To the Graduate Council:

I am submitting herewith a thesis written by Karen Jane Petrey entitled "An Evaluation of Grape Cultivars Grown on the Cumberland Plateau of Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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AN EVALUATION OF GRAPE CULTIVARS GROWN ON THE CUMBERLAND PLATEAU OF TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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Karen Jane Petrey

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ABSTRACT

Eleven French Hybrid and ten American Bunch grapes were evaluated 1979 and 1980 on the Cumberland Plateau of Tennessee to determine their acclimation to the Plateau and to partially assess their ability to produce quality fruit.

Vines were examined for shoot growth, bud hardiness, plant mortality, yield, and number of clusters produced. Fruit was evaluated for soluble solids, acid, and pH content, and for berry and cluster size.

The American Bunch cultivars had greater cold hardiness but slightly lower fruit quality than the French Hybrid.

Both American Bunch and French Hybrids had lower yields, higher plant mortality, and lower nutrient levels the second year of the study.

The American Bunch cultivars, 'Concord,' 'Moored' and 'Niagara' performed well, exhibiting vigorous growth and adequate yields and fruit quality.

'Rosette' and 'Rougeon' were the most vigorous of the French Hybrids, but fruits of these cultivars were low in both sugar and acids. 'Seyval' and 'Vidal 256' had some winter damage and only moderate yields but fruit quality was good.

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CHAPTER I

INTRODUCTION

The viticultural and enological industries in the northeastern United States have enlarged within the last two decades, partially due to the adoption of French Hybrid grapes. The French Hybrids reportedly produce a higher quality wine than the customary American Bunch grapes of this region.

In the last decade, small, but rapidly developing viticultural and enological industries have emerged in the southeastern U. S. At present there are some 100 hectares of grapes being grown in Tennessee. Three wineries have recently opened, primarily utilizing Tennessee grown grapes. As these industries enlarge in Tennessee and begin competing with other areas of the country, more research concerning the adaptation of available cultivars to the widely varying climatical regions of Tennessee becomes necessary. One of the regions, the Cumberland Plateau, presents a unique situation to viticulturists due to its cool, humid climate. Early results of a 1973 grape cultivar study had indicated problems with grape growing in this area.

The objectives of this investigation were: (1) to continue the research on evaluation of adaptation of several American Bunch and French Hybrid grapes to the climate of the Plateau region, (2) to partially assess the quality of the cultivars, and (3) to determine

vine vigor and nutrient status. It is hoped that this study, along with ongoing grape research, will aid growers in choosing cultivars best suited to marketing requirements and to the climate of the Cumberland Plateau.

CHAPTER II

REVIEW OF LITERATURE

Grapes belong to the botanical genus Vitis, which contains two subgenera: Euvitis, including the labrusca and vinifera grapes grown in the western and eastern sections of the U. S. country, and Muscadinia, the muscadine grape of the southeastern region. Euvitis is characterized by striate-fibrose bark that sheds at maturity, a diaphragmed pith, forked tendrils, elongated flower clusters, berries that adhere to the stem at maturity and pyriform seeds (35).

Of the Euvitis grapes grown in North America, V. vinifera is the principal species grown in the California region. Although V. vinifera is grown in the Eastern United States, other species of Vitis predominate there. Many cultivars are grown that were derived from native species, primarily V. labrusca, V. aestivalis, and V. riparia. Hybrid cultivars which have been obtained by crossing a variety of one species with a variety of another species or with a hybrid already produced are also utilized in the East (3).

Total production of all grapes in the U. S. is about 3,723,540 metric tons, of which less than 500,000 metric tons are grown in the Great Lakes section and less than 4,000 tons in the other regions of the Eastern U. S. (28).

Grapes in the East are grown for the fresh market and for processing, which includes the making of juices, jellys, and wine (13, 28, 35).

Fruit Composition

The organic acids of wine grapes are important for the sour taste that they impart to wine made from them, although hydrogen ion concentration also has an effect on sourness. Sufficiently low pH is important in winemaking for extraction of coloring components, stability of color, and for prevention of spoilage by bacteria during fermentation (26).

Amerine and Winkler (2) reported that malic and tartaric acids constituted over 90% of the acids of the vinifera vines that they studied, although tannic, phosphoric, and ctric acids were also principal acids in the musts. The pH level of wines were similar to that of the musts with 85% of the musts having pH ranging from 3.11 to 3.80, the greatest majority of which fell in the range of 3.41 to 3.50. The pH increased during maturation, reflecting a change in the ratio of acid salts to free acids. In green fruits, from 50-80% of the tartrates were present as free tartaric acid, but only 10-20% were present in that form at maturity.

