DETERMINING A MATURITY INDEX AND THE EFFECT OF CHILLING

REQUIRMENTS, AND CYTOKININ APPLICATIONS ON

THREE NEW KIWI CULTIVARS

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DETERMINING A MATURITY INDEX AND THE EFFECT OF CHILLING

REQUIRMENTS, AND CYTOKININ APPLICATIONS ON

THREE NEW KIWI CULTIVARS

Clinton P. Wall

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THESIS ABSTRACT

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The kiwi industry in Alabama is small but has potential for strong growth. Alabama's climate shares many similarities to several large production regions around the world, including China and New Zealand. But in order for production to be successful in Alabama a viable production system must be established.

The goal of this research was to study two new cultivars of *A. chinensis* that originated from China, 'Golden Sunshine' and 'Golden Dragon', and one *A. deliciosa* cultivar, 'AU Fitzgerald', that was selected from a population of *A. delicosa* plants grown from seed planted in south Alabama. There were three main objectives that focused on production issues. The first concerned fruit quality and development of a maturity index for each cultivar to ensure proper harvest timing. Second, was to determine the chilling requirement of each cultivar to enable the selection of the proper areas in the state

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suitable for their production. The third was to determine the efficacy of cytokinin plant growth regulators for improving fruit size and quality.

In a two year study with 'AU Fitzgerald', optimum maturity was reached 135-150 days from full bloom with a 6.5% soluble solids content (SSC) and having a firmness of 5.8-7.2 kg. It was found a single year study with the two *A. chinensis* cultivars that 'Golden Dragon' entered the climacteric 135 days from full bloom at 7 % SSC and a firmness of 6.75 kg was reached. 'Golden Sunshine was entering the climacteric 95 days from full bloom at 6% SSC and a firmness of 7.2 kg.

'Golden Dragon' and 'Golden Sunshine' had the lowest chilling requirements for flowers at 800 and 900 h, respectively. Thus 'Golden Dragon' and 'Golden Sunshine' would be suitable for more southern regions where chilling hours received are typically below 1,000. 'Golden Dragon' is the earliest flowering cultivar, and 'Golden Sunshine' may show the most promise for major production because of its low chilling and fairly high heat unit requirement. 'AU Fitzgerald' had a chilling requirement of 1100 h and heat requirement of 13,750 growing degree hours (GDH) for optimum flower development,.

Exogenous applications of cytokinin increased fruit fresh weight. There was an 18% increase in fresh weight for 'AU Fitzgerald' treated fruit. 'Golden Dragon' and 'Golden Sunshine' had an average increase in fresh weight of 14% and 27%, respectively for treated fruit. There was no significant difference in SSC (%) or dry matter (%) among the three cultivars. 'Golden Sunshine' had a slight decrease in firmness for treated fruit which appeared to reduce shelf life by about one week.

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I. INTRODUCTION AND LITERATURE REVIEW

Kiwifruit (*Actinidia deliciosa* A.Chev.) and (*Actinidia chinensis* Planch) originated in China. During the 1970's, kiwifruit was classified as *A. chinensis* and the cultivar 'Hayward' was the prominent fruit on the market. 'Hayward' has a sweet green flesh with an acidic after taste and thick hairy skin. In 1985, new *Actinidia* plant material emerged from China that was very different from the green kiwi. This material produced fruit with a smooth nearly hairless skin and flesh color ranging from shades of yellow to gold. Chevalier had originally named the green kiwifruit *Actinidia deliciosa* (Meyer, 2002). Because the 1940 *A. deliciosa* entry predated the *chinensis* naming, the earlier species reference *A. delicosa* was used with the green fleshed kiwifruit and the new smooth skinned yellow flesh species was named *A. chinensis* (Meyer, 2002).

The genus *Actinidia* contains 66 species and 118 taxonomies, most of which are native to China (Huang et al., 2002). Breeding for new commercial cultivars has been pursued heavily in New Zealand. The first vines were fruited in New Zealand in 1910 by Alexander Allison in the Wanganui region, from seed collected in China (Larue, 1994). A breeding program developed from the seeds of those original plants and the cultivar 'Hayward', the most important commercial cultivar, was developed as a result. Recently, one organization in New Zealand patented a new *A. chinensis* plant material naming it 'ZespriGold'. The success associated with the marketing of the Zespri label has

stimulated research to discover new cultivars from within China or from breeding programs in New Zealand.

China continues to collect wild cultivars of kiwifruit at the Wuhan Institute of Botany in Wuhan, Hubei, P.R. China. Two cultivars in this study originated from China, 'Golden Dragon' and 'Golden Sunshine', and were brought to Alabama from the Hubei Fruit and Tea Institute.

The goal of this research was to study two cultivars of *A. chinensis* that originated from China and one *A. deliciosa* cultivar that was selected from a population of plants grown from *A. delicosa* seed planted in south Alabama. There are three areas of emphasis concerning each cultivar and all are production issues. The first concerns fruit quality and development of a maturity index for each cultivar to ensure proper timing of harvest. Second, was to determine the chilling requirement of each cultivar to enable the selection of the proper areas in the state suitable for production of these cultivars. This approach allows the plant to flower and produce fruit while minimizing the risk of freeze damage. The third was to determine to what extent exogenous application of cytokinin can improve fruit size and quality.

Alabama kiwi production

Since the 1980's, a kiwi cultivar evaluation trial has been conducted at The Chilton Area Research and Extension Center in Thorsby Ala. The central portion of Alabama, where the majority of Alabama's peach production is located, has also proven favorable for the production of some cultivars of kiwi. A number of female and male selections are being evaluated at the Thorsby location for possible commercial production.

The central region of Alabama has many similarities to New Zealand's Bay of Plenty and to the Hubei province of China where wild cultivars of kiwi were first discovered and large scale production continues. Latitude, and climate are all comparable to that of central Alabama. These similarities with other major kiwi production regions have stimulated interest in commercial kiwifruit production in Alabama.

Hubei province is located in the central portion of China at approximately 30.58 ° N latitude (National Geographic Society). The growing season extends from March to October and is characterized by high temperature and humidity, and thus is classified as a warm, humid, sub-tropical environment. Average high/low temperatures range from 7-14 ℃ in March and 34-26 ℃ in July and August. Average rainfall varies from 60-110 mm a month during the growing season with the rainy season extending from April to August (World Weather Information Service).

New Zealand's Bay of Plenty is located on the northern coast of the North Island at latitude of 38.07 ℃S (National Geographic Society). The growing season extends from October through May. Average temperatures range from 14.2 ℃ in October to 19.7 ℃ in February. Average rainfall ranges from 78 mm in October to 103 mm in April with the rainy season extending from June to September (World Weather Information Service).

The central portion of Alabama lies in a fertile belt region centered around Chilton County at latitude 32.54 ℃N (National Geographic Society). The growing season extends from April through October. The region receives an average of 120 mm of rainfall a month and 1,377 mm annually. Average high temperatures range from 32 ℃ in July to 25 ℃ in October. Chilton County on average receives approximately 1100

chilling hours a year, and has moderate winters with lows averaging from 3 ℃ in January to 8 ℃ in March.

The similarities in latitude and climate, along with success at the research station in Thorsby, suggest there is potential for kiwi to perform well in the central region of Alabama. A major benefit of production in Alabama is that its growing season is directly opposite that of New Zealand, allowing for a export market when fresh fruit is not available in the southern hemisphere. Also, establishing a production area in the Southeast United States reduces transportation costs for consumers in this region.

Internal quality

Kiwis have a long shelf life of 4-6 months if maintained at 32 °C and 90-95% relative humidity (Powell and Himelrick, 1994). Kiwis are classified as a climacteric fruit characterized by a large increase in respiration during ripening (Wills et al., 1998). Non-climacteric fruit lack an ethylene forming system and hence do not have the sudden burst in ethylene and associated respiration (Willis et al., 1998). Kiwis are picked mature but prior to ripening. Ripening includes high respiration, conversion of starch to sugars, changes in acids, and flesh softening as a result of breakdown of pectic substances (Arpaia et al., 1994). Hubbard (1991) reported that sucrose phosphate synthase (SPS) (EC 2.4.1.14) plays an important role in sucrose metabolism of fruit. The presence of such sucrose synthesizing and sucrose degrading enzymes in *A. delicosa* kiwi fruit indicates that the SPS enzyme is important in determining soluble sugar content for the green kiwi fruit.

In the case of *A. chinensis,* degradation of starch into hexose and other sugars occurs on the vine (Mitchell, 1994). Kiwi fruit must be harvested prior to entering the

climacteric, where respiration will rapidly increase and the fruit becomes too soft for storage. When harvested at 6.5% SSC, *A. delicosa* can be stored for up to 6 months at 0 °C and maintain sufficient quality for export (Crisosto and Crisosto, 2001). One month cold storage is necessary to induce ripening in *A. delicosa* because the SPS enzyme responsible for sucrose biosynthesis increases in response to low temperatures (MacRae, 1992). Low temperature storage usually of 30 days or more at 0 °C (Hubbard, 1991) will activate the SPS enzyme resulting in an increase of glucose biosynthesis and increase in respiration, which mark the beginning of the ripening process.

Maturity index

One difficulty with knowing when to harvest kiwi is that there are no external signs as they approach maturity, thus the concept of multiple harvests is not feasible (Mitchel, 1994). A maturity index is a numerical value based on a combination of fruit firmness, color and percent soluble solids which is used to predict when to optimally harvest kiwi. Although these techniques produce adequate results, no one maturity indicator alone is a suitable index for all cultivars. Each cultivar has a different rate of maturation that must be determined in order to maximize that fruit's quality and determine its optimum maturity index.

Crisosto (2001) reported that when *A. delicosa* fruit are harvested at different phases of maturity, only firmness and SSC were reliable indicators of maturity. During the harvest season, weight, color, length, width and respiration rates did not change significantly and hence were not suitable indexes for maturity.

There are several methods for determining fruit maturation. The first is to test the level of soluble solids content (SSC), or amount of sugars, salts, acids and proteins in

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aqueous solution. In the case of fruit, SSC usually refers to sugar content. In commercial production, SSC refers to the sweetness of the fruit (Crisosto and Crisosto, 2001). The standard in California is 6.5% SSC for *A. chinensis* kiwi and 7.2% SSC for *A. delicosa* (Mitchel, 1994) if a storage period of 12 weeks or more is desired. *A. chinensis* fruit can be allowed to ripen on the vine and picked at 12% SSC if the intent is to market it locally. As fruit ripen and approach eating quality, it will reach over 14% SSC. This is the result of more stored carbohydrate in the form of starch being metabolized into sugars resulting in a sweeter and softer fruit.

Flesh color is not indicative of maturity with *A. delicosa* because the color of the flesh will remain green throughout maturation and ripening. With *A. chinensis,* however flesh color changes from green to yellow, which coincides with the end of maturation and beginning of ripening. Using a digital colorimeter, which measures hue angle, a standard can be set for harvesting *A. chinensis*. In California, a hue angle of 106° for *A. chinensis* cultivar 'Hort 16-A' is required for harvest.

Dry matter accumulates in kiwi at a uniform rate from pollination to harvest, which differs from fresh weight which occurs in three distinct stages. Dry matter refers to the amount of cell wall material composed mostly of cellulose and stored sugars in the form of starch that have accumulated in the fruit. Dry matter is a major concern in kiwi production because as ripening occurs starch, is degraded into sugars. As a result, the amount of dry matter available when the fruit enters storage will have a direct effect on storage life and taste (Wills et al., 1998). In California, a standard of at least 15% dry matter for golden fleshed kiwi is required for adequate storage.

Fruit firmness refers to the softness of the flesh. At harvest, kiwis are very firm, usually in the 14 lb or 6.3 kg range. As fruit tissue enters the climacteric, respiration increases along with degradation of pectic substances. The solubalization of polymeric carbohydrates directly correlates with the rate of softening of fruit (Wills, 1998), although there is high variability in the softness among fruit in an orchard.

Kiwi fruit growth occurs in three distinct stages (Grant, 1994). The first occurs after pollination; the fruit grows at its fastest rate and continues for 30-40 days due to cell division. The second phase is slower but continuous and lasts for another 30-40 days; this growth is due to cell enlargement. The final stage is characterized by even slower growth that lasts until harvest (Grant, 1994). As kiwifruit grows, cell division and cell enlargement are both occurring, but cell division is at its peak immediately after pollination. Cytokinins are natural occurring plant hormones that promote the cellular division stage of fruit growth immediately following pollination (Letham, 1994).

<u>Plant growth regulators</u>

Benefit PZ is a mixture of proteins, vitamins, and the amino acids glycine, asparatic acid, and glutamic acid that have been extracted from plant materials. Benefit promotes cell division during the early stage of development, after fruit set and accelerate metabolic activities, resulting in increased cell division. The manufacturers of Benefit claim that 'an increase in fruit size will be seen as a result of the effect the biostimulant has on the cell division phase of fruit development.

The active ingredient of Prestige is the synthetic cytokinin (N-[2-chloro-4-pyridyl]-N'-phenylurea) or CPPU, which functions as a plant growth regulator on fruit and vegetables resulting in an increase in size. The manufacturer of Prestige report that

the use of their product will result in an increase in fruit size, yield, and improve the pack out by shifting fruit size up one category.

<u>Activity in Fruit</u>

The development of most fruit begins with a short period of cell division followed by a longer period of cell enlargement. Cytokinin concentration in some fruit such as apple has been found in the highest levels during the cell division phase (Letham, 1994). Seed development is a potential site of cytokinin biosynthesis, but other parts of the plant may also act as biosynthesis sites especially areas undergoing increased cell division (Hahn et al., 1974).

<u>Exogenous application of cytokinin on kiwi size and quality</u>

Increases of final fruit weight of 30-40% have been reported using CPPU (Costa et al., 1996). Treated fruit were found to have an increase in thickness of the outer pericarp and a decrease of the inner pericarp, when compared with controls (Cruz et al., 1999). Multiple publications have reported that kiwifruit treated with CPPU 1-2 weeks after full bloom will promote higher soluble solids and lower flesh firmness at harvest when compared to untreated fruit (Antognozzi et al., 1997; Costa et al., 1996, 1997; Fang et al. 1996;). CPPU apparently stimulates ripening and results in advanced softening.

<u>Rates</u>

Fang et al. (1996) concluded that the optimum concentration of CPPU was 10-20 mg/liter, and the best results were achieved when applied by an air blast sprayer that covered all sides of the fruit. When using CPPU alone, several researchers (Antognozzi et al., 1997; Famiani et al., 1996, 1997; Costa et al., 1996) reported that a rate of 20 ppm CPPU significantly increased fruit size.

Ohara (1997) concluded that 2.5-20 ppm CPPU were all effective when compared to the control without a significant difference among rates. The Prestige label recommends a rate of 6g and no more then 8g of active ingredient per gallon of spray material for maximum effect.

Timing

There is wide variation in reports of effectiveness regarding timing of CPPU application. Some reported a significant increase in fruit size of *A. deliciosa* 'Hayward' after applying CPPU 14-15 days from full bloom (Antognozzi et al., 1997; Famiani et al., 1997). Some researchers (Costa et al., 1996) showed that applications made 20-21 days from full bloom (DFFB) were effective, other studies have noted that applications of 10-30 DFFB were optimum (Fang et al., 1996), and another study reported 14-21 DFFB to be optimal (Famiani et al., 1996). According to the Prestige application guidelines, vines should be sprayed 2-3 weeks after full bloom when fruit diameter averages 30-45 mm.

Flower Development

Kiwis are dioecious, with each plant producing either functioning male or female flowers but not both. In order for fruit set to occur, male and female vines must be in close proximity for cross pollination to occur (Grant, 1994). Both male and female flowers are perfect morphologically. The female flower contains anthers but only the stigma is functional. The male vine will often produce twice as many flowers as the female and the flower contains a small vestigial stigma surrounded by 125-185 large anthers (Thorp, 1994).

