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Influence of Environment and Cultural Practices on Rest, Cold Hardiness, and Abscisic Acid Concentration of Gleason Elberta Peach Buds

Ronald H. Walser
Utah State University

INFLUENCE OF ENVIRONMENT AND CULTURAL PRACTICES ON REST, COLD HARDINESS, AND ABSCISIC ACID CONCENTRATION OF GLEASON ELBERTA PEACH BUDS

by

Ronald H. Walser

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Committee Member	Committee Member
Committee Member	Dean of Graduate Studies

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Ronald H. Walser

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ABSTRACT

Influence of Environment and Cultural Practices on Rest, Cold Hardiness, and Abscisic Acid Concentration of Gleason Elberta Peach Buds

by

Ronald H. Walser, Doctor of Philospohy

Utah State University, 1975

Major Professor: Dr. David R. Walker
Department: Plant Science

The effects of temperature, defoliation, light, and certain fall cultural practices on rest and hardiness of Gleason Elberta peach buds were studied. The influence of these factors on abscisic acid concentration in peach buds and a possible role of ABA in rest and hardiness of peach buds were also investigated.

Peach leaf buds enter rest in early fall, reach a rest intensity peak in early winter, then break rest as a chilling requirement is met. Complete defoliation before rest has begun will cause some leaf and flower buds to grow, while defoliation after rest has begun will not cause visible bud growth.

Effective chill-unit accumulation in the fall apparently did not begin until after a certain amount of leaf abscission had occurred. A GA_3 application on August 15, 1974, delayed leaf abscission, and also caused an extension of the rest period. Early fall defoliation was correlated with a reduction in rest intensity and a reduction in the rest period of leaf buds.

A result of this study indicates the possibility of the existence of a rest promoting substance that was apparently translocated from a side of a tree exposed to ambient temperatures to a warm greenhouse covered side.

Decreasing temperatures caused an increase in flower bud hardiness, however, other factors also had effects on hardiness.

An extended day-length treatment caused flower buds to acclimate more slowly than those on untreated trees during the early fall period. The light affect was not evident as colder temperatures prevailed.

Buds on trees that were kept warm, acclimated to the same level as buds on trees kept at cooler but non freezing temperatures. However, it took the warm buds approximately four months longer to acclimate. Buds on trees that were exposed to below freezing temperatures acclimated to a much lower level than those on trees not exposed to freezing temperatures.

Fall pruning and heavy fertilization with ammonium nitrate did not reduce cold hardiness enough to be measured. However, buds on vigorous, large diameter twigs were more hardy during the early winter period than buds on twigs of smaller diameter.

The August 15 and September 19 GA_3 treated trees and the early defoliated trees had a delay in acclimation during the fall period, although they did eventually acclimate to the same level as the untreated buds.

Abscisic acid concentration in peach leaf and flower buds was low before rest began, increased sharply during the rest inception period, and decreased in concentration before the end of rest. ABA may be a controlling factor in the inception of rest in peach.

There was no apparent relationship between ABA concentration and cold hardiness of Gleason Elberta peach flower buds.

(146 pages)

INTRODUCTION

Deciduous plants pass through an annual cycle that is very unique and environment dependent. Samish (1954), Smith and Kefford (1964), and Vegis (1964) have characterized the cycle and divided it into phases, including: (1) the grand period of growth--bud break to terminal bud formation, (2) the inductive phase--the period of cessation of growth during which growth and development may resume under suitable conditions, (3) true dormancy or rest--that period in the cycle in which growth will not occur regardless of environment, (4) quiescence--that period following true dormancy in which the environment is unfavorable for growth, and (5) the growth initiation phase--that period during which the buds swell leading into the grand period of growth.

Environmental temperatures have a great effect on different growth phases of deciduous fruit trees. In some growing areas winter and spring cold temperatures may damage buds, while in other areas temperatures too warm during the rest period may result in crop reduction and physiological tree damage. A knowledge and eventual manipulation of the rest period could prevent many of these problems, by causing a bloom delay in cooler areas, and decreasing the cool temperature requirement to break rest in warmer areas.

In nature the rest period is broken by chilling temperatures, however, peach buds have been induced to grow during the rest period by applications of gibberellic acid (GA_3) (Donoho and Walker 1957). Hatch and Walker (1969), using different concentrations of GA_3 to break rest, found that the rest intensity of peach leaf buds varies

during the rest period. Rest intensity is low from mid-summer until shortly before leaf abscission, increases to a peak during late November or early December, then decreases rapidly as the chilling requirement is satisfied.

Cold resistance (hardiness) in horticultural plants has been studied for over 200 years. Chandler (1954) defined cold resistance as the ability of plant cells to survive ice formation in the tissues of which they are a part. Variations in hardiness are caused either by development of the buds or changes in the environmental temperature. Increases in hardiness during the dormant period are usually associated with decreasing temperatures, loss of hardiness with increasing temperatures (Proebsting 1959).

The effect of the naturally occurring growth inhibitor abscisic acid (ABA) on rest and hardiness of deciduous trees has been studied extensively during the past few years. However, conflicting reports have been published as to the effect of applied or naturally occurring abscisic acid on rest and hardiness of tree buds (Eagles and Wareing 1964; El-Antably et al. 1967; Corgan and Peyton 1970; Ramsay and Martin 1970a; Corgan and Martin 1971; Seeley and Powell 1971; Perry and Hellmes 1973; Mielke 1974).

It was the objective of this study to obtain information that will increase our knowledge of plant rest and hardiness, and hasten the time when growers will be able to manipulate rest and hardiness to meet the environmental requirements of certain geographical areas. Specifically, the influence of environment and certain cultural practices on rest and hardiness, and the possible relationship of the concentration of abscisic acid in buds of Gleason Elberta peach with rest and hardiness was investigated.

LITERATURE REVIEW

This review is concerned with the literature relating to rest and hardiness of buds of woody plants.

Rest and/or Dormancy of Buds

Two terms, rest and dormancy, have been used to describe the temporary suspension of growth of most deciduous trees. The definitions of Samish (1954) have been commonly accepted by horticulturists and physiologists. He suggested the following terminology. Dormancy: is the condition associated with the temporary suspension of visible growth, without regard to its cause; "Quiescence": is growth cessation or dormancy that is caused by external conditions, such as unfavorable temperature, water supply etc.; "Rest": is the dormant state that is caused by internal factors, i.e., a suspension of growth that continues even under favorable external conditions.

Samish further divides the rest period as follows: "Preliminary rest" as an early stage during which the dormant bud will no longer grow in response to favorable conditions, but can be easily "forced" by subjection to cold, heat, wounding etc. "Mid rest", a period when only the most drastic treatments will stimulate a growth response, which even then will be weak. "After rest" is the latter part of rest, where stimuli such as in preliminary rest, will cause growth. After rest may be followed by another period of quiescence if growth conditions are unfavorable.

Vegis (1964) prefers to use the word "dormancy", which he also divides into three stages: predormancy, mid-dormancy and post-dormancy.

Predormancy is similar to the preliminary rest stage of development. The lateral bud inhibition caused by apical dominance would be included under this stage. Mid-dormancy is synonymous with true rest. Post-dormancy applies to the period of exit from true rest when plants can resume growth if provided favorable growing conditions.

For the purpose of this dissertation, the following terminology will be used. "Pre-rest" will refer to that period in the late summer and fall when buds will grow after defoliation and two weeks of favorable weather conditions for growth. "Rest" will refer to the stage of development in which buds on excised, defoliated twigs will not grow within a two week period when placed under favorable environmental conditions. "After rest" will refer to the period following rest, when buds on excised twigs will grow after exposure to favorable growing conditions for two weeks.

The resting stage of buds allows the plant to survive during periods of environmental stress. The rest requirement keeps buds from active growth during unusual mid-winter warm periods. Although very slow bud growth proceeds as long as rest continues, active growth will not commence until the after rest period (Chandler and Tufts 1933; Brown and Katob 1957; Young et al. 1974).

Environmental influence on rest

Light. The induction of dormancy in buds of some plants is under photoperiodic control, with short photoperiods causing terminal bud formation (Nitsch 1957a, 1957b). In Pinus sylvestris, interruption of the long night with a short period of low intensity light prevents induction (Wareing 1950). Kawase (1961) demonstrated in Betula

pubescens that short days cause a stoppage of growth; however, if the long night were interrupted by a short period of low intensity light, the growth of the plants was intermediate between the short and long day treatments.

Nitsch (1957b) divided plants into four classes based on their photoperiodic reactions. These include: (1) when long days prevent the onset of dormancy, causing continuous growth, and short days cause dormancy; (2) when long days prevent the onset of dormancy, cause intermittent growth, and short days cause dormancy; (3) when long days prevent the onset of dormancy, and short days do not cause dormancy; and (4) when long days do not prevent the onset of dormancy.

As indicated by Nitsch (1957b), long days do not prevent the onset of dormancy in some species. Acer pseudoplatanus, Phellodendron amurense, Pinus slyvestris and Syringa spp. became dormant in a short time after exposure to continuous long days (Wareing 1956; Nitsch 1957b). Little or no response to photoperiod is exhibited by Sorbus aucuparia, Syringa vulgaris and species of Fraxinus and Rosa (Wareing 1956). The common cultivated species of fruit trees (Malus, Prunus and Pyrus) appear to be relatively insensitive to daylength changes (Bradley and Crane 1960). However, Erez et al. (1966) reported that in peach, darkness after light preconditioning during dormancy, reduced leaf bud opening, while flower bud break was inhibited in light after dark preconditioning. Supplementary light, producing long-day conditions could partly compensate for insufficient chilling. Erez et al. (1968) also found that a reduction in the amount of light supplied during the mid-rest period caused more leaf buds to open in peach as

compared with natural winter daylength. They suggested that the higher activity of gibberellins and auxin might be one of the results of reduced light exposure.

The location of the photoreceptor varies with species, but it is usually leaves and/or buds. In actively growing Betula pubescens seedlings, the photoreceptor is located in the buds while in Quercus robur, a receptor is located in both the buds and the leaves (Wareing 1954). In Acer pseudoplatanus and Robinia pseudacacia the receptor is located in the mature leaves (Wareing 1954) while in Weigela florida, it is located in the young leaves (Downs and Borthwick 1956). Erez et al. (1966) reports that leafless dormant shoots of peach are light-perceptive.

Temperature. Resting buds of deciduous trees require a certain amount of cold temperature in order to remove the rest influence and "break rest". This is referred to as the "chilling" requirement of the buds. The actual internal effect that low temperature has on breaking rest of buds is not known.

Most of the early research that was reported on the interrelationships of temperature and rest (Chandler and Tufts 1933; Reinecke 1936; Yarnell 1939; Higdon 1954) had to do with the problem of insufficient chilling of peach buds during the winter months. During warm winters with generally less than 700 hours of temperature below 45 F (7.2 C), peach trees have shown physiological defects during their normal spring growing periods. This phenomena is called "delayed foliation". Some of the effects of insufficient chilling on peach buds have been summarized by Lammerts (1941) and Higdon (1954) as follows:

(1) Actual decrease in yield, no crop at all on some varieties,

(2) Weak, misshapen blossoms.

(3) Activity of leaf buds is delayed as compared to flower buds, resulting in small fruit with no leaf cover for protection from the sun.

(4) Poor quality of fruit, including such effects as increased bitterness, exudation of gum and split pits.

(5) Excessive fruit set on some branches and little or no set on others.

Weinberger (1950a), using a delayed foliation severity index, was able to classify many common peach varieties by their chilling requirements. Most varieties required between 700 and 900 hours below 45 F (7.2 C) to complete the chilling requirement, although some varieties require as little as 200 hours, and others over 1200 hours.

Eggert (1951) ranked various species according to the hours of chilling required to break rest as follows from the lowest to highest: red raspberry, black raspberry, prune, peach, currant, sweet cherry, pear, sour cherry, apple, grape, and blueberry. He also found that leaf buds generally required slightly more chilling than flower buds to break rest.

Weinberger (1950b) reported that early exposure to cold temperature did not break rest as soon as when the cold occurred later in the winter. As an example, in 1941 an accumulation of 750 hours below 45 F (7.2 C) by early February was sufficient to satisfy the chilling requirement of 'Hiley' peach buds, yet in 1944, an accumulation of 900 hours of chilling at the same temperature by January 15 was not adequate

to break rest. He also stated that chilling in late winter after some of the buds started to grow was not effective in breaking prolonged dormancy of many varieties.

Overcash and Campbell (1955) determined the effects of warm temperature during the chilling process. They exposed some of their peach trees to continuous 39 F (3.9 C), while others were exposed to intermittent 70 F (21.1 C) and 39 F (3.9 C). The total chilling period was the same for each group of trees, but trees receiving the intermittent warm periods did not start to grow as soon as those receiving continuous cold. The warm periods apparently cancelled a portion of the chilling. This factor could also explain the discrepancy between the amount of chilling received by peach trees during two different seasons (Weinberger 1950b) and the date of rest termination. He did not take into consideration the heat that buds received during this test period.

Erez and Lavee (1971), using controlled conditions, reported that a high temperature of 21 C, when alternated daily with low temperature, nullified the low temperature effect. A high temperature of 18 C had no effect on either accumulating chilling hours or nullifying previous chilling. They suggested that low temperature efficiency in releasing peach buds from dormancy follows an optimum curve in which 6 C is the optimum for leaf buds and 10 C is about half as efficient. They proposed that a "weighted chilling hours" instead of "chilling hours" be adopted as a chilling measurement.

The effect of temperature below freezing on the rest period has not been studied extensively, although Lamb (1948) and Hatch and Walker

(1969) reported that freezing temperature while not as effective as warmer temperature does contribute some to the chilling requirement. Lamb (1948), working with Latham raspberry, found that canes held at 37 F (2.8 C) required 1107 hours to break rest, while those held at 27 F (-2.8 C) required 1251 hours to break rest. (All of the treatments had received some chilling before the experiment began.)

Richardson et al. (1974), using data from the literature, and results of their own research, developed a model relating environmental temperature to the time of rest completion. The model is based on the accumulation of chill-units where one chill-unit equals one hour exposure at 6 C. The chilling contribution becomes less than one as the temperature drops below or rises above the optimum value. A negative contribution to the chill-unit accumulation occurs at temperatures above 15 C and zero unit contribution occurs below 1 C. Chill-unit accumulation begins in the fall after the day when the most negative chill-unit accumulation has occurred. This model accumulates into usable form most of the temperature-rest relationships that have presently been reported, although it is certainly subject to more refinement.

Brown and Abi-Fadel (1953) reported that there does not seem to be any relationship between the efficiency of a given amount of chilling and the stage of flower bud development at the time of chilling. Flower buds of Royal apricot which were in the early stages of development required no more or no less chilling to break rest than did buds in the later stages of development; the stage of development was not, therefore, to be used as an index of the intensity or depth of rest.

Hatch and Walker (1969), using the concentration of gibberellic acid (GA_3) necessary to break rest of peach buds as an index, discovered that the intensity of rest did vary during the rest period. The intensity was low at the beginning of rest, increased to a peak in late November then decreased rapidly at the termination of rest. The rest intensity did not seem to be related to temperature, but rather seemed to be a function of time at low temperature.

Kester (1969) demonstrated that the chilling requirement is genetically inherited. When pollen from varieties of almond and peach with different chilling requirements was used on the same seed parent, a direct correlation was observed between the requirement of the male parent and the resulting progeny. Reciprocal crosses yielded seed populations with the same chilling requirements, demonstrating that the embryo genotype and not the maternal tissue of the seed controls this characteristic.

Defoliation and cultural practices. During the pre-rest period, apical dominance and the presence of leaves are the important factors in maintaining the newly formed buds in a dormant condition. During this period removal of the apical bud or leaves will cause the lateral leaf buds to grow (Fraser 1962; Brown et al. 1967), and in some cases defoliation will cause both leaf and flower buds to grow (Lloyd and Couvillon 1974; Janick 1974).

Ramsay et al. (1970) demonstrated that the effectiveness of decapitation and leaf removal in causing dormant buds to grow depends on the stage of development of the buds. They found that in apricot, decapitation of the shoot in April, while the spurs were still growing and the leaves expanding, would induce axillary bud growth, while both

decapitation and defoliation were required for a similar response in May, after shoots and leaves had stopped growing. Later, after rest had begun neither treatment was effective.

Samish (1954), stated that rest is not casually related to leaf-fall, since leaf-fall occurs after the tree has entered rest. Although no reference of any research that was designed to answer the question of whether or not the time of leaf-fall has any influence on the chilling requirement and rest intensity of buds was found, many indirect inferences that such may be the case were located.

Chandler (1960) reported that apple trees that held their leaves longer in the fall due to high temperatures required more chilling hours to permit normal spring growth than when they were not exposed to the high autumn temperatures. He (Chandler 1957) also reported that cultural practices such as excessive water, fertilizer and pruning which cause excessive growth during the late summer often delay blooming the following spring. Trees under these conditions usually defoliate later in the fall than do normal trees. Chandler and Tufts (1933) found that any time after there has been enough chilling weather to partly break the rest, but before there has been enough to break it completely, buds on long, late-growing shoots will respond more slowly to warm periods, in development, in swelling, or in opening, than buds on shorter, early-maturing shoots. Childers (1973) reported that in milder regions, some peach growers follow a program of cultivation and fertilization with nitrogen, combined with relatively heavy pruning in order to induce the trees to grow late in the fall and thus enter the rest period later. Under these conditions, they usually come out of the rest period later.

Brian et al. (1959) reported that fall applications of gibberellic acid (GA_3) to several species caused a delay in development of autumn color, a delay in leaf-abscission, and a delay of up to three weeks in bud break the following spring. Weaver (1959) also found that GA_3 applications to grapes in the fall also caused delayed growth the next spring. Several researchers (Proebsting and Mills 1964; Edgerton 1966; Correa and Marlangeon 1969; Marlangeon 1969; Stembridge and La Rue 1969; Corgan and Widmoyer 1971; Painter and Stembridge 1971) have reported that GA_3 applications to peach trees shortly before leaf-fall caused bloom delay the following spring. The delay varied from one day (Edgerton 1966) up to ten days (Marlangeon 1969). They also reported that the GA_3 application allowed the foliage to remain greener and remain on the trees longer in the fall than on non-sprayed trees. Painter and Stembridge (1972) mentioned that the mechanism of retardation is not clear, but suggested that GA_3 possibly delays the onset of dormancy and/or delays the completion of rest.

The effect of early fall defoliation on the rest of buds has received little attention. Hill and Campbell (1949) suggested that the degree of delay in the opening of flower and leaf buds is influenced by the experience of the tree in the preceeding year. Thus, after a warm winter, those trees which suffered from drought in the latter part of the preceeding summer, and so lost their leaves early, may exhibit better shoot growth and come into flower a little earlier than usual the following spring. Spiers and Draper (1974) reported that leaf removal greatly reduced the rest period of vegetative buds in Rabbiteye Blueberry.

Internal factors affecting rest

Enzymes. Early theories on rest (Samish 1954) suggested that during the growing season there was an accumulation of photosynthetic products, such as sugars, that gradually inhibited hydrolytic enzymes and stopped growth. It was thought that this accumulation was slowly removed by respiration during the rest period allowing the enzyme to start anew. Chandler (1957) did not accept the idea that the accumulation of enzymes is the factor that breaks rest. He favored the theory that the accumulation of enzymes during chilling or after treatments that break rest may be the result of breaking of the rest and the initiation of growth activities.

Recent work by Bachelard and Wightman (1973) with Populus balsamifera, indicated that there was a significant decrease in the dormancy status of buds during the period March 17-April 3. This was accompanied by an increased level of catabolic metabolism of carbohydrates and protein, and the accompanying increase in enzymatic activity. Kaminski and Rom (1974) suggested that the catalase enzyme possibly plays a function in the rest process. Catalase activity in peach flower buds was high before winter dormancy, with the lowest level occurring near the end of dormancy. Chilling at 5 C resulted in a decrease in catalase activity, with flower buds of cultivars with a longer chilling requirement having the greatest depression in activity. Flower buds near the end of rest when placed in 25 C temperature showed a rapid increase in catalase activity. They proposed the idea that free internal oxygen due to catalase activity may trigger peach flower bud development.

Auxin, gibberellins and cytokinins. A possible role of auxin in the control of rest has been studied for several years. Bennett and Skoog (1938) reported that in cherry and pear buds, no auxin was found in November; however, auxin activity increased from minimum values in December, reaching a maximum in March in response to chilling, but not warm temperatures. Eggert (1953) suggested that the cause of rest is based on the inhibition of bud growth by high auxin concentration. He found that the total auxin concentration of buds increased as they entered into their rest period. He proposed that when the total auxin in buds approaches a critical level growth ceases and the buds enter rest. When the concentration drops below the critical level then growth is again intitiated and the plant is then out of rest. However, Samish (1954) reported that studies of free auxin content of buds during the rest period showed that in July the auxin content gradually diminished and was reversed during the rest-breaking chilling period. Avery, et al. (1937), Gunckel and Thimann (1949), Gregory and Hancock (1955), and Hatcher (1959) all reported that auxin was detected at or slightly before bud break and increased as shoot growth proceeded. Auxin activity and the shoot growth rate both reached a maximum during early summer and decreased thereafter. These reports show no conclusive evidence of any role that auxin might have in controlling rest in buds.

The study of a possible role of natural gibberellins in manipulating rest has gained momentum during the past few years.

GA_3 has been found to break the rest and substitute for some or all of the chilling requirement in several species of deciduous plants. Donoho and Walker (1957) reported that application of 500 ppm

of GA_3 was enough to break the dormancy in 50 percent of the leaf buds of Elberta peaches. The buds had received only 160 hours of chilling temperature. They also found that GA_3 application was not as effective in breaking the rest of apple as peach buds. Couvillon and Hendershott (1974) found that GA_3 would not break the rest of peach flower buds, as reported by Hatch and Walker (1969), during the rest period, but that GA_3 would accelerate blossom development during the after-rest period. Rigby and Dana (1972) reported that applications of GA_3 to resting cranberry plants caused 80 percent or more of the buds to break, regardless of chilling treatment, and caused faster bud break even after adequate chilling. GA_3 did distort the flowers to some extent. Eady and Eaton (1972) found that GA_3 applications to unchilled dormant cranberry plants resulted in only vegetative growth of the terminal buds.

Concentrating on naturally produced gibberellins, Eagles and Wareing (1964) correlated the end of rest with increase in percent GA-like substance in Acer, but there was no relationship with a second, less polar GA-like substance. Also, Ramsay and Martin (1970a) reported a large increase in GA-like activity near the end of rest in apricot buds. Jones and Lacey (1968), and Luckwill and Whyte (1968) detected small amounts of GA-like substances in sap of apple just prior to bud break. The quantity of GA in the sap appeared sufficient to produce important effects on shoot development.

