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

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

by

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A Study of Rest Period, Hardiness, and Bud

Development of the 'Concord' Grape

by

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Utah State University, 1977

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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 curcial 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 (Vistis 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 (Kliewer 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 caribaa_ 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 differenc 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 CO_2, 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/m^2 (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/m^2 (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/m^2 (2,000 foot-candles) were similar. At 46.45 lux/m^2 (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 tempetatures 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 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.

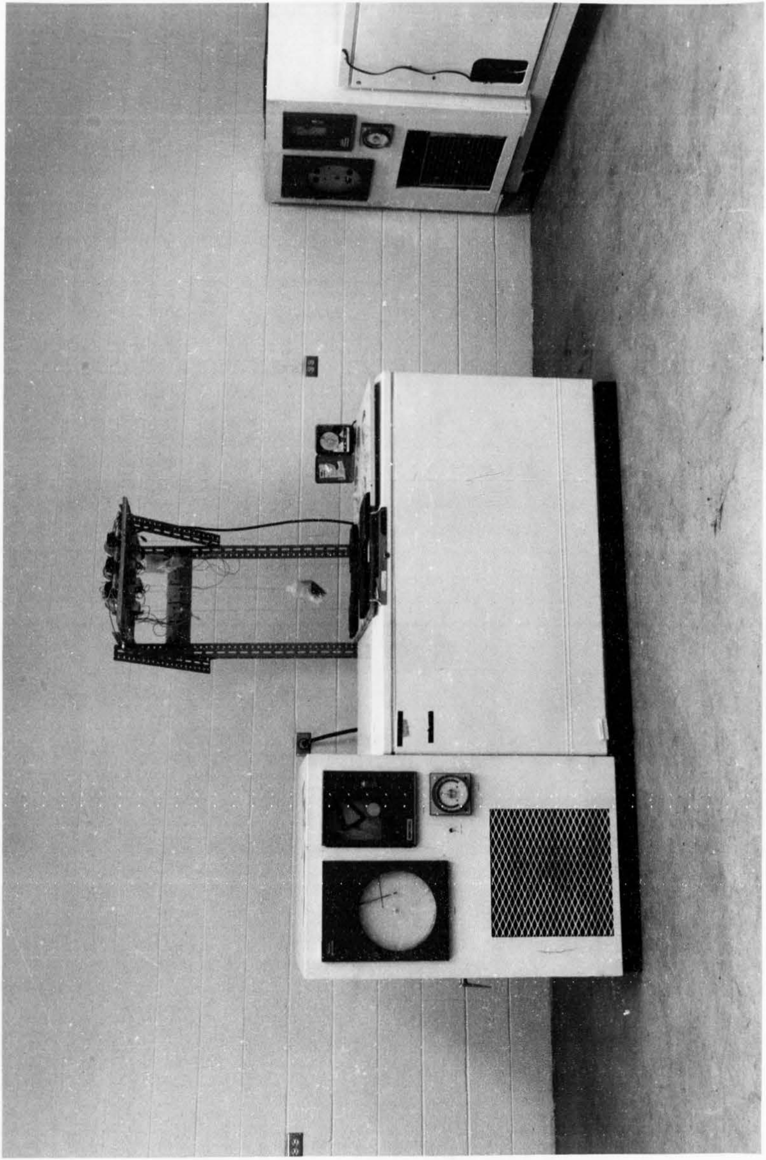
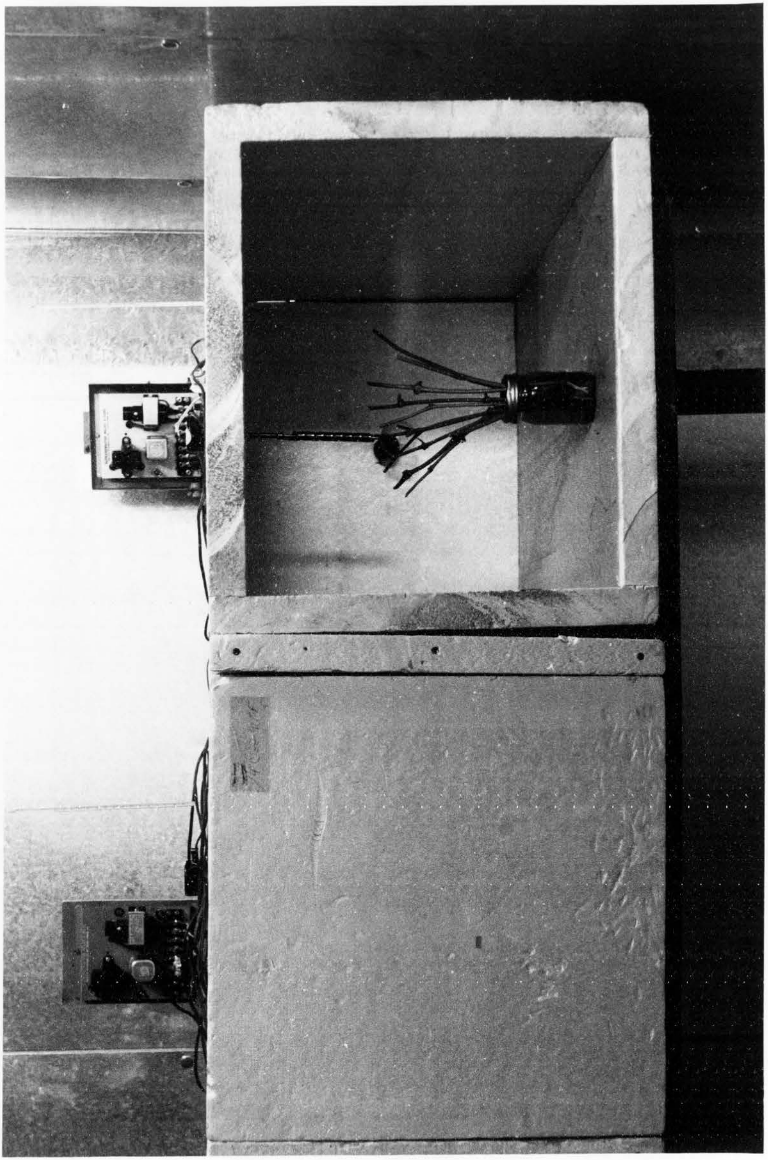


Figure 2. Growth chambers constructed of 51 mm thick styrofoam used for optimum and base temperature study. 'Concord' grape cuttings are shown in a beaker of water in one of the chambers.



