EFFECT OF HEAT ACCUMULATION ON GRAPE CULTIVARS ON THE CAMPBELL AVENUE FARM

by

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Assistant Professor of Plant Sciences

For my brother

MOHAMMAD F. ALWAN

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ABSTRACT

Predicting when major phenological events (i.e. bud burst, flowering, and harvest) occur has been a major concern of orchardists and vineyardists for many years. Growing degree day models have been developed. These work well for the area in which they were developed or in areas which are very similar; however, if climatic factors vary greatly the model is not effective. This means that the growing degree day model can not be used for predicting the suitability of new regions. A model which could accurately predict the suitability of a new region would be valuable.

Growing degree day and heat unit models were constructed for each of 43 cultivars growing in Tucson, Arizona. Early season ripening varieties generally required less growing degree days and heat units to reach each phenological stage than did the mid season varieties, with late season varieties generally requiring a greater accumulation. Growing degree day values were much greater in Tucson than for published data. The heat unit model appears to be better for predictive purposes as it more accurately compares varieties from different areas.

The data presented in this thesis are part of an initial attempt to develop the heat unit model for grapes. Several more years of data will be necessary to perfect the model.

CHAPTER 1

INTRODUCTION

In many parts of the world including the United States, large new areas are being planted to grapes. Establishment of grapes is not difficult where good land exists and proven cultivars are known. Extending the range of planting by either the utilization of new varieties, or exploring new soil and/or climatological regions requires careful study.

Fruit growers need be concerned about field temperatures during winter and spring because of variable sensitivity of cultivars to cold temperatures. Flower buds become more suceptible to cold temperature during transition from mid winter to late spring. As flowering occurs fruit buds become less cold hardy and may be seriously damaged at a temperature of -2 C at bloom time.

The rate at which growth occurs increases as temperatures increase above the base temperature. The base temperature is that temperature below which growth does not occur. The growing degree day or heat unit concept was developed to mathematically express this relationship. Different varieties of grapes respond slightly different to temperature. The linear increase in growth with increasing temperature cannot, however, continue indefinitely. At temperatures (e.g., 45 to

50 C) growth may cease. At even higher temperatures, proteins are denatured and damage to plant cells and death occurs.

The purpose of this study is to access the effect of temperatures on the development of grape cultivars and build the foundation necessary to construct a mathematical model to predict when the different stages of phenological development occur.

The work presented in this thesis is the initial stage in a long term project to develop a model which can be used to predict all stages of phenological development in grapes. This model would not only be able to predict dates of bloom and harvest but would allow for the prediction of the success of a new, as yet untested region.

CHAPTER 2

REVIEW OF LITERATURE

This review will discuss briefly the effect of temperature on deciduous fruits, particularly grapes.

Rest and Dormancy

Anderson et al. (1975) found an increase in cold hardiness occurred in both peach flower buds and wood in late September, but this was not associated with a decrease in temperature. Cold hardiness in the trees held at 15.5 C increased as rapidly as it did in trees held at 4.5 C until mid November, after which the trees in the warm temperatures were not as hardy. Wood was less hardy in the early fall than the flower buds. Wood increased in hardiness much more rapidly than flower buds when both were exposed to cold temperature. Buds and wood on trees held at 15.5 C were not significantly different in cold hardiness. Wood becomes more cold resistant than the buds on trees held at 4.5 C. Trees receiving 1.5 to 4.5 C hardened more deeply than trees held at 15.5 C. The hardiness level was much greater in trees exposed to temperatures below freezing.

Richardson, Seeley and Walker (1974) utilized the standard method of determining the time of rest completed by bringing shoots

into the greenhouse and expose them to growing temperatures of 18 to 24 C. If growth started within a two to three week period, rest was considered completed. They attempted to use climatological data and related accumulated cold with the breaking of rest; however, they found this procedure unsatisfactory since the number of chilling hours varied considerably from year to year.

Bud Break and Chilling

Weinberger (1950) reported that the peach trees at Fort Valley suffered so seriously from a lack of chilling weather that the rest period of flower buds was not broken. His results showed that the greatest difference in the late-foliating varieties was observable on May 2.

Hatch and Walker (1969) used concentrations of gibberellic acid required to cause bud break in peach and apricot as a measure of depth of rest. Lateral and terminal apricot leaf buds developed at the same time, while in peach the terminal bud developed first. Apricot leaf buds reached deepest rest 3 weeks earlier than did peach leaf buds. Leaf bud of both species obtained some level of rest intensity.

Bloom of Sullivan Elberta peach buds was delayed if they were held at temperatures 1.5 to 4.5 C higher than ambient (Weinberger, 1954). Foliation was also slightly delayed, and while most leaf buds had broken, they were less developed than the controls. High night temperatures in December delayed bloom and leaf bud break more than

night temperatures in November. Fruit produced on high temperature-treated branches tended to be long and flat.

Chandler and Tufts (1934) found that buds on peach trees growing late into the fall were later in breaking rest and later in blossoming where less than 3 months of chilling weather occurred. Flower development proceeded in buds during the rest period when it was warm, but at a much slower rate than buds exposed to temperatures too low for growth until rest was broken.

Lamb (1950) found 'Latham Raspberry' canes stored at 3 C required less time to complete rest than canes stored at -3 C. Canes exposed to alternating temperatures required a longer exposure to low temperature to break the rest than either of the lots exposed to a constant low temperature. The initial effect of the below freezing temperatures seemed to be the most important in retarding the breaking the rest.

Little to date has been published concerning the effects of temperature on grapes. Weeks, Anderson and Richardson (1976) determined 860 chill units were required for 'Concord' to complete rest. Kliewer and Soleimani (1972) found the average number of days in the greenhouse required for the first bud to break in nonchilled 'Thompson Seedless' and 'Carignane' vines, to be 34 and 41 respectively. This was reduced to 14 and 21 days respectively with 63 days chilling. No further reduction resulted from additional chilling. The flowering period in 'Thompson Seedless' was reduced from 39 days for unchilled vines to 14 days for vines given 63 or more days of cold treatment.

Vines which received 35 or more days of chilling broke 94 to 98 percent of the buds within a 10 day period.

Weaver and Iwasaki (1977) found that bud break in 'Zinfandel' was most complete and rapid following storage for 4, 8, and 12 weeks at 0 C. Two weeks of storage resulted in a lower level of bud break. Little bud break occurred with three or seven days of storage. Storage for 8 or 12 weeks at 3.9 C was as effective as 0 C; however, storage at 3.9 C for 4 weeks or less resulted in reduced bud break as compared to the 0 C storage. Storage at 37 C resulted in 100 percent bud break.

Weaver, Lavee and Johnson (1975) reported that 'Carignane' cuttings taken from the middle of canes collected October 20 and November 3 and 17, broke more rapidly than apical or basal cuttings. Apical cuttings from canes collected December 15 and 17, January 12, and February 9, were slowest to break, while basal and middle cuttings broke with about equal rapidity. Cuttings obtained October 20 and November 3 generally broke very slowly, whereas canes from subsequent collections had a generally very rapid bud break. Bud break was most rapid in cuttings collected February 9.

'Johnson Elberta' flower buds acclimated to withstand temperatures colder than average by subjecting them to gradual cooling over two or three days (Bitner, 1976). The buds withstood temperatures 5 C below similar buds maintained at the ambient air temperatures. The degree of acclimation was greater as the buds completed their chilling requirement than at full bloom. Buds lost their

hardiness very rapidly in temperatures above 5 C as they accumulated large numbers of growing degree days. Young (1976) concluded that peaches needed to accumulate approximately 375 growing degree days between end of rest and full bloom, for proper development. Reducing the rate of G.D.D. accumulation by evaporative cooling reduced the rate of bud development.

Soil Temperature

Nakamura and Arima (1970) studied the effect of soil temperatures on growth of 'Delaware' grapes. They found shoot length, and fresh and dry weight were obviously promoted at 28 C throughout the entire growing season. Buttrose (1969) reported that while 'Gordo', 'Shiraz', and 'Sultana' attained their maximum dry weight at 20 C, 'Ohanez' obtained maximum dry weight accumulation over the range 20 to 35 C, and 'Rhine Riesling' over the range 25 to 35 C. By extrapolation he concluded that growth would have been close to zero at about 13 C. Considerable cultivar differences with the effect of temperatures on optimal shoot extension have been noted (Buttrose, 1969). 'Shiraz' shoots increased in length most rapidly at 25 C, while 'Rhine Riesling' and 'Ohanez' increased most rapidly at 30 C. During the bloom-set period, shoot growth of 'Carignane' was fastest at 25 C and 'Pinot noir' at 35 C.

Flowering

Buttrose and Hale (1973) studied the effect of temperature on development of the inflorescence after bud burst on 'Cabernet

Sauvignon', 'Clare Riesling', 'Rhine Riesling', and 'Shiraz' maintained at day/night temperatures of 14/9, 20/15, 26/21, 32/27, and 38/33. The number of days from bud burst to flowering decreased from 70 at 14/9 to 24 at 26/21 and 20 at 38/33.

In McIntoch apples, night temperatures most favorable for fruit enlargement were 27.2 C for days 1 to 4 after petal fall, 22.2 C for days 4 to 28, and 18.3 C for days 38 to 70 (Tukey, 1956, 1960). The fastest growth rate occurred at night temperatures higher than the day temperatures for the first 31 to 38 days after petal fall, and at night temperatures lower than the day temperatures following this period. Flower buds did not develop at night temperatures approaching 32.2 C during a six week period following full bloom. Small size leaves and reduced shoot growth resulted from night temperatures approaching 32.2 C during a six week period following full bloom. An increase in the naturally occurring night temperatures during 10 to 13 day period following bloom resulted in faster berry enlargement (Tukey, 1957). Optimal night temperatures were: 32 to 38 C for the first 3 days after full bloom, 28 C for days 3 to 5, and 22 to 23.5 C for days 6 through 13. During the same period optimal day temperatures were 26.6 to 29.4 C. 'Sultana' held at a constant 33 C for 3 months, beginning 20 days after full bloom, exhibited reduced berry size, more rapid sugar accumulation and a faster rate of acid decline (Radler, 1965).

The time of full bloom marks a definite stage in the development of fruit and has been used as an index of future fruit

development. The interval between full bloom and fruit maturity is specific for each variety with variations from year to year due to various factors. Weinberger (1948) suggested that in the case of apples, peaches, pears, and cherries, practical use of this interval may be made in determining harvest dates. With blueberries the length of the development period was too variable to be used in estimating maturity (Weinberger, 1948). The average interval between full bloom and maturity was 113 days at Fort Valley, Georgia, and 128 days of the cooler Geneva, New York and New Jersey (Weinberger, 1948). Peach trees at Fort Valley were delayed in blossoming due to the fact that the rest period was not broken until relatively late in the season, and therefore, the buds were not greatly influenced by relatively high temperatures occurring during mid Winter.

Maturation and Ripening

Grapes, like most fruits, develop and ripen faster when the plants are grown at high rather than low temperatures. Using a G.D.D. heat summation model with a base temperature of 50 F, Winkler and Williams (1939) reported 'Tokay' required 2281±23 G.D.D. between bloom and harvest in the years between 1929 and 1936. Heat summation for ripening (the 28 day period immediately preceding harvest) was 705±45 G.D.D. 'Malaga', 'Red Malaga', and 'Riblier' required 2150±64 G.D.D. to reach 18 brix in the Coachella Valley and Fresno and Kern Counties, and 'Emperor' (the latest maturing variety) required 3300±109 G.D.D. to reach 18 brix over a ten year period (Winkler, 1948).

In 'Thompson Seedless' the number of G.D.D. required only between full bloom and a maturity of 18 brix (percent sugar) varied slightly with location (Winkler, 1948). During a 12 year period in the Coachella Valley 'Thompson Seedless' required 2005±75 G.D.D. Over a 15 year period in Kern County the value was 2015±50 and for an 8 year period at Davis the value was 2000±75.

Coloring and Pigmentation

Temperature affects the coloration of grape berries (Kliewer, 1970). Consumer appeal of many table grapes and wines depends a great deal upon the level of anthocyanin pigments in the skin of the berries. Quantitatively anthocyanins in berries grown under high light intensity were similar and had little effect on berry coloration in black grapes ('Delaware' and 'Muscat Bailey A' grown in Japan); however, the maximum coloration in red grapes was considerably reduced under low light intensity.

Kliewer (1970) found the concentration of anthocyanins in skins of 'Cardinal' and 'Pinot noir' grown at 20 C ambient temperature was 6 to 10 times higher than when grown at 30 C under both high and low light intensities. Pigment density in the skins of 'Pinot noir' at 20 C under high light intensity was 58 percent greater than at 30 C under low light conditions. Pigmentation of 'Cardinal' was much more sensitive to high temperature than was 'Pinot noir', but coloration of 'Cardinal' berries was less effected by light intensity.

Kliewer and Torres (1972) reported that 'Cabernet Sauvignon', 'Cardinal' and 'Pinot noir' ripened at 15 C day temperatures had

anthocyanin levels 2 to 4 times greater than those ripened at 35 C. The inhibitory effect of the 35 C day temperature could not be overcome by low night temperatures. 'Tokay' fruit grown at 35 C did not color visibly during the entire ripening period, and the concentration of anthocyanin in the skin did not significantly change from verasion to fruit maturity. Visually, the coloration of 'Cardinal' fruits ripened at 35 C was also very poor, but anthocyanin concentration increased about two fold between verasion and maturity. In contrast, 'Pinot noir' grown at 35 C had good visual coloration, though the concentration of anthocyanin was significantly less than in fruits ripened at 15 C.