Browning (1973a) reported that during dormancy release of Coffea arabica, GA increased rapidly in the bud, but remained the same in the xylem sap. He concluded that the increase in GA in the buds was due to

its liberation from a bound form. Lavender et al. (1973), however, found that GA-like materials in the sap of Douglas fir increased with bud activity as soil temperature increased, although the air temperature also increased, suggesting that the gibberellins responsible for bud break come from the roots. Adding support to the hypothesis that increasing gibberellin levels are responsible for growth, Crozier et al. (1970) characterized GA_3 and three other gibberellins in the shoots of growing Douglas fir trees but could not detect them in dormant trees.

Seeley (1975a) found that in peach flower buds, a rapid increase in gibberellin content occurs between the end of rest and full bloom. He indicates a 10 fold increase in GA_7, a 100 percent increase in GA_4, a 7 fold increase in GA_3, and an increase from 0 picograms per gram fresh weight during deep rest to 465 at full bloom of a compound tentatively identified as GA_{32}.

Seeley (1975a) proposed the hypothesis that GA_{32} is the active GA form, and may be the end product of the synthetic sequence GA_4 to GA_7 to GA_3 to GA_{32}. Also, that there may be control points (that influence rest) at the steps that convert GA_7 to GA_3 and in the conversion of GA_3 to GA_{32}.

Benes and Veres (1965) reported that applications of cytokinin to resting apple buds would stimulate them to grow within 20 days. Weinberger (1969) found that in peach, application of cytokinins stimulated bud development most when only a little additional chilling was needed to terminate rest and permit normal bud development. He suggested that cytokinin compensates for only a small amount

of chilling. Erez et al. (1971) also noted that kinetin promoted bud opening in peach.

Luckwill and Whyte (1968) found that seasonal changes in cytokinin concentration does occur in xylem sap of apple. They found a cytokinin which remained at a low level from August until just before bud swell in March, when it rose, reached a maximum at full bloom and then declined. Browning (1973b) reported similar results in coffee. Domanski and Kozlowski (1968) showed that in both birch and poplar buds, cytokinin activity was absent during winter, but became apparent when bud dormancy was broken. Activity increased after dormancy breaking treatment of cold temperature, just before bud opening and decreased thereafter.

Hewett and Wareing (1973a) reported that cytokinins were not found in buds of Populus x robusta in December and January, but that parallel increases in cytokinin levels occurred in sap and buds during February and March. The maximum concentration in sap occurred two weeks prior to natural bud burst and 3 weeks prior to the maximum attained in the buds. Cytokinin levels in buds on cuttings paralleled those in buds on intact trees, suggesting that they are synthesized in the shoots or in the buds themselves, rather than in the roots. Five cytokinin-like materials were demonstrated following Sephadex LH-20 column chromatography and bioassay, two of them co-chromatographed with zeatin and zeatin-riboside (Hewett and Wareing 1973a, 1973b). Jones (1973) found that sap sucked from the branches or exuding from the roots of apple trees, showed cytokinin-like activity. Most of this activity was due to a butanol-soluble component which had the properties

of zeatin-riboside. This component promoted the growth of isolated apple shoots.

Abbott (1970) suggested that a cytokinin-budscale relationship is a major factor in the rest of apple buds. He stated that as long as leaves were being produced the shoot continued to grow in an autocatalytic manner, but when cytokinin fell below a threshold level, laminae of leaf primordia towards the apex abort and budscales formed, leading to a state of dormancy in the aerial portion of the tree. Although inert hormonally, scales remained active physiologically and increased in both size and weight. In so doing, he suggested that they provide not only a protective covering to the bud, but also act as a buffer against a resumption of growth. Also, in storing nutrients, scales provide a reserve upon which the early growth of the bud can be sustained, but until senescence they ensure against premature bud break by competitive resorption of growth substances.

Growth inhibitors. Hemberg (1949, 1958) first related endogenous inhibitors to bud dormancy, finding higher levels of inhibitors in Fraxinus bud scales in October, when buds on forced cuttings were unable to grow, than in February when dormancy had been broken. Blommaert (1955) found that inhibitor levels decreased in flower buds of peach during dormancy, even though the level was still high at the start of spring growth. The decrease was slightly more rapid in buds exposed to chilling temperatures as compared to the warm controls (Blommaert 1959).

Hendershott and Walker (1959a) identified the flavanone naringenin as a growth-inhibitor that is found in dormant peach flower buds. In a later experiment (1959b) they showed that the naringenin concentration

was high in August but decreased in October. It increased again in November and remained high through February. Its concentration decreased again during March and disappeared completely from the buds about 2 weeks before bloom.

Erez and Lavee (1969) identified the flavanone prunin in dormant peach buds and found it remained constant from December to March, except for a slight decrease at the end of December. El-Mansy and Walker (1969) reported that total flavanone content was much higher in peach buds during rest than after rest. When expressed on a per bud basis, the lowest values occurred just prior to bloom.

Corgan (1965), and Dennis and Edgerton (1961) confirmed the presence of naringenin in dormant peach flower buds but were unable to correlate it with rest.

Bennet-Clark and Kefford (1953) reported an endogenous growth inhibitor which was named "B-inhibitor." Phillips and Wareing (1958, 1959), and Robinson et al. (1963), working with sycamore leaves, and Eagles and Wareing (1963) with birch leaves, observed the inhibitory activity associated with the "B-inhibitor" zone and found that it varied inversely with photoperiod and growth. During long photoperiods and growth the inhibitor content was low, and it was high during short photoperiods which caused growth cessation.

Abscisic acid (ABA) was isolated from young cotton bolls by Okhuma, et al. (1963) and characterized by Cornforth, et al., (1965). Cornforth, et al., (1965) indicated that it was the main inhibitor of the "B-inhibitor" zone found in birch and sycamore.

Seasonal changes of ABA concentration has been shown to occur in several different types of trees. Phillips and Wareing (1958) found

that the inhibitor was present in a low amount during active growth in May and June, increased to a maximum during the early winter, and decreased to a minimum at bud break. They concluded that the inhibitor might control growth and the state of dormancy in the shoot apex.

El-Antably et al., (1967) reported that ABA when fed to Betula pubescens, Acer pseudoplatanus and Ribes nigrum under long day conditions, caused the cessation of extension growth and the formation of typical resting-buds. In apricot buds, ABA-like inhibitors were high in October, remained constant through mid-December, fell to a low level by mid-January (end of rest), then increased slightly until anthesis (Ramsay and Martin 1970a). The inhibitors were located primarily in the scales but substantial amounts occurred in the floral primordia.

Seeley and Powell (1971), using their gas-liquid chromatography analysis method (Seeley and Powell 1970) found that the levels of free and base hydrolyzable ABA (bound ABA) in apple terminal buds began to increase in June, reached a peak by the middle of September, at which time the free ABA fell slowly until it reached its lowest point and almost disappeared by May. The bound ABA decreased 30 percent from September to October, then began increasing again, reaching a second and higher peak in March, after which it decreased rapidly. The increase in bound ABA appeared to occur at the same rate as the decrease in free ABA, suggesting interconversion.

Wright (1975) determined the levels of free and bound ABA in buds of black currant and beech, using the wheat coleoptile straight-growth

test as a bioassay. In both species the highest level of free ABA occurred in the autumn at about the time of onset of winter dormancy. The free ABA content then declined throughout the winter months reaching its lowest value just before bud burst. He concluded that these results strengthen the view that free ABA plays an important role in the induction and maintenance of winter dormancy.

Perry and Hellmes (1973) reported that in two races of red maple, ABA accumulation was correlated with winter rest, but was not necessarily the cause of winter rest. They confirmed the fact that ABA induces leaf abscission, inhibits growth, and suppresses the development of auxillary buds. They found that ABA did not induce winter rest, normal scale formation, or typical dormant terminal buds. Also, Mielke (1974) found that in sour cherry flower buds, the concentration of ABA in the primordia rose rapidly in late autumn to peak in late November to early December, and then fell rapidly to initial levels. The increase in ABA coincided with the onset, not of bud dormancy, but of leaf abscission, with the maximum levels occurring when about 90 to 95 percent of the leaves had abscissed. But, in two of three years, this peak did coincide with the period of deepest dormancy.

Corgan and Peyton (1970) found in peach flower buds that inhibition of ABA (by wheat coleoptile test) increased in the fall until about the time of leaf abscission, and then decreased near or shortly after the end of the rest period. Peach floral cups were also assayed for ABA using the wheat coleoptile growth test (Corgan and Martin 1971). ABA level fluctuated during rest and was high at the termination of rest, then decreased after the chilling requirement had been met.

Browning (1973a) reported that when dormancy in coffee buds was released by irrigation, ABA levels remained constant prior to bud expansion, then increased as the buds swelled.

Promoter/inhibitor hypothesis. Blommaert (1959) proposed the theory that the rest period is controlled by an auxin/inhibitor balance. Several other scientists (Kawase 1961; Frankland and Wareing 1962; and Eagles and Wareing 1963) have examined the possibility that dormancy and growth are controlled in part by an interaction between endogenous inhibitor and gibberellic acid. Walker and Seeley (1974) summarized the thoughts on this hypothesis by stating: "Most research workers accept the hypothesis that rest in buds and seeds of deciduous fruit trees is regulated by a fluctuating balance between growth promoters and growth inhibitors. In other words, if a plant or seed contains more inhibition units than promotion units, the plant remains in rest and does not grow; when promotion units outnumber inhibition units, rest is completed and growth may occur if the environment is favorable. The balance is controlled by the genetics of the plant and the environment".

Translocation of the rest influence. Denny and Stanton (1928) hypothesized that the rest influence was located in the individual bud, and was not translocated. They broke the rest of one of two adjacent lilac buds with ethylene chorhydrin. The treated buds were forced into growth, while the bud on the opposite side of the twig remained dormant. Also, Bonner and Galston (1952) stated that when a tree has become dormant and is subjected to cold treatment of one stem alone with the rest of the plant remaining under high-temperature

conditions, it is found that the dormancy of only the treated stem is broken. They indicated that the breaking of dormancy does not seem to translocate from one section of the tree to another. Perry and Hellmers (1973) reported that the different behavior of races of Red Maple from northern areas that have a chilling requirement and a race from Florida that does not, and the independent behavior of the stock and scion on interracial grafts indicate that the development of internal rest and cold resistance was mediated by local biochemical processes, and was not transported across a graft union.

Westwood and Chestnut (1964) suggested that the rest influence of Pyrus seemed to reside primarily in the buds, but some translocation of the rest influence appeared to take place. They found that the presence of Pyrus calleriana (low chilling requirement) shoots on the same branch with inadequately chilled Pyrus communis (long chilling requirement) buds caused the P. communis buds to grow much more than when no P. calleriana shoots were present. Also, fully chilled P. communis buds grew less when placed into inadequately chilled host trees than when placed into fully-chilled hosts.

Chandler (1957) proposed a theory that rest is located throughout the above-ground portion of the tree. Roots do not have a rest period so he excluded the roots as a source. Chandler (1960) found that rest can move at least distally in twigs. It moved from unchilled twigs across graft unions and stopped growth from new shoots on well-chilled scions and put them into rest. He also found that rest influence developed earlier in the basal than in the apical part of shoots. He hypothesized that the rest influence may move slowly from the basal parts of shoots to apical meristems and hasten their going into rest.

Smith and Kefford (1964) reported that the renewal of root initiation and root growth on seedlings of Acer saccharinum was dependent upon the release of at least one bud from dormancy. This would imply that there is a translocation of a dormancy influence from the bud to the roots. Also, Lloyd and Couvillon (1974) found that with peaches, neither vegetative nor flower buds were forced when individual shoots were defoliated rather than whole trees. They suggested that leaf removal does not stimulate bud break, but rather eliminates the source of materials which prevent bud break. Growth inhibitors could have been translocated from shoots with leaves to the defoliated shoots, thus preventing bud break.

Cold Hardiness of Buds

Chandler (1954) defined cold resistance (hardiness) as the ability of plant cells to survive ice formation in the tissues of which they are a part. This definition will certainly need to be modified though, because of the recent research George et al. (1974) and Quamme (1974) who indicated that cold hardiness of buds was due to the prevention of ice formation in the bud cells. George et al. (1974) reported that supercooling is the mode of freezing resistance of azalea flower primordia, with injury to the primordia occurring at the moment of freezing. Nonliving primordia freeze at the same temperature as living primordia, indicating that morphological features of primordial tissues are a key factor in freezing avoidance of dormant azalea flower primordia. Quamme (1974) found that flower bud injury in some Prunus species was related to a specific event that involved freezing

of a bound or supercooled fraction of water. This fraction of water remained unfrozen in the flower bud until the temperature fell below a critical level which was as low as -27 C. Death or injury of the bud occurred at the moment this water froze.

Rest/hardiness relationship. Hatch (1967) mentioned that one of the most important functions of rest is to hold a tree, especially in temperate zones, dormant while it is acquiring hardiness to withstand the winter freezes. A tree in a succulent and tender condition would not withstand a winter freeze.

Irving and Lanphear (1967) reported that the development of cold hardiness in 2 woody species (Acer negundo and Viburnum plicatum) was independent of the induction of bud dormancy. They stated that cold hardiness development in woody plants appears to be a photoperiodic phenomenon similar to other processes such as flowering, tuberization, and dormancy induction.

However, Chandler (1957) and Tumonov (1966, 1967) stated that to become frost resistant, plants should pass through 3 stages of preparation, the first stage is the passing into dormancy. Tumonov (1967) proposed that during the passage into dormancy, conditions are created for gel of the protoplasm. This alone increases frost resistance and is a prerequisite for further hardening caused by exposure to low temperature. Tumonov et al. (1972) found that only the lower buds of apricot twigs were able to withstand -20 C to -30 C after hardening at low temperatures, because they entered dormancy under continuous illumination treatment. Buds at the upper regions of the shoot did not enter dormancy under the same treatment (presumably because of more light) and were killed at -5 C.

Proebsting and Mills (1972) reported that cherry and peach fruit buds decreased less in hardiness after exposure to 20 C temperature for 24 hours during dormancy than after dormancy. Hatch and Walker (1969) also reported that the cold hardiness of peach fruit buds appeared to be associated with climate conditions and/or the morphological stage of development of the bud rather than the stage of depth of rest.

Environmental influence on cold hardiness. Meader and Blake (1943) first reported a close relationship between peach fruit bud hardiness and environmental temperatures. They showed that the percentage of live fruit buds increased with changes in air temperature. Proebsting (1959) stated that increases in hardiness during the dormant period are always associated with decreasing temperatures, and conversely, losses of hardiness with increasing temperatures.

The duration of cold is more important in decreasing the cold hardiness of buds than is the degree of cold. When dormant peach fruit buds were exposed to 65 F (18.3 C) for 4 days, little or no change in hardiness resulted, but when the temperature was held at 65 F (18.3 C) for 6 days, appreciable loss in hardiness occurred (Edgerton 1960). Donoho and Walker (1960) found that peach buds from trees held at 65 F (18.3 C) continuously and then moved to 40 F (4.4 C) did not have a significant increase in cold hardiness after 1 day. However, after 7 days there was a significant increase in cold hardiness. The trees that had continuous 40 F (4.4 C) and then moved to 65 F (18.3 C) had just the opposite results.

Ketchie and Beeman (1973) reported that in apple trees there was a correlation between cold resistance and the temperature during 7 days preceeding the cold acclimation measurement. Sustained temperature

below 0 C increased cold resistance more than did very low temperature interrupted by short periods above freezing. However, Howell and Weiser (1970a) reported that short term changes in cold resistance were closely related to the air temperature of the preceeding day. In controlled studies, hardy plants during the winter dehardened as much as 15 C in one day in a warm greenhouse, and rehardened 15 C in 3 days when they were held at -12 C. The dehardening process was only partially reversible. Krasavtsev (1969) found that in both apple and cherry a constant temperature of around -5 C caused the most hardening of the buds.

Proebsting (1963) reported a concept of a minimum hardiness level above which peach fruit bud hardiness will not rise in spite of warm weather. This value is constant until the end of dormancy and then increases gradually as buds develop. Hardening beyond the minimum hardiness level occurs during periods when the temperature does not rise above 28 F (-2.2 C). If the temperature rises above 28 (-2.2 C) to 30 F (-1.1 C) hardiness is lost until it reaches the minimum level. Loss of hardiness can occur before the end of rest provided that hardiness greater than the minimum level has been achieved previously. As the bud develops, the minimum level rises. Rehardening capability is retained but appears to occur less readily.

Howell and Weiser (1970a) found that cold acclimation in apples occurs in two stages which are induced by short days and low temperatures, respectively. Leaves were stimulated by short days to produce translocatable substances which promoted cold acclimation of the living bark. Leaves of plants grown under long days were the source of translocatable substance which inhibited acclimation. The second stage of

hardiness, induced by low temperature did not involve translocatable factors. They also found that inductive short days could overcome the effect of high temperature and cause the tree to acclimate.

Fuchigami et al. (1971a; 1971b) found that in Red Osier dogwood short days would induce cold acclimation. They also found that the hardiness promoting factors produced in the leaves are translocated through the phleom from a foliated to a defoliated branch.

Weiser (1970) summarized the results of many experiments, and indicated that: a) Growth cessation is a necessary prerequisite to cold acclimation in woody plants; b) Plants severely depleted in photosynthetic reserves cannot acclimate; c) Leaves are the site of perception of the short-day stimulus which initiates the first stage of acclimation; d) Low temperature inhibits the short-day induced phase of acclimation; e) Long-day induced leaves are the source of a translocatable factor(s) which inhibits cold acclimation; f) Short-day induced leaves are the source of a translocatable factor(s) which promotes acclimation; g) The hardiness promoting factor moves from the leaves to overwintering stems through the bark; h) The hardiness promoting factor from the leaves of a hardy genotype can enhance the acclimation of a branch of a less hardy genotype when the two are grafted together; i) Frost triggers the second stage of acclimation; j) The frost induced phase of acclimation does not involve translocatable factors; and k) Plants exposed to short days and relatively high temperatures only become hardy to the level of the plateau of the first stage of acclimation.

Influence of cultural practices on cold hardiness. There is some disagreement in the literature as to the effect of certain late season cultural practices on the hardiness of plants.

Edgerton (1957) found that fall applications of nitrogen to apples increased the susceptibility of both twigs and bark to freezing. Chaplin and Schneider (1974) also reported that late nitrogen applications decreased cold hardiness of Redhaven peach.

Higgins et al. (1943), Edgerton and Harris (1950), and Nesmith and Dowler (1973) reported that fall applications of nitrogen had no appreciable affect on the cold hardiness of peach buds during the winter. Pellett (1973) found that nitrogen applied during the summer and fall had little effect on cold acclimation of root or stem tissue of container-grown plants of Forsythia intermedia or Cornus alba.

Proebsting (1961) explained that high nitrogen application to Elberta peach trees actually increased fruit bud survival as compared to low nitrogen trees. There was approximately 1 F (.6 C) difference in hardiness between the low and high nitrogen treatments.

Nesmith and Dowler (1973) reported that pruning peach trees at leaf fall significantly reduced cold hardiness, with marked loss in tree vigor the following spring.

Weaver et al. (1968) found that scion diameter was inversely related to hardiness between peach cultivars. The varieties with long slender twigs were generally more hardy than those with larger diameter. (This would suggest that more vigorous cultivars would tend to be less hardy than less vigorous cultivars.)

Howell and Stockhouse (1973) reported that in Prunus cerasus L. early leaf loss resulted in delayed acclimation in the fall and more

rapid deacclimation in the spring. The greater response of defoliated trees to warm temperatures may reflect either a weak photoperiod mechanism or merely more exposure of twigs and buds to solar radiation. They also mentioned that the loss of photosynthetic capability is detrimental to tissue survival over winter because of reduced carbohydrate accumulation. Fuchigami et al. (1971b) found that leaves were necessary for acclimation in Red Osier dogwood. The plants which were completely defoliated failed to develop hardiness.

Edgerton (1966) and Proebsting and Mills (1974) however, reported that fall applications of GA_3, which delayed defoliation in the fall, decreased cold hardiness of peach fruit buds. (The decrease in hardiness must have been related to other factors rather than the time of leaf fall.)

Wilding et al. (1973) suggested that hardening in apple roots appeared to be influenced by soil temperature and the level of root hydration. One year of the experiment was drier than the next, the roots were more hardy during the drier year. Also, Chen and Li (1973) reported that a 7 day water stress increased the cold hardiness in Red Osier dogwood. McKenzie et al. (1974) reported a significant reduction in stem water content during cold acclimation of Cornus stolonifera. Most of the reduction was from pith cells.

Cold hardiness measurement. One of the generally accepted methods of reporting cold hardiness data is the T_{50} concept introduced by Chaplin in 1948. The T_{50} is the temperature required to kill 50 percent of the buds. Proebsting and Fogle (1956) showed that the hardiness curve used to determine the T_{50} followed a sigmoid response curve.

Proebsting and Mills (1966) used data from T_{50} determinations of peach fruit buds collected during a 3-year period to establish a standardized temperature-survival curve for dormant Elberta peach fruit buds. In compiling the data into a single curve, they expressed all temperatures as deviations from the T_{50} temperature. The point representing the T_{50} on the graph was determined by averaging all points within 0.5 F of T_{50} of the various individual T_{50} determinations. The other points on either side were determined by averaging all individual values within 0.5 F (.3 C) of T_{50} + 1 or T_{50} -1 and so on.

Proebsting and Fogle (1956) devised a method of artificially freezing fruit buds by modifying a home freezer so they could obtain a uniform rate of temperature fall. The modification gave good temperature control, with an hourly drop of about 1.7 F (1 C) per hour. There are commercial freezers available now which automatically lower the temperature at a pre-set rate and can be held at a given temperature for a desired length of time.

MATERIALS AND METHODS

This research project consisted of three studies: involving the evaluation of rest, cold hardiness, and abscisic acid concentration in peach trees as influenced by various temperatures and other treatments. The trees used were 7 year old Gleason Elberta peach trees (Prunus persica (L). Stobes) located at the Utah State University Research Station, Farmington, Utah.

Rest study

In order to control the fall and winter temperatures received by peach trees, clear polyethylene covered greenhouses were constructed and placed over complete trees and over one-half of other trees. Two trees were used for each treatment.

The 2 greenhouses that were placed over the 4 complete trees (one greenhouse enclosed 2 trees) were 40 ft. long, 20 ft. wide and 10 ft. high. They were constructed with a framework of 2X4 lumber and 3/4 inch electrical conduit, and covered with an outside layer of 6 mil uv resistant polyethylene film, and an inside layer of 5 mil film (Figure 1). One 125,000 BTU LP Gas Unit Heater and one 20 inch, 2920 CFM air delivery, shutter mounted exhaust fan, with a two-stage, line voltage, heating-ventilating thermostat that controlled both the heating and ventilating, was located in each greenhouse. (Winds of approximately 60 mph and outside temperatures below 0 F (-17.8 C) during the winter did not cause damage to the structures or cause the inside temperature to go below the desired minimum). When ventilation was desired, the fans would cool the inside temperature to within 5 F (2.2 C) of the outside temperature.

