5-1964

Effects of Chilling, Chemicals and Pruning on the Rest Period of Peach Trees

Ataollah Yazdaniha
Utah State University

EFFECTS OF CHILLING, CHEMICALS AND PRUNING ON THE REST PERIOD OF PEACH TREES

by

Ataollah Yazdaniha

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

of

MASTER OF SCIENCE

in

Horticulture

UTAH STATE UNIVERSITY
Logan, Utah

1964

ACKNOWLEDGEMENTS

I am deeply grateful to Dr. David R. Walker for serving as my major professor and for his many helpful suggestions in performing this study.

I wish to thank Dr. Leonard H. Pollard and Dr. R. L. Smith who also served as my committee members.

Thanks to Dr. LaMar Anderson who helped me in taking the pictures for this thesis and to Dr. Alice Denney for her assistance.

Many thanks to the people at Tehran University and Utah State University who made my stay at Utah State possible and provided financial assistance.

I am sincerely appreciative to my wife, Pouran, who encouraged me in continuing my graduate work and who patiently typed the drafts of this paper.

Ataollah Yazdaniha

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES CONTINUED

INTRODUCTION

Many deciduous trees enter a stage each year when their visible growth ceases. This is not always associated with cold weather or lack of water, and may occur with many species in mid-to-late summer. Trees entering this phase are said to be in rest. Rest is caused when internal factors are unfavorable for growth, while dormancy is defined as external factors being adverse for growth.

Rest in woody plants was first thought, about 1910, to be caused by cold temperatures. However, Coville (1920) states that deciduous trees enter rest regardless of cold temperature, with a certain period of effective chilling being required in order to break the rest. Plants in rest "harden" rapidly and are protected greatly against winter injury.

Investigations on different aspects of rest have been performed for more than half a century. Studies concerning the chilling requirements, optimum effective temperatures in breaking rest, environmental factors affecting rest, effects of chemical treatments on rest, chemical changes during rest and correlations among these factors with initiation and termination of rest have been reported.

Many published papers on chilling requirements of some fruit trees have been of value to the horticultural industry. Growers use this information as part of the basis when selecting desirable varieties for their specific areas.

Contradictory results however, caused by methods of chemical analyses, lack of facilities or improper procedures, especially in the area of biochemical studies of rest have been reported. Hence, much additional information is needed in order to understand the mechanism of rest.

Among climatic factors, suitable temperatures during the year play an important role in regard to the success of a fruit orchard. Extremely cold temperatures in the winter kill the flower buds which are potential fruit and, in severe cases, the trees themselves. Orchards may also suffer from mild winters. Prolonged rest as a result of relatively warm winters has been reported in fruit trees (Samish, 1948; Overcash and Campbell, 1955; Chandler, 1957; and Weinberger, 1956). Delayed foliation causes reduced growth of the trees; yields may be reduced and ripening delayed. Conversely, in those areas where the chilling period is adequate but a fluctuating temperature is present during the early spring, trees bloom as soon as weather is favorable, and late frosts often kill a high percentage of the flowers. In both cases, growers suffer from extensive losses. In order to curtail temperature problems, proper selection of varieties and the use of special cultural treatments are necessary.

Many chemicals for delaying or breaking the rest period have been reported, among which is dinitrocresol. This has been used commercially in Israel and other places for breaking rest (Samish, 1954). Gibberellic acid (GA) has been effective in breaking rest of non after-ripened or non-chilled peach

seeds (Donoho and Walker, 1957), and also non-chilled peach seedlings (Walker and Donoho, 1959).

Objectives

The objective of this study was to learn more about rest by studying the effects of cultural treatments in breaking rest. Specifically, the following objectives were considered:

1. To determine the effects of pruning, nitrogen fertilizer, chilling and gibberellic acid on breaking the rest period of leaf buds of peach seedlings.

2. To determine if there are fluctuations in the intensity of rest.

REVIEW OF LITERATURE

Presence of Rest in Trees

Two terms, rest and dormancy, pertaining to woody plants have been introduced by Samish (1954). Rest is defined as a condition in which growth does not occur under faborable environmental conditions, while dormancy, on the other hand, is a suspension of growth due to unfavorable external factors. Very slow growth occurs in some plant tissues during rest, indicating that all growth has not ceased. Pollock (1950) states that some investigators believe that periodicity and the rest tendency are inherited. Environmental conditions are effective, however, in lengthening or shortening the rest period. Chandler (1957) states that cyclic growth, known to occur in some tropical and subtropical trees, is not terminated by exposure to cold temperature which is the natural agent for removing the rest influence in deciduous trees in temperate regions. He suggests that growth cessations in tropical and deciduous trees are not the same. Mayer et al. (1963) mentions that the buds of temperate-zone trees, which develop during spring and early summer, go into a dormant stage several weeks before leaf abscission in the fall. If leaves are removed in mid-summer this stimulus is sufficient to break rest, and the dormant leaf buds begin to grow.

Both photoperiod and temperature have been reported as being factors in inducing bud dormancy. Long-day photoperiods

are helpful in delaying dormancy. When the leaves are shed, a long photoperiod usually is not able to break dormant buds (Bonner and Galston, 1952).

Samish (1960) states that buds which are in the axils of leaves which remain on the trees during late winter develop earlier than other buds in the spring. He postulates that the leaves are a perceptor of a photoperiodic stimulus causing auxins to be formed and inhibitors destroyed earlier in the spring than in those trees not having leaves.

Theories of Rest Location

In general, rest is believed to occur in the plant parts above ground. Bonner and Galston (1952) believe that the response to cold temperature for breaking rest is localized. They reported a study in which a branch of a resting tree was subjected to adequate cold temperature to break rest, while the remainder of the tree was maintained at a warmer temperature. Normal growth started only on the treated branch when the tree was placed under favorable growing conditions. There was no evidence that a substance was translocated.

Chandler (1957), on the other hand, indicates that the rest influence is not localized but is translocated through the stem, one part to another. He cites an experiment in which a non-resting scion grafted on a non-resting stock grew 26 inches, while a similar grafting with an unchilled stock (resting) on a non-resting scion resulted in only 1.1 inches of growth. He suggested that a substance from the unchilled

stock had been translocated to the growing buds and had stopped their growth.

Rogers (1941), using special methods, observed growth activity of the roots throughout the year. Apple trees under field conditions grew slowly during the winter period when the temperature was between 35 and 45°F. Root activity was correlated with soil moisture and temperature. The rate of root growth increased when the temperature and soil moisture increased, but rapid root growth was not observed. This indicates that apple roots do not have a rest period as do the stems and buds.

Translocation of the rest influence from one part to another part of the tree in some species of Pyrus were studied by Westwood (1963). He grafted Bartlett pear, which has a high chilling requirement, on Pyrus calleriana which has a low chilling requirement. He found that the grafted Bartlett on Pyrus calleriana had a lower chilling requirement as compared to Bartlett on its own roots, and also that a chilled Pyrus calleriana which had been grafted on a partially chilled Bartlett stem induced the resting Bartlett buds to grow. It was suggested that a partial transfer of rest influence between scion and stock was present.

Westwood (1963b) performed another experiment in which he tested chilling requirements for seed germination of different species of Pyrus. Results indicated that Pyrus betulaefolia and Pyrus calleriana have small chilling requirements. Pyrus amygdaliformis when obtained from a warm-climate

area required 15-35 days of cold temperature below 40°F, while those from a cool climate needed a period of 57 days to break their rest. French pear, Pyrus communis, had the highest requirement. Inter-specific cross tests showed that the chilling requirement was inherited. Westwood concluded that "seed chilling requirements are indicative of the winter chilling requirements of similar species or types of trees in the field."

Non-afterripened seeds often result in dwarf trees. The rest influence apparently affects seedling size. Flemion and Waterbury (1945) performed the following grafting experiments in an attempt to determine more about the causes of dwarfing: (1) dwarf scion on dwarf root, (2) dwarf scion on normal root, (3) dwarf seedling with a piece of normal stem interposed by grafting, (4) normal tip on normal root, (5) normal tip on dwarf root and (6) normal seedling with a piece of stem from dwarf seedling interposed by grafting. The trees in numbers 1, 2, and 3 were dwarf, but in numbers 4, 5, and 6 they were quite normal. Ample roots of suitable sizes were formed in all cases, hence it was concluded from this study that the area of rest influence was in the above-ground organs. Unchilled ecotyledonized embryos of peach seeds which were cultured under laboratory conditions produced normal seedlings, while under similar conditions, unchilled seeds with cotyledons produced abnormal seedlings (Flemion and Prober, 1960). The authors assumed that in unchilled seeds either the material for the normal growth for epicotyledonary axis and leaves

were lacking or unavailable, or inhibiting substances may have caused slow growth and abnormality.

External Factors Affecting Rest in Trees

Effect of temperature on rest

Cold temperature has been the main factor in breaking rest. Since early in the twentieth century, the role of heat and temperature on this phenomenon has been investigated.