Dormant buds that break in spring are compound buds that contain both floral and vegetative primordia. As vegetative shoot growth develops from the dormant bud, flower

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clusters are produced in the leaf axil at the first four to six nodes. If sufficient pollination and fertilization occurs, the fruit will be large. The shoots will continue to develop and grow vegetatively providing photosynthates for the developing fruit (Grant, 1994).

The amount of fruit set per vine and the final fruit size is dependent on adequate pollination. Each ovule of a fruit must be pollinated by a single pollen grain to form a seed. A typical 100 g fruit will contain more than 1100 seeds (Grant, 1994). Developing seed produce hormones such as cytokinin that stimulate cell division of the fruit (Letham, 1994).

<u>Chilling Requirement</u>

Uniformity and number of flowers set in the spring is directly related to the amount of chilling received during winter (Snelgar et al., 1997). Several studies have shown buds must be exposed to a specific number of chilling hours to complete dormancy and achieve maximum bud break and optimum bloom (Lionakis and Schwabe, 1984; Snelgar et al., 1997). It has been proposed that a certain number of hours below 7 ℃ are required in order to break bud dormancy in *A. delicosa* (Snelgar et al., 1997). The amount of chilling is measured in "Richardson" units, which is defined as the accumulation of hours below 7 ℃ required to remove a resting organs inhibition to grow (Samish and Levee, 1962).

Kiwi can be forced to break dormancy if exposed to temperatures in excess of 30 °C, even if chilling has not been satisfied, although the uniformity of bud break was less than when chilling had been satisfied (Porlingis and Therios, 1997). It is believed that the triggers for determining chilling requirement are located in the bud scale. Linokis and Schwabe (1984) found that removing the bud scale promoted bud break. This was

attributed to the removal of hormones such as ABA stored in the bud cover which promotes dormancy.

Fruiting cultivars such as 'Hayward' have chilling requirements of about 900 h for vegetative bud break and 1150 h before maximum flowering (Caldwell, 1989). It is believed that some cultivars belonging to *A. delicosa* such as 'Bruno' may have a lower chilling requirement of 700 h (Caldwell, 1989), hence these could be grown in warmer regions where cultivars such as 'Hayward' will not fruit.

Use of dormant cuttings to test phenology

Dormant cuttings of *A. delicosa* cultivar 'Hayward' have been reported to grow and produce flowers when placed in water and held at constant temperatures in a greenhouse or growth chamber (Snowball and Smith, 1996). The effectiveness of these cuttings to study kiwi phenology has had conflicting results. Linokis and Schwabe (1984) reported that results from use of rootless cuttings were similar to those using intact canes (Snelgar 1997). Snowball and Smith (1996) reported that cuttings produced more flowers per dormant bud than field grown plants, and hence were not accurate at rating flowering performance.

A study by Snowball and Smith (1996) reported that the origin of the cutting has a direct effect on flower and vegetative production. More flowers tend to develop on cuttings originating from nodes 6-20, starting from the base of the original cane. The same study reported a direct decrease in the number of flowers to reach anthesis as the nodal placement increased. It was proposed by Snowball and Smith (1996) that inadequate growth of cuttings originating from nodes 20-25 was due to the depletion of

starch reserves. Cuttings originating from nodes 5 and less should be avoided because they may contain no shoot buds and may be less fruitful (Snowball and Considine, 1986).

Size of the cutting was determined to be important when studying flowers. The amount of starch reserves available is directly correlated with stem diameter and hence will affect the development of vegetative and floral parts (Snowball and Smith, 1996). The same study reported cuttings should be at least >12 g in weight, at least 150 mm in length and > 6 mm in diameter. The cuttings must be supplied with a constant supply of water. Use of a nutrient solution did not differ from deionized water in promoting bud break and growth.

II. DEVELOPMENT OF A MATURITY INDEX FOR THREE NEW CULTIVARS OF

KIWIFRUIT *Actinidia chinensis* AND *A. deliciosa*

Introduction

Kiwifruit (*Actinidia deliciosa* A. Chev.) has a long shelf life of 4-6 months if maintained at 32 °C and 90-95 % relative humidity (Powell and Himelrick, 1994). The storage length of kiwi is influenced by its maturity at harvest. Kiwi are climacteric fruit characterized by a large increase in respiration during ripening (Wills et al., 1998). Non-climacteric fruit lack the ethylene forming system of climacteric fruit and hence do not have the sudden burst in associated respiration (Willis et al., 1998). Kiwis are picked mature but prior to ripening.

The ripening process involves increased respiration where starch is converted to sugars, changes in acids occur, and flesh softens as a result of breakdown of pectic substances (Arpaia et al., 1994). Hubbard (1991) reported that the enzyme sucrose phosphate synthase (EC 2.4.1.14) (SPS) plays an important role in sucrose metabolism of fruit. High levels of SPS were found in *A. delicosa* kiwifruit suggesting that SPS may influence soluble sugar content in *A. delicosa* (MacRae et al., 1992).

When harvested at 6.5% soluble solid content (SSC), *A. delicosa* can be stored for up to 6 months at 0 °C and still achieve good quality suitable for export (Crisosto and Crisosto, 2005). SPS activity increases in response to low temperature storage (MacRae, 1992). A storage period of 30 days or more at 0 °C will activate the SPS enzyme

resulting in a significant increase in glucose biosynthesis and respiration, which indicates the beginning of the ripening process. *A. chinensis* starch hydrolysis occurs prior to the climacteric rise (Hubbard, 1991), therefore, early harvest is essential in maintaining optimal quality fruit.

<u>Maturity Index</u>

One difficulty with knowing when to harvest kiwi is that there are no external signs as they approach maturity, thus the concept of multiple harvests is not feasible (Mitchel, 1994). A maturity index is a numerical value based on a combination of fruit firmness, color and percent soluble solids which is used to predict when to optimally harvest kiwi. Although these techniques produce adequate results, no one maturity indicator alone is a suitable index for all cultivars. Each cultivar has a different rate of maturation that must be determined in order to maximize that fruit's quality and determine its optimum maturity index.

When *A. delicosa* fruit were harvested at various phases of maturity, only firmness and SSC were deemed reliable indicators of maturity (Crisosto, 2001). During the harvest season, weight, color, length, width and respiration rates did not change significantly and hence were not suitable indexes for maturity.

There are several methods for determining fruit maturation. The first is to test the level of soluble solids content (SSC) or amount of sugars, salts, acids and proteins in aqueous solution. In the case of fruit, SSC usually refers to sugar content. In commercial production, SSC refers to the sweetness of the fruit (Crisosto and Crisosto, 2001). The standard in California is 6.5% SSC for *A. chinensis* kiwi and 7.2% SSC for *A. delicosa*

(Mitchel, 1994) if a storage period of 12 weeks or more is desired. *A. chinensis* fruit can be allowed to ripen on the vine and picked at 12% SSC if the intent is to market it locally. As fruit ripen and approach eating quality, it will reach over 14% SSC. This is the result of more stored carbohydrate in the form of starch being metabolized into sugars resulting in a sweeter and softer fruit.

Flesh color is not indicative of maturity with *A. delicosa* because the color of the flesh will remain green throughout maturation and ripening. However, *A. chinensis* flesh color transitions from green to yellow, which coincides with the end of maturation and beginning of ripening. Using a digital colorimeter which measures hue angle, a standard can be set for harvesting *A. chinensis*. In California, a hue angle of 106° for *A. chinensis* kiwi is required for optimum harvest.

Dry matter accumulation in kiwi occurs continuously up to harvest. Fresh weight gain occurs in three distinct stages; first, rapid cell division occurs immediately after pollination, followed by a slower period of cell expansion (Grant, 1994). The third phase is a much slower phase of growth that occurs until the fruit is harvested. Dry matter refers to the amount of cell wall material composed mostly of cellulose and stored sugars in the form of starch that have accumulated in the fruit. Dry matter accumulation is a major concern in kiwi production because starch, a major component of dry matter, is metabolized into free sugars during ripening. As a result, the amount of dry matter available when the fruit tissue enters storage will have a direct effect on storage life and taste (Wills et al., 1998). In California, a standard of at least 15% dry matter accumulation is required for optimal storage.

Kiwi fruit are harvested firm, usually at 14 lb or 6.3kg. As fruit enters the climacteric stage, respiration increases, which coincides with degradation of pectic substances. Solubalization of complex carbohydrates directly correlates with the rate of softening (Wills, 1998), although there is high variation in fruit softness within a kiwi fruit orchard.

Materials and Methods

This study was conducted during the 2005-2006 growing seasons to determine the development and quality of fruit from an early stage through harvest.

In the first year, 'AU Fitzgerald' was the only cultivar studied. The vines studied were grown at The Chilton Area Research and Extension Center in Thorsby Ala. All vines were grown from rooted softwood cuttings, and were trained to a winged t-bar trellis system at spacing of 5.48 m by 3.66 m. The vines were mature and were managed according to standard cultural practices.

Starting 90 days from full bloom, five fruit were randomly selected from each of six randomly assigned 'AU Fitzgerald' vines and transported to Auburn University for immediate analysis. External measurements of length and width (mm) were recorded using a digital caliper (model CD-6 BS, Mitutoyo Corp. Japan). Fresh and dry weight (g) were determined using an OHAUS analytical scale (model explorer E16120, Ohaus Corporation Switzerland). Total percent dry matter was calculated by dividing total dry weight by total fresh weight and multiplying times 100. Dry weight was determined after drying at ~78 °C for 48 hours when a constant weight was achieved.

Fruit firmness (kg) was determined using the McCormick fruit pressure tester with an 8 mm tip (Yakima Washington), after removing the skin from the shoulder of each fruit.

Soluble solids content (%) was determined using two slices of fruit, one from both the calyx and basal ends and squeezing two drops of juice from each into a hand held temperature compensated refractometer dish (Palm Abbe Model PA201, MISCO, Cleveland, Ohio). Accuracy was verified using a bench model Leica Mark II plus refractometer (model 10494; Leica Microsystems Inc., Buffalo N.Y.).

In the second year of the study, fruit were harvested earlier in the season (90 day from full bloom) in order to widen the view of maturation and included the cultivars 'Golden Dragon', 'Golden Sunshine', and 'AU Fitzgerald'. All analysis from the previous year was conducted. Additionally, diameter of the outer pericarp and core (mm), and internal flesh and external skin color were determined. Color was assessed using a Minolta colorimeter (model CM-2002; Minolta Camera Co., Japan) to determine hue angle and chroma. Hue angle is a measure of color change from green (160°) to yellow (90°) to orange (45°), while chroma is the intensity of hue angle color from near white to pure color (McGuire, 1992; Voss, 1992).

<u>Statistical Analysis</u>

The data for firmness, brix, color, dry matter and fresh weight were graphed out on the y-axis with days from full bloom (DFFB) on the x-axis. The resulting graphs produced a developmental curve for each cultivar over time. Maturity was assessed for each cultivar by determining when each had entered the climacteric phase and was ready

to harvest. This was usually represented by a sudden increase in percentage SSC and a drop in firmness.

Results and Discussion

Effect of harvest date on soluble solids content

The percent soluble solids refers to the amount of salts, sugars and acids in aqueous solution of the fruit. As the fruit enters the ripening stage, respiration increases and the catabolism of starch produces free sugars. *A. chinensis* fruit enter the climacteric while attached to the vine. Hence, it is crucial to harvest *A. chinensis* fruit when mature but before it enters the climacteric.

A. delicosa requires that the fruit be removed from the vine and placed in cold storage for 30 days before ripening can begin. SSC of fruit slowly increases, but still require harvest and cold storage before a sudden SSC increase characteristic of fruit in the ripening stage will occur.

The *A. chinensis* cultivars, 'Golden Sunshine' and 'Golden Dragon', had a sudden increase in percent soluble solids, once the fruit reached the climacteric, the conversion of starch into free sugars began to occur at a rapid rate. 'Golden Sunshine' went from 5.8% to 14% SSC in 21 days while attached to the vine (Figure 1). 'Golden Dragon' went from 6.4% to 14.5% SSC in 16 days while still attached to the vine, indicating a small window for harvest when a target may be in the 5-7% range and the fruit are only at that stage of ripeness for a week or less.

The *A. delicosa* cultivar 'AU Fitzgerald' exhibited a more gradual increase in SSC. Over the course of thirty days, soluble solids increased from 6% to 16% SSC in

2004 (Figure 2). In 2005, the increase was slower, from 6.4% to 8.5% over a thirty day period. This would increase the harvest window at the 6.5 to 7 % SSC range.

Effect of harvest date on firmness

Fruit firmness decreased over time. There was a sudden drop in the firmness at the same time SSC increased rapidly for all cultivars, which is an indicator that the fruit had entered the climacteric. Hence the use of firmness as an indicator of maturity is suitable for *A. chinensis* and *A. delicosa. A. delicosa* fruit entered the climacteric at 5-7 kg of pressure and *A. chinensis* at 6-8 kg of pressure.

Effect of harvest date on dry matter

There was not a significant change in the percent dry matter for all three cultivars during the harvest season. Dry matter accumulated in the fruit at a steady rate until harvest. Hence, the percent dry matter would not be a suitable indicator of maturation.

Effect of harvest date on internal flesh color

A. delicosa fruit show little change in internal color as they approach maturity (Figure 3). 'AU Fitzgerald' remained at about 105° hue angle throughout maturation and into the ripening stages. Hence, internal color would not be useful in determining the stage of maturity for 'AU Fitzgerald'.

'Golden Sunshine' and 'Golden Dragon' showed a significant change in internal color as they approached maturity. 'Golden Sunshine' had a decrease in hue angle from 108E down to 96E as the internal color changed from green towards yellow. 'Golden Dragon' had an even larger decrease in hue angle as it changed from 106E down to 87E producing a bright yellow colored flesh. Because of this steady movement towards the

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yellow spectrum, the internal hue angle of *A. chinensis* may be useful in determining the level of maturity for 'Golden Sunshine' and 'Golden Dragon'.

Potential maturity index

'AU Fitzgerald' was ready to harvest at 150 DFFB in 2004. The fruit showed a sudden increase in SSC once the 6 to 7.5% range was reached. Firmness at this point was also beginning to decrease rapidly around the 5.8 to 7 kg range. The 2005 harvest data for 'AU Fitzgerald' produced an irregular curve for maturation. Some of this irregularity and inferior quality fruit can be attributed to a stressful year for the vines with pollination issues producing a poor 'AU Fitzgerald' crop for that year.

'Golden Dragon' and 'Golden Sunshine' entered the climacteric as evidenced by a rapid drop in firmness and a rapid increase in SSC. In 2005, 'Golden Dragon' entered the climacteric at 135 to 145 days after full bloom when it approached a SSC of 6.5 to 7.5 % and a firmness of 5.8 to 6.7 kg. In 2005, 'Golden Sunshine' was at full maturation and entered the ripening phase at 95 to 110 DFFB at a SSC of 5.5 to 6.2% and a firmness of 5.8 to 6.7 kg. The internal flesh color during these periods was a hue angle of 104° for 'Golden Sunshine' and 98° for 'Golden Dragon'.

The interval of time from full bloom until fruit was ready for harvest varied among cultivars. 'Golden Sunshine' required the shortest amount of time until harvest at 95 to 110 DFFB. 'Golden Dragon' required 130 to 140 days of growth before fruit were ready to harvest. 'AU Fitzgerald required the most at 140 to 150 DFFB.

Although it seems that there is a large gap between harvest dates for the two *A. chinensis* cultivars, 'Golden Dragon' and 'Golden Sunshine', they are usually harvested

about the same time. Although 'Golden Sunshine' requires a shorter time to develop and mature than 'Golden Dragon', 'Golden Sunshine' will bloom later in the spring compensating for the development time gap.

