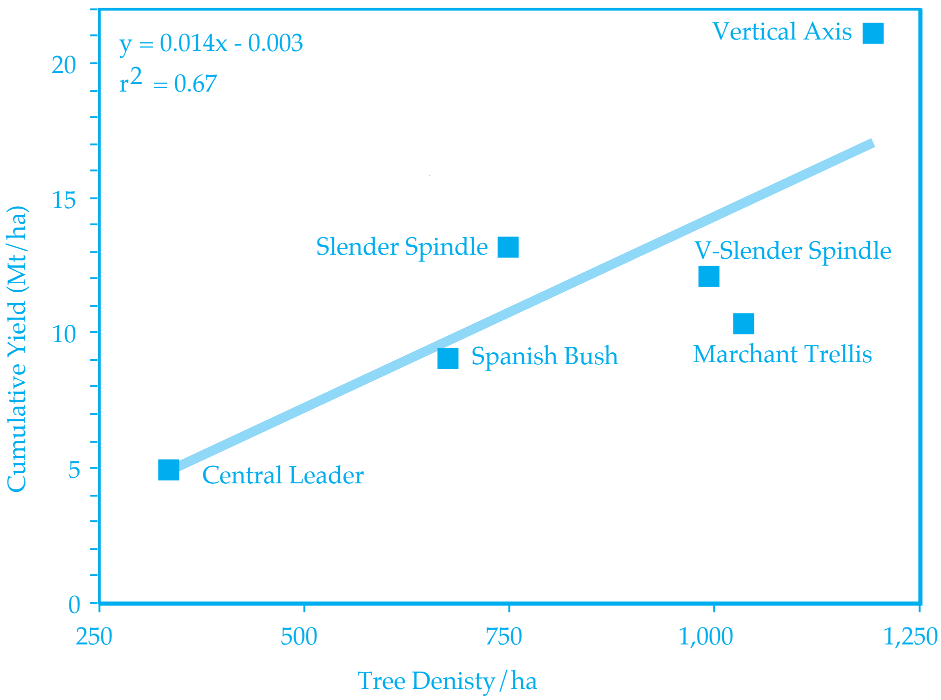

Figure 2. Relationship of tree planting density to cumulative yield/ha of five sweet cherry varieties (Hedelfingen, Lapins, Sweetheart, Regina and Tehranivee) on MXM.2, Gisela 5, Gisela 6 and Mahaleb rootstocks trained to six training systems at Geneva NY.

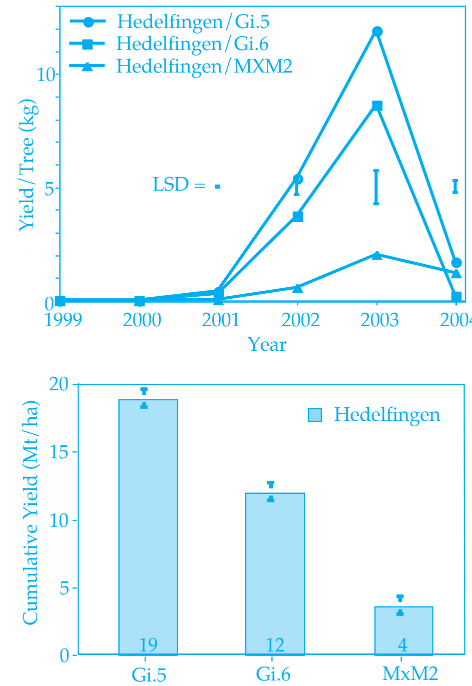

Figure 3. Annual yield/tree and six-year cumulative yield/ha of Hedelfingen sweet cherry on MXM.2, Gisela 5, and Gisela 6 rootstocks at Geneva NY. Vertical bars represent LSD for significant differences between stocks.

were analyzed by analysis of variance with each variety analyzed separately since only the Hedelfingen was planted on three rootstocks, while Lapins and Sweetheart were planted on only two rootstocks and Tehranivee and Regina were planted on only on one stock.

Results

Yield Performance. In the third year (2001) the Vertical-axis system had the highest yield per tree, followed by the Slender-spindle system, the Spanish bush, Central leader, Marchant inclined tree and the V system, respectively (Figure 1). On a hectare basis the Vertical-axis system had the highest yield per tree followed by the Slender-spindle system, the Marchant system, the Spanish bush system, the V system and the Central-leader system (Figure 1). By the fifth year, yield ranged from 6-11 kg/tree and from 3-11 Mt/ha. The cumulative yield per tree over 6 years was highest for the Vertical-axis system (17.6 kg) followed by the Central-leader system (14.9 kg), the Slender-spindle system (14.7 kg), the Spanish bush system (13.5 kg), the V system (12.2 kg) and the Marchant inclined tree system (9.9 kg). On a hectare basis the highest cumulative yield was with the Vertical-axis system (21.1 Mt), followed by the Slender-spindle system (13.2 Mt), the V system (12.1 Mt), the Marchant inclined tree system (10.2 Mt), the Spanish bush system (9.1 Mt) and the Central-leader system (5.0 Mt).

The differences in yield between systems were largely a function of tree density. There was a linear relationship of tree planting density and yield that explained 67% of the variation in cumulative yield per hectare (Figure 2). The Marchant system, and to some extent the V system, had significantly lower cumulative yield than expected from their tree density. The Vertical-axis system, and to a lesser extent the Slender-spindle system, had a higher cumulative yield than expected from their tree density. With the Vertical-axis system, this resulted from the highest yield per tree and the highest tree density.

With Hedelfingen, Gi.5 had the greatest yield each year while Gi.6 was intermediate and MXM.2 had the lowest yield (Figure 3). In the winter preceding 2004, severe winter temperatures killed most of the flower buds in this trial. The drop in yield from 2003 to 2004 shows that Gi.6 was the most sensitive to winter cold while MXM2 was the least sensitive. Gi.5 was intermediate. Cumulative yield of MxM.2 was extremely low compared to the Gisela rootstocks (Figure 3). Cumulative yield over 6 years of Gi.5 was 19.3kg while Gi.6 was 12.9 and MXM.2 was 3.8. With Lapins and Sweetheart there was no large difference in cumulative yield between Gi.5 and G.6 (data not shown).

