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THE EFFECT OF CHANGING TEMPERATURES ON HARDINESS,
RESPIRATION, AND INTENSITY OF REST OF
DORMANT PEACH AND APRICOT BUDS

by

Anthony H. Hatch

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Plant Science

UTAH STATE UNIVERSITY
Logan, Utah

1967

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Anthony H. Hatch
Anthony Herman Hatch

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ABSTRACT

The Effect of Changing Temperatures on Hardiness,
Respiration, and Intensity of Rest of
Dormant Peach and Apricot Buds

by

Anthony H. Hatch, Master of Science
Utah State University, 1967

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

Studies were conducted to better understand the influence of temperature on the rest period of dormant peach and apricot buds. Gleason Elberta peach and Chinese apricot trees in the field at Howell Experiment Station in Ogden were used to evaluate rest intensity, respiration, and cold hardiness in relation to temperature.

A rest intensity curve was obtained for both species using various concentrations of gibberellic acid. It was found that temperature had no direct effect on the depth of rest and that the depth of rest had no measurable influence on respiration and cold hardiness.

Respiration of flower and leaf buds was not affected by temperature until after the rest period was over and the temperature rose above 40 F. However, cold hardiness was directly affected by temperature during the rest period. As the temperatures dropped the cold hardiness increased in both species.

Lovell peach seedlings were placed in 5 gallon containers and placed in controlled temperature chambers. At 3 different periods, 3 trees were removed from 9 different temperature treatments. It was found that 40 F was generally more effective in breaking rest than was 32 F. Light did not seem to affect the rest period significantly.

(102 pages)

INTRODUCTION

Temperature is one of the biggest problems facing the deciduous fruit grower today. Yearly, deciduous fruit growers, the world-over, are faced with crop failures because of temperature. The temperature may not be sufficiently cold during the winter to break the rest period of trees, or spring frosts may destroy the blossoms. In the southern states very often losses are due to early warming trends that cause bloom before the danger of frost is past. In some areas of the world, orchard heating has proven effective in controlling frosts while in other areas it can not be done because of winds, the lack of a good temperature inversion, poor equipment, etc. Although some areas can be heated effectively, the expense is so great sometimes that it is inadvisable to do so. A fruit grower may save his crop one night but on the following night, he may lose everything. If the rest period could be controlled such that it could be extended and/or broken at any given time, regardless of temperature, crop losses would be minimized and the fruit grower would be insured a crop.

The control of rest seems to be an inviting field of study. In recent years, several investigators have and are attempting to control rest. Some success has been achieved in breaking rest or inducing growth by means of chemicals

when the trees have not received the proper amount of chilling (Donoho and Walker, 1957; Smith and Kefford, 1964; and Weinberger, 1939). However, very little success has been achieved in applying an inhibitor to prolong dormancy beyond the danger of spring frosts (White, 1957). Several inhibitors have been isolated but so far the efforts to link them with the rest period have not been successful.

Although extensive chemical analyses of resting buds of deciduous fruit trees have been made, no one has yet attempted, as far as can be determined, to correlate O_2 uptake or respiration with other physiological phenomena that occurs during winter months.

Objective

The purpose of this work was to study the activity of the rest phenomena in buds under field and controlled temperature conditions. It is hoped that a clearer understanding of this phenomena would be obtained.

The activity of the rest phenomena of peach and apricot buds in the field was determined by measuring respiration, hardness, and rest intensity. The daily maximum and minimum temperatures were correlated with these measurements.

The rest period activity of peach seedlings when held under varying controlled temperature conditions and at different lengths of storage periods was determined by respiration and growth measurements. The final results of both experiments were compared for similarities.

REVIEW OF LITERATURE

Presence of rest in trees

The rest period is very essential for the survival of most plants and seeds. It hardens plants and seeds against cold winter temperatures. Otherwise, they would be killed by the cold. Some trees and seeds, especially deciduous- which is emphasized in this review, suspend visible growth until a certain amount of chilling has been acquired before their growth resumes. Why this happens is not clearly understood and has been the objective of exhaustive research.

There seems to be some discrepancy in defining the rest period in the literature. Chandler (1957), a horticulturist, defines rest as "a condition in the part of the tree above the ground in which growth is inhibited or prevented until the tree has been exposed to its required number of hours at temperatures of about 45 F or lower." Samish (1954), a physiologist who agrees with Chandler (1957), says its a period when the plant will not grow even though environmental conditions are favorable due to internal conditions. Bonner and Galston (1952), physiologists, call this period of no visible growth, dormancy. They claim that dormancy is a temporary suspension of growth in healthy plant tissues or organs, even under conditions in which these tissues or organs are furnished with all of the chemical and physical prerequisites ordinarily considered as necessary for growth.

They do not differentiate between dormancy brought about by external factors and what horticulturists call rest which are brought about by internal conditions. Samish (1954) says that dormancy is the period when there is no visible growth. He divides the dormant period into two parts: (1) quiescence which is dormancy due to external conditions and (2) rest period which is due to internal conditions. However, when a plant is in its rest period it continues to grow at a reduced rate (Chandler, 1957; and Seeley, 1967). The morphological activity is very slow until the rest period is broken. The term "rest" for this reason, may be misleading.

Dormancy of lateral buds does not always signify that the bud is in rest. Many lateral buds do not develop even after rest in the tree has been broken and the external conditions are favorable for growth. This type of bud is considered to be a latent bud which is prevented from growing due to apical dominance.

Correlated inhibition (Samish, 1954) is created when an inhibiting factor is produced in a terminal bud or adjacent leaf that causes a bud to remain dormant. Correlated inhibition usually can be overcome by removing the terminal bud or an adjacent leaf.

There seems to be five steps involved when one speaks of a bud entering rest. First, quiescence occurs which is brought on by shorter days, cold, heat, drought, or other conditions unfavorable to growth. This is also known as

"early rest" or "pre-dormancy". Here the trees have lost their ability to grow. Second, "preliminary rest", "relative" or "conditional dormancy" occurs. At this stage growth will only occur within a certain range of external conditions. The third stage may be considered as "main rest", "middle rest", or "mid-rest". At this stage the internal conditions are such that no visible growth will occur until adequate chilling has been achieved. "After-rest" is the fourth stage and is very similar to "preliminary rest". The final stage is another stage of favorable growth (Samish, 1954 and Vegis, 1964).

The time of inception of the rest period seems to be at the time when the terminal bud is set. This occurs at the end of July or early August (Walker, personal communication). There appears to be no relation between presence or absence of leaves on the trees and the rest period. As fruit buds begin to develop in June, or early July, and reach their greatest growth during August and September, they remain in a dormant condition during late summer and fall and resume growth normally the following spring. Their rest-period apparently extends from the time of maturity of the buds until sometime after dormancy begins (Hodgson, 1923). Seeley's (1967) work, however, indicates that there is normal morphological development until December and early January when very cold temperatures occur.

Location of rest

The location of the influence of rest is another controversial aspect of rest. Chandler (1957) proposes a theory that rest is throughout the above-ground portion of the tree. Roots do not have a rest period so he excluded the roots as a source. Bonner and Galston (1952), Denney and Stanton (1928), and Westwood and Chestnut (1964) support the idea that it is in the buds. Chandler (1957) bases his premise on field observations and a grafting experiment. He observed that shoots from buds which had not received adequate chilling remained short through the entire summer. These branchlets were on trees in good soil and had made strong growth the previous year. With grafting experiments of peaches he showed that scions not in rest grew for only a short period when placed on stock with the rest influence still present. When scions with their rest period completed, were placed on stock with their rest broken, trees continued to grow and grew for an adequate period afterward. In comparing the two results he contended that if the rest influence was in the peach buds they should continue to grow once rest had been broken even when grafted on stems still in rest.

Bonner and Galston (1952) defend their premise stating 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 state

that these results indicate that the response of buds to low temperatures is not controlled by hormones. The breaking of dormancy does not seem to translocate from one section of the tree to another.

Denny and Stanton (1928) broke the rest of one of two adjacent lilac buds by means of ethylene chlorhydrin. The treated bud initiated growth while the adjacent bud remained dormant. In this manner they justify their hypothesis.

Westwood and Chestnut (1964) stated that "the rest influence of Pyrus seemed to reside primarily in the buds, but some translocation of the influence appeared to take place." They based this statement on work they performed on P. calleryana and Bartlett pears. Both varieties were treated with different number of hours of temperature 38-40 F and then scions or buds were interchanged by grafting or budding.

External factors affecting rest

There seems to be no single factor that alone influences rest. When speaking of external factors that affect rest, there are three that are commonly mentioned: temperature, photoperiod, and cultural practices.

The photoperiod exerts its greatest influence at the beginning or onset of rest. Long photoperiods can delay defoliation and the onset of dormancy even though the days are cold. As a general rule, long photoperiods cannot break rest after the leaves have fallen. Short days stimulate

abscission layer formation but cold temperatures are required to break rest (Bonner and Galston, 1952).

Some plants, such as the black currant, can combine photoperiod and low temperatures to break rest. There are only a few species like this and are an exception to the general rule. Those few that respond to photoperiodism generally are those that have not lost their foliage (Leopold, 1964). Hoyle (1960), using black currants, demonstrated that rest broke as readily from short-day as long-day treatment when adequate chilling had been achieved. When adequate chilling had not been achieved the long-day treatment was effective in breaking rest but the short-day was not. The long-day was an effective substitute for chilling in this case.

Although photoperiodism does not seem to be important in breaking the rest of buds it is often required for breaking dormancy in seeds (Vegis, 1964). Such is the case with red light required for breaking rest of lettuce seeds (Machlis and Torrey, 1956).

Excessive water, fertilizer and pruning which causes excessive growth during the summer often delays blooming the following spring (Chandler, 1957). Chandler and Tuffs (1933) reported that any time after there has been chilling weather enough 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.

Temperature seems to exert the greatest influence in breaking rest. Deciduous fruit trees require a certain number of accumulated hours of chilling before rest is completely broken. Chilling occurs at temperatures of about 45 F or lower (Chandler, 1957). The length of chilling period required depends on fruit species and varieties and ranges approximately from 400 to 1500 hours (Chandler et al., 1937).

Overcash and Campbell (1955) demonstrated that continuous chilling is more effective in breaking rest than intermittent warm and cold periods. In their experiment they found that continuous chilling at 39 F broke the rest period of more leaf buds of Elberta peach trees than alternating warm and cold periods even though the total hours of chilling temperature were the same. Periods of intermittent high temperatures counteract some of the cumulative chilling influence of low temperatures. It required 750 hours of continuous chilling at 39 F to break rest while 950 hours at 39 F were required with intermittent temperatures. There was no work to be found as to the effect of temperatures under 39 F on the rest period.

Inadequate chilling results in the abscission of fruit buds (Brooks and Philp, 1941), and little or no growth from leaf buds (Chandler, 1957). Brooks and Philp (1941) observed some peach and nectarine varieties in northern California during the extraordinary warm winter of 1940-41. The entire season had less than 1000 hours of accumulated temperatures

of 45 F or below. They observed that the climatic factor or factors, that evidently enter into a tree dropping its flower buds, had been operating during the 1940-41 season by January 10 or earlier. It evidently occurred during the rest period.

The leafy shoots that arise from inadequately chilled vegetative buds are usually so few that they do not support adequate tree growth nor shade to protect the limbs from sunscald. This weakens the tree for the coming winter and there are not enough leafy shoots to provide a good crop the following year (Chandler, 1957).

Inadequate chilling may also be beneficial. It may prevent blossoming to occur in a sudden warm period and also delay blossoming in the spring until the danger of spring frosts are gone and favorable pollinating weather is present (Chandler, 1957).

Internal factors affecting rest

There has been a lot of research done in an attempt to find a chemical explanation of the rest period. A completely acceptable explanation has not been found. Investigations seem to be centered around four divisions: enzymes, auxins, inhibitors, and auxin-inhibitor balance.

A generally accepted theory held 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 action to start anew (Samish, 1954). Chandler (1957) favored the idea 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. He did not think that the accumulation of enzymes was the factor that broke rest. Gardner (1929), in a study of enzymes in pear shoots, found neither inactivation of enzymes in the fall nor reactivation in the spring. Other research evidences that have been presented seem to do away with the theory that enzymes affect rest (Samish, 1954).

Studies of "free" auxin content, of buds during the rest period showed that in July the auxin content gradually diminished and was reversed during rest-breaking chilling (Samish, 1954). This would indicate that "free" auxin may have some influence on rest. Bennett and Skoog (1938) could not find diffusible heteroauxin in resting pear buds and showed that the auxin gradually increased in the cold room while rest was diminishing. Research results seem to indicate that auxin is required for the breaking of rest but they do not exclude the possibility that the cell was previously conditioned by some other process. There is no conclusive evidence that the lack of auxin is the cause of rest.

Eggert (1953) found that the general trend of "free" or diffusible auxin that he obtained from apple spur buds agreed favorably with the results of earlier workers.

However, he found that the total auxin concentration of buds increased as they entered into their rest period. He proposed the idea that a high total-auxin concentration may inhibit the growth of the bud eventhough environmental conditions are favorable. He claims that when the total auxin of buds approach a critical level growth ceases and enters rest. When the concentration drops below the critical level then growth is again initiated and the plant is then out of rest. The young leaves in the spring produce auxin but because of ideal growth conditions, auxin does not accumulate. As the days get warmer and a moisture stress is imposed on the plants growth diminishes while the auxin level increases. This accumulation of auxin eventually reaches the critical level and the plant enters rest. This work proposes that total auxin is the controlling factor of plant growth.

Within the past decade a lot of the research performed has been shifted to growth-inhibiting substances as a possible explanation of trees in and out of rest. This area seems to still be promising but still an inhibitor has not been linked directly to the rest mechanism. Luckwill (1952) found that a growth-inhibiting chemical in mature apple seeds gradually disappeared prior to seed germinating and was replaced by a growth-promoting substance.

Hendershott and Walker (1959) identified 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 rather high during the months of December, January, and February. Its concentration decreased again during March and disappeared completely from the buds about 2 weeks before bloom.

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

El-Mansy (1966) also found that naringenin was at its maximum concentration in late summer and mid winter while it was at its minimum just prior to bloom in Elberta peach flower buds. Chinese apricot flower buds seemed to have no naringenin throughout the season. He found an increase in sucrose, glucose, fructose, pyruvic acid, malic acid, and most of the amino acids prior to or just after the completion of rest in the peach flower buds. Apricot flower buds had a similar trend except that pyruvic, malic, fumaric and citric acids showed a marked increase just prior to bloom. Chao (1966) recorded similar chemical changes in seeds receiving gibberellic acid treatments and 45 F treatment. There was a rapid breakdown of proteins and lipid materials, release of a large amount of total amino acids and sugars, and rapid degradation of starch. These changes occurred more rapidly in the gibberellic acid treatment and may account for the faster germination. The chemical changes in seeds held at 32 F and 72 F indicate that the reserve protein, starch, and lipid materials were not mobilized sufficiently

rapid to meet the requirements of active cell division and enlargement.

