A Study of Rest Period, Hardiness, and Bud Development of the 'Concord' Grape

Mervin Gayle Weeks

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A STUDY OF REST PERIOD, HARDINESS, AND BUD DEVELOPMENT OF THE 'CONCORD' GRAPE

by

Mervin G. Weeks

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

MASTER OF SCIENCE

in

Plant Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1977
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To my wife, three sons and daughter, thanks for their patience while spending valuable time on this research and thesis.

Mervin G. Weeks
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ABSTRACT

A Study of Rest Period, Hardiness, and Bud Development of the 'Concord' Grape

by

Mervin Gayle Weeks, Master of Science

Utah State University, 1977

Major Professor: Dr. J. LaMar Anderson
Department: Plant Science

The length of the 'Concord' grape rest period was evaluated during 1974-75 and 1975-76. Cuttings were placed in a 25 C growth chamber every two weeks from October through April. Number of days to reach 50 percent full bud swell was plotted to determine rest completion. Seven years of weather data and full bloom dates of 'Concord' grapes from Prosser, Washington were statistically analyzed to give another estimate of rest completion. Rest was terminated after about 830 chill units.

During 1974-75 and 1975-76, T_{50} temperatures were determined every two weeks for both cambium and primary buds of 'Concord' grapes. The cambium ranged 2 to 10 C hardier than the primary buds. The T_{50} temperature pattern correlated with the minimum ambient air temperatures.

Cuttings, collected and placed in growth chambers, were analyzed for both optimum and base temperatures.
Optimum bud growth and development occurred at 25°C. The base or temperature of first noticeable bud development was approximately 4.4°C.

Bud phenological stages were followed both years and a standard set of pictures of representative stages was compiled. The growing degree hours (GDH) from end of rest to first bud swell through full bloom to maturity were determined.

A regression line was plotted between the various GDH requirements for the percent soluble solids acquired during the 1975 and 1976 seasons. The GDH accumulation and soluble solids were well correlated with an $r^2$ value of 0.95 percent.

(106 pages)
INTRODUCTION

Climate and its effect upon plant life to survive within a given area have always been important. Whether a given plant species is able to adapt to a specific locale depends on several things. Does a given area have extreme cold and hot spells that would inhibit plant growth? Will a given area have sufficient cool temperatures to allow enough chilling to complete rest? Is the growing season long enough to allow the crop to mature? Within an area, what temperatures give maximum growth and how can these be correlated with phenological stages of plant development? These questions are often asked concerning any given agronomical or horticultural crop. The 'Concord' grape has been an important crop since its discovery at Concord, Massachusetts. It originated from seed planted by Ephraim W. Bull in the fall of 1843, and which bore fruit in 1849. He dug up a wild native fox-type (Vitis labrusca L.) grape plant growing beside a field fence and transplanted it into his garden where other grapes were growing, including 'Catawba'. He gathered seed from this wild vine and planted it. Among the seedlings that emerged was one vine which was outstanding and which he named and introduced as the 'Concord' grape (Tukey, 1966).
Since the introduction of the 'Concord' grape, climate and environment have had a crucial bearing on fruit quality, productivity, and maturity. The 'Concord' grape has long been the standard grape for comparison with other American and American hybrid types.

Temperatures during the growing season influence the growth, percent soluble solids achieved, and the time that fruit matures. Since grapes are a perennial crop, climatic conditions not only affect the current seasons crop but determine the fruiting potential for the following year as well. Weather has a major effect on fruit bud formation, maturity of the current seasons growth, and conditions existing during the dormant period.

In recent years a great interest has developed in the potential establishment of commercial grape production in Utah and adjacent states. Since Utah conditions are somewhat different from other grape growing areas, many questions about their performance under these conditions remain unanswered. Extensive work has been conducted for most other fruit in Utah to determine their rest intensity and bud development. Research on American type grapes (Vitis labrusca L.) in Utah or elsewhere is minimal.

A concise study to determine the requirements to break rest, the $T_{50}$ hardiness level, and the base and optimum temperatures to which they will best respond, would help answer many questions about grape growing in
this area. The correlation of growing-degree-hours (GDH) with different stages of bud development from first swell to full bloom to maturity would be an effective tool to forecast harvest dates. Such information would enable growers to have more insight as to when to arrange picking and harvesting of crops. Information of this type could also enable prospective growers to determine which sites and localities would be best suited for commercial production of grapes. It is commonly accepted that site selection is the most critical factor in vineyard establishment (Stergios and Howell, 1977a).

The purposes of this study were: (1) to determine requirements in completion of rest, (2) hardiness with bud development, (3) to determine base and optimum temperature range for growth and development to which growth best responds, (4) to describe the stages of bud phenology, and (5) to determine the effects of environment on fruit development of 'Concord' grapes.
REVIEW OF LITERATURE

Many studies have been conducted concerning the effects of temperature on the 'Concord' grape. For convenience this literature review has been divided into five parts: (1) requirements for rest completion, (2) hardiness, (3) base and optimum temperatures to which growth best responds, (4) bud phenology, and (5) the effects of environment on fruit development.

Requirements Involved in Rest Completion

The terms, "bud dormancy" and "bud rest", will be used as defined by Samish (1954). Bud dormancy is generally associated with the temporary suspension of visible growth. Growth may be stopped by unfavorable external conditions, such as cold temperature or drought, and is also known as "quiescence", as suggested by Meyer and Anderson (1952). Bud rest is that period when growth will not proceed normally even in a favorable environment. It is generally believed that rest is due to internal factors and that the relative levels of various hormones in buds determine the onset and termination of rest (Kliwer and Soleimani, 1972).

To produce normal growth under favorable conditions however, it is necessary that rest be "broken" by a certain period of cold. The length of this period, which
differs with the cultivar and with the species as well as with physiological conditions, is termed "chilling requirement" (Samish, 1954). The rest requirement keeps buds from active growth during unusual mid-winter warm periods. Although very slow bud growth proceeds as long as rest continues, active growth will not commence until the after-rest period (Young et al., 1974). Richardson et al. (1974, 1975), using data from the literature and results of their own research, developed a model relating environmental temperature to the time of rest completion. The model is based on the accumulation of chill units where one chill unit equals one hour exposure at 6 °C. The chilling contribution becomes less than one as the temperature drops or rises above the optimum value. A negative contribution to the chill unit accumulation occurs at temperatures above 15 °C. Zero unit contribution occurs below 1 °C. Chill unit accumulation begins in the fall after the day when the most negative chill unit accumulation has occurred.

With few exceptions, chilling is generally considered necessary to break bud rest in grapevines. Some Vitis species, e.g. Vitis caribae which is indigenous to the Caribbean area, apparently require no chilling, whereas others, e.g. Vitis davidii, require extended chilling (Chandler, 1937). Even the Vitis vinifera cultivars, which are the leading commercial grapes, have a wide range of the amount of chilling required to terminate
bud rest (Kliewer and Soleiman, 1972).