III. EFFECT OF CHILLING ON AMOUNT AND UNIFORMITY OF BUD BREAK

AND FLOWER DEVELOPMENT FOR THREE KIWI CULTIVARS USING

CUTTINGS OF *Actinidia chinensis* AND *A. deliciosa*

Introduction

Kiwifruit (*Actinidia deliciosa* A.Chev. and *Actinidia chinensis* Planch) are dioecious species producing either functional male or female flowers but not both. In order to set fruit, a male and female vine must be in close proximity for cross pollination to occur (Grant, 1994). Both male and female flowers are perfect morphologically. The female flower contains some anthers but only the stigma is functional. The male vine will often produce twice as many flowers as the female and the flower contains a small vestigial stigma surrounded by 125-185 large anthers (Thorp, 1994).

The uniformity and number of flowers set in the spring is directly related to the amount of chilling received during winter (Snelgar et al., 1997). Several studies have shown buds must be exposed to a minimum number of chilling hours to complete dormancy and achieve maximum bud break and optimum bloom (Lionakis and Schwabe, 1984; Snelgar et al., 1997). It has been proposed that a certain number of hours below 7 °C are required in order to break bud dormancy in *A. delicosa* (Snelgar et al., 1997). The amount of chilling is measured in "Richardson" units and is defined as the accumulation of hours below 7 °C and above 0 °C required to remove a resting organs inhibition to grow (Samish and Levee, 1962).

Kiwi can be forced to break if exposed to temperatures in excess of 30 °C, even if chilling has not been satisfied, although the uniformity of bud break was less than when chilling had been satisfied (Porlingis and Therios, 1997). It is believed that the triggers for determining chilling requirement are located in the bud scale. Linokis and Schwabe (1984) found that removing the bud scale promoted bud break due to the removal of hormones such as ABA stored in the bud cover, which promotes dormancy.

Cultivars such as 'Hayward' have chilling requirements of 900 h for vegetative bud break and 1150 h for optimum flowering (Caldwell, 1989). It is believed that some cultivars belonging to *A. delicosa* such as 'Bruno' may have a lower chilling requirement of 700 h (Caldwell, 1989) hence, these could be grown in warmer regions where cultivars such as 'Hayward' will not produce.

Dormant buds that break in spring are compound buds that contain both floral and vegetative primordia. As vegetative shoots grow from dormant buds, flower clusters are produced in the leaf axil of the first four to six nodes. If sufficient pollination and fertilization occurs, these fruit will develop into large fruit (Grant, 1994).

Use of dormant cuttings to test phenology

Dormant cuttings of *A. delicosa* cultivar 'Hayward' have been reported to grow and produce flowers when placed in water and held at constant temperatures in a greenhouse or growth chamber (Snowball and Smith, 1996). The effectiveness of these cuttings to study the phenology of kiwi has had mixed results. Linokis and Schwabe (1984) reported that results from use of rootless cuttings were similar to those using intact

canes (Snelgar, 1997), but Snowball and Smith (1996) reported that cuttings produced more flowers per dormant bud than field grown plants.

Snowball and Smith (1996) reported that the placement of origin of the cutting has a direct effect on flower and vegetative production. More flowers tend to develop on cuttings originating from nodes 6-20, starting from the base of the original cane. The same study reported a direct decrease in the number of flowers to reach anthesis as the nodal placement increased. It was proposed by Snowball and Smith (1996) that the reason for the poor performance of cuttings originating from nodes >20-25 was due to insufficient starch reserves. Cuttings originating from nodes 5 and less should be avoided because they may contain no shoot buds and may be less fruitful (Snowball and Considine, 1986).

The size of the cutting was determined to be important when studying flowers (Snowball and Smith, 1996). The amount of starch reserves available has a direct affect on the development of vegetative and floral parts. The same study reported cuttings should be at least 12g in weight, at least 150mm, in length and >6mm in diameter. The cuttings must be supplied with a constant supply of water. Use of a nutrient solution did not differ from deionized water in promoting bud break and growth.

Materials and Methods

In 2005-2006, a study was conducted at Auburn University to determine the effect of various chilling requirements on rootless cuttings of *A. chinensis* and *A. delicosa.*

The first year of the study included four female cultivars 'Hayward', 'AU Fitzgerald' (*A. delicosa*), 'Golden Sunshine', and 'Golden Dragon' (*A. chinensis*). Males

included 'Matua' and 'AU Arthur' (*A. delicosa*). Cuttings were obtained from mature vines grown at The Chilton Area Research and Extension Center in Thorsby, Ala. All vines were grown from rooted softwood cuttings, and were trained to a t-bar trellis system at spacing of 2.4m by 4.8m. The vines were mature and had been fruiting several years before the study was conducted. Cuttings were made from dormant one-year canes, on 1-19-2005 after being exposed to 572 chilling hours in the field. Field chill hours were recorded at a weather collection station located 0.1 km from the kiwi vineyard.

A three node cutting was made from nodes number 6-20 starting from the basal end. Multiple vines for each cultivar were selected and cuttings were grouped according to cultivar making no distinction between vines. Cuttings were bound with rubber bands, placed in buckets of water and immediately transported to Auburn University.

In 2005 , cuttings were collected after 572 h were accumulated in the field. The cuttings were held at 4 °C, and removed as shown in table 1.

There were 6 replications per cultivar, with 10 cuttings per replication. Each replication was placed in a glass jar that had been wrapped with aluminum foil and filled with water. The jars were placed in a 27.5m long thermostatically controlled greenhouse on benches 1m from the ground. The jars were arranged in a completely randomized block design on the bench. Each cultivar was blocked by treatment and the six replications were randomized within each block. The greenhouse temperature was set at a 22 °C minimum and the temperature held constant for 24 hours a day, allowing approximately 888 growth degree hours per day. The jars were filled with water (pH of

6.0 and no fertilizer), which kept the basal end of the cuttings saturated throughout the experiment.

Daily counts were made on the number of dormant buds that had broken. Counts were made of floral buds and stage of development including full bloom, petal fall and senescence. Vegetative data was also collected at the end of the experiment of the largest leaf and longest shoot. Data collection was terminated once floral parts were no longer developing or present and vegetation had begun to appear chlorotic or necrotic.

In 2006 the above experiment was carried out in an identical fashion with the exceptions of the following.

1) 'Hayward' and 'Matua' were not used in the study.

2) 'Golden Sunshine' and 'Golden Dragon' cuttings were collected earlier in the winter when 150 h of chilling had been received in the field (On 11-21-05).

3) 'AU Fitzgerald' and 'AU Authur' cuttings were collected when 458 h of field chilling had accumulated (On 12-16-05).

Statistical Analysis

Analysis was carried out using regression analysis to create a fitted curve for each independent variable over chill hours. Data used for the regression was the mean for each day and the maximum day for each treatment. A gompertz regression was used to develop a curve with a pre-set maximum. With hours of chilling on the x axis, the maximum was set and allowed for determination of appropriate chilling units to achieve that maximum. The flower counts were used as potential indicator for floral chilling

requirement and the number of dormant buds broken was used as an indicator of potential vegetative chilling requirement.

The amount of growing degree hours (GDH) required for first bud break and flower development was also determined. The number of GDH was calculated for each day, and the amount of GDH required to reach first bud break and first flowers were graphed for each chilling level.

Results

The average number of dormant buds that commenced growth and the number of flower buds that developed and grew per replication increased as the amount of chilling increased for all cultivars (Figure 4-9). Calculating when 95% of the maximum number of flowers to form or dormant buds to break had been reached a chilling requirement could be assigned to that maximum. This chilling requirement was determined to be the number of hours below 7 °C required for the rest period to be satisfied and optimum growth and flowering could commence.

Effect of chilling on dormant bud break

'Golden Sunshine' had the lowest vegetative chilling requirement at 700 h (Figure 4). 'AU Fitzgerald' and 'Golden Dragon' both were determined to have a vegetative chilling requirement of 800 h (Figure 5 and 6), and 'Hayward' was determined to have a chilling requirement of 900 h for optimum bud break (Figure 7). Both male cultivars, 'Authur' and 'Matua', were determined to have a 900 h chilling requirement for optimum chilling of vegetative buds (Figure 8 and 9).

'Golden Sunshine', the maximum number of dormant buds per replication to break and grow was 18. The regression coefficient was high ($R^2 = 0.95$), with the maximum at 700 h chilling for 'Golden Sunshine'. 'Golden Dragon' had a maximum number of dormant buds to break at 17.5. The regression coefficient was high ($R^2 = 0.71$), with a maximum at the 800 h chilling levels for 'Golden Dragon'. 'AU Fitzgerald' had a maximum dormant bud break of 14. The regression coefficient was low ($R^2 = 0.38$), with the maximum at 800 h chilling. Hayward required 900 h of chilling to reach its maximum bud break of 14 buds, and had a moderate regression coefficient ($R^2 = 0.54$).

The Male cultivar 'Matua' had a maximum bud break of 16 and reached it at 900 h chilling. The regression coefficient was moderate ($R^2 = 0.67$). 'AU Authur' reached its maximum at 900 h when bud break reached 15, and had a low regression coefficient ($R^2 = 0.35$).

The effect of chilling on flowers development

The average number of flowers to develop per replication increased with chilling for all cultivars. 'Golden Sunshine' had a maximum flower count of 70 per replication. The regression coefficient was very high ($R^2 = 0.95$), with a maximum at 900 h chilling. 'Golden Dragon' averaged 12 flowers per replication and had a very high regression coefficient ($R^2 = 0.99$). The maximum flower count was reached at 800 h chilling. 'AU Fitzgerald' averaged 40 flowers per replication and had a low regression coefficient ($R^2 = 0.50$). The maximum number of flower buds was reached at 1100 h chilling. The 'Hayward' cultivar failed to produce any flowers during the study, which likely indicates

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that its chilling range exceeds 950 h, which agrees with previous reported data (Caldwell, 1989).

The male cultivar 'Matua' required 950 h to reach the maximum flower count of 67, and had a high regression coefficient ($R^2 = 0.73$). 'AU Authur' had a flowering chilling requirement of 1,000 h when 38 flowers had been reached. The regression coefficient was very low ($R^2 = 0.24$).

<u>The effect of GDH on time until first bud breaks</u>

In addition to determining the amount of chilling required for each cultivar, the amount of heat units required to resume growth was determined. By graphing the amount of GDH required, for first bud break and first bloom against chill hours, a regression was developed, which was expressed as a polynomial regression inverse of the first order. The line from this regression predicts the amount of heat units required for growth to begin for each cultivar. Once the optimum chilling had been determined using the gompertz regression, the same optimum chill requirement was used to assign a corresponding GDH for first bud break and bloom for each cultivar.

As the amount of chilling increased for each cultivar, the amount of time until first bud break decreased. 'Golden Sunshine' required 15,000 GDH for bud break at the optimum 700 h chilling requirement. 'Golden Dragon' had the lowest number of GDH for first bud break. GDH of 9,000 was required for 'Golden Dragon' bud break to occur and growth to start at 800 h chilling. 'AU Fitzgerald' requirement 10,000 GDH for first bud break at the 800 h chilling. 'Hayward' required 12,500 GDH for bud break to occur at the 900 h chilling level.

The male cultivar 'Matua' required 10,200 GDH for bud break at the 900 h chilling level. 'AU Authur' required 10,750 GDH in order for bud break to occur at the 900 h chilling level.

The effect of GDH on amount of time until first bloom

With all cultivars, the amount of time until first bloom decreased as the amount of chilling increased, this was expressed as a polynomial regression inverse of the first order. 'Golden Sunshine' required 16,000 GDH for first bloom at the optimum 850 h chilling requirement. 'Golden Dragon' had the lowest number of GDH until first bloom at 12,000 GDH, for the 800 h chilling level. 'AU Fitzgerald' required 13,750 GDH for first bloom at the optimum 1,100 h chilling requirement. 'Hayward' did not produce flowers in any treatment thus no data was reported for bloom times.

The male cultivar 'Matua' reported 14,000 GDH were necessary for first bloom at the 950h chilling level. 'AU Authur' required 11,500 GDH in order for bloom to occur at the 1,000h chilling level.

Effect of Chilling on Stem Length

The length of the longest stem was used as an indicator of plant vigor for each treatment. Stem length increased linearly as chilling hours increased for all cultivars (Figures 10-15). 'Golden Dragon' and 'Golden Sunshine' produced the longest stems at 16.2 cm and 16.3 cm, respectively. Stem length of new growth may be attributed to the diameter of the cutting which attributes to the amount of starch reserves available for growth.

<u>Bloom of field grown kiwi</u>

Plants of 'Golden Dragon' grown in central Alabama bloomed earlier than the other cultivars included in this study (Table 3). 'Golden Sunshine' bloomed about two weeks after 'Golden Dragon'. 'Matua', 'AU Fitzgerald' and 'AU Authur' bloomed about 10 days after 'Golden Sunshine'; 'Hayward' was the last to break and bloom.

<u>Discussion</u>

'Golden Dragon' and 'Golden Sunshine' had the lowest chilling requirements for flowers at 800 and 850 h, respectively. 'Golden Dragon' and 'Golden Sunshine' may be suitable cultivars for more southern regions chilling hours received are typically below 1,000 h. 'Golden Dragon' has a lower heat requirement for first bloom of 12,000 GDH, which agrees with the field data that 'Golden Dragon' is an early flowering cultivar. 'Golden Sunshine' may be promising for major production because of its chilling requirement of 850 h and high heat unit requirement of 16,000 GDH for flowering. This would allow 'Golden Sunshine' chilling requirement to be satisfied and still require enough heat units to bloom later in the spring and reduce risk to late frosts.

'AU Fitzgerald' had a chilling requirement of 1100 h for optimum flower development, and a heat unit of 13,750 GDH. 'Hayward' failed to produce any flowers during the study, which implies that its chilling requirement exceeds 950 h, which agrees with another study (Caldwell, 1989). 'AU Authur' may be a suitable pollinator for 'AU Fitzgerald' because the chilling requirements are so close, 1000 h for 'AU Authur' and 1100 h for 'AU Fitzgerald'. The amount of heat units required by 'Matua' indicates it will bloom just before 'AU Fitzgerald', making it a good cultivar for covering the first

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half of 'AU Fitzgerald' bloom period. 'AU Authur' would be a suitable pollinator for the mid to latter part of 'AU Fitzgerald' bloom season and all of the 'Hayward' season.

The effect of chilling on stem length may be inconclusive on the basis of stem diameter. Since the amount of starch reserves available in the cutting could be directly related to that cuttings diameter, the results of such a comparison may be biased towards longer or thicker stems. During this study, the use of rootless cuttings produced data that agreed with bloom periods collected from the field for each cultivar. The amount of control over temperature and chilling allows for more accurate data collection than in a field environment and hence this technique may be suitable for future studies of growth and phenology for cultivars of *A. chinensis* and *A. delicosa*.

IV. INTERACTION OF CYTOKININ SPRAYS ON FRUIT SIZE AND INTERNAL QUALITY OF THREE CULTIVARS OF KIWIFRUIT *Actinidia chinensis* AND *A. deliciosa*

Introduction

Kiwifruit (*Actinidia deliciosa* A.Chev.) and (*Actinidia chinensis* Planch) originated in China. During the 1970's, all kiwi fruit was classified as *A. chinensis.* The cv 'Hayward' has been the most prominent fruit on the market. Since then, a tremendous industry has developed around new cultivars of kiwifruit with different attributes such as yellow flesh, smooth hairless skin, higher nutritional value and a sweeter taste. Sometimes size of the fruit was lost in the effort to harness some of these unique qualities. Consumers demand a large fruit of 100 grams or more with a pleasing symmetrical appearance (Crisosto, 2005).