Hodgson (1923) tested cuttings of 300 varieties of eight different fruit-tree species in the greenhouse. His observations showed that some species enter rest very late in the growing season, while others enter it much earlier. Thirteen commercial varieties of almond did not enter rest until November 20 or later, indicating that almonds start their rest period very late in the year. Apples, on the other hand, have a much longer rest period, entering it in mid-summer and terminating it in late winter. Since all cuttings (except almond) had maintained 2/3 to 1/2 of their leaves when the buds were in rest, he states that the presence or absence of leaves may not be involved with rest.

Chandler et al. (1937) studied chilling requirements for apples, pears, quince, peaches, almonds, apricots, plums, prunes, cherries, and many other trees and shrubs. They suggested that exposure to an average temperature of 48°F. for various periods of time is sufficient for breaking rest. After warm winters, shedding of buds occurs in species which have separate flower and leaf buds. Flower buds may also die

with species having combined (leaf and flower) buds, hence, reducing the number of flower buds per tree.

Yarnell (1939) reported large differences in rest requirements of a variety when the trees were grown in different locations in Texas. Elberta, for example, varied from 400 to 1200 hours of chilling to break rest, depending on where it was growing. In the warmer area of Winter Garden, only 400 hours of cold temperature below 45° F were required to break rest, while in the colder area of the Wichita Valley, 1200 hours of cold were required.

Brooks and Philp (1941) observed that peach and nectarine drop increases in years which have few hours of temperature below 45°F during the cold season. They classified many peach and nectarine varieties into four groups ranging from very light to very high bud drop.

Sisler and Overholser (1943) were able to estimate the approximate flowering time of the dormant buds of Delicious apples which had passed their rest period. A thousand hours above a daily maximum of 43°F from February 1 resulted in full bloom. Cold springs delayed blooming, while early blooming occurred during warm spring weather. A further study on chilling requirements of several peach varieties was performed by Weinberger (1950a). Early exposure to cold temperature did not break the rest as soon as when the cold occurred later in the winter. In other words, cold temperature in early winter is not as efficient in breaking rest as cold during mid-winter. As an example, in 1941 an accumulation of 750 hours below 45°F

temperature by early February was sufficient to satisfy the requirements of Hiley variety 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. Chilling in late winter after some of the buds started to grow was not effective in breaking prolonged dormancy of many varieties.

Generally, leaf buds require a longer period of cold temperature to satisfy rest than do flower buds. There is also a difference in variety requirements. Mayflower leaf buds require about 1250 hours, while Afterglow leaf buds require only 750 hours.

Prolonged dormancy in peaches and its correlation to winter temperature is discussed by Weinberger (1950b, 1956). Symptoms of prolonged dormancy are delayed foliation and flowering, irregular and deformed flowers, poor pollen production, abnormal conditions of stigma and style (they do not grow after the bud stage development), sun scald of fruit, poor crop and irregular size fruit with non-uniform maturity.

Weinberger correlated prolonged dormancy of Hiley and Elberta peach varieties with the mean temperature of November, December, January, and February in Fort Valley, Georgia, during 1937-54. Correlation coefficients of .28, .78, .87, and .59, respectively, occurred. Other correlations included temperatures of combined months including February and November, December and January, and December to February, which gave correlation coefficients of .90, .93, and .91, respectively. He also correlated the total chilling hours with prolonged

dormancy and found a -.91 correlation coefficient. This was interpreted to mean that the less chilling the greater the tendency towards prolonged dormancy. Weinberger stated that the chilling in November was not as effective as that in December and January in preventing prolonged dormancy.

Other studies concerning the effects of warm temperature during the chilling process were performed by Overcash and Campbell (1955a, 1955b). They worked with two peach varieties, Sunhigh, which has a short chilling requirement and Redhaven, which has a long chilling requirement. A portion of the trees were exposed to 70°F temperature for 8 hours each day, while during the remainder of the day they were held at 39°F. 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, which caused a delay in the opening of the buds and also reduced the number of buds that grew.

Brown and Kotob (1957) reported that both the dry and fresh weights of resting buds increased slightly through October and November, but the most rapid growth rate occurred when the major part or all of the rest influence had been removed. They suggested that quantitative measures (increases in weight and development) during the rest period could be used for determining chilling requirements of many varieties.

Effect of light on rest

Germination of certain kinds of resting seeds is induced

by light. As an example, Grand Rapids lettuce variety will not germinate in darkness (Galston, 1961). However, irradiation of the seeds with red light for a few minutes removes the rest influence, causing germination. Far red light has a reverse effect. The influence of red light is cancelled if followed by far red light. Conversely, germination of other seeds, like California poppy, is inhibited by light. Rest of Betula may be controlled by either light or temperature. Kawase and Nitch (1959) reported that the vegetative growth of Betula seedlings was interrupted after exposure to 10 hours of light. When these seedlings were transferred to long-day light conditions, there was a resumption of growth. The length of the long-day photoperiod necessary to cause a resumption of growth increased when the short-day exposure period was increased. The growth inhibiting effect was translocated from the branches which were in rest, but the growth promoting effect was not transferred to the resting branches. A detailed paper by Kawase (1961) explains the effects of light on resting buds of Betula pubescens and Betula lutea. In Betula pubescens, interruption of the short day photoperiod at night broke the rest. In addition, either cold treatment or long photoperiods broke rest. Continuous growth was obtained under 18 hours of light. Hoyle (1960), studying the factors affecting rest in black currant, found there was an interaction between day length and temperature for breaking rest. When the chilling period was inadequate, the long days were effective in breaking the rest of buds, but

under long-day conditions, the effect of chilling was not marked. More lateral buds were formed under the long-day conditions. Piringer and Downs (1959) working with apple and peach trees reported that 8 hours of daylight and 8 hours of supplementary fluorescent light resulted in increased stem length. Additional growth was not obtained from 8 hours of daylight and 8 hours of incandescent light compared to the initial 8 hours of daylight. The maximum number of flowering buds were obtained from 8 hours of daylight and 16 hours of fluorescent light. Peaches treated with an 8 hour photoperiod had shorter stems than when they received a 12 to 16 hour photoperiod.

Effects of water and fertilizer

Water and fertilizer are two important growth stimuli which affect bud development during the current growing season and bud opening the following year. Chandler and Tufts (1933) cited several examples of this having occurred in the mild-climate areas of California. They indicated that vigorous shoots growing in late summer were usually a result of excessive water and/or fertilizer. This type of growth has a longer chilling requirement and consequently will start growing much later in the spring. As an example, during the winter of 1929-30 an extremely mild winter occurred, and vigorous shoots on Northern Spy apple trees did not bloom until July 18, while buds on the weaker branches flowered much earlier. Red Canada and Cox Orange apple trees did not bloom that year on large shoots until July 22 and even in

September, respectively; the shorter shoots flowered much earlier. They cited other examples with peaches to support their theory.

Different results were obtained by Crane (Chandler and Tufts, 1933) who worked in West Virginia. Crane applied nitrogen fertilizer annually for 10 years, but no significant difference in bloom dates was found between treated and non-treated trees. The effect of irrigation on development of flowering buds and the bloom date was studied by Brown (1953). Irrigation treatments of (a) May, July, August and October; (b) July and August; (c) July; (d) None; (e) May and (f) May and July were applied to a Royal apricot orchard near Winters, California. His observations indicate that prolonged drought during July, August and September caused a reduction in the number of flowering buds which were differentiated, slower rate of their development and delay in bloom. Results of his experiment, however, are different from those of Chandler who worked with apples.

Internal Changes Associated With Rest in Trees

Hardiness changes occurring during rest

Deciduous trees start to harden and become more resistant to cold weather with gradual decrease in temperature. This natural process is very helpful for survival of trees during the cold season.

Howard et al. (1962) studied the relationship of some factors which influence hardiness changes of apple trees. A

large number of apple varieties were used in the experiments and the extent of injury was determined by the electrical conductivity method.

Significant differences were obtained in cold-hardiness resistance of apple varieties. As an example, Virginia Crab and Pioneer varieties had their maximum hardiness in the fall which later decreased rapidly during mid-winter, while the varieties Bedford and Anaros did not change in hardiness during the dormant season. The Robin variety gradually increased in hardiness as the season progressed but decreased rapidly in the late winter and early spring. On the basis of these trends and the minimum temperature which injures each variety, suitable varieties were recommended for a particular area.

Cold hardiness studies of peach trees have been performed by Edgerton (1960). He observed that buds which have passed their rest are still hardy, but are influenced more by periods of warm temperature, thus losing their hardiness faster than if they were in rest. Edgerton states that, "peach flower buds attain remarkable hardiness during the late summer and early fall even before cold temperatures prevail." Body tissues harden slowly in the fall with cold temperature, but increase in hardiness and become more hardy than the flower buds during mid-winter.

Extreme resistance of Hale Haven peach buds to cold temperature ($-10^{o}F$) occurred from a pre-exposed extended period of cold from late December to early January, resulting

in little bud injury. Edgerton also concluded that some cultural management practices such as early winter pruning and nitrogen fertilizer decreased cold hardiness of peach trees. Fruit thinning influenced the hardiness of peach flower buds during the following winter; the trees which had a heavier crop were injured more than those with a lighter crop.