Weaver et al. (1968) noted a large varietal difference in time required for grape buds to terminate rest. 'Pearl of Csaba' and several popular California seedless varieties terminated rest rapidly followed by 'Concord'. Weaver used number of days to 50 percent bud break as the criteria for determining termination of bud rest.

Alexander and Woodham (1962) observed that Thompson seedless vines growing in nutrient culture occasionally burst prematurely without going through a winter rest. Wine grape buds near the apex have been observed to break rest without a rest period if the shoot tips were removed (Kliewer and Soleimani, 1972). These observations and those of Weaver et al. (1975) indicated that bud-break of many samples and not just of that of the first bud, should be used to determine the termination of rest.

At Davis, California V. vinifera buds usually enter a rest state in autumn and do not emerge from it until about January (Weaver, McCune, and Coombe, 1961). Weaver et al. (1975) also found that apical cuttings of 'Carignane' grape canes collected in late fall and early winter were slower to break rest than cuttings from the basal or middle portions of the canes.

Eggert (1951) found that 'Concord' grapes require more than 3,000 hours exposure to temperatures below 7 C before more than 50 percent of the buds would develop
during a three-week period in the greenhouse. He ranked various species according to the hours of chilling required to break rest from the lowest to the highest as follows: red raspberry, black raspberry, prune, peach, currant, sweet cherry, pear, sour apple, 'Concord' grape, and blueberry. Leaf buds generally required slightly more chilling than flower buds to break rest.

The results of Magoon and Dix (1943) were not in agreement with those of Eggert. 'Concord' grapes in their study required between 1,200 and 1,400 hours of exposure to temperatures below 7°C to complete rest. It took 25 to 31 days for new growth after cuttings were placed in the greenhouse at temperatures between 18 to 24°C. Rest was considered broken or completed when there was little further increase in percent bud activity. Magoon and Dix also found that as the length of exposure time to cool temperature increased there was a progressive shortening of time required for grape plants to initiate growth.

Richey and Bowers (1924) found that from October 27, 1921 to January 8, 1922 the percentage of total carbohydrates increased in 'Concord' canes, stems, and roots. After January 8 a marked decrease of total carbohydrates occurred in all parts of the vine. Rest was completed by January 8, the high point in carbohydrate accumulation. The following decrease coincided quite closely with the initiation of growth of plants that previously had been
placed in the greenhouse under favorable growing conditions. A similar curve to that of total carbohydrates was shown for free reducing disaccharide and total sugar content. The high point in carbohydrate accumulation for each of the curves with these was January 8. There was a low point at this time for polysaccharide (starch).

**Hardiness Levels**

One of the greatest limiting factors in grape production is winter injury caused by sub-zero temperatures in early winter. Gladwin (1917) pointed out early in this century that winter injury of grapes could be traced to a lack of tissue maturity. Injury depended primarily upon the minimum temperature reached, and in most instances the damage seemed to occur during a single cold night (Potter, 1938).

'Concord' grape plant and bud hardiness have been reported to be influenced by vigor, crop load, soil type, fertility, and moisture conditions during the growing season prior to being exposed to cold temperatures (Clore et al, 1968). Cold injury to grapes can be associated with low temperatures occurring late in the fall or early winter before dormant vines have been preconditioned by temperatures below -2 C (Clore et al., 1974b; Mullner and Mayer, 1970). This natural hardening process is very important to prepare the vines for cold winter temperatures. In the
state of Washington cold temperatures that occur in November and December are more damaging than the same or even lower temperatures that occur in January and February (Hagood, 1975). As plants go into the dormant period, they become increasingly cold tolerant. They are less hardy during late fall and early winter, but increase in hardiness during mid-winter.

Increase in hardiness during the dormant period is usually associated with decreasing temperatures. The loss of hardiness corresponds with increasing temperatures (Proebsting, 1950). Climatic conditions prior to low temperatures determine the amount of cold damage that will occur. A frost following a warm spell or drought and strong winds cause more injury to plant tissues than when preceded by mild to calm cool weather (Hargood, 1975).

Hardiness in the 'Concord' grape seems to be more responsive to short daylength in the fall than in the vinifera grapes (Clore and Brummund, 1965).

According to Edgerton and Shaulis (1953) grape vines that have been pruned in the fall will have tissue more susceptible to winter injury near pruning wounds. Studies in Michigan showed that grapevines pruned $30 + 10$ buds per pound had superior cane hardiness to those pruned $60 + 10$. There was as much a $3$ C difference in $T_{50}$ temperatures of primary bud kill occurring in November, December, and April (Stergios and Howell, 1977b).
Stergios and Howell (1974) maintain that the 'Concord' grape node contains a compound bud, comprised of individual primary, secondary, and tertiary buds. The primary bud is more productive and less hardy than the secondary bud during periods of acclimation and deacclimation. Likewise, the primary bud is more susceptible to winter injury in the field (Clark, 1936; Wiggans, 1926). Defoliation of 'Concord' grape plants during August in southwestern Michigan resulted in a 1 to 5 C hardiness reduction. Defoliated plants acclimated slower in the fall and deacclimated earlier in the spring (Stergios and Howell, 1977b).

Low site versus high site vineyards were evaluated for hardiness. Grapes in low elevation sites developed greater hardiness due to exposure to lower air temperatures. However, the risk of cold injury to low-site plants was greater due to the more severe temperature fluctuations in early fall and late spring (Stergios and Howell, 1977a).

Clore et al. (1974a) evaluated canes of several grape cultivars including 'Concord' for bud survival from vineyards in Washington during the winters of 1972-73, and 1973-74. The hardiest 'Concord' buds found in both winters occurred when the temperatures were lowest. The lowest primary bud T$_{50}$ of -33 C was recorded January 11, 1973. At the same time, the lowest T$_{50}$ readings for secondary and tertiary buds also occurred at -37 and -34 C, respectively.
The 'Concord' grape began to lose hardiness in late winter or early spring when heat units began to accumulate. Clore et al. (1974b) claim dehardening of the grapevine takes place when an average mean temperature of 10°C or more prevails following rest completion.

**Base and Optimum Temperatures for Growth and Development**

**Base temperatures**

The grapevine is considered to be a conservative plant because it does not rush into growth in early spring as do most deciduous fruit trees. The vine remains dormant until the mean daily temperature reaches about 10°C (Winkler et al., 1974). The base temperature used for the 'Concord' grape has been 10°C. Temperatures below 10°C do not contribute to any accumulation of heat units (Winkler, 1948, Winkler et al., 1974). Poenaru and Lazarescu (1959) reported, that in the northern vineyards of Europe, vines began growth at 8°C.

Studies by workers in Europe (Anonymous, 1968) on the bud break of a large number of wine varieties at low temperatures led to a definition of two distinct thresholds of growth in the grape plant. The first "real threshold" corresponds to a stage of development beyond which bud growth cannot continue. This threshold lies within narrow temperature limits, nearer to 0°C. The second or
"apparent threshold" of growth is the temperature below which the rate of bud-break of shoot growth is so reduced that it ceases to be perceptible. This temperature is specific to each genotype. It varies from around 4°C for early varieties to 11°C for late varieties.