In an experiment in which shoots of 'Sultanina' vines with clusters were exposed to $C^{14}O_2$ at an early stage of development and again near ripening, Kliewer (15) found malic acid to be the principal organic acid, with 40-90% of the activity in the organic acid fraction of nearly ripe berries. Tartaric acid contained 4-21% and citric acid contained 2-10% of the activity.

In work done (19) to determine potentially desirable parents for breeding, Lott and Barrett used 39 clones comprised of American

type, French Hydrids and vinifera. They found a significant negative correlation between percent acid and pH, but wide variations in percentage acid among clones with the same pH values, indicating differences among clones in their buffer systems.

In another study, Lott (18) found that titratable acidity decreased during both maturation and storage while pH increased only during maturation, indicating the two measures of acidity were not necessarily negatively correlated. He felt that the lack of correlation was due to a more rapid change in titratable acidity than in the effect of the buffer system.

In a study conducted on grapes grown in Arkansas, Reynolds and Vaile (26) reported a highly significant correlation between titratable acid and pH of fresh grape juice and a higher negative correlation between titratable acid and pH of stored juice. They felt that potassium acid tartrate which could act as a buffer had separated out of the stored juice. While titratable acidity always decreased during storage, changes in pH were in both directions, and no correlation between changes in pH and in titratable acidity were found. Although year to year variation in the composition of the varieties was observed, there was a tendency for cultivars to remain unchanged relative to each other.

Nagel et al. (22) carried out an organoleptic test to determine if pH and total acidity influenced scoring of wines and the perception of quality parameters. They found that lower total acidities were preferred at lower pHs. A pH of 3.3 over a titratable

range of 0.5-0.8% did well in ranking. Titratable acidity 0.9% or more or pH 3.4 or greater generally received poor rankings. Wines of low pH tended to have less body, more fruitiness, and somewhat more acid flavor than wines with high pH.

Sugar content of grapes has been shown to be negatively correlated with acidity (26). In his study with $C^{14}O_2$ (15), Kliewer found glucose to contain from 37 to 52% of the total activity in the sugar fraction of nearly ripe berries. Fructose contained 35-48% of the activity and sucrose considerably less than either fructose or glucose. Winkler et al. (35) reported the actual percentages of the two major sugars in the grape is 8-13% glucose and 7-12% fructose.

Nutrition

Foliar analysis has several advantages over soil analysis as a method of determining plant nutrient needs. By determining nutrients actually contained in the plant, the problems of soil type and nutrient availability are by-passed. Establishment of reference levels and obtainment of samples can be achieved with greater expediency with foliar analysis (9).

As early as 1925, Partridge (24) found a high degree of correlation between vine growth and fruiting the following year. Percentage soluble solids were found to decrease as production increased (25). Therefore, vine growth, fruiting, and fruit quality were shown to be related to one another.

Petiole samples taken by Beattie (3) from 56 vineyards in Ohio showed wide variation in the petiole content of a given element even

though the samples came from vineyards that were similar with respect to yield. Despite this variation, differences in petiole concentration of several elements occurred between vineyards of high, low, and intermediate productivity. Nitrogen and potassium were positively correlated to yields. Magnesium was negatively correlated to yields and no significant differences were found between the three yield levels of vineyards for either phosphorus or calcium. Reductions in average yield were found to be associated with a shift in the K-Mg status of the vines from one of high K-low Mg to low K-high Mg. The author determined critical levels for the five minerals below which economic yields could not be achieved. These were: nitrogen 0.77%, phosphorus 0.14%, calcium 0.70%, magnesium 0.15%, and potassium 2.00%.

In a survey of 'Concord" vineyards conducted in 1952-53, Shaulis and Kimball (27) found that deficiency symptoms occurred in a characteristic and narrow range of values which were not consistently affected by variation in age, vine size, soil texture, soil pH, fertilization, or productivity. The range of the nutrients examined in the vigorous vineyards was: 1.7-2.4% N, 0.4-2.0% K, 0.18-1.5% Mg, 0.10-0.3% P, and 1.0-1.7% Ca. Nitrogen, potassium, and magnesium levels less than 1.5, 0.6, and 0.2% respectively, were considered to be associated with or suggestive of a deficiency. No calcium or phosphorus deficiency symptoms were recognized, nor was there a record of vine response to the addition of either of these two elements.