Chemical changes occurring during rest

Many investigators have been trying to find which specific chemical(s) cause rest in plants but no satisfactory answer has been obtained yet. However, three major hypotheses are present in the literature. These are: 1. Auxin at high concentrations retards growth. 2. Inhibitors synthesized by the plant cause cessation of growth. 3. Auxin and inhibitors are involved in rest.

Biochemical processes which occur during and after termination of rest have been investigated. Enzymatic activity, changes in protein, amino acids, sugars and carbohydrates are some of the biochemicals that have been studied. Auxins and inhibitors have received considerable attention lately and appear as promising chemicals affecting rest. Auxins are naturally occurring growth promoters in plants which were first discovered 30 years ago. Many effects of auxins have been studied, but the primary mechanism of an auxin has not as yet been clearly determined (Galston and Purves, 1960).

An auxin is a growth promoting hormone, although it may also be a growth inhibitor if the concentration reaches a superoptimal level. One of the inhibitory effects of auxin is demonstrated by apical dominance in the plant. Inhibition of lateral buds may be caused by high amounts of auxin produced in terminal buds and translocated to the laterals. The auxin level in the plant may be inhibitory for one organ but promotive for another. Bud growth in general is inhibited at auxin concentrations of about 10^{-7}M, while inhibition of the stems occur at 10^{-3}M (Leopold, 1963).

Leopold postulates that auxin concentration plays an important role in organ differentiation. He stated that depending on the level of auxin, a cluster of meristem cells may develop either callus, root, vegetative or flowering buds.

Eggert (1953) studied the seasonal variations in spur bud auxin content of two varieties of apples, McIntosh and Northern Spy. He found a significant negative correlation between spur bud activity and total auxin content. He assumed that concentration of the total auxin inhibits the growth during the rest period.

Inhibitors in many cases inactivate the effect of auxin or some other plant promoters (Galston and Purves, 1960). A coleoptile growth inhibitor has been reported to occur during the rest period of potato tubers. It appears to reduce growth and amylase activity to a great extent (Hemberg and Larsson, 1961). Another coleoptile growth inhibitor, identified as

naringenin, was discovered in resting peach buds by Hendershott and Walker (1959). The inhibitor was at a high concentration in November, December, January and February and decreased during March. It disappeared two weeks before flowering.

Dennis and Edgerton (1961) studied seasonal fluctuations of methanol extractable inhibitors in Elberta and Halehaven peach varieties. They found a general increase of inhibitor in flower buds of Elberta peach variety during the period of October, 1959 to April, 1960. However, the difference between the levels of inhibitor in samples which were collected prior to rest termination and after rest was insignificant. The twigs which were forced to grow under greenhouse temperature between 65 to 75^{o}F completely eliminated the activity of extracts.

Bioassays of the extracts of the scales and primordia of Halehaven peach variety collected in March, 1959 revealed that the compound was confined to the scales. The results of the studies on Elberta peach variety during 1959-60 suggested that the inhibitor appeared diluted because of the reduction in bud scale to primordia ratio after the buds start to grow.

Breaking Rest by Chemical Sprays

Horticulturists as well as plant physiologists have been interested in identifying chemicals which would break and extend the rest period. They also desire to determine what mechanisms are involved in such reactions. Many

investigators have worked with different chemicals attempting to break rest. A phenolic compound, dinitrocresol, has been used commercially in Israel to break rest in several plants (Samish, 1954).

Chandler (1937) reported the effectiveness of dinitro-o-cyclohexylphenol in breaking the rest of some deciduous fruit trees in California. He indicated that oil emulsion sprays of this chemical on apricot trees hastened blossoming and maturity of fruit.

Weinberger (1939) tested various concentrations of chemicals in oil sprays under Georgia conditions. He found that .2 percent dinitrophenol (DN) and .06 percent of dinitro-o-cyclohexylphenol (DNO) were effective without any injury to the plants. The time of application was an important factor depending on chilling requirements of the variety. He stated that:

> Expressing the optimal dates in terms of previous cold weather the sprays were most effective with Hiley trees at Fort Valley in 1939 when approximately 600 hours of temperatures 45 degrees F or below had accumulated, with Early Rose 800 hours, Elberta flower buds 650 hours, Elberta leaf buds 800 hours, and Mayflower 900 hours.

Other chemicals were tested by Guthrie (1941) who used one-year-old Elberta peach trees and attempted to break rest of leaf buds under greenhouse conditions. In this study, a 1 percent spray of p-thiocresol, 4 chloro-o-phenylphenol and nitro-naphthalene were the most effective chemicals.

Specific information concerning the use of dinitrophenol sprays on a commercial scale in the United States was not

observed in the literature. Bonner and Galston (1952) did mention that it was used commercially, though the area of the world was not indicated.

Weinberger (1950b) mentioned that dinitrophenol sprays in the southeast in 1949 brought about advanced blossoming and foliation if applied at the proper time, but the fruit set was not greatly improved.

Donoho and Walker (1957) reported that GA sprays were able to break the rest of Elberta peach buds. Trees which had received 164 hours of cold temperature below 45°F increased their bud opening percentage and the average growth per shoot as the GA concentration was increased. The maximum dosage used was 4000 ppm.

Further studies were performed by Walker and Donoho (1959) who tested the effect of GA and chilling treatments or resting buds of two-year-old Elberta peach and Delicious apple trees. A 100 ppm GA was sufficient to break the rest of the peach trees which had received only 120 hours of cold temperature. Concentrations of 500 ppm and 1000 ppm GA tended to induce terminal bud but not lateral bud growth. This was less pronounced with lower concentrations of GA. Rest in apples was not broken, even with 4000 ppm GA.

Fogle (1958) was able to germinate non-after-ripened cherry seeds after soaking them in 1000 ppm GA for a period of 24 hours. The seedlings were rosetted, but this was cured by applying 100 ppm GA spray to the foliage of the seedlings.

Schoeneweiss (1963) tested various mixtures of GA with glycerol and ethylene glycol in an attempt to break rest of dormant oak seedlings. He observed that GA induced terminal bud growth while the other two chemicals stimulated lateral buds to grow. A combination of GA and either glycerol or ethylene glycol brought about normal foliation.

MATERIALS AND METHODS

GA (potassium gibberellate, 80 percent) sprays and soil applications of ammonium nitrate were applied to resting leaf buds of pruned and non-pruned young peach seedling trees. Two experiments were performed as follows:

A. A field experiment from September 8 to October 20, 1962.

B. A greenhouse experiment from December 15, 1962 to April 7, 1963. Trees used in the greenhouse study were one year old, while those in the field were three years old.

Field Experiment

On September 8, 1962, 92 three-year-old peach trees were selected from two rows of trees which had been previously planted at the University Experiment Station at Farmington, Utah. The trees were uniform in size with only slight variations. Thirty-six of the trees were used for the first phase of the experiment. Eighteen of them were pruned and treated with nitrogen fertilizer and GA sprays, while the remaining 18 were treated with similar nitrogen and GA treatments but were left unpruned. The pruning treatment consisted of removing one-half of the current seasons growth of all lateral branches. This treatment was the same for all experiments whenever pruning is mentioned.

The following treatments were applied to both pruned and non-pruned groups of trees:

1. GA, 100 ppm spray on foliage, and one pound of ammonium nitrate broadcast around the tree and mixed with the soil (about 2 to 4 inches deep) followed by an irrigation.

2. Same as treatment number 1, except 500 ppm GA was sprayed onto the foliage.

3. No GA spray, but fertilized and irrigated as above.

4. GA, 100 ppm, sprayed onto the foliage and the tree irrigated.

5. GA, 500 ppm sprayed onto the foliage and the tree irrigated.

6. Tree irrigated only (control).

Two weeks later, on September 22, a second group of 36 trees were treated the same as described above. In two additional experiments, 12 trees on September 15, and 8 trees on October 2 were also treated. The concentration of GA was increased to 500 ppm and 1000 ppm in the two smaller experiments (Table 1). There were three replications (single tree per replication) of the large experiments, initiated September 8 and September 22, and two replications of the two smaller experiments. In order to prevent contamination of neighboring trees with the spray materials in the air, polyethylene film was used to cover the adjacent trees at the time of spraying. A randomized block field design was used for interpretation of the results.