Another theory which has been proposed as a rest controlling mechanism is a combination of the previous. Bloomaert (1959) reported that a growth-inhibitor in peach buds decreased during chilling while auxin increased near the end of chilling. He proposed the theory that the rest period was controlled by an auxin/inhibitor balance.

Flemion and de Silva (1960) extracted both growth-promoting and growth-inhibiting substances from dormant peach seeds by paper chromatographic separation. They were unable to establish a correlation between these growth substances and seed germination.

Peach seeds that were chilled at 32 F and 45 F showed a decrease in growth-inhibitors and an increase in growth-promoters as the rest requirement was satisfied when compared to seeds stored at 72 F (Liao, 1966).

If auxins and inhibitors are the internal factors affecting rest, the correlation still needs to be discovered.

Tuan and Bonner (1964) proposes the hypothesis that the dormant cell has its genetic material completely, or nearly completely, repressed. They showed that dormant potato buds synthesized RNA at a rate which was exceedingly small compared to growing buds. It was found that the production of RNA by nondormant potato buds is inhibited by actinomycin D pretreatment. This indicates that RNA production by growing buds is DNA dependent.

They concluded that the genetic material of the buds of dormant potato tubers is largely in a repressed state, and that the breaking of dormancy is accompanied by derepression of the genetic material.

This hypothesis seems to be a very interesting and inviting area to study to further understand the rest period phenomena.

Rest intensity of buds during the rest period

Donoho and Walker (1957) found that the efficiency of gibberellic acid in breaking rest depends upon the concentration and time of application. They concluded from this evidence that rest may be more intense during some periods than others. Dinitroaresol (Samish, 1954) and dinitro-o-cyclohexylphenol (Chandler, 1957), are a couple of other chemicals that have been used in breaking rest. The effectiveness of these chemicals, as is the case with GA, seems to be dependent on the number of hours of chilling the trees have had prior to the chemical application.

Yazdaniha (1964) applied GA to trees in the orchard and showed that rest could be broken before rest "intensified." In his experiment, the trees treated with 500 ppm GA on September 8 responded and initiated growth. However, the same treatment repeated on September 22 did not cause an initiation of growth. He concluded that the trees had entered into a deeper rest since external environmental conditions were favorable for growth.

Cold resistance

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. The study of cold resistance (hardiness) in horticultural plants has been studied for over 200 years and many papers have been published on the subject. Cold resistance is the ability of plant cells to survive ice formation in the tissues of which they are apart (Chandler, 1954).

Rest is accompanied by certain cytological phenomena within cells of certain tissues such as the cambium tissue. The cells shrink and the protoplasm develops an opaque appearance and gel-like properties. The withdrawal of the cell membrane from the cell wall ruptures the plasmodesmata. The protoplast becomes surrounded by a visible lipid layer which prevents drying out and reduces water and solute uptake. The increase of osmotic concentration increases the hardiness of the cell. This cytological phenomena seems to be governed by the genetics of a plant and varies accordingly (Samish, 1954). In 1934, Cullinan and Weinberger experimentally showed that changes in hardiness took place during the dormant season. Meader and Blake, 1943, published the first paper showing a close relationship between peach fruit bud hardiness and environmental temperatures. They showed that the percentage of live fruit buds increased or decreased with changes in air temperature.

Variations in hardiness are caused by development of the buds and the environmental temperature. Donoho and Walker (1960) found that peach trees treated with 40 F were more cold resistant than trees held at 65 F. They also found that when twigs from trees held at 65 F continuously and then moved to 40 F 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 cold hardiness never did reach the level of the trees that were held continuously at 40 F. The trees that had continuous 40 F and then moved to 65 F had just the opposite results. Therefore, as the temperature begins to warm in the spring, there is a gradual loss in cold resistance as the buds swell and approach first pink. About a week before first pink there is a sudden hardiness loss which is followed by relatively constant readings through bloom and developing small fruit. Increases in hardiness during the dormant period are always associated with decreasing temperatures, and conversely, losses of hardiness with increasing temperatures (Proebsting, 1959). Loss of hardiness of peach fruit buds is related to their morphological development during the pre-bloom and bloom period (Proebsting and Mills, 1961).

Proebsting in 1963 introduced a minimum hardiness level concept and defined it as the level above which peach fruit bud hardiness does not rise in spite of warmer weather. In other words, if a warming trend occurred in mid-winter, the cold hardiness would not rise above the minimum hardiness

level. This sometimes plays an important role for orchards in the southern states. This value seems to be constant until the end of the rest period, then increases gradually as temperatures rise in the spring and buds develop. This value varies from season to season.

Proebsting (1963) also states that hardening beyond the minimum hardiness level occurs during periods when the temperature does not rise above 28 to 30 F. The duration of cold is more important than the degree of cold. If the temperature rises above 28 to 30 F, 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.

Rest intensity measurement

The author has been unable to find in the literature an established procedure for determining rest intensity. As has been mentioned, chemicals have been used to break rest as rest was coming to a close. None of these chemicals have been used at intervals during the entire rest period to see if rest does, in fact, "intensify."

Cold resistance measurement

The fluctuations and variability of winter temperatures in the field makes it difficult to evaluate cold hardiness without controlled temperature conditions. Refrigerated

cabinets of various types have been used in the past. One of the earliest ones was built in 1920. It had a freezing chamber cooled by an ice-salt mixture and was warmed by electric heating coils. The temperature was controlled by the heating coils that were connected to a mercury-platinum thermostat regulated mechanically by a clock-driven device (Potter, 1920).

Smith and Potter (1937) redesigned the 1920 model with modern materials. This apparatus gave better temperature control but was quite complex for general use.

Cullinan and Weinberger (1934) placed dormant peach stems in a freezer and the temperature was allowed to fall to a predetermined minimum temperature. No attempt was made to control the rate of fall so it was difficult for them to duplicate their results a day or two later. This same type of system was later used but the rate of fall was controlled manually. The temperature was lowered in stages (Knowlton, 1936).

Another method used was placing peach buds in test tubes and suspending them in an antifreeze bath consisting of 50 percent alcohol in water (Meader, Davidson, and Blake, 1945).

Chaplin (1948) by-passed the antifreeze bath and placed the peach shoots in a wire rack in the freezing chamber. A fan was used to reduce air stratification.

Proebsting and Fogle (1956) modified a home freezer so that they could obtain a uniform rate of fall. An inverse

tension operated thermostat was placed through the wall into the interior storage space. The thermostat was driven by an electric clock motor drive. The operation was controlled by settings of a five-minute interval timer. The drop was about 1.7 F per hour. This modification gave good temperature control and was inexpensive. 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 before the temperature increases or decreases.

There are 3 methods that are generally used for determining hardiness. They are the electrical conductance method, the T_{50} method, and resistance measurements.

Chaplin (1948) introduced the T_{50} concept which is the temperature required to kill 50 percent of the fruit buds. A similar method is used by toxicologists in reporting the LD_{50} of insecticides. LD_{50} is the lethal dosage of an insecticide at which 50 percent of an insect population is killed. This is one of the generally accepted methods for reporting hardiness data. 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 of $T_{50}+1$ or $T_{50}-1$ and so on.

The sigmoid curve brings out two interesting observations. Lowering the temperature an additional 2 F decreased survival 10%. It was noted that survivors of T_{50} minus 3 F or colder were usually under developed buds and although they were still alive they had not developed properly and would not be good buds for production. Because of this observation Proebsting and Mills are of the opinion that the slope of the curve should not decrease to match the points of the survivors below $T_{50}+2$ but should continue to drop at the same rate as it was when $T_{50}+2$ was reached. The second observation is that most buds survive temperatures above $T_{50}+3$. The curve does not follow a smooth sigmoid form to a 100% survival but rather levels off with a 5 to 10% mortality. The reason for this is unknown. The authors of the article indicate this curve may be useful in assessing the possibilities of further damage on succeeding nights after the field data has been collected from the first night of a freeze period.

Emmert and Howlett (1953) and Wilner (1955) used the electrolytic method for determining winter hardiness of woody plants. Emmert and Howlett (1953) worked with 55 apple

varieties while Wilner (1955) used some apple and some shade trees. A given weight of stem sections of the trees were subjected to a given rate of temperature drop until they reached the desired temperature. The stem sections were held at the desired temperature for 6 hours and then the temperature increased to room temperature at a specified rate. The stem sections were then placed in a water bath for 24 hours after which the electrical conductivity was measured. The amount of electrolytes retained by living cells was determined by subtracting the initial and final readings. From these values the percent diffusion of electrolytes due to low temperature injury of the tissue was calculated and this figure was used as the criterion for hardness of the tissue.

Respiration measurement

The measurement of respiratory gas exchange may be made in many different ways. The simplest and perhaps the most straight forward measurement is that of gas analyses. The tissue to be analyzed is placed in a closed container in an atmosphere of known volume and composition. Respiration is allowed to continue for a given period of time. The O_2 is used up and is replaced by CO_2 . A sample of gas from the container is then transferred to a gas analysis apparatus where the concentrations of O_2 and CO_2 are determined directly. Comparing the concentrations of O_2 and CO_2 to the original gas composition, the amount of CO_2 evolved and O_2 consumed during respiration is calculated.

Most measurements of gas exchange during respiration are now being made by manometric methods. The tissue that is to be observed is placed in a closed container connected to a manometer. As O_2 is used up and CO_2 evolved, a vacuum can be created by removing the CO_2 with KOH. The decrease of pressure in the flask is measured by sensitive manometers with the liquid level increasing or decreasing depending on the setup.

Another method of measuring respiration is by allowing the CO_2 being evolved to pass through KOH for a given period of time. The KOH solution is then titrated to determine how much CO_2 has been absorbed by the KOH (Bonner and Galston, 1952).

Pollock (1960) studied the respiratory changes in leaf primordia of maple buds during chilling and compared the results with leaf primordia that was not chilled. The results obtained show the normal rate of oxygen uptake rises slowly as a result of chilling, while that of buds from unchilled trees declined during the same period.

MATERIALS AND METHODS

Selection of sampling material

This research project consisted of two phases: controlled and field temperature studies. Gleason Elberta peach and Chinese apricot trees that were 10 and 15 years-old respectively growing at the Utah State University Howell Experiment Station at North Ogden, Utah, were selected for the field study phase. Lovell peach seedlings that were 3 years-old and also growing at the same experiment station were selected for the controlled temperature phase.

Controlled temperature study

A total of 87 Lovell peach seedlings were dug October 25-29, 1966 and placed in 5 gallon buckets. The trees were then transported to Logan for treatment in controlled temperature chambers. The trees had received a total of 198 hours of temperatures 45 F or less before they were removed from the field. It was necessary to remove the trees from the field at this early date because the temperatures were dropping below 45 F and the trees were accumulating chilling hours.

The buckets containing the trees were placed in polyethylene bags and the tops of the polyethylene bags were tied around the trunk of the trees to avoid the soil from emitting undesirable odors in the cold temperature rooms. Trees

that were to receive intermittent temperatures were placed on carts large enough to hold 9 trees as is shown in Figure 1. There were 8 trees placed on the platform and one was placed on top and in the middle of the other cans.

The 3 cooling units located in the basement of the Agricultural Science Building at Utah State University were chosen for the experiment. One room was maintained at 40 F, another at 32 F, and the third at 40 F which also had 4 300-watt incadescent lamps that were on continuously. There were no lights on in the first 2 rooms. There were 2 lamps on each the north and south walls. Each lamp produced approximately 180 foot-candles at a 3-foot distance. There was a total of 50 foot-candles of light intensity where the trees were in the center of the room. All refrigerated units contained circulating fans to keep the temperature uniform.

There were nine treatments used in this study with nine trees receiving each temperature treatment. Six additional trees were placed in the greenhouse to serve as untreated controls. The temperatures used were as follows:

1. Continuous 40 F
2. Continuous 32 F
3. Continuous 40 F plus 24 hours of light
4. 16 hours of 40 F plus 8 hours of 32 F
5. 16 hours of 40 F plus 8 hours of light at 40 F
6. 16 hours of 32 F plus 8 hours of 40 F
7. 16 hours of 32 F plus 8 hours of light at 40 F
8. 16 hours of light at 40 F plus 8 hours of 40 F

Figure 1. General tree appearance and method of transporting trees from one temperature chamber to another. (The insulation was not needed and was removed before the experiment commenced because freezing temperatures were not used as was planned earlier.)



9. 16 hours of light at 40 F plus 8 hours of 32 F

After 800, 968, and 1240 hours of chilling had occurred, 3 trees were removed respectively from each treatment and placed in the greenhouse. Growth and fresh and dry weight measurements were made on each tree with the average of the 3 trees being reported. Respiration determinations were made only on flower buds because of the small size of the trees. A respiration measurement was made on each treatment 2, 7, and 10 days after the trees had been removed to the greenhouse. The resulting data were used in evaluating the effectiveness of the various cold and length of storage treatments on breaking the rest period.

A Gilson Differential Respirometer was used to determine the respiration rate of the buds used in this experiment. Respiration measurements for each treatment were run in duplicate.

Each respirometer flask contained 2 ml of nutrient solution and 0.2 ml of 20% KOH in the well. A wick was made from filter paper and placed in the well to increase the surface area of the KOH. A total of 20 buds from freshly cut twigs, were cut in half with a razor blade and placed in a flask. The purpose for cutting the buds was to allow free entry of oxygen into the interior cells of the bud. The respirometer flasks were attached to the respirometer and lowered into a constant 25 C water bath. The buds were allowed to equilibrate for 20 minutes before the test was begun. Readings were taken every 10 minutes for an hour,

at which time the experiment was terminated. From preliminary experiments it was found that the rate of respiration during the first hour was all that was needed to determine the constant rate of respiration of the buds.

At the completion of the test the buds were washed from each respirometer flask into a funnel containing filter paper. The buds from each replication were then placed in separate aluminum weighing pans and placed in an oven at 96 F for about 52 hours. The aluminum pans were then removed and the dry weight of the buds were determined. The l of oxygen consumed was determined on both a dry weight and per bud basis.

To convert the dial readings to standard gas conditions the following formula was used.

$$\text{Multiplying factor} = \frac{(273)(P_b - 3 - P_w)}{(t + 273)(760)}$$

P_b was the operating pressure or barometric pressure and P_w was the water vapor pressure.

The average fresh and dry weights of the flower buds from the peach seedlings held in the controlled temperature chambers were determined in a similar manner with the exception that the buds used for the respiration measurements were used. The fresh weight was determined on the 40 buds before they were placed in the respirometer flasks. The dry weight was determined after the respiration measurement had been made by placing the buds in an oven at 96 F until a

constant weight was obtained. This required about 48 hours. When the buds were removed from the oven they were placed over CaCl_2 in a dessicator to cool for 30 minutes. The samples were weighed with the total weight divided by 40 to determine the average dry weight per bud.

