Editorial
Leadership and Accountability

There are those who spend their hours discussing how difficult and unfair the current times are. There are those who reflect longingly about how wonderful and simple life used to be. There are also those who simply fail to see anything positive until it is taken away from them. Then there are those that we call “leaders” who are too busy looking forward to be dragged down by all of this meaningless discussion.

I travel from west to east across New York and have done so all of my six decades. I am humbled by what I recall and what I currently see. The fruit industry has made enormous up-grades to its commercial farming practices in a very short period of time. Orchard acreage in New York State is down but our productivity and quality have never been at this high level. You need to pause and ask the basic question as to how did this happen? Was this a classic “chicken and egg” scenario? Did we arrive at these cultural practices and varieties by accident? What motivated these changes? Who inspired the invisible hours of research behind the scenes that has yielded today’s modern orchard? I think when you ask these questions you need to be grateful for previous unselfish generations of “leaders” who motivated these changes? Who inspired the invisible hours of research behind the scenes work of our researchers. Hopefully several decades from now some other generations will be grateful for the silent financial cash flow would be ideal.

Today like yesterday we are faced with difficult choices as to where and what to do with our dollars. Life one, two, three and four decades ago was not all profits and success stories. Those growers decided that what they knew today was simply never going to be enough. They did not know where they were going but they had the leadership skills to formulate the ARDP and four decades ago was not all profits and success stories. It is good to enjoy the exciting new orchards and storage/packing facilities but we need to continue to support the silent financial cash flow would be ideal.

Today our fruit farms are an inspiration to everyone. While it is exciting to enjoy these new tools we need to make certain we support those same principles of our earlier generations. We need to show by our actions that we have those same qualities of “leadership and accountability”.

Paul Baker
New York State Horticultural Society
An Update on Apple Cultivars, Brands and Club-Marketing

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Since our last articles of new apple varieties (Brown and Maloney, 2008, 2009), there has been a rapid acceleration of new apples and new marketing strategies, as evidenced by the many websites that are tied to consumer marketing of new apples. In 2012 we have also seen the release of new varieties from private breeding programs (including private programs in Ohio, Washington State, Minnesota and Wisconsin) or nursery cooperatives. In investigating new varieties and cooperatives, it quickly becomes apparent that variety development and management has changed globally.

The importance of the name of a new apple cultivar in marketing is evident and supported by research at Cornell, where exciting names led consumers to spend more money for the same variety with a “generic” or non-exciting name (Rickard et al., 2011). Willingness-to-pay auctions are indicating traits of interest to consumers willing to pay a premium, and they are often variety dependent. In addition, the response from buyers is also being examined relative to new varieties and fruit size premiums (Carew et al., 2012).

The three major public US apple breeding programs: Cornell University (Susan Brown), Washington State University (Kate Evans) and the University of Minnesota (Jim Luby/David Bedford) are collaborating on the RosBREED project: Enabling marker assisted breeding in the Rosaceae (www.rosbreed.org). Through this project, apple breeders and their graduate students have developed a standardized phenotyping protocol (Evans et al., 2011) that is being used across all our programs for both characterizations at harvest and after storage, but also as the basis to identify molecular marker-trait associations. New varieties will continue to be released by our programs individually, but the breeding efforts to develop these new varieties will benefit from this coordinated research.

The cultivars discussed below are not an exhaustive summary of new releases. Some varieties were covered in our previous reviews. However this article focuses on new releases discussed in the industry press (web sites and trade journals) and new US plant patents issued (www.uspto.gov). Forty-eight standard varieties and 31 scab resistant releases are discussed. This acceleration in scab-resistant releases represents an increased focus on this breeding objective by many programs worldwide.

New or Increasing Apple Cultivars

‘Arctic series’: ‘Arctic Granny’ and ‘Arctic Golden’: The two varieties that start this list have generated controversy among the industry and consumers because they are the first transgenic, genetically engineered or biotechnology-derived apples, as opposed to all the other apples on this list that were developed using conventional breeding. These apples were created by Okanagan Specialty Fruits to have reduced browning, due to silencing of the PPO gene (polyphenoloxidase gene) that contributes to browning (www.arcticapples.com/). The US Apple Association came out with a position paper that stated while they were supportive of the technology; they were not supportive of these two varieties at this time since flesh browning was not perceived as enough advantage to counteract possible public concern. “The genetically modified apples in the petition offer questionable commercial benefit yet raise serious marketing questions for virtually all segments of our industry”. Public comments on the petition to deregulate these varieties was very emotional, perhaps due to the many transgenic plants already in the marketplace that the public did not have the opportunity to support or argue against.

‘Aurora Golden Gala’ (8S6923): A release from the breeding program in British Columbia, Canada. ‘Aurora’ is a yellow apple that is said to be difficult to pick from young trees and would benefit from research on better harvest indices. Since it is a recently released variety growers are encouraged to contact PICO for advice on harvest and cultural management. ‘Aurora Golden Gala’ information is available at www.picocorp.com/varieties/apples/aurora_golden_gala. Toivonen et al. (2007) used ‘Aurora Golden Gala’ to study factors affecting severity of bruises and bruise recovery, and found that harvest bruises and impact bruises from packing line belts could be managed, but that packing line apple to apple impact bruises were more damaging and there was less prospects for recovery.

‘Autumn Blush’: Derived from ‘Gradirose’, a novel pink skinned apple developed in France, ‘Autumn Blush’ will be marketed by the ABCz international company. ‘Autumn Blush’ will be offered exclusively at Tesco this year (www.abcz-group.com).

‘Autumn Glory’: Offered exclusively by Domex Superfresh Growers in the Pacific Northwest, ‘Autumn Glory’ (a hybrid
of ‘Fuji’ x ‘Golden Delicious’) is described as apple flavor, intensified. It is red on a yellow background and is said to be grower and packer friendly.

‘Blondee’: This clean yellow apple offered by Summit Sales (Integrated Plant Management, Inc.) was granted USPP# 19,007. Its susceptibility to fire blight is similar to ‘Gala’.

‘Cameo’: A new group/club “Cameo Partners International” was formed in Europe to promote this variety.

‘Crimson Snow’® (mc38 S): A variety being commercialized by Kiku Ltd in Europe and Turkey. Mc38 was discovered and had its initial introduction and production in Australia. ‘Crimson Snow’® is distinctive in having white flesh and ripening after ‘Fuji’.

‘DS-22’ (Trademarked name pending): A new variety of unknown parentage from the private breeding program of Doug Sheflebine in Wisconsin will be commercialized and marketed as a club variety by Fred Wescott of Minnesota (Lehnert, 2012)

‘Envy’” (‘Scilate’): A ‘Braeburn’ x ‘Royal Gala’ hybrid (or reverse) with a ruby outer color and crisp white flesh, this apple was developed by NZ researchers and is being produced in NZ (www.envyapple.com) and in Washington State by the Oppenheimer group (www.oppy.com). ‘Envy’ has the same parents as ‘Jazz’, but produces fruits of a larger size.

‘EverCrisp’: The first variety from the Midwestern Apple Improvement Association (MAIA) in Ohio (www.everycrispapple.com). This new apple is a hybrid of ‘Fuji’ x ‘Honeycrisp’, with the sweet flavor of ‘Fuji’, some of the ‘Honeycrisp’ texture attributes and a productive tree. It is reported to have good storage life, befitting its name.

‘Fuji’ sports:
‘Aztec Fuji’® (DT2): A blush strain that originated in New Zealand (Waimea Variety Management Ltd.), ‘Aztec Fuji”® is reported to be a very high coloring strain.

‘Moana’: This limb mutation of ‘Nagafu-6 Fuji’ has nearly a complete red blush. USPP # 21,450 was granted in November 2010.

‘Gala’ sports:
‘Premier Star’: This sport of ‘Royal Gala’ was discovered in New Zealand and was quickly commercialized, with a focus on the Asian markets during its introductory phase. Its good color and high sugar make it especially suited for that market (www.premierstar.co.nz/).

‘Galmac’ (‘Camelot’): Developed in Switzerland, this hybrid of ‘Gala’ x ‘Jerseymac’ has good quality, but a very short harvest period for peak quality. Fruits ripen in late July and are targeted for sale to celebrate Switzerland’s National Day on August 1st. (Figure 1)

‘Genesis’™: A new apple marketed by The Yummy Fruit Company in New Zealand, ‘Genesis’ is a hybrid of ‘Braeburn’ x ‘Royal Gala’ that is red, sweet, firm and crisp.

‘Gradigold’: Granted USPP # 22, 974, this hybrid of ‘Christmas Rose’ x ‘Gradigold’ was developed in France and is described as having a semi-upright habit, free flowering and fruiting and good storage life.

‘Honeycrisp’ sport:
‘Royal Red Honeycrisp’™ (LJ-1000): This sport was discovered in Washington State and granted USPP# 22,244 in November 2011. LJ-1000 is said to color earlier and have higher sugar than standard ‘Honeycrisp’. It will be offered exclusively by Willow Drive Nursery, with sales projected to start in 2013 (Lehnert, 2012).

‘Jazz’ (‘Scifresh’) sport:
‘Southfield’: A limb sport of ‘Scifresh’ that was discovered in New Zealand, this sport is reported to have better color and to mature earlier. It was granted USPP# 22,990.

‘Jonagold’ sport:
‘Jonastar’: ‘Jonastar’ which was granted USPP #20,590, offers a nice red stripe over a red background. Its earlier coloring ensures fully colored fruits at harvest.

‘Jonathan’ sport:
‘Chrisolyn’ (‘Cambell Jonathan’): USPP # 21,300, granted in 2010, ‘Chrisolyn’ is a sport of ‘Robinson’ and is distinctive in having alternating dark red and bright red stripes in contract to the fainter stripes of standard ‘Jonathan’.

‘Junami’™ (‘Milwa’ or ‘Diwa’): Inova fruit in the Netherlands manages the varieties, ‘Junami’, ‘Ruebens’ and ‘Wellant’ and have excellent web pages to cover marketing and information for growers of their varieties (www.inovafruit.nl/pagina/ Junami/1198/en/). In the US, Rainier Fruit markets this Swiss developed variety, which was granted USPP# 19,615 in January 2009. ‘Junami’ resulted from a cross of a hybrid of ‘Idared’ x ‘Maigold’ by ‘Elstar’ and is marketed for its juiciness and crunch, with young consumers targeted (www.junami-apple.com/en/) (Figure 2). The website suggests that the pronunciation of this variety’s name should rhyme with “tuna me”.