Three limbs from each tree having 3 to 10 lateral branches were measured at the time of each treatment and again on October

Table 1. A summary of the treatments applied to three-year-old seedling peach trees at Farmington, Utah, 1962

Treatments		Date of application	
		September 8	September 22
		No. trees	No. trees
A. Treatments applied to pruned trees[a]			
No fertilizer	1. No GA	3	3
	2. 100 ppm GA	3	3
	3. 500 ppm GA	3	3
Fertilizer[b]	1. No GA	3	3
	2. 100 ppm GA	3	3
	3. 500 ppm GA	3	3
		18	18
B. Treatments applied to unpruned trees			
No fertilizer	1. No GA	3	3
	2. 100 ppm GA	3	3
	3. 500 ppm GA	3	3
Fertilizer	1. No GA	3	3
	2. 100 ppm GA	3	3
	3. 500 ppm GA	3	3
		18	18
C. Treatments applied September 15, 1962			
1000 ppm GA and 1 lb. fertilizer		3	
1000 ppm GA		3	
1000 ppm GA and pruning		3	
Control		3	
		12	
D. Treatments applied October 2, 1962			
500 ppm GA		2	
500 ppm GA and pruning		2	
1000 ppm GA		2	
1000 ppm GA and pruning		2	
		8	

[a]Pruning refers to removing one-half of the current season's growth.

[b]One pound of ammonium nitrate broadcasted around the tree and watered into the soil.

20 to determine the amount of growth after treatment. The net growth was determined by subtracting the initial from the final measurement; this was then divided by the number of branches measured.

Numerous branches started to grow in the late fall in response to pruning and the application of the chemicals. The bud development, length of growth and general observations were used in evaluating the various treatments.

Greenhouse Experiment

On October 23, 1962, 36 one-year-old peach seedlings were obtained from a commercial nursery at Uintah, Utah, potted and placed in the greenhouse. On December 5, 1962, 65 more trees were obtained from the same nursery and potted. Thirty trees from the first group (A) and 38 trees from the second group (B) were selected for the experiment.

The first group had received 110 hours of chilling below 45°F in the field, while the second group had received 750 hours below 45°F, according to the Salt Lake Weather Station. All trees were kept in the greenhouse at 60 to 65°F and given natural sunlight until December 15 at which time 18 trees of the first group (lot A2) and 18 trees of the second group (lot B2) were placed in cold storage at 30°F for 8 and 11 days, respectively. The following four groups of cold-treated trees, as summarized below, were used for the greenhouse study.

1. Trees which had 110 hours below 45°F in the field (lot A1).

2. Trees which had 110 hours below 45°F in the field and 190 hours in cold storage beginning December 15, 1962 (lot A2).

3. Trees which had 750 hours of cold treatment in the field (lot B1).

4. Trees which had 750 hours below 45°F in the field and 250 hours in the cold storage room beginning December 15, 1962 (lot B2).

Some of the trees of lot A1 and B1 were treated with solutions of GA which ranged from 100 to 4000 ppm. Other trees were subjected to pruning and fertilizer treatments. This was done December 15 and these trees remained in the greenhouse. These treatments are summarized in Table 2. Trees in lots A2 and B2 were transferred to the greenhouse from the cold storage December 23 and 26, respectively, and treated within one day. One hundred grams of ammonium nitrate were divided into 3 equal portions, and each portion was spread around the tree at 10 days intervals. The approximate surface area of each pot was 30 square inches, and the fertilizer applied was calculated later to be about 20 tons/acre. Only a small amount was applied per pot, but it was not known at the time of application that this was such a large quantity when measured as tons/acre.

The extent of growth 60 and 100 days after treatment in the greenhouse and the number of growing buds after 100 days in the greenhouse were recorded. Branches one inch or longer were used in calculating the total growth. Buds that were green and starting to grow were considered as growing. Since

Table 2. A summary of the treatments applied to one-year-old seedling peach trees in the greenhouse at Utah State University, 1962-63

Code No.	Chilling hours	Treatment	No. trees
A. Group of trees which had 110 hours of chilling in the field			
(A-1)-1[a]	110	Outside control	2
(A-1)-2	110	Fertilizer[c]	2
(A-1)-3	110	Pruning	2
(A-1)-4	110	Pruning & 1000 ppm GA	2
(A-1)-5	110	1000 ppm GA	2
(A-1)-6	110	Control	2
			12
(A-2)-1[b]	300	Control	3
(A-2)-2	300	100 ppm GA	3
(A-2)-3	300	1000 ppm GA	3
(A-2)-4	300	4000 ppm GA	3
(A-2)-5	300	Pruning	2
(A-2)-6	300	Fertilizer[c]	2
(A-2)-7	300	Pruning & 1000 ppm GA	2
			18
B. Group of trees which had 750 hours of chilling in the field			
(B-1)-1[a]	750	Control	3
(B-1)-2	750	100 ppm GA	3
(B-1)-3	750	1000 ppm GA	3
(B-1)-4	750	4000 ppm GA	3
(B-1)-5	750	Pruning	2
(B-1)-6	750	Fertilizer[c]	2
(B-1)-7	750	Pruning & 1000 ppm GA	2
(B-1)-8	750	Outside control	2
			20
(B-2)-1[b]	1000	Control	3
(B-2)-2	1000	100 ppm GA	3
(B-2)-3	1000	1000 ppm GA	3
(B-2)-4	1000	4000 ppm GA	3
(B-2)-5	1000	Pruning	2
(B-2)-6	1000	Fertilizer[c]	2
(B-2)-7	1000	Pruning & 1000 ppm GA	2
			18

[a]A-1 and B-1 were placed in the greenhouse December 15, 1962.
[b]A-2 and B-2 were put in cold storage (30°F) on December 15 to complete the chilling treatment.
[c]Ammonium nitrate 33 percent was added at 10 day intervals and totalled 100 grams of fertilizer.

different lots (A1, A2, B1, and B2) had received pruning and chemical treatments at various dates, the growth measurements were taken at different dates so that each lot of trees had the same number of days for growth before measurement.

Two methods were used in evaluating the above treatments. These were:

a. Disproportional analysis of variance for evaluating the growth measurements of the trees receiving different treatments.

b. Visual observations of bud development (leaf and branch formation) and any other differences caused by treatment which were not apparent by statistical methods.

RESULTS

Results of the experiments are presented in two separate sections, the field experiment and the greenhouse experiment. The effects of time of application, GA concentration, pruning and soil application of nitrogen fertilizer are discussed under each section.

Field Experiment

Effect of GA and the time of GA application on breaking rest

Highly significant differences in growth occurred among the trees treated with GA on the two different dates of application (September 8 and 22). Treatment with 500 ppm GA stimulated the terminal buds, although very few of the lateral buds grew when GA was applied September 8. The same treatment applied September 22 was ineffective on terminal as well as lateral buds. Somewhat unfavorable cold temperature during the period from September 22 to October 20 occurred, which probably reduced the growth to a great extent. An increase in rest intensity might also have occurred and reduced growth.

The trees which received 1000 ppm GA September 15 grew an average length of 1.4 inches, while those receiving 500 ppm GA September 8 grew 1.3 inches. The pruned trees sprayed with 500 ppm GA September 8, those sprayed with 1000 ppm GA September 15, and those sprayed with 500 ppm September 22 had a maximum growth of 11, 7.5, and .5 inches, respectively. Only

a small amount of growth occurred with the trees treated September 22 because of the cold evening temperatures. The trees pruned in September started to grow, although the unpruned trees did not, even though both received 500 ppm GA.

It appears that either rest intensity in late fall increases and/or that GA is not effective on trees which are at slightly above the minimum temperature for growth. Treatments such as pruning or an application of fertilizer increased the rate of growth in addition to GA alone. A suitable temperature, however, is required in order to stimulate growth.

Effect of GA concentration on breaking rest

Unpruned trees responded little to GA treatments, although only the highest concentration (500 ppm) applied September 8, 1962 was effective in starting growth. The average growth of trees receiving the 500 ppm treatment September 8 was 1.36 inches, while the trees which were sprayed with 100 ppm GA and the untreated trees grew an average of .14 inches and .13 inches, respectively.

The analysis of variance indicated that there were no significant differences among trees receiving different GA treatments. The date of application and GA interaction, however, was very close to being significant at the .05 level. The date of application was significant at the .01 level. It is assumed that if the growth of trees treated on the first date (September 8) were analyzed separately a significant difference among GA concentrations would have been evident. The

lack of growth occurring on trees receiving treatments later in the season resulted in overall differences being insignificant. The response to GA treatment varied considerably between trees receiving the same treatment. For example, of the trees receiving the 500 ppm GA treatment on the same date, one tree had an average growth of .23 inches and another one 2.83 inches. The variability situation had greatly affected the statistical analyses. Variation occurred within most of the treatments. This was especially evident with trees treated on the first date (September 8). These variations may have been caused by the depth of rest in the individual trees at the time of treatment.

Pruned trees responded somewhat differently to GA treatments than unpruned ones. GA applied at both 100 ppm and 500 ppm stimulated resting buds to start growing in the fall. The response was very rapid. Trees which were observed September 15, one week after treatment, had grown 1 to 1.5 inches, while the untreated trees had not shown signs of growth. The trees which had received 500 ppm GA had grown more than those receiving the 100 ppm. Apical dominance was removed by pruning the terminals, which resulted in the growth of several lateral buds (Table 3). The uppermost bud on each pruned limb, however, produced a very large shoot, while the lower buds grew very little. Growth of trees receiving 100 and 500 ppm GA was significantly more than growth of the control tree (Table 4). Trees receiving the 500 ppm GA sprays grew much more than those receiving the 100 ppm GA sprays (Table 3, Figure 3).