Tree growth was determined by counting the number of leaf buds that had started to grow. The first growth measurements were made 24 days after the trees were removed from their particular temperature and light treatments and were made at 14 day intervals until the maximum number of buds had started growing.

The data were analyzed statistically with Tukey's test of h.s.d. being used to indicate statistical differences (Snedecor, 1962).

Field temperature study

The effect of field temperatures on the rest period of Chinese apricot and Gleason Elberta peach trees was determined from the results of respiration, cold hardiness, fresh and dry weights, and rest intensity. This information was obtained from 80 twigs collected weekly from October 6, 1966 through March 5, 1967 of each species each containing 10 to 20 leaf and flower buds. These twigs were chosen at random from each of 8 Gleason Elberta peach and 8 Chinese apricot trees. The twigs were wrapped in moistened newspaper and placed in a polyethylene bag to avoid dessication while traveling to Logan.

In the laboratory, the basal ends of 24 twigs of each species were cut such that they were 9 inches long for a rest intensity study. Three twigs of each species were soaked for $1\frac{1}{2}$ hours in each of the following concentrations of gibberellic acid¹: 0, 5, 20, 50, 100, 200, 500, and 1000 ppm. The stems were then removed, set on paper towels to remove excess solution, and placed upright on a mist bench in the greenhouse. After a 2 week period, evaluations were made of the growth.

Each of the three peach stems were rated visually from 0 to 5 with 0 indicating no terminal growth and 5 indicating good terminal growth. An average value of 3 was arbitrarily established as indicating rest was broken. There was no visual growth of lateral buds after 2 weeks.

The apricot leaf buds were generally slower in developing than the peach buds and at the end of 2 weeks the buds were not showing green. However, the developing buds were visibly swollen. Since only the swollen buds eventually developed into leaves, the concentrations showing bud swelling after 2 weeks were considered to have broken rest. The lateral as well as the terminal apricot buds were observed since the lateral buds seemed to develop along with the terminal. This was not observed with the peach twigs where

¹Gratitude is expressed to the Merck & Co., Inc., of Rahway, New Jersey (Chemical Division) for furnishing the gibberellic acid (80% KGA and 20% inert material).

only the terminal bud developed. The rest period was considered over in both species when the untreated twigs showed growth.

For the cold hardiness phase of the experiment, 5 bundles of each species, each containing 5 stems (50-60 buds), were placed in the controlled temperature cabinet to determine the T_{50} . The T_{50} , 50 percent mortality, from the onset of mid-rest to the pop-corn and pink stages of Chinese apricot and Gleason Elberta peach trees respectively, was determined by using a modified temperature-controlled chamber similar to that described by Proebsting and Fogle (1956). This experiment began November 2, 1966 and ended April 5, 1967.

The bundles of stems were placed on a perforated metal platform approximately in the middle of the freezing compartment and 3 inches from the bottom of the compartment. A calibrated thermometer was placed next to the bundles on the platform and was visible through a double-walled plastic observation port in the freezer lid. The chamber was adjusted such that the rate of temperature descent was at approximately 2.5 F per hour.

The twigs were placed in the freezer in the afternoon of the collection day. The temperature was lowered during the night so that the first bundle to be removed the next day was removed at 7:30 a.m. Since the T_{50} of the first group was not known, the bundles were removed at 2-hour intervals. This gave a wide enough temperature range so that the T_{50} would be in the chosen range. Once the T_{50} of

the first group was known, it was possible to narrow the temperature range of the following group by one-half. The previous weeks data was employed for determining the proper temperature range for the subsequent weeks T_{50} determinations. At the selected temperatures, 1 bundle of each species was removed and placed in a large polyethylene bag which contained moistened paper towels to prevent dessication. After 24 hours the buds were cut longitudinally and the mortality assessed. If any amount of brown was found in the pistil or receptacle regions, the bud was considered dead. The data provided a means of drawing a curve to determine the T_{50} . The general methods of Proebsting (1956, 1959, 1963) were followed.

The respiration experiment required 12 twigs of each species which were left wrapped in moistened newspaper in the polyethylene bag for 48 hours at room temperature. This was done so that the rate of respiration would only be influenced by internal rather than external conditions. The respiration of leaf and flower buds were measured separately using the procedure described earlier. All samples were run in triplicate. The data were analyzed statistically using the LSD test to indicate statistical differences (Snedecor, 1950).

To determine the average fresh and dry weights of the leaf and flower buds from the field experiment, 60 buds of each kind (leaf and flower) were removed from the twigs at random and placed in separate aluminum weighing pans.

The temperature was recorded continuously in the field during the experiment and the maximum and minimum temperatures of each day were used. An average of 2 days maximum and minimum temperatures was used to compare with the results obtained from respiration, rest intensity, and cold hardiness.

RESULTS

The data from the controlled and field temperature studies are presented.

The results obtained from respiration and growth of the Lovell peach seedlings held at various temperatures are compared to ascertain the influences of the different treatments on breaking the rest period.

The results from the analyses of Chinese apricot and Gleason Elberta peach trees in regard to respiration, cold hardiness, rest intensity, and fresh and dry weights are presented. These results are compared with the existing field conditions at the time of sampling.

Controlled temperature study

In most cases, the peach trees receiving the highest number of hours of 40 F had a noticeable increase in respiration over the 3 storage periods (Table 1). The trees held at 32 F continuously also followed the same pattern. However, the respiration of trees receiving intermittent treatments did not increase in all cases between the first and second storage periods. Trees in all storage treatments increased markedly in O₂ consumed between the second and third storage periods. This data would indicate that there was an interaction between treatments which delay growth. Light did not seem to have any influence in the treatments.

Table 1. The respiration ($\mu\text{l O}_2$ per g. dry wt.) of flower buds taken from peach trees receiving various temperature treatments for different periods of time.

Treatment	Storage Period (Hours)			
	800	968	1245	Average
Continuous 40 F	59.7 ^a	75.8	102.3	79.3
Continuous 32 F	49.0	70.1	85.0	68.0
Continuous 40 F + 24 hours of light	66.4	88.6	148.2	101.1
16 hours of 40 F + 8 hours of 32 F	68.4	67.9	99.8	78.7
16 hours of 40 F + 8 hours of light at 40 F	57.9	76.6	110.6	81.7
16 hours of 32 F + 8 hours of 40 F	65.4	63.5	76.5	68.5
16 hours of 32 F + 8 hours of light at 40 F	62.1	63.6	93.0	72.9
16 hours of light at 40 F + 8 hours of 40 F	54.3	59.5	73.0	62.3
16 hours of light at 40 F + 8 hours of 32 F	47.4	59.8	95.5	67.6
Average	59.0	69.5	98.2	
h.s.d. (Storage period mean)		.05 22.4 .01 28.0		
h.s.d. (Interaction means)		.05 37.0 .01 40.6		
h.s.d. (Treatment means)		.05 17.3 .01 20.3		

^aAverage of 3 sampling dates. The sampling dates were 2, 7, and 10 days after the trees were placed in the greenhouse. Duplicate measurements were made at each time of sampling.

The rate of respiration of the untreated control trees held in the greenhouse declined slightly between December 8, 1966 to January 13, 1967 (Figure 2).

Weight: Table 2 indicates that, in most cases, the peach trees treated with the highest number of hours of 40 F had a noticeable increase in fresh weight. Likewise, trees held continuously at 32 F had a noticeable increase. Trees receiving intermittent temperatures did not increase in fresh weight in all cases between the first and second storage period. All trees increased markedly in fresh weight between the second and third storage periods. This pattern closely resembles that of respiration. This data would also indicate that there was an interaction between temperatures because light seemed to have no influence in the treatments. All measurements were made at the same time interval, hence a valid comparison can be made.

The average dry weight of the buds was generally not influenced by storage periods (Table 3). There was a slight significant influence of treatment on dry weight at the 0.05 level. It seemed that the difference among the tree replicates were quite different, hence masked any differences that may have occurred between treatments.

The control trees showed a decrease in fresh weight at the beginning but then regained a few milligrams. There was no apparent difference in dry weight (Figure 3).

Growth: Figure 4 shows the type of growth which occurred after various storage periods and cold treatments. Both

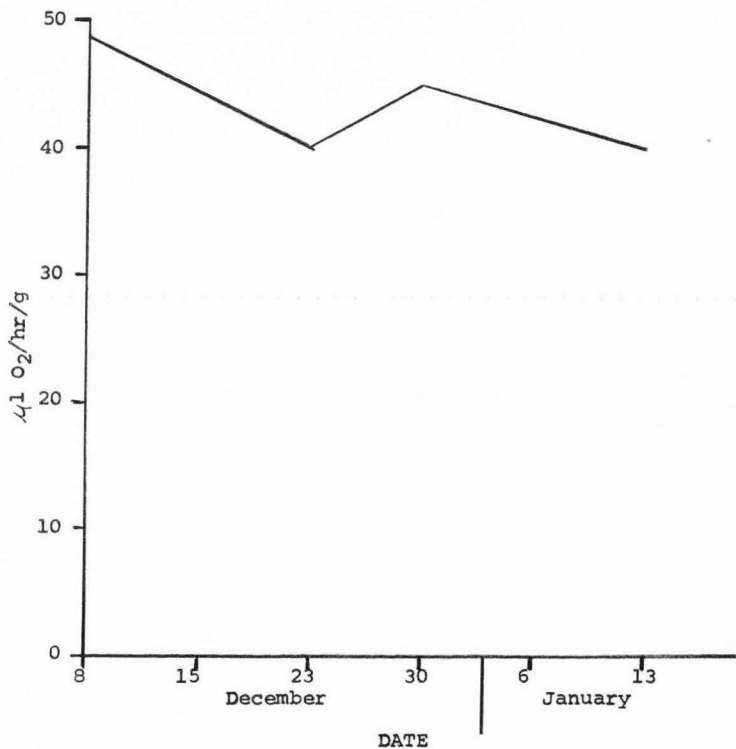


Figure 2. The average rate of respiration of Lovell peach flower buds from trees held in the greenhouse at 65 F.

Table 2. The average fresh weight (mg) of flower buds.

Treatment	Storage Period (Hours)			Average
	800	968	1240	
Continuous 40 F	10.0 ^a	11.0	13.0	11.3
Continuous 32 F	7.6	10.8	11.8	10.1
Continuous 40 F + 24 hours of light	11.7	12.4	17.0	13.7
16 hours of 40 F + 8 hours of 32 F	11.4	10.8	12.0	11.4
16 hours of 40 F + 8 hours of light at 40 F	5.1	11.4	13.9	10.1
16 hours of 32 F + 8 hours of 40 F	6.6	7.7	11.5	8.6
16 hours of 32 F + 8 hours of light at 40 F	11.3	9.2	14.1	11.5
16 hours of light at 40 F + 8 hours of 40 F	11.6	10.3	11.1	11.0
16 hours of light at 40 F + 8 hours of 32 F	8.6	10.3	12.9	10.6
Average	9.3	10.4	13.0	
h.s.d. (Storage period means)	.05	3.6		
	.01	4.7		
h.s.d. (Interaction means)	.05	1.1		
	.01	1.3		
h.s.d. (Treatment means)	.05	0.9		
	.01	1.1		

^aAverage of 3 sampling dates which were 2, 7, and 10 days after the trees were placed in greenhouse. A total of 20 buds were weighed.

Table 3. The average dry weight (mg) of peach flower buds.

Treatment	Storage Period (Hours)			Average
	800	968	1240	
Continuous 40 F	5.5 ^a	5.8	6.3	5.9
Continuous 32 F	5.1	5.8	6.4	5.8
Continuous 40 F + 24 hours of light	6.3	6.1	7.2	6.5
16 hours of 40 F + 8 hours of 32 F	4.1	6.0	5.4	5.2
16 hours of 40 F + 8 hours of light at 40 F	3.2	5.7	6.3	5.1
16 hours of 32 F + 8 hours of 40 F	3.9	4.9	6.1	5.0
16 hours of 32 F + 8 hours of light at 40 F	6.3	5.3	6.6	6.1
16 hours of light at 40 F + 8 hours of 40 F	6.6	5.9	6.3	6.3
16 hours of light at 40 F + 8 hours of 32 F	5.1	6.0	6.4	5.8
Average	5.1	5.7	6.3	
h.s.d. (Storage periods means)	.05	0.7		
	.01	0.9		
h.s.d. (Interaction means)	.05	0.7		
	.01	0.8		
h.s.d. (Treatment means)	.05	0.5		
	.01	0.6		

^aAverage of 3 sampling dates which were 2, 7, and 10 days after the trees were placed in greenhouse. A total of 20 buds were weighed.

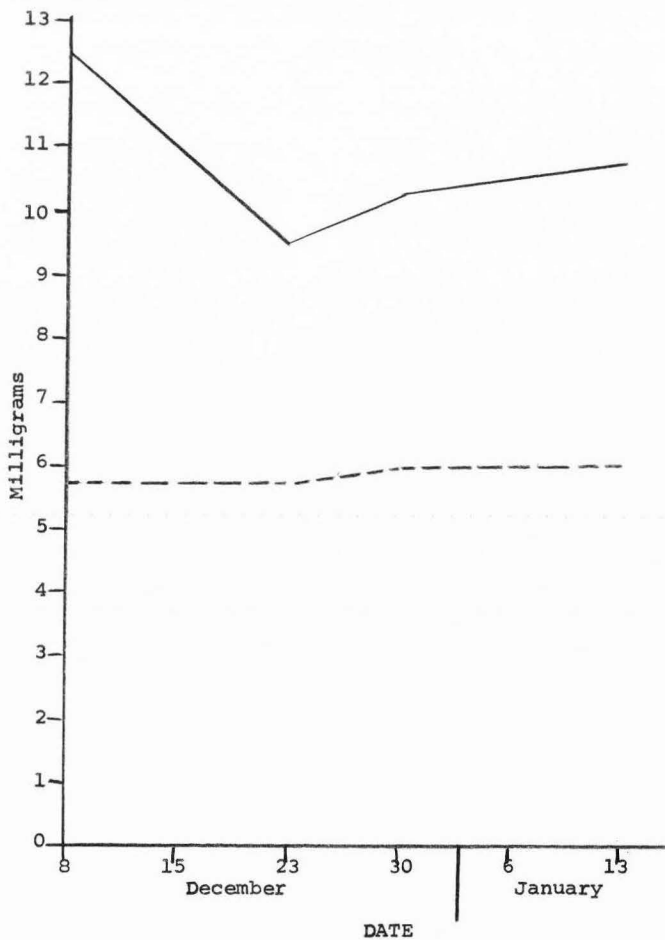


Figure 3. The average fresh and dry weights of Lovell peach flower buds collected from trees held in the greenhouse (untreated control treatment).