**Optimum temperatures**

In controlled outdoor growth chambers, Tukey (1958) found that the maximum growth rate for developing Concord berries during a 13-day period following bloom, occurred at mean daily temperatures approximating 26.1°C. Both higher and lower temperatures appeared to reduce the growth rate of the forming berries. The temperatures below optimum had more effect per degree on growth than did those temperatures above this optimum.

Tukey (1958) also found that raising the night temperatures higher than normal helped to increase size of berries. At harvest the greatest percentage of sugar was found in berries produced from the vine that grew in the 26.1°C exposure.

Kriedmann (1968), who measured changes in the concentration of CO₂, found that the optimum temperature for photosynthesis by grape leaves was about 25°C.

Shaulis (1966) studied two levels of vine growth as affected by light intensity in controlled climate chambers for 14 day-night temperature combinations. At 185.8 lux/m² (2,000 foot candles) there was a maximum net assimilation
rate at 25 C and minima (1/2 the maximum) at 5 and 30 C. High night temperatures were depressing. At 46.45 lum/m² (500 foot-candles) the maximum rate was at 15 C and minima at 5 and 30 C.

The soluble solids accumulation rates of fruit in full sunlight and 185.8 lux/m² (2,000 foot-candles) were similar. At 46.45 lux/m² (500 foot-candles), it was less, especially at the higher temperatures, night or day. The highest rate of fruit solid increase was at moderate night temperatures 10 and 15 C (Shaulis, 1966).

Climate and Its Affect on the Phenological Stages of Growth from First Bud Swell to Full Bloom

Little is mentioned in the literature of any definite set of phenological stages 'Concord' grapes goes through from first bud swell in the spring to full bloom.

Clore et al. (1974b) mention some of the recognizable stages of bud development: full bud swell, first leaf shoot, second leaf shoot, through fifth leaf shoot. The following stages of bud development have been established: first swell, full swell, bud burst, first leaf through seventh leaf, first bloom, and full bloom (Clore, 1975). Winkler et al. (1974) observed that the rudiments of the flower clusters were formed during the season preceding the year in which the flowers bloom.
Temperature affects the bud development in the spring. Late pruning when the sap starts to run will delay growth approximately one week (Hagood, 1975).

The Effects of Environment on Fruit Development
From Full Bloom to Harvest

Winkler et al. (1974) mentions that grapes of the vinifera varieties thrive best if no rain falls between blooming and harvest.

Poor fruit set of 'Sultana' in irrigated vineyards of Australia is sometimes attributed to excessive high heat and water stress at full bloom time (Alexander, 1966).

Spark and Larsen (1965, 1966) reported that seasonal variation in the percent of soluble solids is related to the percent foliage density of the plant. When the foliage density of the plant is higher, soluble solids are higher. Leaf area per unit of fruit is a limiting factor for soluble solids production. Early development of the maximal leaf area resulted in a longer period of photosynthetic activity and, therefore, greater production of soluble solids. The year to year variation in soluble soluds in a particular vineyard could probably be explained on the basis of constancy of the foliage density.

The variation of average soluble solids from year to year was considered to be a response to differences
in temperature and light intensity between years (Spark and Larson, 1965).

Controlled day-temperature studies of fruit set in 'Concord' grapevines were conducted at University Park, Pennsylvania (Haeseler and Fleming, 1967). Low (15.6 to 18.3 C) and high (32 to 35 C) day-temperatures during the fruit-set period were harmful to fruit-set. Under these conditions vegetative development was seriously impeded by low day-temperatures and excessively promoted by high day-temperatures. Lateral shoots often were produced when temperatures prevailed above 32 C, but these shoots produced fruit clusters which did not mature sufficiently for harvesting. Natural conditions and medium day-temperatures were considered more conducive to fruit set, berry growth, cluster development, and vegetative control.

Clore and Bryant (1958) reported that temperatures above 32.2 C appeared to reduce the efficiency of the 'Concord' grape plant to accumulate sugars. Delay of 'Concord' grape maturity in Washington State can be attributed to temperatures over 32 C for extended periods of time (Clore et al., 1967).

Clore and Brummund (1964) reported above average crop maturity could be credited to above average solar radiation. If the skys were cloudy and overcast, then maturity is delayed and quality reduced.
The larger the fruit load per vine, the greater the number of heat units required for the fruit to obtain acceptable quality (Clore and Brummund, 1960). Time of maturity also depends upon which period during the growing season the most favorable temperatures occur (Clore and Bryant, 1957).

Growth, development and maturation of 'Concord' grape is influenced by such factors as size of crop, culture practices, and weather conditions—especially temperature (Van Den Brink, 1974). Correlating average bloom and harvest dates of 'Concord' grape with temperature data, Van Den Brink (1974) has been able to predict harvest dates within an acceptable degree of accuracy and reliability, using 10°C as the base temperature. Temperature variations between seasons spread the maturity period of 'Concord' grapes in Michigan as much as three weeks.
MATERIALS AND METHODS

This study consisted of five parts: (1) evaluation of rest, (2) evaluation of cold hardiness, (3) development of optimum temperatures for growth, (4) determination of base temperature for growth, and (5) correlation of growing-degree-hours with bud development for 1974-75 and 1975-76. The experiments were conducted on eight-year-old own rooted 'Concord' grape vines, located at the Utah State University Horticulture Field Station, Farmington, Utah. The vines were trained to a modified 6-cane Kniffin system and balanced pruned to 30 + 10 buds annually.

Rest Studies

Growth chamber

To determine if rest was completed, cuttings of one-year-old canes were collected biweekly beginning October 23, 1974 until May 6, 1975. From December to February, samples were collected weekly. The following year cuttings were collected biweekly from October 10, 1975 to April 19, 1976. Previous studies (Tukey, 1958) indicated that 25 C was the optimum temperature for bud development in a growth chamber. Cuttings were collected from four different plants, three cuttings per plant, with three to four buds per cutting. Each treatment consisted of approximately 40 buds. They
were placed in beakers of water in a 25 C chamber to determine the length of time required for 50 percent or more of the buds to reach full swell stage. Rest was considered broken when the number of days to reach 50 percent full bud swell made a plateau (e.g., see Figure 3).

**Statistical method**

A recently developed statistical method of estimating the chill unit requirements for deciduous fruit trees from temperature and phenological data (Ashcroft, Richardson, and Seeley, 1977) was used to estimate the chill requirements for 'Concord' grapes from 7 years of climatological and phenological data recorded at Prosser, Washington (1962-1969).

**Cold Hardiness Study**

Clore (1974) stated that the basal buds were more prone to produce abundant fruit than buds beyond these. Therefore, the five or six most basal buds were used for this experiment. One-year-old wood was taken from four individual plants with 18 canes per plant. Each cane had at least one bud, or 18 buds minimum per collection data. Cuttings were divided into six separate groups with three canes each, placed in a freezing chamber.