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 1. Description of phenological stages of 'Concord' grape

Stage	Description
1st swell	Bud begins to increase in size and change to a lighter color
Full swell	Bud has increased to maximum size without any tip separation
Full burst	Tip of bud has burst open and started to spread
1st leaf	Leaf first makes a right angle with the main stem
2nd-8th leaf	Determined when each leaf first makes a right angle with the main stem
1st bloom	First bloom open on 50 percent of the clusters
50 % bloom	Half of flowers on 50 percent of the clusters open
75% bloom	Three-fourths of the flowers open on 50 percent or more of the clusters
Full bloom	Most of the flowers in the vineyard are open

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

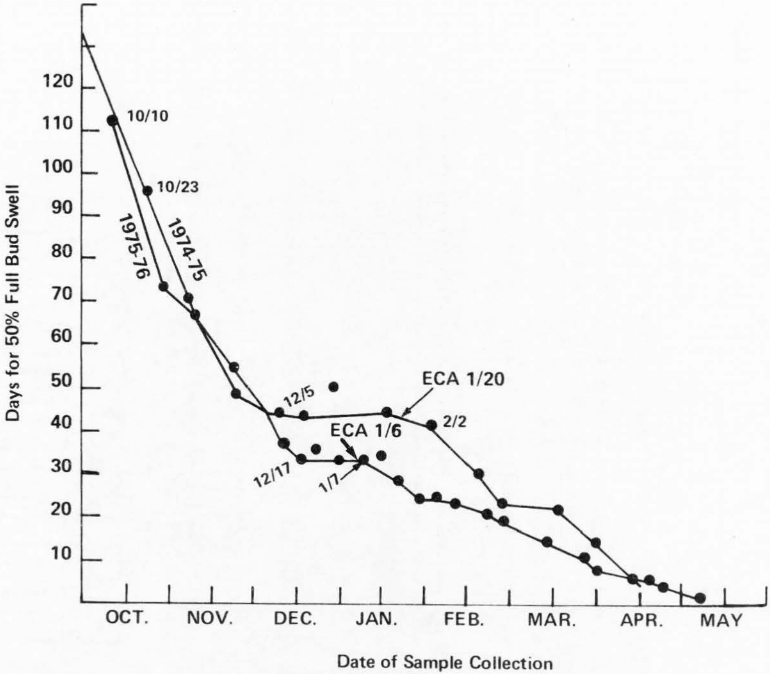


Figure 3 • Days required for Concord grape samples collected on various calendar dates to reach 50 percent full bud swell in a 25 C growth chamber from the time samples were taken in the field. Data was collected from the years 1974-75 and 1975-76.

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

Chill unit estimate	Year 1962-63	1963-64	1964-65	1965-66	1966-67	1968-69	1969-70	Mean	S.D.
600	19566	16133	17189	15934	19280	16120	15548	17110	1658
700	19290	15689	16954	15823	19110	16010	15321	16884	1659
800	18848	15556	16871	15628	18862	15874	15164	16688	1571
900	18742	15378	16833	15534	18754	15757	15109	16587	1573
1,000	18649	15274	16697	15468	18592	15458	15000	16448	1577
1,100	18649	15138	16456	15333	18367	15252	14936	16303	1584
1,200	18474	14953	16291	15179	18316	15106	14746	16151	1607
1,300	18347	14762	15621	15122	18188	15081	14733	15979	1591
Full bloom*	6/9	6/9	6/3	5/28	6/9	5/31	6/5		
Harvest*	10/19	10/12	10.5	9/27	10.1	10.14	9/21 to 10/15		

*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.

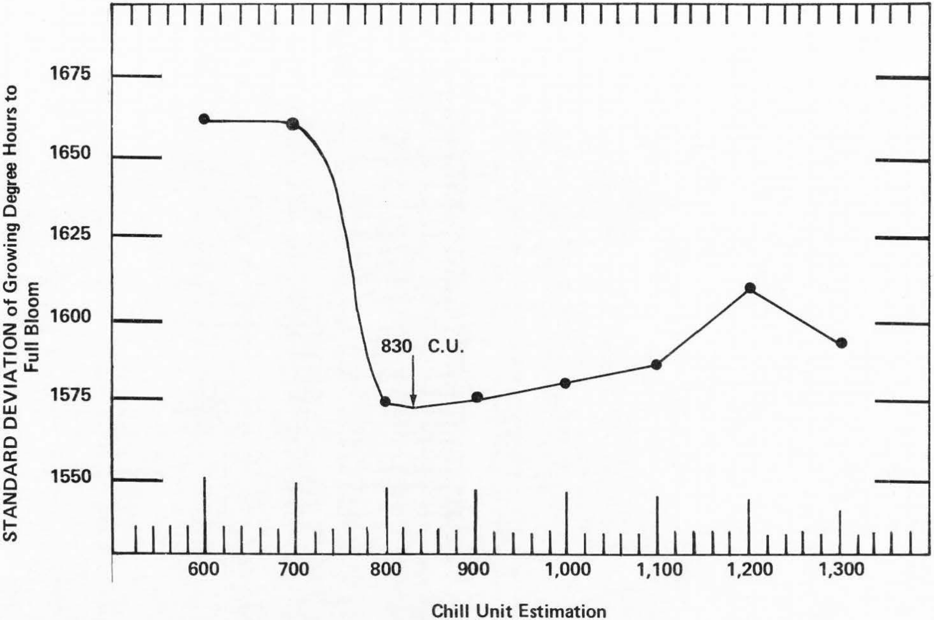


Figure 4 • The relationship between the standard deviation of the accumulation of Growing Degree Hours to full bloom for Concord grapes and selected accumulations of chill units. The curve is based on data from Prosser, Washington 1962-1969.

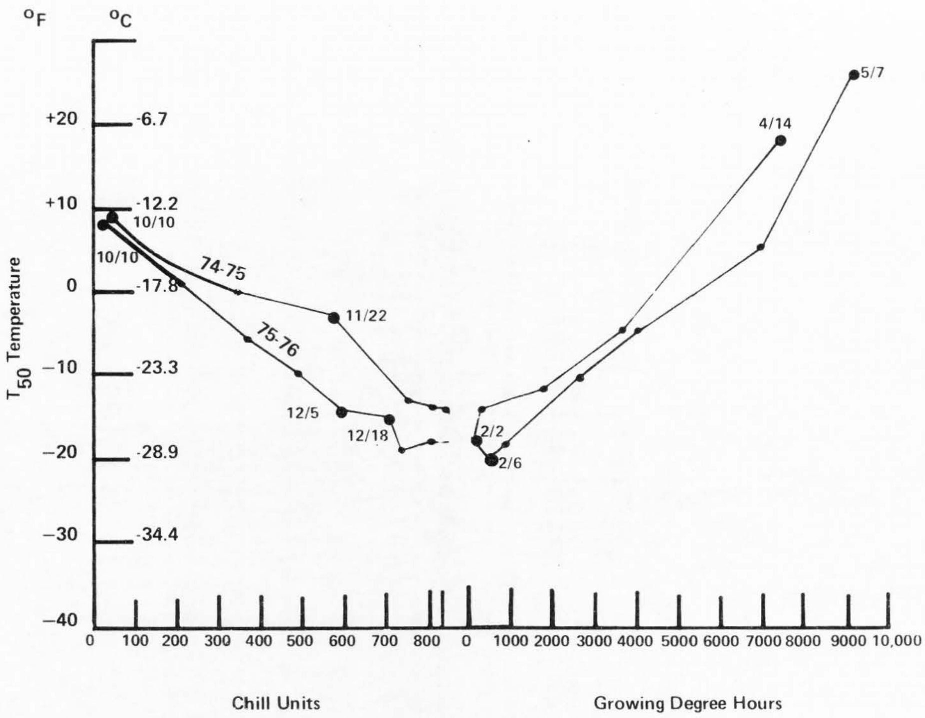


Figure 5 • Relationship of Concord grape primary bud T_{50} to chill unit and growing degree hour accumulations during the 1974-75 and 1975-76 seasons.