The two greenhouses that were placed over one-half of 4 trees (one greenhouse enclosed one-half of each of two adjacent trees) were constructed and furnished similar to the enclosures described above, with the following exceptions. These greenhouses were 20 ft. long, 20 ft. wide, and 10 ft. high. One 75,000 BTU LP gas unit heater and one 18 inch, 1900 CFM air delivery, shutter mounted exhaust fan were used in each greenhouse to control the temperature (Figure 2).

The polyethylene covering was placed over one of the large and one of the small greenhouses (referred to as the warm and one-half warm treatments) on September 17, 1974, after an accumulation of 100,720 growing degree hours (GDH) as explained by Richardson et al. (1975). The temperature in the warm greenhouse remained above 60 F (15.6 C) until February 4, 1975, when it was lowered to a minimum of 36 F (2.2 C). The temperature in the one-half warm greenhouse remained above 60 F (15.6 C) until December 31, 1974 when it was lowered to a minimum of 25 F (-3.9 C). On January 30, 1975, the temperature was adjusted to attain a minimum of 33 F (.5 C).

The polyethylene covering was placed over the remaining large and small greenhouses (referred to as the cool and one-half cool treatments) on October 5, 1974. The temperature in the cool and one-half cool greenhouse remained above 34 F (1.1 C) during the entire season.

The maximum temperature inside the greenhouses was maintained at slightly above the outside temperature except when the outside temperature was below the minimum maintained inside the structure. When rest was complete, the exhaust fans were turned off and the inside temperature was allowed to rise much above the outside temperature on sunny days.

Copper-constantan thermocouples were placed in twigs the approximate diameter of fruit buds on one tree under each of the enclosures and also on a tree in the open. A thermocouple was also placed in the air near each of the twigs. The temperature was recorded three times per hour on a 24 point Leeds and Northrup recorder.

Two trees were hand defoliated on August 15, 1974 (79,814 GDH) and two were defoliated on September 17, 1974 (100,720 GDH).

Three trees were sprayed with 100 ppm gibberellic acid (GA_3) on August 15, 1974, three sprayed on September 19, 1974 (101,860 GDH) and three were sprayed on October 16, 1974 (113,278 GDH).

Three control trees were untreated and received the usual fall cultural practices.

Beginning August 21, 1974 (83,824 GDH) and every 7 to 14 days thereafter until rest was complete, 18 six to eight inch long terminal twigs were cut randomly from each of the trees, placed in moist paper towels, and transported to the laboratory in Logan, Utah in an insulated container.

A modification of the procedure described by Hatch and Walker (1969) was used to determine the rest intensity and the date of inception and termination of rest.

The twigs were re-cut and 3 twigs from each were completely submerged in one of 0, 5, 25, 50, 100 and 200 ppm GA_3 solutions for one hour. The twigs were then removed from the solution, the excess solution was removed with paper towels, and they were placed in small water filled containers. They were then placed in a growth chamber with a constant temperature of 75 ± 1 F (23.9 ± .6 C) and a 14 hour daylength. After two weeks they were examined and rated visually as to

terminal or lateral leaf bud growth. When two out of three shoots in one treatment showed definite signs of growth, rest was considered broken. Rest intensity of the leaf buds was determined by using the lowest concentration of GA_3 that caused bud growth of each treatment on a particular day as an index. Buds were considered out of rest when they grew within two weeks in the growth chamber after a soaking for one hour in distilled water.

Cold hardiness study

All of the trees described in the rest study section and the ones listed below were used in this experiment.

Lights were installed over 2 trees on August 15, 1974. Each tree was illuminated by eight 96 inch high output florescent tubes and eight 100 watt incandescent bulbs. These lights provided 2000 foot candles of light, 12 inches from the source, with a 16 hour lighting period per day. The lighting was discontinued on November 1, 1974 (Figure 3).

Three pounds of ammonium nitrate fertilizer was broadcast on the ground under 3 trees on July 15 (56,902 GDH), and again on August 15, 1974. Three trees were also pruned heavily on November 2, 1974. All trees were kept adequately watered. The moisture stress of the trees in the various treatments was monitored periodically with a pressure bomb as described by Waring and Cleary (1967).

Beginning August 21, 1974 and every 7 to 14 days thereafter until visible bud swell, twigs containing a minimum of 10 flower buds were randomly cut from each experimental tree, and transported in an insulated container to the laboratory. The twigs were then placed in

Figure 3. Lights installed over trees at Farmington, Utah, during the fall of 1974.

Photograph taken: February 26, 1975.

plastic bags and given a cold treatment using a Sears deepfreeze with Honeywell automatic controls that lowered the temperature 2 F per hour. An automatic retrieval system that was designed and built by S.D. Seeley and R.H. Walser was used to automatically extract the samples from the freezing chamber at the specified time. The buds were then placed in a warm room for 24 hours, cut, analyzed visually and categorized as being dead or alive. The T_{50} of that sample was then determined using the method described by Proebsting and Mills (1966).

On December 23, 1969, following a low temperature of -7 F (-22 C) that occurred in the field during the first part of December, an experiment was run on Redhaven peach flower buds on trees located at the Howell Field Station, North Ogden, Utah. The base of twigs was measured, and the twigs placed into diameter categories of 3 mm or less, 4-5 mm, 6-7 mm, and 8 mm or greater. The buds on the twigs of each of the categories were cut and visually determined to be dead or alive. On January 6, 1975 and again on January 28, Gleason Elberta peach twigs containing 200 or more flower buds in each category were brought into the laboratory, frozen in the freeze chamber, and the mortality rate of each diameter category visually determined.

Abscisic acid study

Several grams of twigs containing leaf and flower buds were collected from trees of each of the treatments previously described, (pages 31 and 37), on the same sample dates as the rest and cold hardiness experiments. The plant material was transported on ice in insulated containers to the laboratory. It was immediately placed in cold storage at -30 C. Because of the time and equipment requirement of the ABA

experiment was limited to the controlled temperature trees, the control trees, and the defoliated trees.

The extraction and chromatographic analysis of ABA followed the procedure described by Seeley (1971), with a few modifications. The buds were separated into flower and leaf buds, and dried under vacuum using a VirTis freeze-dryer. (The August 21, 1974 sample was not separated into leaf and flower buds, because of the difficulty in distinguishing them at that early stage of development.) The buds were then weighted, homogenized (VirTis homogenizer), and extracted three times with 75 ml of 95 percent methanol. The methanol was decanted each time through a Hirsch fritted glass funnel under suction. All operations were performed with ice cold methanol and all containers were maintained in ice water baths. The methanol was removed from the water using a flash evaporator.

The pH of the aqueous phase was adjusted to 8.3 with 1 N NH_4OH. The entire aqueous extract was centrifuged at 8,000 x G for 15 minutes. After centrifugation the decanted aqueous extract was partitioned three times with equal volumes of methylene chloride which was discarded. The aqueous extract was then adjusted to pH 3.0 and again partitioned three times with equal volumes of methylene chloride. The ABA was partitioned into the methylene chloride. The methylene chloride was removed using a flash evaporator with the residue quantitatively transferred with methanol to small test tubes for ABA analysis. The ABA was methylated with diazomethane as described by Seeley (1971).

A flow diagram of the above procedure is given in Figure 4. The methylated ABA was dissolved in purified hexane, and samples usually

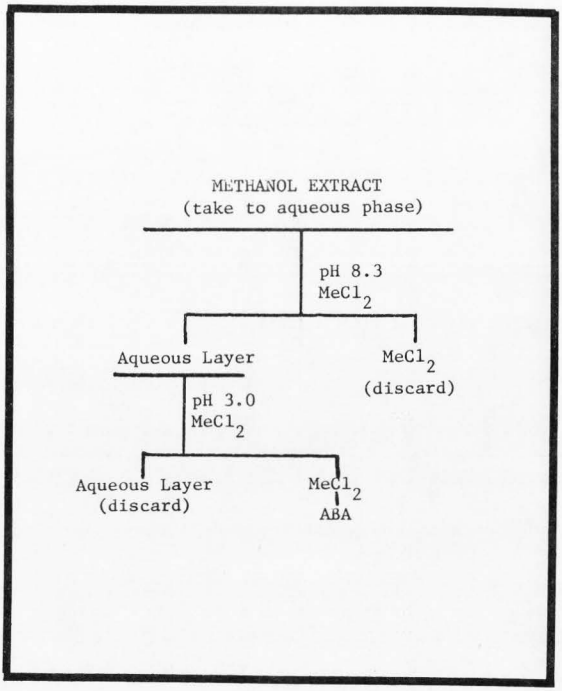


Figure 4. Rapid purification procedure for analysis of abscisic acid.

1 ul in size, were injected into the gas chromatogrpah with a Hamilton 10 microliter syringe.

The gas chromatograph used was a Hewlett Packard 5750, with a ^{63}Nickel electron capture detector. The column used was a 180 cm x 3 mm inside diameter glass column packed with OV 1 on 100-120 mesh Gas Chrom Q. Argon 95 percent, methane 5 percent carried was used at a flow rate of 80 ml/min. Column temperature was 200 C with injection and detector temperatures of 250 C and 265 C respectively.

RESULTS

Rest study

Temperature control in the four greenhouses was excellent. All of the treatments received a few hours of temperatures below 60 F (15.6 C) during the first part of September, but from September 17, 1974 until December 30, 1974 for the one-half warm trees and until February 4, 1975 for the warm trees, the bud temperature did not go below 60 F (15.6 C). Bud temperature of the one-half cool and cool trees did not go below 33 F (.56 C) on any occasion.

Outside temperature was slightly above normal during the period. This resulted in many effective chilling hours, with an earlier than normal accumulation of chill units for completing rest. The initiation of chill unit accumulation began on October 4, 1974 (109,438 GDH).

Samples from the untreated control trees were collected August 17 and 21, and September 2, and started to grow within 2 weeks in the growth chamber, but the sample collected on September 12 required 5 ppm GA_3 to cause the leaf buds to grow. This indicates that rest began between September 2 and 12 (91,914 and 98,284 GDH). As indicated in Figure 5, rest intensity of the control trees formed a bell shaped curve, similar to that reported by Hatch and Walker (1969), with the peak (which required 100 ppm GA_3 to break rest) occurring approximately November 10, 1974. End of rest occurred by December 30, 1974 after an accumulation of 822 chill units. The trees were more than one-half defoliated on October 10, 1974, following a heavy wind. Full bloom occurred on May 8, 1975, after an accumulation of 9,754 GDH from end of rest.

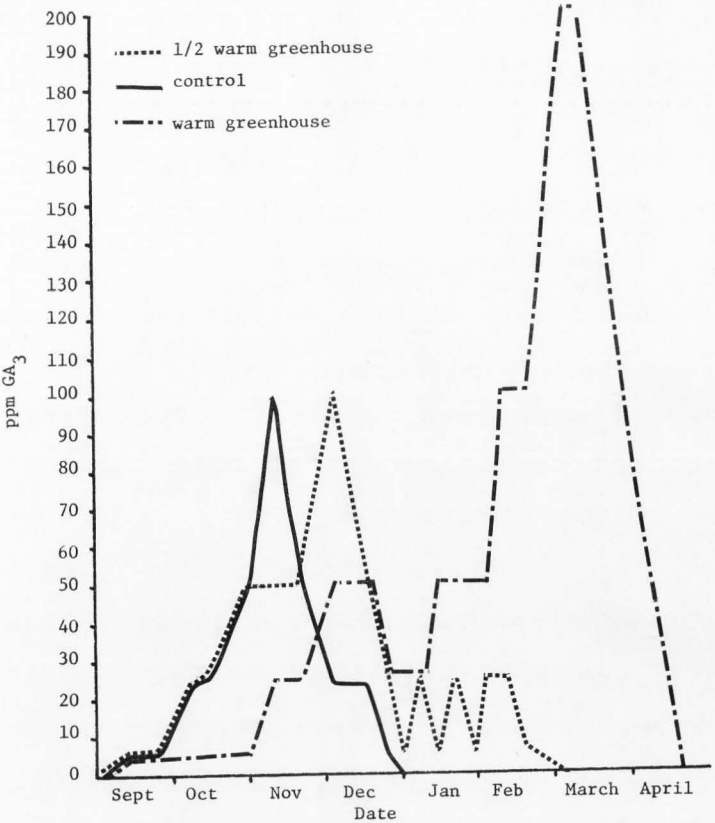


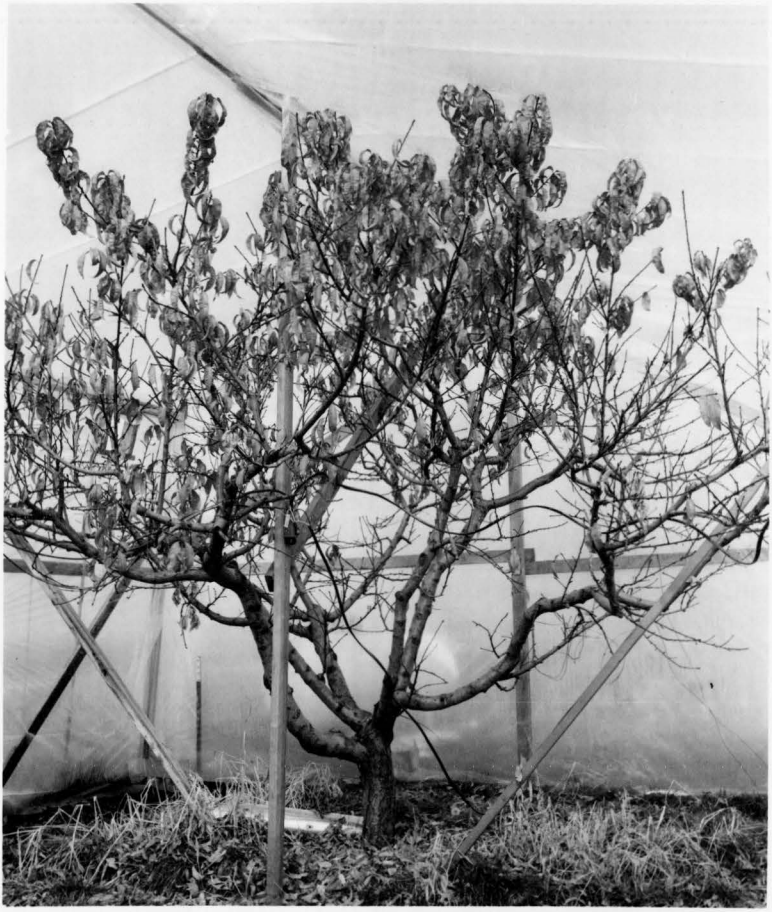
Figure 5. Changes in rest intensity of Gleason Elberta peach leaf buds during the fall, winter, and spring of 1974-75.

The outside one-half of the one-half warm and one-half cool treated trees had the same beginning and ending date of rest and the same bell shaped rest intensity curve as the untreated control trees. Chill unit accumulation, defoliation date, and full bloom date were also similar to the control.

Warm temperature inside the greenhouses had a large effect on the warm and one-half warm trees.

The warm greenhouse trees began rest the same time as the control, but the rest intensity remained at 5 ppm GA_3 until October 30, 1974, and then increased to 50 ppm on November 20, 1974. Rest intensity then varied between 25 and 50 ppm GA_3 until the heat was decreased to a minimum of 35 F (1.6 C) on February 4, 1975. The intensity then increased dramatically, reaching a peak of 200 ppm GA_3 on March 4, then decreased rapidly until rest was broken on April 22, 1975 (Figure 5). Seven hundred forty five chill-units were received during the rest period. The trees were completely defoliated due to leaf senescense by March 1, 1975 (Figure 6). Full bloom on these trees occurred approximately May 12, 1975, after an accumulation of only 5,304 GDH from end of rest. Apparently bud development occurred concurrently with chill-unit accumulation during the latter part of rest. The blossoms appeared normal, even though blossoming on individual trees did occur over a 2 week period. Some fruit did set on the trees, but most of it was deformed and failed to grow (Figure 7).

The one-half warm trees began rest the same time as the control trees, and followed the same rest intensity curve until November 11, when the intensity began to lag behind the control (Figure 5). A rest intensity peak of 100 ppm GA_3 occurred on December 4, 1974, after



Cool Greenhouse Full bloom
February 26, 1975

Control Full bloom
May 6, 1975

Warm Greenhouse Full bloom
May 12, 1975

Figure : Fruit samples from various treatments picked July 10, 1975.

which the intensity dropped to 25 ppm on December 23 and 5 ppm GA_3 on December 30, 1974. During the week of December 23 to 30, 1974, the trunks of the trees froze, resulting in a water stress in the one-half of the warm trees covered by the greenhouse. This stress reached 29 bars in the twigs, and caused the complete defoliation of the trees. In order to reduce the water stress, the temperature was lowered inside the greenhouse on December 31, 1974. During the ensuing chilling period, the rest intensity varied between 5 and 25 ppm GA_3, with rest having terminated by March 4, 1975, after an accumulation of 644 chill-units. Full bloom on these trees occurred approximately April 20, 1975, with 9,930 GDH occurring from end of rest. The bloom period was somewhat staggered. Fruit set and appearance was similar to that on the warm greenhouse trees (Figure 7).

The cool and one-half cool greenhouse trees had similar rest periods and rest intensity curves (Figure 8). Rest began on September 12, 1974. The rest intensity curve was similar to the control until November 12, when it remained at 50 ppm GA_3. The intensity reached a peak of 100 ppm GA_3 approximately November 27, after which it dropped rapidly and reached zero ppm GA_3 by January 6, 1975. When rest had ended, the cool trees had received 1345 chill-units and the one-half cool trees had received 1395 units of chilling temperature. Trees from both treatments were approximately one-half defoliated by November 27, 1974. Full bloom occurred on February 26, 1975 on the cool trees, and on February 28 on the one-half cool trees, with 8,270 and 8,457 GDH respectively occurring from end of rest. Blossoms were normal, with excellent shoot growth and normal fruit development occurring

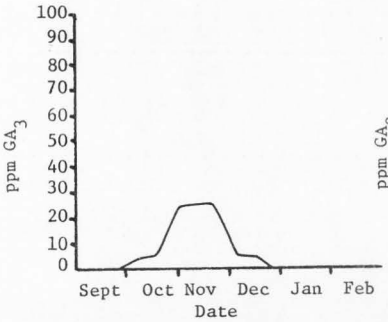


Figure 8. Changes in rest intensity of Gleason Elberta peach leaf buds during the fall of 1974. Trees were defoliated August 15, 1974.

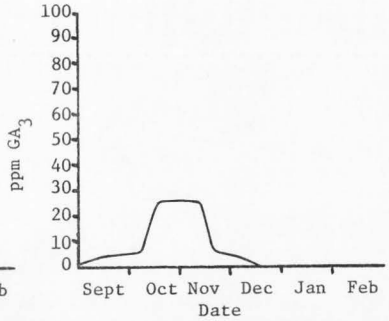


Figure 9. Changes in rest intensity of Gleason Elberta peach leaf buds during the fall of 1974. Trees were defoliated September 17, 1974.

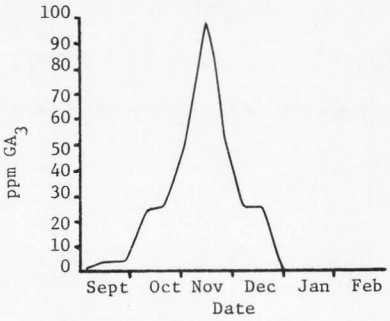


Figure 10. Changes in rest intensity of Gleason Elberta peach leaf buds from control trees during the fall and winter of 1974-75.

(Figure 7). The two day bloom delay on the one-half cool trees as compared to the cool trees was due to slightly lower temperatures inside the one-half cool greenhouse during the blossom development period.

Trees that were hand defoliated on August 15, 1974, resumed growth within 10 days. Most of the terminal buds resumed growth, but grew less than 1 inch, and approximately one-fourth of the lateral buds grew (Figure 11). A few fruit buds opened (approximately 10/tree) within 3 weeks of defoliation, although the flowers were very deformed. Terminal buds had again reformed by October 7, with defoliation of the new leaves not occurring until November. Rest did not begin in the new terminal buds until October 16, 1974. The rest intensity peak which occurred on November 11, 1974, only reached a level of 25 ppm GA_3 (Figure 8). Rest was terminated by December 23, 1974, after 816 chill-units had accumulated.

The early defoliation caused a severe stress on the trees, which resulted in the abscission of the flower buds before February 1, 1975, and the death of over one-half of the limbs on the individual trees. The live limbs leafed out in the spring the same time as the control trees.

The trees that were defoliated on September 17, 1974 (after rest had begun) did not grow in the fall, even though the maximum air temperature was above 80 F (26.7 C) most days during the 2 weeks following defoliation (Figure 11). Rest began in these defoliated trees on September 12, 1974, reached an intensity peak of 25 ppm GA_3 approximately October 30, and was terminated by December 17, 1974 (Figure 9). The trees received 789 chill-units during this period.

Figure 11. Photograph of the defoliated trees. The tree on the ~~right~~ left was defoliated on August 15, 1974. The limited number of new leaves can be seen. The tree on the ~~left~~ right was defoliated on September 17, 1975. It did not leaf out until the spring of 1975. Untreated trees are pictured in the background.

Photograph taken: October 9, 1974.

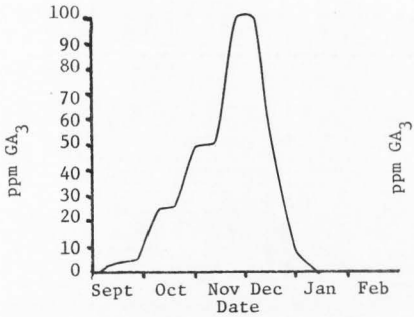


Figure 12. Changes in rest intensity of Gleason Elberta peach leaf buds from cool and 1/2 cool greenhouse treated trees during the winter of 1974-75.

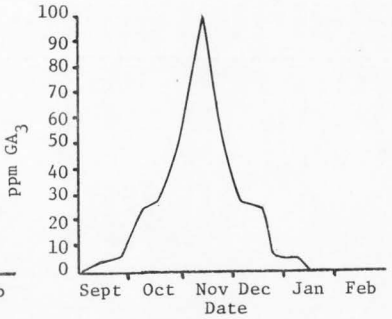


Figure 13. Changes in rest intensity of Gleason Elberta peach leaf buds during the fall and winter of 1974-75. Trees were treated with 100 ppm GA_3 on August 15, 1974.

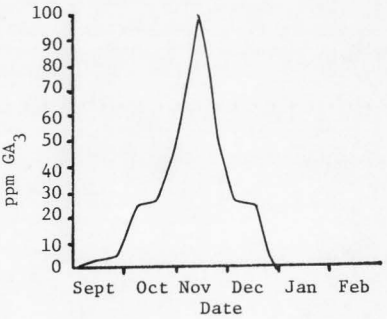


Figure 14. Changes in rest intensity of Gleason Elberta peach leaf buds from control trees during the fall and winter of 1974-75.