Samples were collected every two weeks from early fall until visible signs of bud swell in the spring. Samples were transported in an insulated container to the laboratory
immediately after collection. The canes were randomly separated into plastic bags and given a cold treatment in a Sears deepfreeze programmed with Honeywell automatic controls that lowered the temperature 2 F per hour (Figure 1). An automatic retrieval system was used to extract the samples from the freezing chamber at specified times and temperatures selected to bracket the estimated T$_{50}$ temperature. Samples were kept at room temperature for two to three days before being analyzed.

Canes (bark, cambium, and phloem) and primary bud samples were then evaluated for viability using the browning test (Stergios and Howell, 1972). Cambium and primary bud hardiness was plotted graphically to determine the 50 percent survival temperature (T$_{50}$) (Proebsting and Mills, 1961; Proebsting, 1963). The buds were judged alive when they were all green and dead when their center portions browned (Stergios and Howell, 1974).

**Optimum Temperature**

Growth chambers constructed of 51 mm thick styrofoam (600 x 700 x 930 mm) were equipped with a Supersensitive relay 4-5300 and a Quickset Rustproof thermostat No. 4-235 F (American Instrument Co., Inc., Silver Springs, MD). Temperatures were maintained by a 100 watt incandescent light bulb to an accuracy of ± 0.3 C (Figure 2).
Figure 1. The custom-built freeze chamber built by Mallory Engineering Company, Salt Lake City, Utah. The automatic retrieval system is shown with a sample being extracted.
Figure 2. Growth chambers constructed of 51 mm thick styrofoam used for optimum and base temperature study. 'Concord' grape cuttings are shown in a beaker of water in one of the chambers.
Grape cuttings about 30 cm in length having three or four buds each were collected March 28, 1974; nine to ten canes were taken at random from four different plants and held in the chambers with the basal ends in a beaker of water. The canes were separated into four groups. Each group was placed with the basal end in a beaker of water and each of the four beakers was put into a chamber at 15, 20, 26, and 32 C, respectively. Samples were removed on April 23, 1974. The temperature at which optimum plant growth occurred was visually determined.

Base Temperature

Base temperature is defined as the temperature at which 'Concord' grape buds begin noticeable growth and development following rest completion.

Samples were collected in early spring before noticeable bud swelling had occurred. Three cuttings per plant, with three to four buds each, were selected at random from several plants. Cuttings were placed in beakers of water in the same growth chambers described above for the optimum temperature experiment. Chambers were placed in a 0 C cold room. Growth chamber temperatures were 0, 5.5, 7, and 10 C in 1975. In 1976, based on 1975 results, chambers were held at 3, 4.5, 5.5, and 8 C.
Correlation of Bud Stage with Growing Degree Hours

Daily maximum and minimum air temperatures were recorded with a thermograph in a standard weather shelter for the two years. The maximum and minimum values are given in Tables 15 and 16 (see Appendix).

Visual observations were taken periodically as grape buds began to swell and continued from spring through harvest of 1975 and 1976. A series of pictures were taken of the different stages of bud development in the field. Table 1 gives the description of grape phenological stages and their correlation to growing degree hours.

Soluble solid readings were taken in the field with a Bausch and Loam hand refractometer as fruit approached maturity. Five to six samples were taken at random and then averaged for the percent soluble solid reading.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st swell</td>
<td>Bud begins to increase in size and change to a lighter color</td>
</tr>
<tr>
<td>Full swell</td>
<td>Bud has increased to maximum size without any tip separation</td>
</tr>
<tr>
<td>Full burst</td>
<td>Tip of bud has burst open and started to spread</td>
</tr>
<tr>
<td>1st leaf</td>
<td>Leaf first makes a right angle with the main stem</td>
</tr>
<tr>
<td>2nd-8th leaf</td>
<td>Determined when each leaf first makes a right angle with the main stem</td>
</tr>
<tr>
<td>1st bloom</td>
<td>First bloom open on 50 percent of the clusters</td>
</tr>
<tr>
<td>50 % bloom</td>
<td>Half of flowers on 50 percent of the clusters open</td>
</tr>
<tr>
<td>75% bloom</td>
<td>Three-fourths of the flowers open on 50 percent or more of the clusters</td>
</tr>
<tr>
<td>Full bloom</td>
<td>Most of the flowers in the vineyard are open</td>
</tr>
</tbody>
</table>
RESULTS

Rest Studies

Growth chambers

'Concord' grape cuttings held in the 25 C growth chamber all reached full bud swell except for the sample collected October 23, 1974. Two or three buds of this sample began to swell and develop by March 6, 1975, but growth was abnormal and did not reach the 50 percent full bud swell standards used by Weaver, Yeou-Der, and Pool (1968). Samples collected after October 23, 1974 reached 50 percent full bud swell if allowed sufficient time. The November 6, 1974 sample took 70 days to reach 50 percent bud swell with each sample collected afterwards requiring less time (Figure 3). Following January 14, 1975 the time required to break rest dropped consistently until the last sample collected on May 6, 1975 required only one day to reach the 50 percent full swell stage. Samples collected during the 1975-76 season had a comparable pattern. The first sample on October 10, 1975 reached 50 percent full bud swell January 30, 1976, 112 days later. Samples collected thereafter required less time with a noticeable difference following February 2, 1976. Cuttings were collected until April 14, 1976 which required 5 days to reach 50 percent full bud swell. It took a few more days during
Figure 3 - Days required for Concord grape samples collected on various calendar dates to reach 50 percent full bud swell in a 25 C growth chamber from the time samples were taken in the field. Data was collected from the years 1974-75 and 1975-76.
1975-76 for the samples to bud out following end of chill accumulation than in 1974-75. During 1974-75, it took 33 days to reach 50 percent full bud swell, whereas during 1975-76 it took 43 days.

Statistical method

Table 2 shows the different values of GDH C calculated for different chill unit estimates to full bloom. The standard deviation is plotted against chill units (Figure 4) to find the calculated chill unit requirement. Figure 4 shows graphically 830 chill units to be the point in the curve with less error in the standard deviation.

Cold hardiness

Cambium and primary bud $T_{50}$ temperatures were comparable for both seasons. The cambium $T_{50}$ was 2-10 C lower than the bud $T_{50}$ each year. During 1974-75 the vines developed winter hardiness slower than 1975-76. Both the primary buds and cambium were hardier for 1974-75 than the 1975-76 season, and deacclimation was slower during Spring 1975.

The hardiest $T_{50}$ temperatures, both cambium and primary bud, were recorded on February 6, 1975. The $T_{50}$ temperatures are recorded in Figures 5 and 6 for both years.