In an effort to improve fruit size, plant growth regulators such as naturally occurring cytokinins (Benefit PZ) or synthetic cytokinins (Prestige) have been used to increase cell division. The purpose of this study was to determine if cytokinins would improve fruit size and internal fruit quality of *Actinidia chinensis* and *A. delicosa* cultivars.

Kiwi fruit growth occurs in three distinct stages (Grant, 1994). The first occurs after pollination; where fruit grows at its fastest rate and continues for 30-40 days. The initial rapid flush of growth is attributed to cell division. The second phase of growth is slow and continuous, lasting for another 30-40 days; this growth is due to cell enlargement.

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The final stage is a stage of even slower growth that will last until the fruit is harvested (Grant, 1994). As kiwi fruit grows, cell division and cell enlargement are both occurring, but cell division is at its peak immediately after pollination. Cytokinin is a natural occurring plant hormone that is believed to affect the cellular division phase of fruit growth immediately following pollination (Letham, 1994).

Plant growth regulators

Benefit PZ is a mixture of proteins, vitamins, and the amino acids glycine, asparatic acid, and glutamic acid that have been extracted from plant materials. Benefit promotes cell division during the early stage of development, after fruit set. The manufacturers of Benefit claim that an increase in fruit size will be seen as a result of the effect the biostimulant has on cell division phase of fruit development.

Prestige is a synthetic cytokinin. The active ingredient, (N-[2-chloro-4-pyridyl]-N'-phenylurea) or CPPU, it functions as a plant growth regulator on fruit and vegetables resulting in an increase in size. The manufacturer of Prestige reports that its use promotes fruit growth, yield, and improves the pack out by shifting fruit size up one category.

Cytokinin and fruit growth

The development of most fruit begins with a short period of cell division followed by a longer period of cell enlargement. Cytokinin levels in some fruit such as apple have been found in the highest levels during the cell division phase (Letham, 1994). Seed development is a potential site of cytokinin biosynthesis, but other parts of the plant may also produce cytokinin, especially areas undergoing cell division (Hahn et al., 1974).

Cytokinin and there effect on kiwi size and quality

Increases of final fruit weight of 30-40% have been reported with exogenous application of CPPU (Costa et al., 1996). Treated fruit were found to have an increase in thickness of the outer pericarp and a decrease of the inner pericarp, when compared with controls (Cruz et al., 1999). Many reports indicate that kiwifruit treated with CPPU 1-2 weeks after full bloom promote higher soluble solids and lower flesh firmness at harvest when compared to untreated fruit (Antognozzi et al., 1997; Costa et al., 1996, 1997; Fang et al. 1996;). CPPU apparently accelerates ripening and advances softening.

Rates

Fang et al. (1996) concluded that the optimum concentration of CPPU was 10-20 mg/liter active ingredient, and the best results were achieved when applied by an air blast sprayer that covered all sides of the fruit. When CPPU was used alone, a rate of 20 ppm CPPU significantly increased fruit size (Antognozzi et al., 1997; Famiani et al., 1996, 1997).

Ohara et al. (1997) concluded that 2.5-20 ppm CPPU were effective when compared to the control without a significant difference between rates. The Prestige label recommends a rate of 6g and no more then 8g of active ingredient per gallon of spray material for maximum effect.

Timing

Several researchers (Antognozzi et al., 1993, 1997; Famiani et al., 1997) reported a significant increase in the fruit size of *Actinidia deliciosa* cv Hayward after applying CPPU 14-15 days from full bloom. There is wide variation in reports of effectiveness regarding timing of CPPU application. Some researchers found that applications made

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20-21 days from full bloom (DFFB) were effective (Costa et al., 1996). Other studies reported that applications of 10-30 DFFB were optimum (Fang et al., 1996) and another study reported 14-21 DFFB to be optimal (Famiani et al., 1996). According to the Prestige application guidelines, a timing of 2-3 weeks after full bloom, when fruit diameter averages 30-45 millimeters, is the ideal time of application.

<u>Materials and Methods</u>

This study was conducted in the fall of 2005-2006. Mature kiwi vines of the cultivars *A. delicosa* 'AU Fitzgerald', *A. chinensis* 'Golden Sunshine', and *A. chinensis* 'Golden Dragon' were grown at The Chilton Area Research and Extension Center in Thorsby Ala. All vines were grown from a rooted softwood cuttings, and were trained to a winged t-bar trellis system at spacing of 2.4m by 4.8m. Vines were mature and fruiting for several years before this study was conducted.

Treatments consisted of Benefit, Prestige, or no spray treatment and were assigned to individual vines in a completely randomized design within the orchard. Prestige was applied to provide an observational study of how Prestige would perform on an *A. chinensis* kiwi, such as 'Golden Sunshine'. 'Golden Sunshine' plants were randomly selected and the results are reported as observational because sufficient replications of plants were not available to warrant proper statistical analysis.

Benefit treatments were applied three times at seven day intervals with the first application one week after full bloom. Benefit was applied at 3.17 ml/1 liter of water. Prestige was applied once, two weeks after full bloom at 2.54 ml/ 1 liter of water. Both

chemicals were applied using a 9.46 liter capacity SOLO back pack sprayer (Model 475, Cincinnati Ohio), making sure to get good coverage on all sides of the fruit.

Starting around 90 days from full bloom, five fruit from each cultivar were randomly selected from each treated and non-treated vine and transported to Auburn University fruit lab for immediate analysis.

External measurements of length and width (mm) were recorded using digital calipers (model CD-6 BS, Mitutoyo corp. Japan). The same calipers were used to record inner and outer pericarp, and core diameters (mm). Fresh and dry weight (g) were recorded using an OHAUS explorer analytical scale (model Explorer E16120, Ohaus Corp. Switzerland). Dry weight was determined by slicing the entire fruit into pieces and placing them in individual aluminum weigh boats, and weighed for fresh weight and then placed in a drying oven (Precision Scientific Company) at ~78 °C for at least 48 h until a constant weight was attained. A total percent dry matter was then calculated by dividing total dry weight by total fresh weight and multiplying by 100.

Internal flesh color and external skin color were determined using a Minolta colorimeter (model CM-2002; Minolta Camera Co., Japan) and data was expressed in hue angle and chroma. Hue angle is a measure of color change from green (160°) to yellow (90°) to orange (45°), while chroma is the intensity of hue angle color from near white to pure color (McGuire, 1992; Voss, 1992).

Fruit firmness (kg) was determined by removing a thin layer of skin from the shoulder of each fruit, and using a McCormick fruit pressure tester (Yakima, Washington) with an 8 mm tip.

Soluble solids content (%) was determined by removing two slices of fruit, from the calyx and basal ends, and expressing two drops of each into a refractometer dish. The unit used for analysis was the Palm Abbe (Model PA201, MISCO, Cleveland, Ohio) hand held temperature compensated refractometer. The results were crossed checked for accuracy using a bench model Leica Mark II plus refractometer (model 10494; Leica Microsystems Inc., Buffalo N.Y.).

Statistical Analysis

Means for the five fruit sample were calculated and the data for firmness, SSC, color, dry matter and fresh weight were graphed on the y-axis with days from full bloom (DFFB) on the x-axis. The resulting graph created a curve that indicated when the fruit was entering the climacteric phase which was determined by a rapid increase in SSC and a rapid drop in firmness.

Data prior to the climacteric were analyzed using the GLM procedure and regression analysis, which allowed treatment comparison up to harvest. Significance was set at the $P = 0.05$.

All statistical analysis was carried out using SAS V8 computer software. All graphs were created using Sigma Plot 9.0.

Results

Benefit effect on kiwi growth and fruit quality

There was an increase in fresh weight of all cultivars treated with Benefit at a rate of 3.17 ml/1 liter of water when compared to the controls (Table 4). 'AU Fitzgerald' increased by an average of 18%, 'Golden Dragon' treated fruit increased by an average of

14%, and 'Golden Sunshine' treated fruit increased an average of 27% when compared to the controls. Average fruit width of the fruit for 'Golden Sunshine' and 'AU Fitzgerald' were influenced more by Benefit sprays than was the fruit length. Fruit length and width were equally increased for 'Golden Dragon' by Benefit application (Tables. 5-7, Figures. 16-18).

Fruit firmness was affected by Benefit treatment when the fruit were harvested at 6.5 % SSC. There was a significant difference between treated and non-treated fruit for firmness ($P = 0.02$) as the harvest dates approached the beginning of the climacteric. 'Golden Sunshine' showed the most significant difference in firmness prior to entering the climacteric.

Percent SSC of 'Golden Dragon' and 'AU Fitzgerald' were affected by Benefit treatment. Treated 'Golden Sunshine' fruit showed the most significant difference in percentage SSC between treatments. The percent SSC was higher for the treated fruit and reached the 6.5 % SSC point 20 days ahead of the control fruit.

Percent dry matter, internal and external color of the fruit of the three cultivars were not affected by Benefit application.

Discussion

There was a positive increase in total fresh weight of 'Golden Dragon', 'Golden Sunshine', and 'AU Fitzgerald' fruit treated with Benefit with little to no effect on internal quality or timing of harvest, with the exception of 'Golden Sunshine'. The increase in size is attributed to an increase in cell division immediately following pollination. The percent increases in size and weight are listed for each cultivar and

treatment. 'Golden Dragon' growth was observed to increase fruit length and width similarly.

Cytokinins promote cell division immediately following pollination (Letham 1994). It is proposed that the maximum cell size is not affected by Benefit application. Sugar content is not directly affected by an increase in cell division and the sugars are not being diluted by excess water that move into the cell vacuole. Cellular division is the key component of the increased fruit size as indicated by the lack of difference in % SSC and % dry matter for all three cultivars.

If increased cell enlargement was involved with the increase in size, we would expect to see a decrease in percentage SSC as the cells of the fruit swelled with water and soluble solids were diluted. Also, if cell enlargement was involved, a decrease in percentage dry matter would be attributed to the lack of cellulose and other polysaccharides in the cell walls being laid down as cell walls enlarged. If cell enlargement were involved, the fresh weight would increase as a result of water absorption and the loss of this water during drying would result in a lower percentage dry matter.

A maturity index based on percent SSC or internal color should not be affected by Benefit application, for the cultivars 'Golden Dragon' and 'AU Fitzgerald'. The effect Benefit application has on firmness and percent soluble solids of 'Golden Sunshine' fruit could produce earlier harvest dates of this cultivar by one to two weeks. Early softening was not observed for any of the other cultivars in the study as a result of Benefit

application.

Prestige effect on fruit growth and internal quality

Prestige did not affect fresh weight compared to controls for 'Golden Sunshine' (Figure 19). The percent dry matter was not affected by application of Prestige. There was no change in firmness or SSC as a result of application of Prestige.

There was large variation in fresh weights of fruit between samples from the same vine and treatments. Certain irregularities in percentage increase of fresh weight could be attributed to pollination. The randomness of the five fruit sample would invariably contain some fruit that were poorly pollinated. As pollination has a direct affect on final fruit size, these poorly pollinated fruit were that skewed data on fresh weight to appear lower then the actual average for production graded fruit.

RESEARCH IMPLICATIONS AND FUTURE RESEARCH

In order for kiwi production industry to develop in Alabama, there must be a thorough groundwork of cultural practices and production methods that will work best in this region. Alabama, although similar in climate to regions of New Zealand and China, is a very different environment that must be understood before a new commodity can be produced on a large scale.

One of the more fundamental questions a grower would want to know is which cultivars they can grow and sell. Not only must the fruit have a desirable physical appearance and good taste, it must successfully grow in this region. This research provides a new level of understanding as to some of the techniques and requirements to grow kiwi successfully in Alabama.

Certain questions about chilling requirements, maturity indexes and use of plant growth regulators (PGR) were all addressed in this study. More importantly, these questions were addressed for three new cultivars that show potential for production in Alabama.

The chilling requirement is an important consideration in kiwi production due to kiwi's tendency to flower inadequately when chilling requirements are not met. Data on heat required for first bud break and bloom provides useful information on which cultivars could be grown with the least possibility of frost damage in the spring.

Although 'Golden Dragon' has a low chilling requirement of 800 h, its heat unit requirement of 12,000 GDH would put it at danger of freeze damage in more northerly region, where early bud break would be at risk of frost. 'Golden Sunshine' also has a low chilling requirement of 850 h, but its heat requirement of 16,000 GDH would reduce its risk to late spring frost.

'AU Fitzgerald' had a chilling requirement of 1100 h for optimum flower development, and a heat unit of 13,750 GDH. The 'Hayward' cultivars failed to produce any flowers during the study, which indicates that its chilling requirement exceeds 950 h, and agrees with another study (Caldwell, 1989). 'AU Fitzgerald' may be a more suitable green kiwi cultivar for this region due to its lower chilling and heat unit requirement.

Understanding the optimum timing of harvest is a crucial factor for achieving maximum shelf life. By knowing when fruit is at its peak quality with maximum storage potential, a quality product can be marketed. For *A. chinensis* cultivars, 'Golden Dragon' and 'Golden Sunshine', and the *A. delicosa* cultivar, 'AU Fitzgerald', percent SSC and firmness were both reliable indicators of maturity. In the case of the *A. chinensis* cultivars, internal flesh color was also useful in determining the stage of maturation. 'Golden Dragon' entered the climacteric at 135 days from full bloom when it approached a 7% SSC and a firmness of 6.75 kg. 'Golden Sunshine' was at full maturation and entered ripening at 95 DFFB at 5.5% SSC and a firmness of 6.75 kg. The internal flesh color at these specific dates was a hue angle of 98° for 'Golden Dragon' and 104° for 'Golden Sunshine'. 'AU Fitzgerald' was ready to harvest at 150 DFFB in 2004 at 6 to 7.5% SSC. Firmness at this stage ranged from 5.8 to 7.2 kg.

The use of Benefit at a rate of 3.17 ml\1 liter of water effectively increased size of all three cultivars in this study by as much as 27%. There was a slight increase in soluble solids and a decrease in firmness at harvest, for the cultivar 'Golden Sunshine'. Advanced ripening of 'Golden Sunshine' by Benefit application advanced harvest by 20 days. Further studies should use larger fruit samples for each harvest date, which would help determine rate of maturation more clearly. Benefit applications were superior to Prestige at increasing fruit size.

Future Research

Future Research should address marketing issues of kiwi in the southeast. Many consumers are unaware of the taste and health benefits of kiwi, especially golden kiwi. A sensory survey should be conducted with the three cultivars in this study compared to the standards 'Hayward' and 'Hort 16-A'. Consumer preference could also be studied as to preferences of packaging.

Pollination is still a major production concern with these cultivars. Evaluation of male cultivars as potential pollinizers for each female cultivar should be conducted. A study using pollen sprays for supplemental pollination could provide an alternative to relying on bees alone.

Trellising is always an area of interest with any vine crop. New techniques such as 'strings' where next years fruiting wood is trained to vertical wires or bi-annual cropping should be considered as alternative management practices.

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The potential for 'value added' products is substantial with kiwi, ranging from wine, preserves, juice, and fragrances. If a processing system could be developed for culled fruit, substantial revenues could be redeemed.

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Treatment #	Cultivar	Maximum number of chilling hours exposed
1	GD, GS, FF, AA, H, M	600
2	GD, GS	643
3	GD, GS, FF, AA, H, M	712
4	GD, GS	750
5	GD, GS, FF, AA, H, M	800
6	GD, GS	850
7	FF, AA. H, M	900
8	FF, AA, H, M	950

Cultivar Abbreviations
GD = 'Golden Dragon'
GS = 'Golden Sunshine'
FF = 'AU Fitzgerald'
H= Hayward
M='Matua'
AA = 'AU Authur'

Table 1. Treatments and cultivars studied in 2005.