Full bloom occurred on the same date as the control trees, with blossoms and growth appearing normal, although the defoliated trees did have approximately 25 percent less fruit crop than the control trees.

Trees sprayed with 100 ppm GA_3 on August 15, 1974, had the same rest inception date and rest intensity curve as the control, except at the end of rest (Figure 13). Rest ended in the sprayed trees on January 13, 1975, after an accumulation of 847 chill-units. The wind of October 10, 1974, also caused some defoliation of these trees, but they were defoliated less than the control trees, and the remaining leaves were greener and remained on the trees longer in the fall than those on the control trees.

The trees sprayed with 100 ppm GA_3 on September 19, and October 16, 1974, had rest periods and rest intensity curves that were similar to the control trees. Leaves on the September 19 treated trees did remain greener a few days longer than the control leaves, although the trees were more than one-half defoliated by the wind of October 10, 1974.

Full bloom on all of the GA_3 treatments occurred on the same date as the control trees. No apparent fruit bud abscission occurred during the winter, as the fruit crop was normal on all of the treated trees.

Cold hardiness study

Cold hardiness of flower buds from control trees exposed to ambient air temperatures followed a curve similar to that reported by Proebsting and Mills (1966) and Hatch and Walker (1969) (Figure 15).

The T_{50} was 17 F (-8.3 C) when the study began on August 21, 1974, during hot summer temperatures. The T_{50} then decreased steadily until

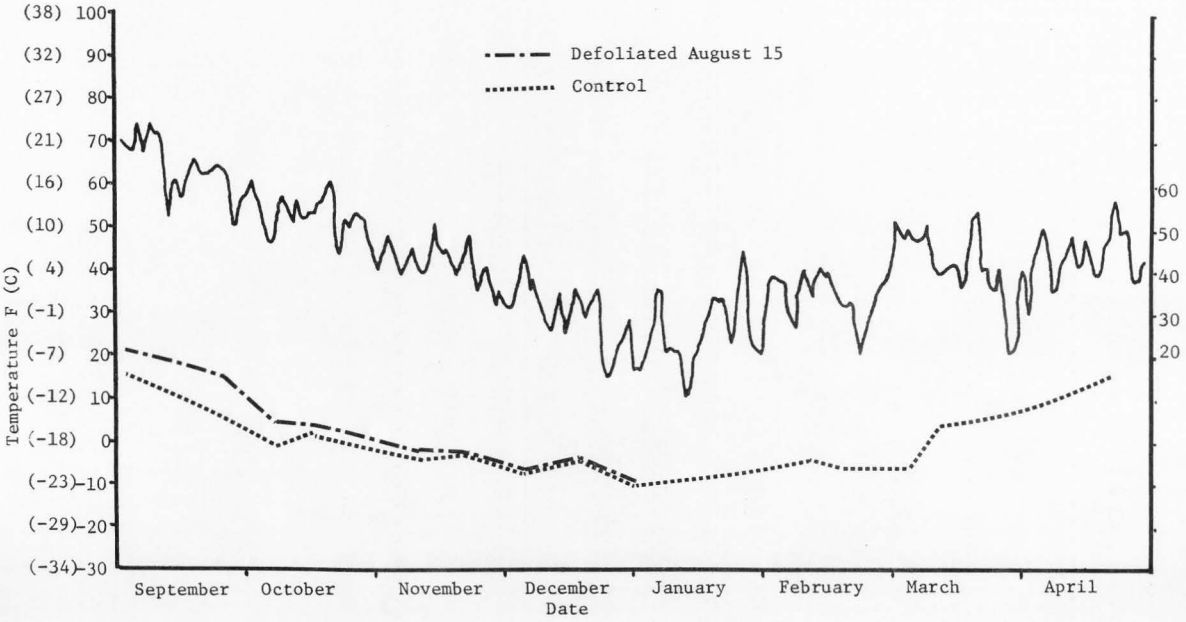


Figure 15. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. August 15 defoliation treatment compared with control. Upper line is the average of the daily maximum and minimum level temperatures. Points on the lower lines represent T_{50} determinations.

it reached -1 F (-18 C) on October 7, 1974. At this time leaf abscission had not occurred but rest had begun. The T_{50} remained fairly constant until December, when it again decreased, reaching a low of -10 F (-23.3 C) on December 30, 1974. It remained low until the March 11, 1975 sample, when it rose dramatically, apparently due to the increased temperature and bud development. T_{50} increased steadily as bud swelling occurred in the spring. With the exception of the early fall period, fluctuations in T_{50} seemed to coincide with the minimum bud temperatures of the preceeding few days.

Change in cold hardiness of flower buds from trees in the warm greenhouse showed some surprising results. Even though the temperature in the greenhouse remained fairly constant and did not go below 60 F (15.6 C), the T_{50} decreased from 17 F (8.3 C) on August 21, 1974, to 1 F (-17.2 C) on February 3, 1975 (Figure 16). The temperature inside the greenhouse was then lowered, with no resulting increase in bud hardiness. Apparently a minimum hardiness level had been reached without exposure to cool temperatures. Another interesting observation was the 7 F (4 C) increase in T_{50} during the October 29-November 12 period. Bud temperatures during the previous two weeks did not vary significantly from temperatures recorded prior to the two week period or after the T_{50} change occurred.

Flower buds from the one-half warm greenhouse had fall T_{50} measurements similar to the warm greenhouse buds, including an increase during the October 29-November 12 period. The T_{50} decreased from 9 F (-12.8 C) on December 18 to 0 F (-17.8 C) on December 30, 1974, with no previous or accompanying decrease in bud temperature (Figure 17). This dramatic increase in cold hardiness must have resulted from a water stress of

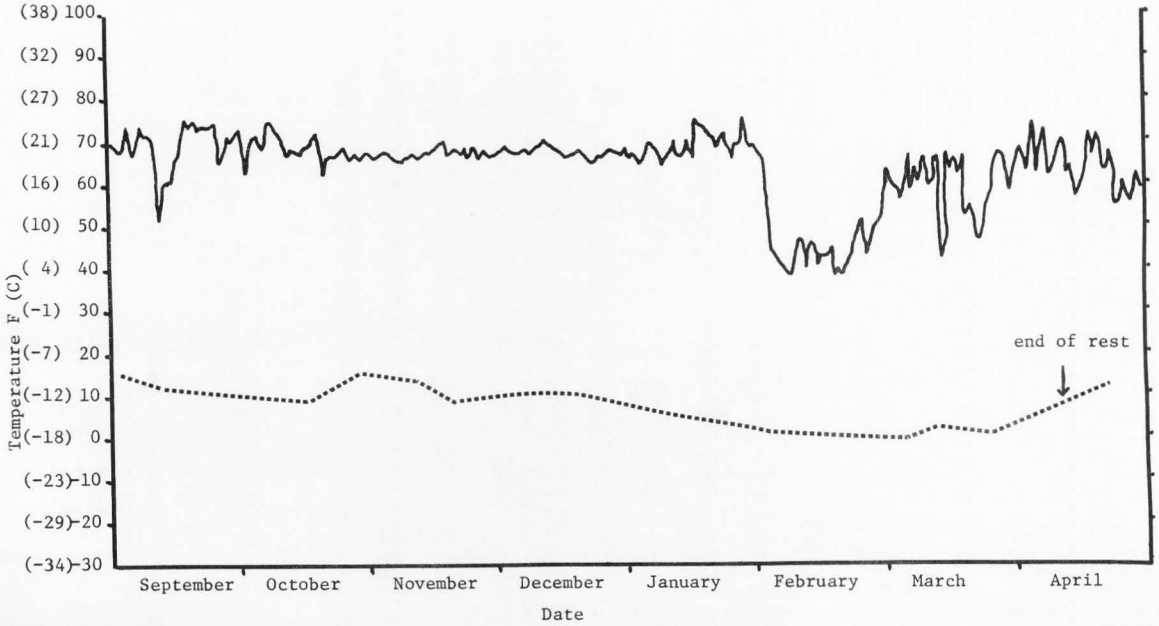


Figure 16. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. Upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower line represent T_{50} determinations of buds from the warm greenhouse treatment.

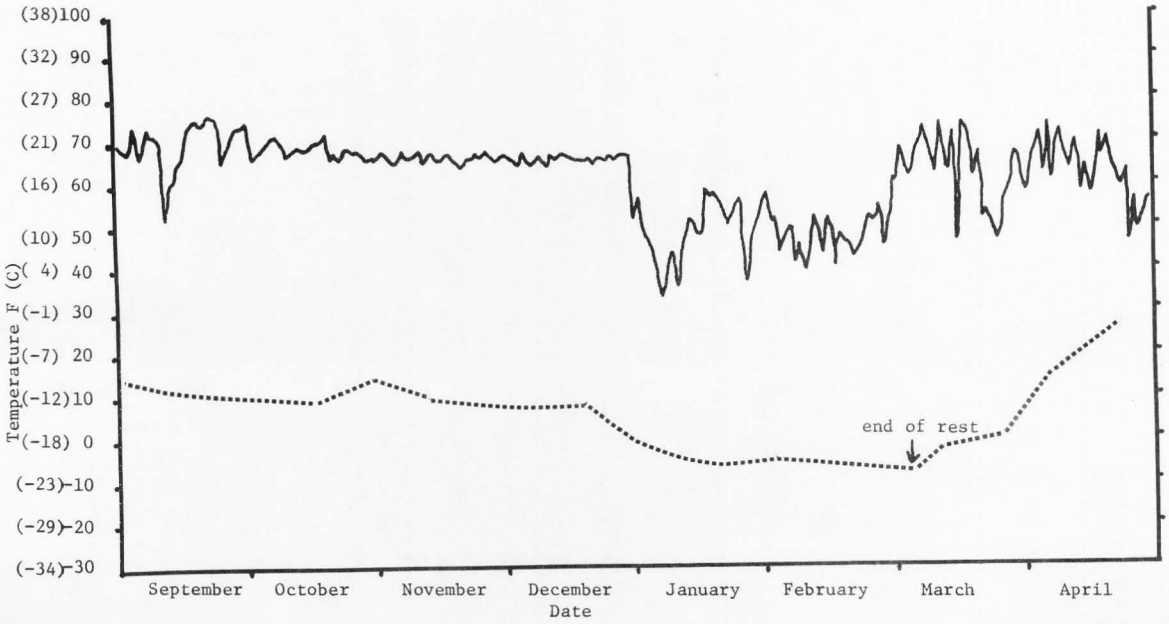


Figure 17. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. The upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower line represent T_{50} determinations of buds from the 1/2 warm greenhouse treatment.

approximately 29 bars that came from the freezing of the tree trunks sometime during the December 23-30 period. The temperature inside the greenhouse during January was lowered considerably, with many nights of below freezing temperatures occurring. This resulted in a continuance of the T_{50} decrease, with a low of -7 F (-22 C) occurring on March 4, 1975. The T_{50} then increased steadily as active bud development occurred.

Flower bud cold hardiness of cool greenhouse treated trees was similar to the untreated control trees until December 4, 1974. T_{50} of the cool greenhouse buds remained near 0 F (-17.8 C) from December 4, 1974, until the latter part of January, when it began to increase rapidly as bud development progressed (Figure 18).

Cold hardiness of flower buds from the one-half cool greenhouse treated trees was similar to the cool treated buds except during the active bud development stage (Figure 19). The slower decrease in bud hardiness of one-half cool treated flower buds during this period was apparently due to the slightly lower temperatures in the one-half cool greenhouse and subsequent slower bud development than that of the cool greenhouse flower buds.

The August 15, 1974 tree defoliation caused a substantial reduction in the rate of early acclimation of flower buds as compared to the control (Figure 15). The T_{50} remained unusually high until the September 25-October 7 period, when it dropped from 15 F (-9.4 C) to 4 F (-15.6 C). This was also the same period when terminal growth ceased and the terminal buds were reformed. T_{50} then decreased steadily until November 12, when it reached -3 F (-19 C) which was similar to the control.

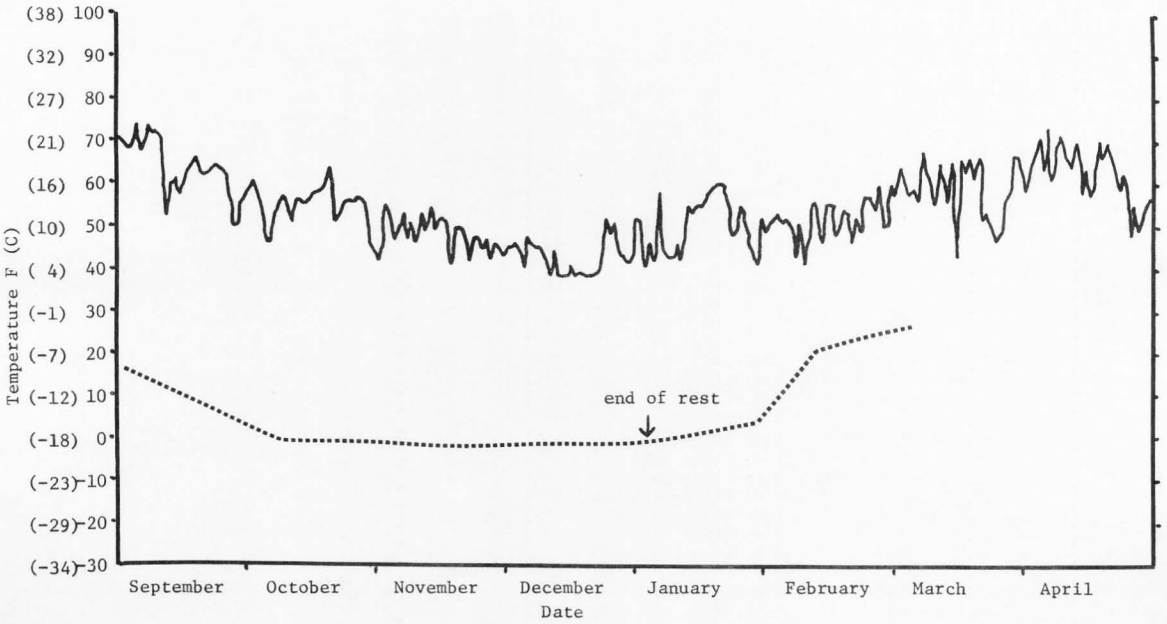


Figure 18. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. Upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower line represent T_{50} determinations of buds from the cool greenhouse treatment.

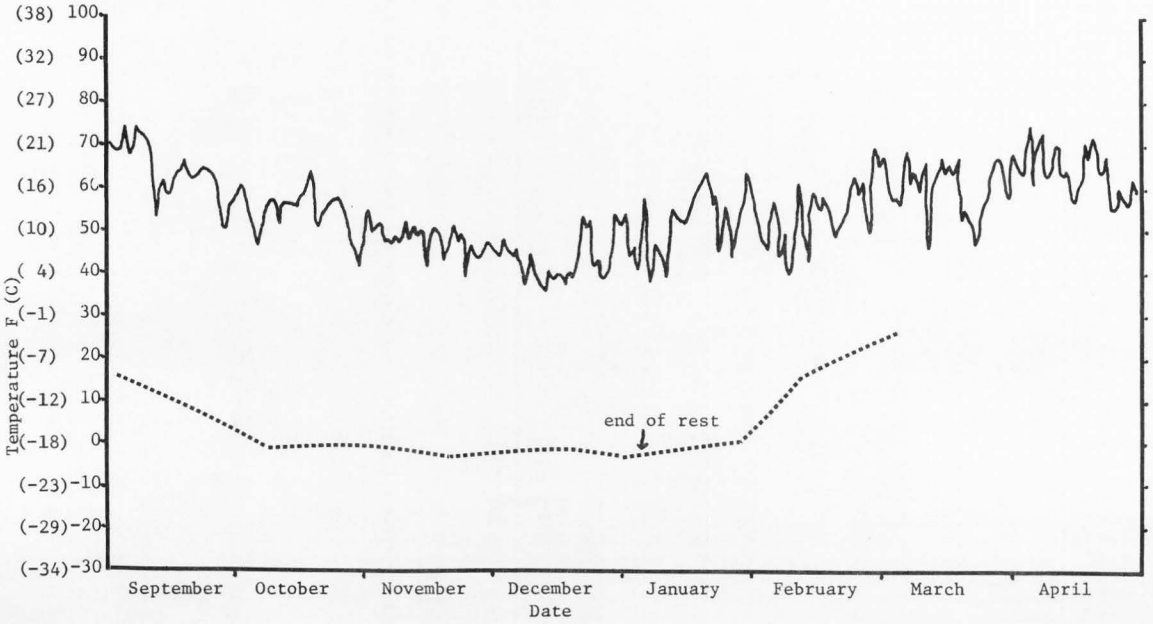


Figure 19. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. Upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower line represent T_{50} determinations of buds from the 1/2 cool greenhouse treatment.

T_{50} measurements were discontinued after December 30, 1974, due to the small size and eventual abscission of the flower buds.

The T_{50} of flower buds from September 17, 1974 defoliated trees was a few degrees less than the control during the October 7-16 period, but was similar by the end of October. No difference in flower bud hardiness between this treatment and the control was observed after October.

A day-length effect during the early part of the fall season was observed on trees treated with an extended day-length. The maximum effect was observed on September 12, 1974, when the long-day flower buds had a T_{50} of 19 F (-7.2 C) and the control 12 F (-11.1 C) (Figure 20). The effect had disappeared by the end of September, and was not observed during the remainder of the season.

The August 15, 1974 GA_3 application caused a substantial decrease in cold hardiness of flower buds (as compared to control buds) during the October 7-16 period, but not any other time during the season (Figure 21). The hardiness decrease occurred even though no visible bud development occurred, and after rest had begun.

The September 19, 1974 GA_3 application also caused a reduction in fruit bud cold hardiness during the October 7-16 period, but was much less evident than with the August 15 treatment. The T_{50} of flower buds from the October 16 GA_3 treated trees was similar to the control throughout the season.

Late-summer nitrogen applications and fall pruning caused no observable differences in flower bud T_{50} as compared to control buds. All of the treated trees had normal fruit crops and vigorous shoot growth during the following spring and summer.

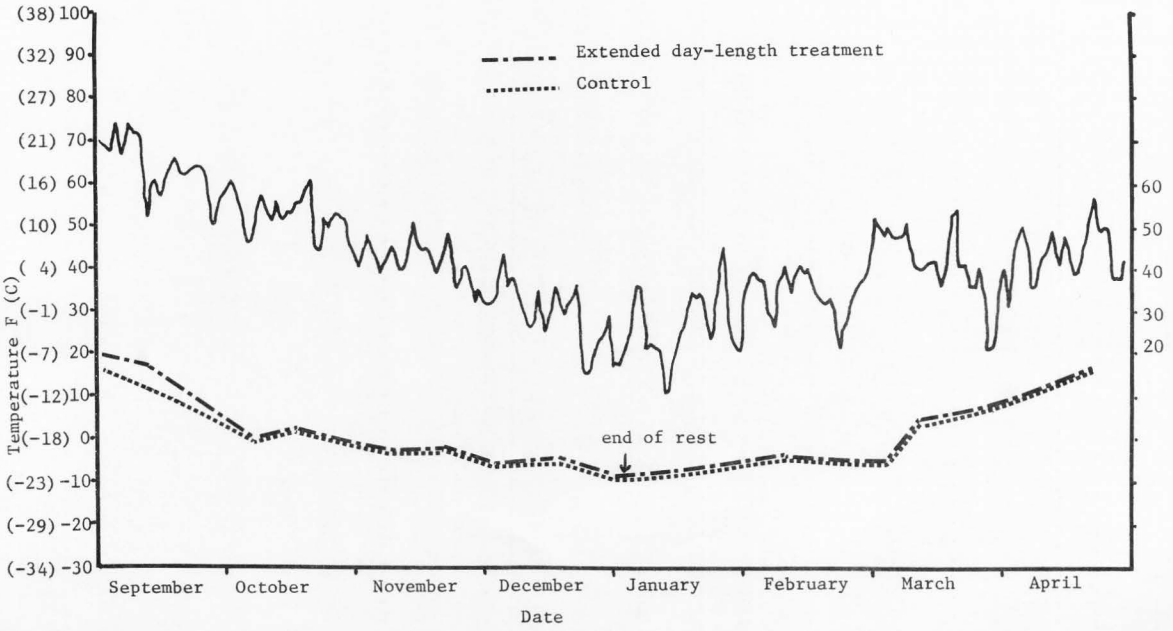


Figure 20. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. Extended day-length treatment compared with control. Upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower lines represent T_{50} determinations.

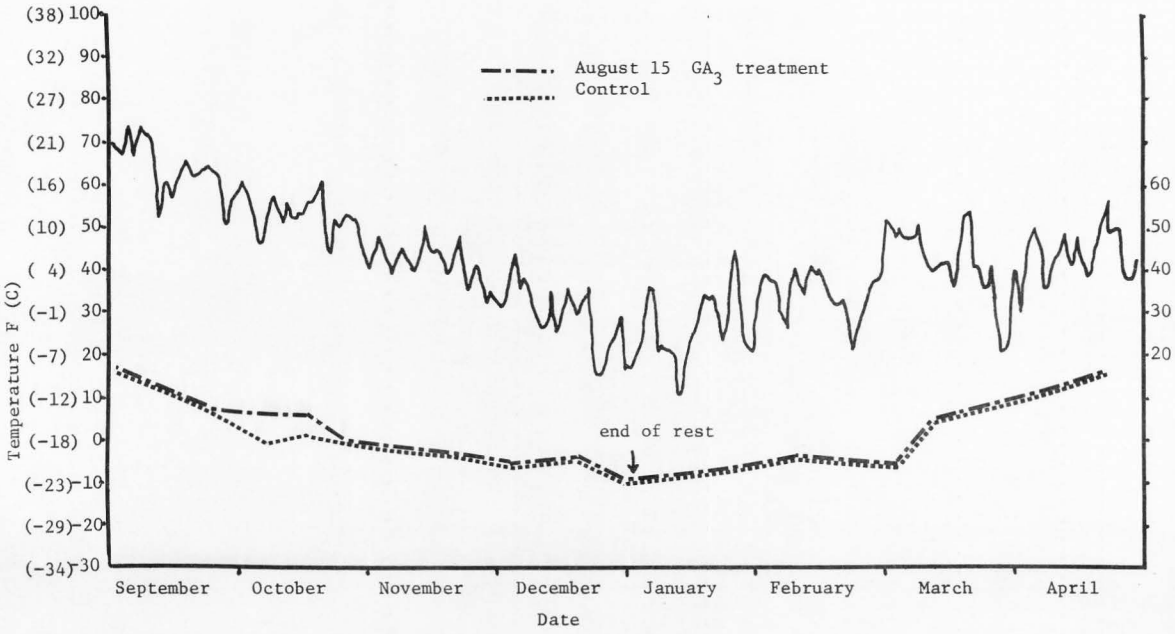


Figure 21. Cold hardiness of Gleason Elberta peach flower buds as related to temperature of 1974-75. GA_3 treatment on August 15, 1974 compared with control. Upper line is the average of the daily maximum and minimum bud temperatures. Points on the lower lines represent T_{50} determinations.