Figure 1. Galmac, a Swiss bred apple variety, which ripens near Aug. 1 the Swiss National Day.

Figure 2. Junami, a Swiss bred apple variety, which is managed by Rainer Fruits in the US.
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'Lady Alice': A chance seedling discovered in Washington, Rainer Fruit markets 'Lady Alice'. The round, dense apple is sweet and has flesh that resists browning after it is sliced.

'Lemonade': A yellow apple said to have a "fizzy" taste, elongated shape and a slightly tart taste and firm texture. 'Lemonade' is one of several new apple varieties marketed by Yummy Fruit Company in NZ (www.yummyfruit.co.nz). This variety is susceptible to bruising.

'Lola' ('Maribelle'): This variety resulted from a cross of a hybrid of 'Meiproncine x 'Gloster' by 'Elstar'. This is a product from the private breeding program of Ingl de Sonnaville in the Netherlands and fruits are grown by 73 growers and marketed by Jabema BV. The large fruits are a deep pink color and store similar to 'Jonagold'. This is not a club variety.

'Mairac' (La Flamboyante): This apple from the Swiss breeding program is a hybrid of 'Gala' x 'Maigold' and was released in 2002 (www.mairac.ch). Although rating very well in taste tests, crop regulation and sensitivity to cold and CO2 injury are challenges being addressed by researchers.

'Maloni Lily': A very small sized genetically dwarf apple tree from the same breeding program that developed the red-fleshed 'Redlove' series.

New York apples: 'New York 1' and 'New York 2' (Trademarked names pending): These two new Cornell apple varieties are being marketed in North America by New York Apple Growers NYAG, LLC, in a cooperative partnership with the NY industry and Cornell. Trademarked names are being tested and should be released in the near future. 'New York 1' is a hybrid of 'Honeycresp' x an advanced NY breeding selection that has quality similar to 'Jonagold'. Fruits are very crisp, juicy and have a sweet flavor (Brown and Maloney, 2011 a, b). 'New York 1' is not prone to the many challenges of its 'Honeycresp' parent and also offers well-colored fruits. It was granted USPP # 22,228. 'New York 2' is a 'Braburn' by 'Autumnccrisp' hybrid that combines a grower-friendly tree with well-colored red fruits with good resistance to flesh browning after slicing. The fruits are crisp, juicy and have a good balance of sugar and acid. NY 2 has USPP # 22,207. The Cornell program will have future "open" releases available to all growers, not just New York. For any future managed varieties, NYAG LLC will have a seat at the table as will other interested parties. New high quality selections as well as new scab resistant and columnar forms will be patented and released in the near future.

'Pink Lady'' sports: A few new sports of 'Pink Lady' are available this year:

'Maslin' cv.: PLMAS98: This sport boasts early maturing, ripening 2 weeks ahead of 'Cripps Pink', with some reports stating it is 3 to 4 weeks earlier. Granted USPP # 21,412.

'Pflogg' cv.: This sport is a spur-type, with a compact tree type and the fruits are reported to ripen one-two weeks earlier than 'Pink Lady'. Granted USPP # 21,555 in 2010.

'RGLORS': A limb sport of 'Rosy Glow' (itself a sport of 'Cripps Pink') discovered in Italy, and being distinctive in having a uniform russet. USPP # 21,272 was granted in 2010.

'Pinova' sport:

'Chantelop' (Daligris): This whole tree sport of 'Pinova' is being marketed by Guy Ligonniere in France. It has been granted USPP #21,722 in 2011. 'Daligris' is distinctive in having a fine russet on the fruit and an orange-red coloration. It ripens about a week earlier than 'Pinova' and has a distinct aniseed flavor.

'PremA153': USPP#21,936, offered by Brandt's Fruit Trees, Inc. is a hybrid of 'Gala' x 'Braburn'. Trees are very productive and fruits are elongated in shape. PremA153 is a green/yellow apple with a blush. Fruits should be picked when the green color is breaking to gold. This is a very dense fruit, which benefits from storage for flavor enhancement.

'Premier Star': See 'Gala' sports.

'Redlove' series: Red fleshed apples developed by a private breeder (Markus Kobelt, Lubera nursery in Switzerland, and the company Frutite (partners with a Swiss commercial tree nursery and a Swiss apple grower) and offered in exclusive licensing to different companies in different territories (Figure 3). There is a private company, Fruit of Tomorrow, or Next Generation Fruits, located in the Netherlands that is associated with Lubera (www.nextfruitgeneration.nl/products/red_flesh_apple/). Some of the selections in this line are stated to be scab resistant noted below while others do not have that designation.

'Redlove' 119/06: This selection is referred to as the "sweet line".

'Redlove' Calypso: The web site states that 'Calypso' is scab resistant.

'Redlove' Circe: Ripening in late August/early September, 'Circe has a sweet/sour balance and can be stored until the end of September.

'Redlove' Era: Stated to be scab resistant, 'Era' is said to ripen in mid-September and can be stored until December/January. It is sweet/sour.

'Redlove' Sarena: Said to be scab resistant and similar to 'Elstar in its acidity. 'Sarena' ripens in August/September and can only be stored about one month.

'Salish'' (SPA 493): This new Canadian apple is from a cross of 'Splendour' and 'Gala' that was made in 1981. This cross, also produced progeny that became 'Nicolai' and 'Aurora Golden Gala'. 'Salish' was released from Ag-Canada in Summerland, B.C. in cooperation with PICO, the Okanagan Plant Improvement Corporation (www.picocorp.com/varieties/apples). This is a crisp, juicy apple that is grower friendly. Fifteen growers in Canada have signed agreements to grow 'Salish'. These Okanagan growers will have a five-year start on the competition. The name 'Salish' describes Aboriginal languages used in regions of Canada.

'Smaragd': A reduced branching (columnar) apple tree form with green fruit. This hybrid of 'Granny Smith' x 'Wijcik McIntosh' (the original source of the columnar gene) was developed in Serbia by breeder Prof. Ognjanov.

'Smitten'' (PremA17): This NZ hybrid from Prevar has a...
pedigree that includes ‘Royal Gala’ and ‘Braeburn’ and the UK varieties ‘Fiesta’ and ‘Falstaff’. The tag line “Once bitten, forever Smitten” will be part of the marketing by six NZ companies under a Seventeen Limited umbrella. Information about the variety and the organization is found at www.smittenapple.co.nz/why-nz/. Chief attributes include high Brix, great crunch and long storage life. ‘Smitten’ is harvested about two weeks before ‘Royal Gala’. Initial introduction in the UK has been very favorable, perhaps in part due to its pedigree including two popular English varieties.

“Sweetie” (PremA280): Another apple from the Prevar™ program in New Zealand, ‘Sweetie’ is a cross between ‘Braeburn’ and ‘Royal Gala’ that matures just before ‘Royal Gala’. The elongated fruit is bicolored and has a sweet, rich taste. ‘Sweetie’ is being grown by Broetje Orchards and sold by First Fruits Marketing in the US. Consumer testing suggests that fans of ‘Gala’ and ‘Fuji’ will favor ‘Sweetie’. PLU 3628 issued. Started with a 30-acre test block in Washington.

**Washington (WA) State University’s new apples:** Washington State’s apple breeding program has named three apples that will be restricted to Washington State: ‘WA 2’, a hybrid of ‘Splendour’ x ‘Gala’, that was granted USPP# 21, 710 (Evans et al., 2010), ‘WA 5’, a hybrid of ‘Splendour’ x ‘Co-op 15’ (Evans et al., 2011), and ‘WA 38’, a hybrid of ‘Enterprise’ x ‘Honeycrisp’ (Evans et al., 2012).

‘Zari’: A hybrid of ‘Elstar’ x ‘Delbardestivale’ developed by the Better3Fruits company in Belgium. ‘Zari’ is a vigorous growing tree.

‘Zonga’: A creation of the Better3Fruit breeding program in Belgium, ‘Zonga’ is a hybrid of ‘Alkmene’ x ‘Delcof’. It is an early season apple, ripening in Belgium in mid-August, or about 10 days before ‘Delcof’.

### Disease Resistance Breeding

Brown and Maloney (2008) reviewed research on disease resistance breeding in apple and detailed scab-resistant varieties available for testing or recently commercialized. Since that time the options for testing have expanded and research is leading to a better understanding of the mechanisms of resistance. Unfortunately, the majority of scab resistant selections are still derived from Malus floribunda (Vg gene), which has broken-down in many regions of production. With the increase in temperatures in many of our production region, new pathogens are becoming increasingly problematic: including Alternaria, marsonnia and assorted leaf spots and fruit rots.

Information on sustainable, organic and/or integrated fruit production is increasingly available. The National Sustainable Agriculture Information Service ATTRA project published an Apple Organic Production Guide (Hinman and Ames, 2011). Peck and Merwin (2009) at Cornell also have a manual that can be downloaded. Books by Phillips (2012 and 2005) provide detailed information on orchard practices. In addition, Becker man (2009) developed a bulletin on how best to manage scab resistant cultivars, including a spray at peak infection for scab. Shredding and treating leaf litter with urea is recommended as a means to reduce overwintering ascospores of apple scab (Sutton et al., 2009).

### New or Increasing Scab Resistant Apple Cultivars

‘Adore’: Delbard Nurseries in France created and released the varieties ‘Divine’ and ‘Adore’ which are being grown and packed by the NZ apple exporter Heartland Fruit. ‘Adore’ is a small, sweet apple with “kid appeal” that may be sold in bags as part of the merchandising.

‘Antares’ (‘Dalinbel’): A hybrid of ‘Elstar’ by x 3191 developed in France, shares the strong acidity of its ‘Elstar’ parent, yet with high sugar content.

‘Ariane’ (x 6407): Hybrid of two advanced breeding selections, one selection, a hybrid of ‘Florina’ x ‘Prima’, the other a selection from ‘Golden Delicious’ open-pollinated.

‘Bella’ (‘Rebella’ cv): A disease resistant apple from the Pilnitz/Dresden breeding disease resistance program in Germany, now being marketed in the US. ‘Rebella’ was noted to have resistance to scab and fire blight.