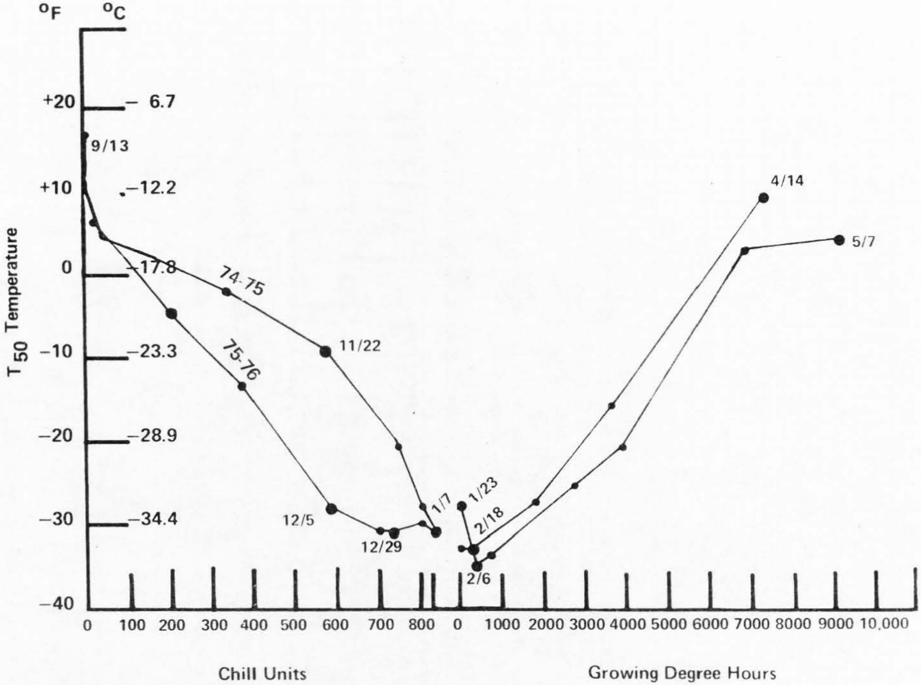


Figure 6 ● Relationship of Concord grape Cambium T_{50} to chill unit and growing degree hour accumulations during the 1974-75 and 1975-76 seasons.

sample date. The lowest primary bud maximum T_{50} temperature was on December 29, where as 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


CONCORD APRIL 18 - AUGUST 6 1975
50°
45°
42°
32°

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*

Stages	Physiodates		
	Chill units	GDH C	GDH F
Begin chill unit accumulation	0		
End chill unit accumulation	830		
1. First swell		4,220	7,590
2. Full swell		5,500	9,890
3. Bud burst		6,490	11,680
4. First leaf		7,360	13,240
5. Second leaf		8,240	14,840
6. Third leaf		9,050	16,290
7. Fourth leaf		10,190	18,340
8. Fifth leaf		12,080	21,740
9. Sixth leaf		12,620	22,720
10. Seventh leaf		15,940	28,700
11. Eighth leaf		15,110	27,200
12. First bloom		15,510	27,920
13. Fifty percent bloom		16,190	29,150
14. Seventy-five percent bloom		16,890	30,400
15. Full bloom		17,880	32,180

*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.

Dormant

First Swell

Full Swell

Bud Burst

First Leaf

Second Leaf

Fourth Leaf

50% Bloom

Full Bloom

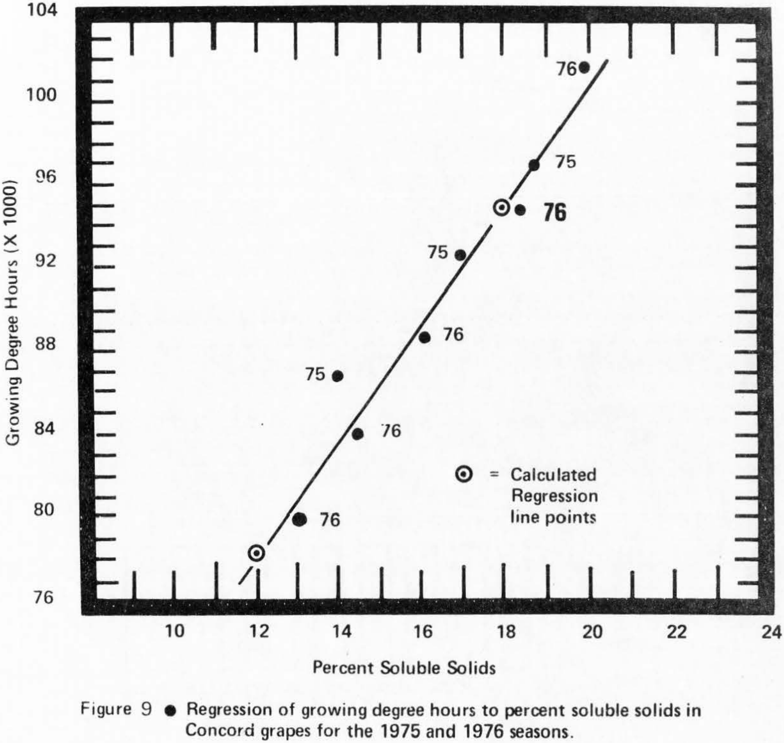


Figure 9 ● Regression of growing degree hours to percent soluble solids in Concord grapes for the 1975 and 1976 seasons.

DISCUSSION

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

Collection date	Plant No. or segment	Number of buds breaking Date analyzed 1975 Feb. 11	Stage	Date analyzed 1975 Feb. 18	Stage	% bud break full swell or more
	Random					
Jan. 21, 1975	#1	1 out 6	1st swell	5 out 6	3(full swell) 2(1st swell)	50%
Jan. 21, 1975	#2	1 out 8	1st swell	3 out 8	3(full swell)	38%
Jan. 21, 1975	#3	2 out 6	1st swell	3 out 6	2(full burst) 1(full swell)	50%
Jan. 21, 1975	#4	2 out 8	1st swell	7 out 8	1(1st leaf) 4(full swell) 2(1st swell)	63%
	Segments					
Jan. 21, 1975	Base	9 out 9	1st swell	9 out 9	5(full burst) 4(full swell)	100%
Jan. 21, 1975	Middle	6 out 9	1st swell	6 out 9	2(1st leaf) 2(full burst) 2(full swell)	67%
Jan. 21, 1975	Apex	2 out 13	1st swell	7 out 13	1(full burst) 3(full swell) 3(1st swell)	31%

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 T_{50} temperatures on both cambium and primary bud for both 1974-75 and 1975-76 seasons are graphed in Figures 10 and 11. If T_{50} temperatures could have been taken every few days, the T_{50}'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 T_{50} 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

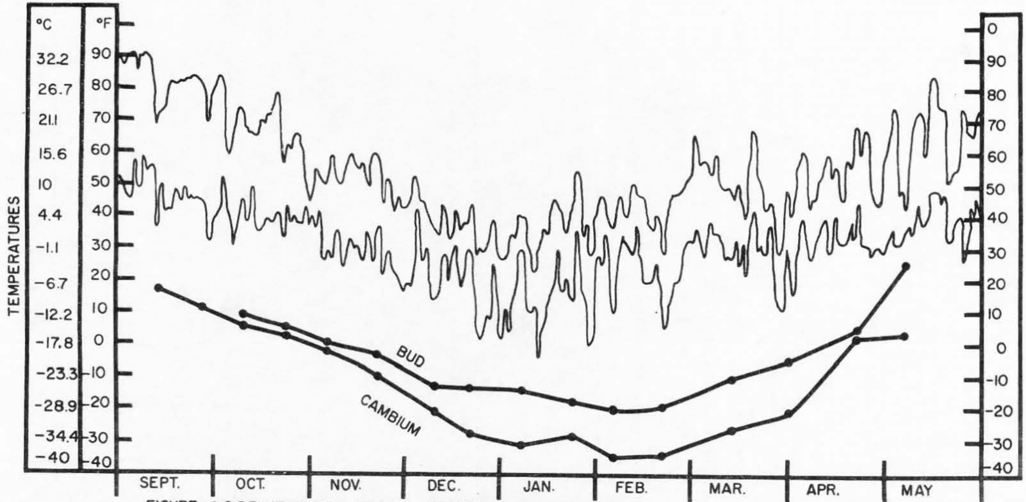


FIGURE 10 ● RELATIONSHIP OF T_{50} TEMPERATURES OF PRIMARY BUDS AND CAMBIUM OF CONCORD GRAPE TO DAILY MAXIMUM & MINIMUM TEMPERATURES DURING THE 1974—75 SEASON.