Berries of 'Thompson Seedless' clusters exposed to the sun were 0 to 12 C hotter than shaded ones (Kliewer and Lider, 1968). Accumulated heat received was 43 to 62 percent greater for fruits exposed to the sun. Individual berries exposed to the sun were 0.3 to 3.3 C hotter near their surface than at their center. Fruits exposed to the sun had a lower total acidity and higher pH. Malate concentrations were 2 to 3 times as great in shaded berries, whereas the tartrate level was little affected by exposure to sun. Total soluble solids were about the same. Differences in composition and ripening patterns between exposed and shaded fruits were attributed largely to the higher and more variable temperatures in the exposed fruits.

The influence of night temperature on fruit coloration was dependent, at least in part, on the day temperature and on the differential between day and night temperatures (Kliewer and Torres, 1972).

Early in the ripening period, grapes from all cultivars grown at 15/25 C (day/night) had a slightly greater color intensity than grapes grown at 15/15 C. At a day temperature of 25 C, coloration of 'Pinot noir' and 'Tokay' fruits was significantly greater at 15 C night temperature than at 25 C. At a day temperature of 15 C, anthocyanin concentration of 'Cardinal' fruits did not differ significantly with either night temperature. At a 35 C day temperature however, night temperature of 25 C and 30 C produced better colored 'Pinot noir' than did night temperatures of 15 and 10 C. 'Cabernet Sauvignon' grown at 25/30 C produced 20 to 25 percent the anthocyanin of fruit ripened at 25/20 C.

Fruit Composition

Temperature is the most important climatic factor influencing the composition of grapes. In the warm, interior regions grapes tend to be high in sugars and low in acids, while in contrast grapes grown in the less sunny, cooler coastal regions are usually higher in acid and lower in sugar at harvest (Kliewer, 1968). 'White Riesling' fruits ripened at a faster rate in a sunlit phytotron (20 C day, 15 C night) than under field conditions, while phytotron grown 'Petite Sirah' fruits ripened at approximately the same rate as in the field (Kliewer, 1968). The lower temperature in the phytotron resulted in higher total titratable acidity and the lower pH. Concentrations of tartaric and malic acid in ripe 'Petite Sirah' and 'White Riesling' were 2 to 3 times greater, with the percentage of tartrates and malates, percent as free acid, about twice as great. Generally, malates accounted for

a greater percentage of the total titratable acidity than did tartrates. Tartrates increased and malates decreased with degree of fruit ripeness.

'Cabernet Sauvignon' maintained in artificially lit growth cabinets from berry set until maturity at day temperatures of 20 C and night temperatures of 15 C exhibited enhanced pigmentation and malic acid levels over fruit grown at 30 C day temperatures (Buttrose, Hale and Kliewer, 1971). No differences in berry volume or sugar tartaric acid levels were observed.

Heat Summation Models

Many factors in the environment are responsible for, or at least modify, the rate at which a plant develops; however, temperature exerts the greatest control over rate of development. Ability to tollerate temperatures in a given area is the major factor in determining plant adaptability. Within a given area, plant development can be correlated to the temperatures which occurred since growth began. Predictive models, based on maximum and minimum temperatures, allow an additive measure of the heat occurring in the given area to be obtained. Correlation of phenological stages (i.e. flowering, maturity) to the accumulated heat, over a number of years, led to the development of a growing degree day (G.D.D.) model (Winkler, 1948). This model could accurately predict the date of maturity given date of bloom and the intervening temperatures. While the model worked well in the area in which it was developed or in areas which were very

similar; however, it did not work satisfactorily in areas which were significantly warmer or cooler.

Heat-unit accumulation models in their present state of development, have not given exact answers to practical problems even when they are based on accurate temperature measurements. There are several reasons for this (Arnold, 1960): a) in computing heat units it is usually assumed that the relationship between temperature and the rate of plant development is linear when it is undoubtedly curvilinear; b) other environmental factors besides temperature affect the rate of development; and c) the temperature measured in a single location is used as a basis for predictions in the varied micro climates of many fields. Thus heat units are used for estimating the time of harvest but the actual time is determined by observations of the crop itself.

Recent refinements in the G.D.D. model and a better understanding of the role temperature plays in plant development, and the relative differences in growth rate caused by different temperatures, has led to the development of a heat unit (HU) model (Young, 1976). This model has proven usable over a wide range of climatic regions with some crops (i.e. peaches) and also serves as a predictive model for new regions.

CHAPTER 3

METHODS AND MATERIALS

Vines growing in two locations at the University of Arizona Campbell Avenue Experimental Farm were used in this study. The farm is located in Tucson, Arizona at an elevation of 720 meters. The first location, planted in 1962, was on Agua Loam. Multiple rows (28 vines per row) of 'Beauty Seedless', 'Cardinal', 'Perlette' and 'Thompson Seedless' were planted 2.45 x 3.66 meters. Four vines of each variety were randomly selected for this study.

The second location (about 300 meters from the first) was planted in 1976 on Brazita Loam. Four vines of each of 42 varieties were randomly planted at a spacing of 1.83 x 3.35 meters. The varieties planted include: 'Barbera', 'Bengenda Red', 'Cabernet Sauvignon', 'Canaiolo Nero', 'Carignane', 'Carmine', 'Carnelian', 'Centurian', 'Chardonnay', 'Chenin blanc', 'Clairette blanche', 'Cortese', 'Emerald Riesling', 'French Colombard', 'Gamay (Napa Gamay)', 'Gewürztraminer', 'Green Hungarian', 'Grey Riesling', 'Grignalino', 'Helena', 'Malvasia bianca', 'Mission', 'Nebbiolo', 'Palomino', 'Petite Sirah', 'Pinot blanc', 'Pinot noir', 'Pinot noir GB (Gamay Beaujolais clone)', 'Ruby Cabernet', 'Sangioveto (Sangiovese)', 'Sauvignon blanc', 'Semillon', 'Souzao', 'Sylvaner', 'Tinta Madeira', 'Trebbiano (St. Emillion)', 'White Riesling', and 'Zinfandel'. Three rootstocks ('Champanel',

'Dogridge' and Vitis Arizonica) were also included in the study. All four vines of each variety were utilized.

Phenological data on each variety was collected during the 1978 growing season. Phenological development of the vine was divided into eleven stages. The stages used were: 0 -- completely dormant; 1 -- first swell; 2 -- full swell; 3 -- bud burst; 4 -- first leaf; 5 -- second leaf; 6 -- fourth leaf; 7 -- 50 percent bloom; 8 -- full bloom; 9 -- verasion (color breal); and 10 -- maturity (harvest). Data collected was the date at which the variety attained each stage. Each of the four vines of each variety was assessed separately and the data presented as average data for the four vines. Data was collected on a two to three day basis from March to October. Assessment interval was increased to weekly between stages 8 and 10. The three rootstocks were not carried to maturity as the fruit is not considerable edible. 'Carmine' and 'Carnelian' were not allowed to produce fruit as they were young vines (planted in 1977). 'Chenin blanc', 'Gewürztraminer', 'Helena' and 'Sylvaner' were not harvested as they did not ripen due to infestation with Texas Root Rot (Phymatotrichum omnivorum). Root rot infestation resulted in the loss of some of the other vines, in which case the data presented is the average of the number of vines available.

Maximum and minimum temperature data was obtained from the Experiment Station's weather station. This station is an official station which reports to the National Oceanographic and Atmospheric Administration (NOAA). Heat accumulation during the season was

determined by the standard growing degree day model (G.D.D.) developed in California (Winkler, 1948) or by a heat summation model (heat units) similar to the one developed in Utah (Weeks, Anderson and Richardson, 1976). The formula used was:

$$HU_{(DAY)} = 24 \times e$$

where e was the efficiency of the growing temperature determined by the formula:

$$e = 0.033\ (T - 50)$$

where T was the temperature in degrees fahrenheit. The efficiency factor was allowed to range between 0 and 1. Negative values were considered to be 0, and values greater than 1 were considered to be 1. The base temperature of 50 F (10 C) was chosen as it is considered to be the point at which grapes begin growth.

CHAPTER 4

RESULTS AND DISCUSSION

The date at which the varieties reached each of the ten measured stages is shown in Table 1. Stage 1 (first swell) occurred between March 6 and March 26; stage 2 (full swell) from March 11 to April 4; stage 3 (bud burst) from March 13 to April 10; stage 4 (first leaf) from March 15 to April 12; stage 5 (second leaf) from March 17 to April 14; stage 6 (fourth leaf) from March 19 to April 16; stage 7 (50 percent bloom) from April 16 to May 15; stage 8 (full bloom) from April 22 to May 18; stage 9 (verasion) from June 4 to July 25; and stage 10 (ripening) from July 21 to September 11.

Computation of growing degree days (base (50 F) is shown in Table 2. Growing degree days were accumulated January 1 to harvesting (maturation). In California five climatic regions based on growing degree days between April 1 and October 31 have been established (Winkler et al., 1974). They are: Region I, less than 2000 degree days; Region II, 2501 to 3000 degree days; Region III, 3001 to 3500 degree days; Region IV, 3501 to 4000 degree days; and Region V, 4001 or more degree days. On this basis Tucson would be considered to be a long Region V as 5938 degree days were amassed between April 1 and October 31.

Table 1. Date of attainment of the indicated phenological stages in the 1978 growing season. Value shown is the mean value for 4 vine plots growing in Tucson, Arizona.

	Variety	Date Stage Attained									
		1	2	3	4	5	6	7	8	9	10
1.	Barbera	3-15	3-17	3-20	3-22	3-24	3-26	4-28	5-3	7-15	9-10
2.	Beauty Seedless	3-6	3-11	3-13	3-15	3-17	3-19	4-22	4-28	6-15	7-28
3.	Bengenda Red	3-15	3-17	3-20	3-22	3-24	3-26	4-28	5-3	6-15	7-25
4.	Cabernet Sauvignon	3-20	3-22	3-24	3-26	3-28	3-31	4-28	5-3	7-1	9-11
5.	Champanel	3-10	3-15	3-20	3-27	3-30	4-1	4-16	4-22	--	--
6.	Canaiolo Nero	3-17	3-24	3-28	4-2	4-6	4-10	5-7	5-12	7-22	9-3
7.	Cardinal	3-15	3-17	3-20	3-24	3-26	3-28	4-28	5-3	7-1	8-8
8.	Carignane	3-18	3-20	3-22	3-25	3-27	3-30	4-28	5-3	7-17	8-31
9.	Carmine	3-17	3-20	3-22	3-24	4-4	--	--	--	--	--
10.	Carnelian	3-17	3-25	3-28	3-31	--	--	--	--	--	--
11.	Chardonnay	3-7	3-11	3-15	3-17	3-19	3-22	4-19	4-25	6-25	8-1
12.	Chenin blanc	3-7	3-15	3-20	3-20	3-24	3-26	4-28	5-3	7-22	--
13.	Clairette blanche	3-26	3-28	3-31	4-3	4-6	4-10	5-7	5-12	7-22	9-4
14.	Cortese	3-17	3-20	3-24	3-27	3-31	4-3	4-27	5-3	6-4	--
15.	Dogridge	3-17	3-20	3-24	3-28	4-7	4-10	4-25	4-28	7-10	--
16.	Emerald Riesling	3-16	3-18	3-21	3-25	3-27	3-30	4-28	5-7	7-24	8-10
17.	French Colombard	3-17	3-19	3-20	3-23	3-26	3-28	4-25	5-3	7-15	9-2
18.	Gamay Beaujolais	3-15	3-17	3-20	3-22	3-24	3-26	4-22	4-28	6-5	8-10
19.	Gewürztraminer	3-15	3-20	3-24	3-27	3-29	3-31	4-25	5-3		--
20.	Gray Riesling	3-15	3-17	3-19	3-20	3-22	3-24	4-28	5-3	7-17	7-24
21.	Green Hungarian	3-20	3-24	3-26	3-28	3-31	4-4	5-3	5-12	7-22	8-10
22.	Helena	3-26	3-28	3-31	4-3	4-6	4-10	5-12	5-15	--	--
23.	Malvasia blanca	3-20	3-24	3-28	4-3	4-6	4-10	5-7	5-12	7-20	8-16
24.	Mission	3-17	3-20	3-22	3-24	3-26	3-29	5-3	5-10	7-22	9-5
25.	Napa Gamay	3-20	3-22	3-24	3-26	3-28	3-31	4-28	5-3	6-5	9-1
26.	Nebbiolo	3-15	3-17	3-20	3-22	3-24	3-26	4-28	5-3	7-15	9-10
27.	Palomino	3-22	3-26	3-28	3-31	4-3	4-10	5-7	5-12	7-22	8-10
28.	Perlette	3-14	3-17	3-20	3-22	3-24	3-26	4-28	5-3	7-1	7-21
29.	Petite Sirah	3-15	3-17	3-20	3-22	3-24	3-26	4-22	4-28	6-5	8-30