Some surprising results were observed from the twig diameter/ flower bud hardiness study (Figure 22). In the field study of December 1969, Redhaven peach flower buds on twigs 3 mm in diameter at the base of the twig had 51 percent live buds. Flower buds on twigs 4-5 mm in diameter were 72 percent alive, while those on 6-7 mm diameter twigs were 86 percent alive. Flower buds on twigs 8 mm or greater in diameter were 86 percent alive.

The January 6, 1975 study of Gleason Elberta peach flower bud hardiness as compared to twig diameter indicated results similar to that observed with Redhaven peach buds. Following exposure to -8 F (-22 C), flower buds on twigs 3 mm or less in diameter were only 9 percent alive, while those on twigs 8 mm or greater in diameter were 30 percent alive. Also, buds on twigs 3 mm or less in diameter were all dead, while 8 percent of those on twigs 8 mm or greater in diameter survived a cold treatment of -12 F (-24.6 C). These results indicate an approximate 4 F (2.6 C) difference in T_{50} between buds on small diameter twigs and those on twigs of larger diameter.

The January 28, 1975 treatment showed that flower buds on small diameter twigs had increased in cold hardiness from January 6, while buds on large diameter twigs had not changed. A -6 F (-20.7 C) temperature exposure resulted in 81 percent viable flower buds on twigs 3 mm or less in diameter, while buds on twigs 8 mm or greater in diameter were 88 percent alive. Similarly, exposure at a temperature of -9 F (22.6 C) resulted in 24 percent live flower buds on twigs 3 mm or less in diameter and 30 percent live buds on large diameter twigs.

The automatic sample retrieval system used with the programmed plant freezing chamber (Figure 23) functioned as expected. Samples

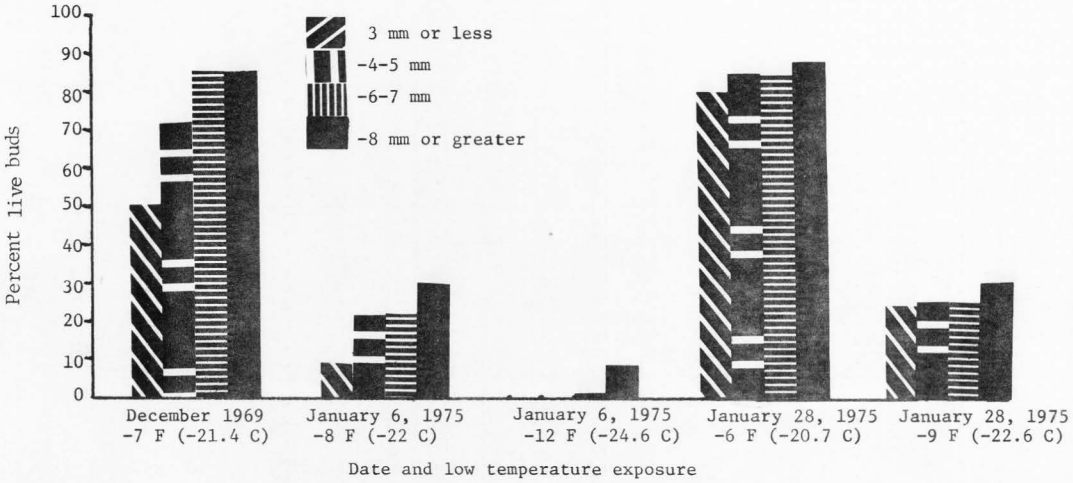
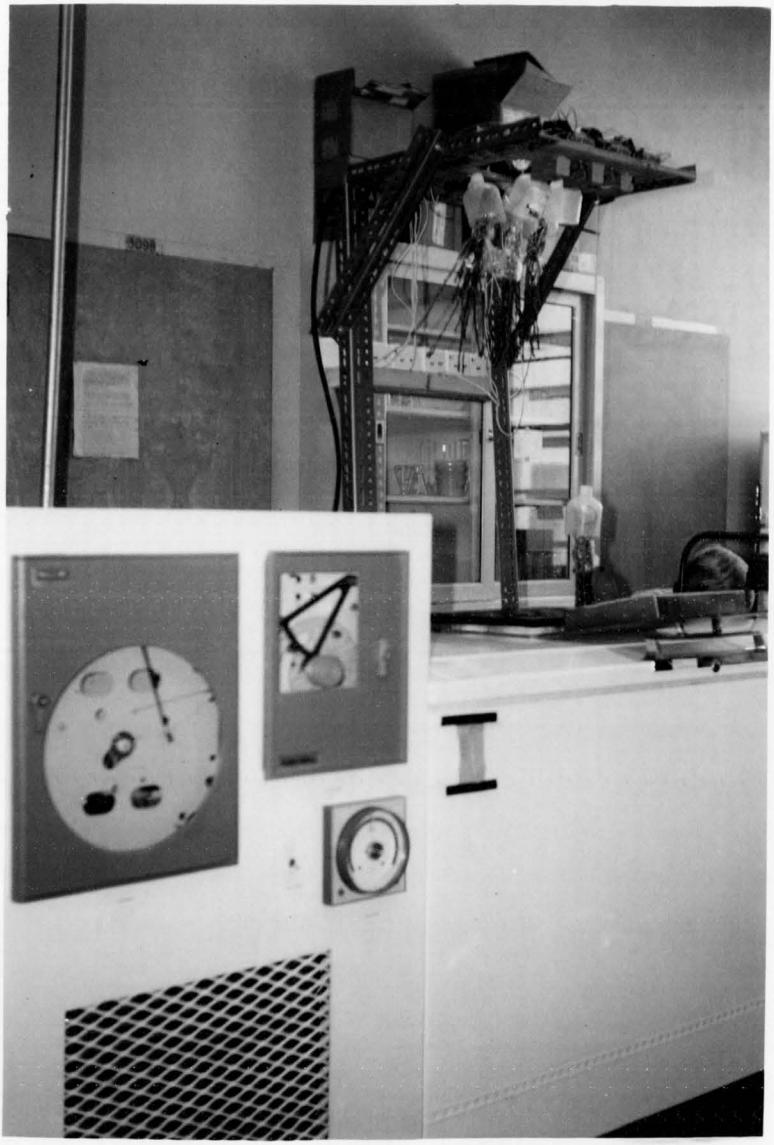


Figure 22. Percent live Redhaven (1969) and Gleason Elberta (1975) peach flower buds as related to twig diameter. Buds were exposed to sub-zero F temperatures on the dates noted above.

Figure 23. The custom-built freeze chamber built by Mallory Engineering Company, Salt Lake City, Utah, and the automatic retrieval system built by S. D. Seeley and R. H. Walser. The cam follower mechanism and the temperature recorder are shown in the low left corner. The automatic retrieval system is shown with a sample being extracted.

Photograph taken: February 26, 1975.



were retreived from the freezing chamber using one of six Hurst model 2541, 6 rpm, 115 volt electric motors. These motors were each started at a specified time by a 6 switch industrial timer, and stopped by the sample triggering a micro-switch. The micro-switch also stopped an electric clock which was used to determine the time of sample extraction. This system was reliable to within ± 1/2° F (.3 C) of the specified temperature treatment.

Abscisic acid study

Abscisic acid was observed in leaf and flower buds of Gleason Elberta peach during all of the sample periods. ABA concentration did vary between treatments and between different bud development stages.

ABA concentration in the untreated control flower buds, expressed as nanograms of ABA/gram of plant material dry weight, was below .1 ng during August, increased to .7 ng during the rest inception period, decreased during late September, and reached a peak of .9 ng during the leaf abscission period in October. ABA concentration then decreased rapidly to below .2 ng at the time of rest termination. ABA levels remained low throughout the spring months, although a slight increase was noted shortly before full bloom. ABA concentration in untreated leaf buds had similar changes, although the total ABA concentration was less than in flower buds (Figure 24).

ABA levels in leaf and flower buds of the cool greenhouse treated trees was similar to the control except for a small increase in flower bud ABA during mid-November and late December (Figure 25). The mid-November increase occurred during the leaf abscission period. A decrease in leaf bud ABA concentration that occurred during late December coincided very well with the end of rest. ABA concentration of both

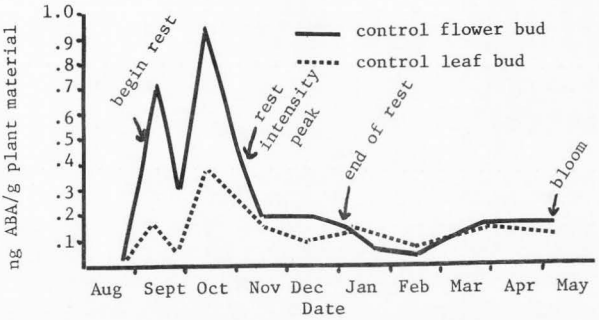


Figure 24. Changes in abscisic acid concentration in Gleason Elberta peach flower and leaf buds under ambient-conditions during the fall, winter, and spring of 1974-75.

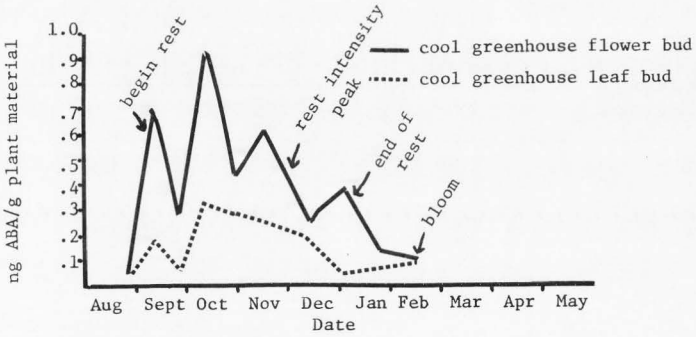


Figure 25. Changes in abscisic acid concentration in Gleason Elberta peach flower and leaf buds under cool temperatures during the fall, winter, and spring of 1974-75.

leaf and flower buds did not differ significantly (LSD .05%) from the levels in the control during and stage of development (Figures 26 and 27).

The warm greenhouse treatment caused the ABA concentration in flower buds to fluctuate widely during the winter season (Figure 28). Concentration peaks occurred at the inception of rest, during late October, and again in late January. The late January increase coincided with the beginning of leaf abscission. A small increase occurred during the active bud development stage. ABA concentration in the warm greenhouse treated flower buds was significantly lower than in the control during rest, but not during other stages of development. Warm greenhouse treated leaf bud ABA concentration followed a curve similar to the control, but was significantly lower during the post-rest stage (Figures 26 and 27).

The one-half warm greenhouse treatment also caused a wide fluctuation in ABA concentration in flower buds (Figure 29). Concentration peaks occurred during early September, late October, mid-February, and at full bloom. ABA levels in both leaf and flower buds increased after the trees had suffered a water stress during late December. The ABA level in the one-half warm flower buds was significantly lower than the control during rest, bud did not differ significantly during the other stages of development (Figures 26 and 27). ABA concentration in leaf buds of the one-half warm greenhouse trees did not increase as much as in the control during the early fall period, but only differed significantly during the active bud swell stage, when it was greater than in the control leaf buds.

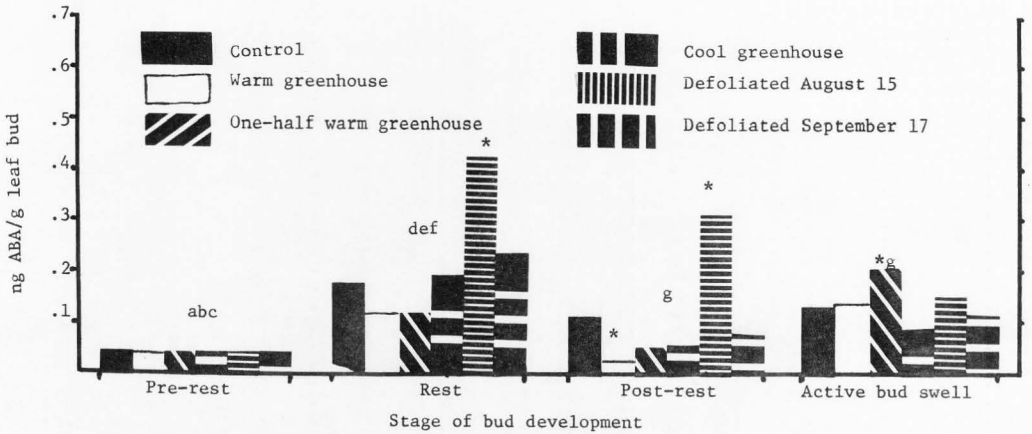


Figure 26. Concentration of abscisic acid in Gleason Elberta peach leaf buds during different stages of bud development. Average of one or more samples within stage of development. Significant differences for treatments within stages (LSD test): 5%= .0510; between stages, 5% = .0367. Asterisks indicate treatments which are significantly different from the respective control within stages at the 5% level. Stages of development preceeded by the same letter are not significantly different at the 5% level.

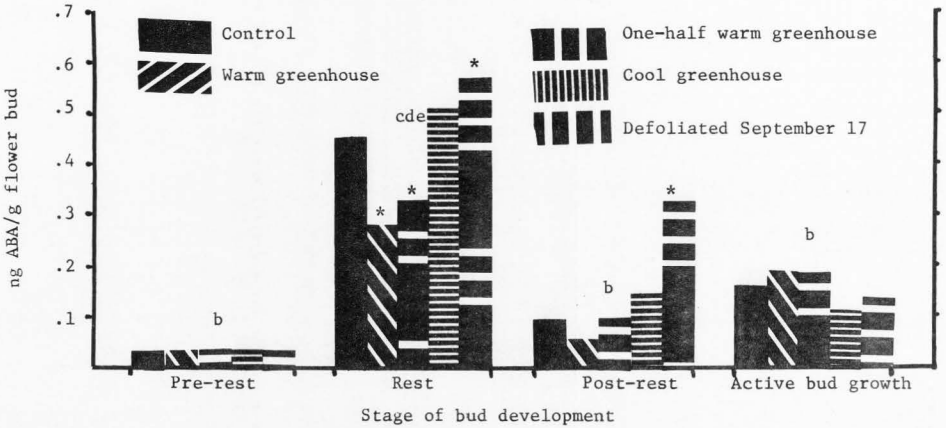


Figure 27. Concentration of abscisic acid in Gleason Elberta peach flower buds during different stages of bud development. Average of one or more samples within stage of development. Significant differences for treatments within stages (LSD test): 5% = .1084; between stages, 5% = .1948. Asterisks indicate treatments which are significantly different from the respective control within stages at the 5% level. Stages of development preceeded by the same letter are not significantly different at the 5% level.

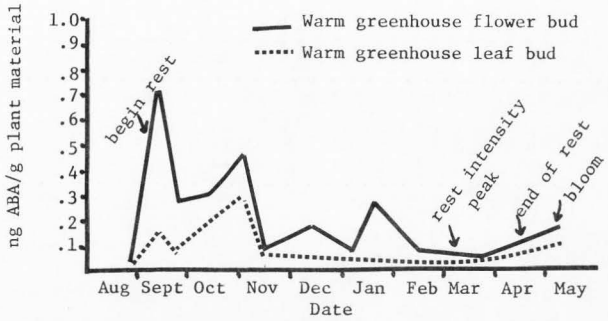


Figure 28. Changes in abscisic acid in Gleason Elberta peach leaf and flower buds under warm temperature during the fall, winter, and spring of 1974-75.

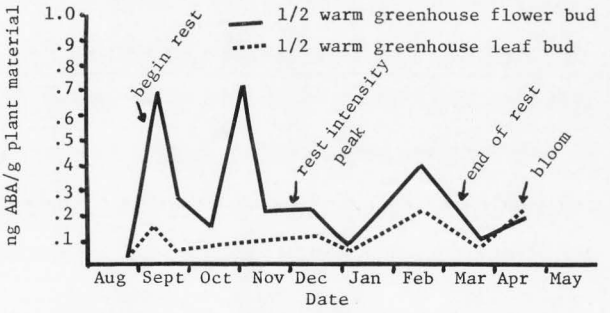


Figure 29. Changes in abscisic acid concentration in Gleason Elberta peach flower and leaf buds from one-half warm-ambient trees during the fall, winter, and spring of 1974-75.

ABA in leaf buds of trees defoliated August 15, 1974, reached concentration levels that were much higher than in the control (Figure 31). ABA concentration was high during rest, then decreased rapidly up to the time of rest termination. A small concentration increase occurred shortly after rest termination. With the exception of the pre-rest period, ABA level in the leaf buds of the defoliated trees was significantly higher than in the control during all of the stages of development (Figure 26).

ABA concentration in flower buds of trees defoliated on September 17, 1974, was high during the rest period, but decreased rapidly before the end of rest (Figure 30). A small increase occurred during early January, followed by a gradual decrease as active bud development occurred. The ABA level in the flower buds of this treatment was significantly higher than in the control during rest and post-rest. Leaf bud ABA concentration increased to approximately .5 ng during rest, followed by a rapid decrease approximately one month before the end of rest. ABA concentration then remained low through the active bud development stage. ABA level in the leaf buds of these defoliated trees did not differ significantly from the control during any stage of development analyzed (Figures 26 and 27).

When all of the treatments were considered together, ABA concentration in flower buds was significantly greater during the rest stage than during the pre-rest, post-rest, or active bud swell stage of development (Figure 27). ABA levels were not significantly different during pre-rest, post-rest, or active bud swell stages.

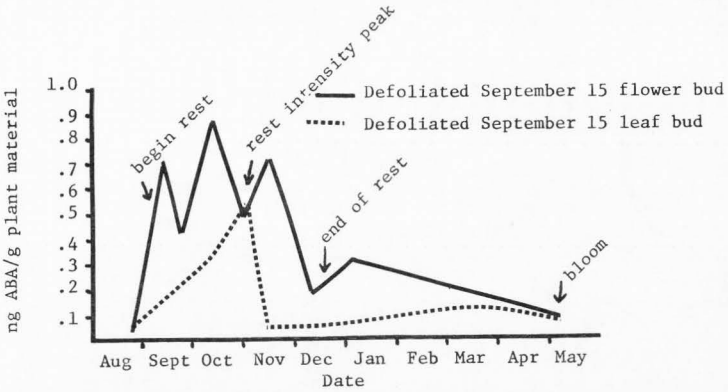


Figure 30. Changes in abscisic acid concentration in Elberta peach flower and leaf buds during the fall, winter, and spring of 1974-75.

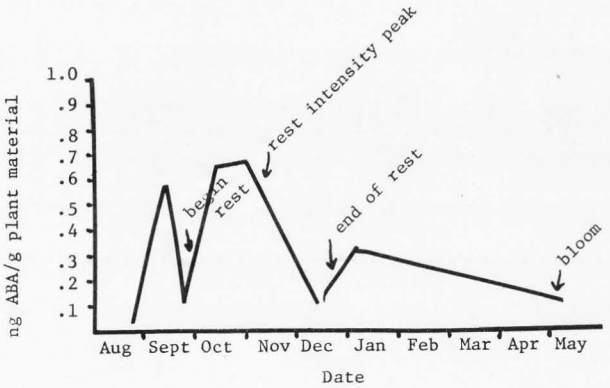


Figure 31. Changes in abscisic acid concentration in Elberta peach leaf buds during the fall, winter, and spring of 1974-75 after defoliation August 15, 1974.

ABA level in leaf buds of all of the treatments considered together was also significantly greater during rest than during pre-rest, post-rest, or active bud swell. The pre-rest ABA concentration was significantly lower than that of the other stages of development. There was no significant difference in ABA level in leaf buds during the post-rest and active bud swell stages of development (Figure 26).

DISCUSSION

Rest study

The duration and intensity of rest of untreated peach trees during the winter of 1974-75 was similar to that reported by Hatch and Walker (1969). Their report that peach leaf buds do follow a bell-shaped rest intensity curve that can be measured using GA_3 concentration gradients, was clearly substantiated by this work.

The rest intensity peak did not seem to be associated with temperature change, but did seem to be associated with leaf abscission. On all of the treatments except those that were prematurely defoliated, the rest intensity peak occurred during the leaf abscission period, or within one or two weeks following leaf abscission.

The length of time that leaves remain on trees in the fall also seems to affect rest intensity. The trees defoliated in early fall only required 25 ppm GA_3 to break rest, while trees under the warm greenhouse where defoliation occurred during mid-winter, required a maximum of 200 ppm GA_3 to break rest. Trees under the cool and one-half cool greenhouses retained their leaves longer than the control, and subsequently had a rest intensity peak that was 3 weeks later and broader than that of the control. It therefore appears that early fall defoliation will cause a low rest intensity peak, and late fall defoliation will cause a higher and delayed rest intensity peak.

Strong evidence was obtained which suggests the presence of a translocatable rest promoting substance that will move from a portion of a tree exposed to cold temperatures, to a side exposed to warm temperatures (Figure 5). Even though the warm and one-half warm

greenhouse treated trees received similar environmental conditions, the rest intensity of the one-half warm trees during the early fall period was similar to the control and the one-half of the tree not under the greenhouse. On October 30, 1974, both the one-half warm and control trees required 50 ppm GA_3 to break rest, while only 5 ppm GA_3 broke the rest of trees entirely exposed to warm temperatures. The rest promoting substance was presumably translocated from buds or bark of the cold side into the roots, then up to the buds of the warm side. Since the warm side was fully foliated, the leaves could have functioned as a sink for the translocatable substance. There was no indication that this substance was abscisic acid. There was no evidence of the translocation of a rest breaking substance.

The Richardson et al. (1974) chill-unit model method of determining the date of rest termination was fairly accurate on trees exposed to normal environmental conditions, but was very inaccurate when abnormal conditions prevailed. They determined by use of the model, that 790 chill-units are required to break rest of Gleason Elberta peach leaf buds. This agrees fairly well with the control trees, which required 822 chill-units to break rest, but does not agree with the requirements of the one-half cool and cool greenhouse treated trees, which required 1395 and 1345 chill-units respectively to break rest.