Treatment #	Cultivar	Maximum number of chilling hours exposed
1	GD, GS	150
2	GD, GS	220
3	GD, GS	270
4	GD, GS	320
5	GD, GS	370
6	GD, GS	442
7	GD, GS, FF	500
8	M, FF	552
9	FF	560
10	FF	608
11	FF	652
12	AA	654
13	AA, FF	720
14	FF	750
15	FF	852
16	AA	875
17	FF	955
18	AA, FF	1065
19	FF	1160

Cultivar Abbreviations

GD = 'Golden Dragon'

GS = 'Golden Sunshine'

FF = 'AU Fitzgerald'

AA = 'AU Authur'

Table 2. Treatments and cultivars studied in 2006.

Cultivar	
Golden Dragon	4/9[1]-----------4/15[2]
Golden Sunshine	4/29[1]------------------5/10[2]
Arthur	5/12[1]----------------5/16[2]
Matua	5/9[1]------5/12[2]
Fitzgerald	5/9[1]---------------------------5/16[2]
Hayward	5/12[1]---------------5/16[2]

Table 3. Bloom period of kiwifruit cultivars at Chilton Research and Extension Center in Thorsby, Ala., 2005.

[1] 10 % bloom
[2] > 90 % bloom

	Fruit Size								
	Length (mm)			**Fruit Width 1 (mm)**			**Fruit Width 2 (mm)**		
Days From Full Bloom	**Benefit**	**Control**	**% Increase**	**Benefit**	**Control**	**% Increase**	**Benefit**	**Control**	**% Increase**
92	57.1	56.5	1.2	50.1	51.8	-3.4	45.4	44.6	1.8
96	59.2	52	12.2	53.2	47.8	10.2	47.3	43.8	7.5
120	58.8	55.3	6	52.7	52.4	0.6	48.8	47.2	3.3
134	60.9	63.3	-3.9	57	57.4	-0.7	52.3	50.4	3.6
148	59	55.4	6.1	52.6	50.3	4.5	47.9	45.8	4.3
154	70.9	68.4	3.5	61.4	58.4	5	55.9	53.7	3.9
161	59.5	55.6	6.5	55.3	53.9	2.5	50.8	47.7	6.1
176	63.2	58.5	7.4	55.3	53.1	3.9	52.1	47.9	8

	Weight					
	Fresh Wt (g)			**Dry Wt (g)**		
92	74.9	72.9	2.7	9.7	9.8	-1.9
96	86.2	64.8	24.8	11.7	9	23.2
120	87.6	77.2	11.9	12.3	11.3	8.1
134	112.2	105.6	5.9	17.7	17.4	1.7
148	90	74.9	16.8	12.5	11.5	8.4
154	145.7	123.8	15	21.1	18.8	10.9
161	105.4	88.3	16.2	17.4	14.4	17.2
176	108.8	88.3	18.8	19.1	15.2	20.7

Table 4. Effect of Benefit application on fruit size and weight for 'Golden Dragon'.

	Fruit Size								
	Length (mm)			Fruit Width 1 (mm)			Fruit Width 2 (mm)		
Days From Full Bloom	Benefit	Control	% Increase	Benefit	Control	% Increase	Benefit	Control	% Increase
37	58.2	53.4	8.1	41.5	37.2	10.4	38.8	35.8	7.8
53	64.0	61.8	3.3	46.3	41.9	9.5	42.3	39.6	6.6
67	60.3	63.1	-4.6	44.2	41.2	6.9	40.9	39.7	3.1
81	65.3	58.1	11.0	47.6	39.7	16.4	43.7	38.3	12.4
95	69.7	66.8	4.1	51.5	46.4	9.9	47.7	45.0	5.7
109	72.9	66.6	8.7	52.6	44.8	14.9	47.9	43.1	9.9
115	73.5	75.6	-2.8	52.4	50.4	3.7	47.1	45.5	3.4
122	73.6	63.7	13.4	52.1	42.3	18.8	48.1	41.4	13.9

	Weight					
	Fresh WT (g)			Dry WT (g)		
37	57.5	43.6	24.2	5.5	4.2	23.4
53	78.8	62.1	21.2	8.4	7.4	12.4
67	68.1	60.4	11.3	8.9	8.8	1.2
81	86.8	51.4	40.8	12.4	8.2	33.7
95	109.4	81.1	25.9	17.5	14.0	19.8
109	117.6	77.9	33.8	18.9	12.2	35.8
115	120.9	103.1	14.7	18.5	18.1	1.9
122	122.1	67	45.1	19.7	11.8	40.0

Table 5. Effect of Benefit application on fruit size and weight for 'Golden Sunshine'.

		Fruit Size							
	Length (mm)			Fruit Width 1 (mm)			Fruit Width 2 (mm)		
Days From Full Bloom	Benefit	Control	% Increase	Benefit	Control	% Increase	Benefit	Control	% Increase
104	66.9	66.4	0.8	49.0	44.6	9.1	40.8	38.9	4.8
118	71.6	64.3	10.2	48.3	43.3	10.4	43.2	38.5	10.8
131	70.2	63.7	9.3	48.8	44.6	8.6	42.6	38.8	8.8
142	74.1	67.1	9.5	51.4	46.0	10.7	45.2	39.9	11.7
146	69.2	66.2	4.3	49.8	45.2	9.3	42.4	40.2	5.3
163	71.3	73.6	-3.2	49.0	49.0	0.1	43.2	41.5	3.9

		Weight				
	Fresh WT (g)			Dry WT (g)		
104	78.5	68.5	12.7	12.0	11.0	8.7
118	88.7	65.5	26.1	14.5	11.2	23.0
131	89.3	66.4	25.7	14.7	11.1	24.8
142	105.2	93.5	11.1	18.2	17.4	4.4
146	87.0	74.0	14.9	14.4	12.4	13.9
163	91.1	72.8	20.1	16.9	13.3	21.4

Table 6. Effect of Benefit application on fruit size and weight for 'AU Fitzgerald'.

Source	Fresh Wt.	Width	Length	Firmness	Brix	Dry Matter	Int. H*	Ext. H*
Var	0.0715	0.7585	0.1890	0.0014	0.2427	<.0001	<.0001	0.0199
Spray TRT	0.0001	0.5622	0.2650	0.0224	0.01847	0.0777	0.7625	0.5311
DFFB	<.0001	0.7303	0.3814	<.0001	<.0001	<.0001	0.0007	0.0005
Var*Sprat TRT	0.2143	0.7604	0.2464	0.0766	0.1314	0.5435	0.6973	0.5385
DFFB*Var	0.0661	0.8724	0.6733	<.0001	0.7318	<.0001	0.0159	0.0545
DFFB*Spray TRT	0.5015	0.7143	0.4862	0.68	0.6127	0.6157	0.8162	0.578
DFFB*VAR*SrayTRT	0.687	0.8649	0.6393	0.5279	0.3863	0.474	0.7831	0.8475

Using the GLM procedure of SAS analysis was carried out on the linear regression of values prior to the climacteric. P-values were considered significant if <.05 level.

Source: Var = cultivar, Spray TRT = spray treatment, DFFB = Days from full bloom, Var* Spray TRT = interaction between cultivar and spray treatment, DFFB*Var = interaction between days from full bloom and cultivar, DFFB*Spray TRT = interaction between days from full bloom and spray treatment, DFFB*VAR*Spray TRT = interaction between days from full bloom, cultivar and spray treatment.

Table 7. P-values of internal quality measurements across cultivars and Benefit applications.

'Golden Sunshine'
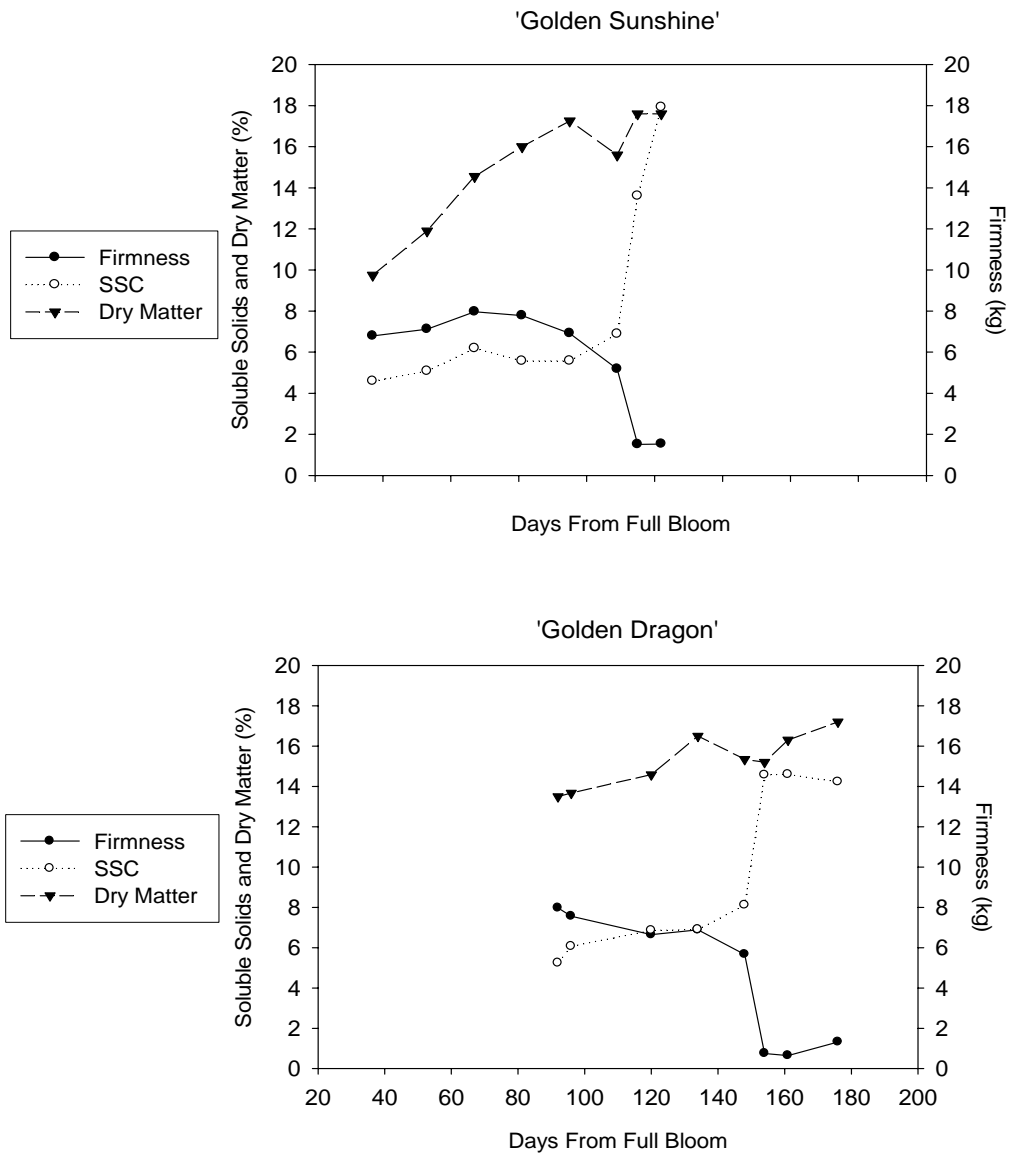
'Golden Dragon'