Table 1, continued

Variety	Date Stage Attained									
	1	2	3	4	5	6	7	8	9	10
30. Pinot blanc	3-9	3-15	3-19	3-19	3-20	3-22	4-22	4-28	7-22	8-1
31. Pinot noir GB	3-15	3-17	3-20	3-22	3-24	3-26	4-22	4-28	6-5	8-10
32. Ruby Cabernet	3-17	3-20	3-22	3-24	3-26	3-29	4-28	5-3	7-1	9-10
33. Sangiovito	3-15	3-21	3-24	3-26	3-30	4-3	5-7	5-12	7-25	9-4
34. Sauvignon blanc	3-20	3-24	3-28	3-31	4-3	4-6	5-3	5-12	7-11	8-7
35. Semillon	3-17	3-20	3-22	3-24	3-27	3-30	4-28	5-3	7-22	8-10
36. Souzao	3-26	3-29	4-3	4-6	4-10	4-12	5-7	5-12	7-22	8-30
37. Sylvaner	3-15	3-17	3-20	3-22	3-24	3-26	4-25	4-28	7-22	--
38. Tinta Madeira	3-17	3-22	3-24	3-28	3-29	3-31	5-3	5-12	6-5	8-10
39. Thompson Seedless	3-15	3-18	3-20	3-23	3-25	3-27	4-28	5-6	6-15	7-28
40. Trebbiano	3-24	4-4	4-10	4-12	4-14	4-16	5-15	5-18	6-27	9-2
41. Vitis Arizonica	3-17	3-22	3-24	3-28	3-31	4-4	--	--	--	--
42. White Riesling	3-15	3-17	3-20	3-22	3-24	3-26	4-22	5-3	7-2	8-10
43. Zinfandel	3-17	3-22	3-26	3-28	3-31	4-3	5-3	5-7	7-11	8-16

Table 2. Growing degree day accumulation for Tucson, Arizona in the 1978 season.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
January			
1	56	6	6
2	53	3	9
3	55	5	14
4	55	5	19
5	54.5	4.5	23.5
6	53	3	26.5
7	51.5	1.5	28
8	52.5	2.5	30.5
9	54	4	34.5
10	58	8	42.5
11	49.5	0	42.5
12	52	2	44.5
13	48	0	44.5
14	55.5	5.5	50
15	56	6	56
16	54.5	4.5	60.5
17	52.5	2.5	63
18	51	1	64
19	51.5	1.5	65.5
20	51.5	1.5	67
21	50.5	0.5	67.5
22	49	0	67.5
23	49	0	67.5
24	45.5	0	67.5
25	41.5	0	67.5
26	46.5	0	67.5
27	51	1	68.5
28	55	5	73.5
29	58	8	81.5
30	61	11	92.5
31	58.5	8.5	101
February			
1	57	7	108
2	53	3	111
3	56	6	117
4	55	5	122
5	67.5	17.5	139.5
6	59	9	148.5
7	59	9	157.5
8	57	7	164.5
9	57.5	7.5	172

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
10	56	6	178
11	50.5	0.5	178.5
12	44	0	178.5
13	50	0	178.5
14	46	0	178.5
15	49.5	0	178.5
16	45.5	0	178.5
17	41.5	0	178.5
18	42	0	178.5
19	41	0	178.5
20	47	0	178.5
21	52	2	180.5
22	54.5	4.5	185
23	58.5	8.5	193.5
24	58.5	8.5	202
25	55.5	5.5	207.5
26	58	8	215.5
27	55	5	220.5
28	60.5	10.5	231
March			
1	59	9	240
2	59	9	249
3	58.5	8.5	257.5
4	58	8	265.5
5	56	6	271.5
6	53.5	3.5	275
7	56	6	281
8	57	7	288
9	59	9	297
10	59.5	9.5	306.5
11	54	4	310.5
12	53.5	3.5	314
13	50.5	0.5	314.5
14	50	0	314.5
15	55	5	319.5
16	57	7	326.5
17	64.5	14.5	341
18	65.5	15.5	356.5
19	71.5	21.5	378
20	67	17	395
21	66.5	16.5	411.5
22	67.5	17.5	429
23	64.5	14.5	443.5
24	60.5	10.5	454

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
25	63	13	467
26	66.5	16.5	483.5
27	68.5	18.5	502
28	65.5	15.5	517.5
29	70	20	537.5
30	70	20	557.5
31	70.5	20.5	578
April			
1	66.5	16.5	594.5
2	61.5	11.5	606
3	62.5	12.5	618.5
4	62.5	12.5	631
5	61.5	11.5	642.5
6	64	14	656.5
7	63	13	669.5
8	53	3	672.5
9	50	0	672.5
10	53.5	3.5	676
11	61	11	687
12	65	15	702
13	67.5	17.5	719.5
14	71	21	740.5
15	65.5	15.5	756
16	60.5	10.5	766.5
17	59.5	9.5	776
18	60	10	786
19	65	15	801
20	65	15	816
21	63	13	829
22	61.5	11.5	840.5
23	64	14	854.5
24	67.5	17.5	872
25	73.5	23.5	895.5
26	70.5	20.5	916
27	67	17	933
28	66	16	949
29	64.5	14.5	963.5
30	63	13	976.5
May			
1	63.5	13.5	990
2	57.5	7.5	998.5
3	69	19	1016.5
4	69.5	19.5	1036

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
5	68.5	18.5	1054.5
6	55	5	1059.5
7	59	8	1062.5
8	63	13	1075.5
9	69.5	19.5	1095
10	70.5	20.5	1115.5
11	69	19	1134.5
12	73	23	1157.5
13	78.5	28.5	1186
14	80	30	1216
15	78	28	1244
16	75	25	1269
17	70	20	1289
18	69.5	19.5	1308.5
19	76.5	26.5	1335
20	77.5	27.5	1362.5
21	78	28	1390.5
22	78.5	28.5	1419
23	75	25	1444
24	71.5	21.5	1465.5
25	73	23	1488.5
26	70.5	20.5	1509
27	69	19	1528
28	73	23	1551
29	75	25	1576
30	79	29	1605
31	78	28	1633
June			
1	75.5	25.5	1658.5
2	77	27	1695.5
3	76	26	1711.5
4	78.5	28.5	1740
5	77.5	27.5	1767.5
6	79	29	1796.5
7	80	30	1826.5
8	85.5	35.5	1862
9	85.5	35.5	1897.5
10	85.5	35.5	1933
11	84	34	1967
12	82.5	32.5	1999.5
13	85.5	35.5	2035
14	86	36	2071
15	86.5	36.5	2107.5

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
16	83	33	2140.5
17	84.5	34.5	2175
18	85.5	35.5	2210.5
19	87.5	37.5	2248
20	86	36	2284
21	84	34	2318
22	87	37	2355
23	90	40	2395
24	88.5	38.5	2433.5
25	88.5	38.5	2472
26	89	39	2511
27	87	37	2548
28	83.5	33.5	2581.5
29	82	32	2613.5
30	83.5	33.5	2647
July			
1	82	32	2679
2	84	34	2713
3	85	35	2748
4	85	35	2783
5	86	36	2819
6	84	34	2853
7	88.5	38.5	2891.5
8	87.5	37.5	2929
9	89	39	2968
10	89.5	39.5	3007.5
11	90	40	3047.5
12	89.5	39.5	3087
13	85.5	35.5	3122.5
14	92	42	3164.5
15	92	42	3206.5
16	91	41	3247.5
17	91.5	41.5	3289
18	89	39	3328
19	96	46	3374
20	93	43	3417
21	85.5	35.5	3452.5
22	83.5	33.5	3486
23	83	33	3519
24	90.5	40.5	3559.5
25	85	35	3594.5
26	84.5	34.5	3629
27	86.5	36.5	3665.5

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
28	86	36	3701.5
29	88.5	38.5	3740
30	87	37	3777
31	84	34	3811
August			
1	85.5	35.5	3846.5
2	81.5	31.5	3878
3	85.5	35.5	3913.5
4	85	35	3948.5
5	83.5	33.5	3982
6	83.5	33.5	4015.5
7	86	36	4051.5
8	84	34	4085.5
9	89	39	4124.5
10	86	36	4160.5
11	86	36	4196.5
12	83.5	33.5	4230
13	83	33	4263
14	81.5	31.5	4294.5
15	84.5	34.5	4329
16	84	34	4363
17	84.5	34.5	4397.5
18	85	35	4432.5
19	84	34	4466.5
20	84.5	34.5	4501
21	86.5	36.5	4537.5
22	83.5	33.5	4571
23	86	36	4607
24	88	38	4645
25	86.5	36.5	4681.5
26	85	35	4716.5
27	83	33	4749.5
28	83	33	4782.5
29	84	34	4816.5
30	86	36	4852.5
31	89.5	39.5	4892
September			
1	92	42	4934
2	89.5	39.5	4973.5
3	85.5	35.5	5009
4	85	35	5044
5	86	36	5080
6	85	35	5115

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
7	86	36	5151
8	82	32	5183
9	92.5	32.5	5215.5
10	83	33	5248.5
11	80.5	30.5	5279
12	77	27	5306
13	81	31	5337
14	81	31	5369
15	78.5	28.5	5396.5
16	80	30	5426.5
17	73	23	5449.5
18	75	25	5474.5
19	72	22	5496.5
20	69.5	19.5	5516
21	74.5	24.5	5540.5
22	78	28	5568.5
23	81	31	5599.5
24	83.5	33.5	5633
25	85.5	35.5	5668.5
26	82.5	32.5	5701
27	81.5	31.5	5732.5
28	81	31	5763.5
29	80.5	30.5	5794
30	82.5	32.5	5826.5
October			
1	78.5	28.5	5855
2	80.5	30.5	5885.5
3	80	30	5915.5
4	79	29	5944.5
5	79.5	29.5	5974
6	78.5	28.5	6002.5
7	82.5	32.5	6035
8	78.5	28.5	6063.5
9	79	29	6092.5
10	75.5	25.5	6118
11	75	25	6143
12	73.5	23.5	6166.5
13	75	25	6191.5
14	79	29	6220.5
15	75	25	6245.5
16	74	24	6269.5
17	74.5	24.5	6294
18	73	23	6317

Table 2, continued. Growing degree day accumulation.

Date	Mean Temperature	G.D.D.	G.D.D. Accumulations
19	78	28	6345
20	69.5	19.5	6364.5
21	67	17	6381.5
22	65	15	6396.5
23	66.5	16.5	6413
24	62	12	6425
25	60	10	6435
26	61	11	6446
27	63.5	13.5	6459.5
28	63.5	13.5	6473
29	69.5	18.5	6491.5
30	67	17	6508.5
31	69.5	19.5	6528

Harvest began in July and continued through September. Varieties ripening in July were considered early season, those ripening in August mid-season, and those ripening in September late season. A list of varieties by season is shown in Table 3. In 1978 early varieties ripened July 21 to July 28; mid-season varieties August 1 to August 16; and late season varieties August 30 to September 11.

Rootstocks were not carried to maturity as the fruit was not considered edible. Other varieties for which no ripening date is given did not ripen due to infestation with Texas Root Rot (Phymatotrichum omnivorum). Growing degree day accumulations to each phenological stage for each variety is shown in Table 4 and Figures 1, 2, 3 and 4. Growing degree accumulations for early varieties (Table 4, Figure 1) were: stage 1 (first swell) ranged from 275 to 319 degree days; stage 2 (full swell), from 310 to 356 degree days; stage 3 (bud burst), from 315 to 395 degree days; stage 4 (first leaf), from 319 to 443 degree days; stage 5 (second leaf), from 341 to 467 degree days; stage 6, (fourth leaf), from 378 to 502 degree days; stage 7, (50 percent bloom), from 517 to 949 degree days; stage 8 (full bloom), from 949 to 1059 degree days; stage 9 (verasion), from 2107 to 3289 degree days; and stage 10 (harvest), from 3452 to 3701 degree days.

Growing degree accumulations from mid-season varieties (Table 4, Figure 2) were: stage 1, 281 to 429; stage 2, 310 to 483; stage 3, 319 to 517; stage 4, 341 to 619; stage 5, 378 to 657; stage 6, 429 to 676; stage 7, 801 to 1063; stage 8, 949 to 1157; stage 9, 1767 to 3559; and stage 10, 3847 to 4363 degree days.

Table 3. Seasonal ripening patterns for grapes grown in Tucson, Arizona.

	Variety	Date of Ripening
I.	Early Season:	
1.	Beauty Seedless	7-28
2.	Bengenda Red	7-25
3.	Gray Riesling	7-24
4.	Perlette	7-21
5.	Thompson Seedless	7-28
II.	Mid Season:	
1.	Barbera	8-16
2.	Cardinal	8-8
3.	Chardonnay	8-1
4.	Emerald Riesling	8-10
5.	Gamay Beaujolais	8-10
6.	Green Hungarian	8-10
7.	Malvasia blanca	8-16
8.	Palomino	8-10
9.	Pinot blanc	8-1
10.	Pinot noir GB	8-10
11.	Semillon	8-10
12.	Tinta Madeira	8-10
13.	White Riesling	8-10
14.	Zinfandel	8-16
III.	Late Season:	
1.	Cabernet Sauvignon	9-11
2.	Canaiolo Nero	9-3
3.	Carignane	8-31
4.	Clairette blanche	9-4
5.	French Colombard	9-2
6.	Mission	9-5
7.	Napa Gamay	9-1
8.	Nebbiolo	9-10
9.	Petite Sirah	8-30
10.	Ruby Cabernet	9-10
11.	Sangiovito	9-4
12.	Souzao	8-30
13.	Trebbiano	9-2

Table 4. Growing degree days (base 50 F) accumulated from January 1 to the indicated phenological stages in the 1978 season in Tucson, Arizona.