This chill-unit requirement discrepancy between normal and abnormal environmental conditions appears to be in the determination of the date of inception of effective chill-unit accumulation, rather than in the conversion of different temperatures into chill-units (Figure 32). It appears that effective chill-unit accumulation does not begin until

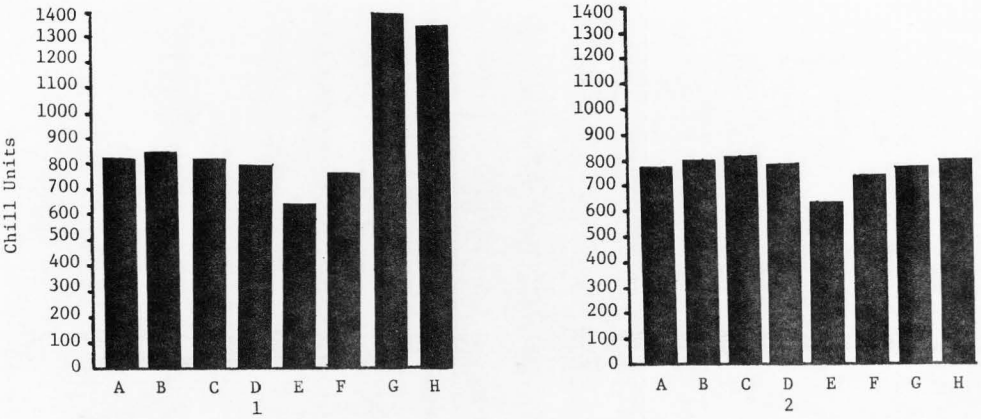


Figure 32. Total chill units accumulated during the rest period when initiation of chill units was determined from the date of greatest negative accumulation of chill units in the fall (1), and total chill units accumulated during the rest period when initiation of chill units was determined from approximately one half leaf-fall (2).

A = Control, B = August 15 GA_3, C = Defoliated August 15, D = Defoliated September 17, E = 1/2 Warm greenhouse, F = Warm greenhouse, G = 1/2 Cool greenhouse, H = Cool greenhouse.

a certain amount (as yet undetermined) of defoliation has occurred in the fall. Three different results of this study add reliability to this hypothesis:

(1) When an arbitrarily appointed index of one-half defoliation was used as the inception date of chill-unit accumulation rather than the date of the greatest negative accumulation of chill-units, a more uniform correlation of total chill-units required to break rest was obtained between the various treatments. As an example, the control chill-unit requirement decreased from 822 to 777 chill-units, while the one-half cool and cool greenhouse tree requirement decreased from 1395 and 1345 to 770 and 804 chill-units respectively. Apparently the chill-units received by the one-half and cool greenhouse trees while they were fully foliated were not effective in breaking rest.

(2) The August 15, 1974 GA_3 treatment caused a retardation in defoliation, with the leaves remaining in a greener condition compared to the control. As a probable result of the delay in leaf abscission and senescence, rest ended 2 weeks later in the GA_3 treated trees (Figure 9). This delay in rest termination was most likely due to the delay in leaf senescence and abscission caused by the GA_3 application. It thus appears that August fall GA_3 applications extend the rest period as a result of the delayed fall defoliation. This could also explain why different researchers (Edgerton 1966; Marlangeon 1969) have reported different delays in peach full bloom following fall applications of GA_3. In colder climates (Edgerton 1966) GA_3 application would delay fall defoliation less than in warmer climates. Also, in colder climates, the cool temperatures that GA_3 treated and untreated

trees would generally be exposed to after the end of rest would prevent the untreated tree from accumulating growing degree hours with subsequent bud development. Thus, a rest termination delay in GA_3 treated trees would not result in a bloom delay in these trees compared to untreated trees, because of the depressing effects on bud development of cool temperatures received by untreated trees during the rest delay period of GA_3 treated trees. However, in warmer climates (Marlangeon 1969) a delay in rest termination could cause a delay in bloom time of GA_3 treated trees as compared to untreated trees. This delay could be a result of the accumulation of many growing degree hours of warm temperature and subsequent bud development of untreated trees, while the extended rest period could prevent the GA_3 treated trees from effectively utilizing the growing degree hours received during this same period.

(3) Trees that were defoliated on September 17, 1974, broke rest two weeks earlier than the untreated trees, after an accumulation of 789 chill-units. Apparently all of the early chill-units were effective, since these trees had no leaves on them. Trees that were defoliated on August 15, 1974, broke rest one week earlier than the control, after an accumulation of 816 chill-units. The new leaves that grew on these trees apparently had some effect on the chill-unit accumulation. Since these trees were only approximately one-fourth refoliated, it appears that the chill-unit accumulation was delayed, not as much as in the untreated tree, but more than in the September 17 defoliated trees.

It thus appears that leaves on trees in the fall may result in a substance in the buds that may prevent the buds from utilizing exposure

to cool temperatures and begin the accumulation of effective chill-units. The results of this study would suggest that when conditions exist that delay fall leaf senescence and defoliation, the Richardson et al. (1974) chill-unit model be modified so as to utilize an index of leaf abscission rather than the day of greatest negative chill-unit accumulation as the inception of effective chill-unit accumulation.

Cold hardiness study

Temperature seemed to provide the greatest influence on cold hardiness of flower buds of Gleason Elberta peach, although other factors also influenced cold hardiness.

Cold hardiness appears to be influenced by an ageing or maturity factor in the buds. During the early fall period (August 17) flower buds had attained a T_{50} hardiness measurement of 17 F (-8.3 C) without experiencing any cool temperatures. Flower bud cold hardiness apparently will increase to a minimum level without exposure to cool temperatures, although this same hardiness level will be reached much faster after exposure to cool temperatures. For example, flower bud hardiness of the cool and one-half cool greenhouse trees reached 0 F (-17.8 C) by October 29, 1974, and then remained at this level ± 3 F (1.9 C) until active bud growth began in the spring. The warm greenhouse flower buds also eventually (February 3, 1974) acclimated to this same level, even though they had not been exposed to temperatures below 60 F (15.6 C). Flower buds on trees in the warm greenhouse did not increase in cold hardiness after the temperature was lowered to a minimum of 34 F (1.1 C). The results of this study indicate the existance of a minimum hardiness level as proposed by Proebsting (1963) which can

be achieved rapidly by cool temperatures or eventually under warm temperatures, due to a maturity factor. Possibly cool temperatures cause an acceleration of the process that leads to a certain stage of maturity, while warm temperatures delay the process.

Shortening day-length also seems to be involved to a certain extent in flower bud hardiness during the early fall period. A decrease in cold hardiness of buds exposed to long days as compared to control buds was most evident during early September, but had disappeared by late September. Apparently long-days delay flower bud maturity, which in turn delays acclimation. This delay is overcome by cooler temperatures of the later fall period.

Dehydration of the tree can also cause flower buds to acclimate. Flower buds on the one-half warm greenhouse trees increased 9 F (5 C) in cold hardiness from December 18, 1974, to December 30, 1974. During the same period trees under the warm greenhouse that were exposed to similar temperatures only increased 3 F (1.9 C) in hardiness. The extra 6 F (3.2 C) increase in hardiness of flower buds of the one-half warm greenhouse trees was undoubtedly due to the water stress caused by the freezing of the trunks during late December.

GA_3 treated and fall defoliated trees showed a delay in flower bud acclimation during the fall. This was apparently due to a delay in bud maturity or possibly even a short internal bud development period following treatment. In the case of the defoliated trees, a reduction in carbohydrate reserves caused by early leaf removal could have been a factor in delayed acclimation.

The twig diameter/flower bud hardiness study showed results that were contrary to that reported by Weaver *et al.* (1968). They found

that peach varieties with long slender twigs were generally more hardy than those with larger diameter twigs. The findings of the current study indicate that at least during early winter, flower buds on large diameter twigs (greater than 6 mm) are more hardy than those on smaller twigs. However, Weaver et al. (1968) was comparing differences between cultivars and was examining wood hardiness, while this study examined flower bud hardiness on twigs of different diameter within cultivars. The results of this study would indicate that cultural practices that produce vigorous, healthy shoot growth would provide more hardy flower buds during the early winter months. Another factor that could be involved is that flower buds on the base of long, large diameter twigs are the first ones formed, and thus would possibly acclimate or reach maturity at an earlier period than those on smaller twigs. This idea is supported by the results, as in December there was a much larger difference in percent live buds on twigs of different diameter than in late January.

Fall nitrogen applications and pruning caused no observable differences in flower bud T_{50} as compared to control buds. This would indicate that at least under Utah conditions similar to those of the winter of 1974-75, fall fertilization and pruning could be done without increasing the susceptibility of peach flower buds to damaging cold winter temperatures.

Abscisic acid study

Abscisic acid was present in leaf and flower buds of Gleason Elberta peach, although in less concentration than in apple (Seeley 1971) or sour cherry (Mielke 1974).

ABA in all treatments measured was low before rest, but increased rapidly during the rest inception period. The concentration fluctuated some during the rest period, but generally remained high, then decreased during the rest termination period. ABA concentration generally remained low during the post-rest and bud growth stages.

Mielke (1974) reported that ABA in sour cherry reached a peak that coincided not with the onset of rest, but with the onset of leaf abscission. He also reported that mechanical defoliation of trees 2 to 6 weeks prior to the onset of natural leaf abscission prevented the ABA increase. The results of Mielke (1974) are not in agreement with the results of this study performed on peaches. ABA in both flower and peach buds increased greatly following defoliation on August 15 and September 17, 1974. This would indicate that in the fall, ABA does not come from leaves, but is either formed in the buds, or released from a bound form as explained by Powell and Seeley (1974). However, except for the warm and one-half warm greenhouse trees, the largest ABA concentration peak did coincide with or follow leaf abscission.

Mielke (1974) concluded that ABA in sour cherry was not a controlling factor in rest, however, Seeley (1971) reports that ABA could be a controlling factor in rest of apples. The results of this study indicate that ABA could be a controlling factor in the inception of rest in peach.

Seeley (1975b) expressed the idea that different stages of plant development occur when the environment cues a physiological phase shifting mechanism in the plant. This mechanism could call for the production of ABA or its release from a bound form under fall conditions, which could cause the inception of rest. The next phase could then be

the production of gibberellin or interconversion of different gibberellin forms during chilling (Seeley 1975a). When GA increased to a certain level, this could signal the next phase to begin (post-rest). In such a mechanism, only the concentration of growth hormones at the beginning of a phase would be important in manipulating that one phase (ABA at rest inception and GA at rest termination or inception of post-rest).

There was no evidence of a correlation between ABA levels and cold hardiness of Gleason Elberta peach flower buds.

SUMMARY

The effects of temperature, defoliation, light, and certain fall cultural practices on rest and hardiness of Gleason Elberta peach buds were studied. The influence of these factors on abscisic acid concentration in peach buds and a possible role of ABA in rest and hardiness of peach buds were also investigated.

Peach leaf buds enter rest in early fall, reach a rest intensity peak in early winter, then break rest as a chilling requirement is met. Complete defoliation before rest has begun will cause some leaf and flower buds to grow, while defoliation after rest has begun will not cause visible bud growth.

Effective chill-unit accumulation in the fall apparently did not begin until after a certain amount of leaf abscission had occurred. A GA_3 application on August 15, 1974, delayed leaf abscission, and also caused extension of the rest period. Early fall defoliation was correlated with a reduction in rest intensity and a reduction in the rest period of leaf buds.

A result of this study indicates the possibility of the existence of a rest promoting substance that was apparently translocated from a side of a tree exposed to ambient temperatures to a warm greenhouse covered side.

Decreasing temperatures caused an increase in flower bud hardiness, however, other factors also have effects on hardiness.

An extended day-length treatment caused flower buds to acclimate more slowly than those on untreated trees during the early fall period. The light affect was not evident as colder temperatures prevailed.

Buds on trees that were kept warm, acclimated to the same level as buds on trees kept at cooler but non freezing temperatures. However, it took the warm buds approximately four months longer to acclimate. Buds on trees that were exposed to below freezing temperatures acclimated to a much lower level than those on trees not exposed to freezing temperatures.

Fall pruning and heavy fertilization with ammonium nitrate did not reduce cold hardiness enough to be measured. However, buds on vigorous, large diameter twigs were more hardy during the early winter period than buds on twigs of smaller diameter.

The August 15 and September 19 GA_3 treated trees and the early defoliated trees had a delay in acclimation during the fall period, although they did eventually acclimate to the same level as the untreated buds.

Abscisic acid concentration in peach leaf and flower buds was low before rest began, increased sharply during the rest inception period, and decreased in concentration before the end of rest. ABA may be a controlling factor in the inception of rest in peach.

There was no apparent relationship between ABA concentration and cold hardiness of Gleason Elberta peach flower buds.

LITERATURE CITED

Abbott, D.L. 1970. The role of budscales in the morphogenesis and dormancy of the apple fruit bud. Physiology of Tree Crops. Academia Press. London:New York. 382 p.

Avery, G.S., P.R. Burkholder and H.B. Creighton. 1937. Production and distribution of growth hormone activity in shoots of Aesculus and Malus and its probable role in stimulating cambial activity. Amer. J. Bot. 24:51-58.

Bachelard, E.P. and F. Wightman. 1973. Biochemical and physiological studies on dormancy release in tree buds. I. Changes in degree of dormancy, respiration capacity, and major cell constituents in overwintering vegetative nuds of Populus balsamifera. Can. J. Bot. 51:2315-2326.

Benes, J. and K. Veres. 1965. New types of kinins and their action on fruit tree species. Nature 206:830-831.

Bennett, J.P. and F. Skoog. 1938. Preliminary experiments on the relation of growth-promoting substances to the rest period in fruit trees. Plant Physiol. 13:219-225.

Bennet-Clark, T.A. and N.P. Kefford. 1953. Chromatography of the growth substances in plant extracts. Nature 171:645-647.

Blommaert, K.L.J. 1955. The significance of auxin and growth inhibiting substances in relation to winter dormancy of the peach tree. U.S. Afr. Dept. Agr. Sci. Bull. 368:1-23.

Blommaert, K.L.J. 1959. Winter temperature in relation to dormancy and the auxin and growth inhibitor content of peach buds. S. Afr. J. Agr. Sci. 2:507-514.

Bonner, J. and A.W. Galston. 1952. Principles of plant physiology. W.H. Freeman and Company, San Francisco, California. 499 p.

Bradley, M.V. and J.C. Crane. 1960. Gibberellin-induced inhibition of bud development in some species of Prunus. Science 131:825-826.

Brian, P.W., J.H.P. Petty and P.T. Richmond. 1959. Extended dormancy of deciduous woody plants treated in autumn with gibberellic acid. Nature 184:69.

Brown, C.L., R.C. McAlpine and P.P. Kormanik. 1967. Apical dominance and form in woody plants: a reappraisal. Amer. J. Bot. 54: 153-162.

Brown, D. S. and J.F. Abi-Fadel. 1953. The stage of development of apricot flower buds in relation to their chilling requirement. Proc. Amer. Soc. Hort. Sci. 61:110-118.

Brown, D.S. and F.A. kotob. 1957. Growth of flower buds of apricot, peach and pear during the rest period. Proc. Amer. Soc. Hort. Sci. 69:158-165.

Browning, G. 1973a. Flower bud dormancy in Coffea arabica L. I. Studies of gibberllin in flower buds and xylem sap and of abscisic acid in flower buds in relation to dormancy release. J. Hort. Sci. 48:29-41.

Browning, G. 1973b. Flower bud dormancy in Coffea arabica L. II. Relation of cytokinins in xylem sap and flower buds to dormancy release. J. Hort. Sci. 48:297-310.

Chandler, W.H. 1954. Cold resistance in horticultural plants: a review. Proc. Amer. Soc. Hort. Sci. 64:552-569.

Chandler, W.H. 1957. Deciduous orchards. Lea and Febiger, Philadelphia, Pennsylvania. 492 p.

Chandler, W.H. 1960. Some studies of rest in apple trees. Proc. Amer. Soc. Hort. Sci. 76:1-10.

Chandler, W.H. and W.P. Tufts. 1933. Influence of the rest period on opening of buds of fruit trees in spring and on development of flower buds of peach trees. Proc. Amer. Soc. Hort. Sci. 30:180-186.

Chaplin, C.E. and G.W. Schneider. 1974. Peach rootstock/scion hardiness effects. J. Amer. Soc. Hort. Sci. 99:231-234.

Chen, P. and P.H. Li. 1973. Biochemical changes in association with water stress-induced cold hardiness in Res Osier dogwood. HortScience 8:46.

Childers, N.F. 1973. Modern fruit science. Somerset Press, Inc. Somerville, New Jersey. 960 p.

Corgan, J.N. 1965. Seasonal change in narigenin concentration in peach flower buds. Proc. Amer. Soc. Hort. Sci. 86:129-132.

Corgan, J.N. and G.C. Martin. 1971. Abscisic acid levels in peach floral cups. HortScience 6:405-406.

Corgan, J.N. and C. Peyton. 1970. Abscisic acid levels in dormant peach buds. Amer. Soc. Hort. Sci. 95:770-773.

Corgan, J.N. and F.B. Widmoyer. 1971. The effects of gibberellic acid on flower differentiation, date of bloom, and flower hardiness of peach. J. Amer. Soc. Hort. Sic. 96:54-58.

Cornforth, J.W., B.V. Milborrow and G. Ryback. 1965. Synthesis of (±) abscisin II. Nature 206:715.

Correa, N.C. and R.C. Marlangeon. 1969., Atraso de floración en duraznero inducido con ácido giberelico y su relación con los tenores de azucares solubles y actividad de y-amilasa y regyladores naturales del crecimiento en sus yemas florales. Phyton 26:113-122.

Couvillon, G.A. and C.H. Hendershott. 1974. A characterization of the "after-rest" period of flower buds of two peach cultivars of different chilling requirements. J. Amer. Soc. Hort. Sci. 99:23-26.

Crozier, A., H. Aoki, R.P. Pharis and R.C. Durley. 1970. Endogenous gibberellins in Douglas-fir. Phytochem. 9:5137-5143.

Dennis, F.G., Jr. and L.J. Edgerton. 1961. The relationship between inhibitor and rest in peach flower buds. Proc. Amer. Soc. Hort. Sci. 77:107-116.

Denney, F.E. and E.N. Stanton. 1928. Localization of response of woody tissues to chemical treatments that break the rest period. Amer. J. Bot. 15:337-344.

Domanski, R. and T.T. Kozlowski. 1968. Variations in kinetin-like activity in buds of Betula and Populus during release from dormancy. Can. J. Bot. 46:397-403.

Donoho, C.W. and D.R. Walker. 1957. Effect of gibberellic acid on breaking of rest period in Elberta peach. Science 126:1178-1179.

Donoho, C.W. and D.R. Walker. 1960. The effect of controlled temperature treatments on hardiness of Elberta peach trees. Proc. Amer. Soc. Hort. Sci. 75:148-154.

Downs, R.J. and H.A. Borthwick. 1956. Effects of photoperiod on growth of trees. Bot. Gaz. 117:310-326.

Eady, F.C. and G.W. Eaton. 1972. The role of gibberellic acid and gibberellic-like substances in the dormancy of the cranberry. Can. J. Plant Sci. 52:263-271.

Eagles, C.F. and P.F. Wareing. 1963. Dormancy regulators in woody plants. Nature 199:874.

Eagles, C.F. amd P.F. Wareing. 1964. The role of growth substances in the regulation of bud dormancy. Physiol. Plant. 17:697-709.

Edgerton, L.J. 1957. The effect of nitrogen fertilization on cold hardiness of apple trees. Proc. Amer. Soc. Hort. Sci. 70:40-45.

Edgerton, L.J. 1960. Studies on cold hardiness of peach trees. Cornell Agr. Exp. Sta. Bul. 958:30.

Edgerton, L.J. 1966. Some effects of gibberellin and growth retardants on bud development and cold hardiness of peach. Proc. Amer. Soc. Hort. Sci. 88:197-203.

Edgerton, L.J. and R.W. Harris. 1950. Effect of nitrogen and cultural treatment on Elberta peach fruit bud hardiness. Proc. Amer. Soc. Hort. Sci. 55:51-55.

Eggert, F.P. 1951. A study of rest in several varieties of apple and in other fruit species grown in New York State. Proc. Amer. Soc. Hort. Sci. 57:169-178.

Eggert, F.P. 1953. The auxin content of spur buds of apple as related to the rest period. Proc. Amer. Soc. Hort. Sci. 62:191-200.

El-Antably, H.M.M., P.F. Wareing and J. Hillman. 1967. Some physiological responses to d, l abscisin (Dormin). Planta 73:74-90.

El-Mansy, H.I. and D.R. Walker. 1969. Seasonal fluctuations on flavanones in 'Elberta' peach flower buds during and after the termination of rest. J. Amer. Soc. Hort. Sci. 94:298-304.

Erez, A. and S. Lavee. 1969. Prunin identification, biological activity and quantitative change in comparison to naringenin in dormant peach buds. Plant Physiol. 44:342-346.

Erez, A. and S. Lavee. 1971. The effect of climatic conditions on dormancy development of peach buds. I. Temperature. J. Amer. Soc. Hort. Sci. 96:711-714.

Erez, A., S. Lavee and R.M. Samish. 1968. The effect of limitation in light during the rest period on leaf bud break of the peach (Prunus persica). Physiol. Plant. 21:759-764.

Erez, A., S. Lavee and R.M. Samish. 1971. Improved methods for breaking rest in the peach and other deciduous fruit species. J. Amer. Soc. Hort. Sci. 96:519-522.

Erez, A., R.M. Samish and S. Lavee. 1966. The role of light in leaf and flower bud break of the peach (Prunus persica). Physiol. Plant. 19:650-659.

Frankland, B. and P.F. Wareing. 1962. Changes in endogenous gibberellins in relation to chilling of dormant seeds. Nature 194:313.

Fraser, D.A. 1962. Apical and radial growth of white spruce (Picea glauca) (Moench Voss) at Chalk River, Ontario, Canada. Can. J. Bot. 40:659-668.

Fuchigami, L.H., D.R. Evert and C.J. Weiser. 1971a. A translocatable cold hardiness promoter. Plant Physiol. 47:164-167.

Fuchigami, L.H., C.J. Weiser and D.R. Evert. 1971b. Induction of cold acclimation in Cornus stolonifera Mich. Plant Physiol. 47:98-103.

George, M.F., M.J. Burke and C.J. Weiser. 1974. Supercooling in overwinter Azalea flower buds. Plant Physiol. 54:29-35.

Gergory, F.G. and C.R. Hancock. 1955. The rate of transport of natural auxin in woody shoots. Ann. Bot. 19:451-465.

Gunckel, J.E. and K.V. Thimann. 1949. Studies of development in long shoots and short shoots of Ginko bilboa L. III. Auxin production in shoot growth. Amer. Jour. Bot. 36:145-151.

Hatch, A.H. 1967. The effect of changing temperatures on hardiness, respiration, and intensity of rest of dormant peach and apricot buds. M.S. Thesis, Utah State University, Logan, Utah. 92 p.

Hatch, A.H. and D.R. Walker. 1969. Rest intensity of dormant peach and apricot leaf buds as influenced by temperature, cold hardiness and respiration. J. Amer. Soc. Hort. Sci. 94:304-307.

Hatcher, E.S.J. 1959. Auxin relations of the woody shoot. Ann. Bot. 23:409-423.

Hemberg, T. 1949. Growth inhibiting substances in buds of Fraxinus. Physiol. Plant. 2:37-44.

Hemberg, T. 1958. The occurrence of acid inhibitors in resting terminal buds of Fraxinus. Physiol. Plant. 1:610-614.

Hendershott, C.H. and D.R. Walker. 1959a. Identification of a growth inhibitor from extracts of dormant peach flower buds. Science 130:798-800.