‘Choupette’ (‘Dalinnette’): Developed in France as a hybrid of two advanced breeding selections, ‘Choupette’ ranked well for quality in a trial of scab resistant selections (Militaru et al., 2010).

‘Crimson Crisp’ (Co-op 39): US plant patent #16, 622 was granted to this scab resistant selection, a hybrid of two advanced selections, from the PRI program. In the NE183 planting, ‘Crimson Crisp’ was noted to be quite susceptible to powdery mildew, cedar apple rust and quince rust. Fruits are attractive and small to medium in size. ‘Crimson Crisp’ is also being offered for sale in Europe.

‘Dalinsweet’: A good quality apple, but with poor fruit appearance ratings (www.dalicom.com).

‘Diva’ (SJC7123-1): This hybrid of ‘McIntosh’ by an advanced breeding selection is suited to northern apple production regions, for ice wine and cider production and for the fresh market (Khanizadeh et al., 2009). It was developed in Quebec, Canada.

‘Divine’: Delbard Nurseries in France created and released the varieties ‘Divine’ and ‘Adore’ which are being grown and packed by the NZ apple exporter Heartland Fruit and will be available in the US, via Washington State’s Giumarra Wenatchee. ‘Divine’ is said to have a traditional appearance (red on a yellow background and conspicuous lenticels) and a strong sweet flavor. It is a hybrid of (‘Golden Delicious’ x ‘Grive Rouge’) x ‘Florina’ and it ripens with ‘Braeburn’.

‘Gaia’: One of five new scab resistant apples released under the “Sweet Resistance” designation in 2011 by Consorzio Italiano Vivaisti (CIV).

‘Gemini’: One of five new scab resistant apples released under the “Sweet Resistance” designation in 2011 by CIV in Italy. This variety should not be confused with the Canadian ‘Gemini’, which is a hybrid of ‘Norland’ by ‘Haralson’.

‘Goldlane’: Granted USPP # 21, 413 in October 2010, this columnar (reduced branching), scab resistant apple (Vg gene) is from the Czech Republic. It is a hybrid of an advanced selection x ‘Bohemia’, which is unpatented.

‘Fujion’: One of five new scab resistant apples released under the “Sweet Resistance” designation in 2011 by CIV. This apple is very sweet and can be picked in fewer harvests than ‘Fuji’. It is not prone to alternate bearing.

‘Inored’ is a scab resistant hybrid of ‘Pinova’ by an advanced breeding selection (x6398) made at Angers, France, the same program that released ‘Ariane’. ‘Inored’ was granted USPP# 22,794 in June 2012.

‘Isaaq’ (CIV323): The commercialization of ‘Isaaq’ represents a new partnership between CIV and Kiku Ltd. (www.isaaq.com). ‘Isaaq’ is advertised as a small snack apple.

‘Kalei’: This first scab resistant variety from the Stanthorpe program in Australia funded by the Queensland govern-
by and Broetje LLC from Pal US FirstFruits the in apple 'Opal' (UEB 3264/2): This new yellow apple is marketed by 'Moonlight': A columnar (reduced branching), scab resistant 'MonaLisa': 'Orion': 'Modi': 'Luna': This hybrid of 'Topaz' x 'Fuji' hybrid that is a new release from the Swiss breeding program. 'TopGold': US plant patent # 16,084 granted in January of 2005. Another apple in the “Golden Sunshine Line” from the Czech republic, this yellow skinned apple shares the 'Golden Delicious' and 'Topaz' (scab resistant) pedigree. Fruit thinning is recommended. Integrated fruit production, rather than organic production is recommended in all but the drier EU sites. 'Mercury': This hybrid of 'Topaz' x 'Rajka' was developed in the Czech Republic. 'Modi': 'Modi', a hybrid of ‘Gala’ x ‘Liberty’, is increasing in production, due at least in part to the innovative marketing associated with commercialization (www.modiapple.com/en-UK/consorzio). 'Modi' was named for the artist Modigliani. 'Solaris': A yellow-skinned, scab resistant, late ripening apple suited to the hobbyist or for the home gardener. 'Story’ (’Inored’ cov): A new red apple from the NOVADI cooperative in France, this variety has the Vf gene for scab resistance and also low to average susceptibility to powdery mildew. The taste is very sweet, with very low acidity. It is recommended for southern European climates and is said to have outstanding storage potential when stored at 3°C. 'Topaz sport': ‘Royal Crimson Topaz’ (Tupy 2 cv): This is a highly colored sport of the selection ‘Crimson Topaz’. 'WineCrisp’™ (Co-op 31): This variety from the PRI cooperative was derived from a cross of two advanced selections. Dark red fruits ripen about two weeks after ‘Delicious’ and are said to be similar to ‘Gala’ in size. Fruits store well (Korban et al., 2009).

Brands, Breeding Groups and Marketing Groups

ABC z group: This collaborative group (Carolus C., Pepinieres Grard and Fresh Fruit Services Europe) has as its slogan “your partner from A to Z”. The group consists of tree fruit nurseries, producers and marketers. The partners are involved in a number of breeding programs such as ZIN, Novadi and Pepinieres Grards own breeding program. Information is available at www.abcz-group.com/en.

AIGN: The Association of International Nurseries includes many nurseries throughout the world. AIGN started the branding of apple varieties, with the 'Pink Lady' brand.

Artevos group; Modern Fruit Varieties: Artus-Gevo group: This group resulted from merging the ARTUS-GROUP and GEVO GmbH (equivalent to Ltd. in Germany) to promote and market new varieties. Forty apples are listed on the web site, including new releases from several breeding programs. Shareholders include national and international partners www.artevos.de/en/about-artevos.html).

Better 3 Fruits: This private breeding program in Belgium has named 4 varieties (‘Kanzi’, ‘Greenstar’, ‘Zari’ and ‘Zonga’) and lists advanced selections (Apple 65, BCF44 (US plant patent application filed for this ‘Gala’ x ‘Fraeburn’ hybrid) and BCF45- same parentage as BCF44 and US patent application filed) available for licensing on its website (www.better3fruits.com). A company called GKE, for Greenstar–Kanzi-Europe, was developed to help promote these two varieties in Europe.
Czech Republic: Many new apples are released, marketed, and commercialized from the breeding programs in the Czech Republic, and the degree of outreach and unique marketing approaches is generating interest in branding. “The Golden Sunshine™” line and “Urban apple trees” (discussed below) are two branding programs that involve materials developed by Czech Republic breeding programs.

Consorzio Italiano Vivaisti (CIV): A consortium of three enterprises in Italy (www.cit.it), CIV has released ‘Rubens’ (‘Civi’), ‘Modi’ (Civg 198) and an improved sort of ‘Fuji’, called ‘Toshiro’. CIV has also partnered with Kiku for commercialization of ‘Isaac’ apple. They also developed the “Sweet Resistants™” line of scab resistant apples.

Hungarian apple breeding: Four new disease resistant apples were released: ‘Artemisz’, ‘Cordelia’, ‘Heszta’ and ‘Rosmerta’ (Toth et al., 2012).

IFO: International Fruit Obtention specializes in research and development of new pome fruits and rootstocks.

INN: International Nursery Network (www.inn.org) represents groups of nurseries internationally that test and produce trees of new varieties for commercialization.

Prevar: Named for “Premium varieties”, selections from this group have the Prem prefix (www.prevar.co.nz). Prevar is an organization comprised of PFN - Pip Fruit NZ (45%), APAL-Apple and Pear Australia Ltd. (45%) and Plant and Food Research in NZ- the breeding organization. The AIGN® (Associated International Group of Nurseries) is a key service provider. Exclusive rights have been assigned to some of the “Prem” selections for commercialization.


“The Golden Sunshine Line™”: This group of scab resistant yellow apples from the Czech Republic share the parentage of ‘Golden Delicious’ and ‘Topaz’. Pfeiffer et al. (2011) reviewed their performance. At www.goldensunshinel ine.org/index.html, information is provided, along with the slogan “Our varieties are made in nature”.

“Urban columnar apple series”: Columnar, reduced branching apples from the Czech Republic that are targeted to the home garden market. New varieties in this series include: ‘Blushing Delight™’, ‘Golden Treat™’, ‘Tasty Red™’ and ‘Tangy Green™’. Information at www.gardendebut.com states these varieties are “Tall on taste for a limited space”.

ZIN: Zuchtungsinitiative Niederelbe (Breeding Initiative Niederelbe): A breeding program started in 2002 with private funding to develop varieties for Northern Germany. Members of the initiative include fruit breeding farms, Altes Land Fruit and some retailers. Breeding work is in cooperation with the Carolus nursery in Belgium and the Institute of fruit growing at the University of Applied Sciences Osnabruceck.

Future Articles on Apple Breeding and Genetic Improvement

A future New York Fruit Quarterly article will detail the advances being made in genetics and genomics in apple. Additional sources of information are available in a video on Cornell Apple Breeding: Taste the Apples of the Future that is available for viewing on YouTube (www.youtube.com/watch?v=UovFTCSY-hg) and a review of the apple breeding and genetic research is also found in Brown (2012).

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Apple Fruit Growth

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This work was supported by the New York State Apple Research and Development Program

The apple fruit goes through a complex developmental sequence over a growing season. Understanding the processes involved, what supports fruit growth and what limits it, helps to support good crop management. This article describes the basic processes of fruit growth and the factors that support or limit fruit growth.

The apple fruit derives from the base of the apple flower after pollination and fertilization of the egg cells in each of the 10 ovules in the base of the flower (Figure 1). After petal fall the base ovary of the flower begins to expand to make the fruit we harvest, as the diagram shows.

Apple growth is properly measured in weight gain. Diameter can be measured but since it is only one dimension of a 3-dimensional fruit, diameter expansion can be deceiving. For example, a 1-mm increase in diameter very early in the season may represent only part of a gram while near harvest a 1-mm increase can mean several grams of weight growth. So, we use weight growth in this discussion.

Seasonal Growth Pattern of Apple Growth

Once the flower is fertilized, the fruitlet grows initially by exponential cell division; that is, cells divide to produce twice as many cells, then divide again to give 4 times as many, then 8 times, etc. This gives an ever-increasing rate of growth. For the first week or so growth is only by cell division as cells do not get bigger (Figure 2).