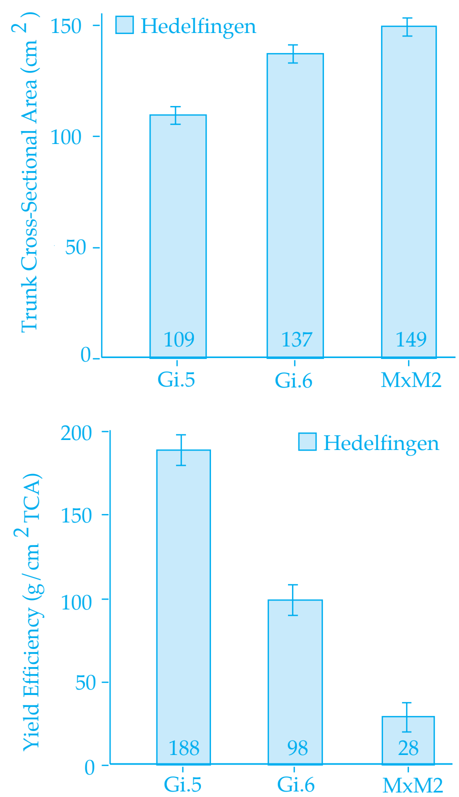

Figure 4. Effect of rootstock on final trunk cross-sectional area and cumulative yield efficiency of Hedelfingen sweet cherry trees on MXM.2, Gisela 5, and Gisela 6 rootstocks at Geneva NY. Vertical bars represent LSD for significant differences between stocks.

Among varieties, Sweetheart was the most productive followed by Tehranivee, Lapins, Hedelfingen and lastly Regina (data not shown). Regina had significantly lower production than any of the other varieties. However, following the winter of 2004, which killed most flower buds on Sweetheart and Lapins and many flower buds on Hedelfingen, Regina had the highest flower bud survival. Thus it appears to be slightly more winter hardy than the others.

There was an interaction of rootstock and training system with Hedelfingen, but not with Lapins and Sweetheart. The combination of Vertical axis training and Gi.5 rootstock resulted in very high six-year cumulative yields per hectare of 31.8, 19.7 and 26.5 tons/ha for Hedelfingen, Lapins and Sweetheart, respectively. In contrast, the Vertical-axis system with the full vigor MXM.2 rootstock had a cumulative yield of only 8.3 tons/ha with Hedelfingen.

Tree Size. There was a clear rootstock effect on tree size, as measured by trunk cross-sectional area, with trees on Gi.5 being significantly smaller (30%) than trees on Gi.6 which in turn were about 20% smaller than trees on MXM.2 (Figure 4). Planting system also had a significant effect on final trunk cross-sectional area. The central-leader trees were the largest and the Marchant-trellis trees were the smallest. There was a significant negative curvilinear relationship between tree planting density and tree size with the highest density Vertical Axis trees being only 60% as large as the lowest density central leader trees (Figure 5).

Yield Efficiency. There was a significant effect of rootstock on yield efficiency. Trees on Gi.5 were four times as efficient as trees on MXM.2 (Figure 4). Trees on Gi.6 were intermediate. Among training systems, the Vertical-axis system was substantially more efficient than any other system and almost twice as efficient as the traditional Central-leader system. There was a significant positive curvilinear relationship between tree density and yield efficiency (Figure 5). However, the Marchant trellis and the V-Slender Spindle were significantly less efficient than predicted by the regression equation.

Fruit Quality. With Hedelfingen, the largest average fruit size over the three cropping seasons was with Gi.6, while MXM.2 was intermediate and Gi.5 had

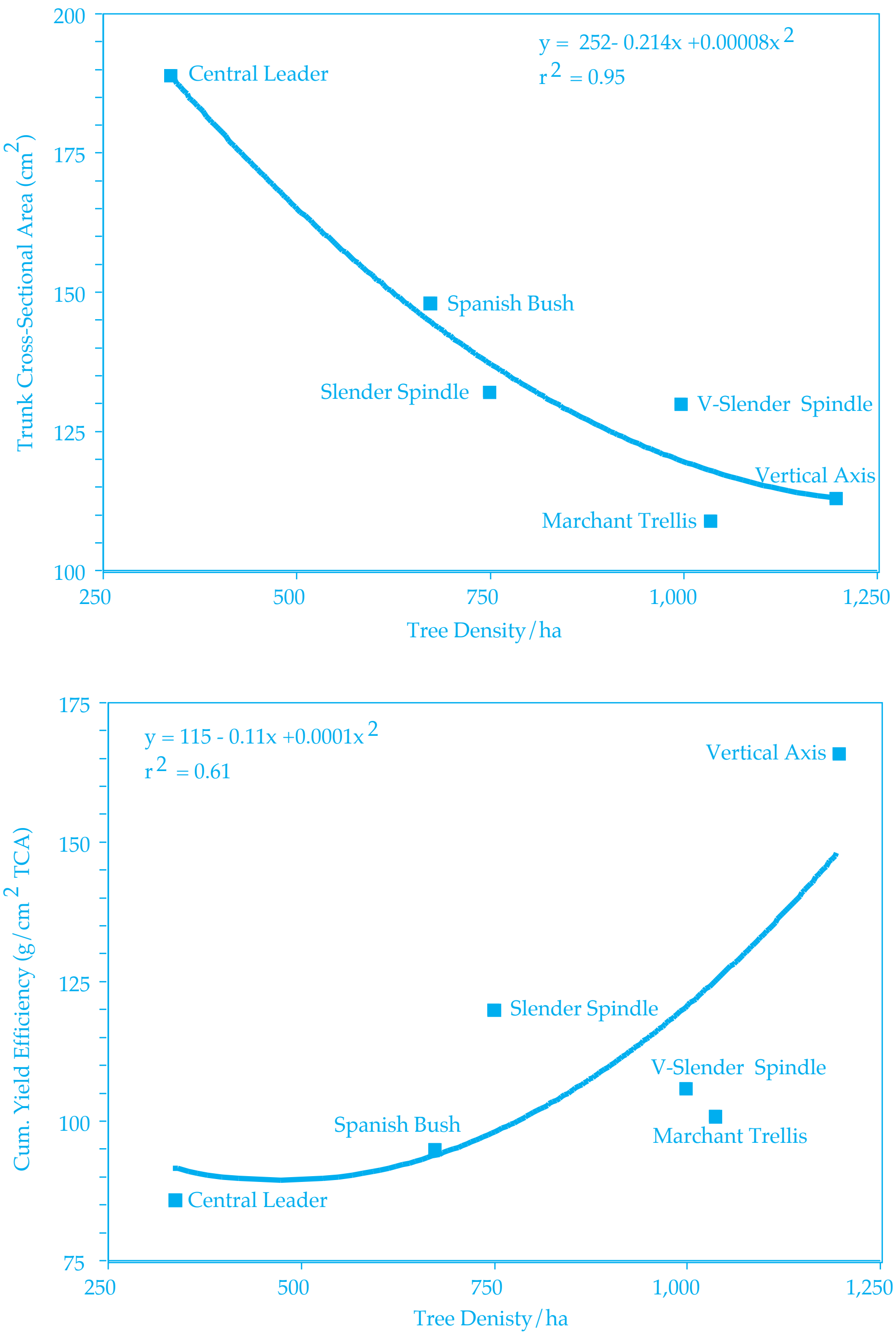

Figure 5. Relationship of tree planting density to final trunk cross-sectional area or yield efficiency of five sweet cherry varieties (Hedelfingen, Lapins, Sweetheart, Regina and Tehranivee) on MXM.2, Gisela 5, Gisela 6 and Mahaleb rootstocks trained to six training systems at Geneva NY.