During 1975-76 the lowest maximum $T_{50}$ temperatures for cambium and primary buds were not recorded on the same
Table 2. GDH C accumulations for 'Concord' grapes from end of rest to full bloom for selected estimated chill unit requirements

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>19566</td>
<td>16133</td>
<td>17189</td>
<td>15934</td>
<td>19280</td>
<td>16120</td>
<td>15548</td>
<td>17110</td>
<td>1658</td>
</tr>
<tr>
<td>700</td>
<td>19290</td>
<td>15689</td>
<td>16954</td>
<td>15823</td>
<td>19110</td>
<td>16010</td>
<td>15321</td>
<td>16884</td>
<td>1659</td>
</tr>
<tr>
<td>800</td>
<td>18848</td>
<td>15556</td>
<td>16871</td>
<td>15628</td>
<td>18862</td>
<td>15874</td>
<td>15164</td>
<td>16688</td>
<td>1571</td>
</tr>
<tr>
<td>900</td>
<td>18742</td>
<td>15378</td>
<td>16833</td>
<td>15534</td>
<td>18754</td>
<td>15757</td>
<td>15109</td>
<td>16587</td>
<td>1573</td>
</tr>
<tr>
<td>1,000</td>
<td>18649</td>
<td>15274</td>
<td>16697</td>
<td>15468</td>
<td>18592</td>
<td>15458</td>
<td>15000</td>
<td>16448</td>
<td>1577</td>
</tr>
<tr>
<td>1,100</td>
<td>18649</td>
<td>15138</td>
<td>16456</td>
<td>15333</td>
<td>18367</td>
<td>15252</td>
<td>14936</td>
<td>16303</td>
<td>1584</td>
</tr>
<tr>
<td>1,200</td>
<td>18474</td>
<td>14953</td>
<td>16291</td>
<td>15179</td>
<td>18316</td>
<td>15106</td>
<td>14746</td>
<td>16151</td>
<td>1607</td>
</tr>
<tr>
<td>1,300</td>
<td>18347</td>
<td>14762</td>
<td>15621</td>
<td>15122</td>
<td>18188</td>
<td>15081</td>
<td>14733</td>
<td>15979</td>
<td>1591</td>
</tr>
</tbody>
</table>

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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest*</td>
<td>10/19</td>
<td>10/12</td>
<td>10.5</td>
<td>9/27</td>
<td>10.1</td>
<td>10.14</td>
<td>9/21 to</td>
<td>10/15</td>
<td></td>
</tr>
</tbody>
</table>

*Full bloom and harvest dates were obtained from Washington State Horticulture Association Proceedings (Clore, 1963-70). Dates correspond for Irrigated Agriculture Research and Extension Center, Prosser, Washington.
Figure 4 • The relationship between the standard deviation of the accumulation of Growing Degree Hours to full bloom for Concord grapes and selected accumulations of chill units. The curve is based on data from Prosser, Washington 1962-1969.
Figure 5 - Relationship of Concord grape primary bud $T_{50}$ to chill unit and growing degree hour accumulations during the 1974-75 and 1975-76 seasons.
Figure 6 • Relationship of Concord grape Cambium $T_{50}$ to chill unit and growing degree hour accumulations during the 1974-75 and 1975-76 seasons.
sample date. The lowest primary bud maximum $T_{50}$ temperature was on December 29, whereas the cambium was hardiest February 2 and 18, 1976. The $T_{50}$ curves of the primary bud and cambium were generally parallel. With warmer air-temperatures in late winter and early spring of 1976 the vines deacclimated sooner than in 1975, thus losing their hardiness.

**Optimum temperature**

Cuttings from plants that had completed rest were allowed to develop under controlled temperatures in growth chambers in 1974. Growth in the 20 and 26 C chambers was normal. Grape shoot growth in the 32 C chamber appeared to be spindly and showed epinasty, whereas the growth was slow and rather minimal at 15 C.

The study tended to verify the results of Tukey (1958), who reported that 25 C appeared to be the optimum temperature for 'Concord' grape growth and development.

This study was not continued as this phase has been adequately described in the literature.

**Base temperature**

Bud growth and development took place at each of the selected growth chamber temperatures, except in the 0 C chamber during 1974-75. Figure 7 shows the bud swell growth rate comparison. At 5.5 C noticeable bud swell and growth
did take place. Growth and development occurred more rapidly at both 7 and 10 C temperatures.

The same experiment was repeated during 1976 with a narrower range of temperatures. The second experiment was shortened due to mechanical failure of the cold room in which the growth chambers were located. The experiment proceeded long enough, however, to notice visual swelling of the buds at the 4.5 C growth chamber.

**Correlation of Bud Stages with Growing Degree Hours**

Determination of GDH values to reach each of the described stages of bud development are shown in Table 3. This table summarizes data collected from two growing seasons (1974-75 and 1975-76) and represents the average of the two years data.

Figure 8 is a series of pictures showing the standard phenology stages of the 'Concord' grapes from dormancy to full bloom.

Percent soluble solids were recorded for both years as the fruit approached maturity. An average percent soluble solids for each date sampled was correlated to the accumulated GDH and plotted in Figure 9. A regression line was plotted through the determined percent soluble solid values for 1975 and 1976 seasons. The calculated regression line has a $r^2$ value of 0.95 which shows a high correlation between GDH and percent soluble solids.
Table 3. Preliminary phenoclimatography model for Concord grapes*

<table>
<thead>
<tr>
<th>Stages</th>
<th>Physiodates</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chill units</td>
<td>GDH C</td>
<td>GDH F</td>
</tr>
<tr>
<td>Begin chill unit accumulation</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End chill unit accumulation</td>
<td>330</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. First swell</td>
<td>4,220</td>
<td>7,590</td>
<td></td>
</tr>
<tr>
<td>2. Full swell</td>
<td>5,500</td>
<td>9,890</td>
<td></td>
</tr>
<tr>
<td>3. Bud burst</td>
<td>6,490</td>
<td>11,680</td>
<td></td>
</tr>
<tr>
<td>4. First leaf</td>
<td>7,360</td>
<td>13,240</td>
<td></td>
</tr>
<tr>
<td>5. Second leaf</td>
<td>8,240</td>
<td>14,840</td>
<td></td>
</tr>
<tr>
<td>6. Third leaf</td>
<td>9,050</td>
<td>16,290</td>
<td></td>
</tr>
<tr>
<td>7. Fourth leaf</td>
<td>10,190</td>
<td>18,340</td>
<td></td>
</tr>
<tr>
<td>8. Fifth leaf</td>
<td>12,080</td>
<td>21,740</td>
<td></td>
</tr>
<tr>
<td>9. Sixth leaf</td>
<td>12,620</td>
<td>22,720</td>
<td></td>
</tr>
<tr>
<td>10. Seventh leaf</td>
<td>15,940</td>
<td>28,700</td>
<td></td>
</tr>
<tr>
<td>11. Eighth leaf</td>
<td>15,110</td>
<td>27,200</td>
<td></td>
</tr>
<tr>
<td>12. First bloom</td>
<td>15,510</td>
<td>27,920</td>
<td></td>
</tr>
<tr>
<td>13. Fifty percent bloom</td>
<td>16,190</td>
<td>29,150</td>
<td></td>
</tr>
<tr>
<td>14. Seventy-five percent bloom</td>
<td>16,890</td>
<td>30,400</td>
<td></td>
</tr>
<tr>
<td>15. Full bloom</td>
<td>17,880</td>
<td>32,180</td>
<td></td>
</tr>
</tbody>
</table>

*Above information based upon data collected from Horticulture Field Station, Farmington, Utah, 1974-75 and 1975-76 growing season.
Figure 8. Bud phenology stages of the 'Concord' grape from dormancy to full bloom.
Figure 9  Regression of growing degree hours to percent soluble solids in Concord grapes for the 1975 and 1976 seasons.
Rest studies

Magoon and Dix (1943) found that 'Concord' grapes require a rather short chill period when compared to tree fruits; whereas Eggert (1951) found that they require a longer chilling period similar to that of apples.