Then from about 1 week after bloom until about 4 or 5 weeks after bloom, growth occurs by both cell division and cell expansion. Finally, growth for the rest of the season occurs essentially only by cells expanding. During this cell expansion period the fruit adds a similar amount of weight per day until harvest, although with very heavy crops or cold weather the rate of fruit growth may decline before harvest. We have found that large fruit have higher growth rates than smaller fruit (for example, 2
grams per day versus 1.2 grams per day respectively). When we measured cell numbers per fruit, we found that the difference in growth rate was directly controlled by cell numbers, as each cell grew the same amount per day in all fruits.

Because the apple tree, with a heavy bloom, will produce 10-15 times more flowers and potential fruit than desirable at harvest, 90-95% of the fruits must fall off to avoid overcropping. If too many fruit compete for too long, cell division is curtailed. In a detailed anatomical study we found that fruit size variation at harvest from thinning trials was about 85% explained by cell numbers and only a small amount due to cell size variation.

The bottom line is that the final fruit size potential, and generally the actual size at harvest, depends primarily on the number of cells in the fruit. And since cell numbers are set in only the first few weeks after bloom, that is a critical time for the whole season. Fruit with low cell numbers from excess competition after bloom, due to late or inadequate thinning, can never catch up later to become large fruit.

Good fruit size requires a lot of cells. Since cell numbers are a result of cell division that occurs only in the first several weeks after bloom, the critical time to adjust fruit numbers by thinning is as early as possible after bloom. If thinning is done early, the retained fruit will have time for further cell division, thus improving size potential. However, if thinning is done late, the fruit will have suffered from competition for too long, have too few cells and have little to no time to catch up in cell numbers.

Additionally, next year’s flower buds are already developing at the same time fruitlets are setting in the weeks after bloom. If thinning is delayed too long, not only is fruit size decreased, but return flowering and next year’s crop potential will be reduced as well. Both these factors place an emphasis on early crop adjustment.

As fruit grow in weight, the apple fruit accumulates large amounts of starch during the season. We have found that the starch is not available to support fruit growth, but it appears that the starch is saved to be converted to sugars as harvest approaches. Presumably this was a natural selection for making fruits in the wild sweeter and more attractive to animals to increase seed dispersal. This change from starch to sugar provides a useful common indicator of fruit maturity.

**Why Do Some Fruit Drop and Some Stay on the Tree?**

Since often 90% or more of the young apple fruitlets need to fall, either naturally or by chemical or hand thinning, we wondered why some fruits drop but others stay on the tree? It turns out that **fruit that can maintain a continuously high growth rate stay on the tree.** However, **fruit that have a slow growth or slow their growth for several days will drop.**

We have monitored the growth of thousands of fruit over many years and find a consistent general relationship between fruit growth rate and drop (Figure 3). Although varying a bit, it is the same for many varieties as well as for fruit drop caused by different thinners, natural stresses of low light or just excess competition among fruits. A decrease in growth rate that leads to fruit drop can also occur for only a few days, but once it happens the fruit is destined to drop in the next week or so. **So the bottom line is that anything that reduces fruit growth will increase drop.** That seems to explain why so many different things (stresses, different chemical, cloudy or hot periods, etc.) can increase fruit drop.

![Figure 3. General relationship between apple fruit drop and growth rate showing that fruit have to retain a high growth rate to be able to stay on the tree.](image)

**Fruit Respiration and Mineral Uptake**

Fruit respiration (that generates energy for growth) is very high early in the season, as cell division requires a lot of energy. As the fruit shifts more in mid and late season to cell expansion that requires less energy, the respiration rates decline. However, apple is what is called a "climacteric" fruit that has a marked increase in respiration and the production of ethylene just at harvest. This indicates a striking change in the metabolism of the apple fruit as it reaches maturity.

As well as accumulating carbohydrates and water, the fruit take up mineral nutrients during the season such as nitrogen, potassium and calcium that are needed for growth and cell function. Calcium is particularly critical for fruit quality and postharvest storability. Calcium is taken up more rapidly in the first half of the season, during the cell division period. As the fruit grows and a thicker waxy cuticle forms there is progressively less calcium uptake. This means that as the fruit is expanding but taking up less and less calcium, the calcium concentration in the fruit declines as harvest approaches. It has been found that uptake of calcium depends on the spur leaf area associated with the fruit. Again this focuses our attention on the early season activity. Early thinning removes fruit competition and therefore helps calcium uptake of the retained fruit.

The take-home message is that the first few weeks after bloom are critical for fruit nutrition also. Good crop management requires early and effective thinning.

**Support for Fruit Growth**

The inherent growth pattern of the apple fruit is genetically determined. Fruit growth requires substantial support of carbohydrates, water and nutrients; however, it can be limited by lack of these resources.

**Carbohydrate reserves** - The initial growth of the shoots and flowers at bud break in the spring is supported by carbohydrate reserves in the roots and branches. Gradually, as leaves are produced, there is a transition from solely depending on reserves to obtaining greater support from current photosynthesis of the leaves. Several studies have found that the carbohydrate reserves bottom out just about bloom then begin to increase again, indicating that after bloom the fruit are not depending on reserves any
more. Several other studies have shown that after bloom, fruit are almost entirely supported by current tree photosynthesis.

**Current Photosynthesis.** Do all leaves on the tree support the fruit or do some support other competing organs such as shoots and roots? We have done studies to determine which leaves on the trees support fruit development at different times over the season. These and studies of several other labs have clarified the picture.

Extension shoot leaves support the growth of the shoot with carbohydrates until at least 10-12 leaves have unfolded. After that, the most basal leaves on the shoot can export carbohydrates to the fruit. However, we have found that if the shoot is shaded, then as many as 20 leaves will send their carbohydrates to the shoot and not to the fruit. Eventually, when extension shoots stop growing, all the leaves can send their carbohydrates to the fruit. That is why very light pruning that gives a large number of shoots that stop growth quite early, will support fruit set and early fruit growth better than heavy heading cuts that give more long, vigorous extension shoots that compete with the fruit for longer times.

In the first few critical weeks after bloom the carbohydrate support for fruit growth comes from the spur leaves and small “spur like” leaves on the short lateral shoots on last years stems, not from the new extension shoot leaves. This was very clearly seen when we shaded whole trees for 6 days when the fruit averaged about 16 mm diameter and then measured how much growth occurred in fruit versus extension shoots (Figure 5). Even down to 12% of full sunlight, shoots continued to grow at the same rate while fruits were reduced to essentially zero. This heavy shade to 12% of full sun led to complete de-fruiting of the trees while having no effect on shoot growth.

It appears that under limiting light, the tree puts its limited energy into extending shoots to obtain more light and survive till another year. This is also consistent with (1) the tree replenishing reserves after bloom even though the tree is supporting young fruitlet growth, and (2) the mechanism of juvenility for apple seedlings which is the tendency to not flower or set fruit for several years to allow the tree to get established and can support a crop.

The general pattern of support for fruit growth after bloom (Figure 6) is that primary spur leaves (those that come out before bloom) initially are important to support the fruit, but their importance gradually declines due to their small leaf area. Next, the leaves on the lateral (“bourse”) shoots in the spur develop after bloom and support the fruit unless they are extremely vigorous. Finally, the leaves on the extension shoots with more than about 12 leaves begin to support the fruit. Gradually as shoots stop growing, all their leaves can support fruit growth. For the last 2/3 of the season both bourse leaves and shoot leaves support the fruit.

From these studies it seems clear that we need to expose spur canopy of leaves to sun as much as feasible the during the weeks just after bloom since they are the primarily supporting the fruit. Using a laser as an artificial sunbeam, we analyzed what percentage of the sun was captured by spur leaves versus shoot leaves 3 weeks post-bloom in several orchards. We related the sunlight capture to the yields of those orchards.

As expected from the discussion above, we found that:

1. Orchard yields were positively related to sunlight capture by

the spur leaves. This combined the total sunlight capture of the whole orchard and the relative sunlight capture by the spurs versus extension shoots.

(2) Conversely, excessive sunlight capture by extension shoot leaves, by reducing the light available to the spurs in denser canopies, led to lower orchard yields.

(3) By about a month after bloom, all or most shoot leaves can support fruit, the local effects of light seen earlier are much less important.

Summary
In summary, there are many aspects of apple development that have been learned. Many of the key points are:

• Fruits develop from the base of the apple flower after pollination and fertilization and the flower walls around the seed cavity expand to become the fruit flesh.
• The apple fruit grows initially by cell division for about a week, then by both cell division and cell expansion for 3-4 more weeks, then predominantly by cell expansion.
• Final potential fruit size depends primarily on cell numbers, which are produced shortly after bloom. So, for good fruit size thinning effectively and early is critical (that is, small fruits at 1 month after bloom will never make big fruit).
• Carbohydrate reserves support flower development but are apparently not supporting the fruit growth after bloom. Post-bloom fruit growth is supported by the current photosynthesis of the leaves.
• Spurs support fruit growth in the first few critical weeks after bloom. Extension shoots do not support fruit initially as they support themselves until a few weeks after bloom.
• If light is limited (cloudy, etc.), shoot growth seems to have priority and fruit growth and set will suffer if there are too many shoots to support.
• Yields of apple orchards depend strongly on the sunlight captured by the spurs in the critical weeks after bloom.
• All of these results emphasize the importance of open canopies to get light to spurs, light pruning to have fewer vigorous shoots, and early thinning to allow maximum cell numbers to be produced.

Alan Lakso is a research and teaching professor located at Cornell’s Geneva campus who leads Cornell’s program in apple and grape physiology. Martin Goffinet is a retired Senior Research associate who specializes in anatomy and morphology.
Recent Advances of Mechanization for the Tall Spindle Orchard System in New York State – Part 1

Over the past 5 years we have witnessed the rapid adoption of motorized platforms in many Tall Spindle apple orchards in New York State to reduce production costs. Cornell mechanization research and extension efforts have increased the awareness of the economic benefits of orchard mechanization. The simple, narrow, and very adaptable canopy of the Tall Spindle system has facilitated the use of motorized platforms for partial mechanization of several orchard tasks. During the last three years we have introduced several platforms to growers (self-propelled or pulled by a tractor and single row or 2-row types) at each of the pruning demos conducted in Western NY and in the Champlain and Hudson Valley fruit production regions. NY growers and employees are using platforms for pruning (with loppers, pneumatic pruners, or a chainsaw on a pole), hand thinning, tree training and trellis construction and repair. The use of platforms has increased worker efficiency and also improved the successful adoption of the horticultural techniques of limb renewal pruning, and tree height control.

