STRATEGIES TO IMPROVE GROWTH AND YIELD IN THE EARLY LIFE OF A TALL SPINDLE APPLE PLANTING

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ABSTRACT

The success of a new high-density apple planting depends on how fast the grower can recoup the high investment that these systems require. That is why it is imperative to get new plantings into production as early as possible and recoup the costs of establishment in the first five years. In order to achieve high early yields, the grower needs to find the right balance between vegetative growth and cropping during the early life of the planting where trees grow adequately to fill the allotted space at the same time produce good early crops. In this study we evaluated several management strategies to improve growth and yield, and to find the right balance between them. These results will improve understanding how to manage these intensive systems in the most profitable way.

In 2009, an orchard with five varieties (Crispin, ‘Gala’, ‘Honeycrisp’, ‘Jonagold’ and ‘Macoun’) on M.9 size rootstocks was planted at the New York State Agricultural Experiment Station, Geneva, NY. In this experiment we compared the use of calcium nitrate at the rate of (113 kg N/ha) applied through fertigation, broadcast with no irrigation and broadcast with irrigation. We evaluated the use of biostimulants and plastic mulch and compared the use of unbranched nursery trees (whips), with nursery trees having 5 and 10 feathers, with the lateral branches managed at a natural angle or positioned below horizontal.

Our results showed that fertigation and irrigation increased yield and tree growth compared to the unirrigated treatment. The use of biostimulants did not have any effect on tree growth or yield with the exception of ‘Honeycrisp’. Plastic mulch increased yield in ‘Honeycrisp’ and ‘Jonagold’ but there was no improvement in growth or yield with the other varieties. Bending the feathers below horizontal increased yield early in the life of the planting especially for more vigorous varieties with upright growth.

BIOGRAPHICAL SKETCH

Leonel Ivan Dominguez was born and raised on a family farm in Cd. Cuauhtemoc, Chihuahua, Mexico. He attended the Autonomous University of Chihuahua, in Chihuahua City, Mexico and earned his Bachelor’s degree in Agronomy from the Department of Horticulture. After graduation in 2006, he traveled to Washington state to gain some practical experience where he worked in orchards of apple, cherry and pear where new concepts of high density plantings and rootstocks got him more interested in fruit production. He also worked in a Research Laboratory as a technician and in his free time he picked fruit. In 2007 he traveled to Geneva, NY to work as a temporary field technician at Cornell University with Dr. Terence Robinson. After three months he accepted a permanent Research Support Specialist position with Dr. Robinson. In 2010 he was accepted in the Department of Horticulture to pursue a Master’s degree in pomology under the Cornell employee degree program. During these years of living in Geneva, Leo enjoyed the outdoors, especially hunting and fishing. In his free time he also loved riding bikes with his wife and 2 daughters both born in Geneva.

To my Wife and Daughters

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GENERAL INTRODUCTION-LITERATURE REVIEW AND HYPOTHESIS

Introduction

Plant growth is one of the most important factors affecting fruit production. For decades research has been focused in this area as one of the most important and relevant topics around the world. As a general rule, fruit trees need to develop a structure in the early life of the orchard (years one through five), to be able to intercept light and support upcoming crops. However, this rule does not apply in today's modern high-density plantings, where trees have to grow vegetatively to fill the allotted space in the first 2-3 years while at the same time beginning fruit production in the second year. Trees need to get into production as early as possible in order to recoup the establishment costs as quickly as possible (Robinson et al., 2007).

The most fundamental factor affecting plant growth is total light interception (Palmer and Jackson 1974; Palmer 1989). Although this relationship has been demonstrated for apple and for other temperate fruits it holds for essentially all crops (Monteith and Moss 1977). The productivity of a high-density apple orchard is a function of the light interception by the canopy and not the light that hits the orchard floor. Many reports have indicated that yield of apple plantings are correlated with light interception.

These reports have shown a linear relationship between light intercepted by the canopy and maximum attainable yields of apple. Jackson (1978) showed that yields increased linearly as light interception was increased up to about 60% of available light. Palmer and Jackson (1974) reported that production in a young high-density orchard increased linearly with increasing light interception between 20% and 60%. Studies done by Barritt (1988), Wagenmakers and Callesen (1988), reported that yield/ha was related to light interception. Wertheim et al. (1984) tested light interception in single rows and multi-row system, and they found that light interception by these systems was positively related to yield.

With low-density orchards of the past, fruit production was delayed until year 7-10. Trees were planted on non-precocious vigorous rootstock and pruned very hard in the first years to encourage tree growth and develop a strong tree architecture that eventually would partially fill the allotted space without any tree support. However, light interception and distribution were very poor due to the low planting densities and canopy shape. Wertheim et al. (1984) reported that light interception was linearly proportional to tree density, with light interception ranging from 57% to 81%. Robinson (2004) found that the cumulative yield in high-density trees was three times greater than at lower tree density. Canopy shape and size not only affected light interception but they also affected light distribution within the canopy, influencing leaf development and bud differentiation as well as fruit growth and quality. The shaded areas of the canopy have reduced fruit size, color, soluble solids and a general reduction in the capacity of the tree to sustain marketable yield.

These principles have guided the evolution of orchard design and training systems towards maximizing the amount of light intercepted and its distribution within the canopy. One of the first attempts of maximizing light interception was done by Wertheim (1970) in Holland. His high-density system was called the slender spindle and had significantly higher yields than the traditional systems. Tree density was 1500 trees/ha and tree height was limited to 2 m, to form a "pedestrian" orchard. However the relatively moderate density and tree height did not intercept more than 55% of total light (Robinson et al., 1991). The slender spindle system was the platform for development of many other systems. Lespinasse (1987) developed a system that used medium densities (1000-1500 trees/ha) but had a tree height of 3-4 m. This system was the first in introducing the renewal pruning concept to maintain a conic shape to increase light distribution in the lower part of the canopy.

Based on this premise, orchard systems have been evolving towards maximizing the amount of light intercepted and its distribution within the canopy. During the 1990 decade a proliferation of new apple production systems occurred around the world, including the V or Y system (Robinson 1992; Robinson 1998), the HYTECH (Barritt 1998), the super spindle (Nüberlin 1993), and the SolAxe (Lauri and Lespinasse 2000).

Late in the same decade a new apple system was developed by the amalgamation of several previous systems. It incorporates some of the aspects of the Slender Spindle, Vertical Axis, SolAxe and Super Spindle system, and it was called the Tall Spindle orchard system (Robinson 2006; Robinson et al., 2008) This system uses higher tree densities than the slender spindle (2,500-3,300 trees/ha) with highly preformed trees (i.e. branched trees) from the nursery (10-15 feathers). It requires pendant branch manipulation techniques like the SolAxe system to induce cropping and reduce vigor only for the first and second year of planting in cool climates. Minimal pruning is done for the first 3 years after planting while the tree is grown very fast to reach the desired height at 90-100% of row width. When mature it has a narrow canopy like the Super spindle system but trees are taller. Limb renewal pruning is utilized as branches get too large, as in the Vertical Axis system.

The Tall Spindle system is proving to be one of the best and most popular options that growers have for replanting orchards. However some growers have the problem of poor tree growth the first season which limits second and third year yields. This is in part because feathered trees have a large above ground canopy with not enough roots to support it, because many roots are damaged in the nursery and at planting. Additionally many new plantings are left without irrigation especially in Northeastern US climates, and this can result in a pronounced stress in some years where water supply is not consistent.

Hypothesis

The use of fertigation, biostimulant products, plastic mulch, or feather positioning below horizontal on highly feathered apple trees will have a positive effect on growth, yield and fruit quality in new Tall Spindle apple plantings.

Research Objectives

The objectives of this project were: (i) test different approaches and techniques that will result in a better understanding on the management of highly feathered trees in the Tall Spindle system; (ii) evaluate the use nitrogen and growth-stimulating products to improve growth in the early life of the Tall Spindle planting and clarify the relationship between growth and yield, (iii) assess the use of irrigation and fertigation to improve growth and yield of a new Tall Spindle, (iv) and disseminate the results to the whole apple industry.

Vegetative growth and yield affected by different factors

Initial tree Caliper

Tree caliper is one of the most commonly used standards that determine tree quality and price for commercial nurseries. Usually larger caliper trees are more expensive than small caliper trees. With the adoption of high-density systems the quality of nursery trees has become a priority among growers. Large caliper trees have been proven to have better tree establishment and growth than small whip trees, especially if irrigation is provided. Sadowski et al. (2007) showed in their experiment that the largest diameter trees (range from 13.1 to 25.4 cm) produced the most shoot length after planting.

The most important aspect of high tree quality in the early life of the planting is that it can positively influence early cropping in young fruit trees. Studies done by Van Oosten (1976) showed that large caliper trees produced higher yields than small caliper trees after three yearsin the orchard.

Usually small caliper trees do not crop significantly until year 4 or 5, which increases the carrying cost of an already high investment in a high-density orchard. This delays potential returns and negates the benefit of high tree density in profitability (Robinson et al., 2008) thus, the importance of starting an orchard with a large caliper, quality tree.

Number of feathers at planting

Planting feathered trees in high-density orchards is becoming a more common practice among growers. This is mainly because these trees have a big impact in early yields since the tree already has a bearing surface for upcoming crops. In contrast, whips need to develop this structure in the orchard to support a commercial crop. Sanders (1993) defined a feather as a lateral branch or shoot that is the same age of the leader (trunk). Whips are trees consisting of just the leader without any feather branches.

Feathered trees are now being produced in large scale by commercial nurseries. This is being made possible by the use of plant growth regulators that enhance the formation of lateral shoots when the tree is still in the nursery (Forshey 1982; Wertheim and Estabrooks 1994; Elfving and Visser 2005). As these nursery practices have been implemented, the number of feathers has been improved considerably. Therefore the number of feathers is being used as another criterion for determining the quality of the tree. Since there is more management involved by the nursery, well-feathered trees are more costly than whip trees.

The main advantage that growers have with the adoption of these highly feathered trees is the potential of high early yields compared to the whips. This statement is in agreement with the results obtained by Van Oosten (1976) where he found that the more feathers the tree has at planting the higher the early yields. Ferree and Rhodus (1987) tested 3 varieties with different growth habits: a vigorous variety ‘Lawspur’, a moderately vigorous variety ‘Smoothee’ and a low vigor spur variety ‘Redchief’. They demonstrated the benefits of planting well-feathered trees even with a non-precocious rootstock. They found an increase in yield during the third and fourth year especially for the vigorous varieties. They stated that there is an economic benefit for the grower in adopting feathered trees. More recently Robinson et al. (2004) demonstrated that the use of large caliper feathered trees was more profitable at medium-high densities 2600 trees/ha.

During the year of establishment the feathered tree produces more leaves and can potentially generate a greater leaf area than the whip tree. On the one hand this could be an advantage resulting in an increased production of assimilates that aid with the current season structural growth. Also this large leaf area could provide increased reserves for the following season where the first yield is expected. However, the large leaf area combined with a damaged root system at planting, often results in drought stress much more quickly than with whip trees.

Feather angle

It has been documented that bending of branches is a management practice to reduce vegetative growth in cherry and plum (Wareing and Nasr 1961) and increase flowering and fruiting of apple (Luckwill 1969). In apple Wareing and Nasr (1961) found that when shoots are in a horizontal position their growth is less as compared with the vertical shoots, but the uppermost shoots show a greater reduction when trained horizontally than do the lower ones. They also found that when the shoots are trained vertically the upper shoots showed a well-marked apical dominance. Lespinasse and Chol (1977) found that branch angles above 45 degrees resulted in vigorous growth and little flowering. Branches at 45 degrees produce less growth, heavy flowering, good fruit size and quality. But when the branches were bent below horizontal it resulted in almost no terminal growth with small spurs that gave small fruit size. In pears (Lawes et al., 1997), tested and compared leader bending with headed and unheaded leaders. He found that bending the leader increased the short shoot (spur) development, flower number and bloom density on 'Comice' pears.

Bending feathers at planting has become a necessary management practice for some high-density systems. It has been integrated into different training systems such as the slender spindle (Wertheim 1970), the SolAxe (Lauri and Lespinasse 2000) and more recently the tall spindle (Robinson et al., 2008). This technique has been implemented as an alternative to pruning to induce early flowering and to maintain the tree within its allowed space. This is especially true for the tall spindle system in which branch manipulation is done right after planting, due the relatively high tree density in this system.

Some other studies on branch manipulation have been contradictory; depending on the study it either increased (Tromp 1970) or did not have a consistent effect (Longman et al., 1965) on flower bud formation. Some of these contradictory results could simply be due to the growth and fruiting characteristics of the varieties tested. Lauri and Lespinasse (2001) tested different bending times with 2 varieties. One was a breeding selection X.3318, which was characterized with upright growth and the production of water sprouts when branches were bent, the other was

'Chantecler' which was characterized by wider branch angles. They concluded that fruiting is highly affected by the genotype. With X.3318 the no-bending treatment had more fruit than any of the bending treatments. The time of bending could also influence the type of buds during the year of bending, and the following years. This could be the reason for such variability in previous work on this topic. With more information about differences among varieties the recommendation of bending branches with the tall spindle system could be adapted to the specific growth and fruiting habits of each variety.

Water supply

Water is the most essential and limiting factor affecting plant growth and development. It is involved in all the metabolic processes that take place in the plant. Consequently, drought stress is a situation that fruit trees have to deal with all too frequently. Water deficit early in the season can be detrimental not only to tree growth but also to yield and fruit quality. With the adoption of high density systems water management became a critical factor for the success of the planting. In new plantings the most common cause of death of transplanted trees is desiccation. More commonly newly planted trees exhibit very poor growth due water stress. Highly feathered trees with damaged roots often undergo water stress when transplanted, because the water uptake is insufficient to keep up with the water losses through transpiration of the large canopy (Pereira and Pires 2011). If dry weather occurs shortly after planting this could have a long term negative effect on the trees.

After planting and during the first year of growth, the focus should be on establishment of the root system and on improved growth of the aerial tree parts. Growth is driven by photosynthesis, which is the primary process for carbohydrate production. Photosynthesis is affected adversely by drought (Davies and Lakso 1978). Minimizing water stress to maximize canopy growth positively influences the amount of photosynthates produced due the increase in light interception by the cumulative leaf surface.

Early in the season the growth of young leaves depends on cell division followed by cell expansion. The latter process increases leaf surface area and results from cell wall loosening induced by plant hormones and driven by the influx of water. To increase growth, maximum turgor must be maintained above the point at which the cell wall extension becomes the limiting factor and not water deficit (Taylor and Davies 1984). Boyer (1968) demonstrated the correlation between turgor and growth, with sunflower plants. He showed that when soil moisture is high during the night, water potential returns to the high level of growth limited only by the cell wall extension; however when the soil becomes drier the water influx is less and turgor does not rise to the minimum turgor required for leaf expansion, hence growth stops.

Lack of water in established orchards in the first few weeks after bloom could have a negative effect on shoot growth as well as affecting fruit development. Consequently drought stress early in the season could result fewer cells in the fruit and reduced final fruit size. This statement is especially true for small fruited varieties such as ‘Gala’, ‘Macoun’ and ‘Jazz’.

Irrigation has been used for centuries in drier environments where rainfall is inadequate to supply the crop needs for growth and productivity. In the US the development of irrigation started in the 1900’s as population increased and there was need for more production in arid regions (Howell 2001). However in humid regions of the US the use of irrigation is not yet been widely implemented. The main reason some fruit growers give for not using irrigation in NY is they do not see the economic benefits it will bring to their operations. However, even in humid climates periods of drought can occur frequently in some years, affecting not only growth of young tress but also fruit production and quality in established orchards. In the past when orchards used non precocious rootstocks with bigger and deeper root systems and with less competition from adjacent trees, irrigation in humid climates was not essential since these types of plantings could reach their full potential without irrigation. In modern plantings which use dwarfing precocious rootstocks that have generally lower root density and more competition from adjacent trees, irrigation becomes quite important if a grower wants to maximize growth in the first years of the plantings.

To reach the maximum potential growth and yield in a high-density apple orchard three questions must be answered regarding irrigation: How much water to apply, when to apply, and how to apply it. A good manager should use quantitative measures to answer these questions in a precise manner. Optimum irrigation frequency changes and varies with crop type, canopy size and stage of growth of the plant; for example the water requirements for a whip tree are much less than those required for a well-fathered tree.

Soil type and climatic conditions are also important. These can be used to estimate the crop evapotranspiration or water demand, and determine the water application frequency and volume. Optimizing the amount of water in the root zone not only satisfies the crop demand but also increases mineral movement, especially for non-mobile elements such as phosphorus.

There have been several irrigation systems developed over the years. Surface or flood irrigation is the oldest method of applying water to the land. However it is a system with many drawbacks. It requires good land leveling for water flow and in coarse textured soils it is inefficient due to rapid percolation of the water through the root zone. In fine textured soils excessive retention of water can lead to problems of waterlogging and fungal diseases like Phytopthora. Over the years flood irrigation has been replaced with more efficient systems such micro sprinkler and trickle or drip irrigation.

Micro sprinklers are small emitters that deliver 5 to 25 gallons per hour (Parsons et al., 1993). Water is distributed to a large portion of the root zone, consequently large root densities are established, which enhances better tree anchorage and increases nutrient uptake. However micro sprinklers can cause nutrient leaching in coarsed texture soil, especially for mobile nutrients. Also in semiarid conditions sprinkler water losses due to wind and high temperatures are higher than with drip systems. In a desert climate Rumayor-Rodriguez and Bravo-Lozano (1991) compared the use of three different irrigation systems (drip, micro sprinklers and flood irrigation), and reported an increase in total yield and yield efficiency with the largest fruit weights in micro sprinkler systems. The authors concluded that this was due to the uniformity of wetting compared to the drip system, since the drip is dependent on the progressive wetting affected by the soil properties. However the distribution of water with micro sprinklers is aerial as a spray and soil properties do not interfere with the water pattern distribution. In almond

Koumanov et al. (1997) concluded that soil water uniformity was high with the use of the micro sprinklers with an application efficiency of 73 -79%. However they noted that the system should be operated during evening and night hours due to high temperature and winds during days.

In the early 1960s the first commercial drip irrigation system was introduced in Israel. The use of trickle or drip irrigation has created interest among growers due its more precise delivery of water to the trees and the lower water volumes required. Small but frequent applications of water can maintain good moisture conditions for long periods of time, which is beneficial for tree growth compared to the fluctuations of moisture with flood irrigation. One of the limitations of drip systems is that on coarse textured soils the lateral movement of water under the drip line is limited, so this type of soil may need two lines per row, one in each side of the tree. In dry climates with little rainfall the use of drip irrigation creates a dense root system directly under the emitter since there is little soil moisture in other parts of the soil. This is not the case in humid climates where rainfall maintains roots in all regions of the soil.

This system is widely used in vegetable production. Yield improvements in tomato by different studies have been different in different agro-climatic and soil conditions (Shrivastava, Parikh et al. 1994). Drip irrigation is also used worldwide in orchards (Bravdo and Proebsting 1993) especially in regions where water supply is limited. With the transition from conventional low-density orchards to high-density systems, the use of trickle is gaining acceptance among growers even in the humid climates, mainly because it allows more precise management of water and fertilizer applications than other systems.

Fertigation is the term used for the application of soluble fertilizers in the irrigation water. Micro sprinkler systems can be used for this purpose but under some conditions and types of soils it can cause nutrient leaching; hence drip fertigation is the most common method of fertigation. One of the advantages of fertigation is the potential for more close synchronization of nutrient application with plant demand (Haynes 1985). The nutrients are delivered directly to the root system, therefore the uptake of minerals is more efficient and nutrient leaching and runoff are limited.

The use of fertigation in the humid eastern part of the US has not been fully adopted. This is due partly to previous studies done in NY that showed no improvement in growth or yield from fertigation, compared to drip irrigation with ground-applied fertilizers (Robinson and Stiles 1994). Their trial compared ground-applied fertilizers without irrigation to ground applied fertilizers plus irrigation with fertigation, using Oregon-Spur Delicious, Mutsu and Empire apple varieties. However average fruit size in this study was improved with the use of fertigation. In contrast (Bubán and Lakatos 2000) found that fertigation improved yield compared to the standard drip irrigation, but irrigation was very similar in terms of growth to the fertigated trees. In semiarid climates there is considerable literature that compares the use of fertigation with broadcast application. Studies done in those conditions have focused on the advantages of nutrient movement and retention in the roots by the use of fertigation on sandy loam soils, especially for N, P and K (Neilsen et al., 1999). This allows increased flexibility in the applications of the nutrients in response to plant demands and climatic conditions.

Fertilization and fruit quality

Mineral nutrients are essential for plant growth and development. They are the building blocks of the plant structure and metabolic processes. Mineral nutrition is directly related to growth and partitioning of resources to harvestable plant organs (yield). Total biomass production is dependent on the photosynthetic activity of the leaves but also nutrients are required for growth and yield and are an important component of the photosynthetic process.

The success of a new high-density planting depends upon high fruit production of high quality fruit. In this context, nutrient management should be considered as one of the most important management practice, since it has a direct effect on tree growth, yield and fruit quality. Therefore nutrient management should be integrated with the other components of the orchard system puzzle (Barritt 1992). The primary objective of a nutrition program is to favor the development of healthy trees that can support high yields. Deficiencies or excess of any element can negatively affect tree performance in one season or throughout the life of the planting (Stiles 1991). Effective nutrient management requires a good understanding of the tree demands, both the amount and the timing. Cheng and Raba (2009) showed clearly that changes in concentration of nutrients cannot be used to deduce changes in the total amount of nutrients, when total biomass is changing.

Therefore proper nutrient management is essential for the orchards to grow and fill their allotted space for the upcoming years of production. However too much growth can lead to a dense canopy requiring excessive pruning, which results in reduced yield and fruit quality—especially fruit color. On the other hand, too little growth can lead to trees not filling their allotted space. In NY State this is a major problem in high density orchards on precocious dwarfing rootstocks. In some cases the trees become stunted and never fill their allotted space due to poor nutrient management, inappropriate crop load management, and not choosing the right rootstock especially for weak varieties. Either too little or too much mineral nutrition is detrimental to the success of these plantings; hence growers should see the right balance between vegetative growth and cropping, through more precise use of nutrients.

Nitrogen is one of the most important elements affecting growth and yield of plants. This element is a constituent of amino acids, proteins, enzymes and nucleic acids—the building blocks of plant growth. Nitrogen is a highly mobile element in the plant and in the soil, which in some cases results in leaching into ground water due inappropriate water management especially with coarse soils. This causes economic losses for the farmer and can also contribute to pollution of the water table.

There are three different sources of nitrogen supply for growth. The first is nitrogen and carbohydrates (starch and soluble sugars) reserves that the tree accumulated the previous season. With a newly planted tree this represents the reserves that came from the nursery. These two sources of reserves are essential for initial tree growth in spring before any photosynthesis and nitrogen uptake occur. Both are interrelated because carbon assimilation depends on N metabolism, and N assimilation requires carbohydrate input for the carbon skeleton and energy supply. However the initial growth of apple trees is primarily related to reserve nitrogen (Cheng and Fuchigami 2002). Therefore nitrogen reserves before plantings are critical for growth of newly planted trees because root uptake is delayed due to the damaged root system, the lack of absorptive roots, and low soil temperatures in spring (Cheng, et al., 2001).

The second source of nitrogen is that supplied by the soil through the mineralization process principally through the breakdown of organic matter. In NY some soils with high organic matter content have the capacity of supplying from 60 to 80 pounds of nitrogen per acre with out any additional nitrogen applications (Stiles 1991) especially soils in groups I, II, III. Cheng and Schupp (2004) suggested that a soil with 3 percent organic matter, can release about 50 to 70 pounds of nitrogen by mineralization processes, however only about 40% of that N can be used by the tree. Lastly, the third source is the nitrogen is that supplied by the applications of fertilizers either to the soil or to the tree foliage.

Efficient nitrogen fertilization programs should take into consideration these three pools of nitrogen. Accounting for the first two sources of nitrogen should be integrated with the demands of the crop in terms of amount and timing. This should allow more accurate and precise nitrogen applications and avoid the negative effects of poor N management.

Tree demand for N is high early in the season when canopy development and rapid leaf growth occur in 1st year nonbearing trees. However, in the succeeding cropping years, N is not only required for the canopy and vegetative growth but is also essential for ensuring fruit growth especially with small fruited varieties. However as the season progresses N supply should be lowered due potential negative effects on fruit quality, and to ensure adequate tree hardiness in cold climates. Cheng and Schupp (2004) applied the same amount of N to Empire/M.9 trees at three different timings: budbreak, active shoot growth and preharvest. They found that early application of N at budbreak resulted in significant uptake between budbreak and the end of spur leaf growth, but N levels in the fruit were low, suggesting no negative effects on fruit quality. Nitrogen content in the fruit was the highest when N was applied during active shoot growth. The preharvest timing did not increase N content in the fruit nor in the vegetative tissue, but this late application did contribute positively to N reserves for the following year.

Fruit quality involves a combination of external and internal characteristics. In general it represents an integration of visual appearance like color and size, with texture, flavor and the capacity to be stored for long periods of time. Color and size are used by the United States Department of Agriculture to define apple fruit quality into fruit grades and depending in these two characteristics the apples are graded as follow: U.S. Extra Fancy; U.S. Fancy; U.S. No 1 and U.S. Utility. However, the concept of quality for consumers is not simple, and it varies according to personal preference, being affected not only by exterior characteristics but also by unique attributes such as crunchiness and flavor characteristics that are distinctive to every variety.

The major nutrients affecting fruit quality are N, K, P and Ca (Neilsen and Neilsen 2009). High rates of N fertilization have been associated with reduced fruit color and firmness and increased development of storage disorders such bitter pit, soggy breakdown and core breakdown in apples (Bramlage 1993). Nevertheless N fertilization is needed to increase fruit size of apples. Therefore, N management requires a more precise way to deliver the element to the tree so that the negative effects of this element are minimized.

Calcium (Ca) is the nutrient that has been most oftenrelated to fruit quality, especially after storage. High N in the tree and excessive amounts of pruning affect Ca content in the fruit indirectly, since there is more shoot growth competing for the available Ca, in other words the N:Ca ratio becomes too high, which may lead to storage disorders affecting fruit quality. Fallahi et al. (1997) found more Ca in leaves than in the fruit. Part of the reason is that Ca moves with the transpiration stream, and fruits transpire much less than leaves. Shoots are stronger sinks for Ca than fruits, due the fact that Ca is required for wood lignification.

To increase fruit Ca levels, 4 to 6 foliar applications of $CaCl_2$ at 10 to 14 days apart are being recommended to growers. Some advisors believe that the earlier applications are the ones that increase Ca content in the fruit. However results by (Neilsen et al., 2005) suggest that Ca concentration in the fruit is increased most by the late sprays, although these do not decrease the incidence of bitter pit.

Potassium (K) is the mineral element with the highest concentration in the fruit , comprising more than two thirds of the total tree requirements (Cheng and Raba 2009). In new plantings where high applications of nitrogen and phosphorus fertilizers are done to increase canopy size and root development, K deficiencies arise especially in orchards with dwarf rootstocks under fertigation through trickle. The root density of a young tree is very small in these types of systems and zones of depletion can form. Therefore, to achieve high yields, large amount of K are needed. However K may compete with magnesium and Ca uptake and low Ca results in increased incidence of storage disorders.

Lastly, weather, site and varietal genetics are also important factors that affect nutrient uptake and fruit quality. Results of nutritional studies in relation to fruit quality tend to vary from year to year indicating that efficient nutrient management should be adjusted according to the conditions of every growing season.

Crop Load

Crop load, is defined as the amount (number or weight) of fruit produced per tree or branch unit. Crop load is another very important factor that has a direct effect on fruit quality, yield and indirect effects on tree growth.

In the tall spindle system high yields are expected starting in the second year after planting. For varieties such as ‘Honeycrisp’ this can result in biennial bearing. Equally important is the effect of crop load on tree growth. If crop load is too high it will result in very poor growth and stunted trees in the high crop year. Because of these issues some growers question the value of second year crop production (Robinson 2008). However to increase the profitability of any high density system, second year production is essential to repay some of the production costs and increase profitability over time. There is always a cost in growth from cropping the trees in the second year, but this reduction in growth can be minimized with proper irrigation, nutrient management and crop load management. If the crop load is precisely controlled, trees can be allowed to fruit in the second year without harming tree growth that is essential for achieving high yields in the upcoming years.

High crop loads can have a negative effect in total shoot growth, and a very similar effect on total tree leaf area. However, (Palmer 1992) found very small differences in leaf area per tree among the different crop load treatments imposed. Wunsche and Lakso (2000) found that heavy cropping on ‘Braeburn’ apple resulted in trees that had much less leaf area than deblossomed trees, which resulted in increased light interception with the deblossomed trees. These results showed that when crop load is low, vegetative growth (leaves and shoots) are an alternative sink for photosynthates. This illustrates the importance of achieving the right balance between growth and fruiting in the first five years after planting, with the aim of increasing profitability over the life of the planting.

Thinning is the cultural practiced most used to reduce crop load to the optimum level for maximized returns. Every variety has its own optimum level of crop load, based on the market and the characteristics of the variety. Therefore a balance between quantity and quality must be achieved (Link 2000). However thinning is a risky task for many growers bcause chemical concentration, timing and environmental factors are involved in its efficacy. Lakso and Johnson (1989) developed a simplified model to estimate apple dry matter production. This model uses sunlight and temperature to predict carbohydrate supply and demand. Lakso and Robinson (2007) used this model to estimate carbohydrate availability to support fruit growth and predict chemical thinning responses based on weather conditions.

A different model developed by Greene et al. (2005) called the fruitlet growth model, has been used to assess chemical thinner response after the application by measuring the growth rate of the fruit. In this model fruit that are growing less than 50% as rapidly of the fastest growing fruit are categorized as likely to drop. Lately these two models have been integrated into a precision thinning program to manage crop load more precisely with the aim to reduce variability.

Although crop load is the most important factor affecting fruit size, irrigation also has an important effect. Mpelasoka et al. (2001) tested the use of deficit irrigation with commercial crop loads, and a low crop load equivalent to 60% of the commercial load. They found that the proportion of small fruit tended to be higher in deficit irrigation with a commercial crop load, whereas larger fruit size was achieved with normal irrigation (control) and low crop load. This highlights that these two factors are both important in determining fruit size (Naor et al., 2008).

The negative relationship between fruit weight and crop load is related to fruit-to-fruit competition (Palmer et al., 1997). The increase in fruit weight under low crop loads is associated with the higher availability of carbohydrates (Wünsche and Ferguson 2005). Very high crop loads can also negatively affect fruit color, especially with bicolor varieties such as 'Jonagold' where fruits from low-cropping trees had more blush, increased firmness and a high percentage of soluble solids (Stopar et al., 2002).

Biostimulant Products

This group of materials is loosely defined as non-fertilizer products purported to have a beneficial effect on plant growth or development. They are also called by other names including biofertilizers, phytostimulators and biostimulators. These products contain biologically active substances, i.e. plant hormones, enzymes vitamins, macro and microelements and other compounds that may stimulate growth and increase yield of plants but are harmless to humans or the environment (Glinicki et al., 2010).

These biostiumant products have been used primarily in vegetable and field crop production. However they are gaining acceptance and popularity among apple growers, because of the potential enhancement of growth, yield and/or fruit quality. The biostiumalatory potential of many of these products has not been fully determined, due lack of scientific data proving their efficacy in plant growth. Nevertheless biostimulant products have been used in organic apple production to supplement mineral nutrition (Delate et al., 2008). Bradshaw et al. (2012) tested the use of two different products in organic production. They concluded that the application of these products had little effect on tree growth, mineral nutrition, and yield or fruit quality compared to the non-treated control.

The use of biostimulant products remains controversial in commercial apple production in terms of tree growth performance and yield increase. Depending on the experiment, improvements in tree growth, yield, return bloom or fruit quality were observed (Bertschinger et al., 1996, Thalheimer and Paoli 2001), or no positive responses were observed (Sahain et al., 2007). Spinelli et al., (2009) tested a seaweed extract to moderate the negative effects of alternate bearing. They found that the use of this biostimulant had no effect on production in the "on" year, but in the "off" year yield was substantially greater than the control.

For most of previous studies using standard management practices and good growing conditions, the application of biostiumants has not improved tree growth or yield, and did not provide any commercial benefits. However under more stressful conditions biostimulants may improve overall apple tree performance.

Mulch Materials

A variety of inorganic (plastics), and organic materials (compost, paper, hay) can be used as mulches in high density apple production (Neilsen et al., 2003). Mulches are being adopted by some growers, due the benefits to fruit production and soil health, especially with organic production, where the use of chemicals to control weeds is prohibited. Most of the organic mulches offer some degree of weed control, provide more efficient use of water and enhance soil conservation. However some materials containing a high C/N ratio, such as sawdust, can result in N immobilization, which can lead to a reduction in tree growth. On the other hand materials with large amount of N such as composted animal manure result in high rates of N mineralization (Forge et al., 2003).