Grapes are much more conservative than tree fruits (that is, they respond more slowly to environmental factors). For example, 'Concord' grapes require 2 to 3 times more growing degree hours to reach full bloom than peaches, apples, prunes, cherries, and pears. Because grape buds develop slowly, the criterion used to determine end of rest for tree fruits (blooming in 2 weeks in a greenhouse) would not be expected to be a good criterion for grapes.

Other differences exist between the response of grapes and deciduous tree fruits. Grape samples collected early in the season can be "stressed out" of rest. Tree fruit buds are much more difficult (or impossible in some cases) to "stress out" of rest. For example, buds will develop in the greenhouse, albeit slowly, on grape samples collected early in the rest period, but buds do not develop on analogous fruit tree samples. These differences may be associated with the fruiting habit. Grape berries are produced on current season's wood, whereas the tree fruits are
produced on wood of the previous season. Whatever the cause, it does require that a different rest criterion be used for grapes than for the tree fruits.

The criterion used to determine end of rest involved plotting sampling date vs. days required for 50 percent full bud swell. Such a plot produced a plateau in the curve (see Figure 3). This plateau was considered to represent the end of rest. The plateau occurred, however, at 33 days in 1974-75 and at 43 days in 1975-76 (Figure 3). It would seem that the plateau should have occurred both years with the same number of days required to reach full bud swell. There are several possible reasons why the values were not the same for the two years. During the second year it was difficult to maintain a constant temperature in the student-constructed chamber which did not have controls. This could have made some difference in the fact that the number of days to the same stage (full bud swell) was not the same at end of rest completion. The difference in time could also be the result of differences in sampling. It was determined (Table 4), as confirmed by Weaver et al. (1975), that there was a gradient in development from the base to apex of the cane, with basal buds developing much faster. If some samples contained more basal cuttings than others, sampling errors would occur.

The statistical method of determining rest completion (Ashcroft et al., 1977) was also used. Seven years of
Table 4. Rate of bud break from samples of specific segments in comparison to random samples

<table>
<thead>
<tr>
<th>Collection date</th>
<th>Plant No. or segment</th>
<th>Number of buds breaking</th>
<th>Stage</th>
<th>Date analyzed 1975</th>
<th>Date analyzed 1975</th>
<th>Stage</th>
<th>% bud break full swell or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 21, 1975</td>
<td>Random</td>
<td>1 out 6</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>3(full swell)</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>#1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2(1st swell)</td>
<td></td>
</tr>
<tr>
<td>Jan. 21, 1975</td>
<td>#2</td>
<td>1 out 8</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>3(full swell)</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>#3</td>
<td>2 out 6</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>2(full burst)</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>#4</td>
<td>2 out 8</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>1(1st leaf)</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2(1st swell)</td>
<td></td>
</tr>
<tr>
<td>Jan. 21, 1975</td>
<td>Segments</td>
<td>9 out 9</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>5(full burst)</td>
<td>100%</td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4(full swell)</td>
<td></td>
</tr>
<tr>
<td>Jan. 21, 1975</td>
<td>Middle</td>
<td>6 out 9</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>2(1st leaf)</td>
<td>67%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2(full burst)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2(full swell)</td>
<td></td>
</tr>
<tr>
<td>Jan. 21, 1975</td>
<td>Apex</td>
<td>2 out 13</td>
<td>1st swell</td>
<td>Feb. 11</td>
<td>Feb. 18</td>
<td>1(full burst)</td>
<td>31%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3(full swell)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3(1st swell)</td>
<td></td>
</tr>
</tbody>
</table>
temperature data from Prosser, Washington, and known full-bloom dates for 'Concord' grapes were used in application of the statistical method. Selecting different chill unit estimates, figuring the growing degree hours to full bloom, and plotting the standard deviation with the point of least error gives the chill unit requirement. This method seems to be accurate and reliable.

Another estimate of the chill unit requirement was used for comparison. If it were to be assumed that rest is completed when samples placed in the growth chamber reach full bud swell in two weeks, then the chill unit requirement would be around 1,400 for the 2 years data (1974-75 and 1975-76). In 1974-75 the standard of two weeks for bud growth to reach the full bud swell came on March 13, (1428 CU); in 1975-76, March 31 (1392 CU). Whereas using 830 chill units, the end of rest would be January 6, 1975 and January 20, 1976, respectively. The average of these two years at Farmington, Utah for GDH at full bloom would be 16,123 C (29,021 F) for the 1,410 CU requirement and 17,876 C (32,177 F) for the 832 CU requirement.

Statistical standard deviations (SD) were used to compare differences of GDH requirements to reach each of the bud phenology stages using 1,410 as the chill unit requirement vs 832 CU. Comparing 15 stages of bud development, the SD was 985.29 for 1,410 CU and 802.36 for 832 CU.
The SD for five more easily recognized stages were 1,111.89 (1,410 CU), and 845.40 (832 CU). The full bloom stage is easiest to recognize so it probably has the least error in the phenological observations. Therefore, full bloom is probably the best observation to use for comparison. The SD for full bloom stage was 999.8 for 1,410 CU and 340.83 for 832 CU (Appendix Tables 11 and 12). For the full bloom stage, the 832 estimate had 1/3 the SD and appears to be the most accurate.

**Hardiness**

An artificial freeze chamber to duplicate nature is difficult to use. Information received from running T50 temperatures on both cambium and primary bud for both 1974-75 and 1975-76 seasons are graphed in Figures 10 and 11. If T50 temperatures could have been taken every few days, the T50's might be closely correlated to changes in maximum and minimum temperatures. Generally speaking, when minimum temperatures continue to drop during a few days period, then T50 temperatures drop. After rest completion, if the maximum temperatures begin to rise, GDH accumulate, and when accumulation is substantial, dehardening will take place quite rapidly.

**Optimum temperatures**

Studies by other researchers indicate that low temperatures (15 C) and high temperatures (32 C) produce less than
FIGURE 10 - RELATIONSHIP OF T50 TEMPERATURES OF PRIMARY BUDS AND CAMBIUM OF CONCORD GRAPE TO DAILY MAXIMUM & MINIMUM TEMPERATURES DURING THE 1974-75 SEASON.
FIGURE 11: RELATIONSHIP OF $T_{50}$ TEMPERATURES OF PRIMARY BUDS AND CAMBIUM OF CONCORD GRAPE TO DAILY MAXIMUM AND MINIMUM TEMPERATURES DURING THE 1975–76 SEASON.
optimum growth with 'Concord' grapes. It was found, supported by Tukey (1958), that 25 to 26 C temperatures were optimum for 'Concord' grape vine, flower bud, and fruit development.