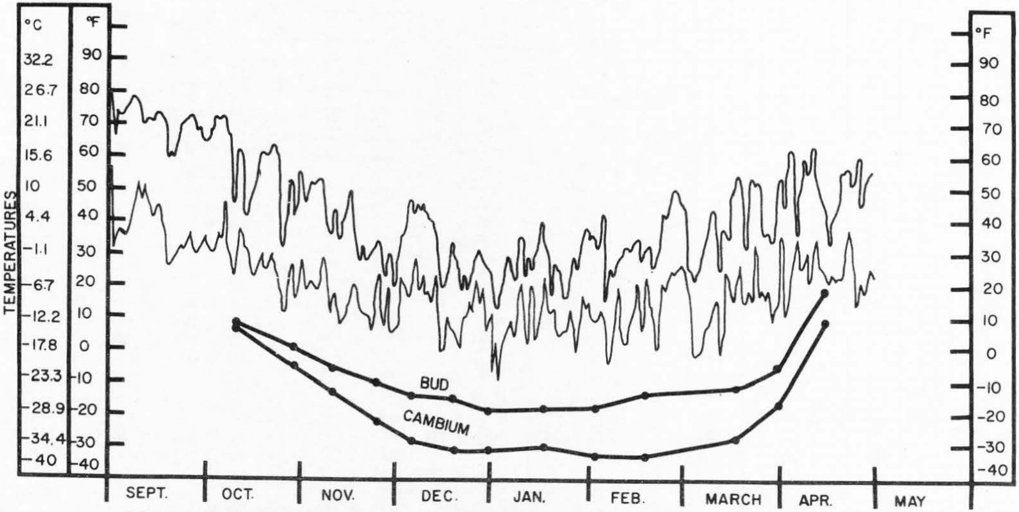


FIGURE 11 ● RELATIONSHIP OF T_{50} TEMPERATURES OF PRIMARY BUDS AND CAMBIUM OF CONCORD GRAPE TO DAILY MAXIMUM AND MINIMUM TEMPERATURES DURING THE 1975—76 SEASON.

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,

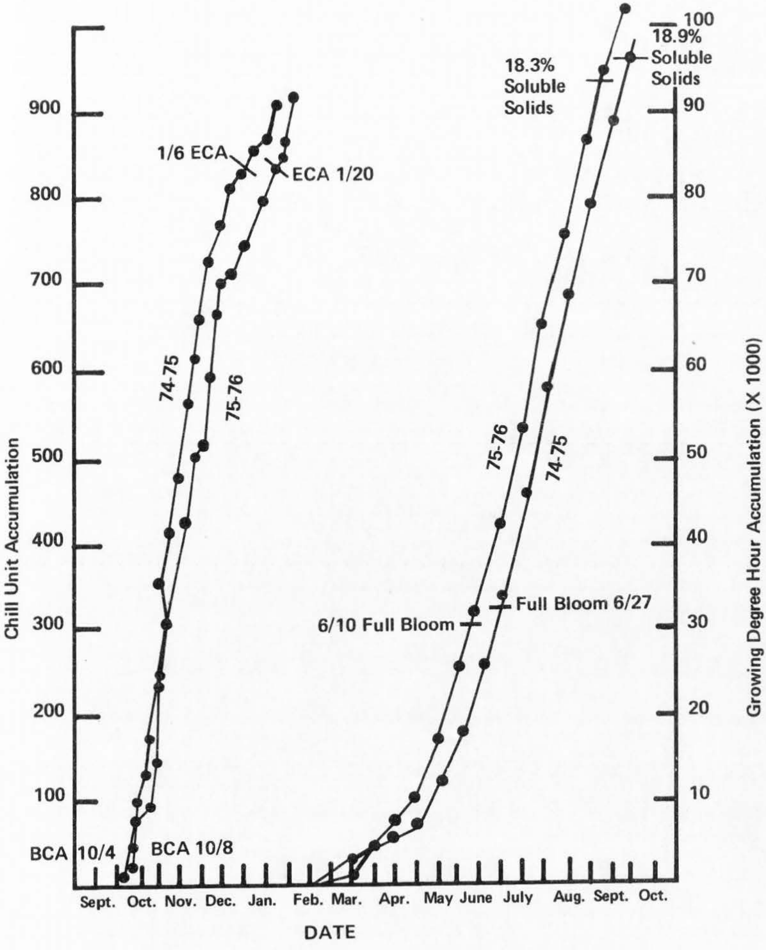


Figure 12 ● Comparison of two growing seasons and chill units and growing degree hour accumulations for the years of 1974-75 and 1975-76.

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.

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APPENDIX

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

Sample dates	Date 50% bud full swell	No. days to reach 50% bud full swell
Oct. 23	Never	Never
Nov. 6	Jan. 15	70
Nov. 22	Jan. 15	54
Dec. 10	Jan. 16	37
Dec. 17	Jan. 19	33
Dec. 21	Jan. 24	34
Jan. 1	Feb. 2	33
Jan. 7	Feb. 9	33
Jan. 14	Feb. 17	34
Jan. 21	Feb. 18	28
Jan. 29	Feb. 22	24
Feb. 4	Feb. 28	24
Feb. 11	Mar. 6	23
Feb. 21	Mar. 14	21
Feb. 26	Mar. 17	19
Mar. 13	Mar. 27	14
Mar. 25	Apr. 4	10
Apr. 1	Apr. 9	8
Apr. 10	Apr. 16	6
Apr. 18	Apr. 23	5
Apr. 23	Apr. 27	4
May 6	May 7	1

Table 6. 'Concord' grape rest studies, 1975-76

Sample dates	Date 50% bud full swell	No. days to reach 50% bud full swell
Oct. 10	Jan. 30	112
Oct. 28	Jan. 9	73
Nov. 10	Jan. 15	66
Nov. 24	Jan. 11	48
Dec. 5	Jan. 18	44
Dec. 18	Jan. 30	43
Dec. 29	Feb. 17	50
Jan. 16	Feb. 29	44
Feb. 2	Mar. 14	41
Feb. 18	Mar. 19	30
Feb. 27	Mar. 21	23
Mar. 16	Apr. 7	22
Mar. 31	Apr. 14	14
Apr. 14	Apr. 19	5

Table 7. Hardiness studies, 'Concord' grape, 1974-75

Sample date	T_{50} primary bud	T_{50} cambium
Sept. 13	--	17 F
Sept. 27	--	11 F
Oct. 10	9 F	5 F
Oct. 23	5 F	3 F
Nov. 6	0 F	-2 F
Nov. 22	-3 F	-9 F
Dec. 10	-13 F	-21 F
Dec. 21	-14 F	-28 F
Jan. 7	-14 F	-31 F
Jan. 23	-18 F	-28 F
Feb. 6	-20 F	-35 F
Feb. 21	-19 F	-34 F
Mar. 13	-10 F	-26 F
Apr. 1	-5 F	-21 F
Apr. 22	5 F	3 F
May 7	26 F	4 F