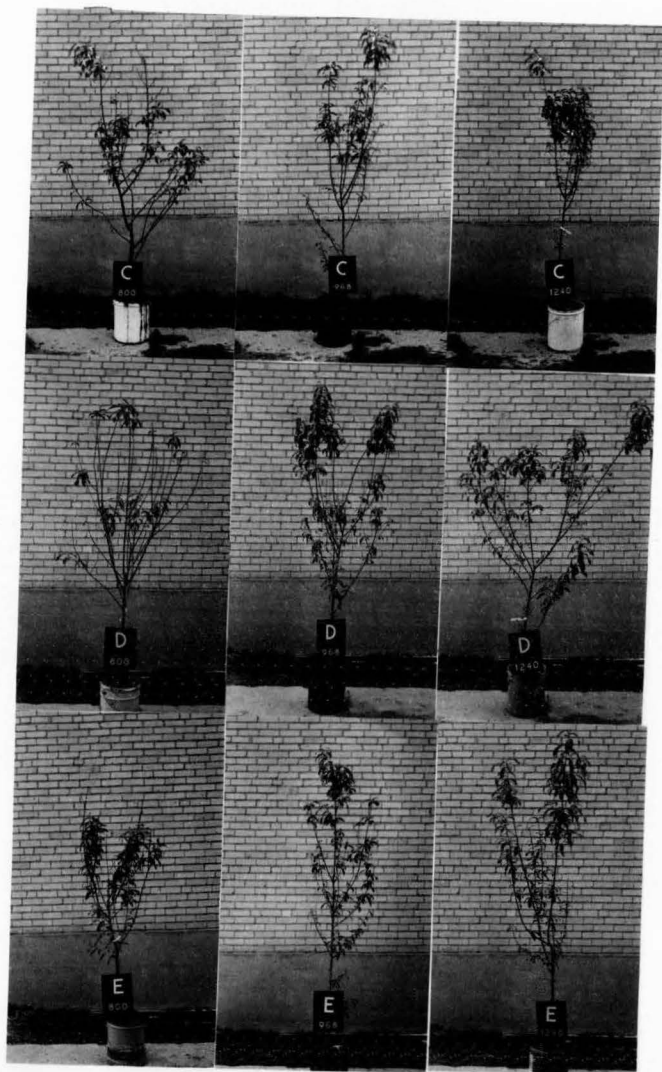


Figure 4. The effect of 3 storage periods on growth. The numbers represent total number of hours of each treatment. C is continuous 40 F, D is continuous 32 F, and E is continuous light at 40 F.

groups of trees stored at 40 F continuously (with and without light) grew better than the trees held at 32 F continuously. The trees that were removed from all treatments after 800 hours of cold treatment required approximately 66 days, the ones removed after 968 hours required 52 days, and the ones removed after 1240 hours required approximately 40 days. Table 4 gives the percentage of buds growing for each treatment after they had reached their full potential. It was apparent from the results that 40 F was more effective in breaking rest than at 32 F or at 40 F with 24 hours of continuous light.

The control trees remained dormant and did not show any signs of growth.

Field temperature study

Respiration: The data compiled in Tables 5 and 6 indicate that there was no significant differences in respiration for flower buds of either species during the season until the week of February 8. An increase in respiration occurred in the leaf buds approximately 2-4 weeks after the corresponding flower buds increased.

There was no significant increase of respiration on January 4 when the rest period was considered to be over. Also, there was no significant decrease in respiration when the buds were considered to be in "deep rest" or "mid rest". This information indicates that the rest period does not influence the rate of respiration.

Table 4. The percent of peach leaf buds growing. Maximum growth was achieved 66, 52, and 40 days respectively for the 3 storage periods after the trees were placed in the greenhouse.

Treatment	Storage Period (Hours)			Average
	800	968	1240	
Continuous 40 F	37.1 ^a	56.8	79.9	57.9
Continuous 32 F	2.3	28.3	26.0	18.9
Continuous 40 F + 24 hours of light	11.4	56.0	75.3	47.6
16 hours of 40 F + 8 hours of 32 F	30.3	47.5	96.5	58.1
16 hours of 40 F + 8 hours of light at 40 F	28.5	51.5	84.9	55.0
16 hours of 32 F + 8 hours of 40 F	8.3	43.4	63.0	38.2
16 hours of 32 F + 8 hours of light at 40 F	19.1	21.2	68.6	36.3
16 hours of light at 40 F + 8 hours of 40 F	18.4	66.9	71.9	52.4
16 hours of light at 40 F + 8 hours of 32 F	3.0	43.0	69.1	38.4
Average	17.6	46.1	70.6	

^aThe percent buds growing from a total of 3 trees from each treatment and storage period.

Table 5. The microliters of O₂ consumed by Chinese apricot flower and leaf buds.

Sampling date	Flower buds		Leaf buds	
	$\mu\text{l O}_2$ (per hr/g) ^a	$\mu\text{l O}_2$ (per hr/bud)	$\mu\text{l O}_2$ (per hr/g)	$\mu\text{l O}_2$ (per hr/bud)
1966				
Oct. 6	57.0 ^b	3.0	49.9	0.9
13	51.0	2.8	51.3	1.4
19	66.9	4.0	64.2	2.5
26	60.4	4.1	66.1	3.1
Nov. 2	63.6	3.7	55.4	2.2
9	66.9	4.1	70.7	1.7
16	65.7	4.8	51.3	1.5
23	84.5	5.0	60.0	2.1
30	64.0	3.9	53.1	1.7
Dec. 7	65.8	4.5	61.1	2.1
14	54.5	4.1	62.6	2.2
21	64.5	4.8	57.2	2.3
28	61.1	4.8	62.7	2.1
1967				
Jan. 4	61.2	5.2	55.0	2.3
11	65.2	4.8	54.9	1.5
25	79.5	5.6	70.6	1.8
Feb. 8	106.2	8.3	80.6	2.3
22	117.4	11.3	81.1	2.2
Mar. 1	173.9	18.9	83.9	2.3
8	175.8	19.4	110.9	2.9
15	233.2	36.8	147.2	3.7
22	284.7	52.7	157.2	5.1
LSD				
.05	33.0	7.5	58.1	2.2
.01	44.0	10.0	77.5	3.0

^aDry weight basis.^bAverage of 3 replications.

Table 6. The microliters of O₂ consumed by Gleason Elberta peach flower and leaf buds.

Sampling date	Flower buds		Leaf buds	
	$\mu\text{l O}_2$ (per hr/g) ^a	$\mu\text{l O}_2$ (per hr/bud)	$\mu\text{l O}_2$ (per hr/g)	$\mu\text{l O}_2$ (per hr/bud)
1966				
Oct. 6	62.1 ^b	2.6	47.0	0.8
13	50.9	2.5	31.3	0.7
19	70.6	4.1	59.5	2.0
26	74.1	4.0	53.8	1.7
Nov.				
2	67.7	4.5	66.6	1.8
9	76.9	4.9	59.9	1.9
16	82.2	4.8	59.1	1.4
23	88.1	5.5	82.7	2.4
30	77.5	5.5	65.1	2.0
Dec.				
7	90.9	6.1	65.9	2.0
14	81.8	4.9	81.5	2.0
21	79.7	5.2	76.8	2.1
28	83.6	5.9	72.5	2.1
1967				
Jan.				
4	93.9	6.6	74.5	1.6
11	88.2	7.0	61.3	1.6
25	89.6	6.9	77.9	2.6
Feb.				
8	118.9	8.6	102.5	3.2
22	122.1	10.1	105.4	2.9
Mar.				
1	137.1	12.3	120.4	3.3
8	168.4	16.8	118.7	3.7
15	180.1	19.1	132.3	4.0
22	289.5	47.3	177.1	6.5
Apr.				
5	341.3	66.0	214.6	6.4
LSD				
.05	59.0	9.1	74.4	3.2
.01	81.3	12.5	102.5	4.2

^aDry weight basis.^bAverage of 3 replications.

The fluctuating temperatures before January 25 did not cause any measurable differences in respiration. It was not until the first of February that there was a significant increase in respiration. The respiration followed the same pattern whether it was reported on a dry weight or bud basis.

Cold hardiness: Figure 5 indicates the influence temperature has on cold hardiness. The period of greatest cold hardiness for the apricot flower buds was December 16 and December 23 for the peach flower buds. It was during these 2 periods that the temperature dropped the lowest.

The T_{50} measurements of both species remained quite close together until the last of January. The apricot flower buds then began to lose their cold resistance faster than the peach flower buds.

The results from the T_{50} determinations (Figure 6) followed closely a pattern suggested by Proebsting and Mills (1966).

Weight: As Figures 7 and 8 indicate, the fresh and dry weights did not significantly increase until late February, except for the fresh weight of the flower buds, which corresponds closely to the pattern of respiration. A rapid increase in fresh and dry weights occurred at the end of February and the beginning of March.

Rest intensity: The rest intensity curves of both species is shown by Figure 9. The graph indicates that the Chinese apricot trees do not enter as "deep of rest" as do the Gleason Elberta peach trees since only 100 ppm gibberellic

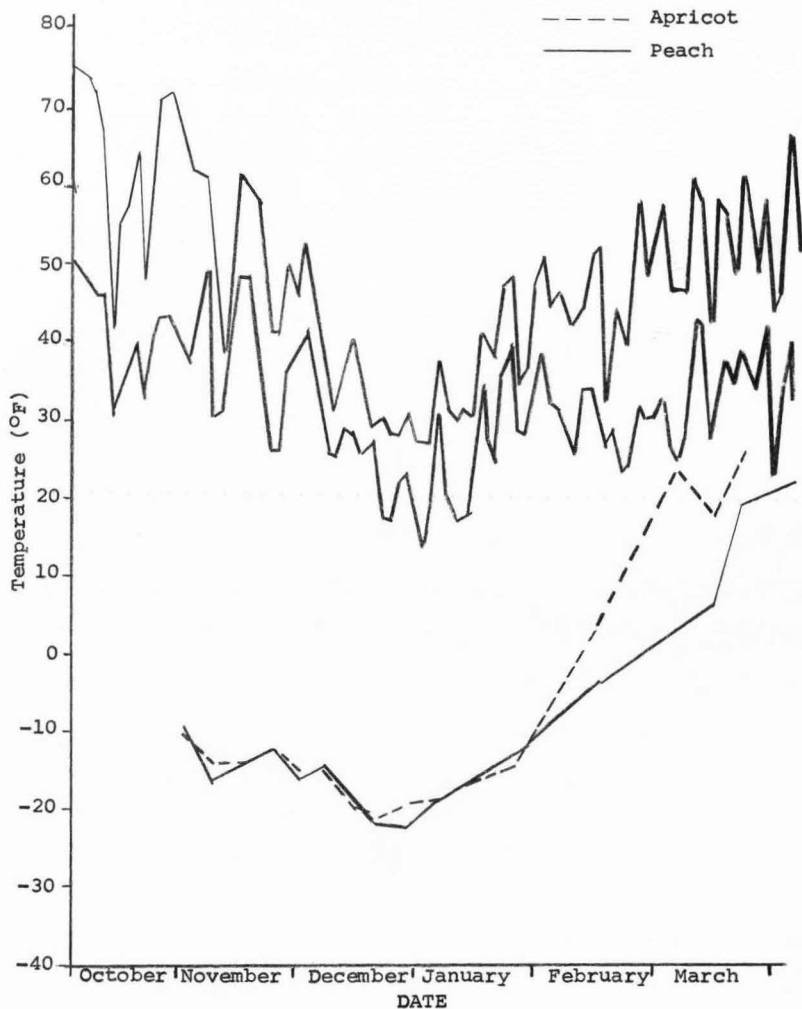


Figure 5. Cold hardiness of Chinese apricot and Gleason Elberta peach flower buds as related to temperatures of 1966-67. Points on lower lines represent T_{50} determinations. The upper lines are two-day averages of maximum and minimum field temperatures.

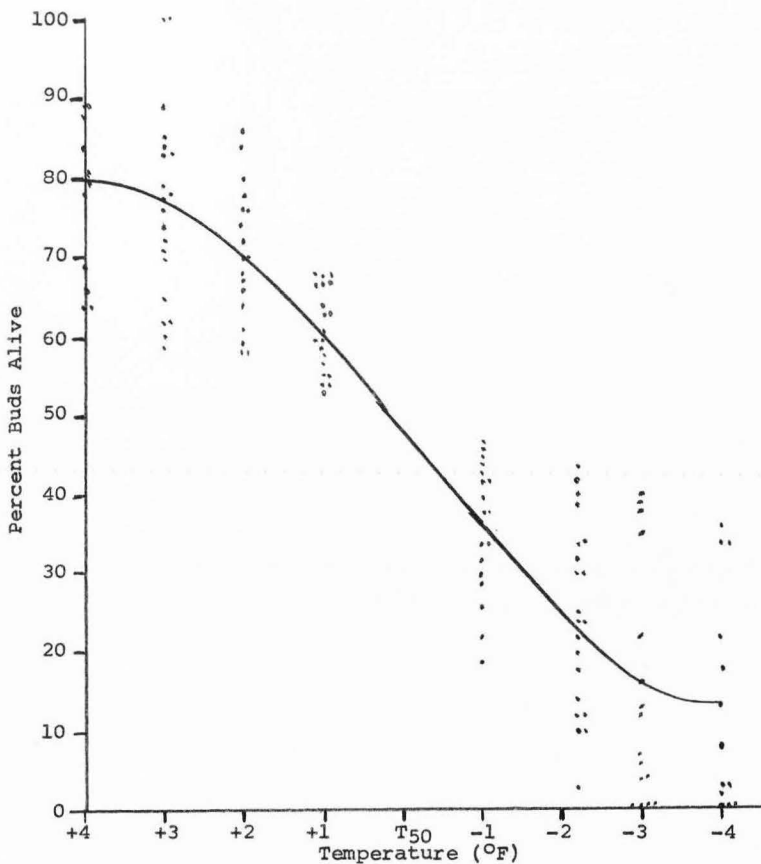


Figure 6. A standardized temperature-survival curve for dormant Gleason Elberta peach trees. The points near the curve are the weekly T₅₀ measurements beginning November 2, 1966 and continuing through April 5, 1967.