	Variety	Stage									
		1	2	3	4	5	6	7	8	9	10
1.	Barbera	319	341	395	429	454	483	816	949	3047	4363
2.	Beauty Seedless	275	310	315	319	341	378	841	949	2107	3701
3.	Bengenda Red	319	341	395	429	454	483	949	1045	2107	3595
4.	Cabernet Sauvignon	395	454	483	557	595	631	1017	1157	3047	5279
5.	Champanel	307	319	395	483	557	595	767	841	--	--
6.	Canaiolo	341	454	517	606	657	676	1063	1157	2891	5009
7.	Cardinal	319	341	395	454	483	517	949	1017	2679	4085
8.	Carignane	357	395	429	467	502	557	949	1017	3289	4892
9.	Carmine	341	395	429	454	631	--	--	--	--	--
10.	Carnelian	341	467	517	578	--	--	--	--	--	--
11.	Chardonnay	281	310	319	341	378	429	801	895	2472	3847
12.	Chenin blanc	281	319	395	429	454	483	517	1016	3486	
13.	Clairette blanche	483	502	578	619	657	676	1063	1157	3486	5044
14.	Cortese	341	395	454	502	578	619	933	1017	1740	
15.	Dogridge	341	395	454	517	669	676	895	949	3007	--
16.	Emerald Riesling	327	357	411	467	502	557	949	1063	3559	4161
17.	French Colombard	341	378	395	443	483	517	895	1017	3207	4973
18.	Gamay Beaujolais	319	341	395	429	454	483	841	949	1767	4161
19.	Gewürztraminer	327	395	454	502	537	578	895	1017	--	--
20.	Gray Riesling	319	341	378	395	429	454	949	1017	3289	3559
21.	Green Hungarian	395	454	483	517	578	631	1017	1157	3486	4161
22.	Helena	483	517	578	619	657	676	1157	2107	--	--
23.	Malvasia blanca	395	454	517	619	657	676	1063	1157	3417	4363
24.	Mission	341	395	429	454	483	537	1017	1115	3486	5080
25.	Napa Gamay	395	429	454	483	517	578	949	1017	1767	4934
26.	Nebbiolo	319	341	395	429	454	483	949	1017	3207	5249
27.	Palomino	429	483	517	578	619	676	1063	1157	3486	4161
28.	Perlette	315	341	395	429	454	483	517	1017	2679	3452
29.	Petite Sirah	319	341	395	429	454	483	841	949	1767	4853

Table 4, continued

Variety	Stage									
	1	2	3	4	5	6	7	8	9	10
30. Pinot blanc	297	319	341	378	395	429	841	949	3486	3847
31. Pinot noir GB	319	341	395	429	454	483	841	949	1767	4161
32. Ruby Cabernet	341	395	429	454	483	537	949	1017	2679	5249
33. Sangiovito	319	411	454	483	557	618	1063	1157	3595	5044
34. Sauvignon blanc	395	454	517	578	619	656	1017	1157	3047	4051
35. Semillon	341	395	429	454	502	557	949	1017	3486	4161
36. Souzao	483	537	631	657	676	702	1063	1157	3486	4853
37. Sylvaner	319	341	395	429	454	483	895	949	3486	
38. Tinta Madeira	341	429	454	517	537	578	1017	1157	1767	4161
39. Thompson Seedless	319	356	395	443	467	502	949	1059	2107	3701
40. Trebbiano	454	631	676	702	740	767	1244	1308	2548	4973
41. Vitis Arizonica	341	429	454	517	578	631	--	--	--	--
42. White Riesling	319	341	395	429	454	483	841	1017	2713	4161
43. Zinfandel	341	429	483	517	578	619	1017	1063	3047	4363

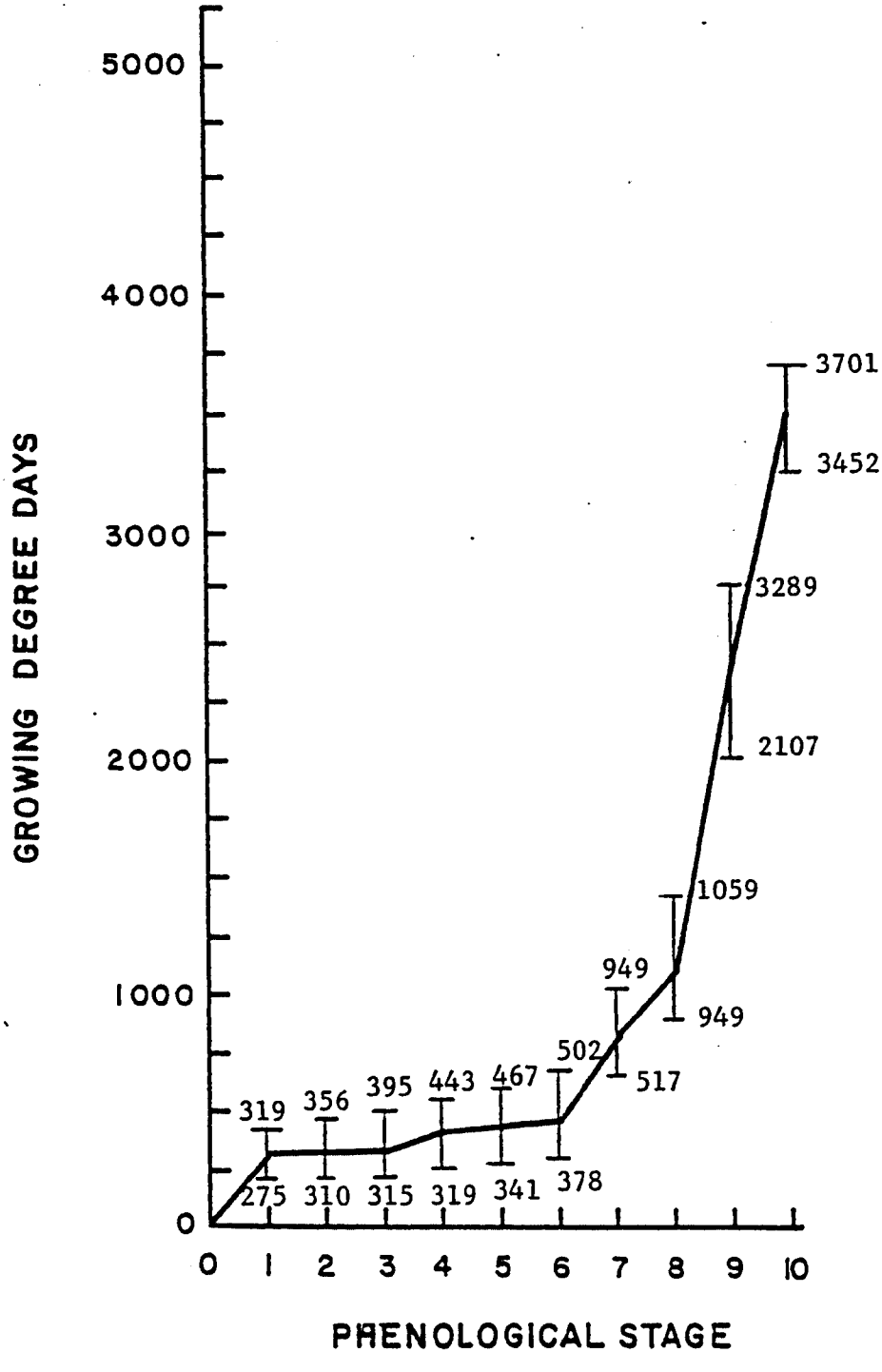

Figure 1. Growing degree day accumulation by early season varieties in Tucson, Arizona in the 1978 growing season.

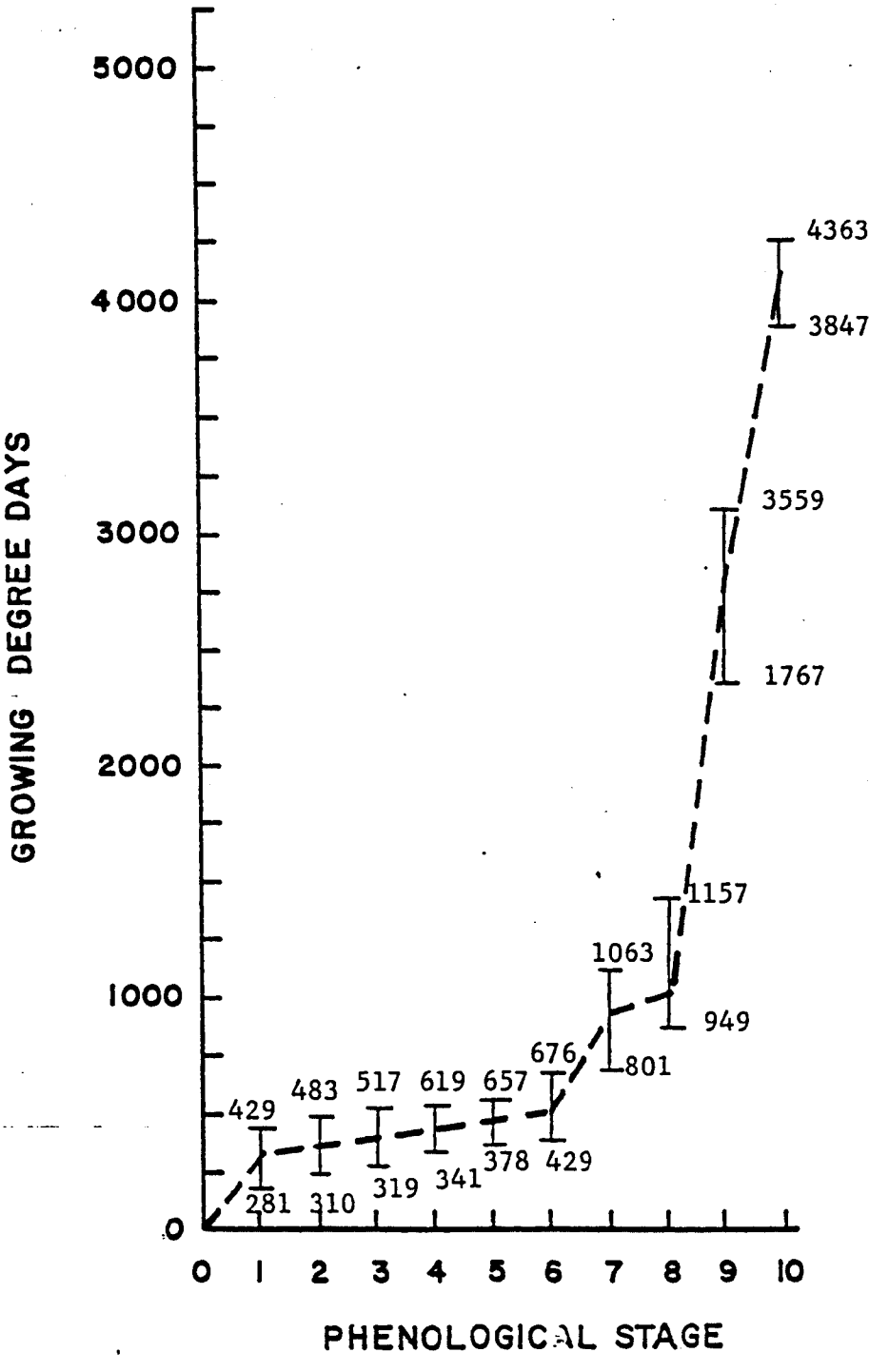

Figure 2. Growing degree day accumulation by mid season varieties in Tucson, Arizona in the 1978 growing season.

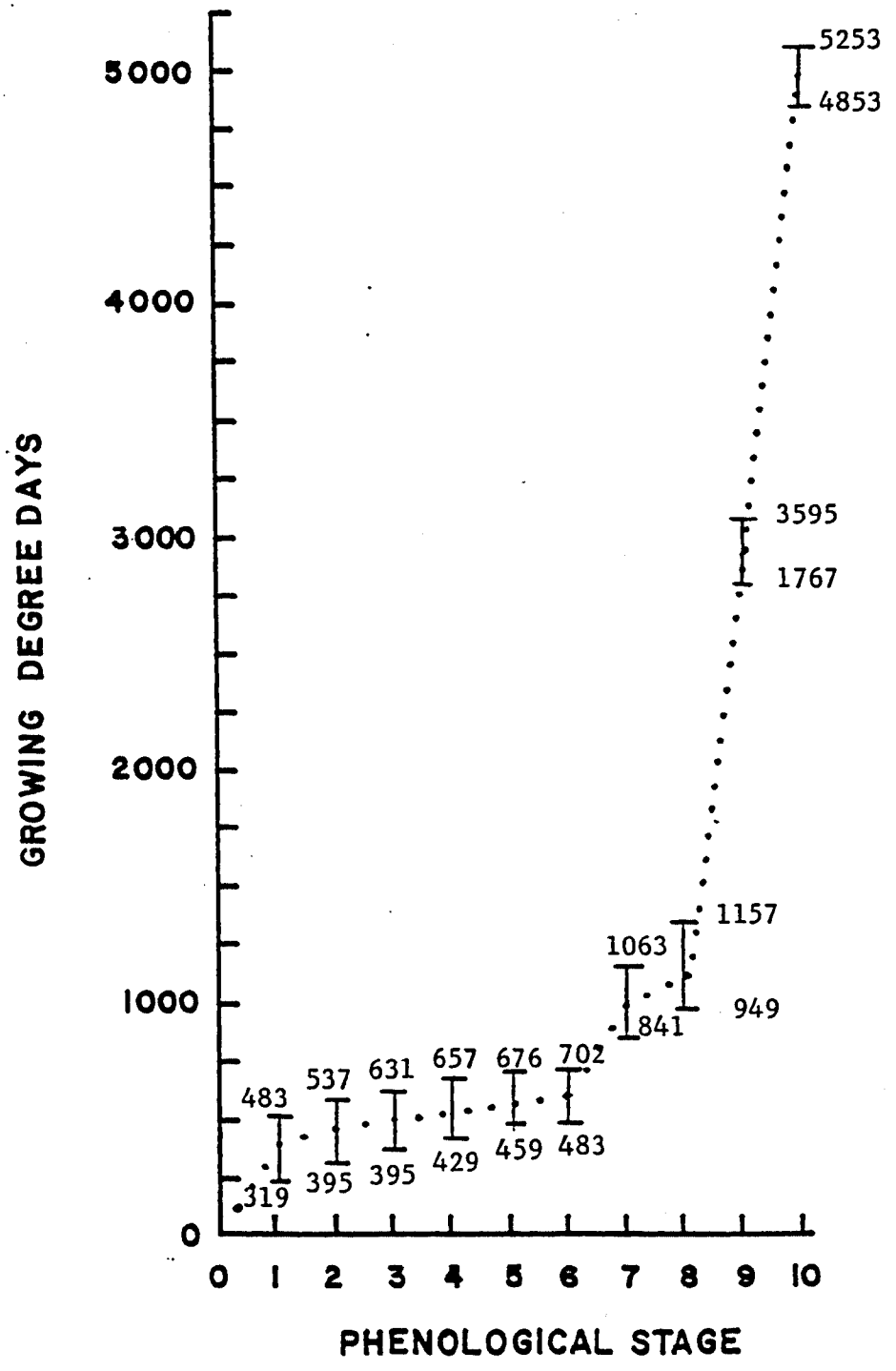

Figure 3. Growing degree day accumulation by late season varieties in Tucson, Arizona in the 1978 growing season.