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

Sample date	T_{50} primary bud	T_{50} cambium
Oct. 10	8 F	7 F
Oct. 28	1 F	-5 F
Nov. 10	-6 F	-13 F
Nov. 24	-10 F	-22 F
Dec. 5	-14 F	-28 F
Dec. 18	-15 F	-31 F
Dec. 29	-19 F	-31 F
Jan. 16	-18 F	-30 F
Feb. 2	-18 F	-33 F
Feb. 18	-14 F	-33 F
Mar. 16	-12 F	-28 F
Mar. 31	-5 F	-16 F
Apr. 14	18 F	9 F

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

Sample collection Date 1974-75	CU's	GDH's	Sample collection Date 1975-76	CU's	GDH's
Oct. 10	44		Oct. 10	26	
Oct. 23	120		Oct. 28	210	
Nov. 6	344		Nov. 10	374	
Nov. 22	578		Nov. 24	492	
Dec. 10	752		Dec. 5	586	
Dec. 17	784		Dec. 18	710	
Dec. 21	810		Dec. 29	738	
Jan. 1	824		Jan. 16	808	
Jan. 6	ECA		Jan. 20	ECA	
Jan. 7	844	0	Feb. 2	898	110
Jan. 14	852	0	Feb. 18		288
Jan. 21	896	54	Feb. 27		942
Jan. 29		348	Mar. 16		1,756
Feb. 4		416	Mar. 31		3,622
Feb. 11		540	Apr. 14		7,384
Feb. 21		744			
Feb. 26		800			
Mar. 13		2,690			
Mar. 25		3,880			
Apr. 1		3,968			
Apr. 10		4,902			
Apr. 18		5,900			
Apr. 23		7,150			
May 6		9,118			

Dec. 17, 1974-Jan. 6, 1975

50 CU's accumulated
26 GDH's accumulated

Dec. 5, 1975-Jan. 20, 1976

244 CU's accumulated
770 GDH's accumulated

Dec. 5, 1975-Feb. 2, 1976

540 CU's accumulated
880 GDH's accumulated

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

	1974-75			1975-76			
Stage	Date	CU's	GDH's	Date	CU's	GDH's	Ave GDH's
BCA	10/4		Base	10/8		Base	
ECA	1/6	834	5,695	1/20	830	4,063	
1st bud swell	4/29		7,792	4/14		7,384	7,588
Full bud swell	5/10		10,076	4/27		9,708	9,892
Full burst	5/14		11,632	5/3		11,728	11,680
1st leaf shoot	5/16		12,870	5/7		13,618	13,244
2nd leaf shoot	5/22		14,788	5/10		14,884	14,836
3rd leaf shoot	5/27		16,328	5/13		16,254	16,291
4th leaf shoot	5/30		17,514	5/18		19,180	18,342
5th leaf shoot	6/6		21,330	5/24		22,148	21,739
6th leaf shoot	6/8		22,512	5/26		22,918	22,715
7th leaf shoot	6/11		23,742	5/31		25,652	24,697
8th leaf shoot	6/17		27,606	6/2		26,802	27,204
1st bloom	6/21		29,042	6/2		26,802	27,922
50% bloom	6/23		30,206	6/4		28,092	29,149
75% bloom	6/25		31,396	6/6		29,394	30,395
Full bloom	6/27		32,418	6/10		31,936	32,177
Soluble solids (%)				Soluble solids (%)			
14	9/12		86,824	13.0	8/20	79,296	
17	9/23		92,354	14.4	8/27	84,112	
18.9	10/1		96,054	16.0	9/3	88,728	
				18.3	9/13	94,678	
				19.8	9/24	101,224	

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

	1974-75			1975-76			
Stage	Date	CU's	GDH's	Date	CU's	GDH's	Ave GDH's
BCA	10/4			10/8		Base	
ECA	3/13	1432			1392		
1st bud swell	4/29		5,102	4/14		3,762	4,432
Full bud swell	5/10		7,386	4/27		6,086	6,736
Full burst	5/14		8,942	5/3		8,106	8,524
1st leaf shoot	5/16		10,180	5/7		9,996	10,088
2nd leaf shoot	5/22		12,098	5/10		11,262	11,680
3rd leaf shoot	5/27		13,638	5/13		12,632	13,135
4th leaf shoot	5/30		14,824	5/18		15,558	15,191
5th leaf shoot	6/6		18,640	5/24		18,526	18,583
6th leaf shoot	6/8		19,822	5/26		19,296	19,559
7th leaf shoot	6/11		21,052	5/31		22,030	21,541
8th leaf shoot	6/17		24,916	6/2		23,180	24,048
1st bloom	6/21		26,352	6/2		23,180	24,766
50% bloom	6/23		27,516	6/4		24,470	25,993
75% bloom	6/25		28,706	6/6		25,772	27,239
Full bloom	6/27		29,728	6/10		28,314	29,021

Soluble solids (%)			Soluble solids (%)		
14	9/12	84,134	13.0	8/20	75,674
17	9/23	89,664	14.4	8/27	80,490
18.9	10/1	93,364	16.0	9/3	85,106
			18.3	9/13	91,056
			19.8	9/24	97,602

Full Bloom

Standard deviation = 999.85

Standard error = 707.00

Table 12. Two seasons (1974-75 and 1975-76) differences in GDH requirements to different chill unit exposure for 'Concord' grapes

		CU's	GDH's	CU's	GDH's
BCA	10/4				
ECA	3/14	1392-1428		830-834*	
1st bud swell			1,340		408
*Full bud swell			1,300		368
Full burst			836		96
*1st leaf shoot			184		748
*2nd leaf shoot			836		96
3rd leaf shoot			1,006		74
4th leaf shoot			734		1,666
5th leaf shoot			114		818
6th leaf shoot			526		406
7th leaf shoot			978		1,910
8th leaf shoot			1,736		804
*1st bloom			3,172		2,240
50% bloom			3,046		2,114
75% bloom			2,934		2,002
*Full bloom			1,414		482

5 Stages (1,400 CU's)

Mean = 1,381.2	n = 15	n = 15
SD = 1,111.89	Mean = 1,343.73	Mean = 948.80
SE = 497.25	SD = 985.29	SD = 802.36
	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

X = % Soluble solids

Y = GDH's

$$Y = 44,911.54 + 2,770 \text{ x } (\% \text{ SS})$$

$$Y = a_o - a_1 x$$

a_o = 44,911.54

a_1 = +2,770

r^2 = 0.95

r = .975

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

	Total heat unit							
Month	Ave.	Year						
	1924-69*	1957*	1958*	1959*	1960*	1961*	1962*	1963*
April	39							
May	273		102					
June	450	398	579	350	352	542	327	370
July	642	543	749	644	720	690	612	535
Aug.	592	494	692	498	516	721	545	618
Sept.	375	448	247	326	392	268	434	520
Oct.	62	16		73	90		58	186
Total	2433	1899	2369	1891	2070	2221	1976	2229
Full bloom		6/5	5/27	6/7	6/8	6/3	6/12	6/9
Harvest		10/1	9/16	10/14	10/7	9/21	10/12	10/19
		1964*	1965*	1966*	1967*	1968*	1969*	1978*
April						82	60	
May				36		256	368	232.5
June		306	434	390	446.5	442	584	507.0
July		638	668	577	698	698	623	647.9
Aug.		512	650	642	754.5	529	510	533.2
Sept.		319	340	424	537.5	356	376	213
Oct.		89	62			22	26	
Total		1864	2154	2069	2436.5	2385	2547	2134.0
Full bloom		6/9	6/3	5/28	6/9	6/3	5/31	6/5
Harvest		10/12	10/5	9/27	10/1	10/8	10/14	9/21-10/15