Our current research and extension efforts for orchard mechanization are proceeding along three fronts: motorized platforms to position human workers for greater canopy management efficiency, mechanical pruning with hedging machines and harvest aid machines to improve the efficiency of harvest. In this article we describe the current advances and future applications of (1) new motorized platforms for dormant pruning, hand thinning, tree training and trellis construction, (2) the Cornell concept for a fruiting wall via mechanical pruning and other fruit wall experiences from around the world, and (3) the potential benefits and future challenges of robotic pruning. A future article will cover the current advances for mechanized apple harvest in NY and the US.

Labor-Positioning Motorized Platforms

The use of motorized platforms for pruning was popularized by northern Italian growers in the South Tyrol region more than 20 years ago. However due to few tall, high-density orchards in the US and our system of contract pruning there were few platforms put into use here. With the rapid adoption of Tall Spindle orchards over the last 10 years, the use of motorized platforms has increased rapidly in New York State with approximately 50 platforms being used in NY Tall Spindle apple orchards. The platforms range from simple tractor pulled wagons built by growers to self-propelled single row or 2-row machines built in factories.

The simple wagon type of platforms built by growers have low cost (often built from scrap materials already on the farm) but have few adjustable features, require a tractor driver and often do not have adequate safety features. In contrast factory built machines have the proper safety features and adjustable features but are more expensive. There are currently 2 dealers of Italian factory-made platforms in North America (McQueen’s, of Wolcott, NY who sells the N-Blosi platforms and Bartlett’s ofBeamsville, Ontario, Canada who sell the Orsi platform). There are also 3 platform manufacturers in the US (Lagasse Works, Lyons, NY, Phil Brown Welding, Conklin, Michigan and BlueLine Manufacturing, Yakima, WA). Each of the US manufactures has a self-propelled version, which are more expensive and a tractor pulled version, which are less expensive. With many of the tractor drawn platforms innovative tractor controls have been mounted on the platform, to eliminate the need for a dedicated tractor driver.

The widespread interest in platforms has resulted in 2 new platform prototypes for NY growers in 2012 (Figures 1 and 2). Both platforms were designed and built (from the ideas of Scott VanDeWalle of Alton, NY) by LaGasse Works, of Lyons, NY, USA. Both are mounted on four-wheel drive tractors with the addition of a creeper gear in the transmission. Both have a 7 ft. x 9 ft. platforms mounted over the hood of the tractor from which two workers can prune adjacent trellis walls. The larger of the two has two additional 4 ft. x 5 ft. outboard platforms suspended from booms, which can be swung out, over the adjacent rows. Each of the outrigger platforms carries a single worker. Thus, with four workers, two rows of trees can be trimmed at once while the tractor creeps along. Steering, forward motion engagement, and emergency stop features are accomplished remotely from the platform. The two new platforms were first used during the 2012 dormant pruning season with good results and pruning efficiencies averaged between 25-30%. LaGasse Orchards is cur-
rently building three more of the single row platforms for three more Western New York fruit growers. The cost of the single row trimming platform is approx. $12,000. Market price for the over-the-row trimming platform is not determined yet.

The same concept of using a platform mounted over the top of a four-wheel drive tractor was also recently developed by Burrows Tractor, Wenatchee, WA. Their self-propelled platform has a remote steering unit and can also be removed from the tractor, which allows the grower to use tractor for other orchard tasks the rest of the year. This “Burrows platform + tractor package” of a mounted platform on a 35hp New Holland tractor is offered at approximately $19,400 dollars.

The main advantage of worker positioning platforms is the time and labor savings of not carrying ladders through the orchard, and climbing up and down to perform various jobs. In addition, there are two other potential advantages to using an orchard platform: (1) encouraging the same work speed of an entire work crew, with the intention of increasing productivity and preventing over/under pruning or hand thinning of trees that can happen when the rate of speed down the row is NOT controlled (as with ladders), and (2) human physical effort is reduced (if managed well), allowing a wider labor pool, people who could not climb up and down a ladder repeatedly during the day may now be able to perform this work. By using platforms, dormant pruning work is definitely less physically demanding for workers when they no longer have to climb ladders while carrying pruning tools.

There may also be disadvantages to a motorized platform. If the person managing the platform crew and setting the work speed is not experienced, the work speed may be too fast resulting in excessive stress on the workers. If jobs are not rotated throughout the day and care is not taken to prevent repetitive motion injury there may be more injuries from work on a platform. If there are no provisions for worker comfort or there are conflicts within the crew that are not addressed in a timely, effective manner worker satisfaction may be poor. Using an experienced team manager on the platform is critical to successful platform productivity and worker satisfaction.

There are many jobs in addition to dormant pruning that can be completed using a platform: stringing and fastening multiple trellis wires; installing wire tighteners and vertical support wires; fastening trees to the wires, installing mating disruption dispensers, summer pruning, hand thinning, and harvest. U-Pick operations can harvest the tree tops while allowing the bottoms to be harvested by the U-pick customers. This will help avoid customers falling off ladders or ruining fruit and trees while trying to reach fruit in the upper portion of the tree.

Miranda Sazo et al., (2010) studied labor efficiency with a platform and showed that dormant pruning time was reduced from 1.26 minutes/tree to 0.92 minutes/tree when the same workers utilized a platform and pruned mature Gala and McIntosh’s Tall Spindle trees on a dwarfing rootstock in Wolcott, NY. The prun-
ing platforms reduced labor costs by about 27-30 percent. There was little difference in labor efficiency between the three types of platforms used. An economic analysis of investment in a platform, showed that the use of a motorized platform could save $102/acre, $104/acre, and $45/acre for dormant pruning, hand thinning and trellis installation respectively. A 2012 study (Miranda Sazo and Robinson, unpublished) compared the efficiency of hand thinning of four workers with a platform pulled by a tractor (self-steered) and measured a saving of $150/acre when the same workers hand thinned Gala trees with ladders.

**Mechanization of Summer Pruning by Hedging**

When managed correctly, the Tall Spindle apple system at maturity gives a narrow, tall fruiting wall with good fruit quality due to good light exposure in the narrow canopy. After year 5, partial mechanization of dormant pruning by using labor positioning platforms has increased dormant pruning labor efficiency by 25–40%. Further mechanization of pruning by using side wall shearing of the tree canopy in the summer with a cutter bar may offer further reductions in annual pruning costs of the tall spindle. Although mechanical pruning that was conducted in the 1960’s and 70’s it was generally unsuccessful because it resulted in excessive regrowth and poor fruit quality due to vigorous rootstocks and the cutting of large limbs. However, current NY high-density Tall Spindle orchards are now more suitable to mechanized pruning due to the use of dwarfing rootstocks, a better managed and calm tree, and the presence of more small pendant fruiting branches (15-18 branches) at year 5 or 6.

The recent efforts to mechanize pruning were begun by Alain Masseron and Laurent Roche of CTIFL (Center for Techniques of Production and Distribution for Fruit and Vegetables in France) about a decade ago. They began mechanically shearing Tall Spindle trees in the early summer to develop a narrow fruiting wall they named “Le Mur Frutier” (The Fruiting Wall). The trees were sheared in early June (when shoots had about 8-10 leaves) about 15 inches from the trunk. The tops of the trees were also cut mechanically at 10-11 feet height. This left a tall rectangular tree which was confined to a space 32 inches wide by 10 feet tall. Little shoot regrowth occurred at this timing and especially when the trees were carrying a full crop which utilized much of the carbohydrates the tree produces for fruit growth. Some commercial fruit growers who have adopted this system prune only mechanically each year in June with no additional hand pruning. Other commercial fruit growers who have adopted this system implement a follow up dormant hand pruning every third year. The mature fruiting wall tree has many weak and fruitful side branches within the rectangular space allowed by the hedging machine but no branches that extend out into the alleyway between rows.

The initial good success of mechanized summer pruning conducted by CTIFL in France was followed by research trials in Italy (Alberto Dorigoni), Spain (Ramon Monserrat), and Germany (Gerhard Baab). In 2011 and 2012 we began several hedging trials in NY State to study the benefits of mechanized summer pruning of NY Tall Spindle orchards. Our experiments involve both Tall Spindle trees and Super Spindle trees on M.9 or B.9 rootstocks.

Our main goal of mechanized summer pruning is to have a narrow fruiting wall with good light distribution but not create a vigor response in the tree and reduce pruning costs by 2/3. A second important research objective is to study the shoot response of several important apple cultivars in NY State to mechanized summer pruning timings and severities. The ideal response to the mechanical summer cut is to generate a short shoot regrowth (3-8 inches long) with a terminal floral bud (Figure 3) instead of a vegetative bud. The correct timing of mechanical summer pruning is critical for maximum floral bud initiation during the early part of the summer so a very a productive and efficient fruiting wall can be started.

**Materials and Methods**

Initial exploratory hedging trials in 2011 led to 5 replicated trials in 2012 at the following sites: (1) VanDeWalle Orchards, Alton, NY with Tall Spindle Gala and McIntosh, (2) Lamont Fruit Farms, Albion, NY with Super Spindle Macoun, Honeycrisp, Acremac and Gala, (3) Crist Bros Orchard, Marlboro, NY with Tall Spindle Gala and Jonagold, (4) Everett Orchards, Peru, NY with Tall Spindle McIntosh and (5) at the Agricultural Experiment Station in Geneva,
NY with Tall Spindle Gala, Jonagold, Golden Delicious and Fuji. For sites 1 and 2 the hedger cutting bar was positioned almost vertically along the hedge of the canopy (Figure 4). The VanDeWalle site had two severities of hedging at 12 and 24 inches from the trunk. The Lamont site had one severity of hedging at 18 inches from the trunk. For sites 3, 4, and 5 the hedger cutting bar was positioned at a slight angle along the edge of the canopy 24 inches from the trunk at the base of the canopy and 12 inches from the trunk at the top of the canopy (Figure 5). In each study we evaluated the effect of timing of summer sidewall shearing (first week of June, first week of July and first week of August) on Tall Spindle apple trees. At the Lamont site (using mature Super Spindle apple trees) we also evaluated an earlier timing (first week of May) and at the Everett site we only evaluated the early August timing. Tops were not mechanically pruned. For all studies we evaluated proportion of shoots on the whole tree which were cut by the machine, number of fruits cut off, shoot re-growth, light intensity in the canopy at 3 heights and fruit quality at harvest. We plan to evaluate return bloom next spring (May 2013). At each location fruit yield was recorded at harvest and a fruit sample was collected to evaluate fruit color and sugar content.