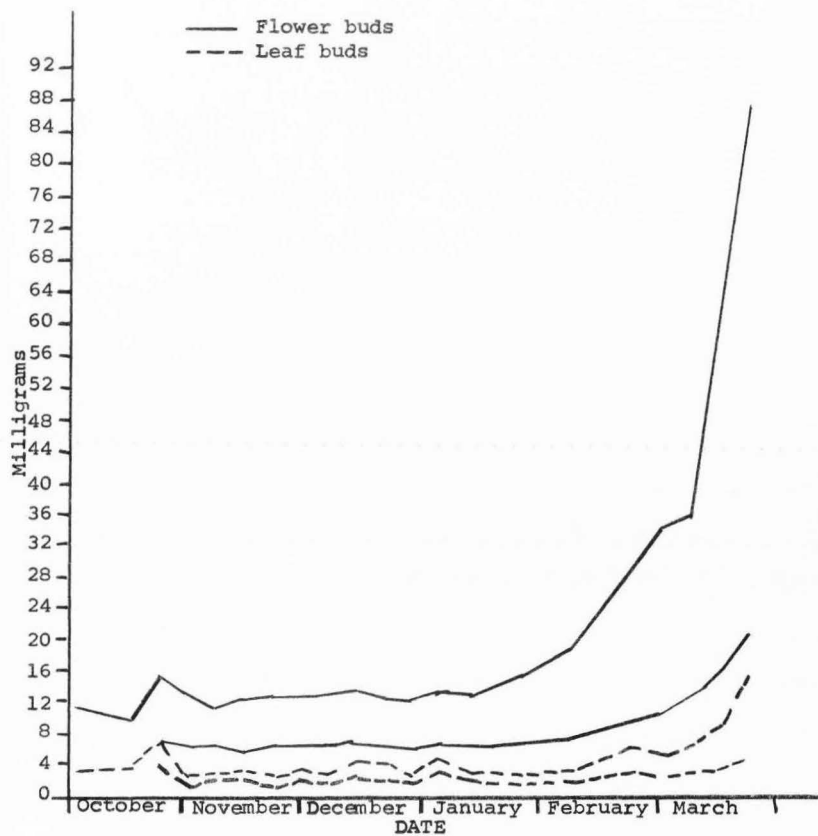


Figure 7. The average fresh and dry weights of Chinese apricot flower and leaf buds from October 1966 to March 1967. The upper line of each type is the fresh weight and the lower is the dry weight.

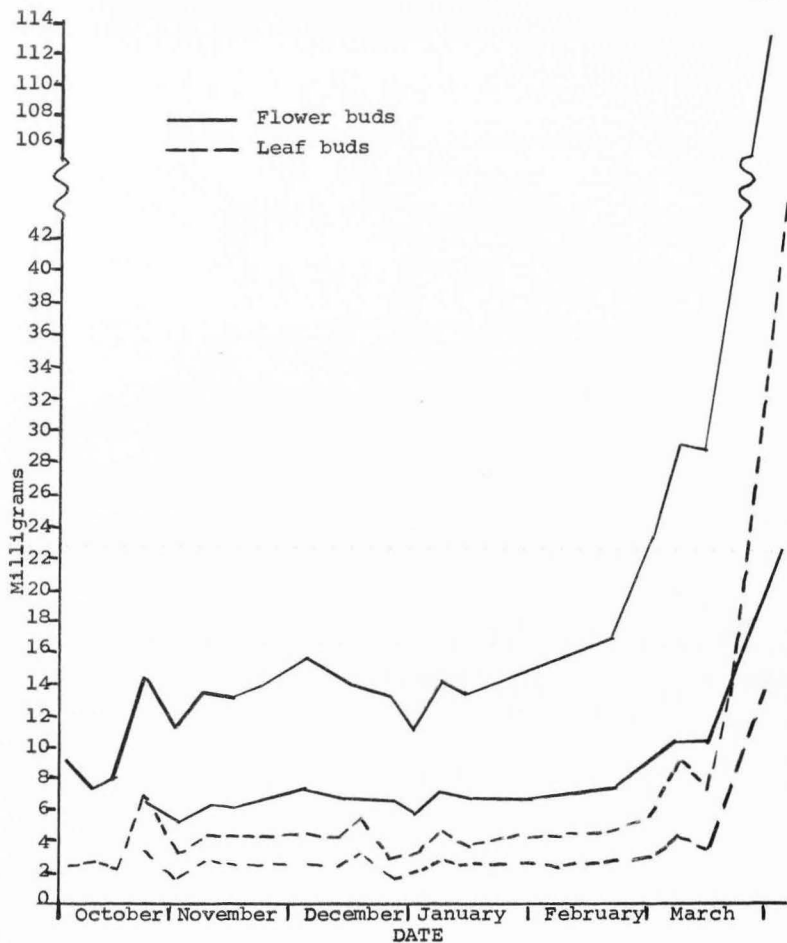


Figure 8. The average fresh and dry weights of Gleason Elberta peach flower and leaf buds from October 1966 to March 1967. The upper line of each type is the fresh weight and the lower the dry weight.

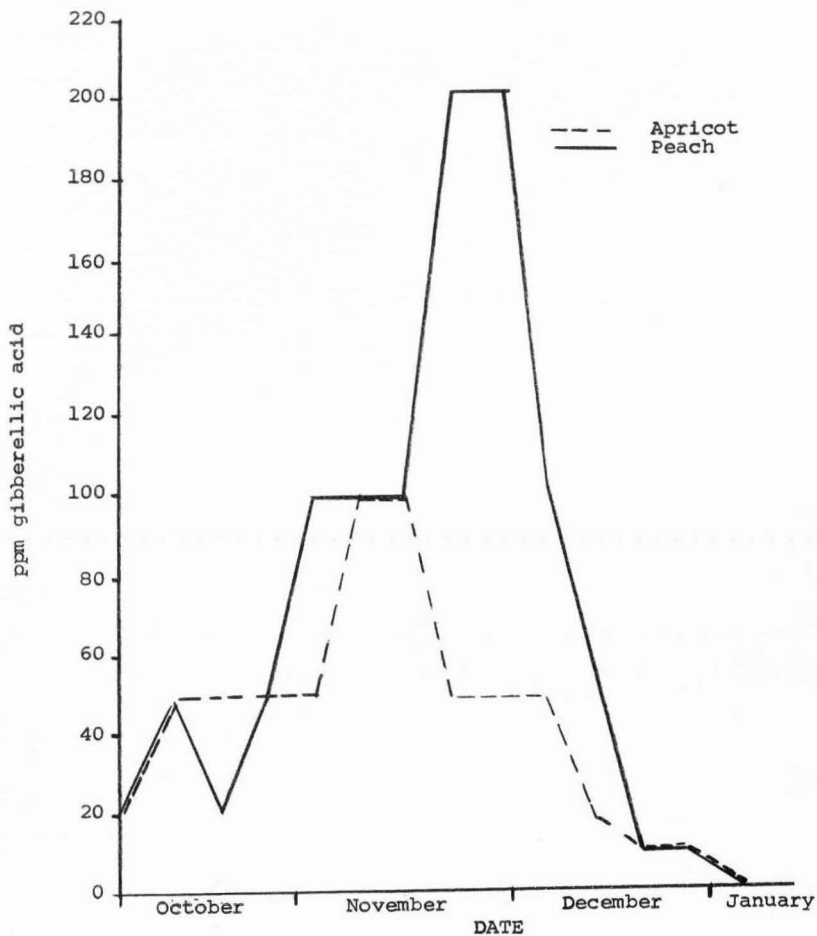


Figure 9. The rest intensity changes of Chinese apricot and Gleason Elberta peach trees during the winter of 1966-67.

acid was required and the peaches required 200 ppm to break rest. Both species were in a deeper rest for about 2 weeks than they were before or after. The rest intensity formed a general normal distribution type curve and seemed to occur regardless of outside temperatures. After "deep rest" had been achieved, the peach twigs lost their "deep rest" intensity very rapidly resulting in the apricots and the peaches completing their rest at the same time.

The rest period seemed to have no influence on cold hardiness. Both species had been in "deep rest" and were nearing the end of their rest period when the flower buds reached their maximum cold resistance.

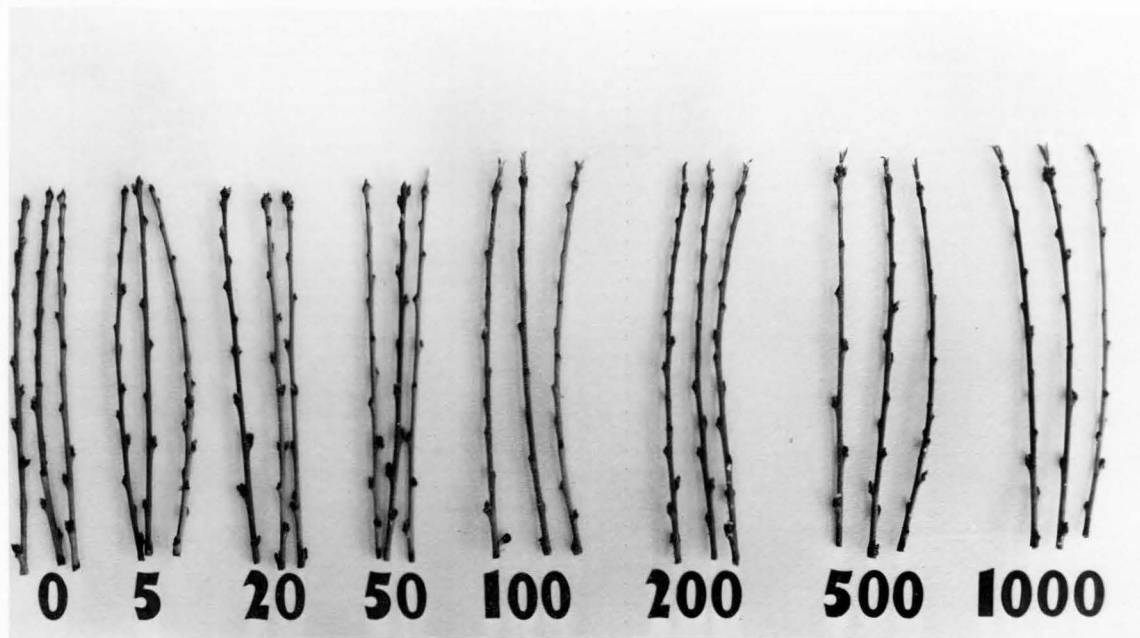


Figure 10. The response of dormant peach twigs to various concentrations of gibberellic acid (ppm). These twigs were collected November 2, 1966 and had been in the mist bench for 14 days.

DISCUSSION

The results obtained from these experiments add further information to the nature of the rest period. Any information that adds light to the nature of the rest period can be helpful and may shorten the time when the controlling mechanism is understood.

During the winter months respiration was independent of temperature until after the rest period had been broken. As was reported, there was no significant increase or decrease in respiration as the field temperatures fluctuated. The control of cell activity during rest must then be controlled by some mechanism that is not influenced by environmental temperatures.

The termination of the rest period was not detected by respirometer measurements. The change in the status of the bud occurs very smoothly without an increase or decrease in cell activity. The increase in respiration did not occur until the maximum temperatures rose above 40 F which occurred during the first week of February. Also, significant increase in fresh weight did not occur until after there was an increase in respiration.

Although respiration of buds in rest seems to be independent of temperature, the internal controlling mechanism is temperature sensitive in that a certain number of hours of chilling is required to trigger growth. The trees that were

held in the greenhouse throughout the winter remained dormant and declined in respiration during this period. Pollock (1960) reported the same results obtained from maple buds. These results again substantiate the importance of cold temperature in breaking rest which enables a dormant tree to start producing the necessary chemicals for growth. It was found that continuous 40 F with and without light were more effective in breaking rest than was continuous 32 F. In most cases, treatments containing the most number of hours of 40 F were more effective in breaking the rest period. This evidence and that of Overcash and Campbell (1955) indicate that continuous 39-40 F exert the greatest influence on the internal mechanism of controlling rest. Temperatures above or below tend to interfere.

Trees held at 40 F with light respired faster than trees held at either 40 F without light and 32 F. However, the light treatment was slower in breaking the rest of trees than was continuous 40 F. Just what type of activity was stimulated by the light is unknown.

In comparing the respiration results of leaf and flower buds taken from trees in the field, there is about a 2 week difference in a significant increase in respiration between the 2 types of buds. Flower buds initiate growth sooner than do leaf buds.

The intensifying of the rest period during the winter months seemed to be independent of external temperatures. This would indicate again that the depth of rest at any

given period is influenced by an internal mechanism. Some type of plant growth inhibitor or gene repressor seemed to accumulate since it required stronger concentrations of gibberellic acid to break rest up to a certain date. The inhibitor or gene repressor then diminishes quite rapidly subsequently a weaker concentration of gibberellic acid is required to break rest. This activity apparently did not influence respiration in any way.

The rest intensity had no direct influence on cold hardiness. The results show that hardiness was induced by low temperatures. However, the trees would have been killed by frost had the rest period not caused a cessation in growth.

SUMMARY

Studies were conducted to better understand the influence of temperature on the rest period of dormant peach and apricot buds. Gleason Elberta peach and Chinese apricot trees in the field were used to evaluate rest intensity, respiration, and cold hardiness in relation to temperature.

A rest intensity curve was obtained for both species using various concentrations of gibberellic acid. It was found that temperature had no direct effect on the depth of rest and that the depth of rest had no measurable influence on respiration and cold hardiness. It was found that apricots reach their "deep rest" sooner than peaches and that they did not enter into as deep of rest as peaches.

Respiration of flower and leaf buds was not affected by temperature until after the rest period was over and the temperature rose above 40 F. However, cold hardiness was directly affected by temperature during the rest period. As the temperatures dropped the cold hardiness increased in both species. The amount of cold hardiness achieved and the rate it was achieved varied only slightly from both the apricot and peach trees. However, apricot trees lost their cold hardiness faster than the peaches.

Lovell peach seedlings were placed in 5 gallon containers and placed in controlled temperature chambers. At 3 different periods, 3 trees were removed from 9 different

temperature treatments. Respiration measurements were made and the days required for the trees to achieve maximum growth were recorded. The results were then compared.

It was found that 40 F was generally more effective in breaking rest than was 32 F. Light did not seem to effect the rest period significantly. It was noticed that trees held continuously in light at 40 F respired faster than trees held continuously in the dark at 40 and 32 F.

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APPENDIX

Table 7. Growth evaluations of Gleason Elberta peach twigs treated with KGA beginning October 6, 1966 and ending January 4, 1967. 0 represents no growth and 5 the most growth.

Date	Twig	ppm KGA							
		0	5	20	50	100	200	500	1000
Oct. 6	1	0 ^a	0	4	1	2	3	0	5
	2	0	0	3	0	3	5	5	5
	3	0	0	2	1	3	4	2	4
Oct. 13	1	0	0	0	4	2	3	4	0
	2	0	0	0	0	1	3	4	5
	3	0	0	0	0	3	4	5	5
Oct. 19	1	0	0	0	5	0	4	4	5
	2	0	0	5	2	3	0	5	3
	3	0	0	0	0	0		1	5
Oct. 26	1	0	0	0	0	1	3	0	4
	2	0	0	0	3	4	0	4	0
	3	0	0	0	0	0	5	3	2
Nov. 2	1	0	0	0	0	5	5	5	5
	2	0	0	0	0	5	5	5	5
	3	0	0	0	2	4	5	5	5
Nov. 9	1	0	0	0	0	1	3	0	5
	2	0	0	0	0	3	5	4	5
	3	0	0	0	0	0	4	5	3
Nov. 16	1	0	0	0	0	2	3	5	5
	2	0	0	0	0	2	4	4	5
	3	0	0	0	0	0	3	5	5
Nov. 23	1	0	0	0	0	1	5	3	3
	2	0	0	0	0	0	3	3	4
	3	0	0	0	0	0	0	1	5
Nov. 30	1	0	0	0	0	1	0	5	4
	2	0	0	0	0	0	3	0	3
	3	0	0	0	0	0	0	3	3
Dec. 7	1	0	0	0	1	5	4	4	5
	2	0	0	0	0	0	3	4	5
	3	0	0	0	0	4	3	0	5

Table 7. Continued

Date	Twig	ppm KGA							
		0	5	20	50	100	200	500	1000
Dec. 14	1	0	0	0	2	0	0	4	4
	2	0	0	1	3	3	5	3	5
	3	0	0	0	0	3	3	0	3
Dec. 21	1	0	2	3	0	4	5	5	5
	2	0	2	0	3	3	5	3	4
	3	0	1	1	0	1	1	0	3
Dec. 28	1	1	2	2	5	5	1	0	4
	2	0	2	1	5	0	2	5	4
	3	0	2	1	5	1	0	5	4
Jan. 4	1	5	3	4	1	2	5	4	5
	2	3	4	3	5	4	3	2	5
	3	0	3	2	4	5	5	3	4

^aEvaluations 2 weeks after treatment.