Hendershott, C.H. and D.R. Walker. 1959b. Seasonal fluctuations in quantity of growth substances in resting peach flower buds. Proc. Amer. Soc. Hort. Sci. 74:121-129.

Hewett, E.W. and P.F. Wareing. 1973a. Cytokinins in Populus x robusta: Changes during chilling and bud burst. Physiol. Plant. 29:393-399.

Hewett, E.W. and P.F. Wareing. 1973b. Cytokinins in Populus x robusta: Qualitative changes during development. Physiol. Plant. 29:386-389.

Higdon, R.J. 1954. The effects of insufficient chilling on peach varieties in South Carolina in the winter of 1948-1949. Proc. Amer. Soc. Hort. Sci. 55:236-238.

Higgins, B.B., G.P. Walton and J.J. Skinner. 1943. The effect of nitrogen fertilizer on cold injury of peach trees. Georgia Bull. 226:1-27.

Hill, A.G.G. and G.K.G. Campbell. 1949. Prolonged dormancy of deciduous fruit trees in warm climates. Empire J. Exper. Agr. 17:259-264.

Howell, G.S. and S.S. Stackhouse. 1973. The effect of defoliation time on acclimation and dehardening in tart cherry (Prunus cerosus L.) J. Amer. Soc. Hort. Sci. 98:132-136.

Howell, G.S. and C.J. Weiser. 1970a. Fluctuations in the cold resistance of apple twigs during spring dehardening. J. Amer. Soc. Hort. Sci. 95:190-192.

Howell, G.S. and C.J. Weiser. 1970b. The environmental control of cold acclimation in apple. Plant Physiol. 45:390-394.

Irving, R.M. and F.O. Lanphear. 1967. Environmental control of cold hardiness in woody plants. Plant Physiol. 42:1191-1196.

Janick, J. 1974. The apple in Java. HortScience 9:13-15.

Jones, O.P. 1973. Effects of cytokinins in xylem sap from apple trees on apple shoot growth. J. Hort. Sci. 48:181-188.

Jones, O.P. and H.J. Lacey. 1968. Gibberellin-like substances in the transpiration stream of apple and pear trees. J. of Exp. Bot. 19:526-531.

Kaminski, W. and R. Rom. 1974. A possible role of catalase in the rest of peach, Prunus persica, Sieb. and Zucc., flower buds. J. Amer. Soc. Hort. Sci. 99:84-86.

Kawase, M. 1961. Growth substances related to dormancy in Betula. Proc. Amer. Soc. Hort. Sci. 78:532-544.

Kester, D.E. 1969. Pollen effects on chilling requirements of almond and almond-peach hybrid seeds. J. Amer. Soc. Hort. Sci. 94:318-321.

Ketchie, D.O. and C.H. Beeman. 1973. Cold acclimation in 'Red Delicious' apple trees under natural conditions during four winters. J. Amer. Soc. Hort. Sci. 98:257-261.

Krasavtsev, O.A. 1969. Effect of prolonged frost of woody plants. Soviet Plant Physiol. 16:188-194.

Lamb, R.C. 1948. Effect of temperature above and below freezing on the breaking of rest in the Latham raspberry. Proc. Amer. Soc. Hort. Sci. 51:313-315.

Lammerts, W.E. 1941. An evaluation of peach and nectarine varieties in terms of winter chilling requirements and breeding possibilities. Proc. Amer. Soc. Hort. Sci. 39:

Lavender, D.P., G.B. Sweet, J.B. Zaerr and R.K. Hermann. 1973. Spring shoot growth in Douglas-fir may be initiated by gibberellins exported from the roots. Science. 182:838-839.

Lloyd, D.A. and G.A. Couvillon. 1974. Effects of date of defoliation on flower and leaf bud development in the peach Prunus persica (L.) Botsch. J. Amer. Soc. Hort. Sci. 99:514-517.

Luckwill, L.C. and P. Whyte. 1968. Hormones in the xylem sap of apple trees. Soc. Chem. Indust. Monograph 31:87-101.

Marlangeon, R.C. 1969. Efectos del ácido giberelico y de otras drogas sobre la permanencia del follaje verde otonal y la induccion de resistencia a helada en flores de duraznero. Phyton 26:107-111.

McKenzie, J.S., C.J. Weiser and P.H. Li. 1974. Changes in water relations of Cornus stolonifera during cold acclimation. J. Amer. Soc. Hort. Sci. 99:223-228.

Meader, E.M. and M.A. Blake. 1943. Seasonal trend of fruit bud hardiness in peaches. Proc. Amer. Soc. Hort. Sci. 43:91-98.

Mielke, E.A. 1974. Hormonal control of flower bud dormancy in sour cherry (Prunus cerasus L.). Ph.D. Dissertation, Michigan State University, East Lansing, Michigan. 124 p.

Nesmith, W.C. and W.M. Dowler. 1973. Cold hardiness of peach trees as affected by certain cultural practices. HortScience. 8:31.

Nitsch, J.P. 1957a. Growth responses of woody plants to photoperiodic stimuli. Proc. Amer. Soc. Hort. Sci. 70:512-525.

Nitsch, J.P. 1957b. Photoperiodism in woody plants. Proc. Amer. Soc. Hort. Sci. 70:526-544.

Okhuma, K., J.L. Lyon, F.T. Addicott and O.E. Smith. Abscisin II, and abscission accelerating substance from young cotton fruit. Science 142:1592.

Overcash, J.P. and J.A. Campbell. 1955. The effects of intermittent warm and cold periods on breaking the rest period of peach leaf buds. Proc. Amer. Soc. Hort. Sci. 66:87-92.

Painter, J.W. and G.E. Stembridge. 1972. Peach flowering response as related to time of gibberellin application. HortScience. 7:389-390.

Pellett, N.E. 1973. Influence of nitrogen and phosphorus fertility on cold acclimation of roots and stems of two container-grown woody plant species. J. Amer. Soc. Hort. Sci. 98:82-86.

Perry, T.O. and H. Hellmers. 1973. Effects of abscisic acid on growth and dormancy of two races of Red Maple. Bot. Gaz. 134:283-289.

Phillips, I.D.J. and P.F. Wareing. 1958. Studies in dormancy of sycamore. I. Seasonal changes in the growth-substance content of the shoot. J. Exp. Bot. 9:350-364.

Phillips, I.D.J. and P.F. Wareing. 1959. Studies in dormancy of sycamore. II. The effect of daylength on the natural growth-inhibitor content of the shoot. J. Exp. Bot. 10:504-514.

Powell, L.E. and S.D. Seeley. 1974. The metabolism of abscisic acid to a water soluble complex in apple. J. Amer. Soc. Hort. Sci. 99:439-441.

Proebsting, E.L., Jr. 1959. Cold hardiness of Elberta peach fruit buds during four winters. Proc. Amer. Soc. Hort. Sci. 74:144-153.

Proebsting, E.L., Jr. 1961. Cold hardiness of Elberta peach fruit buds as influenced by nitrogen level and cover crops. Proc. Amer. Soc. Hort. Sci. 77:97-106.

Proebsting, E.L., Jr. 1963. The role of air temperatures and bud development in determining hardiness of dormant Elberta peach fruit buds. Proc. Amer. Soc. Hort. Sci. 83:259-269.

Proebsting, E.L., Jr. and H.W. Fogle. 1956. An apparatus and method of analysis for studying fruit bud hardiness. Proc. Amer. Soc. Hort. Sci. 68:6-14.

Proebsting, E.L., Jr. and H.H. Mills. 1964. Gibberellin-induced hardiness responses in Elberta peach flower buds. Proc. Amer. Soc. Hort. Sci. 85:134-140.

Proebsting, E.L., Jr. and H.H. Mills. 1966. A standardized temperature-survival curve for dormant Elberta peach fruit buds. Proc. Amer. Soc. Hort. Sci. 89:85-89.

Proebsting, E.L., Jr. and H.H. Mills. 1972. A comparison of hardiness responses in fruit buds of 'Bing' cherry and 'Elberta' peach. J. Amer. Soc. Hort. Sci. 97:802-806.

Proebsting, E.L., Jr. and H.H. Mills. 1974. Time of gibberellin application determines hardiness response of 'Bing' cherry buds and wood. J. Amer. Soc. Hort. Sci. 99;464-466.

Quamme, H.A. 1974. An exothermic process involved in the freezing injury to flower buds of several Prunus species. J. Amer. Soc. Hort. Sci. 99:315-318.

Ramsay, J. and G.C. Martin. 1970a. Seasonal changes in growth promoters and inhibitors in buds of apricot. J. Amer. Soc. Hort. Sci. 95:569-574.

Ramsay, J. and G.C. Martin. 1970b. Isolation and identification of a growth inhibitor in spur buds of apricot. J. Amer. Soc. Hort. Sci. 95:569-574.

Ramsay, J., G.C. Martin and D.S. Brown. 1970. Determination of the time of onset of rest in spur and shoot buds of apricot. HortScience. 5:270-272.

Reinecke, O.S.H. 1936. Environment and its influence upon deciduous fruit production. J. of Pom. and Hort. Sci. 66:87-92.

Richardson, E.A., S.D. Seeley and D.R. Walker. 1974. A model for estimating the completion of rest for 'Redhaven' and 'Elberta' peach trees. HortScience. 9:331-332.

Richardson, E.A., S.D. Seeley, D.R. Walker, J.L. Anderson and G.L. Ashcroft. 1975. Pheno-climatography of spring peach bud development. HortScience. 10:236-237.

Rigby, B. and M.N. Dana. 1972. Rest period and flower development in cranberry. J. Amer. Soc. Hort. Sci. 97:145-148.

Robinson, P.M., P.F. Wareing and T.H. Thomas. 1963. Dormancy regulators in woody plants. Isolation of the inhibitor varying with photoperiod in Acer pseudoplatanus. Nature 199:875-876.

Samish, R.M. 1954. Dormancy in woody plants. Ann. Rev. Plant Physiol. 5:183-203.

Seeley, E.J. 1975a. Application of instrumental gibberellic acid analysis techniques: With special reference to gibberellic acids in after-ripening peach seeds and developing flower buds. Ph.D. Dissertation, Utah State University, Logan, Utah. 85 p.

Seeley, S.D. 1975b. Personal Communication. Utah State University, Logan, Utah.

Seeley, S.D. and L.E. Powell. 1970. Electron capture-gas chromatography for sensitive assay of abscisic acid. Anal. Biochem. 35:530-533.

Seeley, S.D. and L.E. Powell. 1971. Seasonal changes of abscisic acid in vegetative apple buds. HortScience. 6:286.

Smith, H. and N.P. Kefford. 1964. The chemical regulation of the dormancy phases of bud development. Amer. J. Bot. 51:1002-1012.

Spiers, J.M. and A.D. Draper. 1974. Effect of chilling on bud break in Rabbiteye blueberry. J. Amer. Soc. Hort. Sci. 99:398-399.

Stembridge, G.E. and J.J. LaRue. 1969. The effect of potassium gibberellate on flower bud development in the Redskin peach. J. Amer. Soc. Hort. Sci. 94:492-495.

Tumanov, I.I. 1963. Frost resistance of fruit trees. Fed. Proc. 23:793-795.

Tumanov, I.I. 1967. Physiological mechanism of frost resistance of plants. Soviet Plant Physiol. 14:440-455.

Tumanov. I.I., G.V. Kuzina, L.D. Karnikova and N.N. Khvalin. 1972. Effect of vegetation time on ability of woody plants to increase their frost resistance during the process of hardening. Soviet Plant Physiol. 19:31-39.

Vegis, A. 1964. Dormancy in higher plants. Ann. Rev. Plant Physiol. 15:185-224.

Walker, D.R. and S.D. Seeley. 1974. The rest mechanism in deciduous fruit trees as influenced by plant growth substances. Acta Hort. 34:235-239.

Wareing, P.F. 1950. Growth studies in woody plants. I. Photoperiodism in first year seedlings of Pinus sylvestris. Physiol. Plant. 3:258-276.

Wareing, P.F. 1954. Growth studies in woody species. VI. The locus of photoperiodic perception in relation to dormancy. Physiol. Plant. 7:261-277.

Wareing, P.F. 1956. Photoperiodism in woody plants. Ann. Rev. Plant Physiol. 7:191-214.

Waring, R.H. and B.D. Cleary. 1967. Plant moisture stress: Evaluation by pressure bomb. Science. 155:1248-1254.

Weaver, R.J. 1959. Prolonging dormancy in Vitis vinifera with gibberellin. Nature. 183:1198-1199.

Weaver, G.M., H.O. Jackson and F.D. Stroud. 1968. Assessment of winter hardiness in peach cultivars by electric impedance, scion diameter and artificial freezing studies. Can. J. Plant Sci. 48:37-47.

Weinberger, J.H. 1950a. Chilling requirements of peach varieties. Proc. Amer. Soc. Hort. Sci. 56:122-128.

Weinberger, J.H. 1950b. Prolonged dormancy of peaches. Proc. Amer. Soc. Hort. Sci. 56:129-133.

Weinberger, J.H. 1969. The stimulation of dormant peach buds by a cytokinin. HortScience. 4:125-126.

Weiser, C.J. 1970. Cold resistance and acclimation in woody plants. HortScience. 5:3-10.

Westwood, M.N. and N.E. Chestnut. 1964. Rest period chilling requirement of Bartlett pear as related to Pyrus calleriana and P. Communis rootstocks. Proc. Amer. Soc. Hort. Sci. 84:82-87.

Wilding, D.K., C.J. Weiser and H.M. Pellett. 1973. Temperature and moisture effects on hardening of apple roots. HortScience. 8:53-55.

Wright, S.T.C. 1975. Seasonal changes in the levels of free and bound abscisic acid in black currant (Ribes nigrum) buds and beech (Fagus sylvatica) buds. J. Exp. Bot. 26:161-174.

Yarnell, S.H. 1939. Texas studies of cold requirements of peaches. Proc. Amer. Soc. Hort. Sci. 37:349-353.

Young, L.C.T., J.T. Winneberger and J.P. Bennett. 1974. Growth of resting buds. J. Amer. Soc. Hort. Sci. 99:146-149.

APPENDIX

Table 1. Water potentials (expressed in bars) of Gleason Elberta peach twigs from various treatments during the winter of 1974-75.

Treatment	Sampling Dates						
	9/19/74	9/24/74	10/14/74	11/11/74	12/31/74	2/9/75	3/8/75
Control	-14	-13	-7	-2	-1	-17	-6
1/2 cool and cool greenhouse	-14	-13	-7	-1	-1	-9	-3
1/2 warm greenhouse	-14	-13	--	-6	-29	-28	--
Warm greenhouse	-14	---	-8	-6	-6	-6	-2
Defoliated August 15	-11	-14	-7	--	--	--	--
Defoliated September 17	---	-6	-6	--	--	--	--

Table 2. Cold hardiness of Redhaven (1969) and Gleason Elberta (1975) peach flower buds as related to twig diameter.

			Twig diameter											
			3 mm or less			4-5 mm			6-7 mm			8 mm or greater		
Date	Temp. F	(C)	Alive	Dead	% Alive	Alive	Dead	% Alive	Alive	Dead	% Alive	Alive	Dead	% Alive
December 1969	-7	(-21.4)	204	195	51%	477	187	72%	834	138	86%	192	32	86%
January 6, 1975	-8	(-22)	8	73	9%	28	99	22%	33	110	23%	22	52	30%
	-12	(-24.6)	0	110	0%	0	98	0%	1	120	4%	6	68	8%
January 28, 1975	-6	(-20.7)	123	29	81%	113	18	86%	114	20	85%	37	5	88%
	-9	(-22.6)	34	106	24%	24	70	26%	31	95	25%	21	50	30%

Table 3. Control trees: The daily maximum and minimum temperatures (°F) from September 1, 1974 through April 30, 1975.

Date	Maximum	Minimum	Date	Maximum	Minimum
Sep. 1	89	52	Oct. 7	68	36
2	87	51	8	72	41
3	90	46	9	68	47
4	91	45	10	65	42
5	91	57	11	62	41
6	85	49	12	66	46
7	90	48	13	66	38
8	90	58	14	68	37
9	91	54	15	69	38
10	90	55	16	66	41
11	84	56	17	71	41
12	68	36	18	70	42
13	72	49	19	74	42
14	73	50	20	79	38
15	74	41	21	52	38
16	80	42	22	53	35
17	83	44	23	62	43
18	85	46	24	60	40
19	84	48	25	66	39
20	80	44	26	65	42
21	79	46	27	63	41
22	81	45	28	50	41
23	80	48	29	50	41
24	83	46	30	47	37
25	80	47	31	43	38
26	79	46			
27	60	41	Nov. 1	48	41
28	67	34	2	58	38
29	73	40	3	56	34
30	76	39	4	56	29
			5	49	29
Oct. 1	76	42	6	53	31
2	81	42	7	59	30
3	67	48	8	55	36
4	59	45	9	50	31
5	58	35	10	50	29
6	62	31	11	54	26

Table 3. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Nov. 12	58	30	Dec. 19	39	26
13	60	35	20	37	30
14	59	32	21	44	28
15	56	33	22	26	08
16	57	30	23	26	04
17	58	28	24	27	05
18	42	36	25	31	08
19	50	30	26	34	12
20	59	28	27	36	13
21	59	36	28	39	19
22	53	30	29	28	06
23	45	25	30	28	07
24	54	26	31	33	08
25	51	32			
26	49	27	Jan. 1.	27	05
27	39	26	2	31	07
28	48	23	3	40	06
29	45	21	4	35	19
30	43	20	5	41	32
			6	41	30
Dec. 1	43	21	7	39	14
2	46	23	8	33	12
3	52	27	9	33	12
4	49	39	10	32	10
5	41	30	11	24	-1
6	46	29	12	25	-3
7	44	29	13	31	04
8	40	20	14	37	06
9	38	17	15	37	13
10	36	17	16	38	15
11	34	20	17	43	17
12	43	27	18	48	21
13	31	20	19	48	19
14	34	20	20	50	18
15	36	26	21	41	17
16	42	31	22	36	11
17	38	27	23	42	15
18	39	20	24	44	31

Table 3. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Jan. 25	54	36	Mar. 3	63	33
26	51	25	4	60	40
27	29	19	5	55	40
28	34	11	6	55	40
29	35	07	7	56	40
30	45	18	8	62	41
31	45	29	9	54	36
			10	51	32
Feb. 1	48	30	11	50	30
2	46	30	12	51	31
3	45	30	13	54	30
4	41	20	14	50	32
5	40	18	15	53	29
6	40	12	16	44	29
7	43	31	17	52	24
8	48	35	18	59	35
9	42	33	19	65	44
10	38	31	20	66	43
11	50	29	21	53	30
12	51	32	22	51	32
13	45	34	23	43	29
14	50	31	24	43	29
15	45	27	25	45	38
16	42	25	26	41	23
17	41	23	27	29	13
18	40	24	28	29	12
19	42	24	29	35	11
20	37	15	30	49	25
21	31	12	31	46	34
22	34	09			
23	42	15	Apr. 1	41	21
24	46	19	2	45	16
25	48	23	3	56	28
26	51	24	4	57	36
27	45	32	5	61	40
28	54	34	6	60	34
			7	43	29
Mar. 1	69	35	8	46	27
2	61	40	9	46	30

Table 3. Continued

Date	Maximum	Minimum
Apr. 10	52	35
11	53	36
12	58	40
13	60	29
14	53	30
15	56	41
16	56	33
17	46	32
18	46	32
19	58	32
20	56	39
21	68	34
22	69	45
23	60	39
24	68	32
25	68	32
26	48	23
27	45	31
28	44	31
29	45	31
30	56	29

Table 4. Warm greenhouse, tree entirely enclosed: The daily maximum and minimum temperatures (^{o}F) from September 1, 1974 through April 30, 1975.

Date	Maximum	Minimum	Date	Maximum	Minimum
Sep. 1	89	52	Oct. 7	74	63
2	87	51	8	85	65
3	90	46	9	84	65
4	91	45	10	82	65
5	91	57	11	79	65
6	85	49	12	72	64
7	90	48	13	72	63
8	90	58	14	74	63
9	91	54	15	74	63
10	90	55	16	71	63
11	84	56	17	76	63
12	68	36	18	78	61
13	72	49	19	79	62
14	73	50	20	83	61
15	74	41	21	68	57
16	80	42	22	71	62
17	89	43	23	70	63
18	89	46	24	72	62
19	90	62	25	74	62
20	88	60	26	73	65
21	87	62	27	71	62
22	88	62	28	70	64
23	88	60	29	72	63
24	89	59	30	70	61
25	87	61	31	70	66
26	87	62			
27	68	63	Nov. 1	71	64
28	75	62	2	71	62
29	79	64	3	71	63
30	80	61	4	72	63
			5	73	63
Oct. 1	81	64	6	72	63
2	84	63	7	72	61
3	68	63	8	71	61
4	75	64	9	72	62
5	78	64	10	72	62
6	81	63	11	73	63

Table 4. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Nov. 12	71	63	Dec. 19	71	63
13	70	64	20	72	62
14	72	64	21	72	64
15	72	63	22	71	63
16	73	65	23	70	62
17	74	67	25	71	63
18	74	67	25	71	63
19	72	63	27	72	64
20	73	63	27	72	64
21	73	64	28	72	65
22	72	64	29	73	64
23	73	65	30	72	63
24	72	61	31	75	64
25	73	65			
26	74	64	Jan. 1	72	61
27	72	65	2	76	59
28	72	62	3	71	61
29	72	64	4	69	60
30	72	62	5	71	62
			6	62	78
Dec. 1	72	62	7	66	72
2	72	64	8	63	72
3	73	64	9	61	72
4	75	64	10	70	59
5	72	64	11	70	59
6	72	64	12	76	60
7	72	64	13	76	60
8	74	63	14	78	63
9	72	62	15	62	71
10	72	64	16	71	62
11	73	65	17	79	60
12	72	65	18	70	62
13	73	68	19	86	64
14	73	64	20	86	61
15	73	65	21	81	65
16	72	63	22	81	62
17	72	63	23	81	60
18	72	60	24	63	74

Table 4. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Jan. 25	80	63	Mar. 3	94	34
26	79	65	4	82	37
27	72	60	5	77	41
28	78	61	6	77	41
29	76	62	7	72	40
30	88	64	8	95	39
31	76	62	9	79	39
			10	88	40
Feb. 1	73	65	11	87	37
2	73	60	12	96	37
3	69	63	13	86	37
4	69	34	14	80	38
5	52	35	15	94	40
6	50	36	16	47	37
7	47	36	17	96	38
8	46	35	18	88	40
9	41	35	19	88	41
10	41	36	20	78	46
11	58	36	21	88	47
12	55	39	22	64	42
13	45	34	23	66	42
14	55	37	24	59	42
15	52	38	25	50	40
16	45	35	26	54	44
17	50	36	27	72	41
18	50	35	28	74	43
19	55	35	29	89	45
20	43	34	30	90	44
21	46	33	31	81	46
22	48	28			
23	53	32	Apr. 1	70	45
24	60	36	2	82	45
25	62	38	3	93	46
26	66	38	4	89	55
27	50	37	5	70	55
28	54	37	6	94	55
			7	67	54
Mar. 1	65	33	8	87	51
2	61	42	9	96	49

Table 4. Continued

Date	Maximum	Minimum
Apr. 10	72	53
11	74	54
12	94	44
13	96	44
14	72	44
15	86	42
16	72	42
17	80	43
18	96	47
19	91	42
20	100	52
21	78	50
22	77	48
23	72	46
24	79	46
25	51	45
26	67	45
27	53	45
28	61	44
29	66	44
30	72	44

Table 5. Warm greenhouse, tree $\frac{1}{2}$ enclosed: The maximum and minimum temperatures (^{o}F) from September 1, 1974 through April 30, 1975.