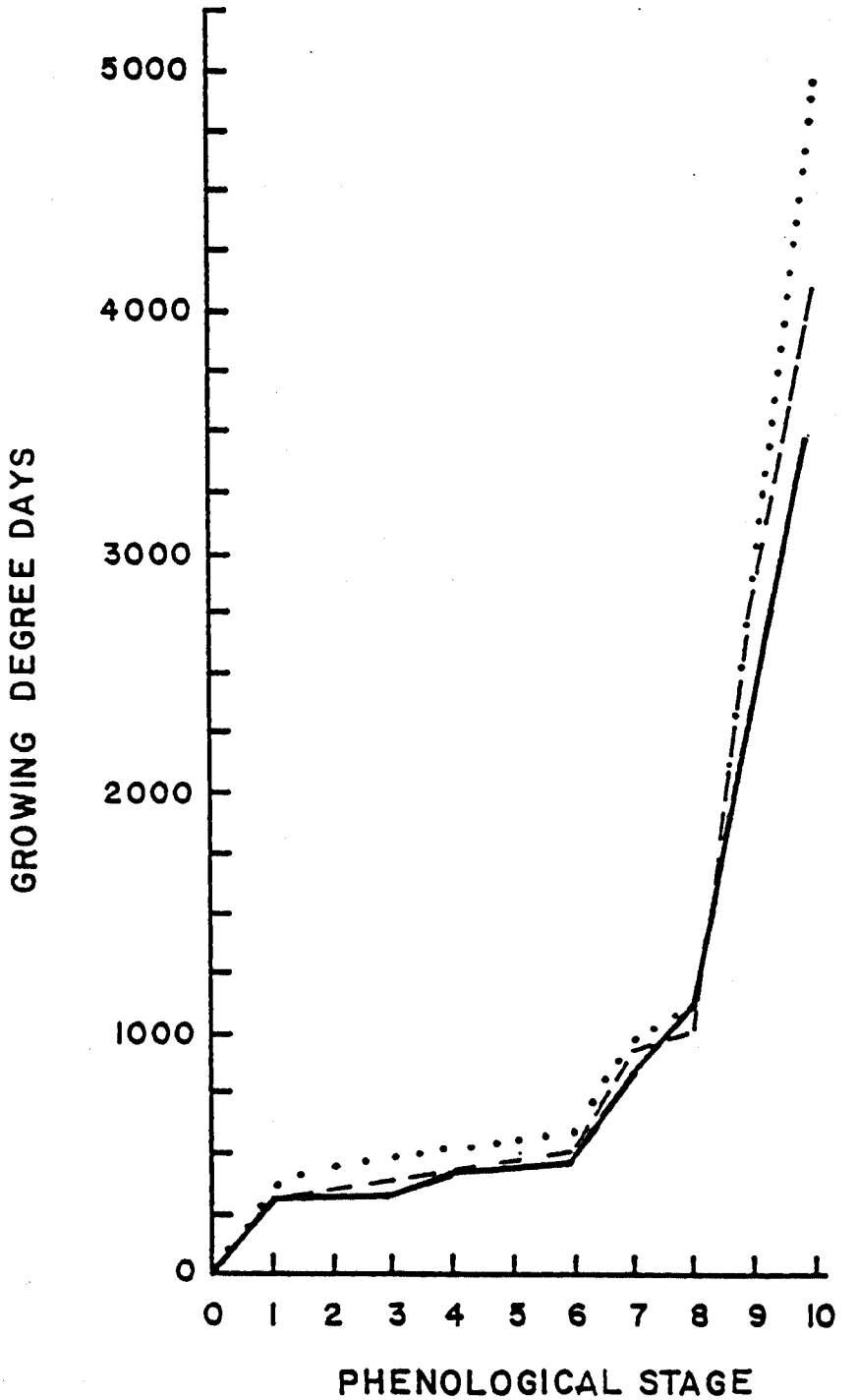

Figure 4. A comparison of growing degree day accumulation by early, mid and late season ripening cultivars in Tucson, Arizona in the 1978 growing season.

Growing degree accumulation for late season varieties (Table 4, Figure 3) were: stage 1, 319 to 483; stage 2, 395 to 537; stage 3, 395 to 631; stage 4, 429 to 657; stage 5, 454 to 676; stage 6, 483 to 702; stage 7, 841 to 1063; stage 8, 949 to 1157; stage 9, 1767 to 3595; and stage 10, 4853 to 5279.

Comparison of the growing degree day curves (Figure 4) indicates that with the exception of phenological stage 8 (full bloom) early season varieties and generally lower growing degree day accumulations at every stage and late season ripening varieties had generally a greater accumulation.

Growing degree day accumulations from first swell (stage 1) to bud burst (stage 3) are shown in Table 5. Accumulation in early season varieties ranged from 40 to 81 degree days, in mid-season varieties from 38 to 143 and in late season varieties ranged from 45 to 222.

Growing degree day accumulations from bud burst (stage 3) to 50 percent bloom (stage 7) is shown in Table 6. The range in growing degree days for early season varieties was 123 to 571; for mid-season varieties, 421 to 563; and late season varieties, 432 to 609.

Table 7 shows the growing degree day accumulations from full bloom (stage 8) to verasion (stage 9). Early season varieties ranged from 1048 to 2273 growing degree days. Mid season varieties accumulated 610 to 2537 degree days and late season varieties 751 to 2437 degree days.

Table 5. Growing degree day accumulation from first swell to bud burst in Tucson, Arizona in the 1978 growing season.

	Variety	G.D.D.		Variety	G.D.D.
1.	Barbera	76	23.	Malvasia blanca	123
2.	Beauty Seedless	40	24.	Mission	88
3.	Bengenda Red	76	25.	Napa Gamay	59
4.	Cabernet Sauvignon	89	26.	Nebbiolo	76
5.	Champanel	89	27.	Palomino	89
6.	Canaiolo Nero	168	28.	Perlette	81
7.	Cardinal	76	29.	Petite Sirah	76
8.	Carignane	73	30.	Pinot blanc	44
9.	Carmine	88	31.	Pinot noir GB	76
10.	Carnelian	177	32.	Ruby Cabernet	88
11.	Chardonnay	38	33.	Sangiovito	135
12.	Chenin blanc	114	34.	Sauvignon blanc	123
13.	Clairette blanche	95	35.	Semillon	88
14.	Cortese	113	36.	Souzao	148
15.	Dogridge	113	37.	Sylvaner	76
16.	Emerald Riesling	85	38.	Tinta Madeira	113
17.	French Colombard	45	39.	Thompson Seedless	76
18.	Gamay Beaujolais	76	40.	Trebbiano	222
19.	Gewürztraminer	128	41.	Vitis Arizonica	113
20.	Gray Riesling	59	42.	White Riesling	76
21.	Green Hungarian	89	43.	Zinfandel	143
22.	Helena	95			

Table 6. Growing degree day accumulation from bud burst to 50 percent bloom in Tucson, Arizona in the 1978 growing season.

	Variety	G.D.D.		Variety	G.D.D.
1.	Barbera	421	23.	Malvasia blanca	545
2.	Beauty Seedless	526	24.	Mission	588
3.	Bengenda Red	445	25.	Napa Gamay	495
4.	Cabernet Sauvignon	533	26.	Nebbiolo	554
5.	Champanel	372	27.	Palomino	545
6.	Canaiolo Nero	545	28.	Perlette	123
7.	Cardinal	554	29.	Petite Sirah	446
8.	Carignane	520	30.	Pinot blanc	500
9.	Carmine	--	31.	Pinot blanc	500
10.	Carnelian	--	32.	Ruby Cabernet	520
11.	Chardonnay	482	33.	Sangiovito	609
12.	Chenin blanc	123	34.	Sauvignon blanc	499
13.	Clairette blanche	484	35.	Semillon	520
14.	Cortese	479	36.	Souzao	432
15.	Dogridge	442	37.	Sylvaner	501
16.	Emerald Riesling	538	38.	Tinta Madeira	563
17.	French Colombard	501	39.	Thompson Seedless	554
18.	Gamay Beaujolais	446	40.	Trebbiano	568
19.	Gewürztraminer	442	41.	Vitis Arizonica	--
20.	Gray Riesling	571	42.	White Riesling	445
21.	Green Hungarian	533	43.	Zinfandel	533
22.	Helena	580			

Table 7. Growing degree day accumulation from full bloom to verasion in Tucson, Arizona in the 1978 growing season.

	Variety	G.D.D.		Variety	G.D.D.
1.	Barbera	2099	23.	Malvasia blanca	751
2.	Beauty Seedless	1159	24.	Mission	2371
3.	Bengenda Red	1062	25.	Napa Gamay	751
4.	Cabernet Sauvignon	1890	26.	Nebbiolo	2190
5.	Champanel	--	27.	Palomino	2329
6.	Canaiolo Nero	1734	28.	Perlette	1663
7.	Cardinal	1663	29.	Petite Sirah	819
8.	Carignane	2273	30.	Pinot blanc	2537
9.	Carmine	--	31.	Pinot noir GB	819
10.	Carnelian	--	32.	Ruby Cabernet	1663
11.	Chardonnay	1577	33.	Sangiovito	2437
12.	Chenin blanc	2470	34.	Sauvignon blanc	1890
13.	Clairette blanche	2329	35.	Semillon	2470
14.	Cortese	724	36.	Souzao	2329
15.	Dogridge	2059	37.	Sylvaner	2537
16.	Emerald Riesling	2497	38.	Tinta Madeira	610
17.	French Colombard	2190	39.	Thompson Seedless	1048
18.	Gamay Beaujolais	819	40.	Trebbiano	1240
19.	Gewürztraminer	--	41.	Vitis Arizonica	--
20.	Gray Riesling	2273	42.	White Riesling	1697
21.	Green Hungarian	2329	43.	Zinfandel	2031
22.	Helena	--			

Growing degree day accumulation from verasion to ripening is shown in Table 8. Growing degree day accumulations were: early season, 271 to 1594; mid season, 361 to 2393; and late season, 1367 to 3167.

Early season varieties required 330 degree days to reach stage 1 from January 1. Mid season varieties required a slightly higher accumulation (339 G.D.D.) and late season ripening varieties required the most (376 G.D.D.). A comparison of the data from Tables 4, 5, 6, 7 and 8 and Figures 1, 2, 3 and 4 indicates that generally the early season ripening varieties were earlier at almost all stages of development. The one exception to this was the attainment of the full bloom stage (stage 8) where the early season ripening varieties required a greater degree day accumulation than did the mid or late season varieties.

Winkler (1948) reported that the growing degree days required for 'Thompson Seedless' was 2007±65 from bloom to harvest in California. There is a significant difference between the results reported by Winkler (1948) and the results reported in this study. The differences maybe due to the influence of the other growth factors in the two different regions. Assuming that when the mean temperature is higher than 80 F, the difference will be nonsignificant. The results found by Winkler (1948) agree with this study by that assumption.

Summation of heat unit accumulation for the 1978 growing season is shown in Table 9. From January 1 to October 31, 4691 heat units were amassed. From April 1 to October 31, 4218 heat units were amassed.

Table 8. Growing degree day accumulations from verasion to harvest in Tucson, Arizona in the 1978 growing season.