In a study conducted in Michigan to determine the relationship between the nutritional condition of a 'Concord' vineyard and yield, data on petiole composition was divided into three classes by yield (17). No difference in nitrogen levels was found among the three yield classes. Phosphorus, calcium, and magnesium were discovered to increase as yields decreased. Potassium levels increased as yields increased. The vineyards showed signs of K deficiency and it was felt that the inverse relationship between yield and levels of the other nutrients was a result of K deficiency.

The average composition for the petioles from the highest producing vineyards was determined. The average N content was 0.82%. Nitrogen showed the least variation as indicated by the coefficient of variation. Average values of P, K, Ca, and Mg were 0.20, 2.0, 1.75, and 0.44% respectively. The coefficient of variation for Mg was above 40% and for P and K was above 30%. Ca showed little variation.

In a study of New York vineyards, Boynton (6) found that four varieties showing K deficiencies had leaf K of 0.36%. Analysis of leaves from the vineyard also revealed extremely high Ca and Mg analysis in comparison to normal levels. Ca was a high as 2.71% and Mg as high as 0.75% on Portland vines exhibiting severe deficiencies.

Potassium has been shown to be a limiting nutrient in both New York and California vineyards (27, 33).

In a nutritional survey of 'Concord' grapes in Erie, Pennsylvania, mean K values of vineyards showing K deficiencies was 0.75%

compared to 2.19% from symptomless vineyards. Five vineyards with symptoms of Mg deficiencies had Mg petiole content of 0.01-0.13% whereas average Mg content from vineyards not showing deficiencies was 0.25% (29).

A highly significant negative correlation between Mg petiole content and K was found. Significant positive correlations between N and K were found. Correlations between K, P, and Ca were not significant. No significant correlations were obtained between levels of N, P, Mg, and yield whether yield was expressed as total yield or as cluster size.

In a study of an irrigated vineyard in Washington State, Benson et al. (5) also found no correlation between yield and petiole N. Phosphorus levels were found to be between 0.3% and 0.6%. Values for K ranged from 1.00-6.0%.

Seasonal trends in nutrient levels have been reported by many researchers. Nitrogen, P, and K levels decreased, and Mg and Ca levels increased as the season progressed (1, 9, 29, 32).

The influence of different levels of nutrients on the quality of grape fruits has been examined. Morris and Cawthon (20) showed that K fertilization increased juice pH. Beattie and Baldauf (4) found that acceptable soluble solids content of 'Concord' fruit could be expected when the petiole nitrogen level was within the range of 0.85-1.30%, but that N petiole levels exceeding 1.30% could adversely affect both soluble solids and yields.

Cold Hardiness

Of major concern in the growing of grapes in many regions of the country is the threat of winter damage to the vines. A grape vine may reduce the amount of freezable water before winter as one method of escaping winter damage. This may be done by such protective measures as storing carbohydrates and proteins, translocating and evaporating excess moisture through open stomates, and depositing hydrophobic substances such as suberin and callose in the phellem and phloem to increase resistance against water uptake through root and trunk surfaces. Native grapes are adapted enough to induce these processes at the appropriate time and reach full maturity before winter. Other cultivars, especially late maturing ones, may not be properly stimulated to achieve the same degree of wood maturity (23).

In a winter hardiness project conducted in Ontario, Paroschy et al. (23) discovered that the late maturing 'Gewurztraminer' was unable to maintain its freezeable water below critical levels during thawing periods due to lack of suberin protection in matured wood. The authors felt that in subsequent freezing periods this resulted in ice formation, causing ruptures in cell and vessel phloem walls and in the phellem epidermis. The earlier maturing 'Chardonnay' and the native 'Concord' and 'Riperia' did not exhibit the increased moisture content in the phloem during thawing weather that the 'Gewurztraminer' did. It was thus considered that lack of suberin coincided with fluctuation in the moisture content of the trunk tissues.

In a study in Washington, Clore et al. (8) found vine growth and fruiting ability to be the best indicator of how well varieties survived injury from below zero temperatures. Vines were tested for injury after December 8 and 14 temperatures of -21 and -14°C. All French Hybrid cultivars examined had less than 50% of the primary buds killed. Among those cultivars that had no appreciable winter vine damage were: 'Aurore,' 'Cascade,' 'Chelois,' 'DeChaunac,' 'Foch,' 'Rossette,' and 'Rougeon.' Only 12.5% of the American varieties had 50% or more of the primary buds killed. 'Concord,' 'Delaware,' and 'Van Buran' had no appreciable vine damage. 'Bath' vines had moderate damage.