Table 8. Growth evaluations of Chinese apricot twigs treated with various concentrations of KGA beginning October 6, 1966 and ending January 4, 1967. 0 represents no growth and + represents swollen buds.

Date	Twig	ppm KGA							
		0	5	20	50	100	200	500	1000
Oct. 6	1	0 ^a	0	+	0	+	+	0	+
	2	0	0	+	+	+	0	0	+
	3	0	0	0	+	+	+	+	+
Oct. 13	1	0	0	0	+	+	+	+	0
	2	0	0	0	+	0	+	+	+
	3	0	0	0	0	0	+	+	+
Oct. 19	1	0	0	0	+	+	+	+	0
	2	0	0	0	+	+	+	0	0
	3	0	0	0	0	0	0	+	0
Oct. 26	1	0	0	0	+	+	+	+	+
	2	0	0	0	+	0	+	0	+
	3	0	0	0	+	+	0	+	0
Nov. 2	1	0	0	0	+	+	0	+	0
	2	0	0	0	+	+	0	0	0
	3	0	0	0	0	0	0	+	+
Nov. 9	1	0	0	0	0	+	+	+	+
	2	0	0	0	0	+	+	+	+
	3	0	0	0	0	0	0	+	+
Nov. 16	1	0	0	0	0	+	+	+	+
	2	0	0	0	0	+	+	+	+
	3	0	0	0	0	+	+	+	+
Nov. 23	1	0	0	0	+	+	+	+	+
	2	0	0	0	+	+	+	+	+
	3	0	0	0	+	+	+	+	+
Nov. 30	1	0	0	0	0	+	0	+	+
	2	0	0	0	+	0	+	+	+
	3	0	0	0	+	+	+	+	+
Dec. 7	1	0	0	0	+	+	+	+	+
	2	0	0	0	+	+	+	+	+
	3	0	0	0	+	+	+	+	+

Table 8. Continued

Date	Twig	ppm KGA							
		0	5	20	50	100	200	500	1000
Dec. 14	1	0	0	+	+	+	+	+	+
	2	0	0	+	+	+	+	+	+
	3	0	0	0	+	+	+	+	+
Dec. 21	1	0	+	+	+	+	+	+	+
	2	0	+	0	0	+	+	+	+
	3	0	+	+	+	+	+	+	+
Dec. 28	1	0	+	+	+	+	+	+	+
	2	0	+	+	+	+	+	+	+
	3	0	+	+	+	+	+	+	+
Jan. 4	1	+	+	+	+	+	+	+	+
	2	+	+	+	+	+	+	+	+
	3	+	+	+	+	+	+	+	+

^aEvaluations 2 weeks after treatment.

Table 9. The average fresh and dry weights (mg) of Gleason Elberta peach flower and leaf buds beginning October, 1966 and ending April, 1967.

Date	Flower buds		Leaf buds	
	Fresh	Dry	Fresh	Dry
Oct. 6	9.2 ^a		2.5	
13	7.3		2.7	
19	8.0		2.1	
26	14.5	6.6	6.9	3.5
Nov. 2	10.6	5.1	3.0	1.8
9	13.5	6.4	4.5	2.7
16	13.0	6.1	4.4	2.5
23	13.8	6.3	4.2	2.5
30	15.7	7.4	4.5	2.7
Dec. 7	14.5	6.8	4.1	2.4
14	13.7	6.6	5.3	3.1
21	13.2	6.7	2.7	1.8
28	10.9	5.9	3.1	2.0
Jan. 4	14.2	7.1	4.7	2.9
11	13.0	6.7	3.8	2.4
25	14.4	6.6	4.3	2.6
Feb. 8	15.5	6.9	4.3	2.4
22	16.7	7.4	4.5	2.6
Mar. 1	22.6	9.1	5.4	2.9
8	29.0	10.4	9.6	4.1
15	28.5	10.3	7.2	3.3
22	39.8	13.1	14.9	5.6
Apr. 5	113.0	23.0	48.5	13.1

^aAverage of 60 buds.

Table 10. The average fresh and dry weights (mg) of Chinese apricot flower and leaf buds from October, 1966 to March, 1967.

Date	Flower buds		Leaf buds	
	Fresh	Dry	Fresh	Dry
Oct. 6	11.2 ^a		3.7	
13	10.5		3.5	
19	9.8		4.0	
26	15.5	7.3	7.0	4.1
Nov. 2	12.8	6.1	2.6	1.7
9	11.2	6.4	3.2	2.1
16	12.3	5.8	3.3	2.1
23	12.9	6.1	2.3	1.6
30	12.9	6.3	3.6	2.3
Dec. 7	13.3	6.5	2.9	1.9
14	14.0	6.9	4.2	2.5
21	12.9	6.4	4.0	2.5
28	12.4	6.3	2.8	1.9
Jan. 4	13.1	6.6	5.0	3.1
11	12.7	6.7	3.3	2.2
25	15.5	7.0	3.0	2.0
Feb. 8	18.6	7.5	3.3	2.0
22	28.0	9.7	6.4	3.5
Mar. 1	34.7	10.6	5.1	2.5
8	36.6	12.9	6.4	3.3
15	63.4	15.8	8.6	3.2
22	87.1	21.1	15.6	5.3

^aAverage of 60 buds.

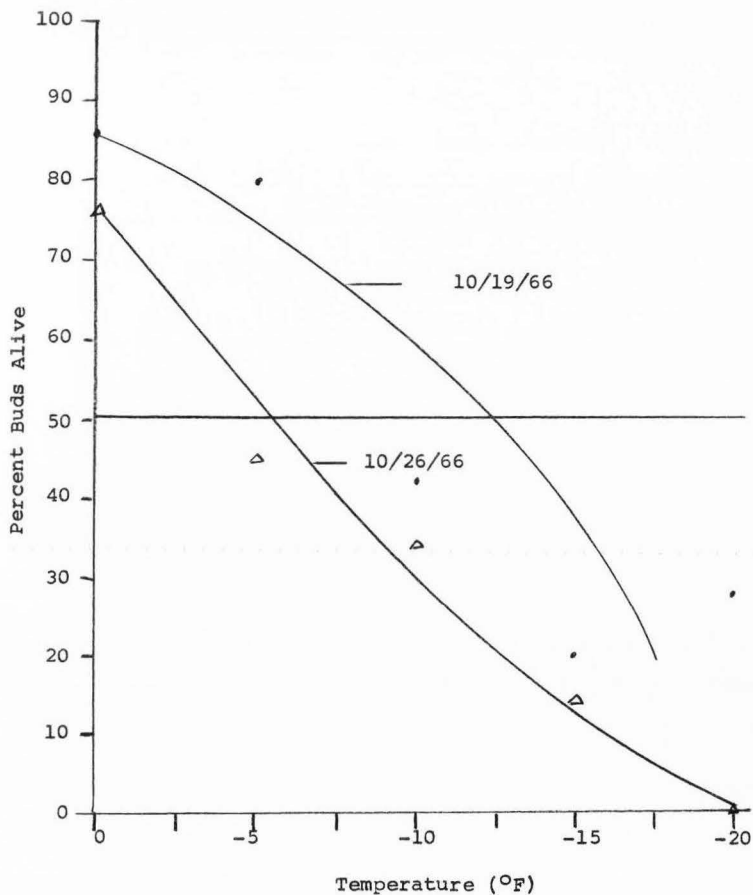


Figure 11. The T_{50} values of Gleason Elberta peach flower buds for October 1966.

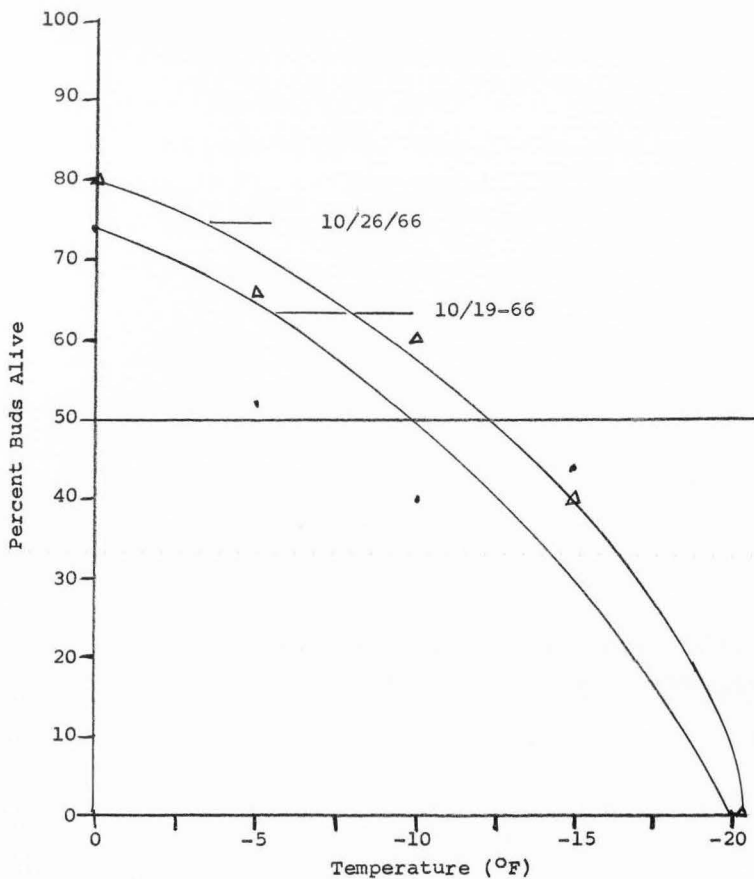


Figure 12. The T_{50} values of Chinese apricot flower buds for October 1966.

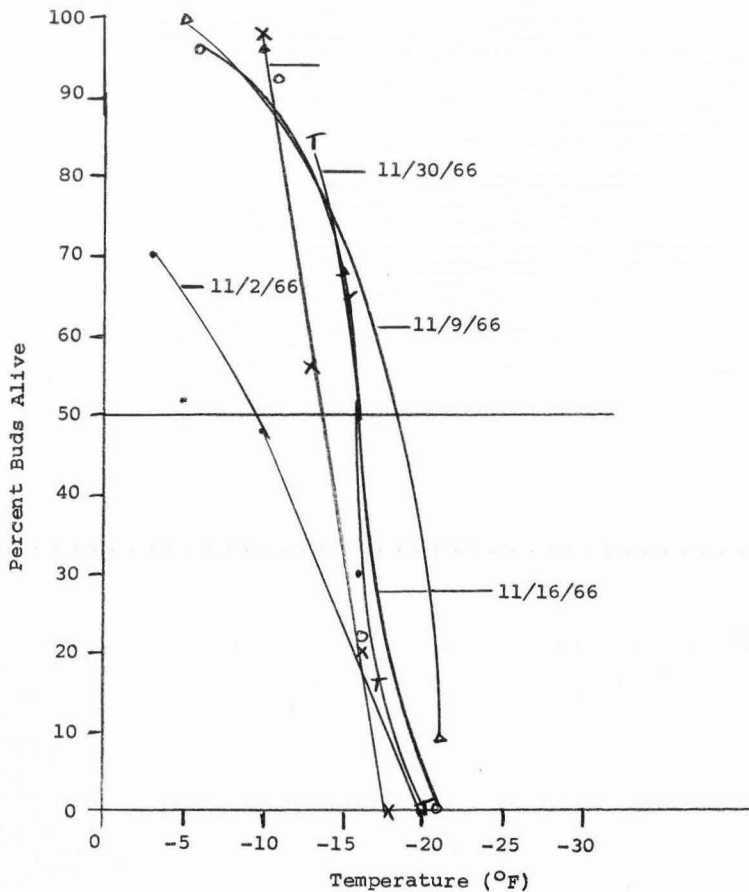


Figure 13. The T₅₀ values of Gleason Elberta peach flower buds November 1966.

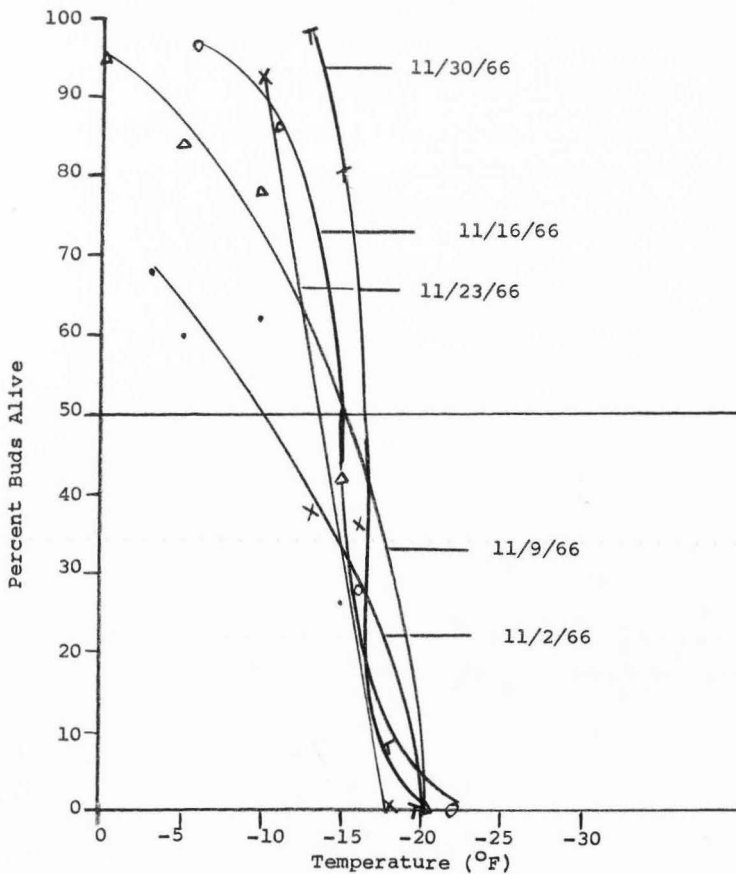


Figure 14. The T₅₀ values of Chinese apricot flower buds for November 1966.