Figure 1. Fruit of quality 'Golden Dragon' and 'Golden Sunshine' in 2005.
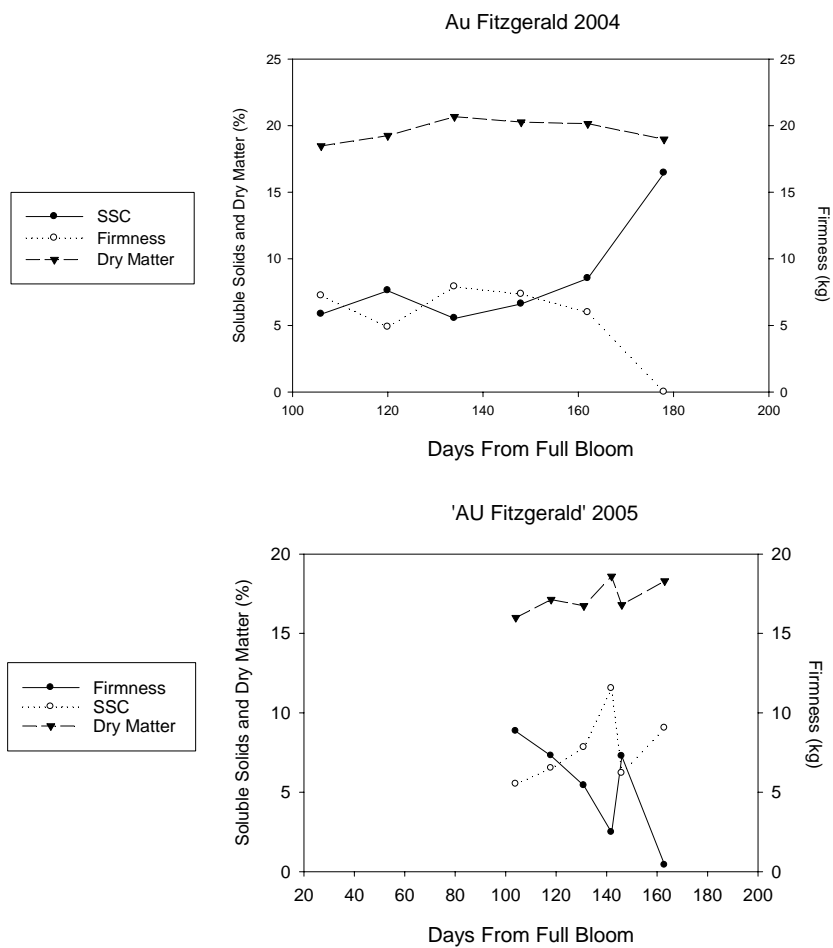
Figure 2. Fruit quality of 'AU Fitzgerald' in 2004 and 2005.
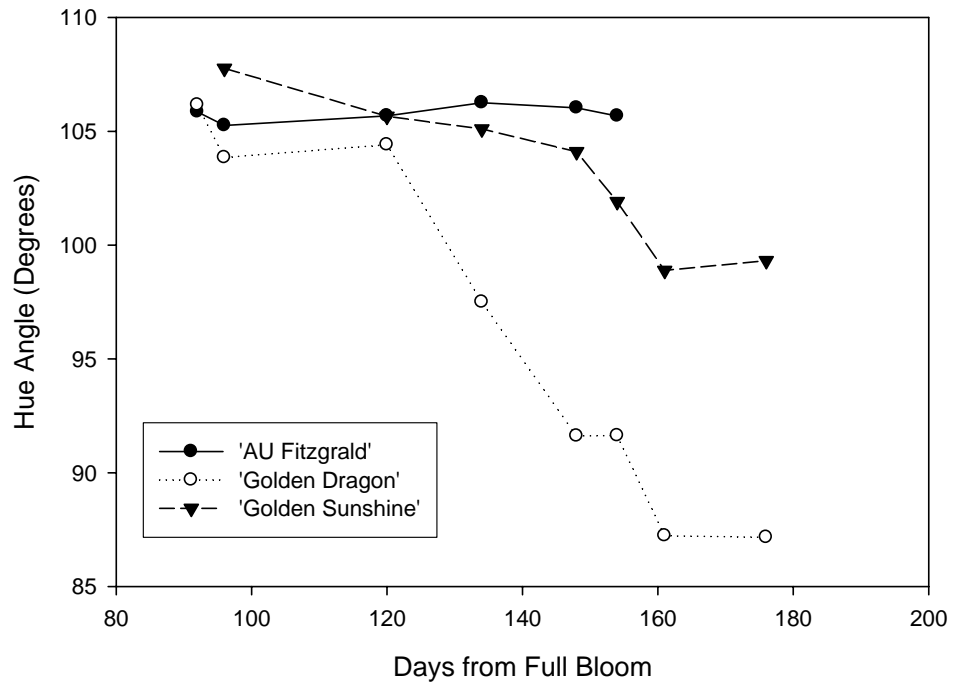
Figure 3. The internal color of 'AU Fitzgerald', 'Golden Dragon', and 'Golden Sunshine'
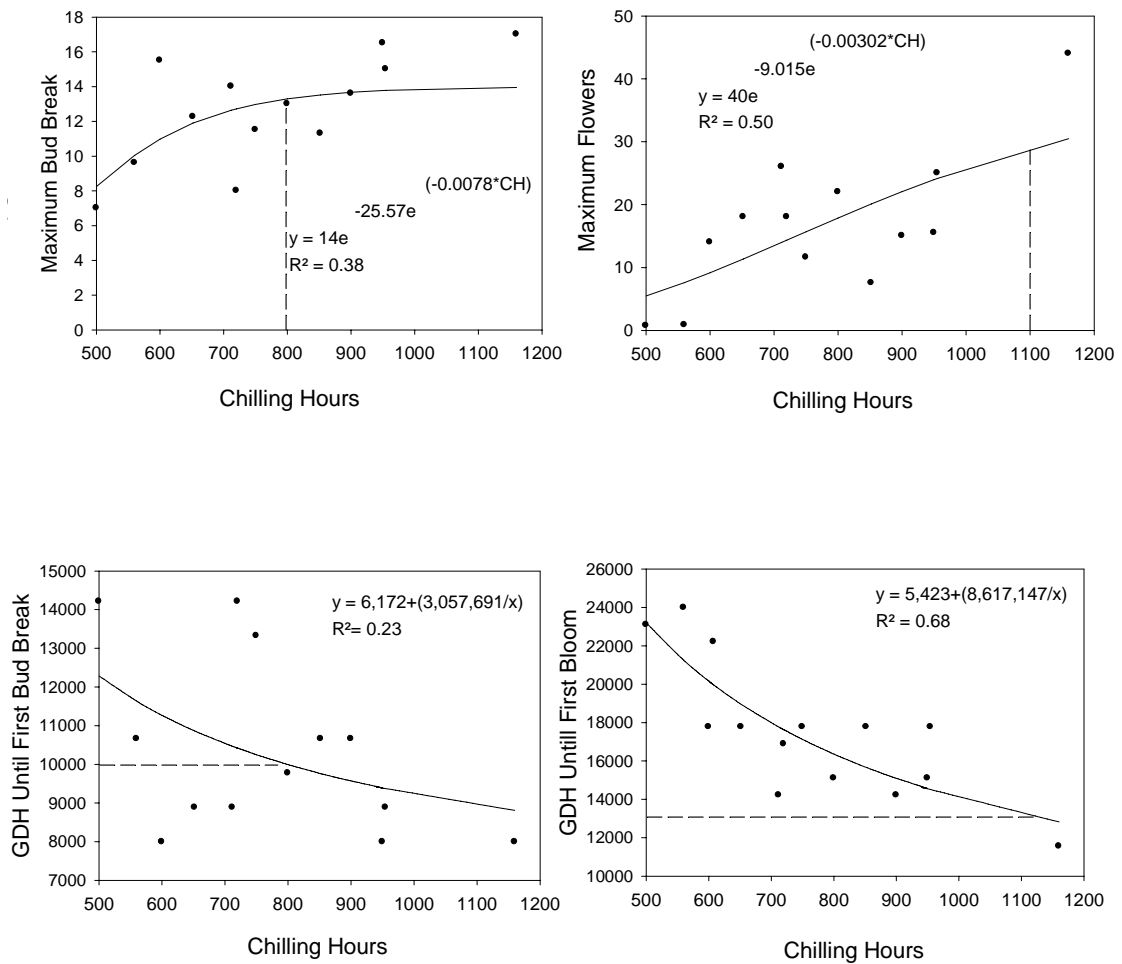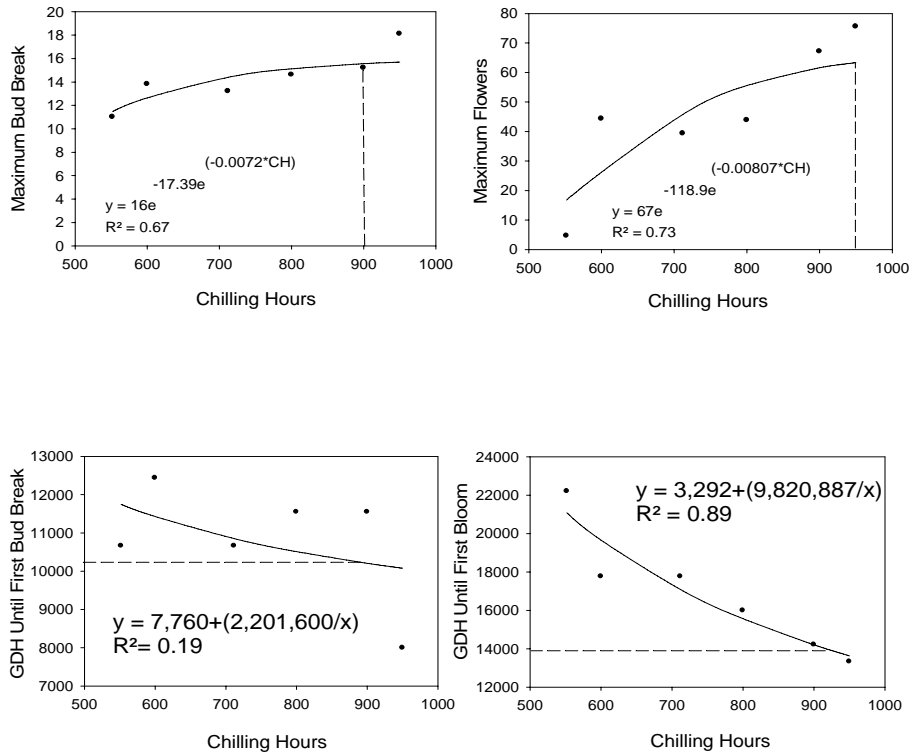in 2005.
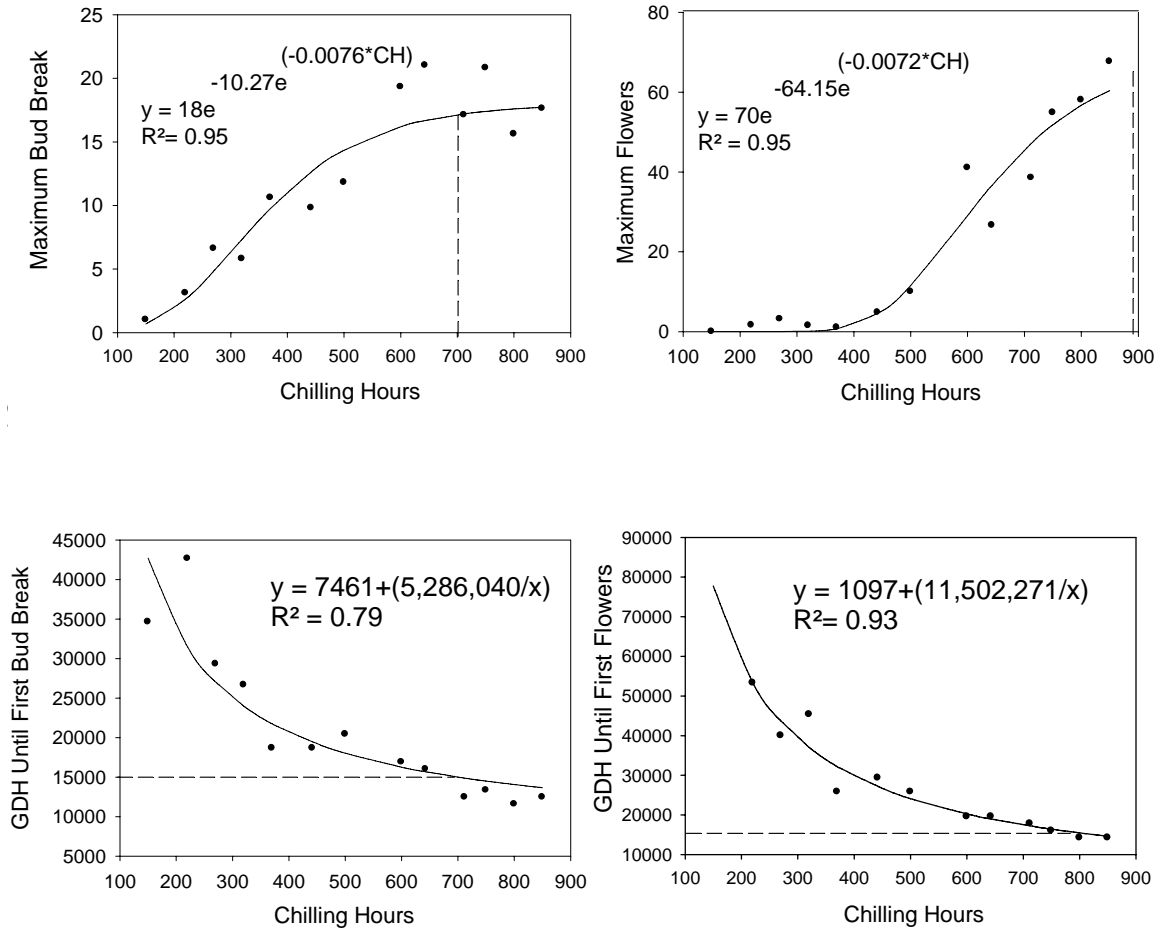
Figure 4. The effect of chilling hours on maximum bud break and maximum flowers for 'Golden Sunshine' and the effect of growing degree hours (GDH) on time until first bud break and first bloom. Verticle dotted line indicates chilling hours for 95% of maximum flowers or buds broke. Horizontal dotted line indicates the number of GDH required to reach first bud break and first bloom at optimum chilling hours.
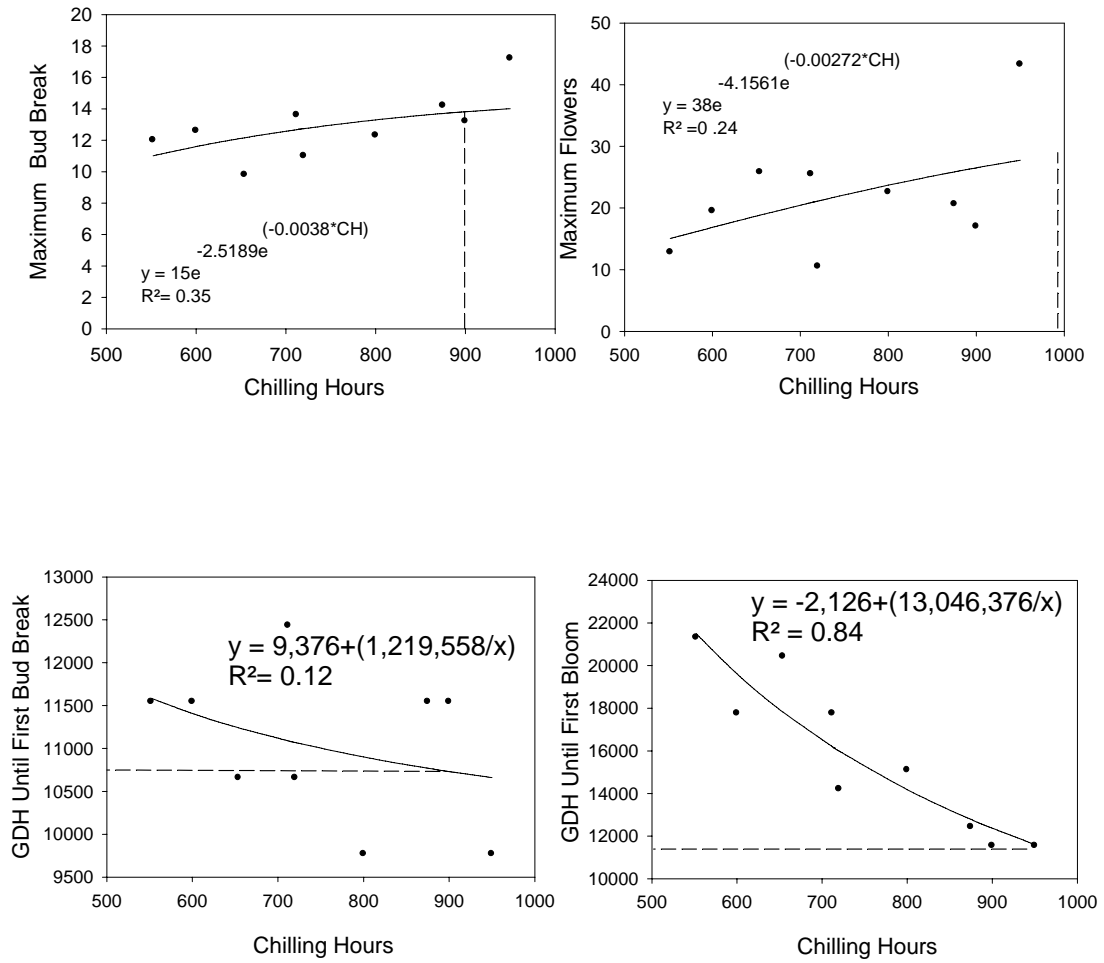
Maximum Bud Break chart:

$(-0.00431*CH)$

$-1.77e$

$y = 17.5e$

$R^2 = .71$

X-axis: Chilling Hours

Maximum Flowers chart:

$(-0.0109*CH)$

$-182.3e$

$y = 12e$

$R^2 = .99$

X-axis: Chilling Hours

GDH Until First Bud Break chart:

$y = 5{,}837 + (2{,}807{,}004/x)$

$R^2 = 0.66$

X-axis: Chilling Hours

GDH Until First Bloom chart:

$y = 1{,}075 + (8{,}488{,}633/x)$

$R^2 = 0.78$

X-axis: Chilling Hours
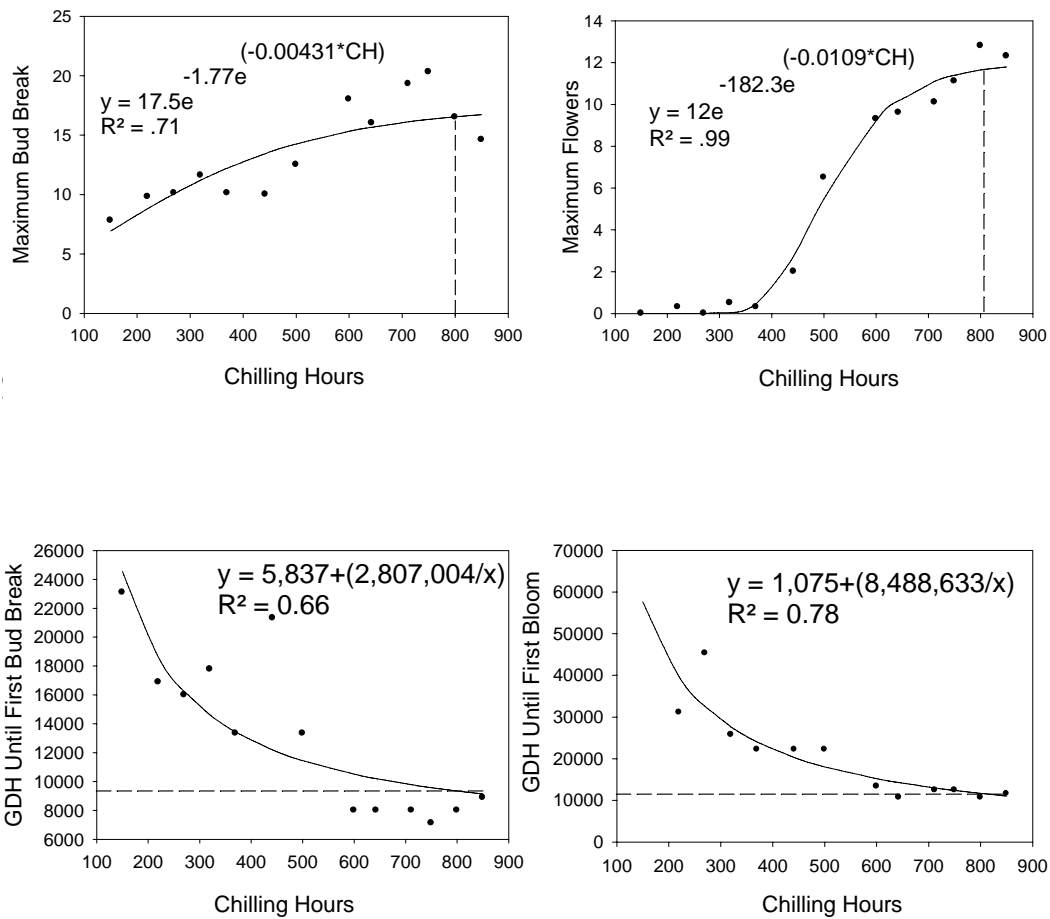
Figure 5. The effect of chilling hours on maximum bud break and maximum flowers for 'Golden Dragon' and the effect of growing degree hours (GDH) on time until first bud break and first bloom. Verticle dotted line indicates chilling hours for 95% of maximum flowers or buds broke. Horizontal dotted line indicates the number of GDH required to reach first bud break and first bloom at optimum chilling hours.