Plastic mulch has been used extensively in vegetable production since 1960 (Lamont 2005). It allows early harvest, higher yields and better quality, more efficient use of water and nutrients through fertigation, weed suppression and increases in soil temperature. For these reasons, there have been attempts using plastic mulches in apple production.

Merwin et al. (1995) compared the costs and benefits of organic and inorganic mulches to conventional herbicide strip at two different locations. They found in the first cropping year that trees produced 50% more fruit with a wood-chip mulch than the other treatments. However there were no differences in cumulative tree size or yield attributed to the ground cover management system. They concluded that for some varieties with high price and good fruit quality, the use of mulch can be justified. Måge (1982) found that the use of black plastic mulch resulted in the most vegetative growth, and had the highest yield compared to herbicides or a grass sod. Similar results were obtained by Neilsen et al. (1986) where yield under the black plastic was higher than full ground cover.

The use of plastic mulch could potentially increase growth in northeastern US climates, where the soil in the spring is wet and cold. However to implement this technology on a large scale require more specialized machinery that would add cost to the already expensive mulch material (Merwin et al., 1995). For these reasons plastic mulches have not been adopted on a large-scale in orchards. Nevertheless the use of some organic mulches has become common with small-scale growers, a few large-scale growers and organic growers.

MATERIALS AND METHODS

This study was carried out at the New York State Agricultural Experiment Station (NYSAES) in Geneva, NY, USA (42N, 77W). The orchard was planted in 2009 and the experiment was carried through 2013. The soil was a Honeoye fine sandy loam (He), with good water holding capacity, well drained and fertile with about 3% organic matter content and a 6% slope.

Plant Material

Five apple varieties were used in this experiment: ‘Crispin’ on M.9T337 rootstock, ‘Brookfield Gala’ on M.9Pajam2, ‘Rubinstar Jonagold’ on B.9, ‘Honeycrisp’ on M.9Nic29, and ‘Macoun’ on B.9. The trees were planted on April 18, 2009, at a spacing of 1m within the rows and 3.5 m between rows, giving 2857 trees/ha, and were trained as tall spindles. The orchard received standard disease, insect and weed control throughout the 5 growing seasons.

Experimental Design

The experiment was designed as a strip-split-plot, randomized complete block with the main plot treatment being variety (‘Crispin’, ‘Gala’, ‘Honeycrisp’, ‘Jonagold’ and ‘Macoun’) and the subplot treatment being 13 management treatments. There were 4 subplot replications within each variety and each subplot was composed of 2 individual trees. Varieties were laid out as strip treatments to facilitate orchard management, especially thinning. The 13 management treatments were randomized within each variety. The experimental orchard was organized in 5 rows of 97 trees each (one row per variety) with rows oriented North-South. Blocking of subplot treatments within each variety was based on initial trunk diameter measured with a digital caliper.

Management Treatments

The 4 related management experiments were: First, a comparison of irrigation, fertigation and no irrigation, each with the same amount for N fertilizer. Calcium nitrate was used as the fertilizer at a rate of (113 kg N/ha). With the fertigation treatment the fertilizer was dissolved in water and then applied through the drip line on a weekly basis. The total annual amount of N was divided into 10 equal amounts applied weekly (13 kg of N/ per week every week) starting after bud break each spring. For the irrigation treatment $CaNO_3$ was manually applied to the soil surface in a donut shaped band around each tree. The total annual amount of N was divided into two equal halves and applied at green tip and late June. Irrigation water was then applied weekly at the same times as the fertigation water. Additional water if needed was applied mid-week without disolved fertilizer. The amount of irrigation water applied every week was dependent on weather conditions. Daily temperature, solar radiation, amount of rain and wind speed were measured and incoroporated in an apple-specific ET irrigation model (Dragoni and Lakso, 2011) that estimated the amount of irrigation water in any giving week (irrigation data not published, mean monthly weather data presented in the appendix).

In the non-irrigated treatment, $CaNO_3$ was manually applied to the soil in a similar manner and at the same timings as the irrigation treatment but with no irrigation. A guard tree of the same variety separated plots of each irrigation treatment to avoid cross treatment contamination.

The second experiment compared the number of feathers (lateral branches) on the tree at planting. Different numbers of branches were achieved by starting with similar diameter branched trees which all had 10+ feathers and then reducing the number of feathers down to 0, 5 or 10 feathers. The branches to be eliminated were preferentially the ones that were lower than 60 cm of height, and any feather with excessive vigor (more than ½ the diameter of the trunk) or with a very narrow crotch angle. In the case of trees with 5 or 10 feathers, two branch management techniques were compared. Branches were either left at their natural angle or were bent down below the horizontal to about 135° from vertical. In the case of the trees with 0 feathers, the lateral branches that grew later in the first season were not bent down.

The third experiment compared the use of biostimulant sprays to unsprayed trees. Each spray contained a tank mix of four bio-stimulating products used at the label rate: Stimplex (24oz/100gal), Nutriphite (16oz/100gal), Vitazyme (16oz/100gal) and SystemCal (32oz/100gal).

Trees were sprayed 5 times each year every 2 weeks starting on June 1st. At each spray timing, trees were sprayed evenly until drip using a 30-gal hydraulic sprayer.

The fourth experiment compared black plastic mulch on the soil to no soil mulch. Plastic mulch was installed 1 week after planting and covered the herbicide strip (1.5m). Regular weed sprays were done in the no mulch treatment.The mulch remained in place for the whole experiment.

Measurements

Growth

Shoot growth was recorded in November each year for the first 4 years at the end of the season. The length of every shoot on the tree including the axis was measured. This procedure was done in 2009, 2010, and 2011. However in 2012 the methodology was different. The leader and 30 randomly chosen shoots were measured and the total number of shoots was counted on the whole tree. The number of shoots on the tree was multiplied by the average length of the 30 randomly chosen shoots to estimate total shoot length on the tree. During the first two seasons floral spurs were also counted. Trunk circumference was measured at planting and in November of each year at 30 cm above the graft union and used to calculate trunk cross sectional area (TCA). In the spring of each year before bud-break the weight of the prunings was also recorded per individual tree.

Yield

During the first year trees were not allowed to crop. But from the second growing season the trees were allowed to crop and harvest data were collected. At each harvest, fruits were counted and weighed. A sample of 35 fruits was collected from the fertilization treatments only and stored in refrigerated storage for 4 to 5 months with a temperature of 2°C and a relative humidity of 75%. After cold storage the samples were evaluated for fruit size and color using a commercial electronic MAF RODA Pomone fruit grader with a camera system for evaluating red color and load cells for evaluating fruit weight. A random 10-apple subsample was also tested for soluble solids concentration (percent) using a portable refractometer, fruit firmness was measured from two peeled sides at the equator of each fruit using a fruit penetrometer (Pressure Tester, Model EPT-1. Lake city Technical products Inc., Kelowna B.C. Canada).Storage disorders such Bitter Pit, Soft Scald, Water Core and Senescent Breakdown were assessed.

Leaf Nutrient Levels

In August of the first 2 years, a 50-leaf sample was collected from mid-position leaves on extension shoots of the 3 trees in each fertilization subplot. Leaves were dried, ground and analyzed for macro and micronutrients at a commercial lab (A&L Great Lakes Laboratory, Fort Wayne, Indiana) using combustion and inductive coupling plasma-spectrometry (ICP).

Statistical Analysis

The final analysis used a separate analysis for each of the management experiments using analysis of variance with a split plot design where variety was the main plot and management treatment (fertilization, branch angle, branch number, biostimulant or mulch treatment) was the sub plot factor and sub-subplots were the 2 individual trees in each sub plot. Mean separation was done by Duncan's multiple range test with $P \leq 0.05$ and the appropriate error term for variety or management treatment and the interaction of variety and management treatment. In the case of the experiment on the number of feathers per tree, regression analysis was used to determine the effect of feather number.

RESULTS

Effect of Fertigation, Irrigation and Unirrigated Treatments

Vegetative Growth

During the first year (2009), the fertigation treatment increased trunk cross-sectional area (TCA) and tree height the most, followed by the irrigation treatment and lastly by the unirrigated treatment (Table 1). Fertigation and irrigation increased leader length, total shoot length, average shoot length, pruning weight and total tree length similarly and significantly more than the unirrigated control. There was a significant interaction in total shoot length in which fertigation and irrigation with 'Crispin', 'Gala', 'Honeycrisp' and 'Macoun' gave similar but significantly higher total shoot length than the unirrigated control. However, with 'Jonagold' fertigation gave greater total shoot length than the irrigation treatment and in turn the irrigation treatment increased total shoot length significantly more than the control. Pruning weight also showed a significant interaction, with 'Crispin' where fertigation resulted in increased pruning weight compared to the irrigation treatment, which in turn had significantly greater pruning weight than the control. With 'Gala', fertigation and irrigation had similar pruning weights but significantly greater than the control. In the case of 'Jonagold', the irrigation treatment had significantly greater pruning weight than fertigation and the unirrigated control, which were similar. 'Honeycrisp' and 'Macoun' did not show any differences in pruning weight between the treatments.

In the second year of growth (2010), the fertigation and irrigation treatments increased trunk cross sectional area (TCA), total shoot length, spur number per tree, pruning weight, number of spurs and number of limbs pruned per tree and total tree length similarly and significantly compared to the unirrigated treatment (Table 2). Fertigation increased average shoot length, while the irrigation treatment was not significantly different than the control.

Table 1. Effect of irrigation and fertigation on tree growth of five apple varieties during the first year (2009) at Geneva, NY.

Variety	Irrigation Treatment	TCA (cm^2)	TCA Increase (cm^2)	Tree Height (cm)	Leader Length (cm)	Total Shoot Length (cm)	Av Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Total Tree Length (cm)
Main Effect Means										
Crispin	.	4.6 a[z]	2.4 a	192 b	33.4 b	249 c	20.6 b	15.7 c	11.6 b	595 c
Gala	.	4.3 b	2.3 ab	210 a	39.3 a	471 a	21.3 b	25.1 b	17.6 a	964 a
Honeycrisp	.	3.8 c	2.1 bc	196 b	37.5 ab	256 bc	13.7 c	43.0 a	0.8 c	608 c
Jonagold	.	4.1 bc	2.5 a	180 c	40.0 a	287 b	24.2 a	17.8 c	9.1 b	672 b
Macoun	.	3.6 d	1.8 c	165 d	41.6 a	205 d	21.0 b	18.3 c	1.7 c	415 d
Variety Significance		**	**	**	**	**	**	**	**	**
.	Unirrigated	3.5 c	1.6 c	182 c	32.0 b	198 b	15.1 b	25.1 a	3.0 b	559 b
.	Irrigated	4.2 b	2.4 b	190 b	40.7 a	329 a	22.2 a	23.4 a	10.9 a	683 a
.	Fertigated	4.5 a	2.6 a	194 a	42.4 a	355 a	23.1 a	23.6 a	10.6 a	703 a
Treatment Significance		**	**	**	**	**	**	NS	**	**
Interaction Means										
Crispin	Unirrigated	3.9	1.7	187	29.1	149 fg	14.2	16.1	2.4 d	504
	Irrigated	4.7	2.5	190	33.9	275 cd	21.8	15.7	11.8 bc	626
	Fertigated	5.0	2.9	198	37.1	318 bc	25.4	15.3	20.3 a	654
Gala	Unirrigated	3.6	1.6	202	31.2	310 bc	16.8	29.8	6.0 cd	801
	Irrigated	4.5	2.5	211	41.6	549 a	23.9	21.8	23.2 a	1038
	Fertigated	4.8	2.8	215	45.4	557 a	23.5	23.7	24.0 a	1068
Honeycrisp	Unirrigated	3.2	1.4	191	34.0	190 efg	11.4	44.3	0.0 d	539
	Irrigated	4.2	2.4	198	38.8	291 cd	15.1	42.3	0.0 d	645
	Fertigated	4.2	2.3	197	39.9	288 cd	14.7	42.4	2.5 d	641
Jonagold	Unirrigated	3.6	2.0	173	33.5	203 ef	18.5	16.3	4.3 cd	593
	Irrigated	4.1	2.5	180	43.0	295 cd	25.9	18.5	18.3 ab	674
	Fertigated	4.6	3.0	186	43.6	363 b	28.1	18.6	4.9 cd	749
Macoun	Unirrigated	3.2	1.4	155	32.1	131 g	14.6	18.5	2.5 d	348
	Irrigated	3.7	2.0	170	46.6	242 de	24.4	18.5	1.6 d	445
	Fertigated	3.8	2.1	170	46.2	240 de	23.9	17.7	1.1 d	448
Interaction Significance		NS	NS	NS	NS	*	NS	NS	**	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicates treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

Table 2. Effect of irrigation and fertigation on tree growth of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Irrigation Treatment	TCA (cm2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means										
Crispin	.	8.8 b[z]	42.3 b	659 cd	23.7 b	37.1 b	101.4 b	7.4 b	0.58 ab	908 cd
Gala	.	10.5 a	57.2 a	1423 a	31.4 a	62.8 a	305.2 a	12.2 a	0.64 ab	1894 a
Honeycrisp	.	7.9 c	29.1 c	1089 b	20.7 b	45.7 b	92.5 b	8.1 b	0.42 b	1345 b
Jonagold	.	7.9 c	46.4 b	791 c	30.5 a	37.0 b	141.2 b	6.9 b	0.53 b	1080 c
Macoun	.	7.8 c	47.6 b	555 d	29.9 a	43.4 b	99.9 b	8.9 b	0.79 a	759 d
Variety Significance		**	**	**	NS	**	*	*	NS	**
.	Unirrigated	7.7 b	44.0 a	810 b	26.7 b	38.9 b	123.3 b	6.4 b	0.46 b	1008 b
.	Irrigated	9.1 a	46.1 a	952 a	27.9 ab	50.0 a	160.7 a	9.3 a	0.66 a	1306 a
.	Fertigated	8.9 a	43.2 a	956 a	27.1 a	46.6 a	160.3 a	10.3 a	0.63 a	1285 a
Treatment Significance		**	NS	**	NS	**	*	**	*	**
Interaction Means										
Crispin	Unirrigated	7.9	37.6	566 fg	21.2 f	29.9	56.8	4.5	0.32	715 f
	Irrigated	9.0	41.9	706 def	24.2 de	35.9	125.3	8.6	0.70	981 cde
	Fertigated	9.5	47.1	702 def	25.5 d	45.0	119.8	8.8	0.70	1020 cd
Gala	Unirrigated	9.4	59.0	1235 b	32.3 a	56.9	286.8	8.8	0.60	1545 b
	Irrigated	10.8	53.2	1509 a	29.5 bc	67.7	315.3	14.7	0.63	2058 a
	Fertigated	11.3	59.1	1530 a	32.3 a	64.0	314.0	13.4	0.70	2087 a
Honeycrisp	Unirrigated	7.0	27.1	870 c	19.6 f	40.7	63.0	6.3	0.25	1060 c
	Irrigated	8.3	30.1	1228 b	21.3 ef	47.4	112.3	10.1	0.45	1519 b
	Fertigated	8.4	30.2	1169 b	21.2 f	49.1	102.3	8.0	0.55	1457 b
Jonagold	Unirrigated	7.6	49.6	839 cd	31.4 ab	32.2	141.0	6.4	0.50	1045 cd
	Irrigated	7.8	43.1	745 cde	30 abc	35.3	112.8	7.6	0.50	1040 cd
	Fertigated	8.3	46.6	790 cd	30.3 abc	43.4	169.8	6.7	0.58	1153 c
Macoun	Unirrigated	6.8	46.6	515 g	28.7 c	34.3	62.6	6.1	0.67	646 f
	Irrigated	8.6	48.5	603 efg	30.9 abc	47.7	142.8	10.9	0.89	845 def
	Fertigated	7.9	47.7	546 g	30.2 abc	48.4	94.2	9.4	0.79	787 ef
Interaction Significance		NS	NS	*	*	NS	NS	NS	NS	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicates treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

The interaction of variety and irrigation treatment was significant with three response variables in 2010. With total shoot length, fertigation and irrigation gave similar responses and were significantly higher than the control with 'Gala' and 'Honeycrisp'. However with 'Crispin', 'Jonagold' and 'Macoun' there were no significant differences between the treatments (Table 2). With average shoot length, fertigation and irrigation gave a significantly greater shoot length than the control with 'Crispin'. However with 'Gala' average shoot length was greatest with the unirrigated control and the fertigation treatment being significantly greater than the irrigation treatment. With 'Honeycrisp', 'Jonagold' and 'Macoun' there were no significance differences among the treatments. Lastly fertigation and irrigation had a similar effect on total tree length and were significantly more than the unirrigated control for 'Crispin', 'Gala' and 'Honeycrisp'. But with 'Jonagold' and 'Macoun' there were no differences between the treatments.

During the third year of growth (2011) fertigation and irrigation similarly increased TCA, pruning weight, spurs and limbs pruned per tree and the total tree length compared to the unirrigated control treatment (Table 3). The irrigation treatment and the unirrigated control increased leader length and average shoot length similarly; however only irrigation was significantly different from the fertigation treatment. Total shoot length was increased the most by irrigation, followed by fertigation and lastly by the unirrigated control, all treatments being significantly different from each other. In 2011 there were four response variables where the interaction between variety and irrigation treatment was significant. With leader length there was no significance difference with 'Crispin', 'Gala' or 'Macoun', but for 'Honeycrisp' fertigation increased leader length significantly greater than the unirrigated control, and for 'Jonagold' the unirrigated control and irrigation treatment increased leader length significantly more than the fertigation treatment. A second interaction resulted with 'Crispin' and 'Honeycrisp' where fertigation increased total shoot length, but with 'Gala' irrigation had the highest total shoot length and was significantly different from fertigation and the unirrigated control. With 'Jonagold' and 'Macoun' there were no significant differences in total shoot length between the treatments.

Table 3. Effect of irrigation and fertigation on tree growth of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Irrigation Treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means									
Crispin	.	12.6 a[z]	33 c	1191 c	22.4 b	331 b	29.7 c	0.76 c	1851 c
Gala	.	13.8 a	48.2 a	2148 a	26.8 a	823 a	96.8 a	1.78 a	3571 a
Honeycrisp	.	10.3 b	28.9 c	1585 b	23 a	371 b	53.9 b	0.98 bc	2674 b
Jonagold	.	10.9 b	39.7 b	1281 c	23.2 a	469 b	51.6 b	1.10 bc	2077 c
Macoun	.	9.7 b	39 b	856 d	22.1 a	362 b	52.4 b	1.05 ab	1410 d
Variety Significance		**	**	**	**	**	**	*	**
.	Unirrigated	9.9 b	37.6 ab	1267 c	23.3 ab	349 b	45.2 b	0.96 b	2081 b
.	Irrigated	12.1 a	39.2 a	1562 a	24.3 a	537 a	62.7 a	1.35 a	2519 a
.	Fertigated	12.4 a	36.4 b	1418 b	22.9 b	528 a	62.5 a	1.38 a	2370 a
Treatment Significance		**	NS	**	*	**	**	**	**
Interaction Means									
Crispin	Unirrigated	10.3	31.2 ef	993 fgh	21.4 efg	176	21.5	0.32	1559 fg
	Irrigated	13.0	36.8 de	1244 efg	22.5 defg	353	34.6	0.90	1949 ef
	Fertigated	14.5	30.9 efg	1327 e	23.3 cdef	456	32.6	1.05	2029 e
Gala	Unirrigated	12.0	46.9 ab	1840 bc	25.4 bc	627	83.4	1.70	3075 cd
	Irrigated	14.4	48.2 a	2611 a	28.5 a	965	107.1	1.78	4120 a
	Fertigated	14.9	49.6 a	2015 b	26.7 ab	883	100.4	1.85	3545 b
Honeycrisp	Unirrigated	8.7	25.1 g	1385 de	21.7 efg	248	39.3	0.75	2255 e
	Irrigated	11.2	29.7 fg	1676 cd	23.9 cde	456	59.4	1.15	2904 d
	Fertigated	11.1	31.8 ef	1694 c	23.3 cdef	408	63	1.05	2863 d
Jonagold	Unirrigated	9.8	43.9 abc	1263 ef	25.0 bcd	416	41.4	0.65	2118 e
	Irrigated	11.2	41.5 bcd	1348 e	23.8 cde	447	52.8	1.15	2093 e
	Fertigated	11.7	33.9 ef	1231 efg	20.8 fg	543	60.6	1.50	2021 e
Macoun	Unirrigated	8.7	40.5 cd	820 h	23.0 cdef	267	39.1	1.37	1334 g
	Irrigated	10.6	40.6 cd	955 gh	23.0 cdef	480	62.1	1.84	1558 fg
	Fertigated	9.7	35.9 de	792 h	20.3 g	338	55.8	1.47	1338 g
Interaction Significance		NS	*	*	*	NS	NS	NS	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

A third interaction resulted when irrigation increased average shoot length with ‘Gala’ but with ‘Jonagold’ and ‘Macoun’ the unirrigated control and the irrigation treatment increased the average shoot length compared to the fertigation treatment (Table 3). A fourth interaction resulted when fertigation increased total tree length relative to the control with ‘Crispin’ but with ‘Gala’ irrigation had the greatest total tree length followed by fertigation and the unirrigated control with all treatments being significantly different from each other. Fertigation and irrigation increased total tree length similarly and significantly different from the unirrigated control treatment for ‘Honeycrisp’. With ‘Jonagold’ and ‘Macoun’ there were no significant difference among treatments.

In the fourth year (2012), fertigation and irrigation treatments increased TCA, total shoot length, average shoot length, pruning weight and total tree length similarly, and significantly more than the unirrigated control (Table 4). Fertigation and irrigation increased leader length similarly, however only the irrigation treatment was significantly greater than the control. With fertigation the number of limbs pruned was higher and significantly different from the control.

During the fifth year (2013), fertigation and irrigation increased TCA similarly and significantly more than the unirrigated control (Table 5). There was significant interaction in TCA increase between variety and irrigation treatment. Fertigation increased TCA the most followed by irrigation and the unirrigated control with ‘Crispin’, but with ‘Gala’ and ‘Honeycrisp’ the fertigation and irrigation treatments increased TCA similarly and significantly more than the control. There were no significant differences in TCA increase among treatments for ‘Jonagold’ and ‘Macoun’.

Cumulative tree growth during the five years of the experiment showed that the fertigation and irrigation treatments increased leader length, total shoot length, pruning weight and average shoot length similarly, and significantly more than the unirrigated control treatment. No significant interaction was found between variety and cumulative tree growth.

Table 4. Effect of irrigation and fertigation on tree growth of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Irrigation Treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average shoot Length (cm)	Pruning Weight (g)	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means								
Crispin	.	15.8 a[z]	34.6 ab	2355 bc	23.9 a	736 b	2.5 b	3546 b
Gala	.	15.7 a	36.7 a	4050 a	25.6 a	1111 a	3.4 a	6198 a
Honeycrisp	.	11.5 bc	27.4 c	1875 cd	20.8 b	520 c	2.2 bc	3460 b
Jonagold	.	12.6 b	33.3 b	2382 b	24 a	647 b	2.2 bc	3662 b
Macoun	.	11.0 c	24.9 c	1415 d	18.6 c	486 c	1.9 c	2270 c
Variety Significance		**	**	**	**	**	**	**
.	Unirrigated	11.6 b	28.6 b	1956 b	21 b	554 b	2.1 b	3224 b
.	Irrigated	14.0 a	33.2 a	2733 a	23.7 a	771 a	2.5 ab	4295 a
.	Fertigated	14.4 a	32.4 ab	2570 a	23.1 a	776 a	2.7 a	3988 a
Treatment Significance		**	*	**	**	**	*	**
Interaction Means								
Crispin	Unirrigated	13.3	27.7	1576	21.2	508	1.9	2570
	Irrigated	16.2	36.2	2598	24.6	793	2.4	3841
	Fertigated	17.7	39.5	2851	25.9	898	3.1	4178
Gala	Unirrigated	13.6	32.3	3358	23.9	903	3.2	5198
	Irrigated	16.6	40.4	4831	27.0	1250	3.4	7442
	Fertigated	16.9	37.7	4001	25.9	1188	3.7	6016
Honeycrisp	Unirrigated	9.8	25.8	1473	19.3	415	1.9	2857
	Irrigated	12.3	29.3	2041	21.8	565	2.2	3717
	Fertigated	12.4	27.2	2111	21.2	580	2.5	3805
Jonagold	Unirrigated	11.4	30.4	2042	22.7	513	1.9	3305
	Irrigated	12.8	34.2	2555	24.8	683	2.4	3904
	Fertigated	13.7	35.2	2547	24.4	745	2.3	3779
Macoun	Unirrigated	9.9	26.7	1280	18.0	424	1.7	2100
	Irrigated	12.1	25.9	1692	20.1	582	2.0	2647
	Fertigated	11.1	22.1	1272	17.9	453	1.9	2065
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P\leq0.05$. *, ** or NS indicate treatment had a significant effect at $P\leq0.05$ or $P\leq0.01$ levels, or had a non significant effect, respectively.

Table 5. Effect of irrigation and fertigation on tree growth and fruiting of five apple varieties in the fifth year (2013) at Geneva, NY.

Variety	Irrigation Treatment	TCA (cm^2)	TCA Increase (cm^2)	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means										
Crispin	.	19.6 a[z]	3.8 a	130.1 b	32.95 a	94.2 a	6.90 ab	1.72 a	253 a	6.27 b
Gala	.	19.3 a	3.6 a	140.4 a	23.07 b	65.9 b	7.52 a	1.23 c	165 c	3.16 c
Honeycrisp	.	14.5 b	3.0 b	43.1 d	8.79 d	25.1 d	3.39 d	0.68 e	223 b	19.33 a
Jonagold	.	15.0 b	2.4 c	87.6 c	21.35 b	61.0 b	5.95 c	1.44 b	247 a	4.66 bc
Macoun	.	13.4 b	2.3 c	79.9 c	12.30 c	35.1 c	6.19 bc	0.95 d	155 d	17.70 a
Variety Significance		**	**	**	**	**	**	**	**	**
.	Unirrigated	14.1 b	2.5 b	96.9 ab	18.90 b	54.0 b	6.88 a	1.33 a	200 b	8.87 b
.	Irrigated	17.2 a	3.2 a	101.8 a	21.10 a	60.3 a	5.94 b	1.22 a	212 a	10.67 a
.	Fertigated	17.7 a	3.3 a	89.7 b	19.12 b	54.6 b	5.13 c	1.07 b	215 a	11.00 a
Treatment Significance		**	**	*	*	*	**	**	**	**
Interaction Means										
Crispin	Unirrigated	16.1	2.8 def	125.1	29.33	83.8	7.86	1.81	232	6.59 d
	Irrigated	20.1	3.9 b	135.8	35.02	100.1	6.91	1.77	259	5.5 de
	Fertigated	22.4	4.7 a	129.1	34.33	98.1	5.98	1.57	267	6.73 d
Gala	Unirrigated	16.8	3.1 cde	137.0	22.11	63.2	8.34	1.35	162	2.98 ef
	Irrigated	20.4	3.8 bc	155.1	25.68	73.4	7.72	1.28	167	4.23 def
	Fertigated	20.8	3.9 b	129.9	21.54	61.5	6.51	1.08	167	2.33 f
Honeycrisp	Unirrigated	11.9	2.1 f	59.8	11.27	32.2	5.29	1.00	212	12.07 c
	Irrigated	15.7	3.4 bcd	43.2	9.12	26.1	3.14	0.64	231	21.93 a
	Fertigated	15.8	3.4 bcd	26.3	5.99	17.1	1.76	0.40	229	24.23 a
Jonagold	Unirrigated	13.8	2.4 ef	83.7	20.13	57.5	6.19	1.48	243	5.23 de
	Irrigated	15.3	2.5 ef	91.0	22.07	63.1	6.04	1.45	242	3.81 ef
	Fertigated	16.0	2.3 f	88.0	21.87	62.5	5.60	1.39	255	4.97 de
Macoun	Unirrigated	12.1	2.2 f	79.6	11.81	33.8	6.75	1.00	151	17.8 b
	Irrigated	14.7	2.6 ef	85.6	13.44	38.4	5.97	0.94	158	17.92 b
	Fertigated	13.3	2.2 f	74.6	11.66	33.3	5.85	0.91	157	17.39 b
Interaction Significance		NS	*	NS	NS	NS	NS	NS	NS	**

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 6. Effect of irrigation and fertigation on cumulative tree growth and fruiting of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Irrigation Treatment	Cumulative Growth and Fruiting Measurements: Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Average: Crop Load (Fruit number/ cm^2 TCA	Fruit Size (g)	Shoot Length (cm)
Main Effect Means										
Crispin	.	143 c[z]	4454 b	1180 bc	57.8 a	165 a	3.05 b	3.6 d	293.8 a	22.6 b
Gala	.	182 a	8092 a	2256 a	55.3 a	158 a	2.95 bc	5.7 a	163.4 d	26.3 a
Honeycrisp	.	123 d	4805 b	984 c	38.3 c	109 c	2.77 c	4.1 c	247.3 b	19.5 c
Jonagold	.	159 b	4727 b	1266 b	50.0 b	143 b	3.41 a	4.7 b	236.0 c	25.5 a
Macoun	.	153 bc	3030 c	949.5 c	32.2 d	92 d	2.50 d	4.9 b	159.5 d	22.9 b
Variety Significance		**	**	**	**	**	**	**	**	**
.	Unirrigated	142 b	4223 b	1030 b	43.7 b	125 b	3.14 a	5.0 a	218.1 b	21.5 b
.	Irrigated	156 a	5580 a	1479 a	49.7 a	142 a	2.94 b	4.5 b	222.8 a	24.3 a
.	Fertigated	157 a	5294 a	1475 a	47.1 a	135 a	2.74 c	4.3 b	220.8 ab	24.2 a
Treatment Significance		**	**	**	**	**	**	**	NS	**
Interaction Means										
Crispin	Unirrigated	126	3284	743	50.5	144	3.20	3.8	297	19.5
	Irrigated	149	4822	1283	62.8	179	3.18	3.7	290	23.3
	Fertigated	155	5198	1494	59.8	171	2.78	3.2	295	25.0
Gala	Unirrigated	169	6743	1822	51.1	146	3.11	6.2	159	24.6
	Irrigated	183	9500	2553	59.6	170	2.94	5.5	168	27.2
	Fertigated	192	8103	2408	55.5	159	2.78	5.4	164	27.1
Honeycrisp	Unirrigated	112	3917	726	37.4	107	3.20	4.7	246	18.0
	Irrigated	128	5236	1133	40.7	116	2.73	4.0	251	20.5
	Fertigated	129	5262	1093	36.7	105	2.37	3.6	245	20.1
Jonagold	Unirrigated	155	4305	1074	49.2	141	3.63	5.1	231	24.4
	Irrigated	162	4943	1261	50.5	144	3.40	4.5	238	26.1
	Fertigated	159	4932	1463	50.3	144	3.20	4.4	239	25.9
Macoun	Unirrigated	146	2746	756	29.8	85	2.52	5.0	160	21.1
	Irrigated	162	3492	1206	34.6	99	2.42	4.7	160	24.6
	Fertigated	152	2851	886	32.4	93	2.55	5.0	159	23.1
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Nutrient Concentration

In the first year (2009), the unirrigated control treatment had the highest N, Mg, S and Zn, concentrations in the leaves being significantly greater than the irrigation and fertigation treatments (Table 7). However, the unirrigated control treatment had the lowest concentration of P followed by the fertigation and then the irrigation treatment. K and B concentrations were lower in the control treatment compared to the fertigation and irrigation treatments, which had similar concentrations. The fertigation treatment and the unirrigated control treatment had the highest concentration of Ca, but only the control was significantly higher than the irrigation treatment. The control treatment had the highest concentration of Mn follow by the irrigation then the fertigation treatment. There were no differences among treatments for Fe, Cu, and Al concentrations. In 2009 there were some interactions between variety and irrigation treatment for N, Ca, and Cu. With 'Crispin', 'Gala' and 'Honeycrisp' the unirrigated treatment had significantly higher N concentrations than the irrigation or fertigation treatments. However with 'Jonagold' and 'Macoun' there were no significance differences among treatments. For Ca the unirrigated control had a higher concentration than the irrigation or fertigation treatments, which were similar with 'Crispin' and 'Gala'. However, with 'Honeycrisp' the unirrigated control had the highest concentration, while the irrigation treatment had significantly higher Ca than the fertigation treatment. With 'Macoun' the fertigation treatment had the highest Ca, which was significantly different than the unirrigated control.

During the second year (2010) there were no significant differences between the treatments in nutrient concentrations in the leaves for N, P, K, Ca, Mg, S, Zn, Fe, B, and Al (Table 8). However the unirrigated treatment had the highest concentration of Mn compared to the irrigation and the fertigation treatments. For Cu, the irrigation treatment had the highest concentration compared to the fertigation treatment. In 2010 there were no significant interactions between the variety and treatments.