**Base temperatures**

Determining the base temperature for 'Concord' grape growth was necessary to develop a working phenological model. Most *V. vinifera* grapes have been assigned 10 C as the temperature at which noticeable growth and bud development begins. Results of this study indicate that the base temperature for 'Concord' grape is about 4.4 C.

**Bud phenology and maturity**

Little research has been done to standardize phenological stages of 'Concord' grape buds with GDH accumulation. With a standardized set of bud phenology stages, the GDH can be calculated following rest completion. Figure 12 shows a comparison for two growing seasons. These two years were quite different from each other. The 1974-75 season had a much cooler spring so development was slower, causing full bloom to be 17 days later in 1975-76. However, the GDH requirements for full bloom were very similar, 17,842 C (32,148 F) for 1974-75, and 17,782 C (31,936 F) for the 1975-76 season. This emphasizes the fact that grapes respond directly to temperature in their development,
Comparison of two growing seasons and chill units and growing degree hour accumulations for the years of 1974-75 and 1975-76.
and that a GDH reference scheme is far superior to a calendar date reference scheme.

As shown in Figure 12, stages of soluble solid readings are close in GDH requirement for the two different years. This shows the value and accuracy in comparing one year at a particular percent soluble solids, to what would be required in a future year to reach that same percent. This information could be correlated with weather data of any given area to predict what percent of soluble solids could be expected, if one wished to grow 'Concord' grapes. Although soluble solids are probably dependent on GDH accumulation to a large extent, undoubtedly other factors of environment would be needed for a complete phenological model for soluble solids content.
SUMMARY

The requirements to complete rest in the 'Concord' grape were evaluated. The rest period was found to be approximately 830 chill units. Using weather data and full bloom dates from Prosser, Washington, the statistical method (Ashcroft et al., 1977) verified this duration of rest for 'Concord' grapes.

The cold hardiness of both primary buds and cambium was evaluated. $T_{50}$ temperatures were taken every two weeks. The $T_{50}$ temperature of the cambium was 2 to 10 c lower than that of the primary buds. When daily minimum temperatures dropped during the winter, the $T_{50}$ temperature also dropped. After rest completion, temperatures above 4.4 C contributed to bud growth and development. These warm temperatures induced deacclimation causing $T_{50}$ temperatures to rise.

The evaluation of the base temperature for 'Concord' grapes was conducted in a series of growth chambers. The base temperature was found to be approximately 4.4 C.

Optimum growth was found to be near 25 C.

Bud phenological stages were followed and a standard set of the various stages was developed. The different stages of bud development were correlated with GDH requirement from end of rest to each bud stage. 'Concord' grapes
reach full bloom at approximately 17,800 GDH C (32,000 GDH F).

Grape development was followed from full bloom to maturity. A regression line was plotted between the various GDH requirements for the percent soluble solids acquired during the 1975 and 1976 seasons. GDH accumulation and soluble solids were correlated. Other environmental factors, such as pruning, fertilizing, and watering do effect maturity. Keeping the preceding factors constant, the accuracy of predicting harvest at a desired percent soluble solid can be achieved.
LITERATURE CITED


APPENDIX
Table 5. 'Concord' grape rest studies, 1974-75

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Table 8. Hardiness studies, 'Concord' grape, 1975-76

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Table 9. Comparison of accumulation CU's and GDH to time of sample collection

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Dec. 17, 1974-Jan. 6, 1975  
50 CU's accumulated  
26 GDH's accumulated

244 CU's accumulated  
770 GDH's accumulated

540 CU's accumulated  
880 GDH's accumulated
Table 10. 'Concord' grape growth and bud stage using 830 CU's as rest requirement

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<td>GDH's Date</td>
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Soluble solids (%)       | Soluble solids (%)

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<td>9/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19.8</td>
<td>9/24</td>
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</tbody>
</table>

Full Bloom

Standard deviation = 340.83

Standard error = 241.00
Table 11. 'Concord' grape growth and bud stages using 1400 CU's as rest requirement

<table>
<thead>
<tr>
<th>Stage</th>
<th>1974-75</th>
<th></th>
<th>1975-76</th>
<th></th>
<th>Ave</th>
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<tbody>
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<td></td>
<td>Date</td>
<td>CU's</td>
<td>Date</td>
<td>CU's</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>GDH's</td>
<td></td>
<td>GDH's</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCA</td>
<td>10/4</td>
<td></td>
<td>10/8</td>
<td>Base</td>
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<tr>
<td>ECA</td>
<td>3/13</td>
<td>1432</td>
<td></td>
<td>1392</td>
<td></td>
</tr>
<tr>
<td>1st bud swell</td>
<td>4/29</td>
<td>5,102</td>
<td>4/14</td>
<td>3,762</td>
<td>4,432</td>
</tr>
<tr>
<td>Full bud swell</td>
<td>5/10</td>
<td>7,386</td>
<td>4/27</td>
<td>6,086</td>
<td>6,736</td>
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<tr>
<td>Full burst</td>
<td>5/14</td>
<td>8,942</td>
<td>5/3</td>
<td>8,106</td>
<td>8,524</td>
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<tr>
<td>1st leaf shoot</td>
<td>5/16</td>
<td>10,180</td>
<td>5/7</td>
<td>9,996</td>
<td>10,088</td>
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<tr>
<td>2nd leaf shoot</td>
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<td>12,098</td>
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<td>11,680</td>
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<td>3rd leaf shoot</td>
<td>5/27</td>
<td>13,638</td>
<td>5/13</td>
<td>12,632</td>
<td>13,135</td>
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<tr>
<td>4th leaf shoot</td>
<td>5/30</td>
<td>14,824</td>
<td>5/18</td>
<td>15,558</td>
<td>15,191</td>
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<tr>
<td>5th leaf shoot</td>
<td>6/6</td>
<td>18,640</td>
<td>5/24</td>
<td>18,526</td>
<td>18,583</td>
</tr>
<tr>
<td>6th leaf shoot</td>
<td>6/8</td>
<td>19,822</td>
<td>5/26</td>
<td>19,296</td>
<td>19,559</td>
</tr>
<tr>
<td>7th leaf shoot</td>
<td>6/11</td>
<td>21,052</td>
<td>5/31</td>
<td>22,030</td>
<td>21,541</td>
</tr>
<tr>
<td>8th leaf shoot</td>
<td>6/17</td>
<td>24,916</td>
<td>6/2</td>
<td>23,180</td>
<td>24,048</td>
</tr>
<tr>
<td>1st bloom</td>
<td>6/21</td>
<td>26,352</td>
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<tr>
<td>50% bloom</td>
<td>6/23</td>
<td>27,516</td>
<td>6/4</td>
<td>24,470</td>
<td>25,993</td>
</tr>
<tr>
<td>75% bloom</td>
<td>6/25</td>
<td>28,706</td>
<td>6/6</td>
<td>25,772</td>
<td>27,239</td>
</tr>
<tr>
<td>Full bloom</td>
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<td>29,728</td>
<td>6/10</td>
<td>28,314</td>
<td>29,021</td>
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<tr>
<td>Soluble solids (%)</td>
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<td>75,674</td>
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<tr>
<td></td>
<td>9/23</td>
<td>89,664</td>
<td>14.4</td>
<td>8/27</td>
<td>80,490</td>
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<tr>
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<td>9/24</td>
<td>97,602</td>
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<tr>
<td>Full Bloom</td>
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<tr>
<td>Standard deviation</td>
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<td>Standard error</td>
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<td>707.00</td>
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Table 12. Two seasons (1974-75 and 1975-76) differences in GDH requirements to different chill unit exposure for 'Concord' grapes