Variety	G.D.D.	Variety	G.D.D.
1. Barbera	1316	18. Nebbiolo	2042
2. Beauty Seedless	1594	19. Palomino	675
3. Bengenda Red	1487	20. Perlette	774
4. Cabernet Sauvignon	2232	21. Petite Sirah	3085
5. Canaiolo Nero	2118	22. Pinot blanc	361
6. Cardinal	1407	23. Pinot noir GB	2393
7. Carignane	1603	24. Ruby Cabernet	2570
8. Chardonnay	1375	25. Sangiovito	1450
9. Clairette blanche	1558	26. Sauvignon blanc	1004
10. Emerald Riesling	601	27. Semillon	675
11. French Colombard	2667	28. Souzao	1367
12. Gamay Beaujolais	2393	29. Tinta Madeira	2393
13. Gray Riesling	271	30. Thompson Seedless	1594
14. Green Hungarian	675	31. Trebbiano	2426
15. Malvasia blanca	946	32. White Riesling	1448
16. Mission	1594	33. Zinfandel	1316
17. Napa Gamay	3167		

Table 9. Heat unit summation for Tucson, Arizona in the 1978 growing season.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
January			
1	56	4.752	4.752
2	53	2.376	7.128
3	55	3.960	11.088
4	55	3.960	15.048
5	54.5	3.564	18.612
6	53	2.376	20.988
7	51.5	1.782	22.770
8	52.5	1.980	24.750
9	54	3.168	27.918
10	58	6.336	34.254
11	49.5	0.000	34.254
12	52	1.584	35.838
13	48	0.000	35.838
14	55.5	4.356	40.194
15	56	4.732	44.946
16	54.5	3.564	48.510
17	52.5	1.980	50.49
18	51	0.792	51.282
19	51.5	1.782	53.064
20	51.5	1.782	54.846
21	50.5	0.396	55.242
22	49	0.000	55.242
23	49	0.000	55.242
24	45.5	0.000	55.242
25	41.5	0.000	55.242
26	46.5	0.000	55.242
27	51	0.792	56.034
28	55	3.960	59.994
29	58	6.336	66.330
30	61	8.712	75.042
31	58.5	6.732	81.774
February			
1	57	5.544	87.318
2	53	2.376	89.694
3	56	4.752	94.446
4	55	3.960	98.406
5	67.5	13.860	112.266
6	59	7.128	119.394
7	59	7.128	126.522
8	57	5.544	132.066
9	57.5	5.940	138.006

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
10	56	4.752	142.758
11	50.5	0.396	143.154
12	44	0.000	143.154
13	50	0.000	143.154
14	46	0.000	143.154
15	49.5	0.000	143.154
16	45.5	0.000	143.154
17	41.5	0.000	143.154
18	42	0.000	143.154
19	41	0.000	143.154
20	47	0.000	143.154
21	52	1.584	144.738
22	54.5	3.56	148.302
23	58.5	6.732	155.034
24	58.5	6.732	161.766
25	55.5	4.356	166.122
26	58	6.336	172.458
27	55	3.960	176.418
28	60.5	8.316	184.734
March			
1	59	7.128	191.862
2	59	7.128	198.99
3	58.5	6.732	205.722
4	58	6.336	212.058
5	56	4.752	216.810
6	53.5	2.772	219.582
7	56	4.752	224.334
8	57	5.544	229.878
9	59	7.128	237.006
10	59.5	7.524	244.530
11	54	3.168	247.698
12	53.5	2.772	250.470
13	50.5	0.396	250.866
14	50	0.000	250.866
15	55	3.960	254.826
16	57	5.544	260.370
17	64.5	11.484	271.854
18	65.5	12.276	284.130
19	71.5	17.028	301.158
20	67	13.464	314.622
21	66.5	13.068	327.690
22	67.5	13.860	341.550
23	64.5	11.484	353.034

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
24	60.5	8.316	361.350
25	63	10.296	371.646
26	66.5	13.068	384.714
27	68.5	14.652	398.782
28	65.5	12.276	411.058
29	70	15.840	426.898
30	70	15.840	442.738
31	70.5	16.236	458.974
April			
1	66.5	13.068	472.042
2	61.5	9.108	481.150
3	62.5	9.900	491.050
4	62.5	9.900	500.950
5	61.5	9.108	510.058
6	64	11.088	521.148
7	63	10.296	531.442
8	53	2.376	533.818
9	50	0.000	533.818
10	53.5	2.772	536.590
11	61	8.712	545.302
12	65	11.88	557.182
13	67.5	13.860	571.042
14	71	16.632	587.674
15	65.5	12.276	599.950
16	60.5	8.316	608.266
17	59.5	7.524	615.690
18	60	7.920	623.710
19	65	11.880	635.590
20	65	11.880	647.470
21	63	10.296	657.766
22	61.5	9.108	666.974
23	64	11.088	677.962
24	67.5	13.860	691.822
25	73.5	18.612	710.434
26	70.5	16.236	726.670
27	67	13.464	740.134
28	66	12.672	752.806
29	64.5	11.484	764.290
30	63	10.296	774.586

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
May			
1	63.5	10.692	785.278
2	57.5	5.940	791.218
3	69	15.048	806.266
4	69.5	15.444	821.710
5	68.5	14.652	836.362
6	55	3.960	840.322
7	58	6.336	846.658
8	63	10.296	856.954
9	69.5	15.444	872.398
10	70.5	16.236	888.634
11	69	15.048	903.682
12	73	18.216	921.898
13	78.5	22.572	944.470
14	80	24.000	968.470
15	78	22.176	990.646
16	75	19.800	1010.446
17	70	15.840	1026.286
18	69.5	15.444	1041.730
19	76.5	20.988	1062.718
20	77.5	21.780	1084.498
21	78	22.176	1106.674
22	78.5	22.572	1129.246
23	75	19.800	1149.046
24	71.5	17.028	1166.074
25	73	18.216	1184.290
26	70.5	16.236	1200.526
27	69	15.048	1215.574
28	73	18.216	1233.790
29	75	19.800	1253.590
30	79	22.968	1276.558
31	78	22.176	1298.734
June			
1	75.5	20.196	1318.930
2	77	21.384	1340.314
3	76	20.592	1360.906
4	78.5	22.572	1383.478
5	77.5	21.78	1405.258
6	79	22.968	1428.226
7	80	24.000	1452.226
8	85.5	24.000	1476.226
9	85.5	24.000	1500.226
10	85.5	24.000	1524.226

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
11	84	24.000	1548.226
12	82.5	24.000	1596.226
13	85.5	24.000	1596.226
14	86	24.000	1620.226
15	86.5	24.000	1644.226
16	83	24.000	1668.226
17	84.5	24.000	1692.226
18	85.5	24.000	1716.226
19	87.5	24.000	1740.226
20	86	24.000	1764.226
21	84	24.000	1788.226
22	87	24.000	1812.226
23	90	24.000	1836.226
24	88.5	24.000	1860.226
25	88.5	24.000	1886.226
26	89	24.000	1908.226
27	87	24.000	1932.226
28	83.5	24.000	1956.226
29	82	24.000	1980.226
30	83.5	24.000	2004.226
July			
1	82	24.000	2028.226
2	84	24.000	2052.226
3	85	24.000	2076.226
4	85	24.000	2100.226
5	86	24.000	2124.226
6	84	24.000	2148.226
7	88.5	24.000	2172.226
8	87.5	24.000	2196.226
9	89	24.000	2220.226
10	89.5	24.000	2244.226
11	90	24.000	2269.226
12	89.5	24.000	2292.226
13	85.5	24.000	2316.226
14	92	24.000	2340.226
15	92	24.000	2364.226
16	91	24.000	2388.226
17	91.5	24.000	2412.226
18	89	21.000	2436.226
19	96	24.000	2460.226
20	93	24.000	2484.226
21	85.5	24.000	2508.226
22	83.5	24.000	2532.226
23	83	24.000	2556.226

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
24	90.5	24.000	2580.226
25	85	24.000	2604.226
26	84.5	24.000	2628.226
27	26.5	24.000	2652.226
28	86	24.000	2676.226
29	88.5	24.000	2700.226
30	87	24.000	2724.226
31	84	24.000	2748.226
August			
1	85.5	24.000	2772.226
2	81.5	24.000	2796.226
3	85.5	24.000	2820.226
4	85	24.000	2844.226
5	83.5	24.000	2868.226
6	83.5	24.000	2892.226
7	86	24.000	2916.226
8	84	24.000	2940.226
9	89	24.000	2964.226
10	86	24.000	2988.226
11	86	24.000	3012.226
12	83.5	24.000	3036.226
13	83	24.000	3060.226
14	81.5	24.000	3084.226
15	84.5	24.000	3108.226
16	84	24.000	3132.226
17	84.5	24.000	3156.226
18	85	24.000	3180.226
19	84	24.000	3204.226
20	84.5	24.00	3228.226
21	86.5	24.000	3252.226
22	83.5	24.000	3276.226
23	86	24.000	3300.226
24	88	24.000	3324.226
25	86.5	24.000	3348.226
26	85	24.000	3372.226
27	83	24.000	3376.226
28	83	24.000	3426.226
29	84	24.000	3444.226
30	86	24.000	3468.226
21	89.5	24.000	3492.226

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
September			
1	92	24.000	3516.226
2	89.5	24.000	3540.226
3	85.5	24.000	3364.226
4	85	24.000	3588.226
5	86	24.000	3612.226
6	85	24.000	3636.226
7	85	24.000	3660.226
8	82	24.000	3684.226
9	82.5	24.000	3708.226
10	83	24.000	3732.226
11	80.5	24.000	3756.226
12	77	21.384	3777.610
13	81	24.000	3801.610
14	81	24.000	3825.610
15	78.5	22.572	3848.182
16	80	24.000	3872.182
17	73	18.216	3890.398
18	75	19.800	3910.198
19	72	17.454	3927.652
20	69.5	15.444	3943.096
21	74.5	19.404	3962.500
22	78	22.176	3984.676
23	81	24.000	4008.676
24	83.5	24.000	4032.676
25	85.5	24.000	4056.676
26	82.5	24.000	4080.676
27	81.5	24.000	4104.676
28	81	24.000	4128.676
29	80.5	24.000	4152.676
30	82.5	24.000	4176.676
October			
1	78.5	22.572	4199.248
2	80.5	24.000	4223.248
3	80	24.000	4247.248
4	79	22.968	4270.216
5	79.5	23.364	4293.580
6	78.5	22.572	4316.152
7	82.5	24.000	4340.152
8	79.5	22.572	4362.724
9	79	22.968	4385.692
10	75.5	20.196	4405.888
11	75	19.800	4425.688

Table 9, continued. Heat unit summation.

Date	F Mean Temperature	Heat Units	Heat Unit Accumulations
12	73.5	18.612	4444.300
13	75	19.800	4464.100
14	79	22.968	4447.068
15	75	19.800	4466.808
16	74	19.008	4485.876
17	74.5	19.404	4505.280
18	73	18.216	4523.496
19	78	22.176	4545.672
20	69.5	15.444	4561.116
21	67	13.464	4574.580
22	65	11.880	4586.460
23	66.5	13.068	4599.528
24	62	9.504	4609.032
25	60	7.920	4616.952
26	61	8.712	4625.664
27	63.5	10.692	4636.356
28	63.5	10.692	4647.048
29	68.5	14.652	4661.700
30	67	13.464	4675.164
31	69.5	15.444	4690.608

The heat units accumulated from January 1 to each phenological stage are shown in Table 10 and Figures 5, 6 and 7. Heat unit summations for the early season varieties (Table 10, Figure 5) were: first swell, 220 to 225; full swell, 248 to 284; bud burst, 251 to 315; first leaf, 255 to 353; second leaf, 272 to 372; fourth leaf, 301 to 390; 50 percent bloom, 667 to 753; full bloom, 753 to 840; verasion, 1644 to 2412; and ripening, 2508 to 2676.

Heat unit summations for varieties ripening in the middle of the season (Table 10, Figure 6) were: first well, 224 to 315; full swell, 248 to 385; bud burst, 255 to 411; first leaf, 272 to 491; second leaf, 301 to 521; fourth leaf, 342 to 537; 50 percent bloom, 667 to 847; full bloom, 710 to 922; verasion, 1405 to 2580; and ripening 2772 to 3132.

Summations of heat units for late ripening varieties (Table 10, Figure 7) were: first swell, 255 to 385; full swell, 272 to 501; bud burst, 315 to 537; first leaf, 343 to 557; second leaf, 361 to 588; fourth leaf, 385 to 608, 50 percent bloom, 667 to 991; full bloom, 753 to 1042; verasion, 1405 to 2604; and ripening, 2492 to 3732.

A comparison of the early, mid and late season ripening varieties is shown in Figure 8. As with degree day accumulation, early ripening cultivars reached each phenological stage with a lower accumulation of heat units. Late season cultivars required a greater number of heat units to reach each stage. At full bloom (stage 8) heat unit accumulation was progressively higher as one progressed from early to late season cultivars (unlike degree day accumulation, Figure 4).

Table 10. Heat units accumulated from January 1 to the indicated phenological stage in the 1978 growing season in Tucson, Arizona.