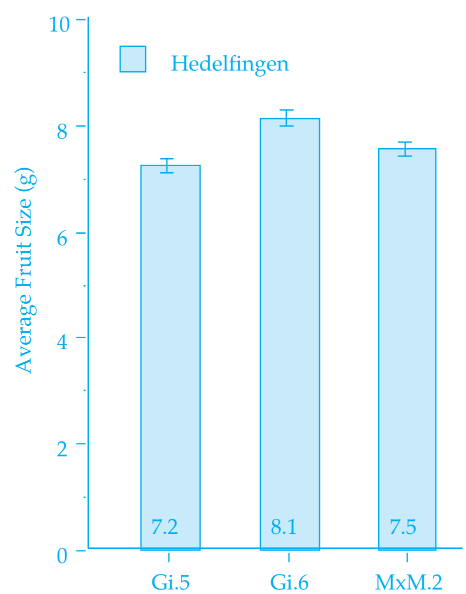

Figure 6. Effect of rootstock on average fruit size of Hedelfingen sweet cherry trees on MXM.2, Gisela 5, and Gisela 6 rootstocks at Geneva NY. Vertical bars represent LSD for significant differences between stocks.

the smallest fruit size (Figure 6). However, there was an interaction with variety. With Lapins and Sweetheart there was no difference in fruit size between Gi.5 and Gi.6 (data not shown). Among training systems, average fruit size was greatest for the Slender-spindle system followed by the Central leader, V system, Spanish bush, Marchant and Vertical-axis systems, respectively. Although the difference between the top two systems and the bottom two systems was significant, these differences were not great (Figure 7).

With Hedelfingen, Gi.6 had significantly higher soluble solids than MXM.2, which had greater soluble solids than Gi.5 (data not shown). Among rootstocks, there was an interaction with variety. With Lapins and Sweetheart, there were no significant differences in soluble solids content between Gi.5 and Gi.6. Among systems, fruit-soluble-solids was highest with the V system followed by the Central leader, Slender spindle, Vertical axis, Spanish bush and the Marchant system (data not shown). Although the maximum difference in soluble solids was only 0.5%, the bottom two systems had significantly lower soluble solids than the top four systems. This likely reflects the thick canopies resulting in excessive shade within the Spanish bush and the Marchant canopies.

Economics. Cumulative crop value was greatest for trees on Gi.5 followed by Gi.6 and then MXM.2 (Figure 8). Among rootstocks there was an interaction with variety. With Hedelfingen and Lapins, the largest cumulative crop value was with Gi.5, intermediate with Gi.6 and smallest with MXM.2. With Sweetheart, there was no difference in cumulative crop value between Gi.5 and Gi.6. Among systems, cumulative crop value over the first six years of the orchard's life was greatest for the Vertical-axis system ($37,500/ha), followed by the V system ($22,100/ha), the Slender-spindle system ($20,900/ha), the Marchant inclined tree system($17,100/ha), the Spanish bush system ($16,400/ha) and the Central-leader system ($9,000/ha). The difference between the top system and the bottom system was more than four fold. There was a significant positive curvilinear relationship between tree density and crop value (Figure 9). The Marchant trellis had significantly lower cumulative crop value than predicted by the regression relationship.

Discussion

Our results after six years show the strong correlation of tree densities and level of early yields that can be achieved. This is similar to the results of studies of planting density with apple (Robinson, 2003). With our cherry data the relationship appears to be linear over the densities we considered, whereas with apple, the relationship is curvilinear. It is likely, that over a broader range, the relationship would be curvilinear with cherry.

A second result is that the systems, which utilized the least pruning, had the highest yield in the first six years. An important component of the high yields

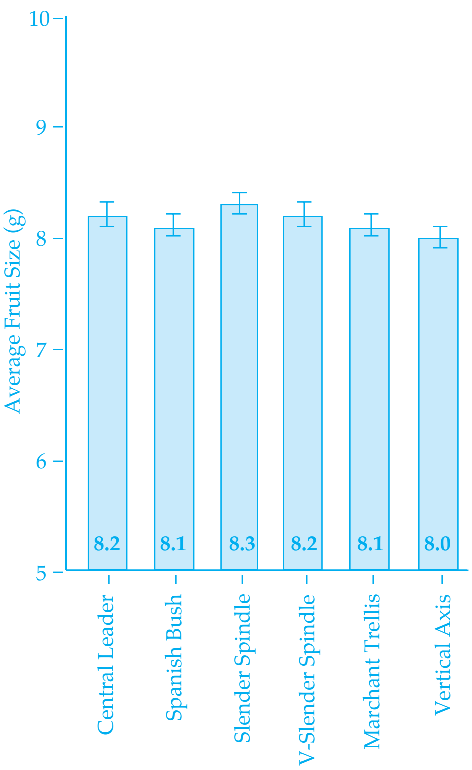

Figure 7. Effect of training system on average fruit size of five sweet cherry varieties (Hedelfingen, Lapins, Sweetheart, Regina and Tehranivee), on MXM.2, Gisela 5, Gisela 6 and Mahaleb rootstocks at Geneva NY. Vertical bars represent LSD for significant differences between systems.

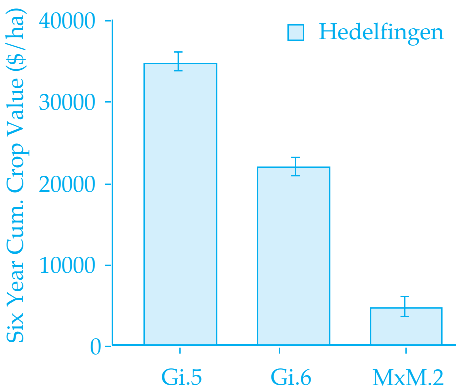

Figure 8 Effect of rootstock on six-year cumulative crop value per hectare of Hedelfingen sweet cherry trees on Gi.5, Gi.6 and MXM.2 rootstocks at Geneva NY. Vertical bars represent LSD for significant difference between rootstocks.