Table 7. Effect of irrigation and fertigation on leaf nutrient concentration of five apple varieties during the first year (2009) at Geneva, NY.

Variety	Irrigation Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Al (ppm)
Main Effect Means													
Crispin	.	2.85 a[z]	0.159 d	2.07 a	1.22 c	0.33 a	0.2 bc	21.6 c	53.8 ab	68.8 a	5.71 c	27.9 c	35.6 b
Gala	.	2.71 bc	0.172 c	2.04 a	1.20 c	0.31 ab	0.2 bc	27.6 b	47.3 bc	64.9 a	6.41 b	30.4 b	43.7 a
Honeycrisp	.	2.79 ab	0.176 bc	1.67 c	1.35 b	0.28 bc	0.2 a	28.2 ab	51.7 ab	63.2 a	8.18 a	33.8 a	39.5 ab
Jonagold	.	2.63 c	0.186 a	1.67 c	1.48 a	0.28 bc	0.2 c	29.9 a	34.9 c	56.9 a	5.71 c	27.7 c	38.0 ab
Macoun	.	2.76 ab	0.18 ab	1.78 b	1.25 c	0.26 c	0.2 ab	21.0 c	65.8 a	60.3 a	5.70 c	22.1 d	33.6 b
Variety Significance		**	**	**	**	*	*	**	*	NS	**	**	NS
.	Unirrigated	2.85 a	0.152 c	1.74 b	1.36 a	0.35 a	0.2 a	28.1 a	68.9 a	63.1 a	6.37 a	27.6 b	38.2 a
.	Irrigated	2.71 b	0.188 a	1.93 a	1.26 b	0.26 b	0.2 b	24.2 b	47.8 b	64.4 a	6.32 a	28.7 a	37.2 a
.	Fertigated	2.69 b	0.183 b	1.87 a	1.29 ab	0.26 b	0.2 b	24.8 b	35.1 c	61.0 a	6.36 a	29.0 a	38.8 a
Treatment Significance		**	**	**	*	**	*	*	**	NS	NS	**	NS
Interaction Means													
Crispin	Unirrigated	3.00 a	0.138	1.88	1.32 cdef	0.41	0.2	25.2	84.2	61.7	6.05 cd	27.1	27.9
	Irrigated	2.78 cd	0.170	2.17	1.16 gh	0.29	0.2	20.6	46.5	84.0	5.32 f	27.6	34.3
	Fertigated	2.77 cde	0.168	2.14	1.18 fgh	0.28	0.2	19.1	32.3	60.4	5.78 cdef	28.9	44.3
Gala	Unirrigated	2.85 bc	0.152	1.93	1.26 defg	0.38	0.2	32.4	62.1	71.1	6.21 bc	29.8	39.8
	Irrigated	2.62 g	0.183	2.13	1.10 h	0.27	0.2	24.2	41.4	57.9	6.79 b	30.8	47.7
	Fertigated	2.66 defg	0.180	2.06	1.23 efgh	0.28	0.2	25.9	38.1	65.4	6.26 bc	30.7	43.8
Honeycrisp	Unirrigated	2.97 ab	0.149	1.60	1.55 ab	0.35	0.2	29.3	71.3	64.0	7.98 a	33.1	42.8
	Irrigated	2.75 cdefg	0.195	1.77	1.35 cde	0.27	0.2	26.3	48.9	63.7	8.16 a	33.9	37.8
	Fertigated	2.64 efg	0.186	1.65	1.15 gh	0.24	0.2	29	34.8	61.9	8.39 a	34.2	38.0
Jonagold	Unirrigated	2.64 efg	0.166	1.67	1.47 abc	0.29	0.2	26.9	44.8	57.1	6.22 bc	27.1	41.3
	Irrigated	2.62 g	0.200	1.70	1.41 bcd	0.26	0.2	31.2	29.5	56.5	5.53 def	27.7	39.8
	Fertigated	2.63 fg	0.193	1.65	1.57 ab	0.28	0.2	31.7	30.4	57.3	5.36 ef	28.3	33.0
Macoun	Unirrigated	2.78 cd	0.157	1.64	1.16 gh	0.30	0.2	26.7	83.4	61.7	5.31 f	20.2	38.9
	Irrigated	2.76 cdef	0.194	1.87	1.26 defg	0.23	0.2	18.4	73.7	59.5	5.79 cdef	23.1	26.8
	Fertigated	2.75 cdefg	0.188	1.83	1.33 cdef	0.24	0.2	17.8	40.2	59.8	6.01 cde	22.8	35.0
Interaction Significance		*	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

Table 8. Effect of irrigation and fertigation on leaf nutrient concentration of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Irrigation Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Al (ppm)
Main Effect Means													
Crispin	.	3.14 a[z]	0.170 bc	1.54 b	2.43 bc	0.43 ab	0.2 a	190.1 b	62.9 a	76.2 a	7.88 b	42.4 a	14.8 c
Gala	.	2.79 b	0.160 c	1.60 b	1.79 d	0.40 b	0.2 c	145.6 c	54.5 a	71.1 ab	8.00 ab	39.1 bc	28.1 a
Honeycrisp	.	2.79 b	0.169 bc	1.28 c	2.52 ab	0.30 c	0.2 ab	228.9 a	57.3 a	75.2 a	7.15 c	41.1 ab	27.8 a
Jonagold	.	2.88 b	0.174 b	1.81 a	2.19 c	0.46 a	0.2 bc	142.6 c	59.1 a	67.6 b	8.59 a	42.1 a	25.1 ab
Macoun	.	2.81 b	0.187 a	1.82 a	2.74 a	0.31 c	0.3 a	160.3 c	60.2 a	73.4 ab	8.44 ab	37.9 c	18.7 bc
Variety Significance		**	*	**	**	**	**	**	NS	*	**	**	*
.	Unirrigated	2.92 a	0.171 a	1.57 a	2.42 a	0.4 a	0.2 a	174.2 a	65.8 a	72.7 a	7.99 ab	40.2 a	25.1 a
.	Irrigated	2.85 a	0.171 a	1.59 a	2.25 a	0.38 a	0.2 a	175.4 a	55.2 b	71.4 a	8.29 a	41.2 a	21.5 a
.	Fertigated	2.87 a	0.173 a	1.66 a	2.32 a	0.37 a	0.2 a	171.6 a	55.3 b	74.0 a	7.74 b	40.3 a	22.4 a
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	NS
Interaction Means													
Crispin	Unirrigated	3.25	0.177	1.52	2.63	0.48	0.3	190.9	79.1	85.9	8.16	41.9	25.1
	Irrigated	3.20	0.170	1.64	2.37	0.40	0.2	194.2	54.9	73.5	7.56	43.5	13.3
	Fertigated	2.97	0.162	1.44	2.31	0.42	0.2	185.3	55.9	69.8	7.95	41.7	6.7
Gala	Unirrigated	2.79	0.154	1.57	1.91	0.43	0.2	151.9	55.7	67.5	7.83	39.6	29.3
	Irrigated	2.82	0.165	1.58	1.79	0.41	0.2	141.1	59.1	73.1	7.91	38.3	25.9
	Fertigated	2.77	0.162	1.67	1.67	0.38	0.2	143.5	49.1	72.9	8.27	39.5	29.0
Honeycrisp	Unirrigated	2.79	0.169	1.28	2.61	0.31	0.2	232.3	59.3	72.4	7.30	39.7	21.7
	Irrigated	2.68	0.175	1.31	2.47	0.30	0.2	210.2	58.0	82.9	7.33	41.3	32.0
	Fertigated	2.89	0.163	1.25	2.47	0.30	0.2	244.2	54.6	70.3	6.81	42.2	29.7
Jonagold	Unirrigated	2.97	0.177	1.71	2.30	0.50	0.2	153.8	62.4	67.8	8.43	42.1	24.0
	Irrigated	2.88	0.174	1.94	2.27	0.43	0.2	148.1	58.8	69.8	7.88	41.4	25.0
	Fertigated	2.78	0.171	1.79	2.01	0.45	0.2	126.0	56.0	65.3	9.46	42.6	26.3
Macoun	Unirrigated	2.82	0.182	1.76	2.71	0.30	0.2	140.9	74.2	70.7	8.24	37.6	25.1
	Irrigated	2.78	0.180	1.86	2.69	0.29	0.2	161.8	45.4	70.4	8.05	36.4	15.4
	Fertigated	2.84	0.200	1.83	2.81	0.34	0.3	178.2	61.1	79.2	9.02	39.8	15.6
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Flowering and Fruiting

In the second year (2010) the fertigation treatment had the highest blossom number per tree followed by the irrigation treatment, and then the unirrigated control having the lowest number (Table 9). The fertigation and irrigation treatments had the highest fruit number, fruit weight, yield, crop load and yield efficiency compared to the control. However the control treatment had the largest fruit size in 2010 and the fertigation treatment had the smallest fruit size. The percent fruit drop was higher with the unirrigated control treatment compared to the irrigation and fertigation treatments, which were not different from each other. There was a significant interaction between variety and irrigation treatment for crop load and yield efficiency. Fertigation and irrigation had similar crop load or yield efficiency and significantly higher than the control with ‘Crispin’, ‘Honeycrisp’ and ‘Jonagold’ but with ‘Gala’ and ‘Macoun’ there were no differences among treatments. The control treatment had the highest percent fruit drop compared to the irrigation and fertigation treatments with ‘Crispin’ but with ‘Gala’ ‘Honeycrisp’ and ‘Jonagold’ there were no differences in fruit drop between the treatments. With ‘Macoun’ the fertigation and irrigation treatments had the highest fruit drop compared to the control but only fertigation was significantly different from the control.

In the third year (2011) crop load and yield efficiency were highest with the unirrigated control treatment compared with the fertigation and irrigation treatments (Table 10). Despite the few differences among the treatments in the third year, there were various significant interactions of variety and treatment. With ‘Crispin’ the unirrigated control and the irrigation treatment had higher fruit number, fruit weight, yield, crop load, yield efficiency and fruit size than the fertigated treatment. However with ‘Gala’ there were no statistical differences among treatments with any of the variables. With ‘Honeycrisp’, the unirrigated control and the irrigation treatment had similar fruit weight, yield, crop load and fruit size; however only the control was significantly greater than the fertigation treatment. With ‘Jonagold’ the control had the highest fruit number, fruit weight, yield, crop load, and yield efficiency compared to the fertigation and irrigation treatments. With ‘Macoun’ the fertigation and irrigation treatments had the highest fruit number, fruit weight and yield, but only the irrigation treatment was significantly different than the control. With ‘Macoun’ there were no significant difference in crop load, yield efficiency and fruit size among treatments.

In the fourth year (2012), the fertigation and the irrigation treatments had the highest blossom number, fruit weight, yield, and fruit size compared to the unirrigated control treatment (Table 11). The fertigation and irrigation treatments also had the highest fruit number however only the fertigation treatment was significantly different than the control. Crop load was greatest with the control and fertigation treatments but only the unirrigated control was significantly different from than the irrigation treatment. This year there was no significance interactions between variety and treatment.

During the last year of the experiment (2013), irrigation and the unirrigated control treatment had the highest fruit number, while the fertigation treatment was significantly lower than irrigation treatment but similar to the control (Table 5). Fruit weight and yield with the irrigation treatment were statistically greater than with the fertigation and the control treatments. The unirrigated control treatment had the highest crop load, followed by the irrigation treatment and lastly by the fertigation treatment. Yield efficiency was highest with the control and irrigation treatments, which were significantly greater than the fertigation treatment. Irrigation and fertigation had the highest fruit size; however, they also had the highest percent fruit drop, compared to the control. However, there was a significant interaction between variety and treatment with percent fruit drop, in which ‘Crispin’, ‘Gala’, ‘Jonagold’ and ‘Macoun’ did not have differences in drop between the treatments. Nevertheless with ‘Honeycrisp’ the irrigation and the fertigation treatments had more fruit drop compared to the control treatment.

The irrigation and fertigation treatments had the highest cumulative yield per tree, and yield per ha compared to the unirrigated control (Table 6). Yield efficiency was highest for the control treatment followed by the irrigation treatment and lastly the fertigation treatment. Average crop load was very similar for the irrigation and fertigation treatments but lower than the control treatment.

Table 9. Effect of irrigation and fertigation on flowering and fruiting of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Irrigation Treatment	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	58.5 c[z]	20.6 b	7.09 a	20.25 a	2.35 c	0.815 a	362 a	30.3 a
Gala	.	101.8 a	23.7 a	4.59 c	13.13 c	2.29 c	0.442 b	194 d	5.5 d
Honeycrisp	.	100.9 a	21.0 b	6.29 b	17.97 b	2.67 b	0.800 a	301 b	14.9 c
Jonagold	.	77.3 b	25.1 a	6.36 b	18.18 b	3.18 a	0.807 a	256 c	9.8 d
Macoun	.	53.4 c	17.1 c	3.06 d	8.75 d	2.21 c	0.398 b	181 e	20.2 b
Variety Significance		**	**	**	**	**	**	**	**
.	Unirrigated	68.2 c	17.2 b	4.50 b	12.86 b	2.25 b	0.594 b	272 a	18.3 a
.	Irrigated	87.9 b	24.4 a	6.02 a	17.20 a	2.73 a	0.678 a	248 b	15.4 b
.	Fertigated	79.7 a	23.1 a	5.97 a	17.07 a	2.65 a	0.694 a	259 c	14.6 b
Treatment Significance		**	**	**	**	**	**	**	**
Interaction Means									
Crispin	unirrigated	53.4	13.9	5.50	15.73	1.79 e	0.711 b	414 a	45.2 a
	irrigated	58.5	22.7	7.86	22.45	2.60 bc	0.896 a	351 b	23.1 b
	fertigated	63.3	24.8	7.82	22.35	2.63 bc	0.834 a	323 c	23.3 b
Gala	unirrigated	89.6	20.9	3.99	11.40	2.27 d	0.433 cd	192 g	6.1 ef
	irrigated	106.7	25.4	4.95	14.16	2.37 cd	0.460 c	196 g	4.3 f
	fertigated	109.4	25.1	4.85	13.87	2.25 d	0.435 cd	194 g	6.0 ef
Honeycrisp	unirrigated	93.6	16.2	4.85	13.87	2.34 cd	0.702 b	302 d	14.4 cd
	irrigated	103.5	23.5	7.10	20.29	2.84 b	0.861 a	304 d	14.8 cd
	fertigated	105.8	23.5	6.91	19.75	2.84 b	0.836 a	295 d	15.5 cd
Jonagold	unirrigated	62.4	20.4	5.51	15.75	2.72 b	0.735 b	269 e	10.5 de
	irrigated	75.1	25.6	6.55	18.71	3.30 a	0.844 a	257 ef	10.5 de
	fertigated	94.5	29.5	7.02	20.07	3.52 a	0.843 a	241 f	8.3 ef
Macoun	unirrigated	40.0	14.5	2.61	7.45	2.13 d	0.385 d	184 g	16.4 c
	irrigated	54.7	18.0	3.23	9.22	2.12 d	0.380 d	180 g	19.8 bc
	fertigated	65.5	18.7	3.35	9.57	2.40 cd	0.429 cd	180 g	24.3 b
Interaction Significance		NS	NS	NS	NS	**	*	**	**

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 10. Effect of irrigation and fertigation on fruiting of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Irrigation Treatment	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means								
Crispin	.	33.7 b	9.47 a	27.1 a	2.96 cd	0.82 a	299 a	14.4 a
Gala	.	64.4 a	9.60 a	27.4 a	4.78 a	0.71 abc	151 d	5.3 b
Honeycrisp	.	22.8 c	6.08 b	17.4 b	2.40 d	0.64 bc	276 b	17.2 a
Jonagold	.	39.7 b	8.36 a	23.9 a	3.82 bc	0.80 ab	231 c	6.6 b
Macoun	.	36.9 b	5.88 b	16.8 b	3.87 b	0.62 c	161 d	18.6 a
Variety Significance		**	**	**	**	*	**	**
.	Unirrigated	40.9	8.15	23.3	4.16 a	0.84 a	220	11.7
.	Irrigated	40.0	8.14	23.3	3.41 b	0.70 b	223	12.0
.	Fertigated	37.5	7.38	21.1	3.12 b	0.61 b	228	13.2
Treatment Significance		NS	NS	NS	**	**	NS	NS
Interaction Means								
Crispin	Unirrigated	38.2 cd	10.02 ab	28.6 ab	3.94 cde	1.03 a	280 bc	10.1
	Irrigated	37.2 cd	10.45 a	29.9 a	3.06 ef	0.86 ab	291 b	15.8
	Fertigated	26.0 efg	7.97 cd	22.8 cd	1.92 g	0.59 cde	326 a	17.1
Gala	Unirrigated	60.0 a	8.68 bc	24.8 bc	5.10 a	0.74 bc	147 e	5.2
	Irrigated	65.8 a	10.10 ab	28.9 ab	4.60 abc	0.70 bcd	156 e	5.2
	Fertigated	67.5 a	10.06 ab	28.7 ab	4.64 abc	0.69 bcd	150 e	5.4
Honeycrisp	Unirrigated	26.8 efg	7.18 cde	20.5 cde	3.21 def	0.86 ab	286 b	16.4
	Irrigated	22.7 fg	6.09 ef	17.4 ef	2.27 fg	0.61 cde	275 bc	14.2
	Fertigated	18.8 g	4.97 f	14.2 f	1.72 g	0.45 e	265 c	20.8
Jonagold	Unirrigated	48.6 b	9.81 ab	28.0 ab	4.95 ab	1.00 a	221 d	7.9
	Irrigated	32.9 de	7.38 cde	21.1 cde	3.12 ef	0.70 bcd	232 d	7.1
	Fertigated	37.5 cd	7.87 cd	22.5 cd	3.38 de	0.70 bcd	239 d	4.8
Macoun	Unirrigated	30.4 def	4.99 f	14.3 f	3.53 de	0.58 de	165 e	19.4
	Irrigated	42.6 bc	6.69 de	19.1 de	4.09 bcd	0.64 cde	158 e	17.8
	Fertigated	37.7 cd	5.97 ef	17.1 ef	3.97 cde	0.63 cde	159 e	18.7
Interaction Significance		**	**	**	*	*	**	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 11. Effect of irrigation and fertigation on flowering and fruiting of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Irrigation Treatment	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	162 c[z]	32.2 d	8.3 d	23.7 d	2.08 c	0.53 c	261 a	14.2 ab
Gala	.	343 a	126.9 a	18.1 a	51.6 a	8.26 a	1.17 b	144 d	2.9 d
Honeycrisp	.	239 b	90.9 b	17.1 ab	48.8 ab	7.89 a	1.48 a	190 c	11.2 bc
Jonagold	.	225 b	69.2 c	14.3 bc	40.8 bc	5.73 b	1.16 b	211 b	7.9 c
Macoun	.	183 c	78.5 bc	11.0 cd	31.4 cd	7.40 a	1.03 b	141 d	15.2 a
Variety Significance		**	**	**	**	**	**	**	**
.	Unirrigated	209 b	75.3 b	12.1 b	34.6 b	6.72 a	1.08 a	181 b	10.8 a
.	Irrigated	236 a	79.1 ab	14.5 a	41.3 a	5.84 b	1.07 a	197 a	9.5 a
.	Fertigated	248 a	84.2 a	14.8 a	42.2 a	6.25 ab	1.08 a	192 a	10.5 a
Treatment Significance		**	NS	**	**	*	NS	**	NS
Interaction Means									
Crispin	Unirrigated	132	22.2	5.7	16.2	1.72	0.44	261	16.1
	Irrigated	168	36.1	9.5	27.0	2.24	0.59	260	12.4
	Fertigated	185	37.9	9.7	27.7	2.27	0.57	263	14.1
Gala	Unirrigated	325	123.6	16.3	46.6	9.25	1.22	134	2.8
	Irrigated	340	123.0	18.9	53.8	7.32	1.12	156	2.5
	Fertigated	365	134.1	19.1	54.5	8.16	1.16	144	3.3
Honeycrisp	Unirrigated	195	79.0	14.1	40.1	7.94	1.42	183	14.7
	Irrigated	260	93.6	18.4	52.6	7.60	1.50	198	9.5
	Fertigated	263	100.2	18.8	53.7	8.13	1.53	190	9.5
Jonagold	Unirrigated	203	74.4	13.8	39.4	6.71	1.23	190	6.3
	Irrigated	235	67.3	14.5	41.3	5.47	1.16	221	8.0
	Fertigated	237	66.1	14.6	41.7	4.99	1.09	222	9.4
Macoun	Unirrigated	185	75.1	10.4	29.6	7.79	1.08	140	14.5
	Irrigated	181	77.8	11.2	32.0	6.65	0.95	144	14.9
	Fertigated	185	82.6	11.5	32.7	7.78	1.07	139	16.4
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

Fruit Quality and Storage Disorders

Fruit quality was evaluated only during the third and fourth growing season (2011 and 2012). In 2011 the fertigation and the unirrigated control treatments had the highest dry matter concentration in the fruit, but only the fertigation treatment was significantly different from the irrigation treatment (Table 12). Irrigation showed the highest bitter pit incidence, which was significantly different from the fertigation and unirrigated treatments. There was a significant interaction between variety and treatment for bitter pit. With 'Crispin', 'Jonagold' and 'Macoun' there were no differences in bitter pit incidence between treatments. However for 'Honeycrisp' the irrigation treatment had the highest incidence followed by the fertigation treatment, while the unirrigated control had the lowest incidence. With 'Gala' the unirrigated control treatment had the significantly higher incidence of bitter pit compared with the irrigation and fertigation treatments.

During the fourth growing season (2012) the unirrigated control treatment had significantly higher dry matter concentration than the irrigation and fertigation treatments (Table 13). The rest of the fruit quality variables did not show any significant differences among the treatments. However, there was a significant interaction of variety and treatment for superficial scald. With 'Crispin', 'Jonagold' and 'Macoun' no superficial scald was found. However with 'Gala' the unirrigated control and the irrigation treatment had increased incidence of superficial scald compared to the fertigation treatment. With 'Honeycrisp' the fertigation treatment and the unirrigated control had significantly higher incidence than the irrigation treatment.

Fruit Pack out

In the fourth year (2012), we also evaluated fruit packout. There were no significant differences in fruit packout due to treatment, nor was there was a significant interaction between variety and irrigation treatments (Table 14).

Table 12. Effect of irrigation and fertigation on fruit quality and storage disorders of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Irrigation Treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Storage Disorders Incidence (%) Senescent Breakdown	Bitter Pit	Watercore
Main Effect Means							
Crispin	.	59.2 c[z]	14.5 a	15.1	0.0	0 b	0.0 b
Gala	.	67.6 a	14.4 a	14.3	0.0	0.8 b	0.0 b
Honeycrisp	.	62.3 b	13.4 b	13.9	0.0	16.8 a	0.0 b
Jonagold	.	46.3 d	13.6 b	14.1	2.1	0.0 b	0.0 b
Macoun	.	46.7 d	12.8 c	13.2	0.0	0.0 b	3.9 a
Variety Significance		**	**	NS	NS	**	*
.	Unirrigated	53.4	13.8	14.4 ab	0.0	1.6 b	0.0
.	Irrigated	53.4	13.6	13.4 b	1.	5.7 a	1.1
.	Fertigated	53.4	13.9	14.6 a	0.0	2.7 b	1.2
Treatment Significance		NS	NS	*	NS	*	NS
Interaction Means							
Crispin	Unirrigated	57.4	14.2	14.7	0.0	0 d	0.0
	Irrigated	59.6	14.4	14.8	0.0	0 d	0.0
	Fertigated	60.5	15.0	15.7	0.0	0 d	0.0
Gala	Unirrigated	68.1	14.7	15.9	0.0	2.5 c	0.0
	Irrigated	65.8	14.1	11.3	0.0	0 d	0.0
	Fertigated	68.1	14.5	15.4	0.0	0 d	0.0
Honeycrisp	Unirrigated	60.9	13.5	13.7	0.0	5.6 c	0.0
	Irrigated	62.7	13.3	13.8	0.0	28.1 a	0.0
	Fertigated	63.6	13.5	14.1	0.0	16.7 b	0.0
Jonagold	Unirrigated	47.6	13.8	14.2	0.0	0 d	0.0
	Irrigated	44.5	13.7	14.1	6.3	0 d	0.0
	Fertigated	46.3	13.4	14.0	0.0	0 d	0.0
Macoun	Unirrigated	46.7	13.0	13.3	0.0	0 d	0.0
	Irrigated	46.3	12.5	12.8	0.0	0 d	5.8
	Fertigated	46.7	12.9	13.6	0.0	0 d	5.8
Interaction Significance		NS	NS	NS	NS	**	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan’s at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 13. Effect of irrigation and fertigation on fruit quality and storage disorders of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Irrigation Treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Storage Disorders Incidence (%) Superficial Scald	Bitter Pitt	Lenticel Breakdown	Senescent Breakdown	Flesh Browning	Watercore
Main Effect Means										
Crispin	.	61.83 b[z]	17.8 a	20.9 a	0.0 b	0.0 b	0 b	12.8 a	0 b	0.0
Gala	.	64.05 a	16.5 b	19.7 b	0.5 b	0.5 b	0.2 b	0.0 c	3.9 a	0.2
Honeycrisp	.	53.82 c	14.1 e	17.0 d	4.8 a	2.5 a	3.1 a	0.0 c	0 b	0.0
Jonagold	.	46.26 e	16.0 c	19.0 bc	0.3 b	0.0 b	0.4 b	8.0 b	0 b	0.0
Macoun	.	49.82 d	15.1 d	18.2 c	0.0 b	0.3 b	0 b	3.6 bc	0.3 b	0.5
Variety Significance		*	**	**	**	*	**	**	**	NS
.	Unirrigated	55.16	16.0	19.4 a	1.5	0.7	0.7	5.0	1.3	0.1
.	Irrigated	54.71	16.1	18.7 b	0.5	0.8	0.6	5.1	0.7	0.2
.	Fertigated	55.60	15.7	18.7 b	1.4	0.5	1.0	4.6	0.5	0.1
Treatment Significance		NS	NS	*	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	Unirrigated	62.28	17.7	21.5	0.0 c	0.0	0.0	12.1	0.0	0.0
	Irrigated	61.83	18.0	20.9	0.0 c	0.0	0.0	14.0	0.0	0.0
	Fertigated	62.28	17.8	20.3	0.0 c	0.0	0.0	12.3	0.0	0.0
Gala	Unirrigated	64.05	16.7	20.2	0.8 b	0.0	0.0	0.0	6.5	0.6
	Irrigated	64.94	17.0	20.2	0.6 b	0.0	0.0	0.0	2.5	0.0
	Fertigated	63.16	16.0	18.8	0.0 c	1.4	0.7	0.0	2.6	0.0
Honeycrisp	Unirrigated	54.27	14.4	17.6	6.4 a	3.6	3.3	0.0	0.0	0.0
	Irrigated	53.38	14.3	16.2	0.9 b	2.8	3.0	0.0	0.0	0.0
	Fertigated	53.38	13.6	17.4	7.1 a	1.0	3.1	0.0	0.0	0.0
Jonagold	Unirrigated	45.82	16.0	19.2	0.0 c	0.0	0.0	6.3	0.0	0.0
	Irrigated	45.37	16.1	18.6	0.9 b	0.0	0.0	10.1	0.0	0.0
	Fertigated	47.60	16.0	19.1	0.0 c	0.0	1.1	7.6	0.0	0.0
Macoun	Unirrigated	49.82	15.1	18.9	0.0 c	0.0	0.0	7.1	0.0	0.0
	Irrigated	48.49	15.0	17.8	0.0 c	1.0	0.0	1.0	1.0	0.8
	Fertigated	51.15	15.1	18.0	0.0 c	0.0	0.0	2.9	0.0	0.7
Interaction Significance		NS	NS	NS	*	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 14. Effect of irrigation fertigation on fruit packout of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Irrigation Treatment	USDA Grade Packout (%) Utility	Number 1	Fancy	X Fancy
Main Effect Means					
Crispin	.	1.6 c[z]	7.3 b	39.9 a	51.3 b
Gala	.	7.9 b	3.4 b	18.8 d	69.9 a
Honeycrisp	.	12.7 a	20.1 a	36.7 ab	30.5 c
Jonagold	.	3.0 c	5.4 b	22.3 cd	69.4 a
Macoun	.	12.2 ab	28.1 a	28.9 bc	30.7 c
Variety Significance		**	**	**	**
.	Unirrigated	6.9	13.4	31.6	48.1
.	Irrigated	8.0	13.2	26.9	51.9
.	Fertigated	8.0	12.4	29.9	49.7
Treatment Significance		NS	NS	NS	NS
Interaction Means					
Crispin	Unirrigated	3.9	6.5	34.2	55.4
	Irrigated	1.0	5.8	37.2	55.9
	Fertigated	0.0	9.4	48	42.6
Gala	Unirrigated	6.9	5.2	28.1	59.8
	Irrigated	5.8	0.7	13.3	80.1
	Fertigated	10.8	4.1	14.8	70.3
Honeycrisp	Unirrigated	8.8	21.4	36.3	33.5
	Irrigated	13.1	21.3	34	31.7
	Fertigated	16.2	17.7	39.7	26.4
Jonagold	Unirrigated	4.5	7.1	23.8	64.6
	Irrigated	2.5	0.4	18.3	78.8
	Fertigated	1.7	6.1	22.8	69.4
Macoun	Unirrigated	10.4	27.3	35.9	26.4
	Irrigated	14.8	31.9	26.8	26.4
	Fertigated	11.5	25.1	24.1	39.4
Interaction Significance		NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Effect of Branch Angle

Vegetative Growth

During the first year of growth (2009), when feathers were left at their natural angle, total shoot length, average shoot length and pruning weight per tree were significantly higher than when feathers were tied below horizontal (Table 15). However, there was a significant interaction between variety and feather angle with total shoot length. With 'Crispin', 'Jonagold' and 'Macoun', when feathers were left at their natural angle total shoot growth per tree was significantly greater than when feathers were tied below horizontal. However with 'Gala' and 'Honeycrisp' there were no differences in shoot length due to feather angle.

In the second year (2010), the trees with feathers at their natural angle had the highest average shoot length, spur number per tree, pruning weight, and number of spurs and limbs pruned compared to trees with feathers tied below horizontal (Table 16). There was an interaction between variety and feather angle treatment with a few response variables. The natural angle had the highest pruning weight for almost all the varieties, except 'Honeycrisp' where there was no significant difference for the below horizontal treatment. The total number of spurs and limbs pruned was the highest with the natural feather angle treatment for all the varieties compared to the below horizontal treatment, but the difference was much greater for 'Macoun' than the other varieties.

During the third year (2011), the trees with feathers at the natural angle had the highest pruning weight, number of spurs and limbs pruned away, and total tree length, compared to the trees with feathers below horizontal (Table 17). However, there were significant interactions between variety and feather angle with pruning weight and number of spurs and limbs pruned away. The pruning weight, total number of spurs and limbs pruned was consistently higher when feathers were at their natural angle than when feathers were below horizontal but the difference was much smaller for 'Honeycrisp' than the other varieties.

In the fourth year (2012), the trees with feathers at the natural angle had the highest TCA, average shoot length, pruning weight, number of limbs pruned and total tree length compared to trees with feathers below horizontal (Table 18). There were no significant interactions between variety and feather angle.

Table 15. Effect of feather angle on tree growth of five apple varieties in the first year (2009) at Geneva, NY.