Variety	Stage									
	1	2	3	4	5	6	7	8	9	10
1. Barbera	255	285	315	353	372	399	753	840	1644	3132
2. Beauty Seedless	222	247	251	255	272	301	667	753	1644	2676
3. Bengenda Red	255	272	315	342	361	385	753	806	1644	2604
4. Cabernet Sauvignon	315	342	361	385	411	459	753	806	2028	3708
5. Champanel	245	255	315	385	443	472	608	667	--	--
6. Canaiolo Nero	272	361	411	481	521	537	847	922	2532	3364
7. Cardinal	255	272	315	361	335	411	753	806	2028	2940
8. Carignane	284	315	342	372	399	443	753	806	2292	3492
9. Carmine	272	315	342	361	501	--	--	--	--	--
10. Carnelian	272	372	411	459	--	--	--	--	--	--
11. Chardonnay	244	248	255	272	301	342	636	710	1884	2772
12. Chenin blanc	244	255	315	342	361	385	753	806	2532	--
13. Clairette blanche	385	411	459	491	521	537	847	922	2532	3588
14. Cortese	272	315	361	399	459	491	740	806	1383	--
15. Dogridge	272	315	361	411	531	537	710	753	2244	--
16. Emerald	260	284	328	372	399	443	753	847	2580	2988
17. French Colombard	272	301	315	353	305	411	710	806	3264	3540
18. Gamay Beaujolais	255	272	315	342	361	385	667	753	1405	2988
19. Gewürztraminer	255	315	361	399	427	459	710	806	--	--
20. Gray Riesling	255	272	301	315	342	361	753	806	2412	2580
21. Green Hungarian	315	361	385	411	459	501	806	922	2532	2988
22. Helena	384	411	459	491	521	537	922	991	--	--
23. Malvasia blanca	314	361	411	491	521	537	847	922	2484	3132
24. Mission	271	315	342	361	385	427	806	889	2532	3612
25. Napa Gamay	314	342	361	385	411	459	753	806	1405	3516
26. Nebbiolo	254	272	315	342	361	385	758	806	2364	3732
27. Palomino	341	385	44	459	491	537	847	922	2532	2188
28. Perlette	257	272	315	342	361	385	753	806	2028	2508
29. Petite Sirah	255	272	315	342	361	385	667	753	1405	2468

Table 10, continued

Variety	Stage									
	1	2	3	4	5	6	7	8	9	10
30. Pinot blanc	273	255	272	301	315	342	667	753	2532	2772
31. Pinot noir GB	255	272	315	342	361	385	667	753	1405	2988
32. Ruby Cabernet	272	315	342	361	385	427	753	806	2028	3732
33. Sangiovito	255	328	361	385	443	491	847	922	2604	3588
34. Sauvignon blanc	315	361	411	459	491	521	806	922	2268	2916
35. Semillon	272	315	342	361	399	443	753	806	2532	2988
36. Souzao	385	427	491	521	537	557	847	922	2532	3468
37. Sylvaner	255	272	315	342	361	385	710	573	2532	--
38. Tinta Madeira	272	342	361	411	427	459	822	922	1405	2988
39. Thompson Seedless	255	284	315	353	372	390	753	840	1644	2676
40. Trebbiano	361	501	537	557	588	608	991	1042	1932	3540
41. Vitis Arizonica	272	342	361	411	459	501	--	--	--	--
42. White Riesling	255	272	315	342	361	385	661	806	2052	2988
43. Zinfandel	272	342	385	411	459	491	806	847	2268	3132

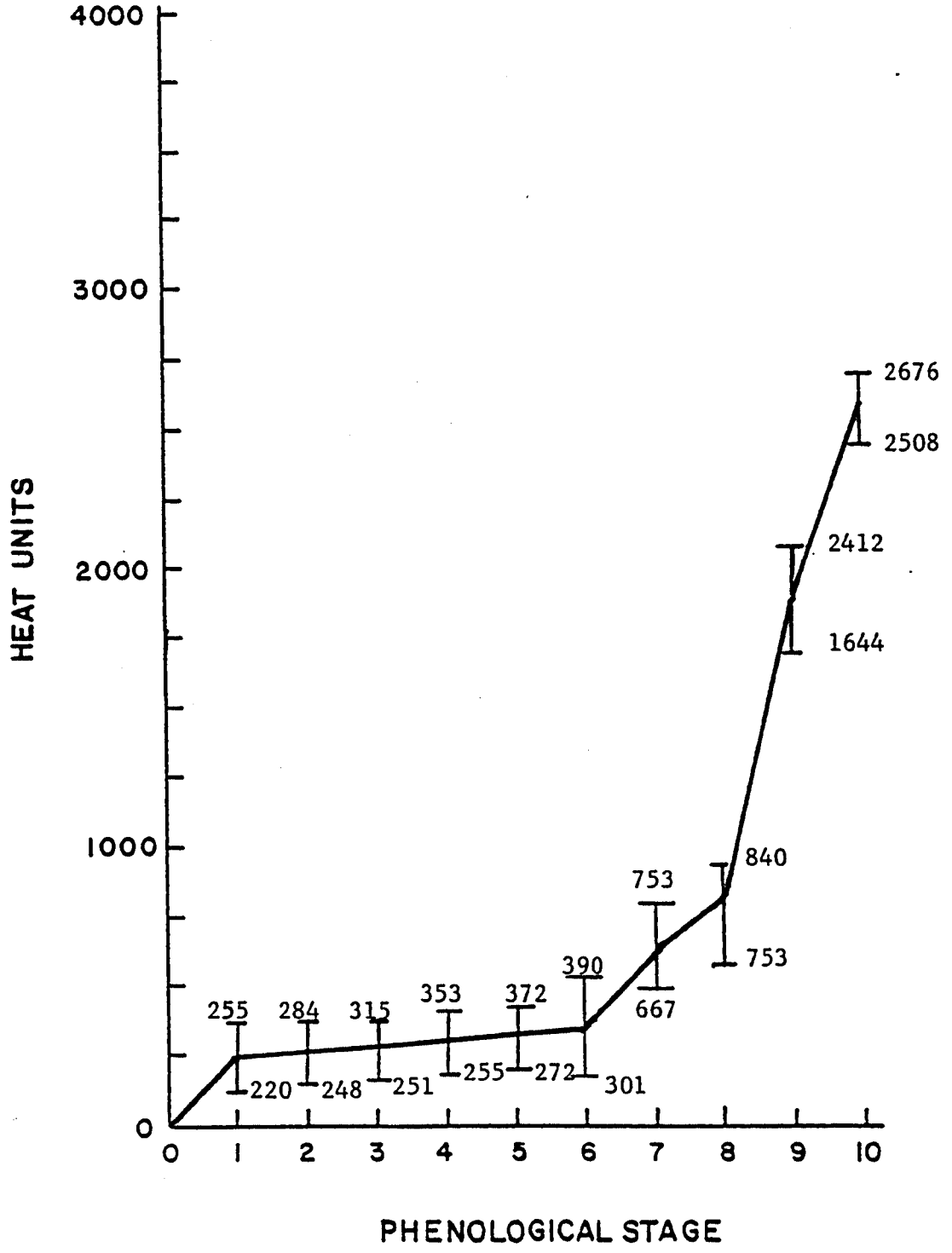

Figure 5. Heat units accomulated by early season varieties in Tucson, Arizona in the 1978 growing season.

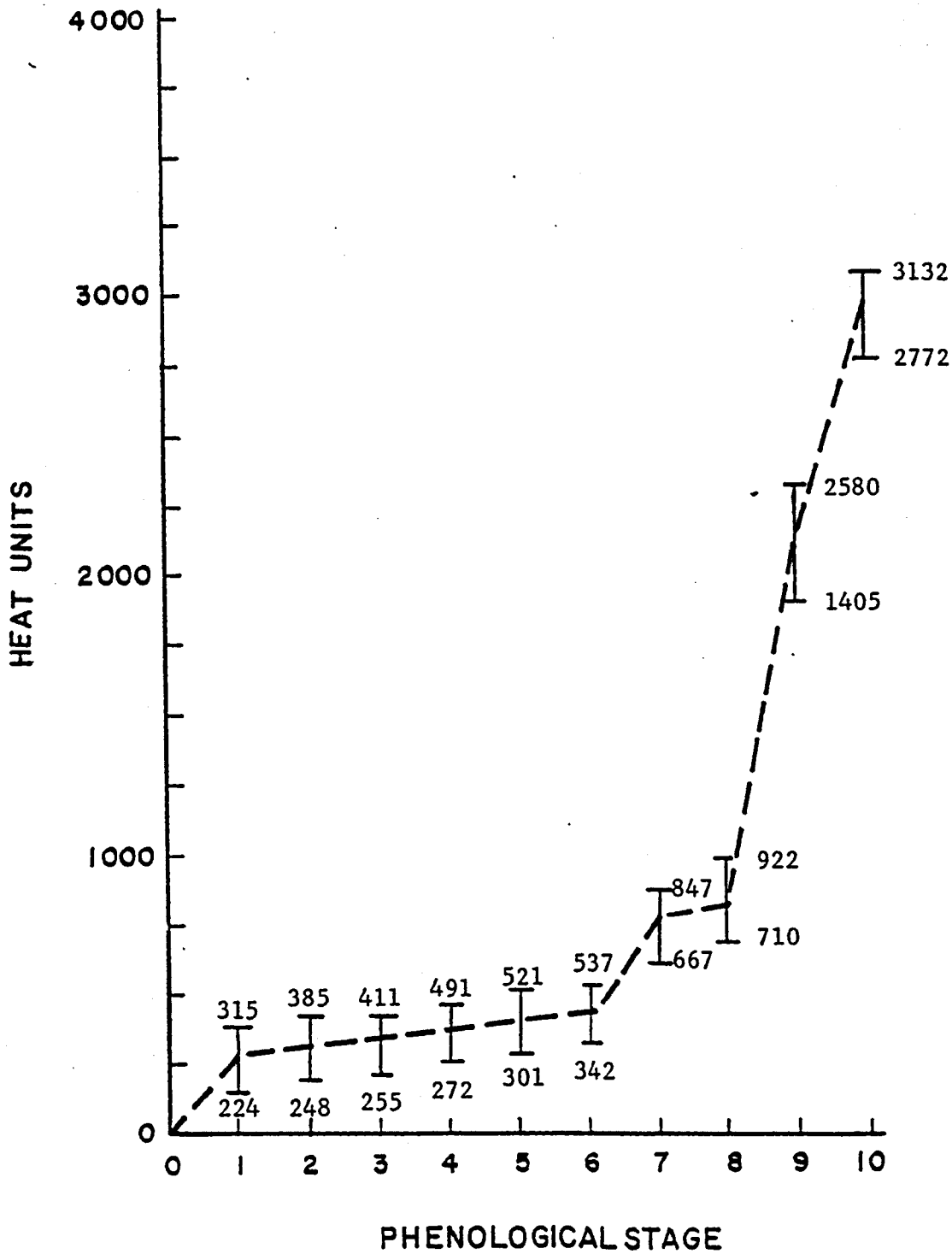

Figure 6. Heat units accumulated by mid season varieties in Tucson, Arizona in the 1978 growing season.

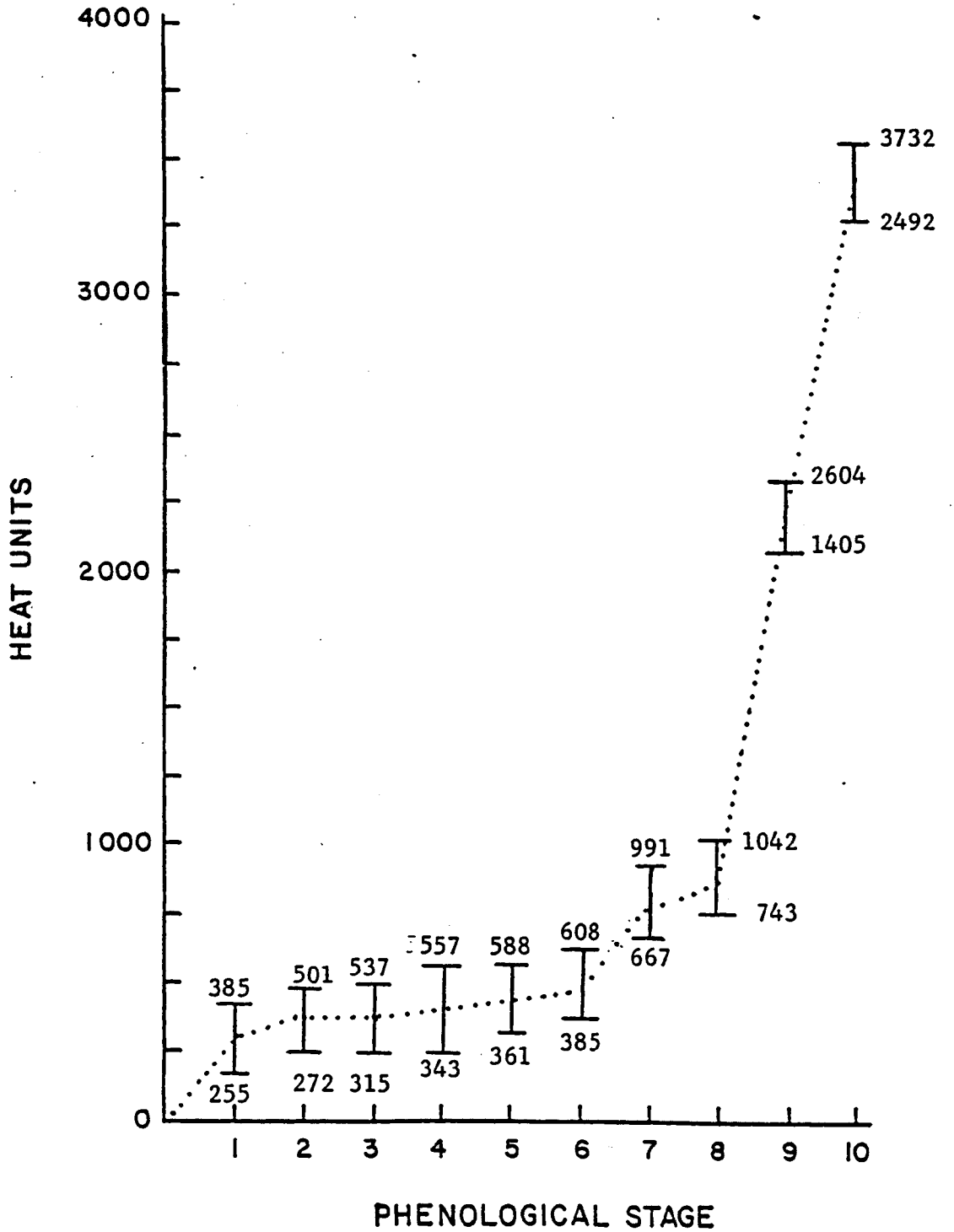

Figure 7. Heat units accumulated by late season varieties in Tucson, Arizona in the 1978 growing season.