1. References* Clore, W. J. et al. (1957-1970), Wash. State Hort. Assoc. Proc.
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

Month September Yr. 1974 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	89	52				
2	87	51				
3	90	46				
4	91	45				
5	91	57				
6	85	49				
7	90	48				
8	90	58				
9	91	54				
10	90	55				
11	84	56				
12	68	36				
13	72	49				
14	73	50				
15	74	41				
16	80	42				
17	82	42				
18	82	48				
19	81	46				
20	82	44				
21	82	49				
22	83	45				
23	83	46				
24	84	45				
25	83	46				
26	82	45				
27	80	44				
28	69	33				
29	77	32				
30	80	38				

Table 15. Continued

Month October Yr. 1974 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	81	40				
2	84	41				
3	83	52				
4	62	45	8	8		
5	59	41	14	22		
6	63	31	10	32		
7	70	35	6	38		
8	74	40	0	38		
9	73	45	-2	36		
10	68	38	8	44		
11	66	39	10	54		
12	66	49	0	54		
13	65	36	10	64		
14	67	35	6	70		
15	70	35	6	76		
16	69	38	6	82		
17	72	39	4	86		
18	72	38	4	90		
19	76	38	2	92		
20	79	41	-2	90		
21	70	38	4	94		
22	56	33	16	110		
23	62	43	10	120		
24	61	38	14	134		
25	65	40	10	144		
26	66	38	10	154		
27	63	38	12	166		
28	62	38	12	178		
29	52	43	16	194		
30	48	37	24	218		
31	44	37	24	242		

Table 15. Continued

Month November Yr. 1974 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	47	40	24	266		
2	55	36	18	284		
3	54	42	20	304		
4	52	27	12	316		
5	50	26	12	328		
6	52	29	16	344		
7	59	27	10	354		
8	55	32	16	370		
9	50	36	22	392		
10	50	27	14	406		
11	54	24	12	418		
12	56	28	14	432		
13	59	33	14	446		
14	60	30	12	458		
15	56	31	14	472		
16	55	27	12	484		
17	57	26	12	496		
18	51	35	20	516		
19	49	34	20	536		
20	58	26	12	548		
21	60	33	12	560		
22	58	37	18	578		
23	44	22	8	586		
24	52	24	12	598		
25	52	29	14	612		
26	48	25	14	626		
27	41	23	6	632		
28	46	22	12	644		
29	43	19	6	650		
30	43	17	8	658		

Table 15. Continued

Month December Yr. 1974 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH'S
1	43	19	6	664		
2	47	18	10	674		
3	53	22	10	684		
4	52	42	20	704		
5	45	34	18	722		
6	45	26	12	734		
7	42	30	12	746		
8	39	21	4	750		
9	37	14	2	752		
10	35	14	0	752		
11	34	17	0	752		
12	44	26	10	762		
13	39	28	6	768		
14	33	20	0	768		
15	34	26	0	768		
16	42	31	12	780		
17	38	26	4	784		
18	36	18	2	786		
19	38	23	4	790		
20	38	30	6	796		
21	44	30	14	810		
22	43	21	8	818		
23	28	4	0	818		
24	30	2	0	818		
25	29	5	0	818		
26	31	9	0	818		
27	35	8	0	818		
28	39	25	6	824		
29	33	19	0	824		
30	26	3	0	824		
31	30	9	0	824		

Table 15. Continued

Month January Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	27	2	0	824		
2	28	11	0	824		
3	34	4	0	824		
4	35	13	0	824		
5	34	16	0	824		
6	41	29	10	*ECA 834		
7	40	30	10	844	0	0
8	40	29	8	852	0	0
9	31	11	0	852	0	0
10	29	10	0	852	0	0
11	25	12	0	852	0	0
12	23	-4	0	852	0	0
13	30	3	0	852	0	0
14	32	6	0	852	0	0
15	36	11	0	852	0	0
16	35	16	0	852	0	0
17	42	17	8	860	4	4
18	46	30	14	874	30	34
19	45	18	10	884	14	48
20	43	17	6	890	6	54
21	39	21	6	896	0	54
22	35	16	0	896	0	54
23	40	14	4	900	0	54
24	45	30			24	78
25	55	36			144	222
26	55	33			126	348
27	34	17			0	348
28	38	15			0	348
29	29	0			0	348
30	28	4			0	348
31	40	18			0	348

*End chill accumulation

Table 15. Continued

Month February Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	42	28			6	354
2	47	25			30	384
3	45	35			32	416
4	40	30			0	416
5	37	18			0	416
6	37	10			0	416
7	44	28			16	432
8	47	33			44	476
9	44	35			22	498
10	41	32			2	500
11	47	30			40	540
12	51	28			68	608
13	47	38			66	674
14	47	28			34	708
15	47	27			34	742
16	41	24			2	742
17	38	20			0	742
18	36	20			0	742
19	41	20			2	746
20	40	26			0	746
21	29	14			0	746
22	29	6			0	746
23	35	13			0	746
24	43	15			8	752
25	45	20			14	766
26	48	20			34	800
27	48	31			48	848
28	53	33			106	954

Table 15. Continued

Month March Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	66	32			244	1,198
2	64	37			258	1,456
3	57	30			132	1,588
4	58	27			134	1,722
5	58	31			148	1,870
6	54	39			158	2,028
7	54	37			140	2,168
8	60	35			194	2,362
9	52	35			104	2,466
10	50	33			74	2,540
11	49	27			50	2,590
12	50	28			58	2,648
13	48	27			42	2,690
14	46	33			36	2,726
15	51	25			60	2,786
16	47	32			42	2,828
17	40	22			0	2,828
18	57	32			144	2,972
19	68	39			326	3,298
20	66	43			346	3,644
21	53	30			92	3,736
22	51	32			82	3,818
23	43	29			10	3,828
24	43	29			8	3,836
25	45	38			44	3,880
26	41	23			2	3,882
27	29	13			0	3,882
28	29	12			0	3,882
29	35	11			0	3,882
30	49	25			46	3,928
31	46	34			38	3.966

Table 15. Continued

Month April Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	41	21			2	3,968
2	45	16			14	3,982
3	56	28			116	4,098
4	57	36			166	4,264
5	61	40			252	4,516
6	60	34			188	4,704
7	43	29			36	4,740
8	46	27			26	4,766
9	46	30			30	4,796
10	52	35			106	4,902
11	53	36			120	5,022
12	58	40			216	5,238
13	60	29			160	5,398
14	53	30			94	5,492
15	56	41			202	5,694
16	56	33			138	5,832
17	46	32			34	5,866
18	46	32			34	5,900
19	58	32			154	6,054
20	56	39			180	6,234
21	63	34			280	6,514
22	69	45			408	6,922
23	60	39			228	7,150
24	68	32			268	7,418
25	68	32			266	7,684
26	48	28			42	7,726
27	45	31			24	7,750
28	44	31			18	7,768
29	45	31			24	7,792
30	56	29			120	7,912

Table 15. Continued

Month May Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	61	31			182	8,094
2	64	34			234	8,328
3	75	37			388	8,716
4	70	32			290	9,006
5	48	32			52	9,058
6	49	32			60	9,118
7	43	37			120	9,138
8	60	38			218	9,356
9	69	35			300	9,656
10	74	41			420	10,076
11	74	45			466	10,542
12	60	39			228	10,770
13	71	38			352	11,122
14	83	41			510	11,632
15	85	49			620	12,252
16	85	49			618	12,870
17	77	49			650	13,420
18	75	45			480	13,900
19	75	48			514	14,414
20	52	33			94	14,508
21	54	33			116	14,624
22	56	37			164	14,788
23	56	41			202	14,990
24	75	41			430	15,420
25	72	27			282	15,702
26	68	30			254	15,956
27	67	44			372	16,328
28	66	39			300	16,628
29	72	47			466	17,094
30	74	41			420	17,514
31	75	50			538	18,052