Results
Summer sidewall shearing was fast and left the trees with a “manicured” look (Figures 4 and 5). The cost and time amounted to a fraction of the time (5%) to do manual summer pruning. At each of the summer timings the shearing cut an average of 30% of the growing points on the tree (range 24-44%) (Table 1). This means that about 70% of the growing points on the trees were not touched by the machine. When the sidewall shearing was done at bloom there were some flowers cut off but the grower viewed it as a dormant pruning. However, when the sidewall shearing was done in June, July or August some fruits were cut off and the growers were more concerned. Fruit counts showed that the number of fruits cut off was about 5 fruits/tree (range 1-13%) (Table 1) and would be no more than dropped to the ground by hand thinning.

PAR (photosynthetically active radiation) measurements at each site showed that the summer sidewall shearing improved light intensity in the lower part of the canopy by about 10%. There was little improvement of light exposure in the top of the canopy. The trees we used in these studies had canopies already quite well shaped for good light distribution and the shearing removed only a small portion of the shoots and thus had a small effect on light distribution in the canopy.

The sidewall shearing treatments did not induce vigorous shoot regrowth regardless of the timing of the mechanical pruning. However, with the early timing (early June) we saw the development of short re-growths (8 inches) with a terminal bud, which likely will be flower buds next spring. With the July timing regrowth was about 5 inches and at the August timing there was no regrowth at all (Table 1).

At harvest there were no large differences in fruit color among treatments. However, the sidewall shearing treatments had slightly better fruit color than the unsheared controls.

Discussion
Our first year results with summer shearing were positive but will require 2 more years to fully determine if this approach has long term positive results or if negative tree growth will negate the labor savings from mechanical sidewall shearing. If side-wall shearing in the summer can reduce summer pruning costs by 95% and improve fruit color without negative effects on return bloom or vigorous growth response it will also have a significant impact on orchard profitability. Results from 2012 are encouraging so far in that there was little or no regrowth from the sidewall shearing treatments with the Tall Spindle system. It appears that the early July timing was the best since it had short regrowth with terminal flower buds.

A long-term strategy that a grower in France (Pomanjou) has implemented is to use annual side-wall shearing of Tall Spindle trees for 3 successive years with no other dormant pruning but

Table 1. Effect time of summer hedging on percentage of shoots cut off, number of fruits cut off and shoot regrowth at Geneva, NY 2012.

<table>
<thead>
<tr>
<th>Variety</th>
<th>% of Shoots Cut Off</th>
<th>N of Fruits Cut Off</th>
<th>Shoot Regrowth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>June</td>
<td>July</td>
<td>August</td>
</tr>
<tr>
<td>Fuji/M.9</td>
<td>33.2</td>
<td>36.7</td>
<td>29.5</td>
</tr>
<tr>
<td>Golden/M.9</td>
<td>32.9</td>
<td>35.3</td>
<td>28.5</td>
</tr>
<tr>
<td>Jonagold/M.9</td>
<td>25.7</td>
<td>24.4</td>
<td>28.2</td>
</tr>
<tr>
<td>Gala/M.9</td>
<td>35.4</td>
<td>38.6</td>
<td>44.6</td>
</tr>
<tr>
<td>Average</td>
<td>31.8</td>
<td>33.8</td>
<td>32.7</td>
</tr>
</tbody>
</table>
in the third year to add a dormant winter corrective pruning to remove limbs that have become large and are causing internal canopy shading and poor fruit quality (Figure 6). Such a pruning strategy could reduce total annual pruning costs in Tall Spindle orchards by about 65% and help NY apple growers remain profitable and competitive.

Bruno Billote, another French apple grower converted his orchard seven years ago to mechanical pruning. His orchard has only had a modest manual pruning input in three of the intervening years and he has been able to keep a narrow wall with mechanized pruning. He prefers the early timing (March/early April). When he tried mechanical pruning in early June, mildew and scab became a problem. He concludes there are some limitations with a fruiting wall: (1) tree height is limited, (2) production (on Gala) is limited to 70-80 ton/ha, and (3) fruit size tends to be about 5 mm smaller. He suggests Golden Delicious performs well with a wall width of 60cm, Honey Crunch with a wall width of 70-80cm, Gala requires a wall width of 80cm, while Granny Smith requires a width of 1m.

Alberto Dorigoni, an Italian scientist from the Agrarian Institute of Saint Michele suggests that different mechanical pruning timings could provide different benefits. Mechanical pruning in winter, could be used in moderate-growing orchards, with the aim of shaping trees for the following early summer shearing. Hedging at Pink bud is useful to prevent a little bit the regrowth, while early summer (8-12 leaves) to maximize flower differentiation and reduce regrowth. Mid-summer minimizes regrowth, and hedging pre-harvest increases fruit color, while hedging after harvest reduces regrowth and shape trees and the fruit wall for winter pruning. He is currently studying the use of a "Window Pruning Machine", or WMP.

**Robotic Pruning**

In the USA there are several efforts to utilize robotic technology in orchard tasks to reduce hand labor. In our opinion the current efforts to develop robotic harvesters will require many more years of research and development due to the extreme complexity of identifying the fruit location, detaching the fruit without bruising, and transporting the fruit to the bin without bruising and may not be practical. However we believe that robotic pruning has a greater potential for success in future Tall Spindle orchards for the following reasons: (1) leaves will not interfere since dormant pruning is done in the winter, allowing the tree structure to be highly visible, (2) the sparse nature of newer tree architectures such as the Tall Spindle allows branches to be visible and reachable by a robot, and (3) when branches are cut, they do not have to be handled with care, unlike fruit.

The robotic pruning process will include sensing the tree with digital cameras, constructing a virtual three dimensional model of the tree, making pruning decisions based on branch lengths, diameters, and density and finally, directing a robotic arm with cutter blades to cut at the branch locations determined from the previous step.

To facilitate such robotic pruning, we believe that future orchards for robotic pruners will basically need simple trees with no permanent branches such as the Tall Spindle or the Super Spindle, and one or two simple pruning rules. The Tall Spindle could be adapted to such robotic system since pruning could be simplified to the single rule of removing any branch that is larger than 2 cm in diameter.

Such robotic pruning technology is possible and would be a valuable tool in orchard management. However, its value to apple growers must be evaluated in economic terms. If the technology is costly with only a small gain in efficiency it will not be of any significant value. If the mechanized shearing in the summer results in reduced costs with good fruit quality it will be much cheaper than a robotic pruner machine. The more costly, complicated and risky the technology, the more thorough the evaluation needs to be (O’Rourke, 2013).
Summary

NY apple growers are rapidly adopting the Tall Spindle planting systems. This is allowing them to adopt motorized labor positioning platforms to reduce pruning, hand thinning and summer pruning costs. There are several new and innovative "design concept" for a motorized mounted platform mounted over a tractor initially developed in NY State, and more recently also available in Washington State. This type of equipment promises versatility, easy maneuvering in snow, higher efficiency, and a much lower investment. The cheapest mounted platform option with self-steering mechanism without considering tractor cost starts at approx. $12,000 dollars ($12,300 dollars for a model with a self-leveling feature) with potential use for medium as well as high-density orchards.

In the future pruning costs may be reduced even further with mechanized summer side-wall shearing. This technology works best with proper trellis design and with tree planting with GPS guided tractors for straight rows. A long-term mechanization strategy that we envision is to use annual side-wall shearing of Tall Spindle trees for 3 successive years with no other dormant pruning but in the third year to add a dormant winter corrective pruning with a motorized platform to remove limbs that have become large and are causing internal canopy shading and poor fruit quality. Such a pruning strategy with the use of a motorized platform in the winter and a hedger in the summer could reduce total annual pruning costs in Tall Spindle orchards by about 65% (averaged over 3 years) and result in a narrow, tall fruiting wall (Figure 7).

The modification or adaptation of a Tall Spindle orchard system to a fruit wall concept could be well suited to the majority of NY apple cultivars. With some cultivars the system may involve a 2 stem tree (bi-axis) or a 3-stem tree (tri-axis) to manage vigor (Figure 8). It could also allow for cheaper production of a similar quantity and quality of fruit (size, color, and eating quality) as from current mature Tall spindle apple orchards. Potentially, the size and color of the fruits could be more uniform as a result of better light penetration and distribution. The water volume needed for good spray coverage for pest control could also be reduced. The uniformity of chemical thinning could also be improved and the fruit wall could be thinned mechanically with the Darwin machine as long as we reduce the potential spreading of fire blight in the orchard during blossom. The fruit wall concept using Tall Spindle trees will increase even more the performance of motorized platforms, future harvest equipment, and worker efficiency. To take full advantage of these advances in mechanization, new orchards should be established at a spacing of 2.5-3ft x 11-12 ft. Trellises should use 12 ft. posts, a correct post spacing of not more than 30 ft., and a minimum of four or five wires.

Acknowledgements

The authors thank the growers who served as cooperators for the four side-wall shearing studies conducted in NY in 2012.

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Terence Robinson is a research and extension professor at Cornell’s Geneva Experiment Station who leads Cornell’s program in high-density orchard systems, rootstocks, and plant growth regulators.
Apple tree growth and development requires an adequate supply of 14 essential mineral nutrients. These nutrients fall into two groups: macronutrients that are required by the tree in large amounts: N, P, K, Ca, Mg and S; and micronutrients that are needed only in small quantities: B, Cu, Zn, Fe, Mn, Mo, Cl and Ni. Each nutrient performs unique functions in tree growth and development, and good tree growth, cropping and fruit quality depend on not only the adequate supply of each nutrient, but also the proper balance between them.