Figure 6. The effect of chilling hours on maximum bud break and maximum flowers for 'AU Fitzgerald' and the effect of growing degree hours (GDH) on time until first bud break and first bloom. Verticle dotted line indicates chilling hours for 95% of maximum flowers or buds broke. Horizontal dotted line indicates the number of GDH required to reach first bud break and first bloom at optimum chilling hours.
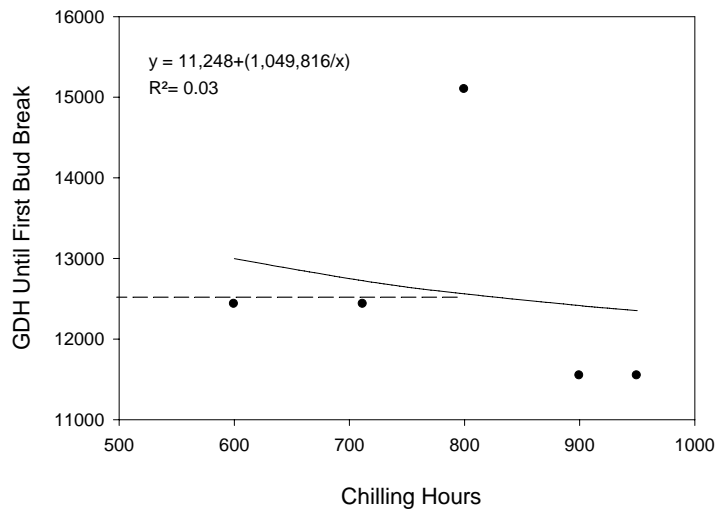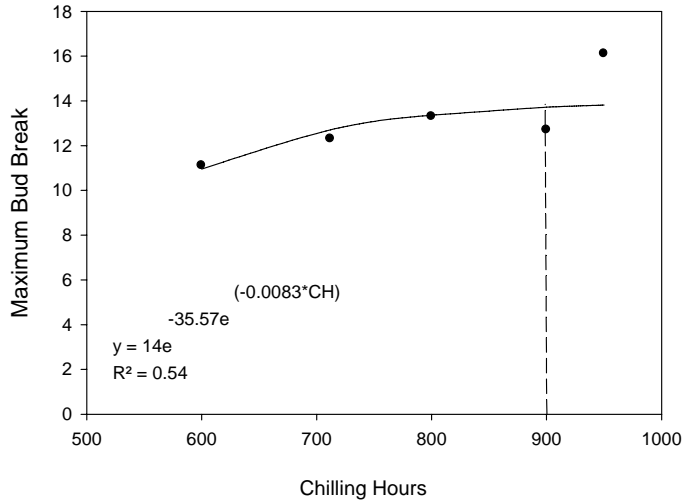
Figure 7. The effect of chilling hours on maximum bud break for 'Hayward' and the effect of growing degree hours (GDH) on time until first bud break. Verticle dotted line indicates chilling hours for 95% of maximum buds broke. Horizontal dotted line indicates the number of GDH required to reach first bud break and at optimum chilling hours.

Figure 8. The effect of chilling hours on maximum bud break and maximum flowers for 'Matua' and the effect of growing degree hours (GDH) on time until first bud break and first bloom. Verticle dotted line indicates chilling hours for 95% of maximum flowers or buds broke. Horizontal dotted line indicates the number of GDH required to reach first bud break and first bloom at optimum chilling hours.

Figure 9. The effect of chilling hours on maximum bud break and maximum
flowers for 'AU Authur' and the effect of growing degree hours (GDH) on time
until first bud break and first bloom. Verticle dotted line indicates chilling hours
for 95% of maximum flowers or buds broke. Horizontal dotted line indicates
the number of GDH required to reach first bud break and first bloom
at optimum chilling hours.

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$$y = 4.9906 + 0.0061 * x$$
$$R^2 = 0.13$$
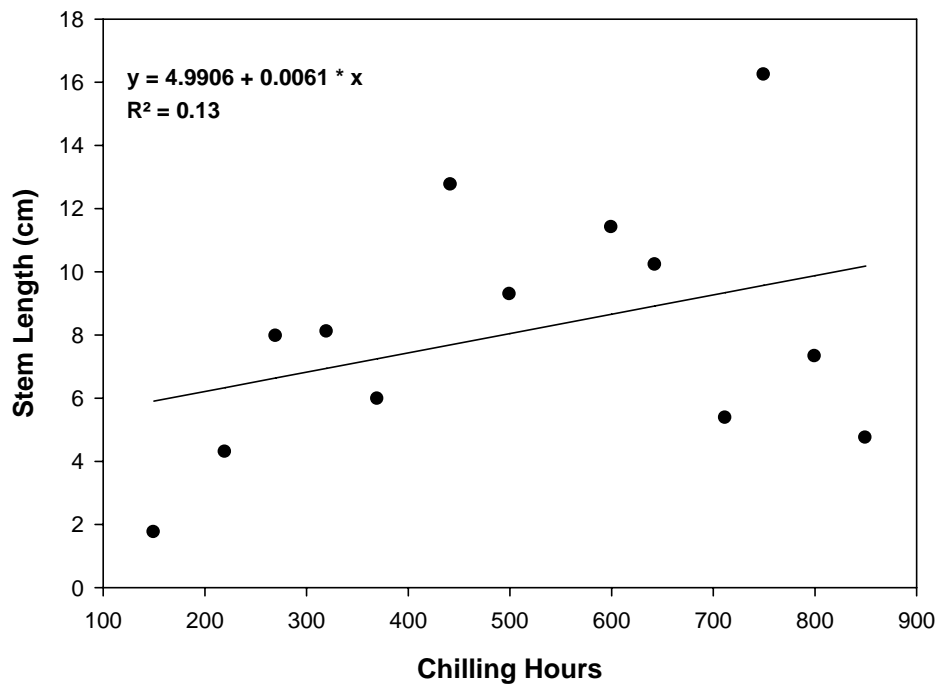
Figure 10. Effect of Chilling on stem length for 'Golden Sunshine'.
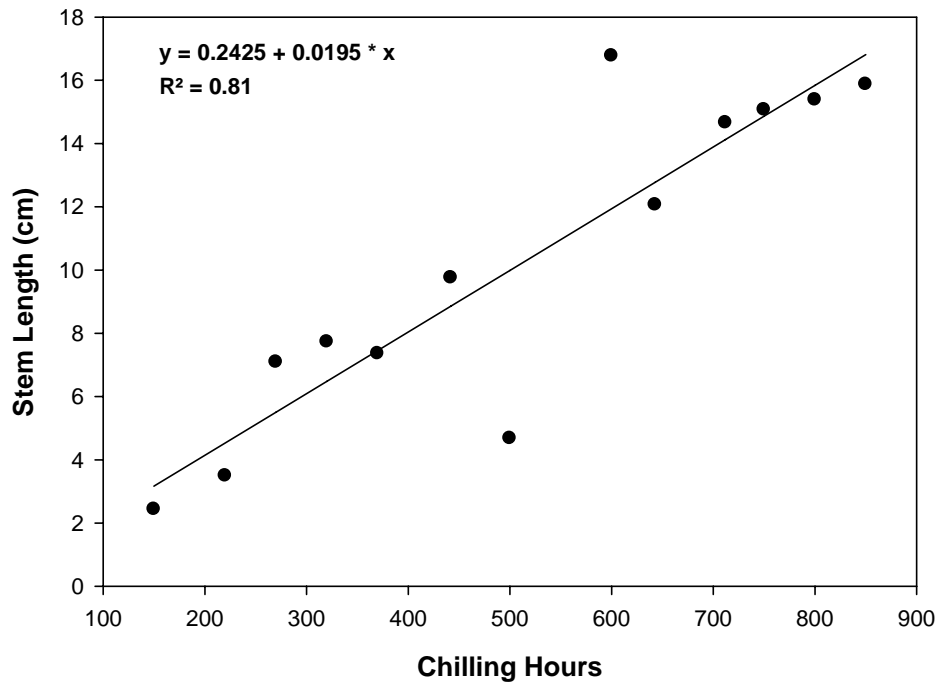
Figure 11. The effect of chilling on stem length for 'Golden Dragon'.