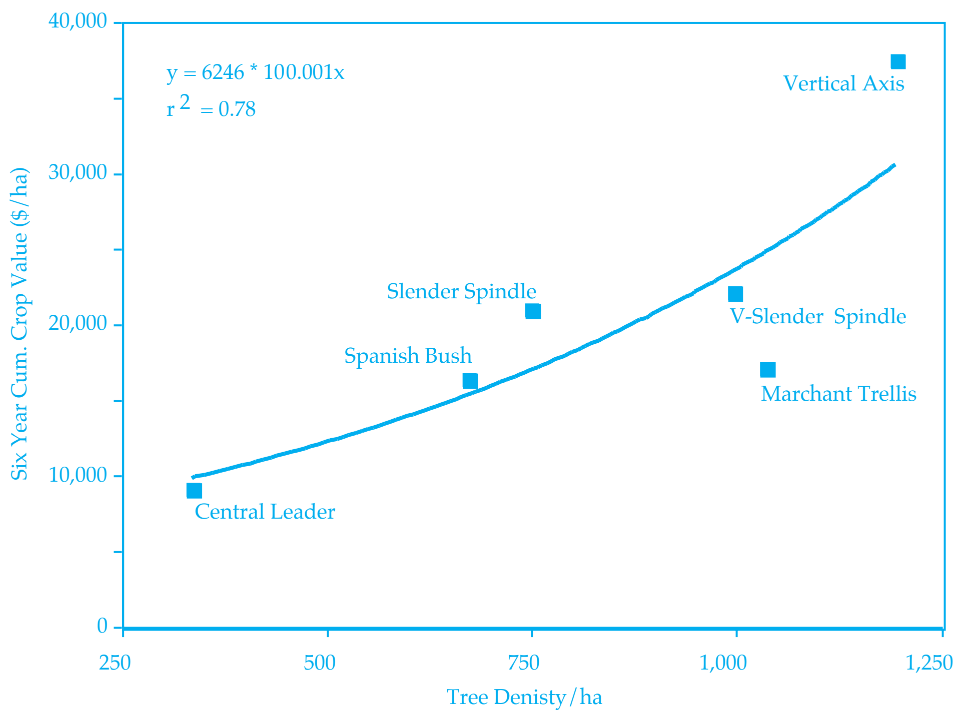

Figure 9. Relationship of tree density and six-year cumulative crop value per hectare of 5 sweet cherry varieties (Hedelfingen, Lapins, Sweetheart, Regina and Tehranivee), on MXM.2, Gisela 5, Gisela 6 and Mahaleb rootstocks trained to six planting systems at Geneva NY.

of the Vertical axis and the Slender-spindle systems, was the minimal pruning during the first two years. In contrast, the Spanish Bush system had very severe pruning during the first two years. The Perpendicular V system had severe pruning at planting, but minimal pruning after that. The severe pruning was related to lower yields of these systems in the 3rd and 4th years. To successfully incorporate minimal pruning with sweet cherry, branching techniques are needed due to the strong apical dominance resulting in a suppression of lateral bud development with most varieties. Our previous work showed bud removal early in the spring was very successful at stimulating lateral bud development without heading the leader (Hoying et al., 2001, Robinson et al., 2004). This technique allows minimal pruning resulting in more rapid development of the canopy and earlier production, yet proper limb placement along the leader. In humid climates like the Northeast of the United States, bacterial canker infection is a high risk with this procedure and the application of copper sprays immediately before and/or after the buds are removed is essential.

A third important result is the reduction in tree size (as measured by trunk cross-sectional area) with increasing tree density. This is important since it means that at higher tree densities trees will be manageable in the smaller allotted space for a greater period of time. It was of interest to note that in the Vertical-axis system with renewal pruning (Zahn, 1994), all of the lateral limbs on each tree were less than 10cm in diameter since when they exceeded that diameter, we removed them back to 10cm stub and developed replacement branches. In contrast, the central leader trees on the same stocks had lower scaffold branches that exceeded 25cm in diameter by the end of the 6th year. The larger branch structure of the Central Leader trees led to larger trunks and probably much larger root systems giving difficulty in managing the tree into a small area.

The Vertical-axis system, because of its high yield per tree due to minimal pruning and the highest tree density, produced 1.5 times the yield per ha of the next best system. As expected, the traditional system (low density Central-leader system) had a very low yield. Among the other four high-density systems, the Slender-spindle and the V system had very similar yield and were significantly higher than the Spanish bush which had reduced early yield due to excessive pruning and relatively low tree density. The Marchant system had unusually low yield. We judge the Marchant system to be inferior since yields were low and labor for tree training was much higher than with any other system.

Considering yield, fruit size, soluble solids and gross economic returns, the Vertical axis, Slender-spindle and the V system were the three best systems in this trial. The Slender-spindle and the V system combined relatively high yields with good fruit size and quality. The Vertical-axis system was extremely productive, but had slightly smaller fruit size and soluble solids content. The large fruit size and the high soluble solids content with the Slender-spindle and the V system indicates that these systems were not over-cropped, whereas, the smaller fruit size and lower sugar content of the Vertical-axis system indicates this system was slightly over-cropped. To make the Vertical-axis system perform better will require modified pruning strategies such as annual heading of one-year-old lateral shoots to reduce the cropping potential of the system.

Our results show the value of the precocious Gisela rootstocks for early production (Balmer, 2001; Lang, 2000; Perry et al, 1996; Weber, 2001). The Gisela 5 trees had a significant crop in the third year and 10 times the yield as the vigorous MxM.2 trees in the fourth year and six times the yield in the fifth year. The Gisela 6 trees had about seven times the yield of the MxM.2 trees in the fourth year and four times the yield in the fifth year. In addition, the Gisela trees have remained smaller than the MxM.2 trees and have a more "calm" appearance than do the MxM.2 trees, which makes them more suited to high planting densities. The Gi.6 trees have had larger fruit size and higher fruit soluble solids than the standard sized MxM.2 trees indicating that they have not over-cropped. In contrast, the Gi.5 trees had such large crops that fruit size and soluble solids were both lower than the Gi.6 trees. This indicates that the Gi.5 trees were over-cropped and that resources were limiting for fruit development. The successful commercialization of Gi.5 will require modified pruning strategies such as heading of all one-year-old shoots. It is also possible that the large crops on Gi.5 may be limiting tree carbohydrate or nitrogen reserve accumulation, thus increasing vulnerability to winter damage (Andersen, et al, 1999; Lang and Ophardt, 2000; Lang and Perry, 2002). Our results after the winter of 2004 indicate that both Gi.6 and Gi.5 may be more vulnerable to severe winter temperatures than the full vigor MXM.2.

The results of this study show that planting systems which use much higher tree densities than the common Central-leader system combined with new precocious rootstocks and minimal pruning, can give substantial yields in the first five years and return significant gross returns. With a high value crop like sweet cherries, this should help rapidly recoup the investment associated with planting a new cherry orchard (Seavert, 1997; Weber, 1998).

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Management of High-Density Sweet-Cherry Orchards

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High-density sweet cherry orchards have unique management challenges that include avoiding tree death due to bacterial canker or root rot, limited lateral branching without pruning, small fruit size on dwarfing rootstocks and rain induced fruit cracking. Through our experiments over the last 10 years we have learned several management techniques to overcome these issues. Taken together these management strategies can form a system of producing sweet cherries in NY that will result in consistent production of high quality cherries. We call this the integrated system of sweet cherry production.