Date	Maximum	Minimum	Date	Maximum	Minimum
Sep. 1	89	52	Oct. 7	78	64
2	87	51	8	81	62
3	90	46	9	80	64
4	91	45	10	78	65
5	91	57	11	71	64
6	85	49	12	75	61
7	90	48	13	74	63
8	90	58	14	75	63
9	91	54	15	75	63
10	90	55	16	75	64
11	84	56	17	78	62
12	68	36	18	78	62
13	72	49	19	79	62
14	73	50	20	83	62
15	74	41	21	71	63
16	80	42	22	73	63
17	87	44	23	71	61
18	87	46	24	76	62
19	86	62	25	76	62
20	89	60	26	76	61
21	88	63	27	76	61
22	88	61	28	72	64
23	89	62	29	69	63
24	90	64	30	69	63
25	89	64	31	70	63
26	88	64			
27	68	63	Nov. 1	71	62
28	79	63	2	74	62
29	82	65	3	73	62
30	83	64	4	70	63
			5	70	60
Oct. 1	83	65	6	70	61
2	84	64	7	74	62
3	69	63	8	70	63
4	70	65	9	71	62
5	73	64	10	72	63
6	76	64	11	72	65

Table 5. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Nov. 12	70	60	Dec. 20	68	63
13	73	62	21	68	64
14	73	63	22	67	63
15	70	63	23	71	60
16	69	62	24	72	61
17	69	64	25	71	61
18	71	65	26	71	63
19	69	63	27	70	62
20	69	62	28	72	62
21	69	60	29	73	61
22	70	63	30	72	61
23	70	63	31	76	30
24	71	64			
25	71	63	Jan. 1	83	31
26	71	65	2	84	30
27	70	64	3	66	30
28	69	62	4	60	33
29	70	63	5	53	34
30	70	63	6	84	33
			7	43	25
Dec. 1	70	65	8	47	25
2	69	64	9	62	26
3	69	62	10	62	25
4	69	64	11	46	25
5	68	61	12	66	24
6	70	66	13	78	25
7	69	63	14	84	18
8	69	61	15	78	17
9	69	62	16	80	17
10	69	65	17	85	33
11	68	62	18	90	25
12	69	65	19	91	25
13	72	61	20	92	22
14	71	61	21	91	20
15	70	63	22	86	15
16	70	64	23	85	19
17	70	63	24	55	34
18	69	62	25	79	35
19	68	63	26	84	28

Table 5. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Jan. 27	50	23	Mar. 4	87	43
28	66	24	5	80	43
29	75	27	6	80	45
30	75	32	7	73	44
31	84	32	8	103	44
			9	97	44
Feb. 1	72	32	10	93	44
2	72	32	11	82	43
3	53	36	12	104	44
4	60	35	13	94	44
5	64	35	14	82	44
6	62	36	15	103	43
7	46	37	16	50	43
8	55	37	17	105	44
9	42	36	18	94	44
10	49	36	19	100	44
11	69	37	20	78	46
12	60	38	21	88	47
13	50	37	22	64	42
14	67	36	23	66	42
15	66	35	24	59	42
16	47	35	25	50	44
17	59	38	26	54	44
18	57	35	27	72	41
19	57	35	28	74	43
20	38	47	29	89	45
21	56	35	30	90	44
22	55	38	31	81	46
23	64	36			
24	68	37	Apr. 1	70	45
25	68	35	2	80	45
26	72	38	3	93	46
27	55	37	4	89	55
28	59	37	5	70	55
29			6	94	55
Mar. 1	85	37	7	67	54
2	83	38	8	87	51
3	101	37	9	96	49

Table 5. Continued

Date	Maximum	Minimum
Apr. 10	72	53
11	74	54
12	94	44
13	96	44
14	72	44
15	86	42
16	72	42
17	80	43
18	96	47
19	91	42
20	100	52
21	78	50
22	77	48
23	72	46
24	79	46
25	51	45
26	67	45
27	53	45
28	61	44
29	66	44
30	72	44

Table 6. Cool greenhouse, trees entirely enclosed: The daily maximum and minimum temperatures (°F) from September 1, 1974 through April 30, 1975.

Date		Maximum	Minimum	Date		Maximum	Minimum
Sep.	1	89	52	Oct.	7	68	36
	2	87	51		8	72	41
	3	90	46		9	68	47
	4	91	45		10	65	42
	5	91	57		11	62	41
	6	85	49		12	66	46
	7	90	48		13	66	38
	8	90	58		14	68	37
	9	91	54		15	69	38
	10	90	55		16	66	41
	11	84	56		17	71	41
	12	68	36		18	70	42
	13	72	49		19	74	42
	14	73	50		20	79	38
	15	74	41		21	52	38
	16	80	42		22	53	35
	17	83	44		23	62	43
	18	85	46		24	60	40
	19	84	48		25	66	39
	20	80	44		26	65	42
	21	79	46		27	63	41
	22	81	45		28	50	41
	23	80	48		29	50	41
	24	83	46		30	47	37
	25	80	47		31	43	38
	26	79	46				
	27	60	41	Nov.	1	48	41
	28	67	34		2	58	38
	29	73	40		3	56	34
	30	76	39		4	56	29
					5	49	29
Oct.	1	76	42		6	53	31
	2	81	42		7	59	30
	3	67	48		8	55	36
	4	59	45		9	50	31
	5	58	35		10	50	29
	6	62	31		11	54	26

Table 6. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Nov. 12	65	33	Dec. 20	41	35
13	78	33	21	43	36
14	66	33	22	44	35
15	71	34	23	54	33
16	71	33	24	70	35
17	71	32	25	62	35
18	48	35	26	69	34
19	67	33	27	52	35
20	65	35	28	51	35
21	60	37	29	48	35
22	50	35	30	51	34
23	57	37	31	70	35
24	62	35			
25	56	35	Jan. 1	69	36
26	56	38	2	71	34
27	49	35	3	48	35
28	57	36	4	57	35
28	55	36	5	49	36
30	52	34	6	78	39
			7	49	39
Dec. 1	55	35	8	49	38
2	56	34	9	49	38
3	58	35	10	56	37
4	49	40	11	48	37
5	44	37	12	63	36
6	60	36	13	72	38
7	56	36	14	74	36
8	54	35	15	73	38
9	54	35	16	73	37
10	48	35	17	76	38
11	42	35	18	80	38
12	52	36	19	82	38
13	41	35	20	83	38
14	40	35	21	83	37
15	40	35	22	78	36
16	47	35	23	62	35
17	41	35	24	56	41
18	44	35	25	72	39
19	44	34	26	70	38

Table 6. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Jan. 27	54	38	Mar. 5	76	41
28	51	35	6	76	42
29	52	30	7	71	41
30	67	38	8	96	40
31	61	38	9	89	38
			10	88	35
Feb. 1	63	39	11	75	36
2	63	41	12	95	36
3	63	43	13	88	36
4	67	35	14	76	36
5	69	36	15	94	37
6	68	34	16	48	38
7	55	31	17	96	36
8	66	36	18	88	39
9	45	35	19	93	41
10	57	36	20	78	46
11	77	35	21	88	47
12	68	35	22	64	42
13	55	37	23	66	42
14	75	36	24	59	42
15	75	35	25	50	40
16	59	38	26	54	44
17	68	35	27	72	41
18	72	36	28	74	43
19	69	37	29	89	45
20	57	35	30	90	44
21	68	36	31	81	46
22	68	30			
23	80	35	Apr. 1	70	45
24	80	35	2	82	45
25	73	35	3	93	46
26	85	35	4	89	55
27	64	37	5	70	55
28	66	35	6	94	55
			7	67	54
Mar. 1	85	36	8	87	51
2	78	39	9	96	49
3	74	35	10	72	53
4	85	36	11	74	54

Table 6. Continued

Date	Maximum	Minimum
Apr. 12	94	44
13	96	44
14	72	44
15	86	42
16	72	42
17	80	43
18	96	47
19	91	42
20	100	52
21	78	50
22	77	48
23	72	46
24	79	46
25	67	45
26	67	45
27	53	45
28	61	44
29	66	44
30	72	44

Table 7. Cool greenhouse, trees ½ enclosed: The daily maximum and minimum temperatures (°F) from September 1, 1974 through April 30, 1975

Date	Maximum	Minimum	Date	Maximum	Minimum
Sep. 1	89	52	Oct. 7	68	36
2	87	51	8	72	41
3	90	46	9	68	47
4	91	45	10	65	42
5	91	57	11	62	41
6	85	49	12	66	46
7	90	48	13	74	39
8	90	58	14	74	38
9	91	54	15	75	38
10	90	55	16	72	40
11	84	56	17	78	40
12	68	36	18	78	40
13	72	49	19	80	40
14	73	50	20	84	44
15	74	41	21	67	37
16	80	42	22	68	35
17	83	44	23	67	44
18	85	46	24	72	41
19	84	48	25	74	40
20	80	44	26	74	42
21	79	46	27	74	42
22	81	45	28	68	41
23	80	48	29	52	42
24	83	46	30	53	39
25	80	47	31	45	39
26	79	46			
27	60	41	Nov. 1	52	41
28	67	34	2	71	38
29	73	40	3	65	35
30	76	39	4	68	34
			5	58	34
Oct. 1	76	42	6	68	34
2	81	42	7	70	33
3	67	48	8	59	36
4	59	45	9	62	34
5	58	35	10	61	33
6	62	31	11	64	33
7					

Table 7. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Nov. 12	61	33	Dec. 22	43	35
13	71	34	23	61	34
14	63	34	24	71	36
15	67	35	25	69	34
17	67	33	26	70	35
18	48	36	27	49	35
19	64	35	28	50	36
20	69	33	29	45	34
21	62	37	30	48	35
22	50	36	31	73	36
23	60	35			
24	67	37	Jan. 1	70	35
25	60	37	2	74	33
26	63	36	3	57	33
27	46	33	4	56	36
28	59	35	5	46	36
29	57	35	6	78	39
30	54	34	7	43	32
			8	44	32
Dec. 1	57	34	9	55	38
2	61	34	10	37	55
3	58	35	11	42	38
4	50	40	12	61	35
5	44	35	13	72	38
6	60	36	14	75	35
7	65	35	15	70	38
8	56	33	16	70	36
9	57	35	17	75	36
10	50	35	18	82	36
11	40	34	19	85	35
12	55	35	20	87	38
13	42	36	21	88	38
14	41	35	22	78	36
15	38	35	23	78	38
16	46	36	24	54	37
17	41	37	25	74	38
18	43	36	26	67	37
19	43	36	27	52	36
20	40	36	28	68	38
21	44	36	29	74	37

Table 7. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Jan. 30	89	38	Mar. 8	94	44
31	82	39	9	81	44
			10	84	44
Feb. 1	73	38	11	75	44
2	65	38	12	88	45
3	63	39	13	79	38
4	56	37	14	72	38
5	81	34	15	89	44
6	77	35	16	49	44
7	53	36	17	86	42
8	64	35	18	82	46
9	44	35	19	86	44
10	55	36	20	78	46
11	86	36	21	88	47
12	67	33	22	64	42
13	50	37	23	66	42
14	78	37	24	59	42
15	80	38	25	50	40
16	72	39	26	54	44
17	78	38	27	72	41
18	78	36	28	74	43
19	66	39	29	89	45
20	52	45	30	90	44
21	64	42	31	81	46
22	67	43			
23	80	44	Apr. 1	70	45
24	83	43	2	82	45
25	78	40	3	93	46
26	80	44	4	89	55
27	60	46	5	70	55
28	64	37	6	94	55
			7	67	54
Mar. 1 93	93	46	8	87	51
2	89	44	9	96	49
3	90	45	10	72	53
4	79	44	11	74	54
5	72	44	12	94	44
6	72	44	13	96	44
7	67	45	14	72	44

Table 7. Continued

Date		Maximum	Minimum
Apr.	15	86	42
	16	72	42
	17	80	43
	18	96	47
	19	91	42
	20	100	52
	21	78	50
	22	77	48
	23	72	46
	24	79	46
	25	67	45
	26	67	45
	27	53	45
	28	61	44
	29	66	44
	30	72	44

Table 8 . Concentration of abscisic acid (nanogram ABA/gram plant material dry weight) in Gleason Elberta peach flower and leaf buds from various treatments during the fall, winter, and spring of 1974-75.

Treatment	Tree	Date											
		8/21	9/12	9/25	10/12	10/30	11/15	12/11	1/3	1/24	2/15	3/25	4/17	5/6
Control flower bud	A	.031	1.0	.391	1.02	.448	.098	.087	.118	.015	.033	.253	--	.166
	B	.04	.424	.156	.864	.448	.249	.310	.198	.100	.039	.075	--	.166
Control leaf bud	A	.031	.179	.058	.241	.266	.112	.063	.126	.164	.056	.154	--	.105
	B	.04	.145	.053	.431	.266	.176	.122	.160	.074	.053	.154	--	.105
Warm greenhouse flower bud	A	.031	1.0	.391	.418	.458	.067	.108	.063	.274	.050	.059	--	.180
	B	.04	.424	.156	.218	.458	.085	.239	.113	.284	.126	.059	--	.180
Warm greenhouse leaf bud	A	.031	.179	.058	.210	.294	.075	.110	.072	.025	.023	.030	--	.134
	B	.04	.145	.053	.230	.294	.027	.051	.075	.050	.018	.030	--	.134
1/2 Warm greenhouse flower bud	A	.031	1.0	.391	.207	.720	.158	.421	.044	.193	.401	.092	1.80	--
	B	.04	.424	.156	.109	.720	.272	.130	.097	.225	.403	.092	1.80	--
1/2 Warm greenhouse leaf bud	A	.031	.179	.058	.103	.107	.104	.125	.080	.066	.105	.051	.212	--
	B	.04	.145	.053	.161	.107	.079	.119	.061	.180	.374	.051	.212	--
Cool greenhouse flower bud	A	.031	1.0	.391	1.02	.448	.701	.380	.389	.120	.141	--	--	--
	B	.04	.424	.156	.864	.448	.503	.152	.388	.163	.071	--	--	--
Cool greenhouse leaf bud	A	.031	.179	.058	.241	.266	.100	.172	.051	.075	.131	--	--	--
	B	.04	.145	.053	.431	.266	.455	.216	.038	.050	.030	--	--	--
Def. August 15 leaf bud	A	.031	.771	.09	.481	.673	.570	.065	.305	--	--	.215	--	.101
	B	.04	.382	.09	.801	.673	.384	.139	.327	--	--	.184	--	.101
Def. Sept. 17 flower bud	A	.031	1.0	.419	.909	.491	.791	.130	.168	--	--	.175	--	.087
	B	.04	.424	.419	.863	.491	.654	.259	.485	--	--	.175	--	.087
Def. Sept. 17 leaf bud	A	.031	.179	.232	.361	.550	.049	.044	.078	--	--	.135	--	.090
	B	.04	.145	.232	.285	.550	.076	.047	.071	--	--	.140	--	.090

Table 9 . Hardiness (T_{50} values) of Gleason Elberta peach flower buds from various treatments during fall, winter, and spring of 1974-75.

Treatment	Sampling Date												
	8/21	9/2	9/12	9/25	10/7	10/16	10/29	11/12	11/20	12/4	12/18	12/30	1/13
Control	17	16	12	6	-1	2	-2	-4	-3	-7	-5	-10	-9
Defoliated August 15	21	20	19	15	4	4	0	-3	-3	-7	-5	-10	--
Defoliated September 17	17	16	12	--	2	5	-1	-3	-3	-7	-5	-10	-9
Extended day-length	17	19	17	7	0	3	-2	-4	-3	-7	-5	-10	-9
GA_3 application August 15	17	16	12	7	6	6	-2	-4	-3	-7	-5	-10	-9
GA_3 application September 19	17	16	12	7	3	3	-3	-4	-3	-7	-5	-10	-9
GA_3 application October 16	17	16	12	6	-1	2	-1	-4	-3	-7	-5	-10	-9
Warm greenhouse	17	16	12	11	10	9	16	14	8	10	10	7	5
1/2 Warm greenhouse	17	16	12	11	10	9	15	10	9	8	9	0	-5
Outside 1/2 warm greenhouse	17	16	12	6	-1	2	-2	-4	-3	-7	-5	-10	-9
Cool greenhouse	17	16	12	6	-1	--	0	--	-3	-1	-1	-2	1
1/2 Cool greenhouse	17	16	12	6	-1	--	0	--	-3	-1	-1	-3	-1
Outside 1/2 cool greenhouse	17	16	12	6	-1	2	-2	-4	-3	-7	-5	-10	-9
Nitrogen application	17	16	12	6	-1	2	-2	-4	-3	-7	-5	-10	-9
Fall pruned trees	17	16	12	6	-1	2	-2	-4	-3	-7	-5	-10	-9

Table 9 continued.

Treatment	Sampling Date 1/21	1/27	2/3	2/11	2/19	3/4	3/11	3/25	4/7	4/21
Control	-8	-7	-6	-4	-6	-6	4	6	10	16
Defoliated August 15	--	--	--	--	--	--	--	--	--	--
Defoliated September 17	-8	-6	-6	-4	-6	-6	4	6	10	16
Extended day-length	-8	-7	-6	-4	-6	-6	4	6	10	16
GA_3 application August 15	-8	-7	-6	-4	-6	-6	4	6	10	16
GA_3 application September 19	-8	-7	-6	-4	-6	-6	4	6	10	16
GA_3 application October 16	-8	-7	-6	-4	-6	-6	4	6	10	16
	-8	-7	-6	-4	-6	-6	4	6	10	16
Warm greenhouse	4	3	1	1	0	0	2	1	6	12
1/2 Warm greenhouse	-6	-5	-4	-6	-6	-7	-2	0	16	26
Outside 1/2 warm greenhouse	-8	-7	-6	-4	-6	-6	4	6	10	16
Cool greenhouse	3	3	9	20	23	26	--	--	--	--
1/2 Cool greenhouse	0	0	5	16	20	26	--	--	--	--
Outisde 1/2 cool greenhouse	-8	-7	-6	-4	-6	-6	4	6	10	16
Nitrogen application	-8	-7	-6	-4	-6	-6	4	6	10	16
Fall pruned trees	-8	-7	-6	-4	-6	-6	4	6	10	16

Table 10. Concentration of GA_3 (ppm) required to break rest in excised Gleason Elberta peach buds from various treatments during the fall, winter, and spring of 1974-75.

Treatment	Tree	Date												
		8/21	9/2	9/12	9/25	10/7	10/16	10/30	11/11	11/20	12/4	12/17	12/23	12/30
Control	A	0	0	5	5	25	25	50	100	50	25	25	5	0
	B	0	0	5	5	25	25	50	100	50	25	25	5	0
	C	0	0	5	5	25	25	50	50	50	25	5	5	0
August 15 GA_3 application	A	0	0	5	5	25	25	50	100	50	25	25	5	5
	B	0	0	5	5	25	25	50	100	50	25	25	5	5
	C	0	0	5	5	25	25	50	50	50	25	25	5	5
September 19 GA_3 application	A	0	0	5	5	5	25	50	100	50	25	25	5	0
	B	0	0	5	5	25	25	50	50	50	25	5	0	0
	C	0	0	5	5	25	25	50	100	50	25	5	0	
Defoliated August 15	A	0	0	0	0	5	5	25	25	25	5	5	0	
	B	0	0	0	0	5	5	25	25	25	5	5	0	
Defoliated September 17	A	0	0	5	5	5	25	25	25	5	5	0		
	B	0	0	5	5	5	25	25	25	5	5	0		
Warm greenhouse	A	0	0	5	5	5	5	25	25	50	50	25	25	25
	B	0	0	5	5	5	5	25	25	50	50	25	25	25
1/2 Warm greenhouse	A	0	0	5	5	25	25	50	50	50	100	50	25	5
	B	0	0	5	5	25	25	50	50	50	100	50	25	5
Cool greenhouse	A	0	0	5	5	25	25	50	50	100	100	50	25	5
	B	0	0	5	5	25	25	50	50	100	100	50	25	5
1/2 Cool greenhouse	A	0	0	5	5	25	25	50	50	100	100	50	25	5
	B	0	0	5	5	25	25	50	50	100	100	50	25	5

Table 10 continued.

Treatment	Tree	Date											
		1/6	1/13	1/21	1/27	2/3	2/11	2/19	3/4	3/11	3/25	4/7	4/22
Control	A												
	B												
	C												
August 15 GA_3 application	A	5	0										
	B	5	0										
	C	0	0										
September 19 GA_3 application	A												
	B												
	C												
Defoliated August 15	A												
	B												
Defoliated September 17	A												
	B												
Warm greenhouse	A	25	50	50	50	50	100	100	200	200	100	50	0
	B	25	50	50	50	50	100	100	200	200	100	50	0
1/2 Warm greenhouse	A	25	5	25	5	25	25	5	0				
	B	25	5	25	5	25	25	5	0				
Cool greenhouse	A	0											
	B	0											
1/2 Cool greenhouse	A	0											
	B	0											

VITA

Ronald H. Walser

Candidate for the Degree of

Doctor of Philosophy

Dissertation: Influence of Environment and Cultural Practices on Rest, Cold Hardiness, and Abscisic Acid Concentration of Gleason Elberta Peach Buds.

Major Field: Horticulture

Biographical Information:

Personal Data: Born at Colonia Juarez, Chihuahua, Mexico, January 24, 1944, son of John Floyd and Annie Jorgenson Walser; married Constance Jensen Walser December 16, 1967; four daughters -- Loni Ann, Shelly Jean, Shannon Alicia, and Brook Diane.

Education: Attended elementary school in Colonia Juarez, Chihuahua; graduated from Academia Juarez High School in 1962; received the Bachelor of Science degree from Brigham Young University, with a major in Horticulture, in 1968.

Professional Experience: 1974 to present, research assistant, Plant Science Department, Utah State University, 1971-1974, manager of greenhouse production at 20th Century Farms, Inc.; 1968-1971, teaching assistant and NDEA fellow, Plant Science Department, Utah State University; Summers of 1966-67-68, biological aid, Utah State Fish and Game.