Variety	Feather Angle Treatment	TCA (cm^2)	TCA Increase (cm^2)	Tree Height (cm)	Leader Length (cm)	Total Shoot Length (cm)	Av Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Total Tree Length (cm)
Main Effect Means										
Crispin	.	4.6 a[z]	2.5 a	191 c	31.8 b	239 b	19.1 a	17.3 c	14.3 b	616 c
Gala	.	4.4 ab	2.4 ab	207 a	37.7 a	464 a	20.0 a	29.1 b	20.4 a	1007 a
Honeycrisp	.	3.9 c	2.1 bc	197 b	37.3 a	250 b	13.0 b	51.7 a	1.0 d	649 c
Jonagold	.	4.2 bc	2.5 a	178 d	37.8 a	272 b	21.0 a	20.2 c	8.8 c	707 b
Macoun	.	3.6 d	1.8 c	164 e	39.9 a	198 c	19.6 a	20.0 c	2.1 d	422 d
Variety Significance		**	**	**	*	**	**	**	**	**
	Below Horizontal	4.2	2.3	187	35.9 a	275 b	17.6 b	28.3	7.3 b	678
	Natural Angle	4.1	2.3	187	37.9 a	294 a	19.4 a	27.1	11.3 a	684
Treatment Significance		NS	NS	NS	*	**	**	NS	*	NS
Interaction Means										
Crispin	Below Horizontal	4.6	2.4	190	30.8	229 d	18.2	17.8	9.0	615
	Natural Angle	4.7	2.5	192	32.8	249 c	19.9	16.8	19.6	617
Gala	Below Horizontal	4.5	2.4	208	38.2	459 a	19.6	28.8	16.3	1001
	Natural Angle	4.4	2.4	206	37.2	468 a	20.5	29.4	24.8	1014
Honeycrisp	Below Horizontal	4.1	2.2	198	37.0	250 c	12.8	54.2	2.1	651
	Natural Angle	3.8	2.0	196	37.5	250 c	13.1	49.2	0.0	646
Jonagold	Below Horizontal	4.1	2.5	177	35.4	252 c	19.6	20.3	6.8	695
	Natural Angle	4.2	2.6	178	40.3	292 b	22.4	20.0	10.8	718
Macoun	Below Horizontal	3.5	1.7	163	38.0	178 e	17.9	19.6	2.2	403
	Natural Angle	3.6	1.9	165	41.7	216 d	21.2	20.3	2.1	439
Interaction Significance		NS	NS	NS	NS	*	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

Table 16. Effect of feather angle on tree growth of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Feather Angle Treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length cm	Average Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means										
Crispin	.	8.9 b[z]	42.1 b	664 cd	22.6 b	37.6 c	95.6 b	7.3 b	0.46 bc	903 cd
Gala	.	10.8 a	57.5 a	1478 a	30.5 a	64.8 a	322.1 a	13.8 a	0.62 ab	1941 a
Honeycrisp	.	8.2 bc	28.5 c	1098 b	20.0 b	49.6 b	90.0 b	8.0 b	0.38 c	1348 b
Jonagold	.	8.0 c	46.4 b	787 c	29.4 a	38.3 c	131.7 b	6.6 b	0.42 bc	1062 c
Macoun	.	7.8 c	47.5 b	550 d	29.2 a	43.8 bc	95.1 b	8.2 b	0.69 a	748 d
Variety Significance		**	**	**	**	**	**	**	*	**
	Below Horizontal	8.7 a	44.6 a	905 a	25.4 b	44.8 b	88.7 b	5.0 b	0.03 b	1180 a
	Natural Angle	8.8 a	44.1 a	929 a	27.2 a	48.7 a	204.0 a	12.4 a	0.97 a	1224 a
Treatment Significance		NS	NS	NS	**	**	**	**	**	*
Interaction Means										
Crispin	Below Horizontal	8.6	42.1	637	22.2	36.2	51.0 fg	3.9 ef	0.04 c	866
	Natural Angle	9.2	42.2	692	23.0	39.1	140.2 cd	10.6 c	0.88 b	941
Gala	Below Horizontal	10.8	60.4	1535	30.5	62.8	211.9 b	8.5 cd	0.00 c	1994
	Natural Angle	10.9	54.5	1418	30.5	67.0	437.2 a	19.3 a	1.26 a	1886
Honeycrisp	Below Horizontal	8.3	27.3	1052	19.8	47.6	60.8 efg	5.8 de	0 .00c	1302
	Natural Angle	8.1	29.6	1144	20.2	51.6	119.2 cde	10.3 c	0.75 b	1394
Jonagold	Below Horizontal	7.7	47.5	738	27.8	35.0	93.5 de f	5.0e	0.13 c	990
	Natural Angle	8.2	45.3	838	31.1	41.6	169.8 b c	8.3 cd	0.71 b	1136
Macoun	Below Horizontal	7.8	45.6	529	27.1	42.4	20.6 g	1.4 f	0.00 c	707
	Natural Angle	7.9	49.2	570	31.1	45.1	163.3 bc	14.1 b	1.29 a	786
Interaction Significance		NS	NS	NS	NS	NS	**	**	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 17. Effect of feather angle on tree growth of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Feather Angle Treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means									
Crispin	.	12.9 a[z]	33.1 cd	1202 c	21.9 b	338 b	31.4 c	0.65 c	1866 c
Gala	.	14.1 a	48.4 a	2174 a	27.0 a	840 a	100.3 a	1.60 a	3652 a
Honeycrisp	.	10.8 bc	28.2 d	1646 b	22.5 b	387 b	55.5 b	0.92 bc	2744 b
Jonagold	.	11.1 b	40.0 b	1277 c	22.1 b	480 b	54.6 b	1.02 bc	2070 c
Macoun	.	9.7 c	38.0 bc	846 d	21.5 b	333 b	47.8 b	1.26 ab	1397 d
Variety Significance		**	**	**	**	**	**	*	**
	Below Horizontal	11.6	38.1	1374	22.2	305 b	44.3 b	0.22 b	2279 b
	Natural Angle	11.8	36.8	1487	23.8	645 a	71.2 a	1.94 a	2421 a
Treatment Significance		NS	NS	NS	NS	*	**	**	**
Interaction Means									
Crispin	Below Horizontal	12.5	30.8	1132	21.3	195 ef	23.0 e	0.13 ef	1769
	Natural Angle	13.2	35.3	1272	22.6	481 c	39.7 d	1.17 d	1964
Gala	Below Horizontal	14.1	51.8	2132	26.6	604 b	88.7 b	0.46 e	3667
	Natural Angle	14.1	44.9	2219	27.3	1085 a	112.5 a	2.78 a	3637
Honeycrisp	Below Horizontal	10.8	28.5	1556	21.6	254 de	41.4 d	0.00 f	2607
	Natural Angle	10.7	27.9	1737	23.4	520 c	69.6 c	1.83 c	2881
Jonagold	Below Horizontal	10.9	40.7	1181	20.9	315 d	44.2 d	0.38 ef	1919
	Natural Angle	11.4	39.3	1372	23.3	645 b	65.0 c	1.67 c	2228
Macoun	Below Horizontal	9.7	39.0	824	20.3	140 f	22.5 e	0.14 ef	1354
	Natural Angle	9.7	37.2	866	22.6	510 c	71.0 c	2.29 b	1436
Interaction Significance		NS	NS	NS	NS	*	**	**	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 18. Effect of feather angle on tree growth of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Feather Angle Treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average shoot Length (cm)	Pruning Weight (g)	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means								
Crispin	.	16.1 a[z]	35.5 a	2452 b	24.4 a	756 b	2.5 b	3655 b
Gala	.	16.1 a	36.4 a	4105 a	25.8 a	1122 a	3.3 a	6280 a
Honeycrisp	.	12 bc	27.1 b	1970 c	20.9 b	543 c	2.1 bc	3616 b
Jonagold	.	12.9 b	34.0 a	2486 b	24.1 a	664 b	2.2 b	3762 b
Macoun	.	11.0 c	25.1 b	1431 d	18.4 c	496 c	1.8 c	2277 c
Variety Significance		**	**	**	**	**	**	**
	Below Horizontal	13.4 b	30.5	2420	21.5 b	630 b	1.9 b	3794 b
	Natural Angle	13.8 a	32.8	2561	23.9 a	802 a	2.8 a	4049 a
Treatment Significance		*	NS	NS	**	**	**	**
Interaction Means								
Crispin	Below Horizontal	15.6	34.7	2429	23.5	644	2.0	3561
	Natural Angle	16.6	36.3	2476	25.2	869	2.9	3748
Gala	Below Horizontal	16.0	35.8	4153	24.9	1031	2.7	6285
	Natural Angle	16.1	37.1	4056	26.7	1217	3.9	6275
Honeycrisp	Below Horizontal	12.0	26.1	1835	20.0	481	1.7	3391
	Natural Angle	11.9	28.2	2104	21.8	604	2.6	3841
Jonagold	Below Horizontal	12.3	31.3	2236	22.2	527	1.7	3417
	Natural Angle	13.5	36.7	2735	26.1	800	2.6	4107
Macoun	Below Horizontal	10.9	24.2	1357	16.7	452	1.5	2181
	Natural Angle	11.1	26.0	1498	19.9	535	2.0	2365
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

During the last year of the experiment (2013), there were no significant differences in tree growth due to feather angle (Table 19). However feather angle had an effect on cumulative tree growth with trees having feathers at the natural angle producing more total shoot length and pruning weight than trees with feathers below horizontal (Table 20).

Table 19. Effect of feather angle on tree growth and fruiting of five apple varieties in the fifth year (2013) at Geneva, NY.

Variety	Feather Angle Treatment	TCA (cm^2)	TCA Increase (cm^2)	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means										
Crispin	.	19.9 a[z]	3.8 a	131.2 b	33.20 a	94.9 a	6.85 ab	1.7 a	252.1 a	6.56 b
Gala	.	19.8 a	3.7 a	141.0 a	23.14 b	66.1 b	7.34 a	1.2 c	164.9 c	2.7 c
Honeycrisp	.	15.0 bc	3.0 b	42.1 e	8.97 d	25.6 d	3.25 c	0.68 e	227.9 b	18.13 a
Jonagold	.	15.4 b	2.5 bc	90.0 c	21.93 b	62.7 b	5.99 b	1.45 b	246.4 a	4.56 bc
Macoun	.	13.3 c	2.3 c	80.1 d	12.34 c	35.2 c	6.22 b	0.95 d	154.9 c	17.51 a
Variety Significance		**	**	**	**	**	**	**	**	**
	Below Horizontal	16.4	3.0	101.7 a	20.53	58.7	6.28 a	1.26 a	207.2	10.2
	Natural Angle	17.0	3.1	92.1 b	19.39	55.4	5.56 b	1.14 b	212.4	9.49
Treatment Significance		NS	NS	**	NS	NS	**	**	NS	NS
Interaction Means										
Crispin	Below Horizontal	19.2	3.6	137 b	34.17	97.6	7.30	1.81	250.9	6.8
	Natural Angle	20.6	4.1	125.5 b	32.23	92.1	6.39	1.59	253.4	6.31
Gala	Below Horizontal	19.9	3.9	153.1 a	24.87	71.0	7.90	1.28	163.1	2.86
	Natural Angle	19.6	3.5	128.4 b	21.34	61.0	6.76	1.12	166.9	2.54
Honeycrisp	Below Horizontal	15.0	3.0	37.5 e	8.00	22.9	3.02	0.63	228.0	19.41
	Natural Angle	15.0	3.1	46.8 e	9.95	28.4	3.48	0.73	227.7	16.79
Jonagold	Below Horizontal	14.4	2.1	95.2 c	22.39	64.0	6.67	1.57	237.7	4.55
	Natural Angle	16.3	2.9	84.7 cd	21.49	61.4	5.31	1.34	255.1	4.57
Macoun	Below Horizontal	13.3	2.4	84 cd	12.66	36.2	6.56	0.98	151.7	17.79
	Natural Angle	13.3	2.2	76.5 d	12.04	34.4	5.90	0.92	157.9	17.26
Interaction Significance		NS	NS	*	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 20. Effect of feather angle on cumulative tree growth and fruiting of five apple varieties in the third year (2011) at Geneva, NY.

		Cumulative Growth and Fruiting Measurements						Average		
Variety	Feather Angle Treatment	Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Crop Load (Fruit number/cm^2 TCA	Fruit Size (g)	Shoot Length (cm)
Main Effect Means										
Crispin	.	143 b[z]	4558 b	1204 bc	57.9 a	165.5 a	3.01 b	3.5 d	294 a	22.0 c
Gala	.	180 a	8221 a	2305 a	56.1 a	160.2 a	2.90 b	5.7 a	163 d	25.8 a
Honeycrisp	.	121 c	4964 b	1021 bc	39.5 c	112.9 c	2.77 bc	4.0c	246 b	19.1 d
Jonagold	.	157 b	4805 b	1284 b	50.5 b	144.3 b	3.37 a	4.5 b	238 c	24.2 b
Macoun	.	151 b	3025 c	926 c	32.6 d	93 d	2.53 c	5.0 b	159 d	22.2 c
Variety Significance		**	**	**	**	**	**	**	**	**
	Below Horizontal	149	4974 b	1031 b	48.6 a	138.7 a	3.03 a	4.8 a	218 b	21.7 b
	Natural Angle	151	5263 a	1662 a	46.3 b	132.1 b	2.81 b	4.3 b	223 a	23.6 a
Treatment Significance		NS	**	**	*	*	**	**	**	**
Interaction Means										
Crispin	Below Horizontal	138	4427	899	58.6 a	167.4 a	3.12	3.7 e	288 b	21.3 d
	Natural Angle	147	4689	1510	57.2 a	163.5 a	2.90	3.3 f	301 a	22.7 bc
Gala	Below Horizontal	186	8279	1864	59.9 a	171.0 a	3.07	6.1 a	161 fg	25.4 a
	Natural Angle	174	8161	2765	52.1 b	148.9 b	2.72	5.2 b	165 f	26.2 a
Honeycrisp	Below Horizontal	119	4693	799	38.8 c	110.9 c	2.75	4.1 d	244 cd	18.6 f
	Natural Angle	123	5235	1244	40.2 c	114.9 c	2.79	4.0 de	248 c	19.7 e
Jonagold	Below Horizontal	155	4407	942	50.3 b	143.7 b	3.55	4.8 c	237 e	22.6 c
	Natural Angle	160	5202	1625	50.7 b	144.9 b	3.2	4.3 d	240 de	25.7 a
Macoun	Below Horizontal	147	2889	615	34.0 d	97.2 d	2.63	5.2 b	160 g	20.5 de
	Natural Angle	154	3151	1211	31.2 d	89.2 d	2.43	4.8 c	158 g	23.7 b
Interaction Significance		NS	NS	NS	**	**	NS	*	*	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Flowering and Fruiting

During the second year (2010) and the third year (2011), feather angle did not influence flowering or fruiting (Table 21, 22). In the fourth year (2012), the treatment with feathers below horizontal had more blossoms per tree, fruit number, fruit weight, yield, crop load and yield efficiency than the treatment with feathers at their natural angle (Table 23). However fruit size and percent fruit drop were significantly lower than when the feathers were at their natural angle. There was a significant interaction between variety and feather angle with fruit number per tree and crop load. With 'Crispin' there was no significant difference in fruit number and crop load due to feather angle. Nevertheless with 'Gala', 'Honeycrisp', 'Jonagold' and 'Macoun' the treatments with feathers below horizontal had higher fruit number and crop load than the treatment with the feathers at their natural angle.

In the fifth year of the experiment (2013), fruit number, crop load and yield efficiency were significantly higher with the feathers below horizontal (Table 19). There was a significant interaction between variety and feather angle with fruit number. With 'Gala' when feathers were tied below horizontal, fruit number was greater than when feathers were at their natural angle, but for all other varieties feather angle did not influence fruit number.

Over the entire five years of the experiment, when feathers were tied below horizontal the yield per tree, yield per hectare, yield efficiency and crop load were significantly greater than when feathers were grown at their natural angle. However when feathers were at their natural angle, fruit size and shoot length were greater than when the feathers were below horizontal. There was a significant interaction between variety and feather angle for yield per tree and yield per hectare. With 'Crispin', 'Honeycrisp', 'Jonagold' and 'Macoun' feather angle did not affect yield. However for 'Gala' yield was higher when feathers were tied below horizontal feathers compared to when the feathers were at their natural angle treatment. Crop load for 'Crispin, 'Gala', 'Jonagold' and 'Macoun' was higher with feathers below horizontal. However 'Honeycrisp' did not show any differences in crop load due to feather angle.

Table 21. Effect of feather angle on flowering and fruiting of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Feather Angle Treatment	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	60.3 c[z]	21.0 b	7.26 a	20.7 a	2.38 c	0.828 a	360 a	31.0 a
Gala	.	107.9 a	24.7 a	4.80 c	13.7 c	2.32 c	0.450 b	194 d	6.2 d
Honeycrisp	.	113.3 a	21.6 b	6.42 b	18.4 b	2.64 b	0.783 a	298 b	15.5 c
Jonagold	.	79.4 b	26.1 a	6.62 b	18.9 b	3.28 a	0.833 a	256 c	10.2 d
Macoun	.	55.4 c	17.6 c	3.13 d	8.9 d	2.27 c	0.405 b	180 e	20.2 b
Variety Significance		**	**	**	**	**	**	**	**
	Below Horizontal	83.2 a	22.1 a	5.59 a	16.0 a	2.59 a	0.660 a	257 a	16.5 a
	Natural Angle	83.6 a	22.4 a	5.75 a	16.4 a	2.57 a	0.666 a	261 a	16.8 a
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means									
Crispin	Below Horizontal	59.0	21.1	7.05	20.1	2.47	0.828	348	27.8
	Natural Angle	61.6	20.8	7.47	21.3	2.28	0.828	372	34.2
Gala	Below Horizontal	107.4	24.8	4.78	13.7	2.33	0.448	193	8.0
	Natural Angle	108.4	24.6	4.81	13.8	2.31	0.452	196	4.4
Honeycrisp	Below Horizontal	114.6	22.2	6.54	18.7	2.68	0.789	296	16.2
	Natural Angle	112.0	21.0	6.31	18.0	2.59	0.777	301	14.8
Jonagold	Below Horizontal	79.0	24.5	6.21	17.8	3.17	0.806	257	11.1
	Natural Angle	79.7	27.8	7.02	20.1	3.39	0.860	256	9.3
Macoun	Below Horizontal	53.4	17.4	3.14	9.0	2.25	0.408	184	19.8
	Natural Angle	57.3	17.8	3.12	8.9	2.28	0.402	177	20.5
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 22. Effect of feather angle on fruiting of five apple varieties in the third year (2011) at Geneva, NY

Variety	Feather Angle Treatment	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/ cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means								
Crispin	.	32.3 b[z]	9.19 a	26.26 a	2.78 cd	0.78 a	304.1 a	16.5 a
Gala	.	66.4 a	9.85 a	28.15 a	4.82 a	0.71 a	150.3 d	5.7 b
Honeycrisp	.	23.1 c	6.14 b	17.55 b	2.34 d	0.62 a	269.2 b	15.6 a
Jonagold	.	37.6 a	8.22 a	23.48 a	3.54 bc	0.77 a	235.0 c	7.2 b
Macoun	.	37.3 a	5.93 b	16.93 b	3.90 ab	0.62 a	160.3 d	19.2 a
Variety Significance		**	**	**	**	NS	**	**
	Below Horizontal	38.9	7.69	21.98	3.45	0.69	225.5	13.4
	Natural Angle	39.5	8.05	23.00	3.49	0.71	222.6	12.1
Treatment Significance		NS	NS	NS	NS	NS	NS	NS
Interaction Means								
Crispin	Below Horizontal	31.9	8.86	25.32	2.76	0.77	300.1	19.8
	Natural Angle	32.6	9.52	27.19	2.79	0.80	308.2	13.1
Gala	Below Horizontal	68.2	9.96	28.46	4.99	0.72	148.3	4.8
	Natural Angle	64.4	9.74	27.82	4.66	0.70	152.3	6.6
Honeycrisp	Below Horizontal	22.3	5.98	17.09	2.27	0.61	274.2	17.3
	Natural Angle	23.9	6.30	18.01	2.41	0.64	264.5	13.9
Jonagold	Below Horizontal	36.3	7.76	22.16	3.51	0.75	241.4	7.3
	Natural Angle	39.0	8.68	24.80	3.57	0.79	228.6	7.2
Macoun	Below Horizontal	35.7	5.75	16.43	3.74	0.60	162.4	18.7
	Natural Angle	38.8	6.09	17.39	4.05	0.64	158.3	19.7
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 23. Effect of feather angle on flowering and fruiting of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Feather Angle Treatment	Total Blossoms per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	168 c[z]	31.7 d	8.27 c	23.6 c	2.02 c	0.52 c	261.7 a	14.11 a
Gala	.	347 a	128.4 a	18.28 a	52.2 a	8.12 a	1.15 b	143.8 d	2.88 c
Honeycrisp	.	250 b	95.2 b	17.97 a	51.3 a	7.95 a	1.50 a	191.0 c	11.24 ab
Jonagold	.	231 b	66.8 c	14.20 b	40.6 b	5.36 b	1.13 b	215.0 b	8.28 b
Macoun	.	188 c	80.0 c	11.17 bc	31.9 bc	7.57 a	1.05 b	140.5 d	15.51 a
Variety Significance		**	**	**	**	**	**	**	**
	Below Horizontal	252 a	87.8 a	14.92 a	42.6 a	6.77 a	1.15 a	186.5 b	9.80 b
	Natural Angle	221 b	72.7 b	13.05 b	37.3 b	5.61 b	0.99 b	195.5 a	10.98 a
Treatment Significance		**	**	**	**	**	**	**	*
Interaction Means									
Crispin	Below Horizontal	179	33.1 g	8.52	24.3	2.15 g	0.55	253	13.82
	Natural Angle	157	30.3 g	8.02	22.9	1.89 g	0.50	270	14.41
Gala	Below Horizontal	356	144.4 a	20.25	57.9	9.13 a	1.27	141	2.84
	Natural Angle	337	111.8 b	16.22	46.3	7.06 cd	1.02	147	2.91
Honeycrisp	Below Horizontal	272	101.3 c	18.29	52.3	8.43 b	1.52	183	10.08
	Natural Angle	228	89.1 d	17.65	50.4	7.47 c	1.48	199	12.40
Jonagold	Below Horizontal	241	71.3 e	14.88	42.5	5.88 e	1.22	211	7.89
	Natural Angle	221	62.3 f	13.52	38.6	4.85 f	1.03	220	8.66
Macoun	Below Horizontal	210	89.1 d	12.45	35.6	8.39 b	1.17	141	14.78
	Natural Angle	167	71.7 e	9.99	28.5	6.83 d	0.95	140	16.17
Interaction Significance		NS	**	NS	NS	**	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Fruit size with ‘Crispin’ was the largest with feathers at the natural angle, while with the rest of the varieties there were no significant differences in fruit size. Trees with feathers at the natural angle had the highest average shoot length for ‘Crispin’, ‘Honeycrisp’, ‘Jonagold’ and ‘Macoun’. However for ‘Gala’ there was no difference in average shoot length due to feather angle.

Fruit Quality, Storage Disorders and Fruit Pack-Out

The treatment of feathers angle showed no significance differences for fruit quality, or storage disorder incidence in 2011 or 2012 (Table 24 and 25) respectively. There were no differences in fruit pack out due to feather angle in 2012 (Table 26).

Table 24. Effect of feather angle on fruit quality and storage disorders of five apple varieties in the third year (2011) at Geneva, NY.

					Storage Disorders Incidence (%)		
Variety	Feather Angle Treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Senescent Breakdown	Bitter Pit	Brown Core
Main Effect Means							
Crispin	.	59.2 c[z]	14.5 a	15.1 a	0.0	0.0 b	0.0 b
Gala	.	67.6 a	14.4 a	14.3 ab	0.0	0.9 b	0.0 b
Honeycrisp	.	62.3 b	13.4 b	13.8 ab	0.0	17.0 a	0.0 b
Jonagold	.	46.3 d	13.6 b	14.1 ab	2.1	0.0 b	0.0 b
Macoun	.	46.7 d	12.8 c	13.2 b	0.0	0.0 b	3.9 a
Variety Significance		**	**	NS	NS	**	NS
	Below Horizontal	56.5	13.8	14.1	0.4	3.4	0.8
	Natural Angle	56.1	13.8	14.1	0.4	3.4	0.8
Treatment Significance		NS	NS	NS	NS	NS	NS
Interaction Means							
Crispin	Below Horizontal	59.2	14.5	15.1	0.0	0.0	0.0
	Natural Angle	59.2	14.5	15.1	0.0	0.0	0.0
Gala	Below Horizontal	67.6	14.4	14.3	0.0	0.8	0.0
	Natural Angle	67.6	14.5	14.3	0.0	0.9	0.0
Honeycrisp	Below Horizontal	62.3	13.4	13.8	0.0	17.0	0.0
	Natural Angle	62.3	13.4	13.8	0.0	17.0	0.0
Jonagold	Below Horizontal	46.3	13.6	14.1	2.1	0.0	0.0
	Natural Angle	46.3	13.6	14.1	2.1	0.0	0.0
Macoun	Below Horizontal	46.7	12.8	13.2	0.0	0.0	4.0
	Natural Angle	46.7	12.8	13.3	0.0	0.0	3.7
Interaction Significance		NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan’s MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively.

Table 25. Effect of feather angle on fruit quality and storage disorders of five apple varieties in the fourth year (2012) at Geneva, NY.

					Storage Disorders Incidence (%)					
Variety	Feather Angle Treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Superficial Scald	Bitter Pitt	Lenticel Breakdown	Senescent Breakdown	Flesh Browning	Watercore
Main Effect Means										
Crispin	.	61.83 b[z]	17.8 a	20.9 a	0.0 b	0.0 b	0.0 b	12.7 a	0.0 b	0.0
Gala	.	64.05 a	16.5 b	19.7 b	0.4 b	0.0.5 b	0.2 b	0.0 c	3.9 a	0.2
Honeycrisp	.	53.82 c	14.1 e	17.0 d	4.8 a	2.5 a	3.1 a	0.0 c	0.0 b	0.0
Jonagold	.	46.26 e	16.0 c	19 bc	0.3 b	0.0 b	0.4 b	8.0 ab	0.0 b	0.0
Macoun	.	49.82 d	15.1 d	18.2 c	0.0 b	0.3 b	0.0 b	3.6 bc	0.3 b	0.5
Variety Significance		**	**	**	**	*	**	**	**	NS
	Below Horizontal	55.16	15.9	19.0	1.1	0.6	0.8	4.9	0.8	0.1
	Natural Angle	55.16	15.9	19.0	1.1	0.7	0.8	4.9	0.8	0.1
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	Below Horizontal	61.83	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
	Natural Angle	61.83	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
Gala	Below Horizontal	64.05	16.5	19.7	0.5	0.5	0.2	0.0	3.8	0.2
	Natural Angle	64.05	16.5	19.7	0.4	0.5	0.2	0.0	3.9	0.2
Honeycrisp	Below Horizontal	53.82	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
	Natural Angle	53.82	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
Jonagold	Below Horizontal	46.26	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
	Natural Angle	46.26	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
Macoun	Below Horizontal	49.82	15.0	18.2	0.0	0.2	0.0	3.6	0.2	0.5
	Natural Angle	49.82	15.1	18.2	0.0	0.4	0.0	3.7	0.4	0.5
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 26. Effect of feather angle on fruit quality, storage disorders and packout of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Feather Angle Treatment	USDA Grade Packout (%) Utility	Number 1	Fancy	X Fancy
Main Effect Means					
Crispin	.	1.7 c[z]	7.2 b	39.8 a	51.3 b
Gala	.	7.9 b	3.4 b	18.9 d	69.9 a
Honeycrisp	.	12.7 a	20.1 a	36.7 ab	30.5 c
Jonagold	.	3.0 c	5.3 b	22.0 cd	69.7 a
Macoun	.	12.2 ab	28.0 a	29.1 bc	30.6 c
Variety Significance		**	**	**	**
	Below Horizontal	7.6	12.9	29.6	49.9
	Natural Angle	7.6	13.1	29.6	49.7
Treatment Significance		NS	NS	NS	NS
Interaction Means					
Crispin	Below Horizontal	1.7	7.2	39.8	51.3
	Natural Angle	1.7	7.2	39.8	51.3
Gala	Below Horizontal	7.9	3.3	18.7	70.1
	Natural Angle	7.8	3.5	19.1	69.6
Honeycrisp	Below Horizontal	12.7	20.1	36.7	30.5
	Natural Angle	12.7	20.1	36.7	30.5
Jonagold	Below Horizontal	3.0	5.3	22.0	69.7
	Natural Angle	3.0	5.3	22.0	69.7
Macoun	Below Horizontal	12.5	28.5	29.5	29.5
	Natural Angle	12.0	27.6	28.8	31.6
Interaction Significance		NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Effect of Number of Feathers

The statistical analysis of the effect of number of feathers on the tree at planting showed an interaction of feather angle and feather number. To simplify the presentation of the data, the effects of feather number on vegetative growth and fruiting are presented separately when feathers were tied below horizontal or when feathers are left at their natural angle.

Vegetative Growth when Feathers were Tied Below Horizontal

During the first year (2009), when feathers were tied below horizontal, the number of feathers had a positive linear effect on TCA, TCA increase and total tree length (Table 27). However, there was a negative linear effect on tree height, leader length, total shoot length and average shoot length. Spur number had a positive quadratic relationship. There was a significant interaction between variety and number of feathers with TCA increase, average shoot length, spur number and total tree length. With ‘Gala’ and ‘Honeycrisp’ there was a positive linear relationship between the number of feathers and TCA increase, but for the other varieties there was no relationship. Average shoot length was negatively related to feather number for all the varieties. With ‘Crispin’ and ‘Macoun’ there was a positive linear relationship between number of feathers and spur number but a positive quadratic relationship with ‘Gala’, ‘Honeycrisp’ and ‘Jonagold’. There was a positive linear relationship between feather number and total tree length with ‘Crispin’, ‘Gala’, ‘Honeycrisp’ and ‘Jonagold’ but not with ‘Macoun’.

In the second year (2010), there was a positive linear relationship between the number of feathers and TCA, and a negative linear relationship with pruning weight (Table 28). Average shoot length and the number of limbs pruned away showed a quadratic negative relationship with number of feathers. However, spur number had a positive quadratic relationship. The relationship between number of feathers and spurs pruned away was quadratic with the least spurs pruned from trees having 5 feathers. There was a significant interaction between variety and number of feathers where with ‘Gala’ total shoot length had a positive linear relationship but with the other varieties there was no effect of number of feathers. The number of spurs pruned away showed a quadratic relationship for ‘Crispin’ where the 0 feathers had the highest number and 5 feathers had the lower number of spurs removed. With ‘Macoun’ the greatest number of spurs pruned away was with 0 feathers while trees with 5 and 10 feathers had similar number of spurs pruned.

During the third year (2011), there was a positive linear relationship between number of feathers and TCA; however, the relationship with average shoot length was negative (Table 29). Pruning weight and the number of spurs pruned showed a quadratic relationship where 0 feathers had the highest values and 5 feathers the lowest for both variables. The number of limbs pruned showed a quadratic relationship with 0 feathers having the most limbs pruned away. The interaction of variety and number of feathers was significant for average shoot length, where ‘Crispin’ had a quadratic relationship in which 0 feathers had the highest average shoot length and 5 feathers had the lowest. ‘Honeycrisp’, ‘Jonagold’ and ‘Macoun’ had a negative linear relationship. Also the number of limbs pruned showed a significant interaction with the number of feathers; with ‘Crispin’ the relationship was linear, but with ‘Gala’ there was a quadratic relationship with the 0 feathers having the most limbs pruned and the 5 feathers having the least pruned. With ‘Honeycrisp’ the relationship was quadratic with 0 feathers having the most limbs pruned. With ‘Jonagold’ there was a negative linear relationship in this case. With ‘Macoun’ the relationship between the number of limbs pruned and number of feathers was a negative quadratic relationship.

During the fourth year (2012), the relationship between the number of feathers and TCA or total shoot length was a positive linear relationship (Table 30). However the relationship with the number of limbs pruned was a negative linear relationship. There was a significant interaction between variety and the number of feathers with average shoot length. With ‘Crispin’ there was a positive linear relationship while with ‘Macoun’ there was a clear negative linear relationship.

In the fifth year (2013), there was a positive relationship between the number of feathers and TCA (Table 31). The interaction of variety and number of feathers was not significant.

The relationship of the number of feathers and cumulative leader length or pruning weight was a negative linear relationship (Table 32).