High-density sweet cherry orchards have some of the same challenges as high-density apple orchards. These include limiting tree size as the orchard matures and managing light distribution in the canopy to maintain fruit quality and good fruiting wood in the bottom of the tree. However, sweet cherries present additional challenges that are unique. These include tree death due to bacterial canker or root rot, limited lateral branching without pruning, small fruit size on dwarfing rootstocks, soft fruit and rain-induced fruit cracking. Over the last six years as we have managed our high-density cherry systems trial, we have learned numerous techniques for successful management of high-density sweet cherry orchards; perhaps they will be of use to cherry growers in the Northeastern US.

Keeping Trees Alive

The saying goes that "Cherry trees love to die". With the heavier soils in New York, cherry tree survival is often poor. There are four important management approaches to limiting tree mortality.

1. Plant trees on broad 12" high berms. Tree death in sweet cherries is often associated with winter damage and excessive soil moisture. In some cases, death is caused by phytophthora and in other cases it is caused by winter injury. We have found that planting trees on broad 12" high berms results in significantly better tree growth and survival than without berms. This is likely due to better soil oxygen levels and to reduced water logging in the fall and in the spring. An important note is that trees planted on berms must be irrigated. The berms can dry out much quicker during hot weather in the summer. In our plots a single trickle line down the tree row has allowed excellent soil moisture management.

2. Use intensive soil tiling. Research on vinifera grapes in Ontario Canada has shown that much of the winter damage is associated with wet areas in a field. Intensive tiling down every row middle has resulted in much less winter damage and vine death. The same is true for cherries. We installed a subsurface tile line in the center of each tractor alley in our plots to remove excess moisture in the spring and to quickly remove excess water following heavy rainfall before harvest. The tile system down every drive row helps keep trees alive since they are never subjected to excessive moisture. The rapid removal of excess water close to harvest also helps limit fruit cracking.

3. Use resistant rootstocks. None of the currently available cherry rootstocks is resistant to phytophthora root rot; however, the Gisela rootstocks show greater tolerance than do Maheleb or Mazzard. In our two cherry systems plots we have lost 15% of the trees on Mazzard and 11% of the trees on Mahaleb but only 2% and 3% of the trees on Gi.5 and Gi.6, respectively. The losses with Mazzard and Mahaleb occurred despite planting the trees on berms and using intensive subsurface tiling. Without these precautions much higher percentages of trees on Mahaleb and Mazzard would have been lost. In addition to greater tree survival, the Gisela stocks also have much higher precocity and production than Mazzard and Mahaleb. Trees on Gisela 5 are about five times as productive over the first six years as trees on seedling rootstocks while trees on Gisela 5 are about three times as productive as trees on seedling rootstocks. Trees on Gisela five are about 65% the size of trees on seedling rootstocks and should be planted at densities from 400-800 trees/acre. Trees on Gisela 6 are about 80% the size of trees on seedling rootstocks and should be planted at densities from 300-500 trees/acre.

4. Control bacterial canker. In the humid climate of NY State it is important to plant varieties that are less susceptible to bacterial canker. In addition, three management practice are important to avoiding tree death due to canker. (a) Pruning should be delayed until growth starts or do all the pruning postharvest in late July. (b) Use a rigorous copper spray program that includes two sprays in the fall near leaf drop (20% leaf drop and 90% leaf drop) and two sprays in the spring at bud break and immediately following pruning if pruning is done in the spring. (c) Never make flush cuts on the leader. Always leave a 6-8" stub. If canker gets in this stub it will progress slowly toward the trunk but will not girdle the trunk. The concept of leaving a stub when removing limbs was developed by Mr. Zahn in Northern Germany. He found that in a humid climate flush cuts led to serious canker infections on the trunk, while leaving a stub prevented infections on the trunk. We have made it a strict rule to always leave a 6" stub when cutting on the main trunk of the tree and to never allow flush cuts. The combination of tolerant varieties, intensive copper sprays and stub cuts has worked wonderfully at Geneva.

TABLE 1

Effect of Branching Treatments on Side Branching of the Leader of Three Sweet Cherry Varieties.

Variety	Branching Treatment	Number of Side Shoots Produced on Bottom Third of Leader	Number of Side Shoots Produced on Middle Third of Leader	Number of Side Shoots Produced on Top Third of Leader
Hedelfingen	Promalin	0.5 c[z]	2.2 b	10.3 a
	Notching	1.2 b	1.7 b	9.3 a
	Bud Removal	2.9 a	4.2 a	4.7 b
	LSD $p \leq 0.05$	**0.7**	**0.7**	**1.1**
Lapins	Promalin	0.2 b	0.2 b	7.5 a
	Notching	0.1 b	0.1 b	6.4 b
	Bud Removal	0.9 a	2.6 a	5.0 c
	LSD $p \leq 0.05$	**0.4**	**0.4**	**0.7**
Sweetheart	Promalin	0.1 c	0.4 b	10.5 a
	Notching	0.6 b	0.3 b	9.1 b
	Bud Removal	1.5 a	3.3 a	5.3 c
	LSD $p \leq 0.05$	**0.4**	**0.5**	**1.1**

[z] Mean separation by LSD. Means within each variety followed by the same letter are not significantly different ($p \leq 0.05$)

Training And Pruning Young Sweet Cherries

Traditionally sweet cherries receive little training and pruning for the first five years. However, with high-density orchards, investments in proper tree training pay dividends. In addition starting with the right tree will result in higher early production. As a result of our trials with sweet cherries we recommend:

1. Plant a high quality tree. The optimum tree to plant differs by system. For the Vertical-Axis, Slender-Spindle and Central-Leader systems, a large-caliper, highly feathered tree is the best and requires little pruning and training during the first few years. The larger caliper feathered tree used in the Vertical-Axis and Slender-Spindle systems have much greater production in the third – fifth years than a small caliper tree. For the Spanish Bush, Perpendicular V and the Steep-Leader systems, smaller caliper whips are better since these three systems employ severe heading of the leader at planting.

2. Minimize heading cuts for the first few years. Our results show that repeated pruning cuts in the first three years results in reduced yield whereas minimal pruning during the first three years results in high early yield. Systems that require significant pruning to form the tree will have much lower cumulative yield over the first five years. The Spanish Bush requires heading cuts two times per year for three years to form the bush and as a consequence it has lower early yield. The Perpendicular V and the Marchant trellis also employ significant early pruning. In contrast the Vertical Axis utilizes almost no pruning for three years. This has resulted in significant yield in the third year and mature yield in the fifth year when using Gisela rootstocks. If minimal pruning is combined with large caliper feathered trees, then very high early yields are possible. The Vogel Slender-Spindle system gives intermediate yields since it requires annual heading of the leader to develop side branches and limit tree height.