In keeping with these other studies, Stergios and Howell (30) found that stress that occurred as a result of cultural practices such as defoliation, too little pruning and overcropping also adversely influenced cane and bud hardiness.

In a study of 'Concord' grapes in Michigan, Howell et al. (12) found that of the various yield components examined, treatments which favored good vine size, yield, fruitfulness, and high levels of soluble solids also favored the cold resistance of primary buds. Therefore cultural practices such as retention of leaves until late fall, proper pruning to maintain vine size, and consistent production of ripe fruit also favored cold resistance of the primary bud. Reduction in vine size and yields was related to a reduction in buds retained and bud fruitfulness (12).

Vine characteristics that favor cold hardiness in grapes include small vine size which would allow maximum exposure of leaves

and the absence of many persistent laterals. Each cultivar has a unique genetic constitution which controls growth, productivity, and stress resistance (11).

Vineyard History

A performance trial of grape cultivars has been in progress since 1973 on the Cumberland Plateau of Tennessee (21). Results from the 1975-1977 growing seasons showed 'DeChaunac,' 'Baco Noir,' 'Rosette,' and 'Foch' to be the highest yielding French Hybrid cultivars. The mean yield for the three year period for all eleven cultivars was 5.2 mt/ha. The highest yielding French Hybrid cultivar was 'DeChaunac' with a three year mean of 7.2 mt/ha. Winter injury for most cultivars in 1977 resulted in significantly lower yields for that year. 'DeChaunac,' 'Rosette,' and 'Aurore' exhibited little or no cold injury. 'Vidal 256' and 'Villard Blanc' were damaged the most severely.

Mean soluble solids of the fresh fruit varied widely over the three year period ranging from 15.9 to 19.6%. The mean soluble solids for the three year period was 17.9%. Soluble solids of the frozen samples were somewhat higher. 'Foch' and 'Vidal' had soluble solid levels that were significantly higher than the other cultivars. With the exception of 'Rougeon' all cultivars had soluble solid levels over 18.0%.

Fruit pH of frozen samples ranged from 3.1-3.7. Cultivar and year had no significant effect on the mean pH. The mean acidity of frozen samples over the three year period was 0.84%. 'Baco Noir'

had a significantly higher mean acidity. There was only a slight difference among years for acidity.

'Concord,' 'Alwood,' and 'Moored' were the highest yielding American Bunch cultivars with yields of 11.6, 10.6, and 9.2 mt/ha respectively. Differences in yield were significant among years with lowest yields in 1976 as a result of a spring frost. Thus, winter injury was also a problem with the American Bunch grapes grown on the Plateau.

CHAPTER III

MATERIALS AND METHODS

The grape cultivars evaluated had been planted in the spring of 1973 at The University of Tennessee Plateau Experiment Station and were growing on Hartsells sandy loam soil. Recommended fertilizer and pest control practices were employed.

The majority of the plants were trained to a modification of the four-cane Kniffen system, utilizing two trunks, and were cane pruned yearly. Three French Hybrid cultivars: 'Seyval Blanc,' 'Vidal 256,' and 'Villard Blanc' were spur pruned. All plants were spaced 2.4 x 3.0 meters. A total of ten American Bunch and eleven French Hybrid cultivars were evaluated (Table 1). The two plantings were arranged in randomized complete block designs with three plants per plot and four replications.

Growth Measurements

Measurements of vegetative growth were taken 11-26 June 1979 and 16-19 June 1980. Counts of growing and non-growing buds were made of buds left on the canes after pruning. For the three spur pruned cultivars, a number of spurs were selected and buds along these counted in the same manner. Growth measurements were taken from buds which exhibited shoot growth. The number of clusters per shoot was counted, regardless of whether or not development was proceeding normally. Each plant was rated each year according to

TABLE 1

CULTIVARS OF AMERICAN BUNCH AND FRENCH HYBRID GRAPES
EVALUATED AT THE PLATEAU EXPERIMENT STATION,
CROSSVILLE, TN. 1979-1980

American Bunch Cultivars

Black Fruit Color
- Alwood
- Bath
- Concord
- Fredonia
- Moore's Early
- Van Buren

Red Fruit Color
- Catawba
- Moored
- Yates

White Fruit Color
- Niagara

French Hybrid Cultivars

Black Fruit Color
- Baco Noir
- Cascade
- DeChaunac
- Foch
- Rosette
- Rougeon

White Fruit Color
- Aurore
- GW 7
- Seyval
- Vidal 256
- Villard Blanc

whether the plant was alive or dead and the percentage of dead plants was determined (percentage plant mortality). Each plant was given a rating of 1 if it was alive and a rating of 2 if it was completely dead. Percentage budbreak, total shoot growth per plant, total number of clusters per plant, and severity of winter kill were determined using the various data collected.