Table 3. The effects of nitrogen fertilizer and GA treatments on resting buds of pruned peach trees

Treatments				
Date of treatment	Ammonium nitrate lb./tree	GA ppm	Largest shoot inches[a]	Remarks
		0	.5	Very few buds growing
	0	100	4.5	Some of buds growing
		500	11.0	Most of the buds growing
9/8/62				
		0	.8	Very few buds growing
	1	100	4.0	Most of the buds growing
		500	12.0	Most of the buds growing (very succulent)
		0	0	Few buds swelling
9/22/62	0	100	.2	Very few buds growing
		500	.5	Few buds growing
		0	0	No growth
9/22/62	1	100	.5	Very few buds growing
		500	.8	Few buds growing
9/15/62	0	1000	7.5	Most of the buds growing
10/2/62	0	1000	.1	Very few buds growing

[a]All measurements and observations were recorded on October 20, 1962. The largest shoot is referred to as the one observed among 3 determinations for each treatment; this shoot developed from one of the lateral buds.

Table 4. Effects of nitrogen fertilizer and GA sprays on growth of pruned, resting peach trees

Date of treatment	Ammonium nitrate lbs./tree	GA sprays (ppm)	Av. growth (inches)[a]
	0	0	.03
		100	2.83
		500	9.66
Sept. 8, 1962			
	1	0	.30
		100	3.50
		500	10.66
	0	0	0
		100	.13
		500	.43
Sept. 22, 1962			
	1	0	0
		100	.16
		500	.70

Date means

Sept. 8	4.5
Sept. 22	.23
LSD .05	NS

Fertilizer means

0 lb.	2.1
1 lb.	2.5
LSD .05	NS

GA means

0 ppm	.08
100 ppm	1.65
500 ppm	5.36
LSD .05	.77
LSD .01	1.14

[a]Growth was measured on October 20, 1962.

Leaves growing on the new shoots were somewhat narrower in size in all cases and slightly yellow. This pattern was more pronounced on trees receiving the high concentrations of GA. Fertilizer treatments had little effect on greening the leaves. The new shoots were thinner than normal, and the internodes were longer than usual.

Effect of pruning on breaking rest

Pruning alone was not effective in breaking rest, although a little growth occurred when the pruned trees were fertilized (average .3 inches). A large interaction occurred between trees receiving pruning and GA treatments (Figure 1 and Table 4). An application of 100 ppm GA on pruned trees caused more growth than when 500 ppm GA was applied without pruning. GA increased terminal growth much more than lateral growth with unpruned trees, but it also stimulated the laterals when pruning occurred. The proportion of stimulated buds was much higher with the pruned trees than with the unpruned trees.

There are a few possibilities that may explain the difference in growth between pruned and unpruned trees receiving GA applications. It seems logical to assume that a chemical change occurred within the plant. This change may be due to a production of hormone(s), which had a synergistic effect with GA, a removal of accumulated high amounts of auxin and/or inhibitors which have been present in the upper part of the shoots or some other chemical change.

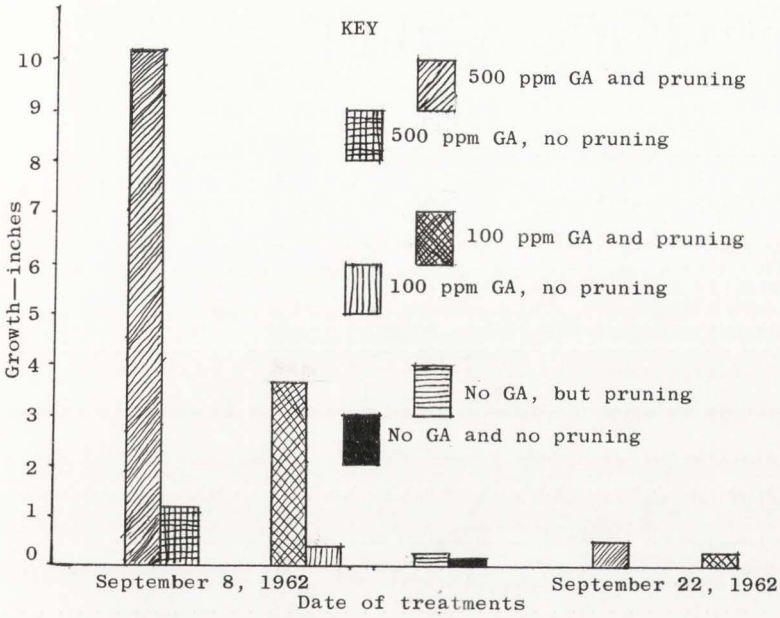

Figure 1. Effects of GA concentrations, time of application and pruning on breaking rest and bud growth of resting peach trees. Growth recorded October 20, 1962. Unpruned trees which were treated September 22 did not grow regardless of GA treatment. The growth of trees treated at either dates of September 8 or 22 were recorded October 20, 1962.

Figure 2. A three-year-old peach tree which had one-half of its current seasons growth pruned September 8. Very few buds were stimulated slightly and started to grow. (Photographed October 20, 1962)

Figure 3. A peach tree treated similarly as in Figure 2, except it received also a spray of 500 ppm GA September 8. The ruler indicates nearly 6 inches of growth occurred from lateral resting buds within 42 days after treatment. (Photographed October 20, 1962)

Effect of nitrogen fertilizer on breaking rest

Under the conditions of this experiment, nitrogen fertilizer did not break the rest, although it caused a little more growth of the buds which were stimulated by GA sprays (Tables 4 and 5).

Greenhouse Experiment

Effects of chilling, GA, pruning, and nitrogen fertilizer treatments were evaluated by analysis of variance and visual observations. Two sets of disproportional analysis of variances were performed. The means of the measurements are shown in Tables 6 and 7. Since the number of trees were different among treatments because of earlier death of some of the trees, the LSD value could not be calculated; however, the differences among the means of Tables 6 and 7 are discussed in the related sections. Table 6 shows the effects of different chilling temperatures on 1000 ppm GA treated, pruned and unpruned peach trees. Table 7 indicates the influence of 4000 ppm GA, pruning plus 1000 ppm GA, 100 ppm GA and no GA treatments on the trees which had received 300, 750 and 1000 hours of cold temperature below $45^{o}F$.

Effect of chilling

Trees which received 110 and 300 hours of cold temperature but not any of the other treatments did not produce any growth of one inch or longer during a period of 100 days in the greenhouse. The average number of buds which showed greening or

Table 5. Effects of nitrogen fertilizer and GA sprays on growth of unpruned resting peach trees

Date of treatment	Ammonium nitrate (lbs./tree)	GA spray (ppm)	Av. growth (inches)[a]
September 8, 1962	0	0	.14
		100	.13
		500	1.36
September 8, 1962	1	0	.44
		100	.38
		500	.90
September 22, 1964	0	0	.03
		100	.01
		500	.01
September 22, 1964	1	0	.06
		100	.25
		500	.04

Date means

Sept. 8	.56
Sept. 22	.07
LSD .05	NS

Fertilizer means

0 lb.	.28
1 lb.	.35
LSD .05	NS

GA means

0 ppm	.17
100 ppm	.19
500 ppm	.57
LSD .05	.76

[a]Growth from date of treatment until October 20, 1962.

Table 6. Summary of the effects of chilling, pruning and 1000 ppm GA treatments on breaking rest and subsequent growth of one-year-old peach trees under greenhouse conditions

Chilling hours	No. trees	Treatment	Average growth 60 days (inches)	Average growth 100 days (inches)	Total growth 60 days (inches)	Total growth 100 days (inches)	Number of buds growing 100 days
110	2	Control	0	0	0	0	3
	2	Pruning	0	0	0	0	3
	2	1000 ppm GA	3.6	3.8	47.4	50.6	24.5
		Average	1.2	1.2	15.8	16.8	10.1
300	3	Control	0	0	0	0	11
	2	Pruning	0	7.4	0	42.1	18
	2	1000 ppm GA	6.9	11.2	23.5	42.4	7.5
		Average	2.3	6.2	7.8	28.1	12.1
750	3	Control	3.5	9.1	7.1	24.6	10.8
	2	Pruning	6.2	8.3	55.8	77.4	22
	3	1000 ppm GA	3.7	5.7	113.2	112	38
		Average	4.4	7.7	58.7	71.3	23.6
1000	1	Control	4.2	5.9	55.6	59.6	17
	2	Pruning	5.4	7.6	41.6	61.4	15
	1	1000 ppm GA	10.4	10.6	83.7	96.4	14
		Average	6.6	8	60.3	72.4	15.3

Measurements	Treatment means		
	Control	Pruning	1000 ppm GA
Average growth 60 days (inches)	1.9	2.9	6.1
Average growth after 100 days (inches)	3.7	5.8	7.8
Total growth after 60 days (inches)	15.6	24.3	66.9
Total growth after 100 days (inches)	21	45.2	75.3
Number of buds growing after 100 days	10.4	14.5	21