Table 27. Effect of number of feathers below horizontal on tree growth of five apple varieties in the first year (2009) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	TCA Increase (cm^2)	Tree Height (cm)	Leader Length (cm)	Total Shoot Length (cm)	Av Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Total Tree Length (cm)
Main Effects										
Crispin	.	4.5 a[z]	2.3 ab	192 b	33.8 b	249 c	21 b	14.9 c	6.1 bc	578 c
Gala	.	4.2 b	2.2 b	212 a	40.7 a	472 a	21.9 b	22.4 b	13.1 a	926 a
Honeycrisp	.	3.9 c	2.1 b	195 b	37.5 ab	260 bc	14.1 c	38.8 a	1.4 c	583 c
Jonagold	.	4 bc	2.4 a	181 c	39.8 a	284 b	25.4 a	16.3 c	8 ab	638 b
Macoun	.	3.5 d	1.8 c	165 d	41.5 a	197 d	20.8 b	16.8 c	1.5 c	397 d
Variety Significance		**	**	**	*	**	**	**	**	**
.	0 Feathers	3.7	1.9	194	44.3	333	26.8	9.1	3.5	469
.	5 Feathers	4.1	2.2	190	38.5	275	19.4	25.5	7.0	610
.	10 Feathers	4.3	2.3	185	33.2	275	15.9	31.1	7.6	745
Regression Significance		L	L	L	L	L	L	Q	NS	L
Interaction Means										
Crispin	0 Feathers	4.2	2.0	197	40.5	292	27.1	8.4	0.0	430
	5 Feathers	4.6	2.5	188	33	241	20.6	15.6	11.7	564
	10 Feathers	4.6	2.3	192	28.6	217	15.9	20.1	6.3	665
			NS				L	L		L
Gala	0 Feathers	3.7	1.7	219	45.6	499	26.6	9.6	6.7	670
	5 Feathers	4.2	2.3	212	42.9	466	21.4	27.7	14.6	908
	10 Feathers	4.7	2.5	203	33.5	452	17.7	29.8	17.9	1094
			L				L	Q		L
Honeycrisp	0 Feathers	3.5	1.7	191	38.5	280	16.7	8.1	0.0	447
	5 Feathers	3.9	2.2	200	37.8	246	13.5	43.5	4.2	591
	10 Feathers	4.2	2.3	196	36.3	254	12.1	64.8	0.0	712
			L				L	Q		L
Jonagold	0 Feathers	3.7	2.3	189	48.7	347	36.8	8.2	10.4	464
	5 Feathers	4.0	2.4	181	39.1	244	22.1	22.0	4.2	605
	10 Feathers	4.3	2.6	174	31.8	260	17.2	18.7	9.4	786
			NS				L	Q		L
Macoun	0 Feathers	3.4	1.8	170	48.5	234	26.6	11.2	0.0	383
	5 Feathers	3.4	1.7	166	39.9	169	19.3	18.0	0.0	361
	10 Feathers	3.7	1.8	160	36.2	186	16.5	21.3	4.4	446
			NS				L	L		NS
Interaction Significance		NS	*	NS	NS	NS	*	**	NS	**

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 28. Effect of number of feathers below horizontal on tree growth of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length cm	Average Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects										
Crispin	.	8.6 b[z]	42.4 b	637 cd	24.2 b	35.6 b	74.7 bc	5.1 a	0.37 a	886 cd
Gala	.	10.2 a	58.9 a	1427 a	31.9 a	60.1 a	220.8 a	7.7 a	0.25 a	1899 a
Honeycrisp	.	7.7 c	28.8 c	1053 b	21.0 b	41.8 b	74.7 bc	6.7 a	0.19 a	1313 b
Jonagold	.	7.7 c	47.0 b	760 c	30.2 a	33.9 b	122.1 b	6.0 ta	0.40 a	1044 c
Macoun	.	7.7 c	46.5 b	543 d	29.1 a	42.2 b	53.7 c	4.9 a	0.41 a	740 d
Variety Significance		**	**	**	**	**	**	NS	NS	**
.	0 Feathers	7.9	45.0	864	30.9	38.6	154.4	8.4	0.91	1197
.	5 Feathers	8.5	46.4	907	26.3	39.9	94.6	4.6	0.03	1182
.	10 Feathers	8.9	42.7	903	24.6	49.8	82.8	5.4	0.03	1178
Regression Significance		L	NS	NS	Q	Q	L	Q	Q	NS
Interaction Means										
Crispin	0 Feathers	8.4	43.0	638	28.4	34.5	126.4	7.7	1.09	930
	5 Feathers	8.7	44.6	667	22.6	34.3	35.4	3.8	0.00	908
	10 Feathers	8.6	39.6	608	21.8	38.1	66.7	4.1	0.08	824
				NS				Q		
Gala	0 Feathers	9.2	55.9	1209	34.8	54.8	238.8	6.1	0.75	1708
	5 Feathers	10.5	63.3	1527	31.0	58.3	226.3	7.7	0.00	1993
	10 Feathers	11.1	57.4	1543	30.0	67.2	197.5	9.4	0.00	1995
				L				NS		
Honeycrisp	0 Feathers	6.7	31.8	1055	23.3	30.1	102.5	8.4	0.58	1335
	5 Feathers	8.1	26.9	1031	19.9	40.1	60.0	5.3	0.00	1277
	10 Feathers	8.4	27.8	1073	19.7	55.2	61.7	6.4	0.00	1327
				NS				NS		
Jonagold	0 Feathers	7.6	46.2	804	34.9	31.7	179.2	8.0	1.00	1151
	5 Feathers	7.5	48.2	739	29.8	28.3	128.8	4.9	0.17	982
	10 Feathers	7.9	46.8	737	25.8	41.7	58.3	5.2	0.08	998
				NS				NS		
Macoun	0 Feathers	7.5	48.2	572	33.0	41.9	120.0	11.7	1.18	806
	5 Feathers	7.5	49.4	539	28.7	38.3	16.2	1.4	0.00	709
	10 Feathers	8.1	41.8	519	25.6	46.5	25.0	1.4	0.00	706
				NS				Q		
Interaction Significance		NS	NS	*	NS	NS	NS	**	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 29. Effect of number of feathers below horizontal on tree growth of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects									
Crispin	.	12.2 b[z]	31.4 c	1136 c	22.3 b	228 c	22.8 c	0.49 b	1773 cd
Gala	.	13.6 a	50.4 a	2102 a	26.5 a	655 a	86.8 a	1.11 a	3529 a
Honeycrisp	.	10.1 c	29.5 c	1483 b	22.7 b	271 bc	43.4 b	0.42 b	2536 b
Jonagold	.	10.6 c	40.1 b	1220 bc	23.1 b	352 b	42.6 b	0.72 ab	1980 c
Macoun	.	9.7 c	40.4 b	848 d	21.7 b	254 bc	38.8 b	1.03 a	1391 d
Variety Significance		**	**	**	**	**	**	*	**
.	0 Feathers	10.4	38.7	1354	25.6	455	52.9	1.84	2219
.	5 Feathers	11.4	39.4	1409	22.7	297	41.2	0.22	2316
.	10 Feathers	11.8	36.9	1339	21.7	312	47.5	0.22	2242
Regression Significance		L	NS	NS	L	Q	Q	Q	NS
Interaction Means									
Crispin	0 Feathers	11.6	32.5	1143	24.6	299	22.4	1.27	1781
	5 Feathers	12.0	31.6	1159	21.0	189	23.1	0.08	1825
	10 Feathers	13.1	30.1	1105	21.5	202	23.0	0.17	1713
					Q		NS	L	
Gala	0 Feathers	12.5	47.6	2044	26.3	755	82.9	2.55	3253
	5 Feathers	14.2	52.9	2226	26.9	537	75.7	0.42	3754
	10 Feathers	14.1	50.6	2037	26.3	672	101.7	0.50	3581
					NS		NS	Q	
Honeycrisp	0 Feathers	8.5	31.5	1337	24.8	303	47.3	1.25	2392
	5 Feathers	11.0	30.3	1555	22.5	280	42.0	0.00	2586
	10 Feathers	10.6	26.8	1556	20.8	228	40.8	0.00	2629
					L		NS	Q	
Jonagold	0 Feathers	10.1	38.8	1297	27.6	425	39.4	1.42	2101
	5 Feathers	10.5	41.4	1245	21.5	333	43.3	0.42	1984
	10 Feathers	11.3	40.0	1117	20.3	296	45.2	0.33	1855
					L		NS	L	
Macoun	0 Feathers	9.6	43.2	894	24.5	482	71.3	2.82	1466
	5 Feathers	9.3	41.0	810	21.3	133	20.2	0.18	1349
	10 Feathers	10.1	36.9	839	19.4	147	24.8	0.09	1358
					L		Q	Q	
Interaction Significance		NS	NS	NS	**	NS	**	**	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 30. Effect of number of feathers below horizontal on tree growth of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average shoot Length (cm)	Pruning Weight (g)	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects								
Crispin	.	15.2 a[z]	33.3 ab	2272 b	23.0 ab	646 b	2.2 b	3407 b
Gala	.	15.4 a	36.5 a	4047 a	24.9 a	1043 a	3.1 a	6149 a
Honeycrisp	.	11.1 bc	26.9 cd	1722 cd	20.0 c	464 c	1.9 b	3205 b
Jonagold	.	12.1 b	30.9 bc	2146 bc	22.6 b	544 bc	1.9 b	3366 b
Macoun	.	10.9 c	24.1 d	1354 d	17.7 d	450 c	1.8 b	2202 c
Variety Significance		**	**	**	**	**	**	**
.	0 Feathers	12.1	30.3	2131	22.0	637	2.6	3485
.	5 Feathers	13.1	31.4	2377	21.5	615	2.0	3786
.	10 Feathers	13.7	29.7	2463	21.6	645	1.9	3802
Regression Significance		L	NS	L	NS	NS	L	NS
Interaction Means								
Crispin	0 Feathers	14.5	30.5	1929	22.0	650	2.5	3072
	5 Feathers	14.9	34.3	2106	21.9	563	1.9	3265
	10 Feathers	16.3	35.1	2752	25.0	725	2.2	3857
					L			
Gala	0 Feathers	14.2	38.0	3834	24.8	1067	4.0	5877
	5 Feathers	16.1	37.8	4209	24.5	1071	2.8	6435
	10 Feathers	16.0	33.8	4097	25.4	992	2.6	6134
					NS			
Honeycrisp	0 Feathers	9.5	28.4	1496	20.2	429	2.3	2834
	5 Feathers	12.0	28.3	1970	21.3	517	2.1	3525
	10 Feathers	11.9	23.9	1701	18.6	446	1.3	3257
					NS			
Jonagold	0 Feathers	11.6	30.3	1966	23.3	579	2.3	3263
	5 Feathers	11.9	31.1	2159	22.3	496	1.5	3404
	10 Feathers	12.7	31.4	2313	22.2	558	1.9	3430
					NS			
Macoun	0 Feathers	11.0	24.0	1348	19.7	446	2.2	2242
	5 Feathers	10.3	24.7	1355	16.9	414	1.7	2165
	10 Feathers	11.5	23.6	1359	16.5	491	1.4	2198
					L			
Interaction Significance		NS	NS	NS	*	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 31. Effect of number of feathers below horizontal tree growth and fruiting of five apple varieties in the fifth year (2013) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	TCA Increase (cm^2)	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percentage Drop (%)
Main Effects										
Crispin	.	18.9 a[z]	3.6 a	133.3 b	33.45 a	95.6 a	7.24 ab	1.80 a	252.7 a	6.24 b
Gala	.	19.1 a	3.7 a	148.1a	24.17 b	69.1 b	8.00 a	1.30 c	164.0 d	3.56 b
Honeycrisp	.	14.1 b	2.9 b	40.6 d	8.02 e	22.9 e	3.34 c	0.65 e	221.2 c	20.95 a
Jonagold	.	14.2 b	2.1 c	89.4 c	21.25 c	60.7 c	6.37 b	1.51 b	240.9 b	4.72 b
Macoun	.	13.4 b	2.4 c	82.5 c	12.49 d	35.7 d	6.40 b	0.96 d	153.0 e	18.03 a
Variety Significance		**	**	**	**	**	*	**	**	**
.	0 Feathers	15.0	2.9	93.2	18.68	53.4	6.22	1.23	206.6	11.5
.	5 Feathers	16.1	3.0	105.6	20.82	59.5	6.71	1.31	202.1	10.27
.	10 Feathers	16.8	3.0	97.7	20.25	57.9	5.86	1.2	212.3	10.14
Regression Significance		L	NS	Q	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	0 Feathers	18.2	3.7	125.2	31.88	91.1	7.11	1.79	256.7	5.01
	5 Feathers	18.2	3.3	146.2	34.89	99.7	8.11	1.92	239.3	5.72
	10 Feathers	20.2	3.9	127.8	33.45	95.6	6.50	1.69	262.5	7.89
Gala	0 Feathers	17.5	3.3	138.1	22.78	65.1	8.21	1.35	165.7	4.95
	5 Feathers	19.9	3.9	159.1	25.88	73.9	8.17	1.32	162.9	2.92
	10 Feathers	19.9	3.9	147.1	23.85	68.2	7.63	1.24	163.3	2.80
Honeycrisp	0 Feathers	12.3	2.8	46.8	8.07	23.0	3.98	0.68	207.5	24.04
	5 Feathers	15.3	3.3	37.3	7.43	21.2	3.23	0.64	219.8	19.96
	10 Feathers	14.7	2.7	37.8	8.57	24.5	2.80	0.63	236.3	18.86
Jonagold	0 Feathers	13.8	2.2	77.9	19.07	54.5	5.77	1.40	247.3	5.06
	5 Feathers	14.2	2.3	96.8	22.41	64.0	6.85	1.61	234.7	4.98
	10 Feathers	14.6	1.8	93.6	22.38	63.9	6.49	1.54	240.7	4.15
Macoun	0 Feathers	13.5	2.4	79.3	12.16	34.7	6.08	0.93	155.6	18.50
	5 Feathers	12.3	2.0	87.4	12.97	37.1	7.21	1.06	149.5	17.97
	10 Feathers	14.3	2.8	80.7	12.35	35.3	5.90	0.89	153.9	17.61
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 32. Effect of number of feathers below horizontal on cumulative tree growth and fruiting of five apple varieties during 5 years at Geneva, NY.

		Cumulative Growth and Fruiting Measurements						Average		
Variety	Number of Feathers	Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Crop Load (Fruit number/cm^2 TCA	Fruit Size (g)	Shoot Length (cm)
Main Effects										
Crispin	.	141 c[z]	4293 b	954 bc	58.2 a	166.4 a	3.15 b	3.7 c	288.8 a	22.6 b
Gala	.	186 a	8048 a	1932 a	57.4 a	164.0 a	3.09 b	6.0 ta	162.2 d	26.3 a
Honeycrisp	.	123 d	4518 b	811 bc	37.0 c	105.6 c	2.75 c	4.2 c	246.6 b	19.4 c
Jonagold	.	158 b	4410 b	1026 b	49.5 b	141.4 b	3.55 a	4.9 b	233.5 c	25.3 a
Macoun	.	153 bc	2942 c	759 c	33.0 c	94.2 c	2.54 c	5.0 b	160.3 d	22.3 b
Variety Significance		**	**	**	**	**	**	**	**	**
.	0 Feathers	158	4682	1250	44.4	126.9	3.01	4.8	218.8	26.3
.	5 Feathers	156	4967	1014	48.5	138.5	3.08	4.9	217.5	22.5
.	10 Feathers	142	4980	1047	48.7	139	2.98	4.7	220.4	20.9
Regression Significance		L	NS	L	L	L	NS	NS	NS	Q
Interaction Means										
Crispin	0 Feathers	147	4002	1075	57.4	164.0	3.22	3.9	290.9	25.5
	5 Feathers	143	4172	798	61.4	175.5	3.41	4.1	282.2	21.5
	10 Feathers	133	4681	999	55.8	159.3	2.83	3.2	293.6	21.1
								Q		L
Gala	0 Feathers	187	7585	2067	52.5	150.0	3.12	6.0	164.0	28.1
	5 Feathers	197	8428	1849	59.9	171.2	3.06	6.0	163.7	25.9
	10 Feathers	175	8130	1879	59.8	170.9	3.08	6.2	158.9	24.9
								NS		L
Honeycrisp	0 Feathers	130	4169	835	33.2	95.0	2.75	4.3	251.2	21.2
	5 Feathers	123	4802	861	37.6	107.4	2.65	4.0	243.7	19.3
	10 Feathers	115	4584	736	40.0	114.4	2.85	4.2	244.9	17.8
								NS		L
Jonagold	0 Feathers	164	4414	1194	47.9	136.8	3.56	5.2	227.4	30.6
	5 Feathers	160	4387	962	47.7	136.2	3.43	4.8	232.9	23.9
	10 Feathers	150	4428	922	52.9	151.3	3.67	4.8	240.3	21.4
								NS		Q
Macoun	0 Feathers	164	3048	1047	30.9	88.4	2.37	4.6	161.5	26.0
	5 Feathers	155	2874	563	34.5	98.6	2.85	5.6	160.3	21.5
	10 Feathers	139	2903	668	33.5	95.7	2.41	4.9	159.0	19.5
								Q		L
Interaction Significance		NS	NS	NS	NS	NS	NS	*	NS	**

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Flowering and Fruiting when Feathers were Tied Below Horizontal

During the second year of growth (2010), the relationship between the number of feathers tied below horizontal and blossom number, fruit number, fruit weight, yield and crop load was a positive linear relationship (Table 33). There was a significant interaction where 'Crispin' had a quadratic relationship in which the 5 feather treatment had the most blossoms and the 0 feather treatment had the least. With 'Gala' and 'Honeycrisp' there was a positive linear relationship.

In the third year (2011), there was no significant relationship between the number of feathers tied below horizontal and the flowering and fruiting variables we measured (Table 34). In the fourth year of growth (2012) the relationship between number of feathers and total blossoms was a positive quadratic relationship with the 5 feather treatment having the highest number of blossom clusters and the 0 feather having the least number. There was a positive linear relationship between the number of feathers and fruit number, fruit weight and yield (Table 35). No significant interaction between variety and number of feathers was found this year.

During the fifth year (2013) the number of feathers per tree had a quadratic relationship with fruit number per tree in which the 5-feather treatment had the highest number of fruits and the 0 feather treatment the least (Table 31). The relationship of number of feathers and cumulative yield per tree and yield per hectare was a clear positive linear relationship (Table 32). The relationship between the cumulative average shoot length and the number of feathers was a quadratic negative relationship. There was an interaction of variety and number of feathers, where average crop load showed a quadratic relationship for 'Crispin' and the 5 feathers had the highest crop load. With 'Macoun' there also was a quadratic relationship in which the 5 feathers treatment had the highest crop load and the 0 feathers had the lowest. There was a significant interaction between variety and number of feathers for average shoot length in which all the varieties except 'Jonagold' had negative linear relationship with number of feathers. With 'Jonagold' the relationship was quadratic.

Table 33. Effect of number of feathers below horizontal on flowering and fruiting of five apple varieties in the second year (2010) at Geneva, NY

Variety	Number of Feathers	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects									
Crispin	.	56.3 c[z]	20.4 b	6.83 a	19.50 a	2.40 bc	0.806 a	355 a	27.6 a
Gala	.	97.6 a	23.2 ab	4.45 c	12.73 c	2.28 c	0.436 b	192 d	6.2 d
Honeycrisp	.	93.6 a	21.0 ab	6.28 ab	17.93 ab	2.73 ab	0.815 a	300 b	15.0 bc
Jonagold	.	75.7 b	23.4 a	5.92 b	16.91 b	3.04 a	0.772 a	256 c	10.1 cd
Macoun	.	50.6 c	16.6 c	3.02 d	8.62 d	2.17 c	0.395 b	184 d	19.9 b
Variety Significance		**	**	**	**	**	**	**	**
.	0 Feathers	59.2	18.8	4.81	13.74	2.42	0.625	262	13.7
.	5 Feathers	76.8	20.9	5.33	15.23	2.50	0.640	258	17.3
.	10 Feathers	89.6	23.3	5.84	16.69	2.67	0.680	255	15.8
Regression Significance		L	L	L	L	L	NS	NS	NS
Interaction Means									
Crispin	0 Feathers	50.4	18.8	6.35	18.14	2.23	0.760	371	27.1
	5 Feathers	64.4	20.8	6.90	19.70	2.43	0.803	344	27.7
	10 Feathers	53.7	21.5	7.20	20.56	2.52	0.852	352	28.0
		Q							
Gala	0 Feathers	78.0	19.9	3.80	10.84	2.19	0.414	192	2.5
	5 Feathers	97.8	23.0	4.49	12.82	2.22	0.434	195	8.6
	10 Feathers	117.0	26.7	5.08	14.52	2.43	0.461	190	7.3
		L							
Honeycrisp	0 Feathers	51.5	18.8	5.75	16.42	2.82	0.867	309	12.7
	5 Feathers	101.9	21.4	6.25	17.86	2.61	0.762	294	17.5
	10 Feathers	127.3	22.9	6.83	19.52	2.75	0.816	297	14.9
		L							
Jonagold	0 Feathers	69.1	21.3	5.33	15.24	2.79	0.703	255	7.9
	5 Feathers	72.4	22.3	5.77	16.50	2.96	0.766	260	10.9
	10 Feathers	85.7	26.6	6.65	19.01	3.38	0.847	253	11.4
		NS							
Macoun	0 Feathers	44.9	15.0	2.78	7.93	1.99	0.370	186	20.1
	5 Feathers	44.7	16.5	3.06	8.73	2.24	0.417	190	22.1
	10 Feathers	62.1	18.3	3.22	9.21	2.26	0.398	178	17.6
		NS							
Interaction Significance		**	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 34. Effect of number of feathers below horizontal on fruiting of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Number of Feathers	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects								
Crispin	.	34.5 b^z	9.44 a	27.0 a	3.08 bc	0.84 a	293 a	15.3 a
Gala	.	64.4 a	9.52 a	27.2 a	4.86 a	0.72 ab	150 c	4.4 b
Honeycrisp	.	22.0 c	5.93 b	17.0 b	2.39 c	0.64 ab	283 a	19.4 a
Jonagold	.	40.1 b	8.14 a	23.3 a	3.98 ab	0.80 ab	232 b	6.3 b
Macoun	.	35.6 b	5.73 b	16.4 b	3.73 b	0.60 b	162 c	17.9 a
Variety Significance		**	**	**	**	NS	**	**
.	0 Feathers	40.4	7.95	22.7	3.94	0.78	221	10.5
.	5 Feathers	38.2	7.77	22.2	3.47	0.71	225	12.1
.	10 Feathers	39.6	7.62	21.8	3.43	0.67	226	14.7
Feather Significance		NS	NS	NS	NS	NS	NS	NS
Interaction Means								
Crispin	0 Feathers	40.1	10.70	30.6	3.75	0.99	278	5.4
	5 Feathers	40.0	10.72	30.6	3.58	0.95	297	15.9
	10 Feathers	23.8	7.00	20.0	1.95	0.58	303	23.8
Gala	0 Feathers	56.7	8.63	24.7	4.62	0.71	153	3.5
	5 Feathers	62.0	9.48	27.1	4.50	0.68	155	4.2
	10 Feathers	74.4	10.45	29.8	5.48	0.76	142	5.4
Honeycrisp	0 Feathers	21.6	5.84	16.7	2.63	0.71	300	23.1
	5 Feathers	19.4	5.40	15.4	2.02	0.56	283	15.1
	10 Feathers	25.1	6.56	18.8	2.53	0.66	267	19.2
Jonagold	0 Feathers	47.7	8.91	25.5	4.93	0.91	214	4.2
	5 Feathers	34.0	7.31	20.9	3.45	0.74	233	7.1
	10 Feathers	38.7	8.20	23.4	3.56	0.75	250	7.5
Macoun	0 Feathers	35.4	5.70	16.3	3.71	0.60	162	16.2
	5 Feathers	35.5	5.78	16.5	3.86	0.63	163	19.4
	10 Feathers	35.9	5.72	16.3	3.63	0.58	162	17.9
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

^{z}Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 35. Effect of number of feathers below horizontal on flowering and fruiting of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Number of Feathers	Total Blossoms per Tree	Fruit Number per Tree	Fruit Weight (kg)	Yield (t/ha)	Crop Load (Fruit number/cm² TCA	Yield Efficiency (kg/cm² TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects									
Crispin	.	166 d[z]	33.5 d	8.51 d	24.3 d	2.22 d	0.56 c	255 a	14.00 ab
Gala	.	347 a	136.6 a	19.26 a	55.0 a	9.03 a	1.26 ab	143 d	2.86 d
Honeycrisp	.	247 b	92.1 b	16.72 ab	47.8 ab	8.17 ab	1.49 a	185 c	10.46 bc
Jonagold	.	228 bc	73.8 c	14.78 bc	42.2 bc	6.31 c	1.24 ab	205 b	7.35 c
Macoun	.	195 cd	83.5 bc	11.74 cd	33.5 cd	7.82 b	1.10 b	141 d	14.56 a
Variety Significance		**	**	**	**	**	**	**	**
.	0 Feathers	208	76.9	12.97	37.0	6.61	1.11	185	9.63
.	5 Feathers	251	88.1	14.89	42.5	6.89	1.16	185	9.28
.	10 Feathers	253	87.5	14.95	42.7	6.65	1.13	188	10.32
Regression Significance		Q	L	L	L	NS	NS	NS	NS
Interaction Means									
Crispin	0 Feathers	138	34.5	8.49	24.3	2.36	0.57	258	14.40
	5 Feathers	174	35.0	8.93	25.5	2.36	0.60	249	13.76
	10 Feathers	183	31.3	8.12	23.2	1.94	0.50	257	13.89
Gala	0 Feathers	330	121.0	17.28	49.4	8.81	1.26	146	2.92
	5 Feathers	362	142.7	20.08	57.4	8.97	1.26	142	2.53
	10 Feathers	350	146.1	20.42	58.3	9.30	1.28	141	3.14
Honeycrisp	0 Feathers	197	73.7	13.58	38.8	7.66	1.42	189	11.22
	5 Feathers	274	101.5	18.50	52.9	8.29	1.52	187	9.63
	10 Feathers	269	101.1	18.08	51.7	8.57	1.52	180	10.53
Jonagold	0 Feathers	201	79.0	14.57	41.6	7.17	1.29	194	6.28
	5 Feathers	233	69.7	14.05	40.1	5.94	1.19	204	7.28
	10 Feathers	249	72.8	15.72	44.9	5.81	1.25	217	8.50
Macoun	0 Feathers	166	72.3	10.31	29.5	6.69	0.96	143	14.11
	5 Feathers	208	91.8	12.72	36.3	9.07	1.25	139	13.56
	10 Feathers	211	86.4	12.19	34.8	7.70	1.08	143	16.00
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Fruit Quality, Storage Disorders and Fruit Pack-Out when Feathers were Tied Below Horizontal

During the third and fourth year of growth (2011, 2012), the number of feathers below horizontal did not show any significant relationship to fruit quality, storage disorder incidence or fruit pack out (Tables 36, 37 and 38)

Table 36. Effect of number of feathers below horizontal on fruit quality and storage disorders of five apple varieties in the third year (2011) at Geneva, NY.

					Storage Disorders Incidence (%)		
Variety	Number of Feathers	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Senescent Breakdown	Bitter Pit	Brown Core
Main Effects							
Crispin	.	59.2 c[z]	14.5 a	15.1 a	0.0	0.0 b	0 b
Gala	.	67.6 a	14.4 a	14.3 ab	0.0	0.8 b	0 b
Honeycrisp	.	62.3 b	13.4 b	13.9 ab	0.0	16.7 a	0 b
Jonagold	.	46.3 d	13.6 b	14.1 ab	2.1	0.0 b	0 b
Macoun	.	46.7 d	12.8 c	13.2 b	0.0	0.0 b	4 ta
Variety Significance		**	**	NS	NS	**	NS
.	0 Feathers	56.5	13.8	14.1	0.4	3.3	0.8
.	5 Feathers	56.5	13.8	14.1	0.4	3.4	0.8
.	10 Feathers	56.5	13.8	14.1	0.4	3.4	0.8
Regression Significance		NS	NS	NS	NS	NS	NS
Interaction Means							
Crispin	0 Feathers	59.6	14.5	15.1	0.0	0.0	0.0
	5 Feathers	59.2	14.5	15.1	0.0	0.0	0.0
	10 Feathers	59.2	14.5	15.1	0.0	0.0	0.0
Gala	0 Feathers	67.6	14.4	14.3	0.0	0.8	0.0
	5 Feathers	67.6	14.4	14.3	0.0	0.8	0.0
	10 Feathers	67.6	14.4	14.3	0.0	0.8	0.0
Honeycrisp	0 Feathers	62.7	13.4	13.9	0.0	16.1	0.0
	5 Feathers	62.3	13.4	13.8	0.0	17.0	0.0
	10 Feathers	62.3	13.4	13.8	0.0	17.0	0.0
Jonagold	0 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
	5 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
	10 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
Macoun	0 Feathers	46.7	12.8	13.2	0.0	0.0	4.0
	5 Feathers	46.7	12.7	13.1	0.0	0.0	4.0
	10 Feathers	46.7	12.8	13.3	0.0	0.0	4.0
Interaction Significance		NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 37. Effect of number of feathers below horizontal on fruit quality and storage disorders of five apple varieties in the fourth year (2012) at Geneva, NY.

					Storage Disorders Incidence (%)					
Variety	Number of Feathers	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Superficial Scald	Bitter Pitt	Lenticel Breakdown	Senescent Breakdown	Flesh Browning	Watercore
Main Effects										
Crispin	.	61.8 b[z]	17.8 a	20.9 a	0.0 b	0.0 b	0.0 b	12.9 a	0.0 b	0.0
Gala	.	64.1 a	16.6 b	19.7 b	0.5 b	0.5 b	0.2 b	0.0 c	3.8 a	0.2
Honeycrisp	.	53.8 c	14.1 e	17.0 d	4.8 a	2.5 a	3.1 a	0.0 c	0.0 b	0.0
Jonagold	.	46.3 e	16.0 c	19.0 bc	0.3 b	0.0 b	0.4 b	8.0 ab	0.0 b	0.0
Macoun	.	49.8 d	15.1 d	18.2 c	0.0 b	0.3 b	0.0 b	3.6 bc	0.3 b	0.5
Variety Significance		**	**	**	**	*	**	**	**	NS
.	0 Feathers	55.2	15.9	18.9	1.2	0.7	0.8	4.8	0.9	0.1
.	5 Feathers	55.2	15.9	19.0	1.1	0.7	0.8	4.9	0.9	0.1
.	10 Feathers	55.2	15.9	19.0	1.1	0.6	0.8	4.9	0.8	0.1
Regression Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	0 Feathers	62.3	17.8	20.8	0.0	0.0	0.0	13.3	0.0	0.0
	5 Feathers	61.8	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
	10 Feathers	61.8	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
Gala	0 Feathers	64.1	16.6	19.7	0.5	0.5	0.2	0.0	3.8	0.2
	5 Feathers	64.1	16.6	19.7	0.5	0.5	0.2	0.0	3.8	0.2
	10 Feathers	64.1	16.6	19.7	0.5	0.5	0.2	0.0	3.8	0.2
Honeycrisp	0 Feathers	53.8	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
	5 Feathers	53.8	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
	10 Feathers	53.8	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
Jonagold	0 Feathers	46.3	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
	5 Feathers	46.3	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
	10 Feathers	46.3	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
Macoun	0 Feathers	50.3	15.2	18.3	0.0	0.4	0.0	3.6	0.4	0.5
	5 Feathers	49.8	15.0	18.2	0.0	0.4	0.0	3.7	0.4	0.5
	10 Feathers	50.3	15.0	18.2	0.0	0.0	0.0	3.6	0.0	0.5
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 38. Effect of number of feathers below horizontal on packout of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Number of Feathers	USDA Grade Packout (%) Utility	Number 1	Fancy	X Fancy
Main Effects					
Crispin	.	1.6 c[z]	7.3 b	39.9 a	51.2 b
Gala	.	7.9 b	3.3 b	18.7 d	70.1 a
Honeycrisp	.	12.7 a	20.1 a	36.7 ab	30.5 c
Jonagold	.	3.0 c	5.4 b	22.5 cd	69.1 a
Macoun	.	12.4 a	28.4 a	29.1 bc	30.1 c
Variety Significance		**	**	**	**
.	0 Feathers	7.6	13.1	29.5	49.9
.	5 Feathers	7.6	13.0	29.7	49.7
.	10 Feathers	7.7	12.8	29.4	50.1
Regression Significance		NS	NS	NS	NS
Interaction Means					
Crispin	0 Feathers	1.3	7.4	40.2	51.1
	5 Feathers	1.7	7.2	39.8	51.3
	10 Feathers	1.7	7.2	39.8	51.3
Gala	0 Feathers	7.9	3.3	18.7	70.1
	5 Feathers	7.9	3.3	18.7	70.1
	10 Feathers	7.9	3.3	18.7	70.1
Honeycrisp	0 Feathers	12.7	20.1	36.7	30.5
	5 Feathers	12.7	20.1	36.7	30.5
	10 Feathers	12.7	20.1	36.7	30.5
Jonagold	0 Feathers	3.0	5.7	23.4	67.9
	5 Feathers	3.0	5.3	22.0	69.7
	10 Feathers	3.0	5.3	22.0	69.7
Macoun	0 Feathers	12.2	28.4	28.1	31.3
	5 Feathers	12.3	29.0	30.3	28.4
	10 Feathers	12.8	27.9	28.8	30.6
Interaction Significance		NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Vegetative Growth when Feathers Left at the Natural Angle

During the first year of growth (2009), the relationship between the number of feathers at their natural angle and TCA, TCA increase, spur number or total tree length was a linear positive relationship (Table 39). However for tree height, leader length, total shoot length and average shoot length the relationship was negative. Pruning weight showed a quadratic relationship where the 5-feather treatment had the greatest pruning weight. The interaction between number of feathers and variety was significant. With 'Crispin' the relationship between number of feathers and spur number was quadratic where the 5-feather treatment had the most spurs. For 'Gala' 'Jonagold' and 'Macoun' the relationship was linear and positive. However with 'Honeycrisp' there was a positive quadratic relationship. Pruning weight had a positive linear relationship with number of feathers for 'Crispin' but a quadratic relationship for 'Gala' where the 5-feather treatment had the greatest pruning weight. The relationship of total tree length and number of feathers with 'Crispin' 'Gala' 'Honeycrisp' and 'Jonagold' was a positive linear relationship but with 'Macoun' there was no relationship.