The grape cultivars were harvested as determined by sensory perception and soluble solid readings. At harvest the number of clusters per plot and the yield in kilograms per plot were recorded for each cultivar.

Nutrient Analysis

A composite petiole sample from each plot was taken with at least twenty petioles collected from each plant. Sampling was done from July 2 to 6, 1979 and from July 8-9, 1980. The petioles were collected from recently matured leaves on fruiting and non-fruiting shoots exposed to sunlight (7, 14, 32). When growth proved inadequate to obtain samples as described, samples from sucker growth were included.

As soon as possible after collection, samples were rinsed with distilled water and oven dried at 70°C. After grinding with a standard Wiley mill, a 0.2 gram sample of the material was digested overnight with 10 ml of concentrated sulfuric acid and then heated 2.5 hours at greater than 200°C until volume was reduced by approximately half. Each sample was then cooled and 15 ml of hydrogen perioxide added. This mixture was then heated at greater than 200°C

for thirty minutes after clearing of the solution. Distilled water was added to bring the volume to 250 ml (31, 34).

Ammonium nitrogen, phosphorus, and magnesium were determined colorimetrically using a Technicon Auto-analyzer. Calcium and potassium were determined using a Technicon Flame Photometer III Auto-analzyer. Data were expressed on a percentage of dry weight basis.

Fruit Juice Quality

In 1979 a fresh fruit sample was taken from each experimental unit and twenty berries were randomly selected and weighed to determine average berry weight. A 908 gram sample of fruit was selected, washed with distilled water and homogenized in a blender for one minute, strained and a 0.70 ml aliquot filtered through #1 filter paper to separate the juice from the seed and pulp. The percentage soluble solids (ss) of the undiluted juice was taken using a Bausch and Lomb refractometer with a scale of 0-30%. A pH reading of the undiluted filtrate was made using a Corning pH meter Model 5. A ten ml aliquot of the filtrate was then titrated with 0.1 N sodium hydroxide to a pH endpoint of 8.1. Percent acidity was determined by conversion to tartaric acid equivalent.

In 1980, fruit samples were frozen at approximately -18^{o}C for 3-4 months before analysis. A random sample of twenty berries was weighed prior to thawing. Samples were then thawed, rinsed with deionized water and crushed using a hand juicer. This procedure proved adequate for obtaining juice relatively free of seed and pulp, thus no further straining or filtration was done.

Soluble solids were determined using a temperature compensated hand refractometer with a scale of 0-30%. Initial pH and titration readings were obtained with a Fisher Accumet pH meter, Model 620. A six ml aliquot of juice diluted with 10 ml of deionized water was used for pH and titration determinations.

Data Analysis

Analysis of variance was performed on all data. Means were separated by Duncan's Multiple Range test. Certain data were correlated using Pearson Product-Moment correlations.

CHAPTER IV

RESULTS AND DISCUSSION

Since the American Bunch grapes possess quite different characteristics from the French Hybrids of the two types of grapes were analyzed separately. Data for 1979, 1980, and the combined years data are presented for both types. In certain cases there was not a year x cultivar interaction, however, the data for both 1979 and 1980 are included to aid in understanding how seasonal differences in rainfall and temperature may explain differences in performances.

Plant Growth Measurements

Vines of American Bunch cultivars showed relatively vigorous vegetative growth as indicated by total shoot growth (Table 2), a high percentage of spring bud break (Table 3), and a low percentage of plant mortality (Table 4) for both 1979 and 1980. An exception was 'Yates' which exhibited weak vegetative growth (Table 2) as well as a 33% loss of plants the first year of the study and a 50% plant mortality by the second year (Table 4). 'Bath,' 'Alwood,' and 'Van Buren' vines also exhibited relatively weak shoot growth both years (Table 2) and all four cultivars displayed low percentage bud break (80.0% or less) for the two year mean (Table 3). The percentage bud break tended to be somewhat higher for all cultivars during the second year.