3. Develop side branches without heading. Results from our systems trials show that repeated heading of the leader in the first three years results in reduced yield whereas leaving the leader unheaded during the first three years as with the vertical axis system results in high early yield. However, the lack of heading the leader often results in blind wood and limited lateral branching on the leader. This led us to experiment in 2000 (the second year) with methods to induce lateral branching that do not involve heading cuts. We compared three methods of stimulating lateral branching along the leader; these were:

1) Promalin (5,000ppm) mixed with diluted white paint (1:1 ratio of paint and water) sprayed on the leader at bud swell.
2) Notching above every 3rd bud along the leader with a saw blade at bud swell.
3) Bud Removal of 2/3 of the buds along the leader (every third bud was left and the others were rubbed out at bud swell).

Promalin and notching were not very effective in stimulating lateral branching in the lower and middle sections of the leader. However, bud removal was very effective and resulted in significantly more side shoots in the lower and middle sections of the leader (Table 1). The bud removal treatment also gave a relatively uniform distribution of lateral branches along the shoot. Hedelfingen had the greatest number of lateral branches. Sweetheart had an intermediate number and Lapins the least.

The bud removal treatment should prove to be very useful for sweet cherry growers in the northeast, allowing more rapid development of the canopy and earlier production without heading cuts. To reduce the risk of bacterial canker infection from the wounds left by the bud removal technique, we recommend the application of a copper spray immediately before and after the buds are removed. A more complete description of these results can be found in Hoying et al., 2001.

4. Bend branches flat. Cherry trees are very apically dominant which results in upright branch angles. If the branches are spread flat the tips turn up and resume vertical growth. With the Slender-Spindle, the Vertical-Axis, the Perpendicular-V and the Central-Leader systems, horizontal branches are critical to producing a conic-shaped tree that has good light distribution at maturity. This requires training lateral branches horizontal. Training branches one time as with apple has not been successful with cherry since the lateral branches turn up after they have been trained down. A more successful system has been to use clothespins when the shoot is first developing. As with apple, we recommend installing clothespins when the young lateral shoot is 3-5" long. With the mouth of the clothespin around the leader, the tail of the clothespin can be adjusted to where it pushes the young shoot down to the horizontal. The clothespins are left in this initial position for about two weeks, after which they are hung from the young leaves of the developing shoot near the tip. The weight of the clothespin on a young growing shoot keeps it in the horizontal position. The clothespins must be moved further out on the shoot near the tip every 7-10 days for the months of May, June and July. The process of moving the clothespins can done quickly on a young tree but it does require a significant labor commitment to accomplish the job. If the job is done in each of the first three years, one-three a conic-shaped tree can be developed which does not require large bench cuts on scaffold limbs to get horizontal limbs. The large bench cuts reduce yield and are undesirable. If additional follow-up limb spreading is necessary, limb tying to an anchor is the best method. We suggest using short pieces of conduit pipe pounded into the ground between each tree and then tying the branches down using avis strap.

Mature Management of Sweet Cherries

Mature high-density sweet cherry trees on dwarfing rootstocks have three major problems: small fruit size, dense canopies with too little light in the lower canopy and soft cherries. Our experience has taught us a few management strategies to overcome these problems.

1. Pruning to obtain large fruit size. The Gisela rootstocks can seem like a 'dream come true' in year's two through four. They fill the orchard space quickly and have lots of fruit below 10 feet high. However in subsequent years they tend to over-crop and produce smaller fruit size due to low leaf to fruit ratios. This requires an intensive management program that includes more aggressive pruning than is currently used with the standard cherry stocks, additional fertilizers, irrigation, and even fruit thinning. We suggest that mature trees on Gisela stocks be pruned more aggressively that trees on Mazzard. The pruning must include the removal of most of the fine and shaded wood each year. This wood tends to set very heavily, especially on less vigorous, precocious scion cultivars like Sweetheart and Somerset and on smaller fruited varieties like Kristin and Ulster. In addition, medium-vigor shoots should be headed by one-third to one-half their length. This reduces the amount of crop they will set two years later and stimulates additional leaf area to support the crop. This type of stubbing back pruning has been successfully used with Gala apples to increase fruit size and with cherries our experience has shown that this type of pruning will increase fruit size by over one gram per fruit. However, it always reduces total yield by approximately 25%. In addition, this style of pruning results in more slender conic- shaped trees which helps maintain high-density cherry trees in their allotted space.

2. Irrigation to obtain large fruit size. In addition to pruning, irrigation is essential for trees on Gisela rootstocks. With young trees, dry periods in late May and early June can cause the trees to stop growing and exacerbate the precocious fruiting character of these stocks. Consistent water supplies can ensure that adequate shoot growth is obtained. As cherries turn from green to straw color they enter the final stage of growth. During this time, large amounts of water are needed to increase fruit size. Daily trickle irrigation has been very beneficial. If trees are planted on berms, there is little risk of over-irrigation but when trees are planted on flat ground care should be taken to not over-irrigate them. When significant irrigation water is combined with aggressive pruning the vigor level of the Gisela trees should remain moderate to high, which will ensure good fruit size the next year.

3. Maintain light exposure of the lower part of the tree. In high-density plantings it is very easy to allow thick orchards and trees to develop. Cherries, like apples, need good light distribution in the lower part of the canopy to produce good fruit quality and healthy buds for next year's crop. Good light exposure of the lower canopy is best achieved with renewal pruning. Removal of one to two large limbs in the top or midsection of the tree each year either at bud swell or post harvest will limit the spread of the top of the tree and create light channels down into the canopy. Remember to leave a 6" stub when removing these limbs to prevent bacterial canker on the leader. If limb renewal is practiced annually a conic shaped tree can be developed which has no large limbs in the top. This also results in new fruiting limbs developing from the 6" long stubs left where a branch was cut out. This new fruiting wood produces large size fruit and can be managed as described above using heading cuts each year.

4. Obtaining firm fruits. One of the challenges for all cherry growers is soft fruit at harvest. Consumers prefer firm, crunchy cherries and the market pays a premium for firm fruit. Gibberrelic acid has been shown to give firm cherries and to delay harvest. We have experimented with GA sprays for several years and have found that harvest is delayed by 5-10 days and that fruit firmness is increased. The delay in harvest results in larger fruit size since cherry fruits grow about 1% per day so a 10-day delay in harvest results in 10% larger cherries. We suggest applying GA (Pro-Gibb) at straw color using 8-12 fluid ounces/100 gallons. Us the lower rate on a cool year and the higher rate on a hot year.