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<th>GDH's</th>
<th>CU's</th>
<th>GDH's</th>
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</tr>
<tr>
<td>ECA 3/14</td>
<td>1392-1428</td>
<td>830-834*</td>
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<tr>
<td>1st bud swell</td>
<td>1,340</td>
<td>408</td>
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<tr>
<td>*Full bud swell</td>
<td>1,300</td>
<td>368</td>
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</tr>
<tr>
<td>Full burst</td>
<td>836</td>
<td>96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*1st leaf shoot</td>
<td>184</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*2nd leaf shoot</td>
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<tr>
<td>3rd leaf shoot</td>
<td>1,006</td>
<td>74</td>
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<tr>
<td>4th leaf shoot</td>
<td>734</td>
<td>1,666</td>
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<tr>
<td>5th leaf shoot</td>
<td>114</td>
<td>818</td>
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<tr>
<td>6th leaf shoot</td>
<td>526</td>
<td>406</td>
<td></td>
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<tr>
<td>7th leaf shoot</td>
<td>978</td>
<td>1,910</td>
<td></td>
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<tr>
<td>8th leaf shoot</td>
<td>1,736</td>
<td>804</td>
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<tr>
<td>*1st bloom</td>
<td>3,172</td>
<td>2,240</td>
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<tr>
<td>50% bloom</td>
<td>3,046</td>
<td>2,114</td>
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<tr>
<td>75% bloom</td>
<td>2,934</td>
<td>2,002</td>
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<tr>
<td>*Full bloom</td>
<td>1,414</td>
<td>482</td>
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</table>

5 Stages (1,400 CU's)

Mean = 1,381.2  n = 15  Mean = 1,343.73  n = 15
SD  = 1,111.89  Mean = 948.80  SD  = 985.29
SE  = 497.25   SE  = 354.40  SE  = 207.17

5 Stages * (830 CU's)

Mean = 786.80
SD  = 845.40
SE  = 378.07
Table 13. Regression for growing degree hours to percent soluble solids in 'Concord' grapes for the 1975 and 1976 seasons

<table>
<thead>
<tr>
<th>X</th>
<th>% Soluble solids</th>
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<td>Y</td>
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<tr>
<td>Y</td>
<td>= 44,911.54 + 2,770 x (% SS)</td>
</tr>
<tr>
<td>Y</td>
<td>= a₀ - a₁x</td>
</tr>
<tr>
<td>a₀</td>
<td>44,911.54</td>
</tr>
<tr>
<td>a₁</td>
<td>2,770</td>
</tr>
<tr>
<td>r²</td>
<td>0.95</td>
</tr>
<tr>
<td>r</td>
<td>.975</td>
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</tbody>
</table>

44,911.54 + 2,770 x 12% = 78,151.54
44,911.54 + 2,770 x 18% = 94,771.54
### Table 14. Fourteen years of heat units, full bloom, and harvest dates from Prosser, Washington

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<tbody>
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<tr>
<td>May</td>
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<tr>
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<td>398</td>
<td>579</td>
<td>350</td>
<td>352</td>
<td>542</td>
<td>327</td>
<td>370</td>
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<td>644</td>
<td>720</td>
<td>690</td>
<td>612</td>
<td>535</td>
<td>618</td>
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<tr>
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<td>494</td>
<td>692</td>
<td>498</td>
<td>516</td>
<td>721</td>
<td>545</td>
<td>614</td>
<td>618</td>
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<td>Sept.</td>
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<td>247</td>
<td>326</td>
<td>392</td>
<td>268</td>
<td>434</td>
<td>520</td>
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<tr>
<td>Oct.</td>
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<td></td>
<td>16</td>
<td>73</td>
<td>90</td>
<td>58</td>
<td>186</td>
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<tr>
<td>Total</td>
<td>2433</td>
<td></td>
<td>1899</td>
<td>2369</td>
<td>1891</td>
<td>2070</td>
<td>2221</td>
<td>1976</td>
<td>2229</td>
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</tbody>
</table>

<table>
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</thead>
<tbody>
<tr>
<td>April</td>
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<td>May</td>
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<td>306</td>
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<td>390</td>
<td>446.5</td>
<td>442</td>
<td>584</td>
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<td>638</td>
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<td>577</td>
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<td>698</td>
<td>623</td>
<td>647.9</td>
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<tr>
<td>Aug.</td>
<td>512</td>
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<td>642</td>
<td>754.5</td>
<td>529</td>
<td>510</td>
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<td>424</td>
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<td>376</td>
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<td>Oct.</td>
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<td>62</td>
<td>22</td>
<td>26</td>
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<tr>
<td>Total</td>
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<td>2154</td>
<td>2069</td>
<td>2436.5</td>
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<td>9/27</td>
<td>10/1</td>
<td>10/8</td>
<td>10/14</td>
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</table>

2. Heat units expressed in accumulative degree days above 50 F full bloom-harvest.
3. Heat units are obtained by the number of degrees above the monthly mean temp. of 50 F times number of days in the month.
4. Weather station at the Irrigated Agriculture Research and Extension Center, Prosser, Wash.
Table 15. Daily temperature to CU and GDH accumulations, 1974-75

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<th>Yr. 1974</th>
<th>Crop</th>
<th>Concord grapes</th>
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VITA
Mervin Gayle Weeks
Candidate for the Degree of
Master of Science

Thesis: A Study of Rest Period, Hardiness, and Bud Development of the 'Concord' Grape

Major Field: Plant Science

Biographical Information:


Education: Attended elementary school at Central Elementary, Vernal, Utah; graduated from Ashley Valley Junior High, 1962 and Uintah High School in 1965; received the Bachelor of Science degree from Brigham Young University with a major in Horticulture, in 1973.

Professional Experience: 1973 to present, research technician, Plant Science Department, Utah State University; Summer of 1972 research aide, Brigham Young University, and 1970–71 manager of golf course grounds at Vernal, Utah. During the above, time has been spent for several years raising small fruits and working in fruit and vegetable crops.