Nutrient supply and balance also has a significant impact on the susceptibility of apple trees to diseases, including fire blight, because it affects the metabolism of the tree, leading to changes in cell wall composition and strength, concentrations of defense compounds, and abundance of sugars and amino acids. Nitrogen and potassium affect the susceptibility of apple trees to diseases in opposite directions. When too much nitrogen is provided, the vegetative growth of apple trees is enhanced to an excessive level. This excessive shoot growth has several consequences in terms of disease susceptibility, in addition to negatively affecting flower bud initiation, fruit color development and storage quality: 1) it increases the actively growing surface that is potentially susceptible to diseases; 2) it increases the concentrations of free amino acids that can serve as a food source for pathogens; 3) it decreases secondary metabolism such as phenylpropanoid pathway that produces phenolic compounds and lignin for plant defense against pathogen attacks; and 4) it increases the needs for other nutrients in general and decreases the uptake of K, Ca and Cu in particular. If the supply of other nutrients, such as K, is low, the imbalance of nutrients would be exacerbated, making the trees even more susceptible to diseases. In contrast, adequate K supply enhances the activation of enzymes, protein synthesis, cell wall lignification, and translocation of carbohydrates, making the tree less susceptible to diseases. Therefore, nitrogen supply and potassium supply must be balanced to minimize the risk of diseases.

In commercial orchards, some soils with high organic matter provide a substantial amount of N during the summer, heavy N fertilization late in the spring with natural release of N from the soil during the summer can elevate tree N status to excess levels, leading to vigorous vegetative growth, poor fruit color development, storage quality problems, and increased disease susceptibility. At the other extreme, lack of N supply from soils with low organic matter can result in poor fruit set, small fruit size, low yield, and alternate bearing. Because nitrogen has differential effects of fruit set and size, fruit color, flesh firmness, storage quality, and disease susceptibility (Cheng and Wang, 2011; Cheng et al., 2007), nitrogen management has to be optimized to balance these various effects with the ultimate goal of producing high yield of quality fruit (Cheng, 2010). Since most orchard soils in New York have low K supply and fruit harvest removes significant amount of K permanently from the orchards, K application must be considered along with N fertilization and other nutrients.

**Demand-supply Relationship of Nitrogen and Potassium**

When developing a nutrient management program, the demand-supply relationship of nutrients in apple trees must be taken into consideration. Early season canopy development and fruit growth require high N supply whereas fruit quality development only requires baseline N supply. Our work with 6-year-old ‘Gala’/M.26 trees grown in sand culture showed that total tree N increased very rapidly from bloom to the end of shoot growth, and then continued to increase but at a much slower rate until fruit harvest (Figure 1A). In contrast, total K in the tree increased slightly from bud break to bloom and then in a near linear manner from bloom to fruit harvest (Figure 2A). (Other nutrients such as P, Ca, Mg, S and B showed a similar trend as K. See Cheng and Raba, 2009b for details). The net gain of total N and total K from bud break to fruit harvest is 20g and 36g per tree, which is equivalent to 50 lbs actual nitrogen and 90 lbs of potassium per acre, respectively (Cheng and Raba, 2009a, b). Shoots and leaves and fruit have differential requirements for N and K (Figures 1B, 2B). Both total N and K in shoots and leaves increased very rapidly from bloom to the end of shoot growth, and then remained unchanged until fruit harvest. In contrast, total N and K in fruit increased gradually from bloom to the end of shoot growth, and then increased rapidly until fruit harvest. At harvest, total N and K in fruit accounted for

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37.6% and 71.3% of the total N and K in the new growth, respectively, indicating fruit has a much higher requirement for K than for N.

There are three sources of nitrogen supply. The first source is the reserve nitrogen that has accumulated in the tree from the previous growing seasons. This pool of nitrogen is readily available for the initial growth during spring. 15N-labelling studies clearly indicated that the majority of the N required for spur leaf growth of apple trees is supported by tree reserve N (Neilsen et al., 1997). Better N supply to spur leaves and young fruits may improve spur leaf development and early fruit growth by promoting cell division. The second source is the natural N supply from soil mineralization process. The supply capacity of this process depends on soil organic matter content, soil temperature, moisture, and aeration of the soil. This process provides substantial amount of nitrogen for trees growing on soils with high organic matter (Stiles and Reid, 1991). The third source is nitrogen supply from fertilizers, either applied into the soil or to foliage. Similar to N, K is mobile in the phloem and there are three sources of K (reserve K, soil K, and fertilizer K) for the new growth as well.

The demand-supply relationship of N and K is reflected in tree N and K status. Throughout the growing season, an ideal pattern of tree nitrogen status is that trees have relatively high nitrogen status early in the season to promote rapid leaf area development and early fruit growth. As the season progresses, nitrogen status declines gradually to guarantee fruit quality development and wood maturity. For K, the concentration in both leaves and fruit also decreases as the season progresses, but it does not decrease to the same extent as N (Cheng and Raba, 2009a).

**Tree Nutrient Status**

Determining tree nutrient status is important for making decisions about whether and how much fertilizer should be applied. Leaf analysis is highly recommended for this purpose as it indicates nitrogen and other mineral nutrients present in the foliage. If leaf samples are taken correctly and the results are interpreted properly, it provides a good tool for developing an effective fertilization program. Apple leaf analysis standards are listed in Table 1.

Tree growth is directly related to its N status. Rapid growth of young trees is highly desirable for developing the canopy to capture sunlight for promoting early cropping. The optimum leaf N for the growth of young apple trees is approximately 2.4 to 2.6%. As trees mature, less vegetative growth is desired and the optimum leaf N level should decrease to improve fruit color, firmness, and storage quality.

Varietal difference in fruit coloring and/or flesh firmness and storage quality is another important consideration. Apple varieties can be categorized into two groups, soft varieties and hard varieties, based on their optimum N status required for fruit quality.

Soft varieties include Cortland, Empress, Golden Delicious, Honeycrisp, Jerseymac, Jonagold, Jonamac, Jonathan, Macoun, McIntosh, Mutsu, Paulared, Spartan, Tydeman Red, and other early ripening varieties.

Hard varieties include Delicious, Empire, Gala, Idared, Liberty, Melrose, R.I. Greening, Rome, Stayman and York Imperial.

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**Table 1.** Apple leaf analysis standards on a dry weight basis (from Stiles and Reid, 1991)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Desired level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Young non-bearing apples</td>
<td>2.4 – 2.6%</td>
</tr>
<tr>
<td>Young bearing apples</td>
<td>2.2 – 2.4%</td>
</tr>
<tr>
<td>Mature soft apples</td>
<td>1.8 – 2.2%</td>
</tr>
<tr>
<td>Mature hard apples and processing</td>
<td>2.0 – 2.4%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.13 – 0.33%</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.35 – 1.85%</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.3 – 1.8%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.35 – 0.50%</td>
</tr>
<tr>
<td>Boron</td>
<td>35 – 50 ppm</td>
</tr>
<tr>
<td>Zinc</td>
<td>35 – 50 ppm</td>
</tr>
<tr>
<td>Copper</td>
<td>7 – 12 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>50 – 150 ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>50+ ppm</td>
</tr>
</tbody>
</table>

**Table 2.** Amount of K removed by fruit harvest and the minimum K₂O application needed in relation to fruit yield in ‘Gala/M.26’ based on the data obtained by Cheng and Raba (2009a).

<table>
<thead>
<tr>
<th>Yield (bushels/acre)</th>
<th>K (lbs/acre)</th>
<th>K₂O (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>27.7</td>
<td>33.3</td>
</tr>
<tr>
<td>1000</td>
<td>55.3</td>
<td>66.6</td>
</tr>
<tr>
<td>1500</td>
<td>83.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2000</td>
<td>110.7</td>
<td>133.3</td>
</tr>
</tbody>
</table>
Care must be taken when interpreting leaf analysis results, as many factors influence leaf composition, especially, crop load and tree vigor. Leaf N tends to be higher on trees with a heavy crop than those with a light crop. Off-year trees are generally lower in leaf N than on-year trees. This is because more vegetative growth of the light cropping trees dilutes the nitrogen in leaves. In contrast, trees that are spur-bound with very limited new growth tend to have higher than desired levels of nitrogen in their foliage, a result of N accumulation caused by the limited growth. To properly diagnose tree N status, one needs to combine leaf analysis with careful examination of tree growth.

When interpreting leaf K analysis results, it should be kept in mind that an inverse relationship exists between leaf K level and crop load. This is because K is mobile in the phloem and fruit is a stronger sink for K than leaves after shoot growth stops. For trees with a heavy crop load, competition for K between leaves and fruit and between fruits themselves lowers both leaf and fruit K concentration. So, a leaf K level of 1.3% may be adequate for trees with a heavy crop, but it might indicate a marginal supply for trees with a light crop. Because of the inverse relationship, leaf K level typically decreases as trees mature and the level of cropping increases.

For both Empire and McIntosh, fruit size and color is positively correlated with leaf K level, and levels in the range of 1.5 to 1.8% are needed for optimal production, fruit size and color (Stiles and Reid, 1991). Because fruit requires more K than any other nutrients, the amount of K removed by fruit harvest is closely related to fruit yield (Table 2). However, it should be kept in mind that excessive K supply can negatively affect fruit Ca level, leading to Ca-deficiency induced disorders such as bitter pit. For many apple cultivars, fruit K to Ca ratio should not exceed 25. The negative effect of K on fruit Ca is exacerbated under low crop load conditions because more vigorous shoot growth and dilution of Ca in larger fruit both contribute to lower fruit Ca level as well.

The requirement for K increases as the supply of N increases. A proper ratio between N and K is important for good tree growth, fruit quality, and tolerance to low temperature stress and diseases. A ratio of 1.00-1.25:1 (N:K) represents a good balance between the two elements for McIntosh while a ratio of 1.25-1.5:1 is more appropriate for Delicious.

### Timing of Application

The best timing for N application should be considered in the context of the seasonal pattern of tree N demand, that is, early season canopy development and fruit growth require large amounts of N while fruit quality development only requires baseline supply of N. We reasoned that there are two windows for regular soil N application that would fit the tree nitrogen demand pattern: one is from bud break to the beginning of rapid shoot growth and other is late in the season when soil N application no longer affects fruit quality (just before or shortly after fruit harvest). Over three years (2000 to 2002), we used 15N-labelled ammonium nitrate to determine the effect of timing of N fertilization on fertilizer N uptake and fruit N status, and found that apple trees grown under New York climate conditions were able to take up significant amount of fertilizer N between bud break and end of spur leaf growth (For details, see Cheng and Schupp, 2004). An advantage of early N application is that when it comes to harvest, fruit N status has decreased to a similar level found in control trees, suggesting no negative effect on fruit quality. It appears that both N applications early in the season (bud break to petal fall) and late in the season just before fruit harvest fit the seasonal pattern of tree nitrogen demand. Nitrogen applied early in the season contributes directly to the spur and shoot leaf development and fruit growth in the current season while N applied late in the fall helps to build up nitrogen reserves, which is used to support leaf development and fruit growth the following year. Considering the uncertainty of N leaching loss during the winter, early soil application of nitrogen between bud break and petal fall is probably the most practical way to meet the tree N demand early in the season. If more than 40 lbs actual N/acre is to be applied, a split application, half at a couple weeks after bud break and the other half at petal fall or shortly thereafter, is recommended. If nitrogen is provided via fertigation, application should be targeted to the high demand period from bloom to end of shoot growth.