'Concord' and 'Moored' exhibited the most vigorous growth, and 'Concord,' 'Moored,' and 'Niagara' the highest percentage bud

TABLE 2

SHOOT GROWTH OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Shoot Growth (m/Plant)[z] 1979	1980	Mean
Black			
Alwood	12.9de[y]	10.6e	11.7d
Bath	13.2de	11.8e	12.5d
Concord	26.8a	28.4a	27.6a
Fredonia	18.9bc	19.0bc	18.9b
Moore's Early	19.4bc	21.4b	20.4b
Van Buren	14.9cde	12.9de	13.9d
Red			
Catawba	17.3bcd	18.3bcd	17.8bc
Moored	20.4b	15.0cde	17.7bc
Yates	11.1e	12.6de	11.7d
White			
Niagara	16.0bcde	14.2cde	15.2cd
Mean	17.1	16.4	16.7

[z]Measured mid-June.

[y]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 3

PERCENTAGE OF PRIMARY BUDS PRODUCING SHOOTS IN 1979 AND 1980 FOR AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN.

Fruit Color / Cultivar	Bud Break (%) 1979	1980	Mean
Black			
Alwood	71.4d[z]	88.7ab	80.0bcd
Bath	76.2bcd	78.0cd	77.1cd
Concord	80.6b	90.4a	85.5a
Fredonia	70.7d	80.8bcd	75.7d
Moore's Early	79.2bc	85.3abc	82.3abc
Van Buren	79.4bc	75.9d	77.6cd
Red			
Catawba	79.0bc	87.4ab	83.2ab
Moored	82.3ab	85.6abc	83.9ab
Yates	72.4cd	90.2ab	80.0bcd
White			
Niagara	87.4a	84.5abc	86.1a
Mean	77.9	84.7	81.1

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 4

PLANT MORTALITY IN 1979 AND 1980 OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN.

Fruit Color / Cultivar	Vine Mortality (%) 1979	1980
Black		
Alwood	0.0n.s.	8.3bc[z]
Bath	0.0	0.0c
Concord	0.0	0.0c
Fredonia	0.0	0.0c
Moore's Early	0.0	0.0c
Van Buren	0.0	0.0c
Red		
Catawba	16.7	16.7bc
Moored	0.0	0.0c
Yates	33.3	50.0a
White		
Niagara	8.3	25.0b
Mean	5.8	10.0

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

break of the American Bunch cultivars in 1979 (Tables 2, 3). 'Concord' performed well in both parameters again in 1980. 'Moored' had somewhat less shoot growth the second year, but was nevertheless above average for the cultivars in both shoot growth and percentage bud break. Although 'Niagara' exhibited a high percentage bud break both years, shoot growth was somewhat below the average of the ten cultivars, and by 1980 plant mortality was 25% (Table 4).

The French Hybrids generally had much less total vegetative growth (9.1 m/plant) than the American Bunch (16.7 m/plant), lower percentage bud break (68.3% versus 81.8%) and higher incidence of plant mortality (36.1% versus 8.0%) (Tables 5, 6, 7).

There were no significant differences in 1979 among the French Hybrid cultivars for either total shoot growth per vine (Table 5) or percentage bud break (Table 6). In 1980 there were significant differences among cultivars for both parameters. Over the two year period 'Rosette' and 'Rougeon' exhibited the most vigorous shoot growth. No differences could be shown among the other cultivars although 'Cascade' and 'DeChaunac' tended to be less vigorous. In general, shoot growth and percentage bud break for the French Hybrids was somewhat higher the second year of the study.

Plant mortality of the French Hybrids was especially high by 1980, with only 'Rosette' and 'Rougeon' escaping any plant loss (Table 7). It is speculated that most of the plant loss was due to a greater susceptibility of the French Hybrids to cold weather damage. Missing data in Table 7 were a result of miscounts in the collection of the data for 1979.

TABLE 5

SHOOT GROWTH OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Shoot Growth (m/Plant) 1979	1980	Mean
Black			
Baco Noir	9.7n.s.	10.4bc[z]	10.1bc
Cascade	7.1	5.4c	6.2c
DeChaunac	5.5	3.9c	5.2c
Foch	8.9	6.4c	8.0c
Rosette	9.2	16.1ab	12.7ab
Rougeon	11.7	18.3a	15.1a
White			
Aurore	9.6	7.8c	8.6c
GW 7	7.8	10.8bc	9.3c
Seyval	5.4	6.4c	6.0c
Vidal 256	6.5	12.0bc	9.7bc
Villard Blanc	6.8	12.1abc	9.0c
Mean	8.0	10.0	9.1

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 6

PERCENTAGE OF PRIMARY BUDS PRODUCING SHOOTS IN 1979 AND 1980 FOR FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN.