Table 7. Summary of the effects of different GA concentrations and chilling treatment on breaking rest and subsequent growth of one-year-old peach trees under greenhouse conditions

Treatment	No. trees	Chilling hours	Average growth 60 days (inches)	Average growth 100 days (inches)	Total growth 60 days (inches)	Total growth 100 days (inches)	Number of buds growing 100 days
Control	3	300	0	0	0	0	11
	3	750	3.5	9.1	7.1	24.9	10.6
	1	1000	4.2	5.9	55.6	59.6	17
		Average	2.5	5.0	20.9	28.1	12.8
100 ppm GA	3	300	0	1.3	0	4.5	26.6
	3	750	1.9	2.8	11.5	17.0	51.0
	1	1000	5.1	7.8	46.2	47.1	14
		Average	2.3	3.9	19.2	19.5	30.5
1000 ppm GA	2	300	4.4	5.8	79.1	88.7	25.6
and	3	750	5.7	5.9	113.6	139.7	43
pruning	3	1000	8	9.5	71.8	77.3	12
		Average	6.0	7.0	88.1	101.9	26.8
4000 ppm GA	2	300	7.3	8.6	178.1	233.6	42
	3	750	4.7	6.2	181.9	238.7	37
	1	1000	0	7.8	0	78.1	23
		Average	4	7.5	120	183.4	34

Measurements	Chilling means		
	300	750	1000
Average growth after 60 days (inches)	2.9	3.9	4.3
Average growth after 100 days (inches)	3.9	6	7.7
Total growth after 60 days (inches)	64.3	78.5	43.4
Total growth after 100 days (inches)	81.7	105	65.5
Number of buds growing after 100 days	26.3	35.4	16.5

leafing were 3 for 110 and 11 for 300 hours. A few leaf buds which opened were mainly terminals and produced rosettes (Figures 4 and 5, and Table 6).

During the first 60 days in the greenhouse, those trees with 750 hours developed new branches and were moderately active between the period of 60 to 100 days. Those trees receiving the 1000 hours of chilling were not very active during this period. Out of this second group only one tree grew. The average growth of those with 750 hours was 3.5 and 9.1 inches after 60 and 100 days, respectively, but the trees chilled for 1000 hours grew an average of 4.2 and 5.9 inches after these time periods (Table 6). This indicates that the less-chilled trees had more growth during the period of 60 to 100 days than they did during the first 60 days. The number of growing buds and total growth on the trees with 1000 hours of chilling were greater than the number on trees receiving 750 hours of chilling (Figures 6 and 7, and Table 7).

Some of the trees which were put in cold storage (at 30°F) for partial fulfillment of their chilling requirement were desiccated when removed and placed in the greenhouse. The high velocity of cold air circulating in the cold storage room probably was the main factor causing this. The trees which remained 250 hours in cold storage showed more injury than those that were chilled 190 hours in storage.

Daily observations indicated that trees which were artificially chilled had a much slower bud activity shortly after treatment with GA than trees not held in cold storage. Many trees recovered from the desiccation in the cold storage

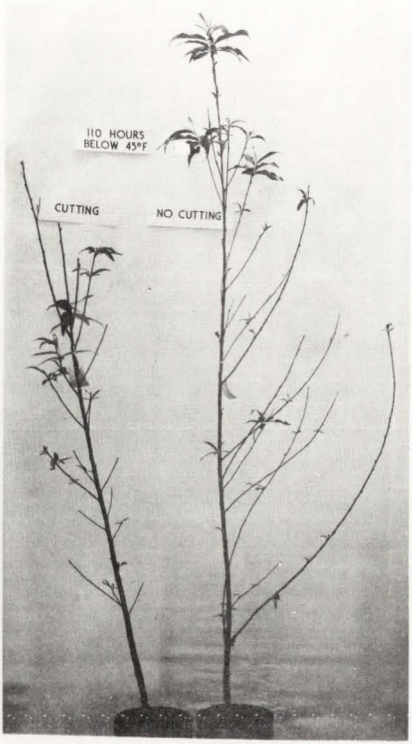

Figure 4. Two trees which had received 110 hours of cold below 45°F in the field and remained in the greenhouse from October 23, 1962 to March 25, 1963. The tree on the left was pruned December 15. Rest was not broken by these treatments, hence growth did not occur. (Photographed March 23, 1963)

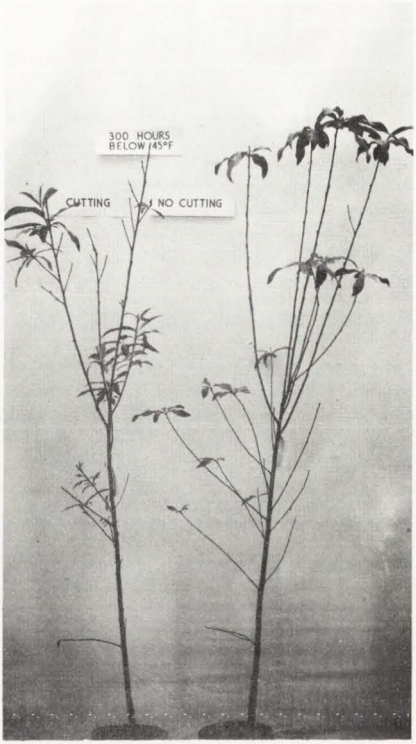

Figure 5. Two trees which had received 110 hours of cold temperature below 45°F in the field and 190 hours in cold storage, followed by 99 days in the greenhouse. Pruning was performed December 24, 1962. Rest was not broken by these treatments, hence growth did not occur. (Photographed March 23, 1963)

Figure 6. Two trees which had received 750 hours of cold below 45°F in the field then remained in the greenhouse during the period from December 5, 1962 to March 25, 1963. The tree on the left was pruned December 27, 1962. (Photographed March 23, 1963)

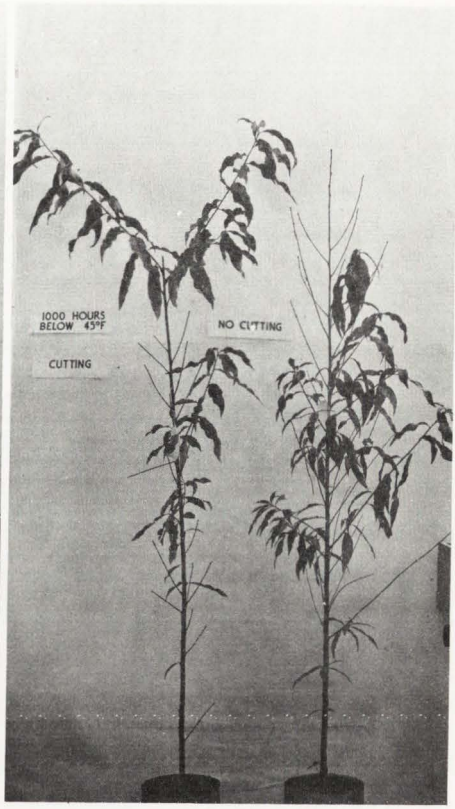

Figure 7. Two trees which had received 750 hours of cold temperature below 45°F in the field and 250 hours in cold storage followed by 96 days in the greenhouse. Pruning was applied December 27, 1962. (Photographed March 23, 1963)

and eventually grew more than trees having less chilling hours. Some of the trees were so seriously injured they died. With many of the trees, part of the branches died, but the rest of the tree recovered. These trees were removed from the experiment. As a result, some of the treatments had only one replication.

Effects of GA treatments

Longer shoot growth and a greater number of buds actively growing were observed on trees that were treated with GA sprays compared with those not receiving this treatment. The 300 hours chilled trees which had been sprayed with 100 ppm GA did not produce any shoots of one inch or longer during the first 60 days after treatment, but had an average growth of 1.3 inches after 100 days. The average number of growing buds was 26.6 which was considerably more than 11, the number for the controls.

Applications of the higher concentrations of GA generally resulted in more growth. The rate of growth was fast immediately after the buds started to grow; the growth slowed down sooner in those trees which received lower concentrations of GA sprays. For example, a comparison between the means of corresponding values for 100 ppm and 4000 ppm GA-treated trees in Table 7 indicates that a high concentration of GA stimulated the resting buds to grow and the buds continued their growth throughout a long period of time. A lower concentration which breaks the rest can not maintain a high rate of subsequent growth, and the growth eventually stops after a

few weeks.

The maximum growth was obtained from the trees treated with 4000 ppm GA sprays (Figure 8 and Table 7).

The results did not show any pruning-GA interaction, and even the growth was slightly less for the pruned trees with 750 hours chilling and 1000 ppm GA sprays as compared with similar treatments but on unpruned trees.

The trees that received 1000 hours of chilling with either 1000 or 4000 ppm GA sprays had less growth than those which had 750 hours of cold treatment and corresponding GA sprays. Conversly, the 1000-hours chilled trees with 100 ppm GA, or no GA sprays grew better than the 300 or 750-hours chilled trees receiving a 100 ppm GA treatment.