Protecting Sweet Cherries from Rain Cracking

One of the biggest obstacles to growing consistent high quality sweet cherries in NY state is rain-induced cracking. Major chain stores view NY producers as inconsistent suppliers delivering cherries of varying quality. This puts NY producers at a serious marketing disadvantage. If we could solve the rain-cracking problem, NY growers could become consistent suppliers of high-quality cherries and develop higher paying markets with local and regional chain stores. This would allow NY growers to expand acreage of this crop. In 2002 we installed a rain shield over one third of our high-density block to evaluate rain-cracking control methods. In 2003 we had significant rainfall events that preceded Lapins harvest by eight days. There was no significant cracking in either the rain protected plot or the unprotected plot. However, a few days later when Hedelfingen and Regina were close to harvest we had three days of rain just before harvest that resulted in 20-40% cracking in the unprotected plot (Figure 1). In the rain- protected plot we had only 5-15% cracking on Hedelfingen and Regina respectively. Sprays of dilute solutions of $CaCl_2$ have also been used for rain-crack prevention. When we applied the sprays by speed sprayer we were unable to prevent cracking. Apparently we needed to apply Ca more often than we could with a speed sprayer. In 2005 we evaluated an automatic sprinkler system of $CaCl_2$ sprays, which worked much better. Thus, it appears that either rain nets or automatic $CaCl_2$ applications can work to limit rain-induced fruit cracking. The economics of covering acres of cherry orchards with

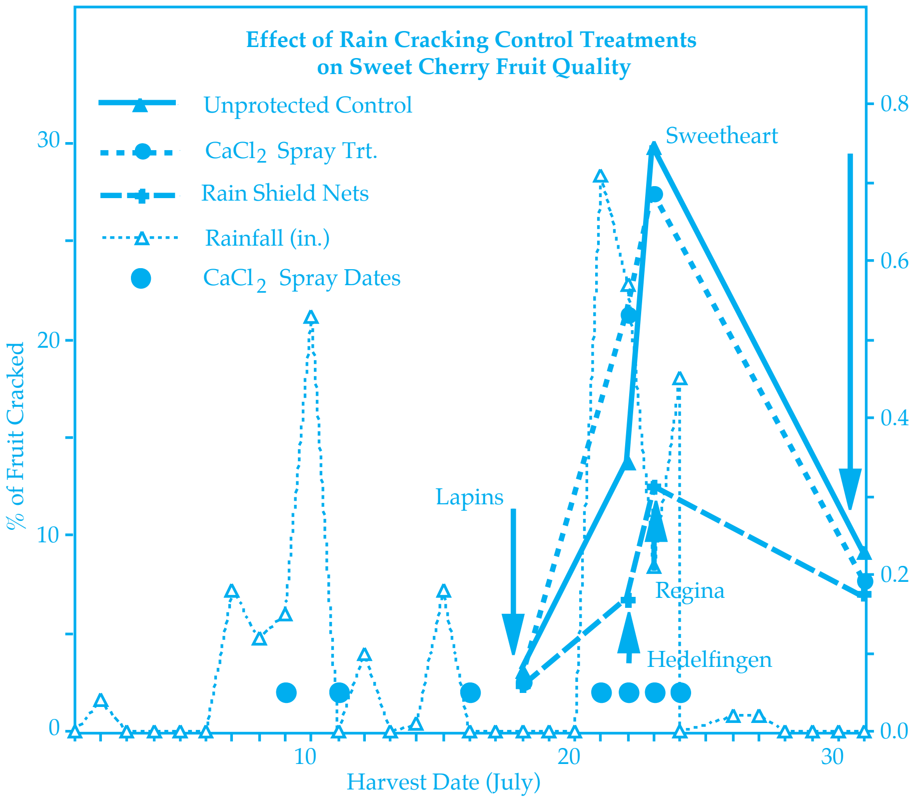

Figure 1. Rain cracking in 2003 with four sweet cherry varieties at the Geneva Sweet-Cherry Systems Trial.

expensive rain shields has not been evaluated, however, it appears to be an effective method for limiting rain-induced cracking and producing high-quality cherries.

Conclusions

Taken together these management strategies can form a system of producing sweet cherries in NY that will result in consistent production of high quality cherries.

We call this the integrated system of sweet cherry production. The essential points of the integrated system are to utilize:

- Berms and Tiling
- Copper spray programs
- Dwarfing Rootstocks
- High Tree Densities (>300 trees/acre)
- Minimal pruning during first four years and bud removal to obtain branching
- New varieties (e.g. Regina and Sweetheart)
- Irrigation
- GA sprays
- Rain Protection Nets or Ca sprays
- Bird Protection - Bird Nets
- Hydrocooling and
- MAP bags

Terence Robinson

Steve Hoying

Robert Andersen

Terence Robinson is a research and extension professor at Cornell's Geneva Experiment Station who leads Cornell's research and extension program in high-density orchard systems. Steve Hoying is a regional extension specialist in orchard management in the Lake Ontario Region of NY State. Robert Andersen is a recently retired emeritus professor of Horticulture at Cornell's Geneva Experiment Station who specializes in the breeding and culture of stone fruits.

Trends in Variety Introduction and Management

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Traditionally new fruit varieties originated from publicly supported breeding programs sponsored by Land Grant Universities or the USDA. Historically, these varieties were released to the public free of charge. Nurseries were the primary agents involved in distributing the varieties to the grower community.

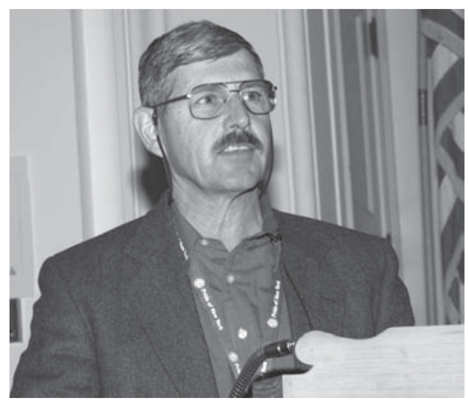
Public funding for fruit breeding has been decreasing steadily forcing universities to either eliminate breeding programs or seek alternative ways to fund these programs. At the same time there has been an increase in private sector breeding activity. As a result, for the last several decades more programs have begun to patent their releases and charge growers a plant royalty, which has traditionally been collected by the nursery and remitted to the breeder.

The most recent trend has been the rise of the club system for new plant introductions. Several variations of the basic model exist. In general, in exchange for limitations on acreage and/or access to the variety, the club members pay the variety owner an annual fee based on acreage or production. In some cases the nurseries have maintained their traditional role of introducing and managing the club varieties. However, marketers are more frequently becoming the key managers of these varieties. In this model, the marketers control the variety and disseminate it to their growers. Growers are willing to pay because they expect to obtain premium prices and not face over supply associated with overproduction of public varieties.

Another trend is the development of private varieties held exclusively by the developer. These varieties are generally developed by very large grower/marketers who develop their own marketing and promotion programs around the varieties.

As chain stores merge and become mega chains, we may well see a new trend with the retailers becoming the owners of new varieties. They might contract with outside companies to coordinate growing of the variety worldwide to provide year-round supplies of their exclusive product.