For soils that have low cation exchange capacity, such as sandy soil with low organic matter, or varieties whose fruit quality is not sensitive to N, multiple split applications during spring-summer period may be desirable.

In addition to soil application, nitrogen can be applied to foliage directly during the growing season to help meet the tree nitrogen demand (Cheng, 2010). An advantage of foliar nitrogen application after shoot growth stops is that it does not stimulate shoot growth, thereby reducing the risk of diseases. So, one strategy for minimizing fire blight risk associated with rapid shoot growth is to provide just enough nitrogen to the soil in the early part of the season to achieve minimum shoot growth required for tree vigor and cropping and then use foliar nitrogen
applications later to satisfy the tree nitrogen needs. Applying high concentrations of foliar urea at the end of the growing season not only increases tree reserve nitrogen, but also directly reduces the ascospore counts of apple scab (Sutton et al., 2000).

Timing of ground K application is not as critical as N application because tree requirement for K is essentially constant from bloom to fruit harvest. However, because K movement in soil is fairly slow and K⁺ is easily adsorbed onto soil clay particles and organic matter (therefore leaching loss is minimal), fall application of K is preferred especially large amounts of K must be applied. If fertigation is used, it should target the period from petal fall to about a couple weeks before fruit harvest (Robinson and Stiles, 2004).

**Amount of Application**

The amount of N fertilizer application depends on three factors: 1) tree nitrogen requirement; 2) natural supply of nitrogen from soil; and 3) uptake efficiency of applied fertilizers. The annual N requirement is estimated to be about 50 to 80 lbs for mature apple trees on dwarfing rootstocks in high-density plantings. The actual N requirement varies from block to block and fruit yield should be taken into account (Cheng and Raba, 2009b). The N supply from soil mineralization process depends on soil organic matter content, soil temperature, moisture, and aeration of the soil. Because orchard soils are not disturbed frequently, the annual mineralization of soil organic nitrogen is less than 1% of the total organic nitrogen pool in the soil (Lathwell and Pech, 1964). For a soil that has a 3% organic matter, the amount of nitrogen released from soil mineralization process is about 50 to 70 lbs. However, only a proportion of the released nitrogen is taken up by the tree. Assuming 60% of the 50 to 70 lbs of N is taken by the tree, this would contribute about 30 to 40 lbs N to the tree. The difference between the total demand and the contributions from soil N is the amount of N the trees need from the fertilizer. Because not all the fertilizer nitrogen is taken up by the trees, nitrogen fertilizer use efficiency should be factored in when determining the actual amount of fertilizer nitrogen to be applied. For soils with high organic matter, the natural supply of N from soils may be sufficient to meet the tree N demand and there is no need to apply any N fertilizer. Generally speaking, for orchard soils in New York and the Northeast, the amount of fertilizer N required is anywhere between 0 and 80 lbs, which would contribute 0 to 30 lbs of N to the trees, assuming the fertilizer uptake efficiency is between 30 to 40%. As a rule of thumb, every 10% increase in N fertilizer application results in a 0.1% increase in leaf N. If N is provided via fertigation, less N is needed as N uptake efficiency is higher in fertigation than in regular soil application.

Since apple trees have a higher requirement for K than for N and most soils in New York have low natural supply of K, the rate of K fertilizer application is higher than N. Unless the soil supply exceeds the recommended values in soil analysis interpretations, a minimum rate of K in the range of 80 to 100 lbs of K₂O should be applied (maintenance application) because significant amount of K is removed from fruit harvest each year in high density plantings and the removal rate increases with increasing fruit yield (Table 2). For soils with low K supply, higher rates of K application (150 to 250 lbs of K₂O) are needed.

Because each orchard soil is unique and all the fertilizer field trials are site specific, the best way to fine-tune the rate of N and K fertilizer applications is to have your own fertilizer rate trials on your farm based on leaf analysis, soil analysis and tree indicators.

**Summary**

The key to fostering tree growth and cropping without increasing the risk of fire blight is to provide just enough nitrogen for tree growth and cropping while keeping a balance between nitrogen, potassium and other nutrients. This can only be achieved by understanding the demand-supply relationship of nitrogen, potassium and other nutrients, and developing a fertilization program that addresses the timing and amount of fertilizer inputs based on tree nutrient needs, soil and tree nutrient status. Controlling nitrogen supply and balancing nitrogen with potassium and other nutrients helps reduce the risk of fire blight and improve fruit quality.

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Optimizing Strawberry Production with a Reduced Tillage System

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Strawberry weed control has long been a challenge for growers. Experiments that attempt to integrate sustainable practices with herbicides have helped growers maintain matted row strawberries, but the planting year remains a challenge. When growers focused on controlling weeds in strawberries during the establishment year by trans-planting dormant berry plants into a killed cover crop, a barrier was observed. Most growers had difficulty planting through the cover crop, which resulted in slower establishment during the first month and a greater number of skips. Previous research has shown that control of weeds during the first weeks of the growing season makes the most difference to yield in a matted row system. There have also been studies that support the use of cover crops as a way to decrease incidence of plant disease. To address this set of circumstances, it was decided to modify the transplanting system and use a reduced till (also called zone-till) system.

Reduced Tillage System

The reduced-till system uses a sub-soiler to loosen soil deeply. Coulters follow the ripper, which are then followed by a rolling basket that all work together to prepare a 6-10” wide seedbed (Figure 1). This technique allows the longer rooted strawberry plant to be correctly planted while still having minimum soil disturbance between the rows. By only tilling this narrow area, the chance of new weed seeds being brought to the surface for germination is reduced. Because the strawberry plants will get off to a good start, they should out-compete weed competitors in the tilled zone. The shank ripped zone allows for improved water drainage hopefully reducing disease pressure from soil borne diseases like Phytophthora root rot (Figure 2). The use of reduced tillage tools usually requires a single trip across a field for it to be fitted for planting – an important advantage that translates into approximately 1/3 less labor when compared to standard primary tillage. Reduced fuel consumption and a decreased risk of soil compaction are other potential benefits of zone tillage.

Materials and Methods

To evaluate the value of the Reduced Tillage System, we conducted a field project, supported by a NESARE Partnership grant, which sought to improve weed control during the establishment year of a perennial matted row strawberry system while also reducing cultivation and herbicide inputs and improving soil health.

Comparison trials were established on 3 farms where the Reduced Tillage System of preparing a strawberry field was compared to a No Till system and to a conventional seedbed preparation system. After the preplant preparation treatments, strawberry plants were transplanted into the field and the weight of weed biomass and the number of annual or perennial weeds was recorded for each system on June 10 and Sept. 10 in the year of planting and on May 11 the second year. At harvest in the second year, yield was measured by harvesting all the trusses from randomly selected areas within each treatment. The berries were counted, put in primary, secondary and tertiary categories and then weighed.

Results and Discussion

The results from the study were variable. The dried weed weight from all sampling dates varied among the farms (Figure 3). All 3 farms saw significantly larger weed biomass during the first month after planting in the conventionally prepared treat-
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ment than for the reduced till or no-till treatments. However, this does not mean that there were more weeds in the conventional treatment, rather the weed number data in Figure 4 suggests that for Farm 1 and 3 that the weeds were more numerous but much smaller in the reduced till treatment than in the conventional treatment. This may be explained because it took longer for the weeds to emerge through the killed cover crop.

The number and type of weeds varied dramatically from farm to farm (Figure 4). Farm 1 showed a higher number of perennial weeds than both other farms, due to the fact that this trial was installed into a killed sod on Farm 1. That high ratio of perennial weeds to annual weeds continued through the next 2 sampling periods. This result does not bode well for the productive life of the planting, as perennial weeds are difficult to eradicate once established in a matted row strawberry system.

With Farm 2, there was greater weed biomass in the control treatment one month after planting than the no-till or reduced till treatments, but the reduced till treatment still had higher numbers of weeds. This same trend was seen with Farm 3 – larger weed biomass in the control treatment, but higher numbers of weeds in the reduced till treatment.

For all 3 farms, the differences in weed biomass in the three treatments diminished as time progressed and the farmer had more tools available to control weeds. The number of weeds however did not follow a clear pattern throughout the year of monitoring. This may be due to the individual farm weed pressure and the type of weeds existing on each farm.

For Farms 1 and 2 the control treatment yielded significantly more berries than did the reduced till or no-till treatments (Figure 5). Farm 3 however, which had the largest volume of berries of all 3 farms, yielded almost 1/3 more in the reduced till treatment than the control. This farmer was so enthusiastic about zone tillage that he has installed 1 acre of reduced till June bearing strawberries during the spring of 2012.

Conclusions
There appears to be promise in using reduced tillage in a matted row strawberry system despite these variable preliminary
results. The speed at which a zone tilled planting can be established will be a benefit to growers that find themselves exceptionally busy during May.

From a farm profitability perspective, labor savings with the reduced tillage system averaged 37% and fuel savings 40% compared to conventional tillage for field preparation. The range reported by growers for savings in fuel ranged from 27 to 60% and savings in labor costs ranged from 25 to 60% (Dr. Anu Rangarajan, Cornell University).

The reduced tillage approach would be more attractive if we could prove that yield of this high value crop would not suffer. The results from this study imply that farmers should experiment with reduced till in their matted row strawberries in order to maximize production and minimize costs.

**Acknowledgements**

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Laura McDermott and Chuck Bornt are Cornell regional extension educators based in Eastern NY specializing in berry and vegetable crop production respectively.

![Figure 5. Effect of tillage system on strawberry yield on 3 farms in the second year.](image)

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