Effect of pruning

Overall means of pruning treatments were higher for average and total growth after 60 and 100 days, and the number of growing buds, after 100 days. Pruning did not break the rest of the trees receiving 110 hours of chilling, but it had some effect on those chilled for 300 hours (Table 6). The growth of the 750-hours chilled and pruned trees was considerably more than that of the controls. Those which received 1000 hours of cold temperature, both pruned and unpruned, had almost the same growth. The shoots which were formed on the pruned trees were fewer in number but more vigorous (Figures 4, 5, 6, 7, and Tables 6 and 7).

Figure 8. Tree on left received 300 hours of chilling below 45°F in the field and in cold storage, then was treated with 4000 ppm GA and remained in the greenhouse for a period of 100 days. Tree on right received treatments similar to that of tree on left, but was treated with 100 ppm GA. (Photographed March 25, 1963)

Effect of nitrogen fertilizer

One hundred grams of ammonium nitrate which were gradually added in three 10 day intervals to each tree inhibited the growth for 80 days. No evident signs of growth were observed on fertilized trees, while opening of buds or shoot development occurred on control trees. The trees chilled for 1000 hours and 750 hours were killed by high amounts of fertilizer. One tree receiving 300 hours cold also died, but the trees of the 110-hour lot remained alive. After 80 days, many buds on the remaining trees opened; they did not form any shoot growth of one inch or longer although the number of opened buds was numerous. In none of the other treatments was there such a high number of buds stimulated. Trees receiving 300 hours of chilling had larger leaves but approximately the same number of growing buds.

This condition may have been caused by a high osmotic pressure in the soil solution which inhibited water uptake in the plant, since no buds grew for long periods of time. Gradual irrigation may have reduced the fertilizer concentration of the soil solution at which time the trees were able to absorb water from the soil. An extended warm period in the greenhouse and high amounts of nitrogen might have influenced some biochemical processes and stimulated lateral bud growth although the buds failed to develop further (Figure 9).

Effect of GA application on lateral and terminal buds

On December 15, 1962 four remaining from the A1 group

Figure 9. Tree on left received 110 hours of chilling below 45°F after which it was placed in the greenhouse October 23, 1962. Tree in center received treatments similar to those given to tree on left, except it was heavily fertilized with ammonium nitrate. Tree on right received treatments similar to those given to tree in center, except it received an additional 190 hours of artificial chilling before fertilizer treatment. (Photographed March 25, 1962)

were chosen for this experiment. A solution of 4000 ppm GA was applied only on the terminal buds of two trees and on the laterals of the other two. The trees were held at 60-65°F temperature.

After five to eight days terminal buds of both groups started to grow but only some laterals of the trees which had received GA on their lateral buds were slightly stimulated. The growth rate was relatively fast during the first two weeks but eventually stopped in those trees in which only terminals were treated, but growth of terminal buds continued in those which only laterals had been treated (Figures 10 and 11).

This observation might be interpreted as follows: the effect of GA is mainly on the terminal bud or closest lateral bud to the tip if pruning occurred. GA itself and/or the other products which might have been formed in the lower buds may have been translocated to the upper parts. A major part of the GA applied on several lateral buds possibly cancelled the effects of rest-causing agents and the remainder translocated to the terminal buds which stimulated them to grow. Presumably the quantity of GA applied on terminal buds was not sufficient to remove the rest influence completely, and as a result, the bud stimulated to burst, and grew only a little. GA may not be translocated down, hence laterals remain dormant when just terminals are treated.

Figure 10. Tree which received 110 hours of cold temperature (below 45° F) in the field before being placed in the greenhouse where terminal buds only were treated with 4000 ppm GA December 15, 1962. (Photographed March 25, 1963)

Figure 11. Tree which received 110 hours of cold temperature (below 45°F) in the field before being placed in the greenhouse where lateral buds only were treated with 4000 ppm GA December 15, 1962. Notice the stimulation of terminal buds but only a little growth of the lateral buds. (Photographed March 25, 1963)

DISCUSSION

Application of GA sprays at 500 ppm under field conditions broke the rest of leaf buds on three-year-old peach trees when applied September 8, 1962. One hundred ppm was not as effective as 500 ppm, perhaps because of the rest intensity at that time. The factor of decreasing temperature during the period of study was an uncontrollable factor in the field. No growth was obtained from trees treated as above on September 22 which may be interpreted as an increase having occurred in rest intensity, however the lower temperature occurring later in the fall may also have been an important factor suppressing growth. Growth did not occur and the temperatures were fairly warm during the day, hence, it was assumed that the intensity of rest increased from September 8 to September 22. GA sprays were able to remove the rest causing agents and/or stimulate the buds, thus activating the growth processes.

Pruning alone had little or no effect on growth under the field conditions. A little growth occurred when pruned trees were fertilized (Table 3) and a small growth response was obtained in the greenhouse when one-year-old peach trees which had received 750 hours of chilling below 45°F were pruned. It seems that pruning does have a little effect on the trees which have completed a major portion of their chilling requirement.

In the greenhouse experiment, however, a 1000 ppm GA spray applied to pruned trees which had received 300, 750, and 1000 hours of chilling below 45°F had little effect as compared with corresponding treatments without pruning.

The data presented in this paper have not determined the reason that GA was highly effective on pruned trees in the field and not so under the greenhouse conditions. However, one or more of the following assumptions may have been involved in this process: (1) Presence of leaves under field conditions increased the absorption surface of GA so that a greater amount of GA may have been absorbed and translocated to the growing points. It is presumed that the existence of the terminal bud, as is believed necessary for apical dominance, contains high amounts of auxin and probably some inhibitors which inhibits growth of lateral buds or even the terminal buds during the rest period. Removal of terminal buds may allow growth of lateral shoots in the absence of rest, but other stimulating treatments such as GA may be necessary in order to bring rapid growth. (2) In certain periods of rest, pruning may cause production of growth promoting substance(s) which may provide a stimulating effect when applied with GA. (3) The function of leaves in production of any growth promoting substance(s) or any change in inhibitor(s) and photosynthesis products necessary for growth presumably are other factors which may have influenced the growth rate in the field experiment. In order to understand more about the changes which occur in the tree after GA and pruning treatments, detailed

chemical analyses would be necessary.

Under the field conditions, both pruned and unpruned trees which were treated with 500 ppm GA grew more than trees receiving 100 ppm GA. Both concentrations were applied September 8, 1962. In the greenhouse, 4000 ppm GA, the highest concentration applied, produced the most succulent growth when applied to trees receiving 300 and 750 hours of chilling (Figure 8 and Table 7).

The data presented in Table 7 for total growth after 60 and 100 days indicates that the lower GA concentration (100 ppm) resulted in less growth during the first 60 day period and also less growth between 60 and 100 days after treatment than those treated with 4000 ppm GA. This would indicate that GA cancelled or interacted with the rest-causing materials and stimulated resting buds to grow shortly after the treatment.

A 4000 ppm GA solution which was applied to all terminal buds of trees chilled 110 hours resulted in little growth of terminals; however, the same treatment applied to lateral buds resulted in large shoot development from terminal buds. This observation could be interpreted as a small amount of GA which had been applied to the terminal buds could not have been very effective, but a larger amount which was applied to several lateral buds perhaps was sufficient to cause further developments.

Four different chilling periods (110, 300, 750, and 1000 hours) of cold temperature below 45°F were applied to

one-year-old peach seedling trees. Resting buds on trees which received 110 hours in the field and those with 110 hours in the field and 190 in the 30°F storage showed bud activity but did not produce any shoots during the period of October 23, 1962 to March 25, 1963. Some of the trees which had 750 hours of cold temperature in the field were placed in the cold storage and received a total of 1000 hours chilling. A high velocity of cold air circulation desiccated many trees. This injury killed some of the trees and injured some of the others. However, the branches which developed from the healthy portion were normal. The trees that did not grow as a result of the storage desiccation were removed from the experiment, reducing the number of replications in this group. Weakened trees of this group probably influenced the results of this experiment to some extent. Application of ammonium nitrate (1 pound/tree) in September had little, if any, effect on the growth of the trees. A large amount of fertilizer (100 grams/pot) which was applied to one-year-old peach trees in the greenhouse promoted the growth of many lateral buds after a period of 80 days following the treatment. The leaves were slightly smaller than normal leaves. The results obtained under the conditions of this experiment suggest that in the presence of rest, heavy fertilizer and extended favorable growing conditions resulted in bud opening, but further development did not occur.

SUMMARY

Growth promoting effects of different concentrations of gibberellic acid (GA) sprays and soil applications of ammonium nitrate were evaluated using resting leaf buds of pruned and unpruned three-year-old peach seedlings. Applications were made at two different dates, September 8, and 22, 1962. In another experiment, combinations of ammonium nitrate, fertilizer, pruning and different concentrations of GA were applied to trees which were chilled for 110, 300, 750, and 1000 hours below 45°F. The growth response of one-year-old trees treated in this manner was evaluated in the greenhouse for three months after treatment. The results are summarized as follows:

1. Under the field conditions, the trees which were treated with 500 ppm GA September 8, started growing and grew an average of 1.36 inches during the period of September 8 to October 20, 1962. Trees receiving a similar treatment September 22 did not grow, indicating either a greater rest intensity within the trees later in the season or the lower temperatures prevented growth. It is thought the former possibility is likely since no signs of growth occurred and there were many warm days for growth.