In the second year (2010), the relationship of number of feathers at their natural angle and TCA or spur number was positive and linear (Table 40). However average shoot length showed a negative linear relationship. Pruning weight and the number of spurs pruned away was related to the number of feathers with a quadratic relationship where the 5-feather treatment was the highest and the 0-feather treatment the lowest for both variables. The number of limbs pruned away also showed a quadratic relationship with the number of feather in which the 5-feather treatment was the highest. There was a significant interaction between the number of feathers and some of response variables. The spur number per tree with 'Gala' 'Honeycrisp' and 'Jonagold' had a positive linear relationship to the number of feathers but not with 'Crispin' or 'Macoun'. Pruning weight with 'Gala' had a quadratic relationship with number of feathers in which the 5-feather treatment had the highest pruning weight but there was no relationship with the other varieties. There was a linear relationship between the number of spurs pruned away and the number of feathers with 'Crispin' but with 'Gala' there was a quadratic relationship where the 5-feather treatment had the highest number of spurs pruned away. The number of limbs pruned showed a quadratic relationship with the number of feathers for only 'Gala'.

During the third year (2011), there was a quadratic relationship between TCA and the number of feathers where the 5 and 10-feather treatments were similar and higher than the 0 feather treatment (Table 41). Total shoot length, pruning weight and total tree length had a quadratic relationship with the number of feathers where the 5-feather treatment had the highest values. Average shoot length had a negative linear relationship with the number of feathers but the number of spurs pruned away had a clear positive linear relationship.

In the fourth year (2012), TCA and average shoot length showed a quadratic relationship with the number of feathers where the 5-feather treatment had the highest values and the 0-feather treatment the lowest (Table 42). Total shoot length, pruning weight and total tree length showed a positive linear relationship with the number of feathers.

During the fifth year (2013), TCA showed a linear relationship with the number of feathers at natural angle (Table 43). The relationship between the number of feathers and cumulative leader length or total shoot length was a negative linear relationship (Table 44). Pruning weight had a quadratic relationship with number of feathers in which the 5-feather treatment showed the highest pruning weight.

Flowering and Fruiting when Feathers Left at the Natural Angle

In the second year of growth (2010) the relationship between the number of feathers at their natural angle and blossom number, fruit number per tree, fruit weight, yield, crop load or yield efficiency was a clear positive linear relationship (Table 45). There was an interaction between blossom number and the number of feathers where 'Gala', 'Jonagold' and 'Macoun' showed a positive linear relation, however 'Honeycrisp' had a positive quadratic relationship while with 'Crispin' there was no relationship.

Table 39. Effect of number of feathers at natural angle on tree growth of five apple varieties in the first year (2009) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	TCA Increase (cm^2)	Tree Height (cm)	Leader Length (cm)	Total Shoot Length (cm)	Av Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Total Tree Length (cm)
Main Effects										
Crispin		4.5 a[z]	2.4 a	193 b	35.2 c	263 c	22.2 b	14.2 c	13.4 b	578 c
Gala		4.2 b	2.2 ab	211 a	40.1 abc	479 a	22.5 b	22.6 b	18.6 a	934 a
Honeycrisp		3.7 cd	1.9 b	194 b	37.9 bc	260 cd	14.3 c	35.5 a	0.0 c	580 c
Jonagold		4.0 bc	2.5 a	181 c	43.1 ab	310 b	27.2 a	16.1 c	10.7 b	654 b
Macoun		3.6 d	1.9 b	167 d	43.8 a	222 d	22.9 b	17.4 c	1.4 c	423 d
Variety Significance		**	**	**	*	**	**	**	**	**
	0 Feathers	3.7	1.9	194	44.3	333	26.8	9.1	3.5	469
	5 Feathers	4.0	2.2	188	39.7	304	22.0	22.8	12.2	626
	10 Feathers	4.3	2.4	186	36.1	284	16.8	31.4	10.5	742
Regression Significance		L	L	L	L	L	L	L	Q	L
Interaction Means										
Crispin	0 Feathers	4.2	2.0	197	40.5	292	27.1	8.4	0.0	430
	5 Feathers	4.5	2.4	194	35.5	267	23.0	17.4	15.8	595
	10 Feathers	4.9	2.7	189	30.1	232	16.7	16.3	23.3	639
								Q	L	L
Gala	0 Feathers	3.7	1.7	219	45.6	499	26.6	9.6	6.7	670
	5 Feathers	4.4	2.4	210	38.4	499	22.6	24.6	33.2	929
	10 Feathers	4.5	2.4	203	36.2	440	18.5	33.8	17.1	1093
								L	Q	L
Honeycrisp	0 Feathers	3.5	1.7	191	38.5	280	16.7	8.1	0.0	447
	5 Feathers	3.7	2.0	197	38.4	248	14.0	40.8	0.0	580
	10 Feathers	4.0	2.1	194	36.7	253	12.3	57.6	0.0	712
								Q	NS	L
Jonagold	0 Feathers	3.7	2.3	189	48.7	347	36.8	8.2	10.4	464
	5 Feathers	3.9	2.4	177	43.1	303	27.0	15.1	12.5	635
	10 Feathers	4.4	2.8	179	37.4	282	17.8	24.9	9.2	801
								L	NS	L
Macoun	0 Feathers	3.4	1.8	170	48.5	234	26.6	11.2	0.0	383
	5 Feathers	3.6	2.0	165	43.0	219	23.6	16.1	1.3	415
	10 Feathers	3.7	1.9	166	40.3	213	18.8	24.4	2.9	463
								L	NS	NS
Interaction Significance		NS	NS	NS	NS	NS	NS	**	**	**

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 40. Effect of number of feathers at natural angle on tree growth of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length cm	Average Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects										
Crispin		9.0 b[z]	42.4 b	675 bc	24.7 b	37.7 b	136 b	9.7 b	0.94 ab	938 cd
Gala		10.3 a	55.0 a	1347 a	32.0 a	62.8 a	369 a	14.7 a	1.09 ab	1825 a
Honeycrisp		7.6 c	30.3 c	1114 a	21.3 b	44.4 b	114 b	9.6 b	0.69 b	1374 b
Jonagold		8.0 c	45.6 b	827 b	32.4 a	38.3 b	173 b	8.2 b	0.80 b	1141 bc
Macoun		7.7 c	48.9 ab	570 c	31.7 a	44.1 b	150 b	13.3 a	1.26 a	792 d
Variety Significance		**	**	**	**	**	**	**	NS	**
	0 Feathers	7.9	45.0	864	30.9	38.6	154	8.4	0.91	1197
	5 Feathers	8.8	44.9	937	28.1	44.5	228	13.3	1.08	1244
	10 Feathers	8.9	43.3	921	26.2	52.9	180	11.6	0.87	1205
Regression Significance		L	NS	NS	L	L	Q	Q	Q	NS
Interaction Means										
Crispin	0 Feathers	8.4	43.0	638	28.4	34.5	126	7.7	1.09	930
	5 Feathers	9.3	46.3	677	23.3	40.1	168	13.0	1.17	944
	10 Feathers	9.1	38.0	706	22.7	38.2	112	8.3	0.58	938
						NS	NS	L	NS	
Gala	0 Feathers	9.2	55.9	1209	34.8	54.8	239	6.1	0.75	1708
	5 Feathers	11.2	56.7	1519	32.0	60.9	508	20.8	1.55	2018
	10 Feathers	10.6	52.4	1326	29.2	72.5	372	17.8	1.00	1766
						L	Q	Q	Q	
Honeycrisp	0 Feathers	6.7	31.8	1055	23.3	30.1	103	8.4	0.58	1335
	5 Feathers	7.8	29.2	1154	20.7	42.1	134	10.5	0.83	1403
	10 Feathers	8.4	30.0	1133	19.8	61.2	105	10.0	0.67	1386
						L	NS	NS	NS	
Jonagold	0 Feathers	7.6	46.2	804	34.9	31.7	179	8.0	1.00	1151
	5 Feathers	8.1	42.7	833	32.3	37.2	207	8.8	0.67	1149
	10 Feathers	8.3	47.7	843	29.9	46.0	133	7.8	0.75	1125
						L	NS	NS	NS	
Macoun	0 Feathers	7.5	48.2	572	33.0	41.9	120	11.7	1.18	806
	5 Feathers	7.8	50.3	542	32.6	43.7	146	13.8	1.25	761
	10 Feathers	8.0	48.2	598	29.6	46.6	180	14.3	1.33	810
						NS	NS	NS	NS	
Interaction Significance		NS	NS	NS	NS	*	**	**	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 41. Effect of number of feathers at natural angle on tree growth of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects									
Crispin	.	12.7 a[z]	34.4 c	1232 c	23.2 b	424 b	34.2 d	1.2 b	1906 c
Gala	.	13.6 a	45.8 a	2159 a	27.0 a	972 a	102.4 a	2.7 a	3505 a
Honeycrisp	.	10.0 b	29.1 d	1604 b	23.9 b	448 b	62.2 bc	1.6 b	2718 b
Jonagold	.	10.9 b	39.1 b	1347 bc	24.7 b	571 b	56.4 c	1.6 b	2185 c
Macoun	.	9.7 b	39.1 b	875 d	23.2 b	501 b	71.1 b	2.5 a	1446 d
Variety Significance		**	**	**	**	**	**	**	**
.	0 Feathers	10.4	38.7	1354	25.6	455	52.9	1.8	2219
.	5 Feathers	11.8	37.4	1559	24.7	655	67.8	2.0	2507
.	10 Feathers	11.8	36.3	1416	23.0	635	74.5	1.9	2337
Regression Significance		Q	NS	Q	L	Q	L	NS	Q
Interaction Means									
Crispin	0 Feathers	11.6	32.5	1143	24.6	299	22.4	1.3	1781
	5 Feathers	13.5	37.7	1291	23.2	526	40.4	1.2	1968
	10 Feathers	12.9	32.9	1253	21.9	436	38.9	1.2	1959
Gala	0 Feathers	12.5	47.6	2044	26.3	755	82.9	2.6	3253
	5 Feathers	14.5	46.4	2453	28.5	1170	112.1	3.1	3972
	10 Feathers	13.8	43.6	2004	26.2	1007	112.9	2.5	3330
Honeycrisp	0 Feathers	8.5	31.5	1337	24.8	303	47.3	1.3	2392
	5 Feathers	10.6	29.0	1897	24.8	530	61.0	1.8	3052
	10 Feathers	10.8	26.8	1577	22.0	511	78.3	1.8	2710
Jonagold	0 Feathers	10.1	38.8	1297	27.6	425	39.4	1.4	2101
	5 Feathers	11.1	40.3	1420	24.6	583	58.3	1.6	2296
	10 Feathers	11.6	38.2	1324	22.0	707	71.7	1.8	2166
Macoun	0 Feathers	9.6	43.2	894	24.5	482	71.3	2.8	1466
	5 Feathers	9.6	34.3	810	22.6	509	71.2	2.4	1352
	10 Feathers	9.9	40.0	924	22.7	512	70.9	2.2	1521
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 42. Effect of number of feathers at natural angle on tree growth of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average shoot Length (cm)	Pruning Weight (g)	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effects								
Crispin	.	15.9 a[z]	34.5 a	2304 bc	24.2 a	800 b	2.8 b	3536 b
Gala	.	15.5 a	37.4 a	3980 a	26 a	1166 a	3.9 a	6138 a
Honeycrisp	.	11.1 c	28.3 b	1901cd	21.3 b	546 c	2.5 bc	3505 b
Jonagold	.	12.8 b	34.6 a	2479 b	25.1 a	726 b	2.5 bc	3826 b
Macoun	.	11.1 c	25.3 b	1451 d	19.9 b	507 c	2.1 c	2326 c
Variety Significance		**	**	**	**	**	**	**
.	0 Feathers	12.1	30.3	2131	22.0	637	2.6	3485
.	5 Feathers	14.0	33.8	2502	24.0	803	2.8	4062
.	10 Feathers	13.7	31.9	2619	23.8	801	2.8	4036
Regression Significance		Q	NS	L	Q	L	NS	L
Interaction Means								
Crispin	0 Feathers	14.5	30.5	1929	22.0	650	2.5	3072
	5 Feathers	17.3	37.2	2509	25.5	883	3.1	3800
	10 Feathers	15.9	35.5	2442	25.0	854	2.8	3696
Gala	0 Feathers	14.2	38.0	3834	24.8	1067	4.0	5877
	5 Feathers	16.8	36.7	3962	25.9	1291	4.1	6415
	10 Feathers	15.5	37.4	4141	27.4	1150	3.7	6146
Honeycrisp	0 Feathers	9.5	28.4	1496	20.2	429	2.3	2834
	5 Feathers	11.8	30.4	2078	22.1	596	2.4	3975
	10 Feathers	12.0	25.9	2129	21.6	613	2.8	3707
Jonagold	0 Feathers	11.6	30.3	1966	23.3	579	2.3	3263
	5 Feathers	13.1	38.8	2587	26.3	729	2.5	4007
	10 Feathers	13.8	34.7	2883	25.9	871	2.8	4207
Macoun	0 Feathers	11.0	24.0	1348	19.7	446	2.2	2242
	5 Feathers	11.0	26.2	1497	20.4	554	2.2	2307
	10 Feathers	11.3	25.8	1500	19.5	517	1.9	2423
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 43. Effect of number of feathers at natural angle on tree growth and fruiting of five apple varieties in the fifth year (2013) at Geneva, NY.

Variety	Number of Feathers	TCA (cm^2)	TCA Increase (cm^2)	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects										
Crispin	.	19.8 a[z]	3.9 a	125.4 a	32.1 a	91.8 a	6.62 ab	1.65 a	254 a	5.9 b
Gala	.	18.9 a	3.4 ab	131.7 a	21.8 b	62.4 b	7.26 a	1.2 b	167 c	3.4 b
Honeycrisp	.	14.1 bc	3.0 bc	46.8 c	9.3 d	26.6 d	3.65 d	0.71 d	221 b	19.3 a
Jonagold	.	15.5 b	2.6 cd	82.4 b	20.7 b	59.1 b	5.46 c	1.36 b	253 a	4.7 b
Macoun	.	13.4 c	2.3 d	77.4 b	12.1 c	34.5 c	5.96 bc	0.93 c	157 c	17.7 a
Variety Significance		**	**	**	**	**	**	**	**	**
.	0 Feathers	15.0	2.9	93.2	18.7	53.4	6.22	1.23	207	11.5
.	5 Feathers	17.0	3.1	91.0	19.1	54.7	5.45	1.11	211	9.9
.	10 Feathers	16.9	3.2	93.1	19.6	56.1	5.67	1.17	214	9.1
Regression Significance		L	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	0 Feathers	18.2	3.7	125.2	31.9	91.1	7.11	1.79	257	5.0
	5 Feathers	21.4	4.1	127.8	32.7	93.5	6.39	1.55	249	6.1
	10 Feathers	19.9	4.0	123.1	31.7	90.7	6.40	1.63	258	6.6
Gala	0 Feathers	17.5	3.3	138.1	22.8	65.1	8.21	1.35	166	5.0
	5 Feathers	20.2	3.4	130.1	21.6	61.6	6.60	1.10	167	2.5
	10 Feathers	19.1	3.5	126.8	21.1	60.4	6.91	1.14	167	2.6
Honeycrisp	0 Feathers	12.3	2.8	46.8	8.1	23.0	3.98	0.68	208	24.0
	5 Feathers	14.8	2.9	48.5	9.7	27.8	3.67	0.71	225	19.4
	10 Feathers	15.2	3.2	45.0	10.2	29.0	3.30	0.74	230	14.4
Jonagold	0 Feathers	13.8	2.2	77.9	19.1	54.5	5.77	1.40	247	5.1
	5 Feathers	15.9	2.8	81.8	20.6	58.9	5.28	1.32	253	4.8
	10 Feathers	16.7	2.9	87.6	22.4	63.9	5.34	1.35	257	4.4
Macoun	0 Feathers	13.5	2.4	79.3	12.2	34.7	6.08	0.93	156	18.5
	5 Feathers	13.1	2.1	70.0	11.2	32.1	5.42	0.87	160	17.0
	10 Feathers	13.6	2.3	83.0	12.8	36.7	6.39	0.98	156	17.5
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable, either linearly, quadratically or not related, respectively.

Table 44. Effect of number of feathers at natural angle on cumulative tree growth and fruiting of five apple varieties during five years at Geneva, NY.

		Cumulative Growth and Fruiting Measurements						Average		
Variety	Number of Feathers	Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Crop Load (Fruit number/cm^2 TCA)	Fruit Size (g)	Shoot Length (cm)
Crispin	.	147 b[z]	4473 b	1373 bc	57.3 a	163.7 a	3 ab	3.5 d	297.8 a	23.6 b
Gala	.	178 a	7964 a	2525 a	52.2 b	149.3 b	2.86 b	5.5 a	164.9 d	26.9 a
Honeycrisp	.	126 c	4880 b	1107 c	37.9 c	108.2 c	2.78 b	4.1 c	249.3 b	20.2 c
Jonagold	.	161 b	4940 b	1481 b	49.8 b	142.2 b	3.32 a	4.6 bc	235.6 c	27.4 a
Macoun	.	157 b	3118 c	1160 c	31.1 d	89 d	2.41 c	4.7 b	159.3 d	24.4 b
Variety Significance		**	**	**	**	**	**	**	**	**
.	0 Feathers	158	4682	1250	44.4	126.9	3.01	4.8	219	26.3
.	5 Feathers	155	5287	1698	45.8	130.8	2.78	4.2	225	24.7
.	10 Feathers	148	5241	1626	46.7	133.5	2.84	4.4	222	22.5
Regression Significance		L	L	Q	NS	NS	NS	Q	NS	L
Interaction Means										
Crispin	0 Feathers	147	4002	1075	57.4	164.0	3.22	3.9	291	25.5
	5 Feathers	157	4744	1594	57.7	164.9	2.88	3.3	304	23.7
	10 Feathers	137	4634	1426	56.8	162.1	2.93	3.4	298	21.6
Gala	0 Feathers	187	7585	2067	52.5	150.0	3.12	6.0	164	28.1
	5 Feathers	178	8433	3003	52.6	150.4	2.64	5.0	165	27.3
	10 Feathers	170	7911	2546	51.6	147.5	2.80	5.4	166	25.3
Honeycrisp	0 Feathers	130	4169	835	33.2	95.0	2.75	4.3	251	21.2
	5 Feathers	127	5378	1260	40.7	116.4	2.86	4.1	251	20.4
	10 Feathers	119	5092	1228	39.7	113.4	2.73	3.9	246	18.9
Jonagold	0 Feathers	164	4414	1194	47.9	136.8	3.56	5.2	227	30.6
	5 Feathers	161	5073	1531	48.2	137.6	3.16	4.2	239	27.5
	10 Feathers	158	5332	1720	53.3	152.2	3.24	4.3	241	23.9
Macoun	0 Feathers	164	3048	1047	30.9	88.4	2.37	4.6	162	26.0
	5 Feathers	154	3068	1211	30.1	86.1	2.35	4.6	159	24.8
	10 Feathers	154	3234	1212	32.3	92.4	2.52	5.0	158	22.6
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 45. Effect of number of feathers at natural angle on flowering and fruiting of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Number of Feathers	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects									
Crispin		58.1 c[z]	20.2 bc	7.12 a	20.3 a	2.27 bc	0.807 a	372 a	32.0 a
Gala		98.0 a	23.0 ab	4.46 c	12.8 c	2.27 bc	0.439 b	194 d	3.8 d
Honeycrisp		91.8 a	20.3 bc	6.12 b	17.5 b	2.67 b	0.807 a	304 b	14.1 bc
Jonagold		76.1 b	25.6 a	6.46 ab	18.5 ab	3.19 a	0.808 a	256 c	8.9 cd
Macoun		53.4 c	16.9 c	3.01 d	8.61 d	2.19 c	0.392 b	180 d	20.4 b
Variety Significance		**	**	**	**	**	**	**	**
	0 Feathers	59.2	18.8	4.81	13.7	2.42	0.625	262	13.7
	5 Feathers	77.2	21.4	5.55	15.9	2.48	0.650	264	17.2
	10 Feathers	89.9	23.4	5.95	17.0	2.67	0.681	258	16.3
Regression Significance		L	L	L	L	L	L	NS	NS
Interaction Means									
Crispin	0 Feathers	50.4	18.8	6.35	18.1	2.23	0.760	371	27.1
	5 Feathers	60.8	20.3	7.50	21.4	2.27	0.846	376	36.6
	10 Feathers	62.3	21.3	7.43	21.2	2.30	0.810	368	31.8
		NS							
Gala	0 Feathers	78.0	19.9	3.80	10.8	2.19	0.414	192	2.5
	5 Feathers	98.0	24.0	4.72	13.5	2.16	0.424	197	4.5
	10 Feathers	118.0	25.2	4.89	14.0	2.46	0.477	194	4.4
		L							
Honeycrisp	0 Feathers	51.5	18.8	5.75	16.4	2.82	0.867	309	12.7
	5 Feathers	106.3	19.3	5.91	16.9	2.45	0.751	308	12.2
	10 Feathers	117.8	22.8	6.71	19.2	2.73	0.804	295	17.3
		Q							
Jonagold	0 Feathers	69.1	21.3	5.33	15.2	2.79	0.703	255	7.9
	5 Feathers	70.9	25.4	6.47	18.5	3.15	0.807	258	10.3
	10 Feathers	88.4	30.1	7.58	21.7	3.63	0.914	254	8.4
		L							
Macoun	0 Feathers	44.9	15.0	2.78	7.9	1.99	0.370	186	20.1
	5 Feathers	51.8	18.0	3.09	8.8	2.33	0.402	173	21.2
	10 Feathers	62.8	17.6	3.15	9.0	2.23	0.401	181	19.8
		L							
Interaction Significance		**	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

In the third year (2011), there were no significant relationships between number of feather at their natural angle and fruiting (Table 46). However during the fourth year (2012), total blossoms had a positive linear relationship with number of feathers (Table 47). Crop load and yield efficiency were negatively related to the number of feathers. A significant interaction between number of feathers with fruit weight and yield was observed. For 'Honeycrisp' the relationship was quadratic where the 5-feather treatment had the highest fruit weight but there was no relationship between yield and the number of feathers for the other varieties.

During the fifth year (2013) there were no relationships between the number of feathers and the natural angle and flowering or fruiting variables (Table 43).

Cumulative yield over the five years of the experiment was not related to the number of feathers in the natural position. However, average crop load showed a quadratic relationship with the number of feathers where the 0-feather treatment had the highest crop load and the 5-feather had the lowest. Also average shoot length average showed a negative linear relationship with the number of feathers over this five-year period (Table 44).

Fruit Quality, Storage Disorders and Fruit Pack-Out when Feathers Left at the Natural Angle

During the third and fourth years of the study (2011, 2012), the number of feathers at natural angle did not show any significant relationships to fruit quality, storage disorder incidence and fruit pack out (Tables 48, 49 and 50)

Table 47. Effect of number of feathers at natural angle on fruiting of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Number of Feathers	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects								
Crispin	.	34.9 b[z]	9.89 a	28.3 a	3.09 b	0.86 a	299 a	10.7 b
Gala	.	61.8 a	9.36 a	26.7 a	4.65 a	0.70 abc	152 d	5.6 b
Honeycrisp	.	23.1 c	6.15 b	17.6 b	2.48 b	0.66 bc	277 b	17.1 a
Jonagold	.	41.9 b	8.76 a	25.0 a	4.02 a	0.83 ab	224 c	6.2 b
Macoun	.	37.7 b	5.97 b	17.1 b	3.94 a	0.63 c	159 d	18.6 a
Variety Significance		**	**	**	**	*	**	**
.	0 Feathers	40.4	7.95	22.7	3.94	0.78	221	10.5
.	5 Feathers	39.1	8.00	22.9	3.47	0.71	225	11.7
.	10 Feathers	39.9	8.10	23.2	3.51	0.71	221	12.6
Regression Significance		NS	NS	NS	NS	NS	NS	NS
Interaction Means								
Crispin	0 Feathers	40.1	10.70	30.6	3.75	0.99	278	5.4
	5 Feathers	31.8	9.49	27.1	2.70	0.79	317	11.5
	10 Feathers	33.3	9.54	27.3	2.88	0.81	300	14.7
Gala	0 Feathers	56.7	8.63	24.7	4.62	0.71	153	3.5
	5 Feathers	63.3	9.42	26.9	4.37	0.65	150	8.6
	10 Feathers	65.5	10.03	28.6	4.92	0.75	155	4.9
Honeycrisp	0 Feathers	21.6	5.84	16.7	2.63	0.71	300	23.1
	5 Feathers	25.5	6.64	19.0	2.60	0.67	265	12.3
	10 Feathers	22.3	5.97	17.1	2.22	0.60	264	15.4
Jonagold	0 Feathers	47.7	8.91	25.5	4.93	0.91	214	4.2
	5 Feathers	38.3	8.51	24.3	3.73	0.82	229	5.5
	10 Feathers	39.6	8.85	25.3	3.41	0.77	228	8.9
Macoun	0 Feathers	35.4	5.70	16.3	3.71	0.60	162	16.2
	5 Feathers	38.5	6.05	17.3	4.01	0.63	159	20.2
	10 Feathers	39.0	6.12	17.5	4.09	0.64	158	19.1
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 47. Effect of number of feathers at natural angle on flowering and fruiting on five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Number of Feathers	Total Blossoms per Tree	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effects									
Crispin		151 c[z]	31.6 d	8.17 b	23.3 b	2.03 c	0.52 c	266.4 a	14.41 ab
Gala		335 a	115.0 a	16.58 a	47.4 a	7.66 a	1.10 b	146.3 d	2.92 d
Honeycrisp		218 b	84.0 b	16.30 a	46.6 a	7.54 a	1.46 a	195.4 c	12.01 b
Jonagold		215 b	67.9 c	13.87 a	39.6 a	5.63 b	1.12 b	211.0 b	7.87 c
Macoun		167 c	71.9 bc	10.09 b	28.8 b	6.79 a	0.95 b	141.1 d	15.52 a
Variety Significance		**	**	**	**	**	**	**	**
	0 Feathers	208	76.9	12.97	37.0	6.61	1.11	185	9.63
	5 Feathers	213	72.5	13.07	37.3	5.55	0.99	197	11.08
	10 Feathers	230	73.0	13.03	37.2	5.67	1.00	194	10.88
Regression Significance		L	NS	NS	NS	L	L	NS	NS
Interaction Means									
Crispin	0 Feathers	138	34.5	8.49	24.3	2.36	0.57	258	14.40
	5 Feathers	155	30.1	8.00	22.8	1.91	0.50	273	11.84
	10 Feathers	160	30.4	8.04	23.0	1.87	0.49	267	16.97
				NS	NS	NS			
Gala	0 Feathers	330	121.0	17.28	49.4	8.81	1.26	146	2.92
	5 Feathers	340	117.2	16.92	48.3	6.97	1.00	146	2.33
	10 Feathers	334	106.9	15.57	44.5	7.14	1.03	147	3.45
				NS	NS	NS			
Honeycrisp	0 Feathers	197	73.7	13.58	38.8	7.66	1.42	189	11.22
	5 Feathers	217	90.8	18.46	52.7	7.72	1.56	204	14.32
	10 Feathers	240	87.5	16.85	48.1	7.22	1.39	194	10.47
				Q	Q	NS			
Jonagold	0 Feathers	201	79.0	14.57	41.6	7.17	1.29	194	6.28
	5 Feathers	206	59.3	12.54	35.8	4.81	0.99	216	9.32
	10 Feathers	236	65.4	14.50	41.4	4.90	1.08	223	8.00
				NS	NS	L			
Macoun	0 Feathers	166	72.3	10.31	29.5	6.69	0.96	143	14.11
	5 Feathers	156	68.8	9.76	27.9	6.44	0.91	143	16.84
	10 Feathers	178	74.5	10.21	29.2	7.22	0.98	138	15.50
				NS	NS	NS			
Interaction Significance		NS	NS	**	**	*	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 48. Effect of number of feathers at natural angle on fruit quality and storage disorders of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Number of Feathers	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Storage Disorders Incidence (%) Senescent Breakdown	Bitter Pit	Brown Core
Main Effects							
Crispin	.	59.2 c[z]	14.5 a	15.1 a	0.0	0.0 b	0.0
Gala	.	67.6 a	14.4 a	14.3 ab	0.0	0.9 b	0.0
Honeycrisp	.	62.3 b	13.4 b	13.9 ab	0.0	16.7 a	0.0
Jonagold	.	46.3 d	13.6 b	14.1 ab	2.1	0.0 b	0.0
Macoun	.	46.7 d	12.8 c	13.2 b	0.0	0.0 b	3.8
Variety Significance		**	**	NS	NS	**	NS
.	0 Feathers	56.5	13.8	14.1	0.4	3.3	0.8
.	5 Feathers	56.0	13.8	14.1	0.4	3.4	0.8
.	10 Feathers	56.0	13.8	14.1	0.4	3.3	0.8
Regression Significance		NS	NS	NS	NS	NS	NS
Interaction Means							
Crispin	0 Feathers	59.6	14.5	15.1	0.0	0.0	0.0
	5 Feathers	59.2	14.5	15.1	0.0	0.0	0.0
	10 Feathers	59.2	14.5	15.1	0.0	0.0	0.0
Gala	0 Feathers	67.6	14.4	14.3	0.0	0.8	0.0
	5 Feathers	67.6	14.5	14.3	0.0	0.9	0.0
	10 Feathers	67.6	14.4	14.3	0.0	0.8	0.0
Honeycrisp	0 Feathers	62.7	13.4	13.9	0.0	16.1	0.0
	5 Feathers	62.3	13.4	13.8	0.0	17.0	0.0
	10 Feathers	62.3	13.4	13.8	0.0	17.0	0.0
Jonagold	0 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
	5 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
	10 Feathers	46.3	13.6	14.1	2.1	0.0	0.0
Macoun	0 Feathers	46.7	12.8	13.2	0.0	0.0	4.0
	5 Feathers	46.7	12.8	13.3	0.0	0.0	3.7
	10 Feathers	46.7	12.8	13.3	0.0	0.0	3.7
Interaction Significance		NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at $P \leq 0.05$. *, ** or NS indicate treatment had a significant effect at $P \leq 0.05$ or $P \leq 0.01$ levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 49. Effect of number of feathers at natural angle on fruit quality and storage disorders of five apple varieties in the fourth year (2012) at Geneva, NY.

					Storage Disorders Incidence (%)					
Variety	Number of Feathers	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Superficial Scald	Bitter Pit	Lenticel Breakdown	Senescent Breakdown	Flesh Browning	Watercore
Main Effects										
Crispin	.	61.83 b[z]	17.8 a	20.9 a	0.0 b	0.0 b	0.0 b	12.9 a	0.0 b	0.0
Gala	.	64.05 a	16.5 b	19.7 b	0.4 b	0.5 b	0.2 b	0.0 c	3.9 a	0.2
Honeycrisp	.	53.82 c	14.1 e	17.0 d	4.8 a	2.5 a	3.1 a	0.0 c	0.0 b	0.0
Jonagold	.	46.26 e	16.0 c	19.0 bc	0.3 b	0.0 b	0.4 b	8.0 ab	0.0 b	0.0
Macoun	.	49.82 d	15.1 d	18.2 c	0.0 b	0.4 b	0.0 b	3.6 bc	0.4 b	0.5
Variety Significance		**	**	**	**	*	**	**	**	NS
.	0 Feathers	55.16	15.9	18.9	1.2	0.7	0.8	4.8	0.9	0.1
.	5 Feathers	55.16	15.9	19.0	1.1	0.7	0.8	4.9	0.8	0.1
.	10 Feathers	55.16	15.9	19.0	1.1	0.7	0.7	4.9	0.8	0.1
Regression Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	0 Feathers	62.28	17.8	20.8	0.0	0.0	0.0	13.3	0.0	0.0
	5 Feathers	61.83	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
	10 Feathers	61.83	17.8	20.9	0.0	0.0	0.0	12.7	0.0	0.0
Gala	0 Feathers	64.05	16.6	19.7	0.5	0.5	0.2	0.0	3.8	0.2
	5 Feathers	64.05	16.5	19.8	0.3	0.5	0.3	0.0	3.9	0.2
	10 Feathers	64.05	16.6	19.7	0.5	0.5	0.2	0.0	3.8	0.2
Honeycrisp	0 Feathers	53.82	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
	5 Feathers	53.82	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
	10 Feathers	53.82	14.1	17.0	4.8	2.5	3.1	0.0	0.0	0.0
Jonagold	0 Feathers	46.26	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
	5 Feathers	46.26	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
	10 Feathers	46.26	16.0	19.0	0.3	0.0	0.4	8.0	0.0	0.0
Macoun	0 Feathers	50.26	15.2	18.3	0.0	0.4	0.0	3.6	0.4	0.5
	5 Feathers	49.82	15.1	18.2	0.0	0.4	0.0	3.7	0.4	0.5
	10 Feathers	50.26	15.1	18.2	0.0	0.4	0.0	3.7	0.4	0.5
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Table 50. Effect of number of feathers at natural angle on packout of five apple varieties in the fourth year (2012) at Geneva, NY.