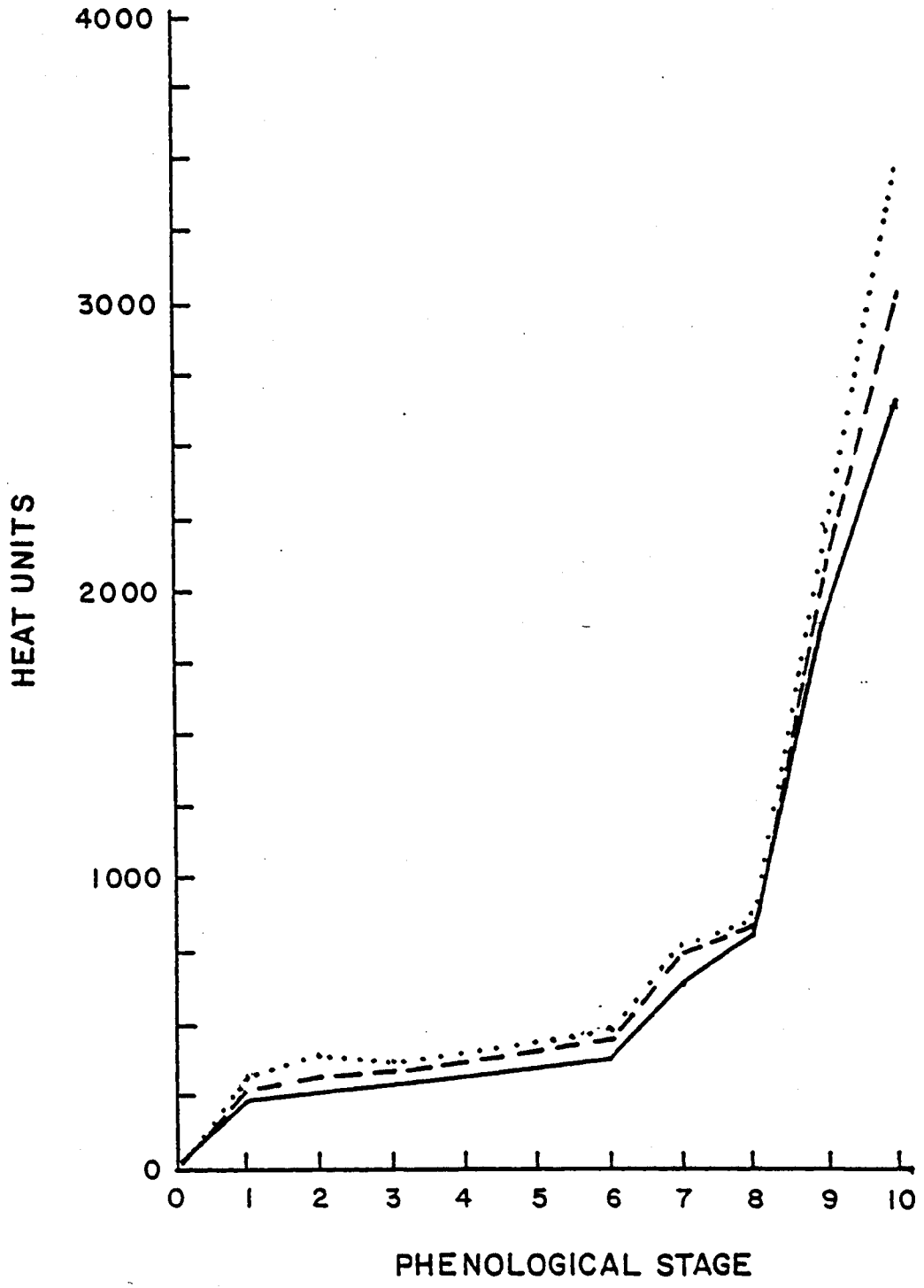

Figure 8. A comparison of heat units accumulated by early, mid and late season ripening cultivars in Tucson, Arizona in the 1978 season.

Very little difference however occurred at this stage with any of the cultivars.

Summations of the heat units accumulated from first swell to bud burst is shown in Table 11. Heat unit summations for early season varieties was 31 to 63; mid season varieties ranged from 30 to 139 heat units, and late season varieties ranged from 43 to 175 heat units.

Heat unit summations from bud burst to 50 percent bloom, in early season varieties were ranged from 418 to 452 (Table 12), while mid season varieties required 352 to 460 heat units, and late season varieties accumulated 352 to 485 heat units.

Heat unit summation from full bloom to verasion is shown in Table 13. Early season varieties accumulated 804 to 1606 heat units; mid season varieties required 652 to 1779 heat units; and late season varieties required 599 to 1682 heat units.

Heat units accumulated from verasion to ripening for early season varieties were 168 to 1032 (Table 14). Mid season varieties accumulated 408 to 1583 heat units, and late season varieties required 832 to 2063 heat units.

Mean heat unit summation for early season varieties was less than the heat unit summation for mid and late season varieties in reaching first swell (Figure 8). The values were respectively 247, 270 and 300 heat units; however, within each group great variability was noted, with overlapping of members of all groups. A similar pattern was noted at each phenological stage of development.

Table 11. Heat units accumulated from first swell to bud burst in Tucson, Arizona in the 1978 growing season.

Variety	Heat Units	Variety	Heat Units
1. Barbera	58	23. Malvasia blanca	96
2. Beauty Seedless	31	24. Mission	70
3. Bengenda Red	60	25. Napa Gamay	47
4. Cabernet Sauvignon	47	26. Nebbiolo	60
5. Champanel	70	27. Palomino	70
6. Canaiolo Nero	139	28. Perlette	63
7. Cardinal	60	29. Petite Sirah	60
8. Carignane	58	30. Pinot blanc	35
9. Carmine	70	31. Pinot noir GB	60
10. Carnelian	139	32. Ruby Cabernet	60
11. Chardonnay	30	33. Sangiovito	107
12. Chenin blanc	90	34. Sauvignon blanc	96
13. Clairette blanche	70	35. Semillon	70
14. Cortese	89	36. Souzao	106
15. Dogridge	89	37. Sylvaner	60
16. Emerald Riesling	67	38. Tinta Madeira	90
17. French Colombard	43	39. Thompson Seedless	60
18. Gamay Beaujolais	60	40. Trebbiano	175
19. Gewurztraminer	107	41. Vitis Arizonica	90
20. Gray Riesling	46	42. White Riesling	60
21. Green Hungarian	70	43. Zinfandel	113
22. Helena	74		

Table 12. Heat units accumulated from bud burst to 50 percent bloom in Tucson, Arizona in the 1978 growing season.

Variety	Heat Units	Variety	Heat Units
1. Barbera	438	23. Malvasia blanca	436
2. Beauty Seedless	416	24. Mission	465
3. Bengenda Red	438	25. Napa Gamay	392
4. Cabernet Sauvignon	391	26. Nebbiolo	438
5. Champanel	294	27. Palomino	436
6. Canaiolo Nero	436	28. Perlette	438
7. Cardinal	438	29. Petite Sirah	352
8. Carignane	411	30. Pinot blanc	395
9. Carmine	--	31. Pinot noir GB	352
10. Carnelian	--	32. Ruby Cabernet	411
11. Chardonnay	381	33. Sangiovito	485
12. Chenin blanc	438	34. Sauvignon blanc	395
13. Clairette blanche	388	35. Semillon	411
14. Cortese	379	36. Souzao	356
15. Dogridge	349	37. Sylvaner	396
16. Emerald Riesling	425	38. Tinta Madeira	460
17. French Colombard	396	39. Thompson Seedless	438
18. Gamay Beaujolais	352	40. Trebbiano	454
19. Gewürztraminer	349	41. Vitis Arizonica	--
20. Gray Riesling	452	42. White Riesling	352
21. Green Hungarian	422	43. Zinfandel	421
22. Helena	463		

Table 13. Heat units accumulated from full bloom to verasion in Tucson, Arizona in the 1978 growing season.

Variety	Heat Units	Variety	Heat Units
1. Barbera	804	23. Malvasia blanca	1562
2. Beauty Seedless	891	24. Mission	1644
3. Bengenda Red	838	25. Napa Gamay	599
4. Cabernet Sauvignon	1222	26. Nebbiolo	1558
5. Champanel	--	27. Palomino	1610
6. Canaiolo Nero	1610	28. Perlette	1222
7. Cardinal	1222	29. Petite Sirah	652
8. Carignane	1606	30. Pinot blanc	1779
9. Carmine	--	31. Pinot noir GB	652
10. Carnelian	--	32. Ruby Cabernet	1222
11. Chardonnay	1174	33. Sangiovito	1682
12. Chenin blanc	1726	34. Sauvignon blanc	1346
13. Clairette blanche	1610	35. Semillon	1726
14. Cortese	577	36. Souzao	1610
15. Dogridge	1491	37. Sylvaner	1779
16. Emerald Riesling	1734	38. Tinta Madeira	652
17. French Colombard	1558	39. Thompson Seedless	804
18. Gamay Beaujolais	652	40. Trebbiano	891
19. Gewürztraminer	--	41. Vitis Arizonica	--
20. Gray Riesling	1606	42. White Riesling	1246
21. Green Hungarian	1610	43. Zinfandel	1422
22. Helena	--		

Table 14. Heat units accumulated from verasion to harvest in Tucson, Arizona in the 1978 growing season.

Variety	Heat Units	Variety	Heat Units
1. Barbera	1488	18. Napa Gamay	2111
2. Beauty Seedless	1032	19. Nebbiolo	1368
3. Bengenda Red	960	20. Palomino	456
4. Cabernet Sauvignon	1860	21. Perlette	480
5. Canaiolo Nero	832	22. Petite Sirah	2063
6. Cardinal	912	23. Pinot blanc	240
7. Carignane	1200	24. Pinot noir GB	1583
8. Chardonnay	888	25. Ruby Cabernet	1704
9. Clairette blanche	1056	26. Sangiovito	984
10. Emerald Riesling	408	27. Sauvignon blanc	648
11. French Colombard	1176	28. Semillon	456
12. Gamay Beaujolais	1583	29. Souzao	936
13. Gewürztraminer	--	30. Tinta Madeira	1583
14. Gray Riesling	168	31. Thompson Seedless	1032
15. Green Hungarian	456	32. Trebbiano	1608
16. Malvasia blanca	648	33. White Riesling	936
17. Mission	1080	34. Zinfandel	864

CHAPTER 5

SUMMARY AND CONCLUSION

Forty-two grape cultivars growing at the University of Arizona Campbell Avenue Experimental Farm were studied with respect to the effect of temperature on phenological development (first swell to harvest). Two methods for mathematically describing the accumulation of heat during the growing season were employed. One was the older growing degree day model which has some limitations. The other was based on the recently developed heat unit concept, which may negate some of the disadvantages of the growing degree day model. The cultivars were studied only during the 1978 growing season.

Each cultivar studied required a different number of growing degree days or heat units to reach each of the indicated phenological stages. Early season varieties required consistently lower growing degree days and heat units than mid and late season varieties. Late season varieties required consistently greater values.

Comparison of data on the same varieties with other regions in U.S.A. has shown no agreement. The difference may be related to climatic conditions (temperature, humidity, light intensity and photoperiod). Differences in soil type may be a factor. Data have been accumulated over only one season. Several more years of data are necessary before an accurate picture can be developed. Also some varieties did not produce mature fruit because of disease or young age.

Growing degree days and heat units accumulation models can serve to indicate the proper date for the beginning of harvest or other managerial operations; however, growing degree days accumulated in 1978 growing season in Tucson, Arizona did not agree with the data that has been published in other regions (California). This was due in part to harvesting the fruit at a higher level of maturity, but primarily to the hotter mean temperatures during the summer. These resulted in an approximately 25 percent higher accumulation in Tucson. If one considers that no increased effect on phenological development occurs at mean temperatures above 80 F, the growing degree day accumulation from bloom to harvest for 'Thompson Seedless' in Tucson, Arizona would more closely compare to the published data.

This limitation of an upper limit to the effective growing temperature range is a basic consideration of the heat unit model. While it will take several more years of data accumulation, both in Arizona and other grape growing areas, it appears that the heat unit model is a more useful predictive analytical tool for phenological development. This is based on the fact that the heat unit model comes closer in predicting the harvest date for 'Thompson Seedless' under both Arizona and published California locations.

While some trends may be suggested after only the one year of study reported here, more years of data collection are necessary in order to establish mean development rates for Arizona. In addition data (both phenological and climatological) needs to be collected on the same cultivars in other areas to be used in perfecting and testing

the model. The other areas selected should be both similar and widely different if an accurate model usable over a wide range of climatic regions is to be developed.

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