2. The trees which received 100 ppm GA sprays in the field grew the same as controls.

3. A substantial growth response occurred when GA was sprayed on the pruned trees in the field. Pruning alone did

not break the rest. The results suggest that GA and pruning have a positive interaction. Very succulent growth averaging 9.66 inches resulted after 500 ppm GA treatments were sprayed on pruned trees September 8. One hundred ppm GA applied to pruned trees produced shoots an average size of 2.83 inches, but the trees sprayed with 500 ppm GA without pruning had an average growth of 1.36 inches.

4. One pound of ammonium nitrate per tree applied September 8, did not break the rest. However, more growth occurred in the trees which were treated with both GA and pruning as compared with GA treatment alone. Combined pruning and fertilizer treatment did not show any noticeable rest-breaking effects.

5. Under the greenhouse conditions (65°F), among three different GA spray treatments, 100, 1000, and 4000 ppm, the growth rate and the total growth was the greatest on the trees which received 4000 ppm GA. The shoots developing on trees receiving 4000 ppm GA were thin with leaves narrower than normal and slightly yellow.

6. During the 100 days observation period very few buds started growing on trees which were previously chilled for 110 hours. Most of the terminal buds of trees chilled 300 hours opened and grew some, although short internodes produced a rosette effect. The trees chilled 750 and 1000 hours produced few shoots during the 100 day period and the shoot growth was normal.

7. One hundred grams of ammonium nitrate applied at three 10-day intervals to trees that had received 110, 300, 750, and

1000 hours of chilling resulted in opening of a large number of buds after a period of 80 days. Shoot development from the buds did not occur during the 100 day period of study. Two trees which received 110 hours chilling and only one that received 300 hours survived the large application of nitrogen fertilizer.

8. Pruning did not break the rest of trees receiving 110 and 300 hours of chilling, but the growth of pruned trees receiving 750 hours chilling was a little more than unpruned trees having the same chilling treatment. Combined pruning and 1000 ppm GA treatments did not show any significant growth differences above 1000 ppm GA treatment during a period of hundred days of study in the greenhouse.

9. A 4000 ppm GA solution which was applied on terminal buds of trees chilled for 110 hours resulted in rosette type growth. A similar treatment on all lateral buds stimulated all terminal buds to grow very succulently, but only a few lateral buds grew.

LITERATURE CITED

Bonner, J. and A. W. Galston. 1952. Principles of Plant Physiology. Freeman and Co. San Francisco, Calif.

Brooks, R. M. and G. L. Philp. 1941. Climate in relation to deciduous fruit production in California I. Effect of warm winter of 1940-41 on peach and nectarine varieties in northern California. Proc. Amer. Soc. Hort. Sci. 39:190-195.

Brown, D. S. 1953. The effects of irrigation of flower bud development and fruiting in the apricot. Proc. Amer. Soc. Hort. Sci. 61:119-124.

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.

Chandler, W. H., M. H. Kimball, G. L. Philp, W. P. Tufts and G. P. Weldon. 1937. Chilling requirements for opening of buds on deciduous orchard plants in California. Calif. Ag. Exp. St. Bul. 611.

Chandler, W. H. 1957. Deciduous Orchards. Lea and Febiger. Philadelphia.

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

Coville, F. V. 1920. The influence of cold temperature in stimulating the growth of the plants. Jour. Agr. Res. 20:151-161.

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

Donoho, C. W. Jr. and D. R. Walker. 1957. Effect of gibberellic acid on breaking of rest period in Elberta peach. Science, 129:1178-1179.

Edgerton, L. J. 1960. Studies on cold hardiness of peach trees. Cornell Agr. Exp. Sta. Bul. 958:1-30.

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.

Flemion, Florence and E. Waterbury. 1945. Further studies with dwarf seedlings of non-after-ripened peach seeds. Cont. Boyce Thomps. Inst. 13:415-423.

Flemion, Florence. 1959. Effect of temperature, light and gibberellic acid on stem elongation and leaf development in physiologically dwarf seedlings of peach and Rhodotypos. Cont. Boyce Thomps. Inst. 20:57-70.

Fogle, H. W. 1958. Effects of duration of after-ripening, gibberellin and other pretreatments on sweet cherry germination and seedling growth. Proc. Amer. Soc. Hort. Sci. 72:129-133.

Galston, A. W. and W. K. Purves. 1960. The mechanism of action of auxin. Ann. Rev. Pl. Physiol. 11:239-276.

Galston, A. W. 1961. The life of the Green Plant. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Guthrie, J. D. 1941. Sprays that break the rest period of peach buds. Cont. Boyce Thomps. Inst. 12:45-47.

Hemberg, T. and J. Larsson. 1961. The inhibitor β complex from resting potato tubers as an inhibitor of α-amylase. Physiol. Plant. 14:861-867.

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

Hodgson, F. R. 1923. Observations on the rest period of deciduous fruit trees in a mild climate. Proc. Amer. Soc. Hort. Sci. 20:151-155.

Howard, R. A. Jr., F. S. Howlett and F. H. Emmert. 1962. Factors affecting apple hardiness and method of measuring resistance of tissue to low temperature injury. Ohio Agr. Exp. Sta. Res. Bul. 901:1-71.

Hoyle, D. A. 1960. Some effects of temperature and daylength on the breaking of winter dormancy in black currant. Jour. Hort. Sci. 35:229-238.

Kawase, M. and J. P. Nitch. 1959. Growth substances and the photoperiod control of growth in Betula Pubscens and B. lutea. Abst. Pl. Physiol. Supp. IV.

Kawase, K. 1961. Dormancy in Betula as a quantative state. Pl. Physiol. 36:643-649.

Leopold, A. C. 1963. Auxins and plant growth. Univ. Calif. Press. Berkeley.

Meyer, S. B., D. B. Anderson and R. H. Bohning. 1963. Introduction to Plant Physiol. D. Van Nostrand Co. Inc. New York.

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

Overcash, J. P. and J. A. Campbell. 1955b. Winter chilling requirements for peach trees. Miss. State. Agr. Exp. Sta. Information Sheet No. 521.

Piringer, A. A. and R. J. Downs. 1959. Response of apple and peach trees to various photoperiods. Proc. Amer. Soc. Hort. Sci. 73:9-15.

Pollock, B. M. 1950. An investigation of the physiology of the rest period in trees with special response to acer. Ph. D. Dissertation, Univ. of Rochester, Rochester, New York.

Rogers, W. S. 1939. Root studies VIII. Apple root growth in relation to rootstock, soil, seasonal and climate factors. Jour. Pom. Hort. Sci. 17:99-140.

Samish, R. M. 1948. Plum growing in the Jewish settlements of Palestine. Jewish Agency for Palestine Agr. Res. Sta. Rehovot Vul. 50.

Samish, R. M. 1954. Dormancy in woody plants. Ann. Rev. Plant Physiol. 5:183-205.

Samish, R. M. 1960. Rest in buds of woody plants. Reprinted from Cryptobiotic stages in Biological systems. Edited by N. Gressowicz. Printed in Netherlands. Elsevier Publishing Co. Amsterdam.

Schoeneweiss, D. F. 1963. Simple methods for breaking dormancy of oak seedlings in the greenhouse. Manuscript obtained prior to publication.

Sisler, G. P. and E. L. Overholser. 1943. Influence of climate conditions on the date of full bloom of deciduous apples in the Wenatchee Valley. Proc. Amer. Soc. Hort. Sci. 43:29-34.

Walker, D. R. and C. W. Donoho, Jr. 1959. Further studies of the effect of gibberellic acid on breaking the rest period of young peach and apple trees. Proc. Amer. Soc. Hort. Sci. 74:87-92.

Weinberger, J. H. 1939. Studies on the use of certain dinitrophenol compounds to break the rest period in peach trees. Proc. Amer. Soc. Hort. Sci. 37:353-358.

Weinberger, J. H. 1950a. Chilling requirements of peach varieties. Proc. Amer. Soc. Hort. Sci. 56:122-129.

Weinberger, J. H. 1950b. Prolonged dormancy of peaches. Proc. Amer. Soc. Hort. Sci. 56:129-134.

Weinberger, J. H. 1956. Prolonged dormancy trouble in peaches in southeast in relation to winter temperature. Proc. Amer. Soc. Hort. Sci. 67:107-113.

Westwood, M. N. 1963a. Growth as related to chilling time and reciprocal grafts of pears having high and low chilling requirements. Oregon State Univ. Personal correspondence.

Westwood, M. N. 1963b. Chilling requirements for seeds of several species of pear (Pyrus). Oregon State Univ. Personal correspondence.

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