Fruit Color / Cultivar	Bud Break (%) 1979	1980	Mean
Black			
Baco Noir	69.7n.s.	79.4abc[z]	73.8ab
Cascade	69.7	69.5bc	69.6bc
DeChaunac	68.2	80.4abc	70.9abc
Foch	65.4	84.4ab	72.5ab
Rosette	71.3	86.8a	79.0a
Rougeon	63.3	71.9bc	67.8bc
White			
Aurore	71.8	78.8abc	75.5ab
GW 7	65.5	71.4bc	68.5bc
Seyval	59.8	65.5cd	63.1cd
Vidal 256	62.2	54.6ed	57.8de
Villard Blanc	54.8	50.5e	53.0e
Mean	65.6	72.1	68.3

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 7

PLANT MORTALITY IN 1979 AND 1980 OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN.

Fruit Color / Cultivar	Vine Mortality (%) 1979	1980	
Black			
Baco Noir	41.7n.s.	58.3ab[z]	
Cascade		25.0bc	
DeChaunac	41.7	83.3a	
Foch	16.7	50.0ab	
Rosette	0.0	0.0c	
Rougeon	0.0	0.0c	
White			
Aurore		25.0bc	
GW 7	25.0	25.0bc	
Seyval		8.3c	
Vidal 256		8.3c	
Villard Blanc	33.3	58.3ab	
Mean	26.4	31.0	36.1

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Yield Measurements

Yields of American Bunch cultivars varied widely. In order of performance, top yields in 1979 were recorded for 'Alwood,' 'Moored,' 'Concord,' 'Niagara,' 'Bath,' and 'Moore's Early.' 'Yates' and 'Van Buren' yielded less than the other cultivars (Table 8). 'Concord' and 'Catawba' yielded highest in 1980 (Table 9). Over the two year period, 'Concord,' 'Alwood,' and 'Moored' were the top yielding cultivars and 'Van Buren' and 'Yates' the lowest yielding cultivars (Table 10).

Since cluster weights for the combined years data were not significantly different, differences in number of clusters per plant probably contributed more to diversity in yields (Table 10). Cluster weight is a product of individual berry weight and number of berries per cluster. Since berry weight varied significantly among cultivars and cluster weight did not, cultivars with small berries apparently compensated by having more berries.

Fewer clusters per plant, smaller clusters, and smaller berries all contributed to the lower yields exhibited by most of the cultivars in the 1980 growing season. 'Catawba' was the only cultivar that showed a marked increase in yield in the second season (Table 9).

The format for the fruit production table for the French Hybrids (Table 11) is different than that for the American Bunch due to missing data. The two years were not combined for the Duncan's Multiple Range test since there were significant year x cultivar interactions for yield and number of clusters. In comparing the means of Table 11

TABLE 8

FRUIT PRODUCTION OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN., 1979

Fruit Color Cultivar	Yield (mt/ha)	Cluster (no/plant)	Cluster Weight (g)	Berry Weight (g)
Black				
Alwood	13.7a[z]	117.8ab	84.8n.s.	3.7b
Bath	9.7ab	75.1bc	205.0	3.0c
Concord	13.2ab	143.3a	68.3	3.5b
Fredonia	8.5bc	93.9abc	66.8	3.8b
Moore's Early	9.6ab	104.3ab	70.0	3.7b
Van Buren	4.2cd	72.6bc	42.5	3.6b
Red				
Catawba	8.4bc	95.5abc	64.5	3.1c
Moored	13.5a	131.3a	78.4	4.3a
Yates	3.5d	50.3c	54.9	3.4bc
White				
Niagara	11.7ab	110.4ab	80.1	3.4bc
Mean	9.6	99.4	81.5	3.6