Table 15. Continued

Month June Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	80	46			544	18,596
2	83	51			630	19,226
3	72	52			526	19,752
4	71	43			406	20,158
5	80	45			534	20,692
6	88	49			648	21,330
7	87	61			762	22,092
8	69	46			420	22,512
9	67	41			334	22,846
10	78	40			452	23,298
11	78	39			444	23,742
12	86	47			602	24,344
13	85	52			654	24,998
14	82	54			662	25,660
15	87	51			656	26,316
16	84	56			692	27,008
17	76	54			598	27,606
18	68	44			384	27,990
19	60	43			274	28,264
20	66	42			334	28,598
21	68	49			444	29,042
22	78	45			512	29,554
23	83	53			652	30,206
24	84	55			682	30,888
25	80	43			508	31,396
26	77	39			432	31,828
27	81	49			590	32,418
28	83	42			522	32,940
29	89	49			644	33,584
30	89	56			718	34,302

Table 15. Continued

Month July Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	92	51			680	34,982
2	95	55			734	35,716
3	88	59			746	36,462
4	90	60			764	37,226
5	91	58			748	37,974
6	91	56			726	38,700
7	94	61			786	39,486
8	95	72			870	40,356
9	94	69			852	41,208
10	94	66			828	42,036
11	79	65			762	42,798
12	87	67			822	43,620
13	88	63			788	44,408
14	90	61			774	45,182
15	90	63			792	45,974
16	89	67			828	46,802
17	88	57			726	47,528
18	89	64			800	48,328
19	93	62			792	49,120
20	94	60			776	49,896
21	96	61			792	50,688
22	95	63			806	51,494
23	92	57			740	52,234
24	93	59			766	53,000
25	95	59			770	53,770
26	95	58			760	54,530
27	98	60			786	55,316
28	93	60			774	56,090
29	85	59			732	56,822
30	87	60			752	57,574
31	83	47			582	58,156

Table 15. Continued

Month August Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	79	47			548	58,704
2	84	45			566	59,270
3	92	50			668	59,938
4	93	52			694	60,632
5	94	57			750	61,382
6	97	64			818	62,200
7	97	66			832	63,032
8	88	48			628	63,660
9	91	52			686	64,346
10	93	55			724	65,070
11	92	63			800	65,870
12	86	61			758	66,628
13	85	54			676	67,304
14	86	59			738	68,042
15	85	59			732	68,774
16	88	53			680	69,454
17	90	59			754	70,208
18	90	55			714	70,922
19	87	65			804	71,726
20	79	52			606	72,332
21	78	51			586	72,918
22	82	50			608	73,526
23	87	57			720	74,246
24	86	53			672	74,918
25	80	42			496	75,414
26	90	49			648	76,062
27	90	58			744	76,806
28	85	52			654	77,460
29	83	46			570	78,030
30	89	47			620	78,650
31	88	52			672	79,322

Table 15. Continued

Month September Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	89	66			818	80,140
2	75	40			418	80,558
3	83	44			546	81,104
4	82	46			562	81,666
5	82	45			550	82,216
6	85	44			562	82,778
7	88	46			604	83,382
8	87	52			666	84,048
9	85	55			688	84,736
10	79	61			814	85,450
11	79	56			654	86,104
12	81	60			720	86,824
13	80	54			640	87,464
14	81	50			600	88,064
15	83	50			618	88,682
16	82	54			656	89,338
17	81	53			636	89,974
18	69	46			418	90,392
19	70	35			312	90,704
20	69	35			300	91,004
21	75	37			390	91,394
22	79	41			474	91,868
23	80	41			486	92,354
24	82	40			490	92,844
25	82	41			502	93,346
26	82	45			550	93,896
27	77	40			444	94,340
28	78	38			432	94,772
29	74	40			406	95,178
30	74	44			456	95,634

Table 16. Daily temperature to CU and GDH accumulations, 1975-76

Month October Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	74	41			420	96,050
2	78	39				
3	82	40				
4	81	46				
5	82	43				
6	82	55				
7	76	40				
8	55	37	20	20		
9	68	32	6	26		
10	72	43	0	26		
11	71	47	-2	24		
12	51	44	20	44		
13	51	39	22	66		
14	55	38	20	86		
15	59	32	10	96		
16	65	33	10	106		
17	70	37	8	114		
18	71	39	4	118		
19	70	34	4	122		
20	70	36	6	128		
21	73	39	4	132		
22	71	35	4	136		
23	44	28	12	148		
24	41	21	8	156		
25	47	21	10	166		
26	62	32	12	178		
27	51	36	20	198		
28	55	25	12	210		
29	65	29	8	218		
30	64	37	12	230		
31	57	34	16	246		

Table 16. Continued

Month November Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	55	28	14	260		
2	60	29	12	272		
3	62	31	10	282		
4	61	29	10	292		
5	62	28	8	300		
6	63	36	12	312		
7	55	38	20	332		
8	48	34	20	352		
9	45	21	10	362		
10	53	27	12	374		
11	43	25	10	384		
12	44	17	6	390		
13	50	19	10	400		
14	53	21	12	412		
15	59	24	8	420		
16	54	30	14	434		
17	45	30	14	448		
18	37	26	2	450		
19	42	21	8	458		
20	37	20	2	460		
21	38	20	2	462		
22	40	15	6	468		
23	41	26	8	476		
24	44	33	16	492		
25	42	25	8	500		
26	32	17	0	500		
27	38	29	6	506		
28	40	15	6	512		
29	29	16	0	512		
30	38	17	2	514		

Table 16. Continued

Month December Yr. 1975 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	45	32	16	530		
2	45	30	14	544		
3	52	27	14	558		
4	56	26	10	568		
5	52	33	18	586		
6	55	38	20	606		
7	53	28	14	620		
8	55	33	16	636		
9	53	27	12	648		
10	50	28	14	662		
11	50	24	12	674		
12	48	33	18	694		
13	39	26	6	700		
14	29	9	0	700		
15	33	10	0	700		
16	43	20	6	706		
17	39	16	4	710		
18	37	15	0	710		
19	34	12	0	710		
20	28	10	0	710		
21	33	20	0	710		
22	28	20	0	710		
23	31	25	0	710		
24	35	21	0	710		
25	40	32	12	722		
26	41	24	8	730		
27	38	31	6	736		
28	36	15	2	738		
29	35	18	0	738		
30	33	21	0	738		
31	27	3	0	738		

Table 16. Continued

Month January Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	24	12	0	738		
2	22	0	0	738		
3	28	10	0	738		
4	34	14	0	738		
5	39	16	2	740		
6	37	19	2	742		
7	32	14	0	742		
8	45	27	12	754		
9	45	31	16	770		
10	38	20	2	772		
11	33	12	0	772		
12	39	30	8	780		
13	35	13	0	780		
14	39	15	4	784		
15	41	23	6	790		
16	50	33	18	808		
17	45	24	12	820		
18	41	21	6	826		
19	27	23	2	828		
20	37	16	2	*ECA 830	0	
21	35	14	0	830	0	
22	26	16	0	830	0	
23	26	16	0	830	0	
24	33	23	0	830	0	
25	39	18	4	834	0	
26	35	9	0	834	0	
27	42	16	6	840	4	4
28	44	27	10	850	14	18
29	48	23	12	862	36	54
30	45	25		872	18	72
31	46	23		884	24	96