		USDA Grade Packout (%)			
Variety	Number of Feathers	Utility	Number 1	Fancy	X Fancy
Main Effects					
Crispin	.	1.6 c[z]	7.3 b	39.9 a	51.2 b
Gala	.	7.8 b	3.4 b	18.9 d	69.8 a
Honeycrisp	.	12.7 a	20.1 a	36.7 ab	30.5 c
Jonagold	.	3.0 c	5.4 b	22.5 cd	69.1 a
Macoun	.	12.1 ab	27.9 a	28.6 bc	31.5 c
Variety Significance		**	**	**	**
.	0 Feathers	7.6	13.1	29.5	49.9
.	5 Feathers	7.6	13.2	29.8	49.5
.	10 Feathers	7.6	13.0	29.4	50.0
Regression Significance		NS	NS	NS	NS
Interaction Means					
Crispin	0 Feathers	1.3	7.4	40.2	51.1
	5 Feathers	1.7	7.2	39.8	51.3
	10 Feathers	1.7	7.2	39.8	51.3
Gala	0 Feathers	7.9	3.3	18.7	70.1
	5 Feathers	7.7	3.6	19.5	69.1
	10 Feathers	7.9	3.3	18.7	70.1
Honeycrisp	0 Feathers	12.7	20.1	36.7	30.5
	5 Feathers	12.7	20.1	36.7	30.5
	10 Feathers	12.7	20.1	36.7	30.5
Jonagold	0 Feathers	3.0	5.7	23.4	67.9
	5 Feathers	3.0	5.3	22.0	69.7
	10 Feathers	3.0	5.3	22.0	69.7
Macoun	0 Feathers	12.2	28.4	28.1	31.3
	5 Feathers	12.0	27.6	28.8	31.6
	10 Feathers	12.0	27.6	28.8	31.6
Interaction Significance		NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively. L, Q or NS indicate the number of feathers was related significantly to the response variable either linearly, quadratically or not related, respectively.

Effect of Biostimulants

Vegetative Growth

During the first year of growth (2009), the biostimulants treatment did not show any significant differences from the no biostimulant control treatment (Table 51). However the interaction between variety and biostimulants treatment was significant with two variables. The total shoot length was increased with biostimulants treatment for ‘Jonagold’, but for ‘Honeycrisp’ the control treatment had higher total shoot length. With ‘Crispin’, ‘Gala’ and ‘Macoun’ there was no significant effect. There was also a significant difference in total tree length for ‘Gala’ where the control had higher tree length than the biostimulants treatment. With ‘Crispin’, ‘Honeycrisp’, ‘Jonagold’ and ‘Macoun’ there were no differences in total tree length.

In the second year (2010), the control treatment had greater TCA than the biostimulants treatment (Table 52). However there was a significant interaction between variety and biostimulant treatment with spur number per tree. The control treatment had higher spur number than the biostimulant treatment with ‘Gala’ and ‘Honeycrisp’ but with ‘Jonagold’ the biostimulants had the higher spur number.

During the third year (2011), biostimulants treatment increased the average shoot length significantly compared to the control (Table 53). The number of spurs pruned per tree showed a significant interaction between variety and biostimulant treatment where treated trees had higher spurs pruned for ‘Gala’ and lower spurs number for ‘Honeycrisp’ compared to the untreated trees. With ‘Crispin’, ‘Jonagold’, and ‘Macoun’ there were no differences between the treatments.

In the fourth year (2012), biostimulants increased TCA significantly compared to the control treatment (Table 54). No significant interactions between variety and biostimulant treatment were found in 2012.

In the last year (2013), biostimulants increased TCA significantly compared to the untreated control treatment (Table 55). There was a significant interaction between variety and biostimulant treatment where biostimulants had the highest TCA increase for ‘Crispin’ and the lowest for ‘Honeycrisp’. There was no significant difference between the treatments for ‘Gala’ ‘Jonagold’ and Macoun.

During the five years of this experiment, biostimulants increased the average shoot length significantly compared to the control (Table 56). However no more differences were observed for the other cumulative variables between the biostimulant treatment and the control.

Table 51. Effect of biostimulants on tree growth of five apple varieties in the first year (2009) at Geneva, NY.

Variety	Biostimulants treatment	TCA (cm^2)	TCA Increase (cm^2)	Tree Height (cm)	Leader Length (cm)	Total Shoot Length (cm)	Av Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Total Tree Length (cm)
Main Effect Means										
Crispin	.	4.9 a[z]	2.7 ab	201 b	38.8 b	331 c	28.7 b	10.6 c	5.9 ab	598 b
Gala	.	4.4 b	2.4 b	221 a	52.9 a	575 a	26.3 b	17.2 b	15.0 a	925 a
Honeycrisp	.	3.7 c	2.0 c	193 bc	40.3 b	262 d	14.5 c	23.8 a	6.3 ab	515 c
Jonagold	.	4.4 b	2.8 a	187 c	50.1 a	422 b	35.4 a	12.7 c	8.1 ab	666 b
Macoun	.	3.7 c	2.0 c	174 d	48.2 a	259 d	27.8 b	12.9 bc	2.7 b	424 d
Variety Significance		**	**	**	**	**	**	**	**	**
.	No Biostimulants	4.2	2.4	198	47.9	377	26.0	15.1	6.4	607
.	Biostimulants	4.2	2.4	193	44.2	366	27.0	15.9	8.9	610
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	No Biostimulants	4.9	2.7	201	39.5	337 cd	28.3	11.0	8.1	581 d
	Biostimulants	5.0	2.7	201	38.1	326 cd	29.1	10.3	3.8	615 cd
Gala	No Biostimulants	4.4	2.4	227	58.5	606 a	26.6	16.0	16.9	1007 a
	Biostimulants	4.4	2.4	216	47.4	544 a	26.0	18.4	13.1	856 b
Honeycrisp	No Biostimulants	4.0	2.1	196	42.8	306 d	16.5	21.9	6.3	557 de
	Biostimulants	3.5	1.8	191	37.8	218 e	12.4	25.6	6.3	474 ef
Jonagold	No Biostimulants	4.3	2.7	189	49.4	379 c	32.2	13.8	0.0	620 cd
	Biostimulants	4.5	2.9	185	50.8	464 b	38.5	11.6	16.3	707 c
Macoun	No Biostimulants	3.6	1.9	174	49.4	239 e	26.5	12.3	0.0	396 f
	Biostimulants	3.7	2.0	174	47.1	277 d e	28.9	13.4	5.0	453 f
Interaction Significance		NS	NS	NS	NS	*	NS	NS	NS	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 52. Effect of biostimulants on tree growth of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Biostimulants treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length cm	Average Shoot Length (cm)	Spur Number per Tree	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means										
Crispin	.	9.6 b[z]	47.3 b	711 cd	28.2 b	42.9 b	96.9 b	6.6 ab	0.63 ab	1042 c
Gala	.	10.7 a	63.4 a	1474 a	33.4 a	64.6 a	294.3 a	10.3 a	0.75 a	2049 a
Honeycrisp	.	7.6 c	31.3 c	1094 b	22.1 c	37.7 b	79.7 b	7.8 ab	0.44 b	1356 b
Jonagold	.	8.3 c	49.5 b	804 c	31.8 a	43.6 b	137.8 b	5.9 b	0.4 b	1226 bc
Macoun	.	8.0 c	48.1 b	554 d	31.4 ab	45.1 b	95 b	7.8 ab	0.73 a	813 d
Variety Significance		**	**	**	**	**	*	NS	*	**
.	No Biostimulants	8.5 b	47.7	891	28.7	48.6	121.8	6.8	0.53	1268
.	Biostimulants	9.2 a	48.1	972	30.0	45.1	160.3	8.5	0.65	1338
Treatment Significance		*	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	No Biostimulants	8.8	44.4	653	26.7	42.3 cde	82.5	6.8	0.63	989
	Biostimulants	10.3	50.1	769	29.7	43.5 cd	111.3	6.4	0.63	1095
Gala	No Biostimulants	10.3	66.8	1414	32.7	71.9 a	208.8	7.4	0.50	2020
	Biostimulants	11.0	60.1	1534	34.2	57.4 b	379.8	13.3	1.00	2078
Honeycrisp	No Biostimulants	7.8	30.6	1089	21.7	45.4 bcd	90.6	7.6	0.50	1395
	Biostimulants	7.4	31.9	1099	22.5	30.0 e	68.8	7.9	0.38	1316
Jonagold	No Biostimulants	7.9	50.1	729	31.2	36.8 de	140.6	4.3	0.29	1109
	Biostimulants	8.7	48.9	879	32.4	50.4 bc	135.0	7.3	0.50	1343
Macoun	No Biostimulants	7.5	46.4	525	31.7	46.3 bcd	81.4	8.0	0.71	764
	Biostimulants	8.4	49.5	579	31.1	44.1 cd	106.9	7.6	0.75	856
Interaction Significance		NS	NS	NS	NS	*	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 53. Effect of biostimulants on tree growth of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Biostimulants treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average Shoot Length (cm)	Pruning Weight (g)	Spurs Pruned per Tree	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means									
Crispin	.	14.0 a[z]	32.4 b	1243 b	23.3 b	398 b	33.2 c	1.06 ab	1954 cd
Gala	.	14.3 a	47.4 a	1991 a	26.9 a	732 a	90.9 a	1.75 a	3465 a
Honeycrisp	.	9.8 b	33.5 b	1683 ab	24.4 ab	313 b	42.1 bc	0.81 b	2777 b
Jonagold	.	11.5 b	35.6 b	1289 b	22.4 b	461 b	52.3 b	1.19 ab	2093 c
Macoun	.	10.1 b	38.5 b	781 c	22.3 b	416 b	56.1 b	1.67 a	1335 d
Variety Significance		**	**	**	*	**	**	NS	**
.	No Biostimulants	11.7	37.4	1313	23.0 b	441	54.3	1.28	2204
.	Biostimulants	12.2	37.5	1496	24.8 a	488	55.5	1.30	2468
Treatment Significance		NS	NS	NS	**	NS	NS	NS	NS
Interaction Means									
Crispin	No Biostimulants	13.4	27.8	1204	22.2	327	25.4 e	1.13	1857
	Biostimulants	14.6	37.0	1282	24.4	469	41.0 de	1.00	2051
Gala	No Biostimulants	14.0	50.0	1740	25.2	628	77.5 b	1.25	3154
	Biostimulants	14.6	44.8	2243	28.6	836	104.4 a	2.25	3777
Honeycrisp	No Biostimulants	10.6	36.1	1538	25.0	378	56.1 cd	1.00	2627
	Biostimulants	9.0	30.9	1829	23.8	248	28.1 e	0.63	2927
Jonagold	No Biostimulants	11.0	34.1	1221	20.9	498	55.0 cd	1.38	1950
	Biostimulants	12.0	37.1	1357	23.9	425	49.6 cd	1.00	2237
Macoun	No Biostimulants	9.2	39.3	796	21.2	365	57.9 c	1.71	1321
	Biostimulants	10.8	37.8	768	23.3	460	54.5 cd	1.63	1346
Interaction Significance		NS	NS	NS	NS	NS	**	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 54. Effect of biostimulants on tree growth of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Biostimulants treatment	TCA (cm^2)	Leader Length (cm)	Total Shoot Length (cm)	Average shoot Length (cm)	Pruning Weight (g)	Limbs Pruned per Tree	Total Tree Length (cm)
Main Effect Means								
Crispin	.	17.6 a[z]	38.1 a	2619 b	25.0 a	856 ab	2.8 ab	3862 b
Gala	.	16.0 a	35.0 a	3993 a	25.4 a	1128 a	3.4 a	5984 a
Honeycrisp	.	11.0 b	26.8 bc	1791 bc	20.9 b	484 c	2.4 b	3474 b
Jonagold	.	13.3 b	34.2 ab	2544 b	24.2 a	706 bc	2.4 b	3833 b
Macoun	.	11.5 b	25.0 c	1445 c	18.4 b	543 c	2.3 b	2226 c
Variety Significance		**	*	**	**	**	*	**
.	No Biostimulants	13.4 b	32.2	2394	22.2	669	2.4	3707
.	Biostimulants	14.4 a	31.7	2586	23.4	821	2.9	4082
Treatment Significance		*	NS	NS	NS	NS	NS	NS
Interaction Means								
Crispin	No Biostimulants	16.1	40.9	2377	22.9	763	2.6	3581
	Biostimulants	19.1	35.3	2861	27.1	950	2.9	4143
Gala	No Biostimulants	15.7	33.4	3699	24.0	1019	3.1	5439
	Biostimulants	16.4	36.6	4287	26.8	1238	3.8	6530
Honeycrisp	No Biostimulants	11.7	27.5	2074	21.7	519	2.4	3612
	Biostimulants	10.2	26.1	1509	20.0	450	2.4	3337
Jonagold	No Biostimulants	12.7	34.0	2319	23.4	600	1.9	3539
	Biostimulants	14.0	34.4	2770	25.1	813	2.9	4127
Macoun	No Biostimulants	10.5	24.0	1377	18.6	414	2.0	2174
	Biostimulants	12.4	25.9	1505	18.2	656	2.6	2272
Interaction Significance		NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 55. Effect of biostimulants on tree growth and fruiting of five apple varieties in the fifth year (2013) at Geneva, NY.

Variety	Biostimulants treatment	TCA (cm^2)	TCA Increase (cm^2)	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA)	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percentage Fruit Drop (%)
Main Effect Means										
Crispin	.	22.2 a[z]	4.7 a	135.3 a	35.13 a	100.4 a	6.47 ab	1.65 a	262 a	6.83 b
Gala	.	20.0 a	3.9 ab	137.3 a	22.81 b	65.2 b	7.13 a	1.18 b	167 c	2.06 c
Honeycrisp	.	14.4 b	3.4 bc	42.3 c	7.19 d	20.6 d	3.62 c	0.60 d	209 b	21.14 a
Jonagold	.	15.9 b	2.6 c	86.8 b	21.49 b	61.4 b	5.47 b	1.36 b	255 a	4.03 bc
Macoun	.	14.2 b	2.7 c	74.1 b	11.75 c	33.6 c	5.53 b	0.87 c	160 c	17.79 a
Variety Significance		**	**	**	**	**	**	**	**	**
.	No Biostimulants	16.6 b	3.3	91.9	19.07	54.5	5.54	1.13	214	12.63
.	Biostimulants	18.1 a	3.7	98.8	20.41	58.3	5.74	1.14	208	7.87
Treatment Significance		*	NS	NS	NS	NS	NS	NS	NS	*
Interaction Means										
Crispin	No Biostimulants	20.1	4.0 bc	133.1 a	34.89 a	99.7 a	6.78 ab	1.75 a	264 a	6.11 de
	Biostimulants	24.4	5.3 a	137.5 a	35.36 a	101.0 a	6.16 abc	1.55 ab	259 a	7.56 de
Gala	No Biostimulants	19.2	3.5 bcd	145.5 a	23.71 b	67.7 b	7.95 a	1.29 bc	164 d	2.06 e
	Biostimulants	20.7	4.3 ab	129.0 a	21.92 b	62.6 b	6.31 abc	1.07 cd	170 cd	2.05 e
Honeycrisp	No Biostimulants	15.7	4.0 bc	12.5 c	2.78 d	7.9 d	0.84 d	0.19 f	227 b	29.55 a
	Biostimulants	13.0	2.8 de	72.0 b	11.61 c	33.2 c	6.39 abc	1.01 cde	189 c	11.52 cd
Jonagold	No Biostimulants	15.0	2.3 e	89.1 b	21.42 b	61.2 b	5.91 bc	1.44 b	253 a	4.57 de
	Biostimulants	16.9	2.8 de	84.5 b	21.56 b	61.6 b	5.03 bc	1.29 bc	257 a	3.56 e
Macoun	No Biostimulants	12.8	2.3 e	77.6 b	11.95 c	34.1 c	6.34 abc	0.98 de	154 d	20.87 b
	Biostimulants	15.4	3.1 cde	71.0 b	11.58 c	33.1 c	4.82 c	0.78 e	164 d	15.10 bc
Interaction Significance		NS	*	**	*	*	**	**	*	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 56. Effect of biostimulants on cumulative tree growth and fruiting of five apple varieties during five years at Geneva, NY.

		Cumulative Growth and Fruiting Measurements						Average		
Variety	Biostimulants treatment	Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Crop Load (Fruit number/cm^2 TCA	Fruit Size (g)	Shoot Length (cm)
Crispin	.	157 b[z]	4904 b	1357 b	63.4 a	181.2 a	3.01 ab	3.5 c	292 a	26.3 ab
Gala	.	199 a	8033 a	2169 a	57.6 a	164.4 a	2.98 ab	5.8 a	165 d	28.0 a
Honeycrisp	.	132 c	4830 b	883 c	37.3 c	106.6 c	2.72 ab	4.2 bc	250 b	20.5 c
Jonagold	.	169 b	5059 b	1313 b	49.5 b	141.3 b	3.15 a	4.3 bc	240 c	28.5 a
Macoun	.	169 b	3039 c	1057 bc	33.4 c	95.3 c	2.48 b	4.9 b	161 d	25.0 b
Variety Significance		**	**	**	**	**	NS	**	**	**
.	No Biostimulants	165	4975	1238	47.0	134.2	2.86	4.6	219	25.0 b
.	Biostimulants	162	5420	1478	49.8	142.3	2.89	4.4	225	26.3 a
Treatment Significance		NS	NS	NS	*	*	NS	NS	NS	*
Interaction Means										
Crispin	No Biostimulants	153	4570	1180	63.1 a	180.2 a	3.21 ab	3.8 ef	285	25.1
	Biostimulants	161	5238	1534	63.8 a	182.2 a	2.81 bcd	3.3 f	299	27.6
Gala	No Biostimulants	209	7458	1872	59.6 ab	170.2 ab	3.26 a	6.3 a	164	27.1
	Biostimulants	189	8608	2467	55.5 bc	158.6 bc	2.70 cde	5.3 b	166	28.9
Honeycrisp	No Biostimulants	137	5007	993	31.0 f	88.6 f	1.97 f	3.4 f	244	21.2
	Biostimulants	127	4654	773	43.6 e	124.6 e	3.48 a	5.0 bc	255	19.7
Jonagold	No Biostimulants	168	4648	1238	46.9 de	134.0 de	3.20 ab	4.6 cd	236	26.9
	Biostimulants	171	5470	1389	52.0 cd	148.7 cd	3.11 abc	4.1 de	244	30.0
Macoun	No Biostimulants	159	2938	861	32.4 f	92.7 f	2.65 de	5.1 bc	160	24.5
	Biostimulants	160	3128	1228	34.2 f	97.6 f	2.33 ef	4.6 cd	163	25.4
Interaction Significance		NS	NS	NS	*	*	**	**	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Nutrient Concentration in the leaves

In the first year of growth (2009), trees receiving the biostimulants treatment had a higher concentration of Fe and Cu in the leaves but a lower concentration of Mn (Table 57). There was a significant interaction of variety and biostimulant treatment with Al concentration where with 'Crispin' the biostimulant treatment had lower concentration of Al than the control treatment. However for 'Jonagold' the biostimulants treatment had the higher Al concentration. No differences in Al concentration were found for 'Gala', 'Honeycrisp' and 'Macoun'.

During the second year (2010), biostimulants gave a higher concentration for K and Cu compared to the control treatment (Table 58). No significant interaction between variety and biostimulant treatment was found for nutrient concentration in 2010.

Flowering and Fruiting

During the second year of growth (2010), the untreated control treatment had higher, blossom number, crop load and yield efficiency than the biostimulants treatment (Table 59). Fruit size was increased with the biostimulants treatment; however, there was an interaction between variety and biostimulants treatment with fruit size, where biostimulants increased the fruit size significantly for 'Crispin' but for 'Gala', 'Honeycrisp' 'Jonagold' and 'Macoun' there was no effect of the biostimulants compared to the control treatment.

In the third year (2011), biostimulant treatment had higher fruit number, fruit weight, yield per hectare, crop load and yield efficiency than the control treatment (Table 60). There was an interaction of variety and biostimulant treatment with yield efficiency where with 'Honeycrisp' yield efficiency with biostimulants was higher than the untreated control. For the rest of the varieties there were no differences between the treatments.

During the fourth year (2012), the control treatment had the higher fruit number and crop load compared to the biostimulants treatment (Table 61). However biostimulants increased fruit size significantly compared to the control. There was an interaction between variety and biostimulant treatment where fruit size of 'Honeycrisp' was greater with biostimulants than the untreated control. However with ‘Crispin’, ‘Gala’, ‘Jonagold’, and ‘Macoun’ there was no difference between the treatments.

In the fifth year (2013), the untreated control treatment had increased fruit drop compared to the biostimulants treatment (Table 55). There was significant interaction between variety and biostimulant treatment, in which biostimulants increased the fruit number per tree, fruit weight, yield per hectare, crop load and yield efficiency but decreased fruit size and fruit drop for ‘Honeycrisp’ while with ‘Crispin’, ‘Gala’, ‘Jonagold’ and ‘Macoun’ there was no effect of biostimulant treatment.

Over the five years of the experiment biostimulants increased cumulative yield per tree, yield per hectare and fruit size significantly compared to the untreated control treatment (Table 56). However, there was a significant interaction between variety and biostimulant treatment with yield per tree and yield efficiency and crop load. Biostimulants increased yield significantly for ‘Honeycrisp’. However for ‘Crispin’ ‘Gala’, ‘Jonagold’ and ‘Macoun’ no effect of biostimulants was found. Yield efficiency and crop load with ‘Honeycrisp’ were significantly higher with the biostimulant treatment than the control while with ‘Gala’ the untreated control had higher yield efficiency and crop load. With the other varieties (‘Crispin’, ‘Jonagold’ and ‘Macoun’) there were no differences between the treatments.

Fruit Quality, Storage Disorders and Fruit Pack-Out

During the third and fourth year (2011, 2012), biostimulants treatment had no effect on fruit quality or storage disorders incidence (Table 62, 63). However in 2011 there was a significant interaction of variety and biostimulant treatment caused by the high incidence of bitter pit with ‘Honeycrisp’ while the other varieties had none.

Biostimulants did not have a significant effect on fruit pack out in 2012 (Table 64). However there was a significant interaction between variety and biostimulant treatment with fancy fruit pack out, where ‘Macoun’ fruits had increased number of fancy fruit with the biostimulants treatment compared to the control treatment.

Table 57. Effect of biostimulants on nutrient concentration of five apple varieties in the first year (2009) at Geneva, NY.

Variety	Biostimulants treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Al (ppm)
Main Effect Means													
Crispin	.	2.80 a[z]	0.172 c	2.14 a	1.18 c	0.30 a	0.2 ab	20.8 bc	32.5 ab	63.1 a	6.52 b	28.9 c	37.4
Gala	.	2.67 b	0.179 bc	2.06 a	1.21 bc	0.28 ab	0.2 b	27.2 ab	36.6 a	70.3 a	6.82 b	31.5 b	44.5
Honeycrisp	.	2.67 b	0.184 b	1.66 c	1.20 c	0.24 bc	0.2 ab	29.9 a	33.8 ab	65.0 a	8.76 a	34.6 a	38.8
Jonagold	.	2.64 b	0.193 a	1.71 bc	1.57 a	0.25 bc	0.2 b	28.2 a	29.9 b	63.2 a	5.92 c	28.3 c	39.1
Macoun	.	2.74 ab	0.187 ab	1.80 b	1.34 b	0.24 c	0.2 a	19.2 c	36.4 a	63.2 a	6.48 b	23.8 d	34.9
Variety Significance		NS	**	**	NS	*	NS	*	NS	NS	**	**	NS
.	No Biostimulants	2.69	0.183	1.87	1.29	0.26	0.2	24.9	35.0 a	61.0 b	6.37 b	29.1	38.9
.	Biostimulants	2.71	0.183	1.88	1.31	0.26	0.2	25.4	32.7 b	68.8 a	7.43 a	29.8	39.1
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	*	*	**	NS	NS
Interaction Means													
Crispin	No Biostimulants	2.77	0.168	2.14	1.18	0.28	0.2	19.1	32.3	60.4	5.78	28.9	44.3 a
	Biostimulants	2.83	0.176	2.14	1.19	0.31	0.2	22.6	32.7	65.9	7.26	28.9	30.5 c
Gala	No Biostimulants	2.66	0.180	2.06	1.23	0.28	0.2	25.9	38.1	65.4	6.26	30.7	43.8 a
	Biostimulants	2.68	0.178	2.06	1.19	0.28	0.2	28.5	35.0	75.2	7.39	32.2	45.3 a
Honeycrisp	No Biostimulants	2.64	0.185	1.65	1.15	0.24	0.2	29.0	34.8	61.9	8.39	34.2	38.0 abc
	Biostimulants	2.70	0.182	1.67	1.25	0.24	0.2	30.8	32.8	68.0	9.14	34.9	39.5 ab
Jonagold	No Biostimulants	2.63	0.193	1.65	1.57	0.28	0.2	31.7	30.4	57.3	5.36	28.3	33.0 bc
	Biostimulants	2.64	0.193	1.77	1.57	0.23	0.2	24.8	29.3	69.2	6.48	28.3	45.3 a
Macoun	No Biostimulants	2.75	0.188	1.83	1.33	0.24	0.2	18.0	39.6	60.1	6.02	22.7	35.0 bc
	Biostimulants	2.73	0.186	1.77	1.35	0.23	0.2	20.2	33.6	65.9	6.89	24.7	34.8 bc
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 58. Effect of biostimulants on nutrient concentration of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Biostimulants treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Al (ppm)
Main Effect Means													
Crispin	.	3.03 a[z]	0.17 b	1.52 c	2.35 b	0.43 a	0.2 ab	176 b	56.5 a	74.6 a	9.80 cd	41.2 a	8.7 b
Gala	.	2.78 b	0.162 b	1.7 bc	1.72 c	0.37 b	0.2 d	146 cd	48.3 a	71.6 a	10.24 bc	39.6 a	25.8 a
Honeycrisp	.	2.77 b	0.167 b	1.32 d	2.4 b	0.29 c	0.2 bc	247 a	53.8 a	70.8 a	9.11 d	42.2 a	25.5 a
Jonagold	.	2.78 b	0.175 b	1.87 ab	1.92 c	0.44 a	0.2 cd	129 d	53.6 a	64.3 a	10.69 ab	42.9 a	21.8 a
Macoun	.	2.87 ab	0.199 a	1.9 a	2.85 a	0.31 c	0.3 a	156 bc	46.9 a	73.7 a	11.41 a	40 a	19.8 a
Variety Significance		*	*	**	**	**	**	**	NS	NS	**	NS	*
.	No Biostimulants	2.85	0.17	1.58 b	2.24	0.38	0.2	175	54.7	71	8.25 b	41.2	21.7
.	Biostimulants	2.85	0.178	1.72 a	2.26	0.35	0.2	170	48.9	71.4	12.25 a	41.1	18.9
Treatment Significance		NS	NS	**	NS	NS	NS	NS	NS	NS	**	NS	NS
Interaction Means													
Crispin	No Biostimulants	2.97	0.162	1.44	2.31	0.42	0.2	185	55.9	69.8	7.95	41.7	6.7
	Biostimulants	3.08	0.177	1.61	2.39	0.44	0.2	166	57.1	79.3	11.65	40.7	10.7
Gala	No Biostimulants	2.77	0.162	1.67	1.67	0.38	0.2	144	49.1	72.9	8.27	39.5	29.0
	Biostimulants	2.79	0.161	1.73	1.76	0.36	0.2	148	47.6	70.4	12.21	39.6	22.7
Honeycrisp	No Biostimulants	2.89	0.163	1.25	2.47	0.30	0.2	244	54.6	70.3	6.81	42.2	29.7
	Biostimulants	2.65	0.172	1.39	2.34	0.29	0.2	250	53.0	71.2	11.40	42.3	21.3
Jonagold	No Biostimulants	2.78	0.171	1.79	2.01	0.45	0.2	126	56.0	65.3	9.46	42.7	26.3
	Biostimulants	2.79	0.181	2.00	1.78	0.42	0.2	133	50.1	62.9	12.53	43.3	15.0
Macoun	No Biostimulants	2.82	0.198	1.81	2.83	0.34	0.3	178	58.5	77.9	8.86	39.9	15.6
	Biostimulants	2.90	0.199	1.98	2.88	0.29	0.2	138	37.3	70.3	13.54	40.1	23.3
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 59. Effect of biostimulants on flowering and fruiting of five apple varieties in the second year (2010) at Geneva, NY.

Variety	Biostimulants treatment	Blossom Number per Tree	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA)	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	61.0 c[z]	23.9 ab	7.90 a	22.6 a	2.56 b	0.836 a	335 a	19.8 a
Gala	.	100.0 a	24.8 a	4.82 d	13.8 d	2.36 b	0.456 b	195 d	6.0 c
Honeycrisp	.	81.1 b	20.2 bc	5.81 c	16.6 c	2.67 ab	0.768 a	294 b	17.1 ab
Jonagold	.	88.5 ab	25.8 a	6.56 b	18.8 b	3.12 a	0.794 a	258 c	9.6 bc
Macoun	.	54.8 c	18.5 c	3.39 e	9.7 e	2.35 b	0.433 b	183 d	23.0 a
Variety Significance		**	**	**	**	*	**	**	**
.	No Biostimulants	82.2	23.6	5.85	16.7	2.82 a	0.700 a	245 b	14.1
.	Biostimulants	72.6	21.8	5.60	16.0	2.41 b	0.621 b	263 a	15.9
Treatment Significance		*	NS	NS	NS	**	**	**	NS
Interaction Means									
Crispin	No Biostimulants	67.3	26.6	7.97	22.8	3.03	0.903	301 b	17.8
	Biostimulants	54.8	21.1	7.83	22.4	2.09	0.768	368 a	21.7
Gala	No Biostimulants	108.5	23.6	4.67	13.3	2.36	0.460	198 e	6.4
	Biostimulants	91.5	25.9	4.96	14.2	2.37	0.452	193 e	5.5
Honeycrisp	No Biostimulants	85.5	23.4	6.67	19.1	3.00	0.860	287 bc	17.1
	Biostimulants	76.6	17.0	4.95	14.1	2.33	0.677	302 b	17.0
Jonagold	No Biostimulants	92.4	25.9	6.40	18.3	3.27	0.811	252 d	7.5
	Biostimulants	84.6	25.8	6.73	19.2	2.97	0.778	264 cd	11.6
Macoun	No Biostimulants	54.0	17.7	3.21	9.2	2.40	0.435	180 e	22.4
	Biostimulants	55.5	19.1	3.56	10.2	2.31	0.431	186 e	23.4
Interaction Significance		NS	NS	NS	NS	NS	NS	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 60. Effect of biostimulants on fruiting of five apple varieties in the third year (2011) at Geneva, NY.

Variety	Biostimulants treatment	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA)	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means								
Crispin	.	35.3 b[z]	10.2 a	29.1 a	2.64 bc	0.76 a	305 a	13.5 a
Gala	.	67.9 a	10.16 a	29.0 a	4.91 a	0.73 a	150 c	3.1 b
Honeycrisp	.	23.3 c	6.45 bc	18.4 bc	2.49 c	0.69 a	285 a	21.3 a
Jonagold	.	41.3 b	8.4 ab	24.0 ab	3.80 ab	0.76 a	227 b	5.0 b
Macoun	.	39.5 b	6.22 c	17.8 c	4.00 a	0.63 a	158 c	16.9 a
Variety Significance		**	**	**	**	NS	**	**
.	No Biostimulants	36.2 b	7.12 b	20.3 b	3.16 b	0.62 b	232	13.7
.	Biostimulants	46.6 a	9.47 a	27.1 a	3.96 a	0.81 a	219	10.0
Treatment Significance		**	**	**	*	*	NS	NS
Interaction Means								
Crispin	No Biostimulants	29.8	8.66	24.8	2.33	0.68 b	319	16.6
	Biostimulants	40.9	11.73	33.5	2.96	0.85 ab	291	10.5
Gala	No Biostimulants	67.3	10.27	29.4	4.98	0.76 ab	154	2.6
	Biostimulants	68.6	10.05	28.7	4.83	0.70 b	147	3.6
Honeycrisp	No Biostimulants	11.9	3.47	9.9	1.06	0.31 c	290	27.1
	Biostimulants	34.8	9.43	26.9	3.92	1.07 a	280	16.3
Jonagold	No Biostimulants	36.6	7.20	20.6	3.64	0.70 b	231	5.2
	Biostimulants	45.9	9.60	27.4	3.96	0.82 ab	223	4.8
Macoun	No Biostimulants	35.4	5.83	16.7	3.87	0.64 b	164	19.2
	Biostimulants	43.0	6.56	18.7	4.12	0.63 b	153	14.9
Interaction Significance		NS	NS	NS	NS	*	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 61. Effect of biostimulants on flowering and fruiting of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Biostimulants treatment	Total Blossoms per Tree	Fruit Number per Tree	Fruit Weight (kg/tree)	Yield (t/ha)	Crop Load (Fruit number/cm^2 TCA)	Yield Efficiency (kg/cm^2 TCA)	Fruit Size (g)	Percent Fruit Drop (%)
Main Effect Means									
Crispin	.	179 c[z]	40.0 d	10.2 c	29.1 c	2.48 c	0.63 c	266 a	15.42 a
Gala	.	361 a	137.4 a	19.8 a	56.5 a	8.79 a	1.26 b	146 c	3.09 c
Honeycrisp	.	218 bc	89.4 b	17.9 ab	51.0 ab	7.96 a	1.61 a	209 b	11.21 ab
Jonagold	.	241 b	65.6 c	14.4 bc	41.0 bc	4.99 b	1.08 b	221 b	7.77 bc
Macoun	.	178 c	83.2 bc	12.0 c	34.3 c	7.56 a	1.09 b	144 c	15.23 a
Variety Significance		**	**	**	**	**	**	**	**
.	No Biostimulants	251	90.6 a	15.4	44.0	7.02 a	1.19	186 b	9.57
.	Biostimulants	222	75.9 b	14.3	41.0	5.68 b	1.08	209 a	11.39
Treatment Significance		NS	*	NS	NS	**	NS	**	NS
Interaction Means									
Crispin	No Biostimulants	192	47.3	11.6	33.0	3.07	0.74	256 ab	14.52
	Biostimulants	165	32.8	8.8	25.2	1.90	0.51	276 a	16.32
Gala	No Biostimulants	373	151.4	20.9	59.8	9.97	1.39	139 f	3.03
	Biostimulants	349	123.4	18.6	53.1	7.61	1.14	153 f	3.15
Honeycrisp	No Biostimulants	272	102.0	18.1	51.6	8.60	1.53	180 e	7.38
	Biostimulants	164	76.9	17.6	50.4	7.33	1.69	239 bc	15.05
Jonagold	No Biostimulants	234	69.6	14.6	41.6	5.62	1.16	211 d	8.43
	Biostimulants	249	61.6	14.2	40.4	4.35	1.00	231 cd	7.11
Macoun	No Biostimulants	174	81.4	11.5	32.7	7.95	1.12	141 f	15.17
	Biostimulants	181	84.8	12.5	35.6	7.22	1.07	147 f	15.29
Interaction Significance		NS	NS	NS	NS	NS	NS	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 62. Effect of biostimulants on fruit quality and storage disorders of five apple varieties in the third year (2011) at Geneva, NY.