y = 5.7486 + 0.0082 * x
R² = 0.67
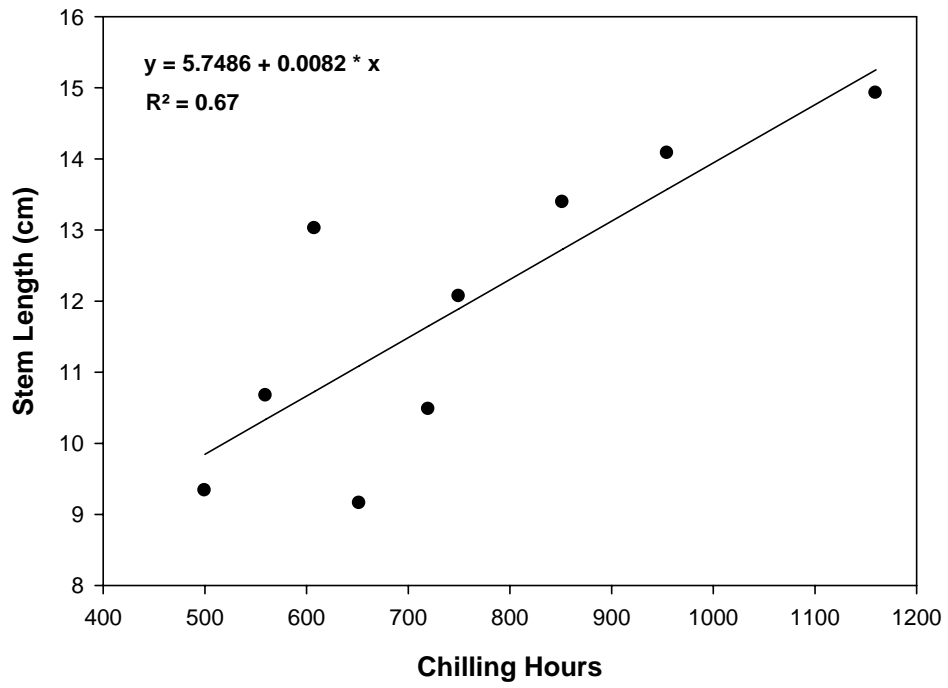
Figure 12. The effect of chilling on stem length for 'AU Fitzgerald'.
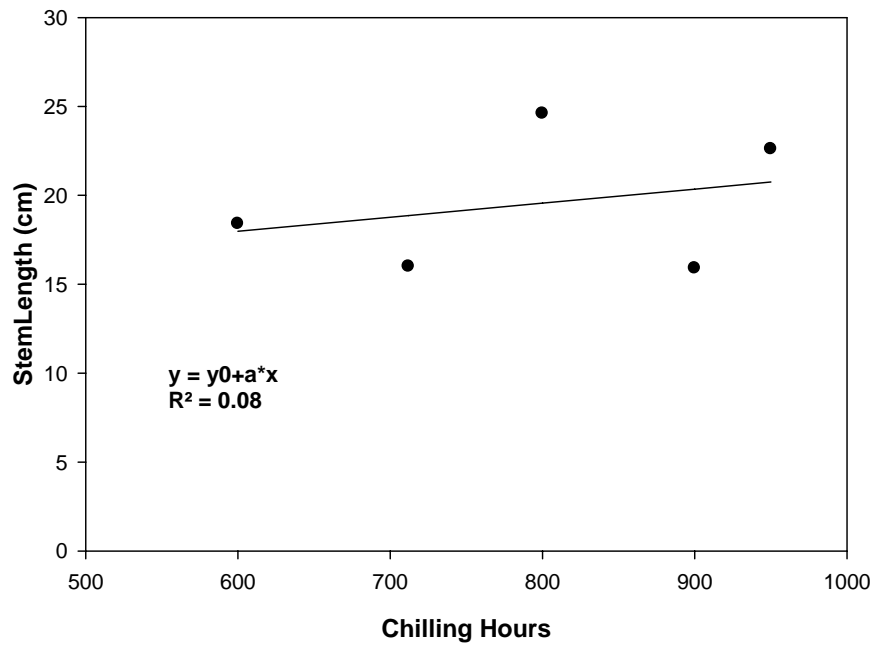
Figure 13. The effect of chilling on stem length for 'Hayward'.
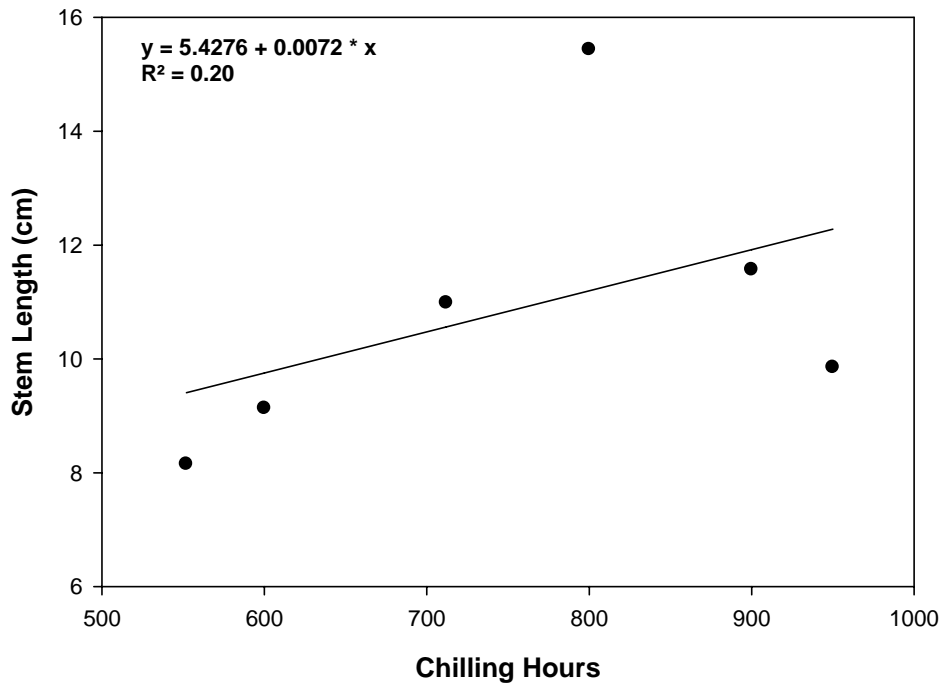
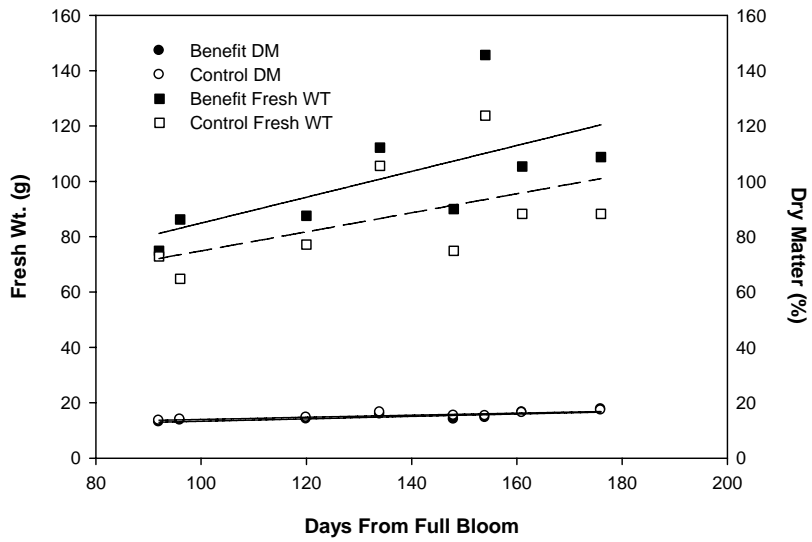Figure 14. The effect of chilling on stem length for 'Matua'.
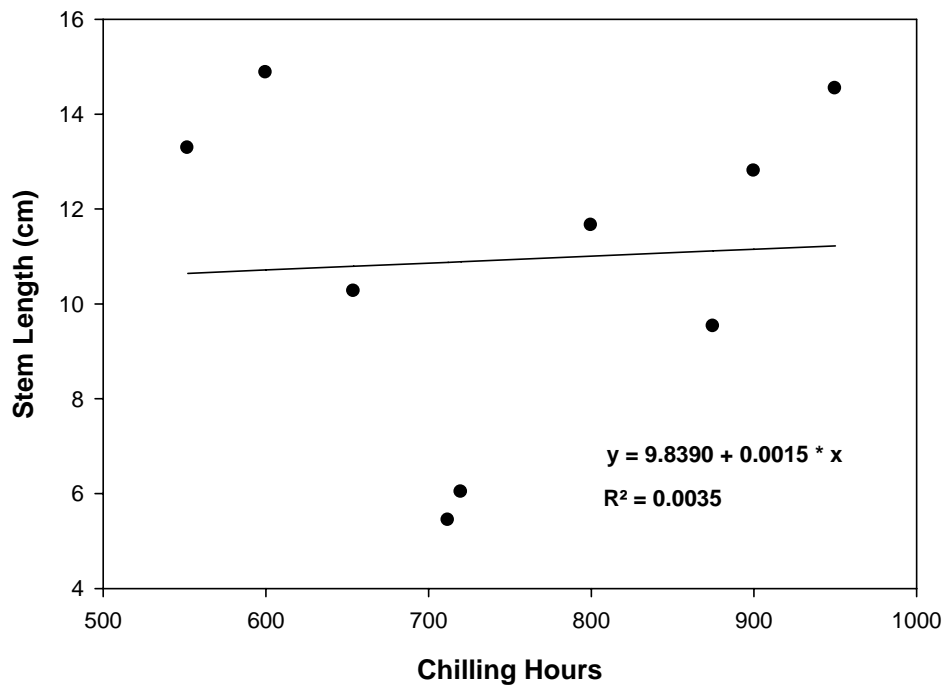
Figure 15. The effect of chilling on stem length for 'AU Authur'.
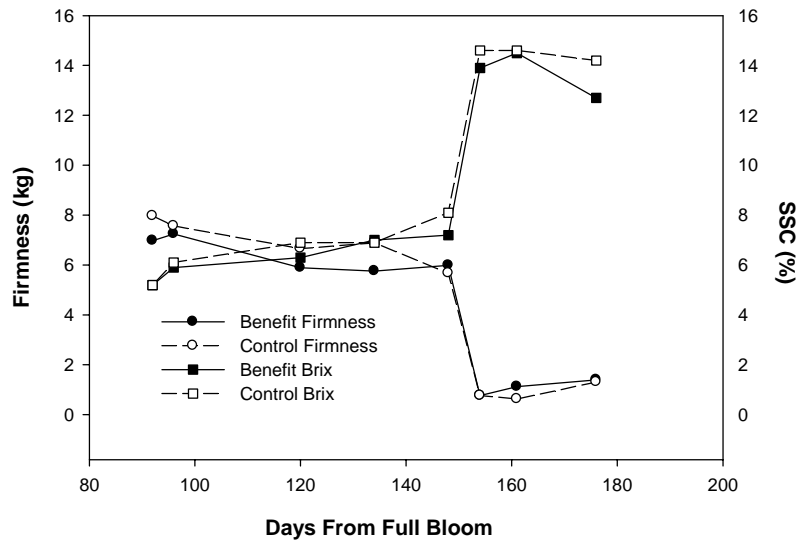
Figure 16. Effect of Benefit on firmness, SSC, fresh weight and dry matter for 'Golden Dragon'.
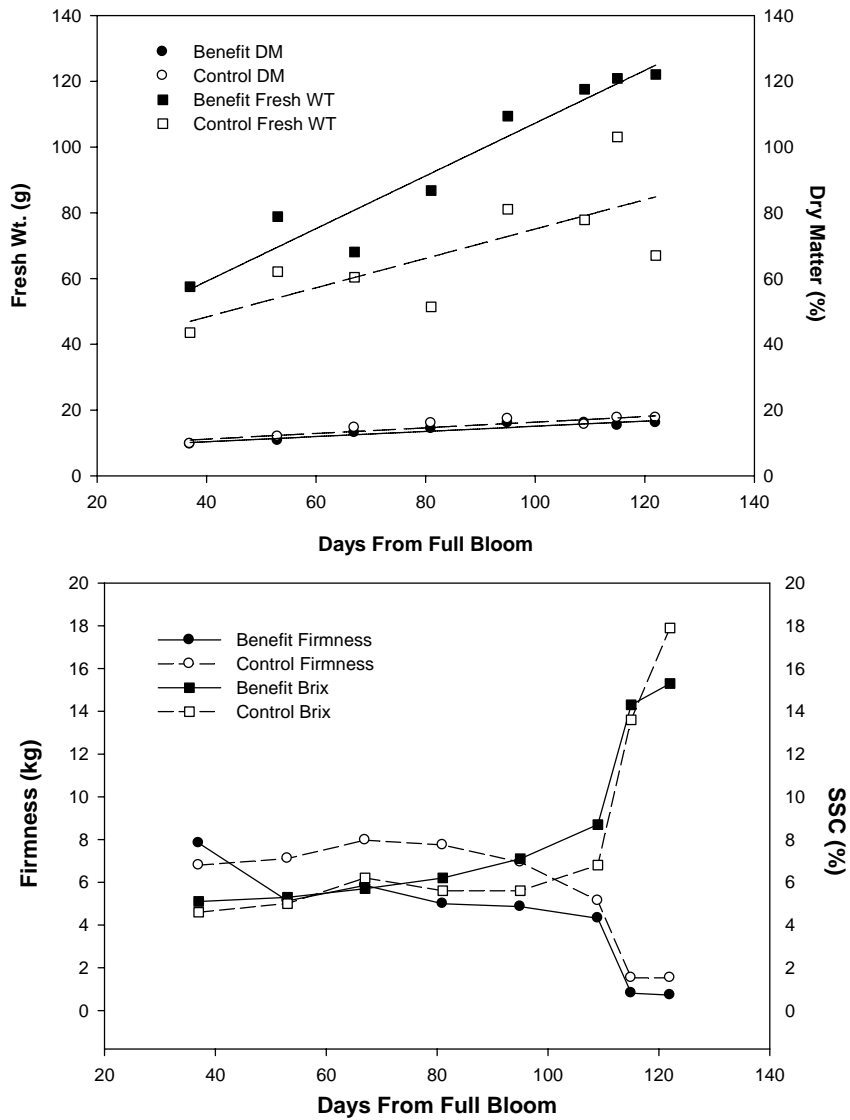
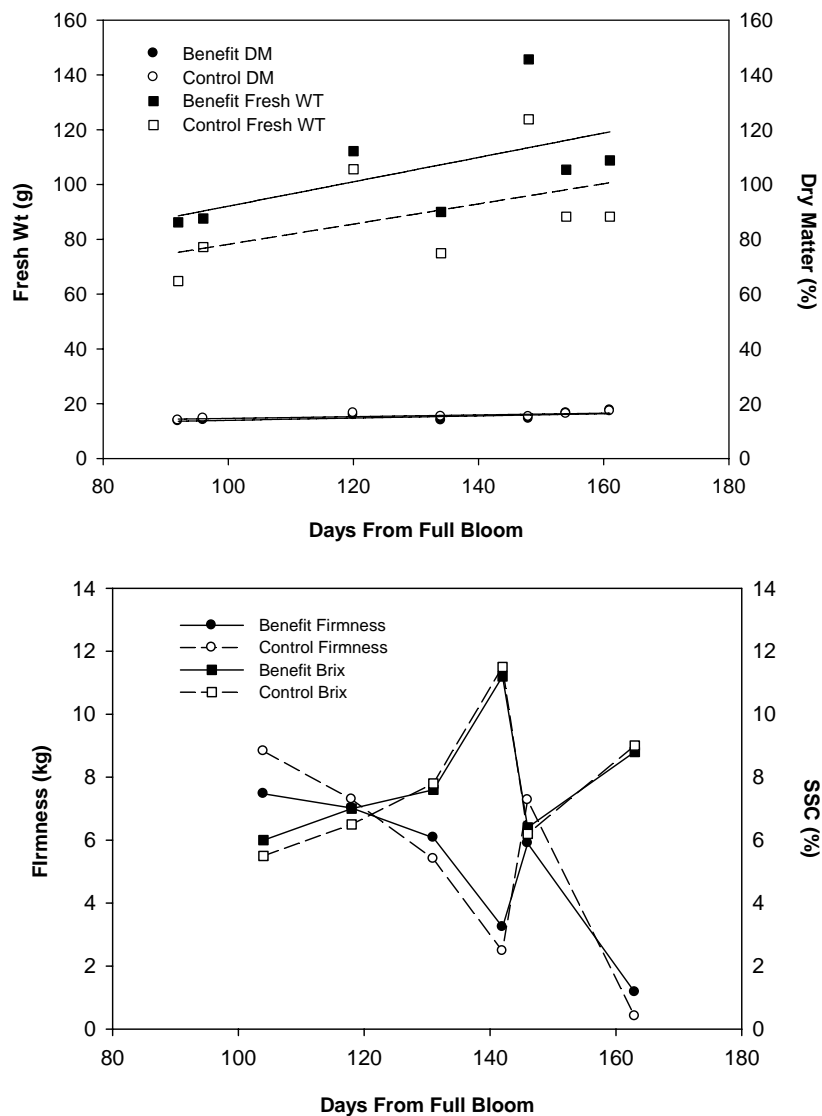Figure 17. Effect of Benefit on firmness, SSC, fresh weight and dry matter for 'Golden Sunshine'.

FIgure 18. The effect of Benefit on firmness, SSC, fresh weight and dry matter for 'AU Fitzgerald'.
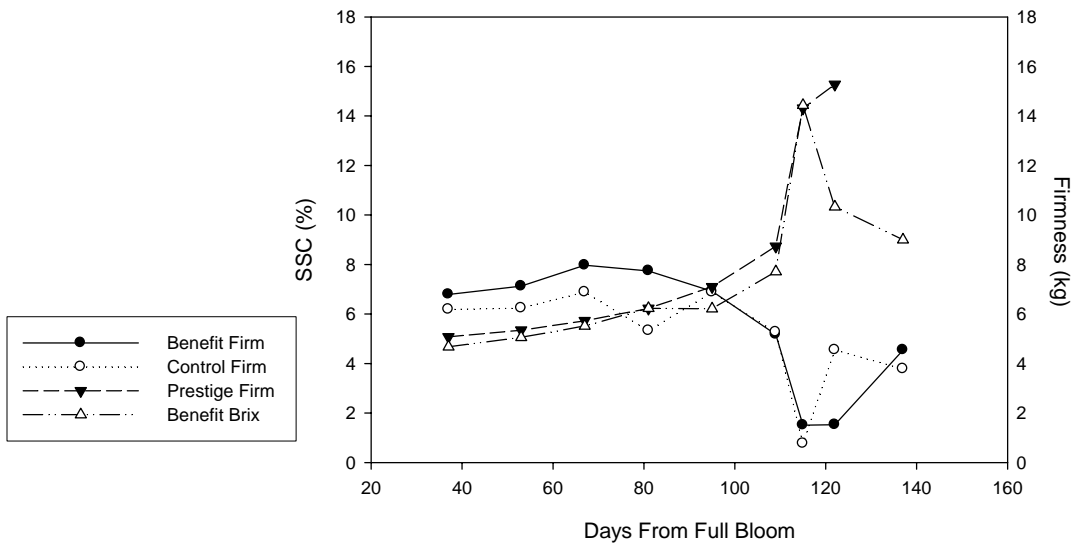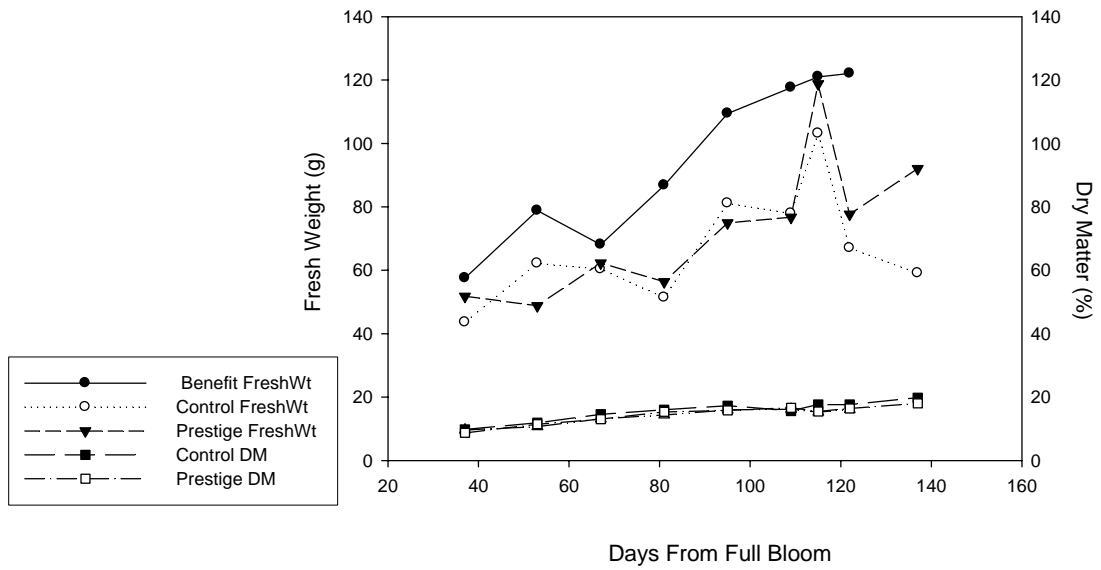
Figure 19. The effect of Prestige on size and internal quality of 'Golden Sunshine'.