*End chill accumulation

Table 16. Continued

Month February Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	44	19	8	892	10	106
2	42	19	6	898	4	110
3	53	20	10	908	70	180
4	51	23			58	238
5	25	19			0	238
6	31	6			0	238
7	35	9			0	238
8	33	17			0	238
9	38	30			0	238
10	39	18			0	238
11	42	12			4	242
12	42	12			2	244
13	41	19			4	248
14	43	21			6	254
15	45	31			24	278
16	38	24			0	278
17	41	17			2	280
18	42	33			8	288
19	43	25			8	296
20	36	23			0	296
21	38	10			0	296
22	42	12			4	300
23	53	20			68	368
24	51	31			76	444
25	56	29			120	564
26	60	33			182	746
27	60	35			196	942
28	56	34			142	1,084
29	56	37			164	1,248

Table 16. Continued

Month March Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	51	28			68	1,316
2	35	14			0	1,316
3	35	10			0	1,316
4	32	8			0	1,316
5	35	9			0	1,316
6	36	10			0	1,316
7	40	14			0	1,316
8	45	18			14	1,330
9	50	19			46	1,376
10	54	23			82	1,458
11	52	26			72	1,530
12	35	9			0	1,530
13	48	15			30	1,560
14	47	35			52	1,612
15	45	32			24	1,636
16	57	26			120	1,756
17	63	29			192	1,948
18	65	37			270	2,218
19	60	25			146	2,364
20	42	25			4	2,368
21	54	29			100	2,468
22	64	26			190	2,658
23	62	43			298	2,956
24	63	27			184	3,140
25	60	29			160	3,300
26	46	26			26	3,326
27	46	29			28	3,354
28	44	19			12	3,366
29	44	26			14	3,380
30	50	24			52	3,432
31	64	26			190	3,622

Table 16. Continued

Month April Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	64	46			358	3,980
2	55	21			88	4,068
3	67	25			216	4,284
4	73	32			324	4,608
5	71	45			432	5,040
6	46	36			44	5,084
7	60	36			202	5,286
8	70	39			348	5,634
9	66	41			324	5,958
10	67	31			248	6,206
11	74	42			432	6,638
12	67	45			382	7,020
13	60	36			202	7,222
14	57	35			162	7,384
15	53	33			104	7,488
16	43	31			10	7,498
17	50	34			78	7,576
18	52	32			92	7,668
19	53	33			104	7,772
20	66	33			250	8,022
21	66	45			372	8,394
22	67	48			418	8,812
23	62	39			252	9,064
24	72	24			268	9,332
25	70	26			254	9,586
26	44	31			18	9,604
27	55	28			104	9,708
28	65	34			246	9,954
29	66	36			274	10,228
30	66	33			250	10,478

Table 16. Continued

Month May Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	71	34			316	10,794
2	76	38			412	11,206
3	79	45			522	11,728
4	78	55			634	12,362
5	70	41			370	12,732
6	70	49			466	13,198
7	70	45			420	13,618
8	69	41			358	13,976
9	74	40			406	14,382
10	78	44			502	14,884
11	75	55			598	15,482
12	67	43			358	15,840
13	77	37			414	16,254
14	85	43			550	16,804
15	84	46			578	17,382
16	77	45			502	17,884
17	87	44			576	18,460
18	87	57			720	19,180
19	86	46			590	19,770
20	79	53			620	20,390
21	75	46			490	20,880
22	58	50			334	21,214
23	75	42			444	21,658
24	74	47			490	22,148
25	72	43			418	22,566
26	71	38			352	22,918
27	78	40			452	23,370
28	83	42			522	23,892
29	80	47			558	24,450
30	74	53			562	25,012
31	80	54			640	25,652

Table 16. Continued

Month June Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	81	42			506	26,158
2	87	50			644	26,802
3	87	50			644	27,446
4	84	52			646	28,092
5	85	52			654	28,746
6	90	49			648	29,394
7	83	50			616	30,010
8	85	53			666	30,676
9	85	48			606	31,282
10	85	52			654	31,936
11	59	44			274	32,210
12	69	40			348	32,558
13	70	32			290	32,848
14	59	33			170	33,018
15	74	37			376	33,394
16	74	52			552	33,946
17	72	45			442	34,388
18	74	44			454	34,842
19	89	43			578	35,420
20	92	43			592	36,012
21	90	52			682	36,694
22	89	53			686	37,380
23	70	42			382	37,762
24	73	41			408	38,170
25	82	47			572	38,742
26	82	40			492	39,234
27	88	44			580	39,814
28	95	50			682	40,496
29	95	58			760	41,256
30	95	70			860	42,116

Table 16. Continued

Month July Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	92	58			752	42,868
2	85	52			652	43,520
3	94	50			678	44,198
4	95	55			732	44,930
5	95	56			742	45,672
6	98	58			770	46,442
7	98	61			794	47,236
8	97	63			810	48,046
9	99	60			788	48,834
10	99	62			806	49,640
11	97	65			826	50,466
12	88	68			834	51,300
13	88	55			704	52,004
14	90	53			690	52,694
15	95	56			744	53,438
16	98	62			802	54,240
17	97	65			826	55,066
18	80	58			688	55,754
19	83	57			696	56,450
20	88	55			704	57,154
21	91	57			738	57,892
22	92	57			740	58,632
23	98	62			804	59,436
24	97	61			794	60,230
25	91	60			768	60,998
26	91	57			736	61,734
27	93	58			756	62,490
28	93	57			744	63,234
29	93	69			850	64,084
30	90	67			830	64,914
31	86	59			738	65,652

Table 16. Continued

Month August Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	84	57			704	66,356
2	86	62			768	67,124
3	86	62			770	67,894
4	85	55			688	68,582
5	87	48			620	69,202
6	88	50			650	69,852
7	88	57			724	70,576
8	85	48			608	71,184
9	83	50			616	71,800
10	86	51			650	72,450
11	84	55			680	73,130
12	89	53			688	73,818
13	88	58			736	74,554
14	88	57			724	75,278
15	88	59			746	76,024
16	87	44			576	76,600
17	87	52			666	77,266
18	87	58			730	77,996
19	84	50			624	78,620
20	89	52			676	79,296
21	93	56			734	80,030
22	93	63			802	80,832
23	84	59			726	81,558
24	85	49			620	82,178
25	91	51			674	82,852
26	91	61			778	83,630
27	82	39			482	84,112
28	82	40			490	84,602
29	92	50			670	85,272
30	88	54			692	85,964
31	88	53			682	86,646

Table 16. Continued

Month September Yr. 1976 Crop Concord grapes

Day	Max	Min	CU	Σ CU	GDH's	Σ GDH's
1	89	55			708	87,354
2	93	51			684	88,038
3	92	52			690	88,728
4	90	51			670	89,398
5	93	53			704	90,102
6	92	58			752	90,854
7	69	51			478	91,332
8	74	38			388	91,720
9	81	43			518	92,238
10	81	50			600	92,838
11	79	61			714	93,552
12	74	56			600	94,152
13	74	50			526	94,678
14	79	47			546	95,224
15	83	57			698	95,922
16	83	59			720	96,642
17	84	55			682	97,324
18	71	50			490	97,814
19	77	42			466	98,280
20	80	47			558	98,838
21	82	53			644	99,482
22	77	49			550	100,032
23	79	49			572	100,604
24	78	54			620	101,224
25	76	49			540	101,764
26	73	51			526	102,290
27	75	43			450	102,740
28	76	41			448	103,188
29	79	42			486	103,674
30	81	41			494	104,168

VITA

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