Public funding for fruit breeding has been decreasing steadily, forcing Universities to eliminate breeding programs. At the same time there has been an increase in private sector breeding activity. A significant trend has been the rise of the club system for new plant introductions. In the future we may well see a new trend with the retailers becoming the owners of new varieties.



Dr. David Cain is a private plant breeder who started his own fruit breeding company, International Fruit Genetics. He was a former graduate student under Bob Andersen.

Commercialization of New Varieties: A Grower's Perspective

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I am always looking for and testing new varieties of stone fruit. We have many acres of test plots of test selections and named varieties, but the question is, what am I looking for in a new variety if I am going to plant it commercially on my farm?

Some more specific questions are:

1. Will it thrive and survive in my location? Hard winters, damp springs and short growing season are my challenges on this front.
2. Will it fruit consistently and give me high quality fruit?
3. How will this new variety fit in with my current tried and true varieties? A few of the qualities in a new variety I am looking for include: are they unique (shape, color, flavor), do they ripen earlier or later, are they larger fruited or have a healthier, longer lived tree than my current varieties.
4. Then I have to ask myself "will anyone buy it"? Will it be a replacement for a current west- coast variety or something completely new? Can I compete on price with my competition? What market will this variety do well in (farm markets or supermarkets)?

Below are some examples of my thought process with regard to specific fruits:

Sweet cherries. Fruit size. 10 row min. Earlier and later ripening. Avoid the July glut. Rain-crack resistant. Canker resistant. Need black or white cherries, not red. Varieties that we are going with include: Rynbrant (real early) and Sweetheart (so far that latest we can plant).

Tart cherries. Need a replacement for Montmorency. Larger fruit. Better color. Better flavor. Earlier and later ripening. Grow for fresh markets. Danube and Jubileum seem to fit the bill. Need more options. Hard to find in the US. Need to test more varieties from Europe.

Apricots. Late Blooming. Spread out the season. Early Blush is a great find. Now I have a 10-day gap until all the other varieties come in.

Japanese plums. I am new with this crop. Need fruit size and consistent cropping. Late blooming. Winners for us so far are Fortune, Early Magic, Obilinaya, Simka, Vanier, and Early Golden. I still have a lot of test selections and varieties to test.

European plums. Fruit size. Must taste good. Spread out season. Skin must be blue/purple, not red, although, I am very interested in yellow European plums. Can pass them off as Japanese plums. We do well with this crop, as long as the fruit taste good. Too many poor tasting fruit on this market (picked too early). I get very concerned about getting the variety I want from a commercial nursery. Different strains or different varieties with the same name (Early Italian for one). Want to use the budwood from the trees I have tested, but then you have the virus issue.

Peaches and nectarines. Flavor, color and fruit size. Very interested in unique shapes and flavors. I am not interested in fruits that are 100% red. If you cannot see the background color, it can not be picked correctly.

Testing new varieties of stone fruit is much easier than testing apples. With apples everything is the variety name. If you have some quantity of an odd variety, you can not sell it readily unless you have a farm market. With stone fruit it is different. A peach can always be called a Red Haven and a black cherry is always a Bing. Marketing small lots of odd varieties is not a problem.

On-site testing of new stone fruit selections and varieties is very important. What looks good in California does not always look good in the East. What looks good in the Carolinas does not always look good in the North and it seems as though nothing ever looks as good as the nursery catalog pictures.

As a side note, I am interested in club or controlled varieties. The concept of controlling the supply and orderly marketing of variety may be foreign to a lot of growers, but it is happening. We must remember, we grow fruit to make a living. It is not a hobby. Anything that can be done to increase the chances that I can grow the crop profitably, I am interested in.

Marketing a new variety of stone fruit is much easier than it is for a new variety of apple. Consequently, marketing small lots of odd varieties is not a problem. However, on site testing of new stone fruit selections and varieties is very important. What does well in California may not do well here. Nonetheless, there are many new exciting varieties to test and develop for NY growers.

Jim Bittner is an apple, pear and stone fruit grower and president of Singer Farms. Jim also serves as president of the New York State Horticultural Society.

Marketing Opportunities for New York Stone Fruit in Canada

Ken Slingerland

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New York pear and peach growers have found marketing opportunities with the processing industry in Ontario Canada. Other marketing opportunities might include the fresh market for stone fruits or pears.

Ontario has a very diverse stone-fruit industry with peaches (fresh and processing), plums, cherries (sweet and sour), nectarines and apricots. Approximately 90% of all tender fruit production in the province of Ontario is located in the Niagara Peninsula, north of the escarpment running east to west from the Niagara River to the City of Hamilton. The unique climate of the area provides a preferred location for stone-fruit production and represents over 75% of the production in Canada.

TABLE 1

Tonnage and Value of Crop (3 year average)

Fresh Market	Tons	Value ($000) Cdn
Peach	17,686	$17,065
Plums	2,030	$ 2,380
Sweet Cherries	1,800	$ 3,200
Processing		
Sweet Cherries	460	$ 457
Sour Cherries	4,321	$ 4,587
Peaches	6,695	$ 3,619

There are currently 600 tender-fruit growers (includes pears) in the province. Ontario produces 50,000 tons of tender fruit with a farm value worth approximately $50 million. Table 1 shows the tonnage and value by crop.

All of Ontario's fresh market production is marketed as 'Product of Ontario' under the 'Foodland Ontario' logo. This logo has brand recognition and consumers recognize the logo as a symbol of fresh, safe food. The shipper dealers also have their brand names attached for their brand loyalty (Figure 1).

Major markets include Toronto, Montreal, Halifax and the rest of the Canadian East Coast, and as far west as Winnipeg, Calgary and Edmonton.

There are five sour cherry processors in Ontario. Kraft Canada Ltd. in St. Davids and Cherry Lane Frozen Foods in Vineland are the two peach processors. Both companies process peaches but Kraft Canada Ltd. also cans pears. Kraft has seen some major expansions over the last 10 years with increased product lines and sales, which has resulted in a major plantings of new Vineland-Research-Station-developed cultivars Vulcan, Vinegold, Virgil and Venture. Thirty-five growers from Western New York located from Lewiston to east of Rochester have been part of Kraft's expansion plans and have collectively planted 136,000 trees or approximately 700 acres.

Marketing opportunities for New York growers have mainly been in the processing industry as they have been part of Kraft's future plans to diversify production in the east. Growers that have taken advantage of this opportunity will be part of any future plans as markets increase or production declines in Ontario. Other opportunities for fresh-peach marketing in the future might include different packages, logos and brand names.

Figure 1. Vineland Growers' shipping box with the "Product of Ontario" and the 'Foodland Ontario' logos.

Ken Slingerland is an extension specialist for the Ontario Ministry of Agriculture and Foods located in the Niagara peninsula who specializes in stone fruits and grapes.