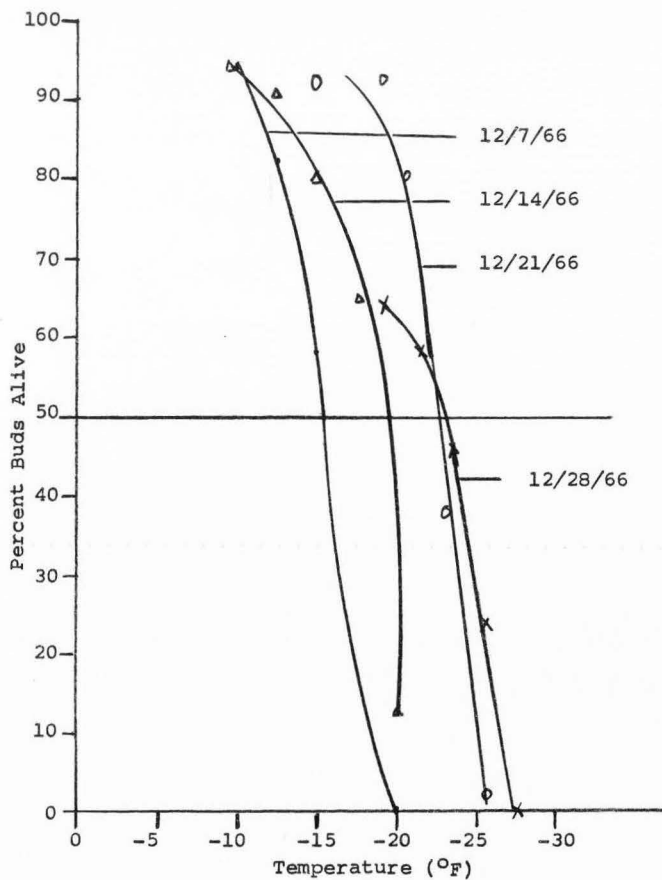


Figure 15. The T_{50} values of Gleason Elberta peach flower buds for December 1966.

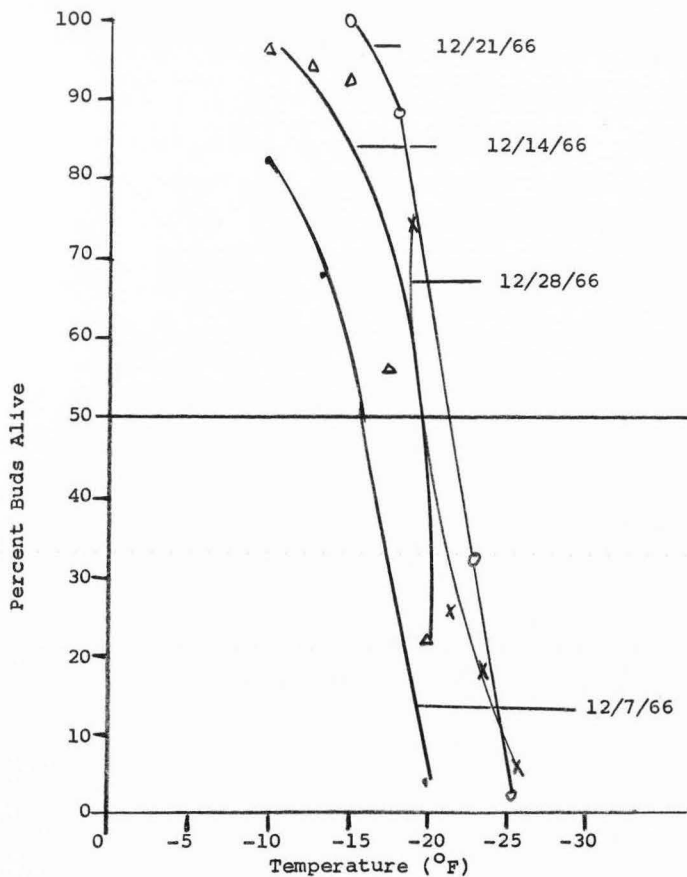


Figure 16. The T_{50} values of Chinese apricot flower buds for December 1966.

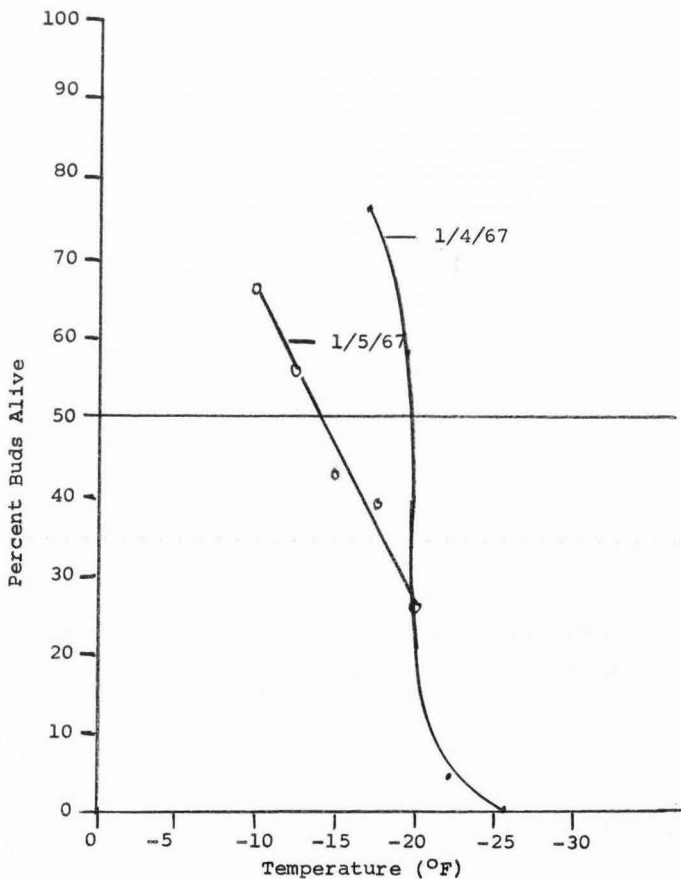


Figure 17. The T_{50} values of Gleason Elberta peach flower buds for January 1967.

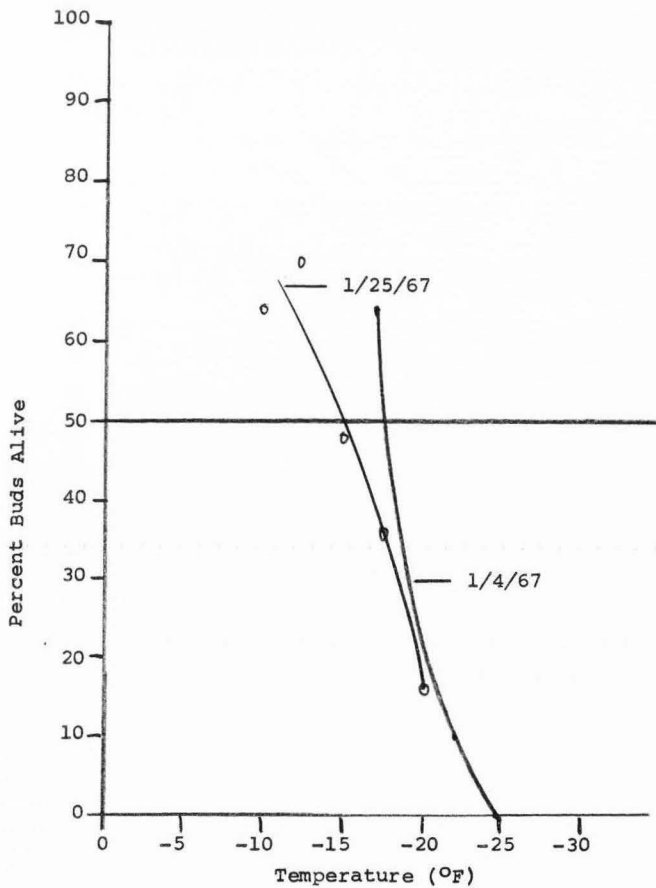


Figure 18. The T_{50} values of Chinese apricot flower buds for January 1967.

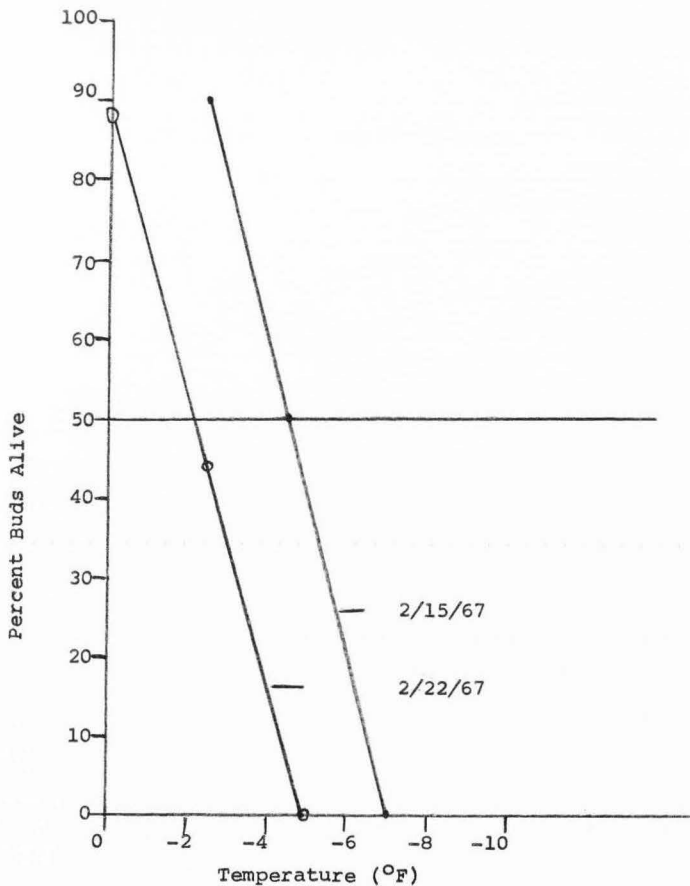


Figure 19. The T₅₀ values of Gleason Elberta peach flower buds for February 1967.

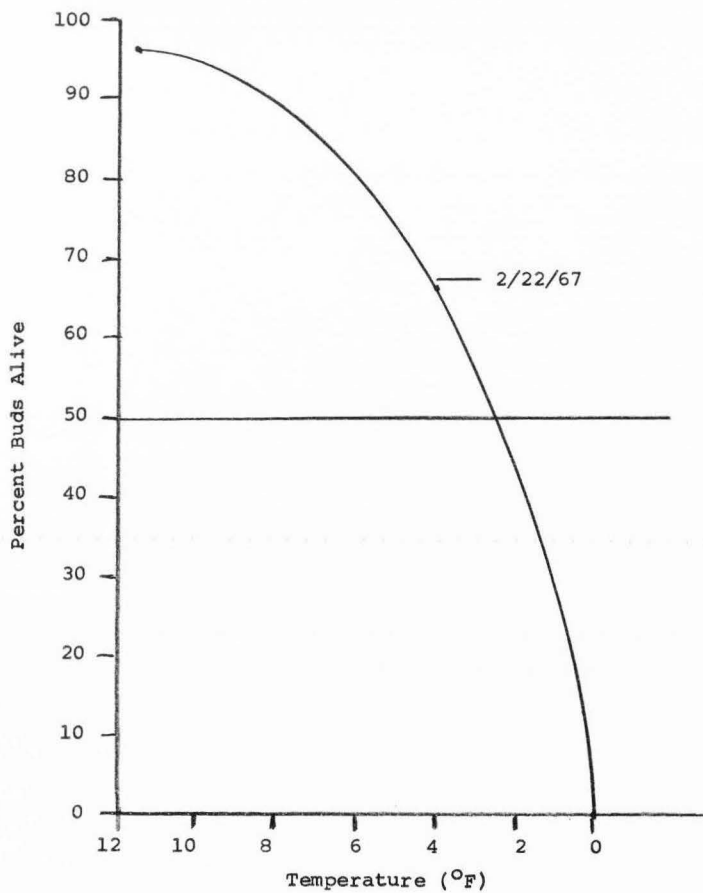


Figure 20. The T_{50} value of Chinese apricot flower buds for February 1967.

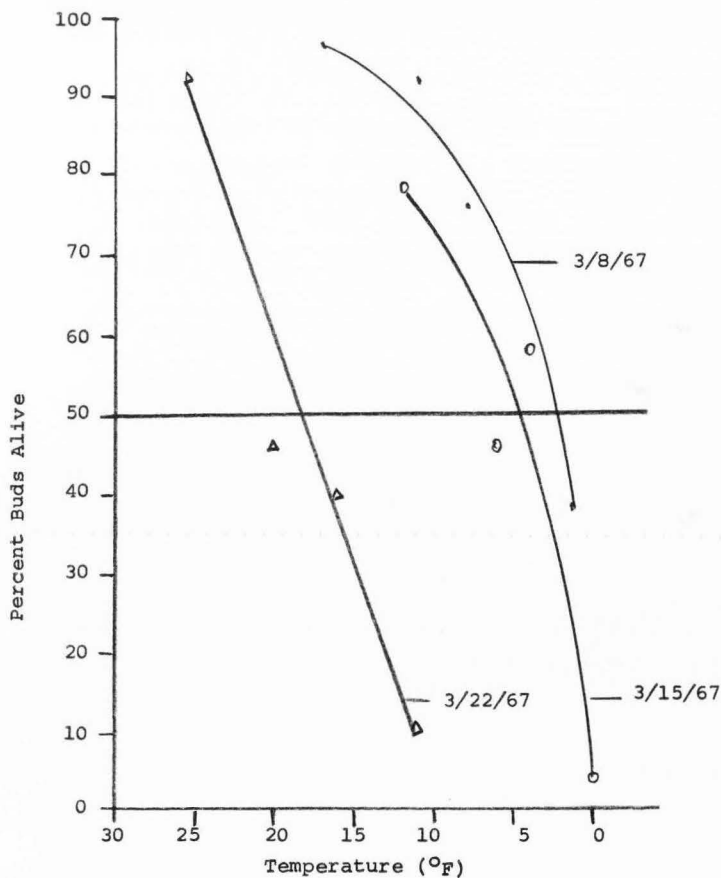


Figure 21. The T_{50} values of Gleason Elberta peach flower buds for March 1967.