					Storage Disorders Incidence (%)		
Variety	Biostimulants treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Flesh Browning	Bitter Pit	Brown Core
Main Effect Means							
Crispin	.	59.6 c[z]	14.6 a	15.3 a	0.0	0.0 b	0.0
Gala	.	68.1 a	14.3 a	13.5 a	0.0	0.0 b	0.0
Honeycrisp	.	62.3 b	13.6 b	13.9 a	0.0	17.3 a	0.0
Jonagold	.	45.8 d	13.5 b	14.3 a	0.0	0.0 b	0.0
Macoun	.	46.3 d	12.6 c	13.0 a	1.3	0.0 b	5.6
Variety Significance		**	**	NS	NS	**	NS
.	No Biostimulants	56.9	13.9	14.6	0.0	2.6	1.2
.	Biostimulants	56.0	13.6	13.5	0.5	3.7	1.0
Treatment Significance		NS	NS	NS	NS	NS	NS
Interaction Means							
Crispin	No Biostimulants	60.5	15.0	15.7	0.0	0.0 b	0.0
	Biostimulants	58.7	14.2	14.9	0.0	0.0 b	0.0
Gala	No Biostimulants	68.1	14.5	15.4	0.0	0.0 b	0.0
	Biostimulants	68.1	14.2	11.6	0.0	0.0 b	0.0
Honeycrisp	No Biostimulants	64.1	13.6	14.2	0.0	15.7 a	0.0
	Biostimulants	61.4	13.7	13.7	0.0	18.4 a	0.0
Jonagold	No Biostimulants	46.3	13.4	14.0	0.0	0.0 b	0.0
	Biostimulants	45.8	13.7	14.7	0.0	0.0 b	0.0
Macoun	No Biostimulants	46.7	12.8	13.5	0.0	0.0 b	6.3
	Biostimulants	45.4	12.4	12.6	2.5	0.0 b	5.0
Interaction Significance		NS	NS	NS	NS	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 63. Effect of biostimulants on fruit quality, and storage disorders of five apple varieties in the fourth year (2012) at Geneva, NY.

					Storage Disorders Incidence (%)					
Variety	Biostimulants treatment	Fruit Firmness (N)	Soluble Solids (%)	Dry Matter (g)	Superficial Scald	Bitter Pitt	Lenticel Breakdown	Senescent Breakdown	Flesh Browning	Watercore
Main Effect Means										
Crispin	.	62.7 a[z]	17.9 a	20.7 a	0.0 b	0.0	0.0 b	10.6 a	0.0 b	0.8
Gala	.	63.2 a	16.1 b	19.3 b	0.0 b	0.7	0.4 b	0.0 b	2.6 a	0.0
Honeycrisp	.	53.4 b	13.8 d	17.2 c	4.4 a	1.7	5.7 a	0.0 b	0.0 b	0.0
Jonagold	.	47.2 d	15.9 b	19.1 b	2.5 ab	0.0	0.5 b	9.4 a	0.0 b	0.0
Macoun	.	49.4 c	14.7 c	17.8 c	0.0 b	0.0	0.0 b	3.3 b	1.1 b	0.4
Variety Significance		**	**	**	NS	NS	*	**	**	NS
.	No Biostimulants	55.6	15.7	18.7	1.5	0.5	1.0	4.6	0.5	0.1
.	Biostimulants	54.7	15.7	18.9	1.3	0.5	1.6	4.8	0.9	0.3
Treatment Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Means										
Crispin	No Biostimulants	62.3	17.8	20.3	0.0	0.0	0.0	12.3	0.0	0.0
	Biostimulants	63.2	17.9	21.1	0.0	0.0	0.0	8.9	0.0	1.7
Gala	No Biostimulants	63.2	16.0	18.8	0.0	1.4	0.7	0.0	2.6	0.0
	Biostimulants	63.2	16.2	19.9	0.0	0.0	0.0	0.0	2.7	0.0
Honeycrisp	No Biostimulants	53.4	13.6	17.4	7.1	1.0	3.1	0.0	0.0	0.0
	Biostimulants	53.4	13.9	17.0	1.7	2.3	8.2	0.0	0.0	0.0
Jonagold	No Biostimulants	47.6	16.0	19.1	0.0	0.0	1.1	7.6	0.0	0.0
	Biostimulants	46.7	15.9	19.1	5.0	0.0	0.0	11.3	0.0	0.0
Macoun	No Biostimulants	51.2	15.0	17.9	0.0	0.0	0.0	2.8	0.0	0.8
	Biostimulants	48.0	14.6	17.6	0.0	0.0	0.0	3.7	2.0	0.0
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Table 64. Effect of biostimulants on packout of five apple varieties in the fourth year (2012) at Geneva, NY.

Variety	Biostimulants treatment	USDA Grade Packout (%) Utility	Number 1	Fancy	X Fancy
Main Effect Means					
Crispin	.	0.0 c[z]	12.0 bc	42.7 a	45.3 b
Gala	.	9.0 ab	5.8 c	16.0 c	69.2 a
Honeycrisp	.	10.7 a	16.8 b	40.5 a	32.0 b
Jonagold	.	2.5 bc	3.7 c	17.8 bc	76.0 a
Macoun	.	12.0 a	28.3 a	33.4 ab	26.3 b
Variety Significance		**	**	**	**
.	No Biostimulants	8.0	12.4	30.2	49.5
.	Biostimulants	5.3	13.1	29.7	51.9
Treatment Significance		NS	NS	NS	NS
Interaction Means					
Crispin	No Biostimulants	0.0	9.4	48.0 a	42.6
	Biostimulants	0.0	14.6	37.4 a	48.0
Gala	No Biostimulants	10.8	4.1	14.8 bc	70.3
	Biostimulants	7.2	7.5	17.1 bc	68.2
Honeycrisp	No Biostimulants	16.2	17.7	39.7 a	26.4
	Biostimulants	5.2	15.8	41.4 a	37.6
Jonagold	No Biostimulants	1.7	6.1	22.8 bc	69.4
	Biostimulants	3.3	1.2	12.9 c	82.6
Macoun	No Biostimulants	11.7	26.2	25.1 b	37.0
	Biostimulants	12.5	30.8	43.0 a	13.7
Interaction Significance		NS	NS	*	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's MRT at P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

Effect of Plastic Mulch

Vegetative Growth and Fruiting

During the five-year duration of this experiment the cumulative growth variables did not show differences due to the plastic mulch treatment compared to the no plastic control treatment. However the plastic mulch increased cumulative yield per tree and yield per hectare significantly compared to the no plastic control treatment (Table 65). Other variables did not show any differences between the treatments.

Table 65. Effect of plastic mulch on cumulative tree growth and fruiting of five apple varieties during five years at Geneva, NY.

		Cumulative Growth and Fruiting Measurements						Average		
Variety	Plastic Mulch Treatment	Leader Length (cm)	Total Shoot Length (cm)	Pruning Weight (g)	Yield (kg/tree)	Yield (t/ha)	Yield Efficiency (kg/cm^2 TCA)	Crop Load (Fruit number/cm^2 TCA	Fruit Size (g)	Shoot Length (cm)
Crispin	.	157.3 b[z]	5193 b	1435 b	62.2 a	177.8 a	2.79 b	3.3 c	290.0 a	24.7 b
Gala	.	195.8 a	8676 a	2337 a	58.2 a	166.3 a	2.84 b	5.5 a	162.8 d	27.4 a
Honeycrisp	.	136.6 c	5338 b	1069 c	39.7 c	113.4 c	2.54 b	3.9 c	247.3 b	20.8 c
Jonagold	.	165.8 b	4999 b	1352 b	52.5 b	150.0 b	3.38 a	4.6 b	237.7 c	26.4 a
Macoun	.	154.9 bc	2915 c	787 d	33.4 d	95.5 d	2.60 b	5.1 ab	157.8 d	23.5 b
Variety Significance		**	**	**	**	**	**	**	**	**
.	No Plastic	158.4	5149	1236	47.6 b	135.9 b	2.8	4.5	220.0	24.1
.	Plastic	166.2	5834	1590	51.7 a	147.7 a	2.87	4.5	221.4	25.1
Treatment Significance		NS	NS	NS	*	*	NS	NS	NS	NS
Interaction Means										
Crispin	No Plastic	149.5	4960	1212	61.9	176.8	2.99	3.5	286.5	24.8
	Plastic	165.2	5427	1658	62.6	178.9	2.60	3.2	293.4	24.6
Gala	No Plastic	199.2	7875	1981	58.2	166.2	2.99	5.8	164.0	26.8
	Plastic	192.4	9478	2694	58.3	166.5	2.69	5.3	161.6	28.0
Honeycrisp	No Plastic	131.7	5107	948.8	34.3	98.0	2.20	3.6	243.7	20.3
	Plastic	141.5	5570	1189	45.1	128.8	2.87	4.2	251.0	21.2
Jonagold	No Plastic	158.6	4612	1192	48.7	139.1	3.27	4.5	240.6	25.3
	Plastic	172.9	5386	1513	56.4	161.0	3.48	4.7	234.8	27.5
Macoun	No Plastic	152.6	3016	811	33.7	96.3	2.53	4.9	160.3	23.2
	Plastic	157.3	2804	761	33.2	94.7	2.67	5.3	155.1	23.8
Interaction Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means within columns and sections with the same letter are not significantly different using Duncan's at MRT P≤0.05. *, ** or NS indicate treatment had a significant effect at P≤0.05 or P≤0.01 levels, or had a non significant effect, respectively.

DISCUSSION

Vegetative Growth

Our results which show that that apple tree growth is improved by irrigation in the first few years is in agreement with (Neilsen et al., 1997) and in contradiction with the results of (Domingo et al., 1996). Other irrigation trials were done in dry climates while our trial was done in a humid climate where many orchards are not irrigated. Nevertheless even in the New York State climate our data showed that irrigation increased tree growth in the early life of the planting when compared to the non-irrigated treatment, even when both treatments had the same fertilization level.

Fertigation also improved tree growth over the non-irrigated treatment; however when N input was the same, fertigation was not different from irrigation. The N concentration in the leaves in the first year of growth was the highest in the unirrigated treatment which we assume was because there was less shoot growth extension, hence the nutrients were more concentrated than in the irrigation-fertigation treatments where there was more shoot extension growth and the nutrients were more diluted.

The similar effect of fertigation and irrigation treatments on growth was probably due to the way that N fertilizer was applied. For the irrigation treatment N was applied to the soil manually per tree, and the irrigation water likely moved the fertilizer into the soil profile for root uptake. This is very similar to fertigation where the only difference is that the fertilizer is added and dissolved already in the irrigation water. In both cases water moved the N very similarly into the soil profile. Hipps (1992) showed that increasing the rate of broadcast application of nitrogen form 68 to 189 kg/ha had no effect on tree growth or yield of apples. However, additional growth can be achieved with the use of fertigation (Kipp 1992, Neilsen et al., 1999) since the nutrients are delivered more precisely to the root system than when broadcasted. This is likely the reason why our irrigation treatment improved tree growth very similarly to the fertigation treatment since the nitrogen was delivered precisely in both cases. However, when growers broadcast N in a new planting this is not always the case. The increase in shoot growth from our fertigation and irrigation treatments increased pruning weights, as also observed by Reynolds et al. (2005).

In our study the trees where the feathers grew at a natural angle had more growth than trees with the feathers bent down below horizontal. This is in agreement with the results of Lauri and Lespinasse (2001). The feathers at the natural angle had significantly more pruning weights than when feathers were bent below horizontal, since the feathers bent down resulted in less total shoot growth (Luckwill 1970). This effect is desirable for high-density systems such the Tall Spindle, in which the tree needs to be kept in a very close space with long-term reproductive branches. Therefore, feathers that are not bent down could potentially have more shoot growth, which could represent a problem in managing the trees at very close spacings.

Although the feathers at the natural angle had the more growth and pruning weights for most varities, this was not true for Honeycrisp, which is a weak variety (Cline and Gardner 2005). This variety tends to have flat branch angles naturally; thus feathers at the natural angle were similar in terms of growth to the feathers below horizontal.

A main hypothesis in our study was that managing the feathers below horizontal would increase the leader growth to attain the goal of desired tree height quicker. With the Tall Spindle system that goal is 3-3.3m tall,based on a between-row spacing of 3.3-3.5m, in accordance with the light interception results of Jackson and Palmer (1972). The rationale of bending feathers at planting was that they would use less of the available resources within the tree for growth, leaving more to support leader growth. However our data did not support that hypothesis, as there was no difference in leader length between trees with feathers at a natural angle and those with feathers tied below horizontal.

The number of feathers had an effect in tree growth. The 5 and 10 feather treatments at either the natural angle and below horizontal had a positive effect on TCA over the five-year duration of this experiment. We assume that the reason for this increment in TCA is because there are more shoots with significantly more leaves that are intercepting more of the available light, which would increase dry matter accumulation by the tree. Jackson (1980) showed that an increase in leaf area can increase trunk circumference linearly. Their results support our findings— tree TCA when the 10 feathers were below horizontal was consistently greater. However when feathers were left at their natural angle, TCA and pruning weights were very similar between the 5 and 10 feathers.

Results from Mika et al. (2003) showed that trees that were heavily pruned resulted in weaker trunk growth than those that were lightly pruned. Our data show a similar trend where the 5 and 10-feather trees with feathers at the natural angle required more pruning every year than the ones with feathers positioned below horizontal. They also showed less growth in TCA, probably due the fact that stored reserves were used to produce more shoots every season, which were then pruned away. When the feathers were managed below horizontal, TCA was larger because very little pruning was done, allowing resources to be allocated to storage organs. Trees with 0 feathers (whips) always required more pruning than the trees where feathers were trained below horizontal. It should be noted that part of the reason for this is that the new shoots growing from the trunk of the 0-feather treatment, were never tied down. In this treatment, as a consequence of the relatively high nitrogen fertilization during the growing season, some of those shoots grew strong and upright with very narrow crotch angles, and were competing with the leader. This required them to be pruned away, resulting in more pruning with the whips. When feathers were not trained below horizontal, the unfeathered whips required less pruning than the feathered trees because the feathered trees also had many narrow-angle, vigorous shoots which needed to be pruned away.

Use of different biostimulant products have been adopted recently in many crops with reported beneficial effects in growth (Russo and Berlyn, 1991; Vernieri et al., 2005; Rathore et al., 2009). In our trial the use of biostimulants as foliar sprays did not improve tree growth consistently over the five-year duration of observations. Rombolà et al. (2001) tested the use of seaweed extracts (brown algae, *Fucus spp*) with similar results as ours.

In our trial we used a combination of a seaweed extract (Stimplex), vitamins and enzymes (Vitazyme), phosphite and organic acids (Nutriphite Magnum) and foliar Ca fertilizer

(System-Ca). The combined use of these biostimulant products has not been reported in the literature. We used the products in combination due the individual positive effects on growth that had been reported by other authors in different crops. We hypothesized that their combined use would result in better growth than when used individually. Is important to point out that our trees with or without biostimulants received the same amount of nitrogen through fertigation. Cheng et al. (1999) tested the application of foliar urea to increase nitrogen reserves and improve growth. He found that if the nitrogen level in the trees was initially high, urea application did not have a significant effect in N reserves and growth. This also could explain why the use of biostimulants did not have a positive effect on growth in our study, becauseour trees were receiving a constant amount of N throughout spring and early summer and probably reached their maximum potential growth given the weather and climate conditions we had.

The use of plastic mulch has been well documented for vegetables and field crops. Many authors have found that the use of plastic mulch increased plant biomass in wheat (Li et al., 1999), in cotton (Dong et al., 2009) in tomato and cucumber (Wolfe, et al., 1989). In apple (Måge 1982) found that young apple trees with the soil covered with black plastic had significantly higher vegetative growth. In our data the plastic mulch did not improve the overall tree growth, with results similar to the findings of Neilsen et al. (1986). However, their study found higher N concentrations in leaves with plastic mulch, which is the opposite of our findings where we did not find any differences in leaf N concentrations. In our trial the use of plastic mulch only improved tree growth in 'Gala' where shoot length and pruning weights were significantly higher than the non-plastic control treatment.

Flowering and Fruiting

Irrigation and fertigation treatments had significantly higher cumulative yields over the 5 years of this trial than the unirrigated control. This result is supported by previous findings in which fertigation did not enhance flowering nor increase productivity in fertile soils when compared with irrigation (Ramirez and Hoad, 1981; Dencker and Hansen, 1990; Hipps, 1992). For all the varieties tested in this trial, the fertigation and irrigation treatments behaved very similarly in terms of yield. This indicates that the use of drip irrigation in humid climates aids in the utilization and movement of the applied fertilizer, weather the fertilizer is soil applied or already dissolved in the irrigation water (fertigation). These results are similar to those obtained by (Robinson and Stiles 2004) on ‘Redchief’, ‘Mutsu’ and ‘Empire’. Studies done in Hungary by Bubán and Lakatos (2000) showed that with 2 different forms of nitrogen (ammonium and calcium nitrate), flowering and yield were affected much more by the method of nitrogen application rather than the form of N. The use of fertigation resulted in higher cropping and flowering than the conventional standard treatment with the two different types of nitrogen fertilizers.

Fruit firmness, soluble solids and dry matter were unaffected by the irrigation treatments in our study. These results are in contradiction to the results of Porro et al. (2013) who found that fertigation significantly improved fruit quality, with higher soluble solids concentration and firmer fruit than the granular application. Moreover, in our trial fruit packout was not improved by the use of irrigation or fertigation compared to the unirrigated treatment.

During the 2011 season bitter pit incidence was higher with irrigation and fertigation for ‘Honeycrisp’, than the unirrigated treatment. This result can be explained by the negative effects of nitrogen fertilization on bitter pit incidence, which usually occur under excessive supply conditions (Neilsen and Neilsen, 2009). We assume that more nitrogen was moved into fruit by the use of irrigation, although the fruit was never tested for nitrogen content in this trial. Shoot growth was more pronounced on the irrigated-fertigated trees; hence we can assume that some of the calcium absorbed by the soil moved to the shoots rather than the fruit.

In our trial, the effects of feather management angle were inconsistent in the second and third growing season. No clear effect of feather angle treatment was found on the number of blossoms, fruit number, yield, fruit quality or fruit packout. This is in agreement with results of Longman et al. (1965) who found no consistent effect of bending feathers in fruiting and flowering. However our data show that bending of the feathers resulted with an increase in cumulative yield by the end of the fifth year. It seems that the effect of bending feathers at planting on yield is more pronounced in the fourth and fifth year of the life of the planting. Other work done in the past has been inconsistent with some studies reporting an improvement in fruiting and yield (Preston 1978) while others studies (Mullins 1965) showed no increase in bloom or yield.

In some of the varieties we tested, bending of the feathers was more beneficial than in others, in terms of blossom number and fruiting. Lauri (2001) found that the mean number of fruit was dependent on the fruiting type of the genotype, but he also found that the time of bending greatly influenced the number and type of buds later developed, affecting fruiting in the following years.

In our trial, bending feathers below horizontal resulted in increased cumulative yield for 'Crispin' 'Gala' and 'Macoun', however, for 'Honeycrisp' and 'Jonagold' bending the feathers below horizontal did not improve yield compared to the feathers at natural angle. This can be explained by studies done by Lauri et al., (1995) where they found that growth and fruiting are defined by morphological traits. They tested type IV, type III and type II varieties classified according to Lespinasse, et al. (1992), and recorded the type of growth of these varieties for five successive years in a solen training system. Based on their work the growth and fruiting habit of 'Honeycrisp' and 'Jonagold' in our study suggests that these two varieties tend to have very flat horizontal branches in the first year of growth even with no feather management. In the second growing season the weight of the crop helped maintain those branches flat and even below horizontal. Therefore bending of the feathers at planting did not have a significant effect for these two varieties.

Although the 10-feather treatment with feathers bent below horizontal had the highest yield of any treatment, the number of feathers on trees with the feathers trained at natural angle did not have a significant effect on yield; in this case the number of fruits and yield were very similar for 0, 5 and 10 feathers. The results on feathered trees and pruning severity done by Mika et al. (2003) were similar for the feathers at a natural angle in our study. They found that trees planted with side shoots produced roughly the same yield as those without shoots, however there was no branch manipulation in their trial.

Van Oosten (1976) tested feathered trees of two varieties, ‘Cox’s Orange Pippin’ and ‘Golden Delicious’, and he found that trees with more feathers had higher yields in the early life of the plantings. It is noteworthy that the feathered trees from this experiment were almost horizontally growing, whereas the whips often grew more vertical branches. This is similar to our results, in which whips which were never tied down developed upright growing branches that required more pruning. In consequence more shoot growth takes place and fewer flower buds are formed (Forshey 1976).

Neither feather angle treatment nor the numbers of feathers affected fruit quality, packout or storage disorders. ‘Honeycrisp’ had high bitter pit incidence in 2011 but this was independent of the feather treatment or the number of feathers.

In our trial the effect of biostimulants on cumulative yield was variable among varieties. Although ‘Honeycrisp’ was the only variety for which the use of these products improved yield significantly from the control, with ‘Crispin’, ‘Jonagold’ and ‘Macoun’ there was a numeric improvement in yield but it was not statistically different from the control. However with ‘Gala’ the untreated control treatment had more crop than the biostimulant treatment. Thalheimer and Paoli (2001) tested 3 different biostimulant products on ‘Braeburn’, ‘Golden’ and ‘Fuji’, and found no differences in yield or return bloom. However Spinelli et al. (2009) found that the use of an algae base product decreased the oscillation in yield between the on and the off year and increased yield in the off year.

It is important to note that our work and the previously cited work were done in a climates with very favorable conditions. In addition trees were irrigated properly, in our case fertigated and with the standard cultural and disease management practices. However the use of biostimulants products in a more stressful environment could potentially have a positive effect in yield. Sahain et al. (2007) tested the use of two biostimulant products with different concentrations in a more adverse environment (hot and dry climate, calcareous soil and the use of flood irrigation) and found that biostimulants improved growth and yield of ‘Anna’ compared to the untreated control treatment.

Although fruit growers in NY State commonly use many biostimulants products, there is incomplete scientific evidence regarding their effectiveness in apple tree growth and yield in humid climates. The vast majority of the work with these products is done in annual crops (Abetz and Young, 1983; Russo and Berlyn, 1991; Rathore et al., 2009). For tree fruits there are few scientific trials that have tested the use of biostimulants.

In general fruit quality or pack out was not improved by the use of biostimulant products in our trial. This is similar to the results of Thalheimer and Paoli (2001) who found no significant improvement in the internal or external fruit quality (size, color, fruit firmness, soluble solids and acidity). However in our data ‘Macoun’ showed an improvement in Fancy grade fruit with the use of these products. Bitter pit was high for ‘Honeycrisp’ in 2011 and the use of biostimulants did not reduce the incidence of such disorder.

The use of black plastic mulching typically increases soil temperature as well as maintaining a constant moisture condition on the root zone. We hypothesized that this microclimate modification could potentially increase vegetative growth and yield in tree fruits. We found that the use of black plastic mulch did not improve the cumulative yield for ‘Crispin’, ‘Gala’ and ‘Macoun’; however for ‘Honeycrisp’ and ‘Jonagold’ the black plastic mulch improved yield significantly. These results are in agreement with the results from Måge (1982) where trees under plastic mulch yielded twice as much as trees growing in a herbicide strip. Neilsen et al. (1986) compared the use of black plastic mulch with full ground cover and found higher yields under the plastic. In a separate trial Neilsen et al. (2003) compared the use of black plastic mulch with other organic mulches. They found shredded paper with or without biosolids and the black plastic mulch increased the yield of ‘Spartan’ apple significantly more than the control (herbicide strip). In humid climate the use of organic and plastic mulches was tested by Merwin et al. (1995). They concluded that organic mulches can provide long-term improvements in soil fertility and water conservation. However these benefits sometimes do not compensate for the additional costs of the mulches. Fruit quality, pack out and storage disorders were not affected by the use of black plastic mulch.

Many other crops have shown improved yield with the use of plastic especially on vegetable production. The use of black plastic mulch increased yield and reduced weed infestation with tomato (Shrivastava et al. 1994). Moreno and Moreno (2008) tested the use of different biodegradable mulches showing very similar results with tomato. Also the use of plastic has been tested in field crops, in corn. Liu et al. (2009) tested the use of mulching at different timings and found that mulching applied before sowing gave early germination and better plant establishment and better yield.

CONCLUSIONS

The success of a high-density apple orchard depends on choosing the right planting system and getting the trees into production as fast as possible so that the high investment can be recovered as soon as possible. Firstly, the tree must grow and develop a framework suitable for early production. However many orchards experience difficulties that inhibit good tree growth in the early life of the planting, therefore affecting early cropping. This study was intended to overcome some of these problems with the objective to improve growth and maximize yield of high quality fruit.

Our results showed that the use of irrigation in humid climates is beneficial for tree growth and productivity in the early life of the planting. Growers should not rely solely on rain since in some years it is sporadic and will not provide sufficient water. Fertigation can provide a more precise method of delivering nutrients and water, especially in the first year of growth where the root system is small and has not been established. Both irrigation and fertigation resulted in larger trees with greater bearing capacity. These results are especially important with highly feathered trees, where the water stress can be more pronounced due the extensive leaf area and limited root system. This type of tree is the one with the highest yield potential in the first five years if managed under irrigation.

A calculation of the economic benefit of having irrigation in tall spindle orchards showed that the increase in crop value was greatest for 'Crispin' followed by 'Gala' and then 'Honeycrisp' (Table 66). The benefit to Macoun and Jonagold was much less but still greater than the cost of the irrigation system. The the adoption of this technology by NY State apple growers will improve their profitability.

Bending the feathers below horizontal is one of the management practices that growers often do not do since the cost that this practice about 70 to 80 man hours/ha or $800/ha. However our study shows that bending the feathers below horizontal had a positive effect on yield in the first 5 years especially with vigorous varieties with more upright growth such, 'Crispin', 'Gala' and ‘Macoun’. Our economic estimates indicate that this increase in yield could potentially result in a economic benefit of $4,000-7,000/ha (Table 67). Therefore the cost of bending the feathers could be easily repaid by the increase in yield. However this is not true for weak cultivars with naturally flat angle feathers such as ‘Honeycrisp’ where bending of the original feathers did not result in yield improvement.

Overall our results with the use of biostimulant products were not beneficial and do not support our hypothesis that these products could increase tree growth and yield. This is especially true when orchards already are in an adequate nutritional status, which was the case for this orchard. However cumulative yield of ‘Honeycrisp’ was improved by 36 t/ha compared to the control. It seems that the use of biostimulants may help this variety in the off year, resulting in better yields.

The use of synthetic black plastic in orchards could be beneficial but has some drawbacks. First, most growers lack the specialized equipment needed to lay out the plastic in large scale, and also the cost and durability of the mulch is a deterrent. However if yields are improved like in our case especially for high price varieties such as ‘Honeycrisp’ this could be a feasible alternative to the conventional systems.

Table 66. The effect of irrigation on cumulative crop value over the first five years of aTall Spindle planting of five apple varieties at Geneva, NY.

Variety	Irrigation treatment	Cumulative yield (t/ha)	Cumulative crop value ($/ha)	Difference between best treatment and unirrigated control ($/ha)
	Unirrigated	144	$93,795[z]	
Crispin	Irrigated	179	$116,610	$22,815
	Fertigated	171	$111,085	
	Unirrigated	146	$94,900	
Gala	Irrigated	170	$110,630	$15,730
	Fertigated	159	$103,155	
	Unirrigated	107	$138,710	
Honeycrisp	Irrigated	116	$151,320	$12,610
	Fertigated	105	$136,240	
	Unirrigated	141	$91,455	
Jonagold	Irrigated	144	$93,730	$2,275
	Fertigated	144	$93,340	
	Unirrigated	85	$55,250	
Macoun	Irrigated	99	$64,155	$8,905
	Fertigated	93	$60,190	

[z]The economic analysis utilized fruit prices of $0.65/kg for ‘Crispin’, ‘Gala’, ‘Jonagold’ and ‘Macoun’ while the fruit price for Honeycrisp $1.3/kg.

Table 67. The effect of feather angle and feather number on cumulative crop value over the first five years of aTall Spindle planting averaged over five apple varieties at Geneva, NY.

Feather angle treatment	Number of feathers	Cumulative yield (t/ha)	Cumulative crop value ($/ha)	Difference between 10 feathers and 0 feathers ($/ha)
	0	126.9	82,485[z]	
Natural angle	5	130.8	85,020	$4,290
	10	133.5	86,775	
	0	126.9	82,485	
Below horizontal	5	138.5	90,025	$7,865
	10	139.0	90,350	

[z]The economic analysis utilized fruit prices of $0.65/kg for ‘Crispin’, ‘Gala’, ‘Jonagold’ and ‘Macoun’ while the fruit price for Honeycrisp $1.3/kg.

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APPENDIX

Table 68. Historial weather data during the 5 year duration of this experiment at Geneva, NY.

Year	Month	Maximum average tempreature (C°)	Minimum average temperature (C°)	Precipitation (mm)	Pan Evaporation (mm)
Year	**Month**				
2009	April	14	2	40	-[z]
	May	20	7	89	148
	June	23	12	122	158
	July	24	14	92	164
	August	26	15	83	149
	September	22	11	44	117
	October	13	5	90	60
	Seasonal total 2009	**Average=20**	**Average=10**	**Total=560**	**Total=796**
2010	April	17	4	47	-
	May	22	10	65	139
	June	25	15	168	163
	July	28	17	131	188
	August	26	16	114	145
	September	22	11	70	107
	October	15	7	161	85
	Seasonal total 2010	**Average=22**	**Average=11**	**Total=755**	**Total=826**
2011	April	13	3	162	-
	May	20	10	115	41
	June	25	15	59	182
	July	29	18	18	229
	August	26	16	174	146
	September	22	13	112	61
	October	15	6	129	67
	Seasonal total 2011	**Average=22**	**Average=11**	**Total=768**	**Total=726**
2012	April	12	2	61	-
	May	23	11	64	175
	June	23	13	66	178
	July	29	18	71	203
	August	27	15	57	161
	September	23	10	50	121
	October	16	7	124	64
	Seasonal total 2012	**Average=22**	**Average=11**	**Total=493**	**Total=903**
2013	April	13	1	80	-
	May	22	9	97	138
	June	24	14	147	155
	July	27	17	119	168
	August	25	15	103	151
	September	21	10	47	111
	October	17	7	85	68
	Seasonal total 2013	**Average=21**	**Average=10**	**Total=678**	**Total=790**

[z] Pan evaporation was not recorded in April of each year. Budbreak ranged from March 22 in 2012 to April 15 in 2011. Harvest began in early September with 'Gala' and 'Honeycrisp and ended with 'Crispin on Oct. 15 each year.