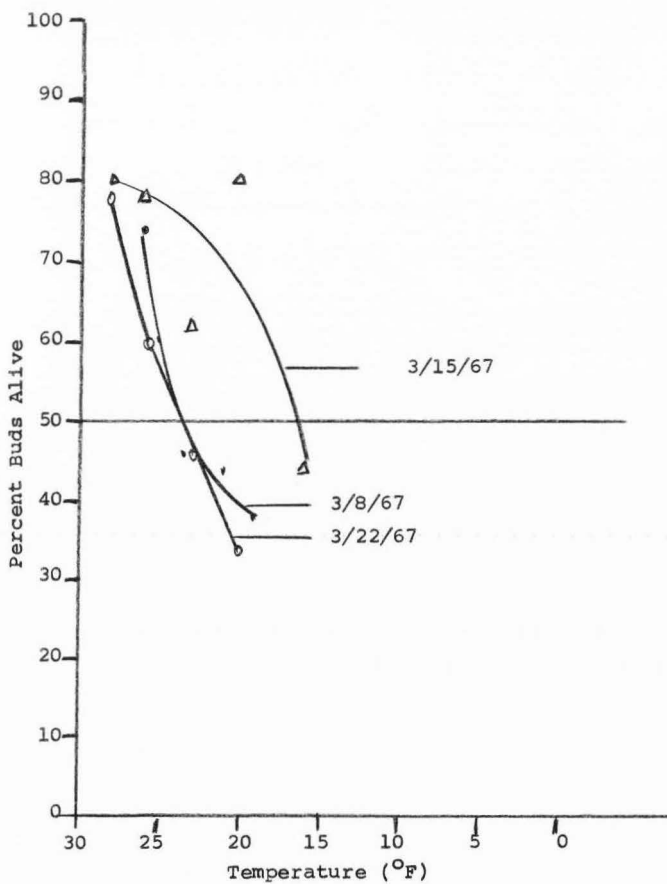


Figure 22. The T₅₀ values of Chinese apricot flower buds for March 1967.

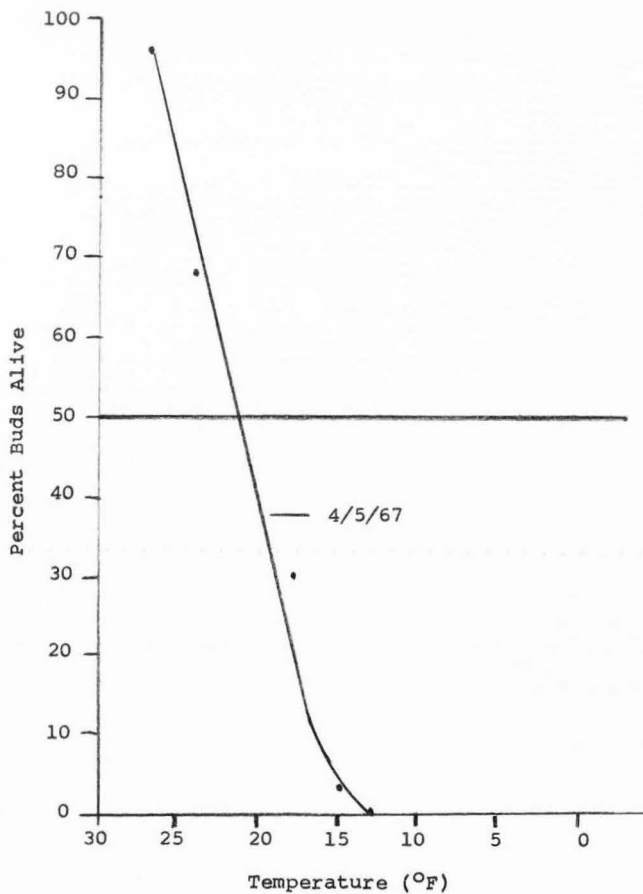


Figure 23. The T_{50} value of Gleason Elberta peach flower buds for April 1967.

Table 11. The average respiration ($\mu\text{l O}_2/\text{hr/g}$)^a, fresh and dry weights (mg) of Lovell peach seedlings flower buds removed after 800 hours of treatment.

Treatment	Respiration			Fresh weight			Dry weight		
	sampling periods ^b			sampling periods			sampling periods		
	1	2	3	1	2	3	1	2	3
Continuous 40 F	56.3 ^c	64.3	58.5	9.5 ^d	11.1	9.5	5.8 ^d	5.1	5.5
Continuous 32 F	56.7	42.1	48.3	7.9	6.8	8.0	5.0	5.7	4.7
Continuous light at 40 F	66.0	60.8	72.6	11.2	11.9	12.0	6.3	6.5	6.2
16 hrs of 40 F + 8 hrs of 32 F	65.8	61.7	77.8	10.2	11.9	12.2	5.9	6.5	6.5
16 hrs of 40 F + 8 hrs of light at 40 F	64.2	58.3	51.3	7.5	8.1	7.7	4.8	5.2	4.7
16 hrs of 32 F + 8 hrs of 40 F	68.8	64.9	62.5	9.2	9.6	10.6	5.6	5.5	6.1
16 hrs of 32 F + 8 hrs of light at 40 F	66.8	57.5	62.3	10.3	12.2	11.4	5.8	6.8	6.2
16 hrs of light at 40 F + 8 hrs of 40 F	70.6	48.7	43.6	11.1	13.2	10.4	6.5	7.4	6.0
16 hrs of light at 40 F + 8 hrs of 32 F	62.3	46.9	49.9	7.8	9.2	8.7	4.7	5.5	5.1

^aDry weight basis.

^bSampling periods were 2, 7, and 10 days after the trees were placed in the greenhouse.

^cAverage of 2 replications.

^dAverage of 40 buds.

Table 12. The average respiration ($\mu\text{l O}_2/\text{hr/g}$)^a, fresh and dry weights (mg) of Lovell peach seedlings flower buds removed after 968 hours of treatment.

Treatment	Respiration			Fresh weight			Dry weight		
	sampling periods ^b			sampling periods			sampling periods		
	1	2	3	1	2	3	1	2	3
Continuous 40 F	74.7 ^c	75.6	77.0	9.3 ^d	10.9	12.9	4.9 ^d	5.7	6.8
Continuous 32 F	69.2	70.3	70.9	8.4	11.9	12.0	4.9	6.2	6.3
Continuous light at 40 F	78.3	89.5	97.9	10.4	12.5	14.3	5.4	6.0	6.8
16 hrs of 40 F + 8 hrs of 32 F	68.1	65.6	70.0	9.7	11.3	11.4	5.7	6.2	6.2
16 hrs of 40 F + 8 hrs of light at 40 F	72.0	71.4	86.4	10.8	10.7	12.6	5.8	5.5	5.8
16 hrs of 32 F + 8 hrs of 40 F	59.9	62.5	68.0	8.2	8.0	6.9	5.3	5.0	4.5
16 hrs of 32 F + 8 hrs of light at 40 F	64.2	62.1	64.6	8.0	9.5	10.0	4.8	5.4	5.6
16 hrs of light at 40 F + 8 hrs of 40 F	66.8	60.3	67.1	9.3	11.7	9.8	5.6	6.5	5.6
16 hrs of light at 40 F + 8 hrs of 32 F	61.8	60.8	56.8	9.3	11.1	10.4	6.3	6.1	5.6

^aDry weight basis.

^bSampling periods were 2, 7, and 10 days after the trees were placed in the greenhouse.

^cAverage of 2 replications.

^dAverage of 40 buds.

Table 13. The average respiration ($\mu\text{l O}_2/\text{hr/g}$)^a, fresh and dry weights (mg) of Lovell peach seedlings flower buds removed after 1240 hours of treatment.

Treatment	Respiration			Fresh weight			Dry weight		
	<u>sampling periods^b</u>			<u>sampling periods</u>			<u>sampling periods</u>		
	1	2	3	1	2	3	1	2	3
Continuous 40 F	84.4 ^c	79.4	143.3	11.3 ^d	12.1	15.7	6.4 ^d	6.1	6.5
Continuous 32 F	64.4	58.2	132.3	11.0	9.5	14.9	6.3	6.2	6.8
Continuous light at 40 F	81.9	94.6	268.0	12.4	13.5	25.0	6.6	6.3	8.7
16 hrs of 40 F + 8 hrs of 32 F	76.4	81.3	141.7	9.8	10.0	16.1	5.2	5.0	6.0
16 hrs of 40 F + 8 hrs of light at 40 F	84.7	91.1	156.2	11.2	13.5	17.0	6.1	6.3	6.5
16 hrs of 32 F + 8 hrs of 40 F	64.6	67.4	97.7	11.1	10.2	13.1	6.3	5.7	6.2
16 hrs of 32 F + 8 hrs of light at 40 F	77.9	76.6	124.6	10.5	14.0	17.8	5.7	6.9	7.3
16 hrs of light at 40 F + 8 hrs of 40 F	68.4	72.5	78.3	10.8	11.6	10.8	6.4	6.5	6.1
16 hrs of light at 40 F + 8 hrs of 32 F	77.3	84.7	124.5	10.3	13.2	15.3	5.7	6.6	6.8

^aDry weight basis.

^bsampling periods were 2, 7, and 10 days after the trees were placed in the greenhouse.

^cAverage of 2 replications.

^dAverage of 40 buds.

Table 14. The percentage of Lovell peach seedling leaf buds growing on trees removed on December 17, 1966 after 800 hours of treatment and placed in the greenhouse.

Treatment	Sampling dates			
	1/10/67	1/24/67	2/10/67	2/21/67
Continuous 40 F	3.0 ^a	27.8	38.7	37.1
Continuous 32 F	0.2	1.4	1.8	2.3
Continuous 40 F + 24 hrs light	0.1	2.2	7.2	11.4
16 hrs of 40 F + 8 hrs of 32 F	0.3	8.9	27.0	30.3
16 hrs of 40 F + 8 hrs of light	0	1.9	24.7	28.5
16 hrs of 32 F + 8 hrs of 40 F	0	0.4	1.8	8.3
16 hrs of 32 F + 8 hrs of light	0	4.3	15.9	19.1
16 hrs of light + 8 hrs of 40 F	0.4	4.5	16.0	18.4
16 hrs of light + 8 hrs of 32 F	0	0	0.1	3.0

^aTotal of 3 trees.

Table 15. The percentage of Lovell peach seedling leaf buds growing on trees removed December 24, 1966 after 968 hours of treatment and placed in the greenhouse.

Treatment	Sampling dates			
	1/17/67	1/31/67	2/14/67	3/1/67
Continuous 40 F	1.0 ^a	34.1	56.4	56.8
Continuous 32 F	1.2	13.6	26.9	28.3
Continuous 40 F + 24 hrs of light	0.2	14.9	53.0	56.0
16 hrs of 40 F + 8 hrs of 32 F	0.2	24.9	46.6	47.5
16 hrs of 40 F + 8 hrs of light	0.1	33.2	50.1	51.5
16 hrs of 32 F + 8 hrs of 40 F	0	0.9	30.7	43.4
16 hrs of 32 F + 8 hrs of light	0	9.7	19.0	21.2
16 hrs of light + 8 hrs of 40 F	0.5	11.6	65.5	66.9
16 hrs of light + 8 hrs of 32 F	0.1	11.9	40.8	43.0
^a Total of 3 trees.				

Table 16. The percentage of Lovell peach seedling leaf buds growing on trees removed on January 4, 1967 after 1240 hours of treatment and placed in the greenhouse.

Treatment	Sampling dates		
	1/30/67	2/13/67	2/27/67
Continuous 40 F	8.3 ^a	79.8	79.9
Continuous 32 F	19.0	34.1	26.0
Continuous 40 F + 24 hrs of light	3.9	77.5	75.3
16 hrs of 40 F + 8 hrs of 32 F	47.4	95.0	96.5
16 hrs of 40 F + 8 hrs of light	10.8	82.1	84.9
16 hrs of 32 F + 8 hrs of 40 F	2.8	54.3	63.0
16 hrs of 32 F + 8 hrs of light	14.6	66.7	68.6
16 hrs of light + 8 hrs of 40 F	6.0	69.4	71.9
16 hrs of light + 8 hrs of 32 F	4.0	61.5	69.1

^aTotal of 3 trees.

Table 17. The daily maximum and minimum temperatures (°F) from October 1, 1966 to April 5, 1967.

Date	Maximum	Minimum	Date	Maximum	Minimum
Oct. 1	73	47	Nov. 15	61	53
2	66	47	16	57	41
3	60	38	17	55	39
4	64	42	18	59	39
5	72	48	19	61	40
6	73	49	20	63	47
7	74	48	21	47	35
8	72	43	22	51	28
9	68	41	23	42	26
10	71	49	24	38	24
11	71	56	25	39	24
12	60	36	26	40	27
13	36	29	27	47	29
14	44	29	28	50	40
15	52	30	29	44	38
16	56	35	30	44	37
17	57	37			
18	54	35	Dec. 1	47	37
19	67	38	2	54	44
20	59	39	3	46	35
21	48	30	4	44	35
22	44	31	5	48	34
23	58	39	6	35	30
24	64	39	7	35	30
25	66	41	8	33	20
26	72	43	9	30	20
27	71	43	10	30	27
28	68	40	11	35	27
29	68	40	12	33	28
30	66	40	13	40	28
31	64	36	14	38	26
			15	36	24
Nov. 1	62	38	16	36	23
2	64	38	17	30	24
3	61	35	18	29	26
4	58	35	19	28	26
5	61	40	20	27	26
6	56	56	21	28	19
7	51	34	22	30	12
8	36	24	23	29	12
9	34	28	24	25	20
10	40	33	25	28	22
11	45	40	26	31	25
12	49	41	27	29	18
13	60	44	28	22	17
14	60	49	29	22	12

Table 17. Continued

Date	Maximum	Minimum	Date	Maximum	Minimum
Dec. 30	30	12	Feb. 13	56	36
31	28	22	14	45	20
Jan. 1	30	22	15	30	23
2	32	16	16	32	26
3	34	26	17	42	32
4	40	33	18	44	24
5	38	18	19	36	23
6	22	20	20	37	20
7	30	13	21	41	21
8	28	19	22	43	24
9	32	16	23	53	31
10	30	16	24	60	31
11	27	18	25	52	31
12	30	16	26	44	27
13	38	30	27	47	29
14	42	37	28	56	29
15	44	29	Mar. 1	63	36
16	33	25	2	50	27
17	37	22	3	46	27
18	37	22	4	44	24
19	44	27	5	40	24
20	45	42	6	50	19
21	47	45	7	38	22
22	47	32	8	52	31
23	34	26	9	61	41
24	32	27	10	58	42
25	32	26	11	57	41
26	38	27	12	54	40
27	44	32	13	41	27
28	47	32	14	38	24
29	50	39	15	52	24
30	49	36	16	63	38
31	40	31	17	61	37
Feb. 1	42	30	18	50	36
2	44	32	19	46	32
3	44	30	20	50	33
4	45	30	21	56	35
5	41	27	22	65	40
6	40	26	23	65	
7	41	25	24	47	28
8	41	25	25	49	28
9	46	36	26	44	35
10	40	30	27	52	40
11	45	30	28	60	42
12	52	36	29	50	21
			30	34	21

Table 17. Continued

Date	Maximum	Minimum
Mar. 31	42	29
Apr. 1	42	31
2	47	30
3	62	40
4	67	38
5	44	29

VITA

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Candidate for the Degree of

Master of Science

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