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 9

FRUIT PRODUCTION OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN., 1980

Fruit Color Cultivar	Yield (mt/ha)	Cluster (no/plant)	Cluster Weight (g)	Berry Weight (g)
Black				
Alwood	7.4bcd[z]	85.7ab	65.4abcde	2.6e
Bath	7.2bcd	68.3bc	75.9abcd	2.6e
Concord	12.7a	116.9a	81.1ab	3.2bc
Fredonia	8.8bc	92.1ab	71.3abcd	3.4bc
Moore's Early	5.1cde	68.3bc	55.8cde	3.9a
Van Buren	4.4de	72.0bc	44.3e	2.7de
Red				
Catawba	9.6ab	91.8ab	78.0abc	2.6e
Moored	8.0bcd	97.8ab	59.7bcde	3.6ab
Yates	2.3e	27.5d	54.1ed	3.1cd
White				
Niagara	6.1bcde	49.6cd	87.4a	3.4bc
Mean	7.2	77.0	67.2	3.1

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 10

FRUIT PRODUCTION OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. 1979-80

Fruit Color Cultivar	Yield (mt/ha)	Cluster (no/plant)	Cluster Weight (g)	Berry Weight (g)
Black				
Alwood	10.5ab[z]	101.8bc	75.1n.s.	3.1e
Bath	8.5bc	71.7d	140.4	2.8e
Concord	12.9a	130.1a	74.7	3.3de
Fredonia	8.7bc	93.0bcd	69.0	3.6bc
Moore's Early	7.3c	86.3bcd	62.9	3.8ab
Van Buren	4.3d	72.3d	43.4	3.1de
Red				
Catawba	9.0bc	93.7bcd	71.2	2.8f
Moored	10.8ab	114.5ab	69.1	4.0a
Yates	2.9d	38.9e	54.5	3.2de
White				
Niagara	8.9bc	80.0cd	83.7	3.4cd
Mean	8.4	88.2	74.4	3.3

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 11

FRUIT PRODUCTION OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. 1979-80

Fruit Color Cultivar	Year	Yield (mt/ha)	Cluster (no/plant)	Cluster Weight (g)
Black				
Baco Noir	1979	4.0defgh[z]	73.8cd	38.9c
	1980	1.9fghi	43.4cdefgh	32.7c
Cascade	1979	6.2cde	133.1b	33.6c
	1980	1.6ghi	55.4cdefgh	25.5c
DeChaunac	1979	1.2hi	29.4defgh	35.4c
	1980	1.2hi	27.9fgh	30.6c
Foch	1979	3.9efghi	73.8cd	38.1c
	1980	1.4ghi	35.8defgh	22.8c
Rosette	1979	8.3bc	165.6b	37.3c
	1980	9.7b	149.8b	47.1c
Rougeon	1979	5.3def	83.3c	47.5c
	1980	15.2a	210.9a	53.8c
White				
Aurore	1979	5.6cde	86.1c	46.3c
	1980	1.2hi	16.8gh	174.4a
GW 7	1979	4.3defg	63.8cdef	50.5c
	1980	1.8ghi	27.1fgh	49.3c
Seyval	1979	4.0defg	38.8defgh	73.9bc
	1980	6.3cde	68.4cde	73.3bc
Vidal 256	1979	7.0bcd	57.4cdefg	79.9bc
	1980	6.3cde	59.1cdef	76.5bc
Villard Blanc	1979	0.7i	5.8h	93.0bc
	1980	4.8defg	21.9fgh	162.0ab
Mean		4.6	69.4	60.1

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

with the combined years data for the American Bunch cultivars (Table 10), it can be seen that the French Hybrid tended to have lower yields, fewer numbers of clusters/plant, and smaller size clusters.

Mean berry size of the French Hybrid cultivars also was generally less than the American Bunch cultivars. Berry size varied greatly among the cultivars. 'Villard Blanc' had the largest berries (2.9 g) (Table 12), nearly as large as the average American Bunch berry (3.3 g) (Table 10). 'Rougeon' (2.5) and 'Gw7' (2.3 g) also had large berries. Most cultivars, i.e., 'Foch' (0.9 g), 'Baco Noir' (1.1 g), 'DeChaunac' (1.4 g), 'Rosette' (1.5 g), 'Aurore' (1.6 g), and 'Cascade' (1.6 g) had berries less than half the average size of the American Bunch. Although berry size for most of the American Bunch and French Hybrid cultivars decreased somewhat the second year, the size of berry of one cultivar in respect to another remained consistent, indicating that comparative size is likely a cultivar characteristic.

The black-fruited 'Rosette' and 'Rougeon,' and the white-fruited 'Vidal 256' and 'Villard Blanc' were the only consistently high yielding cultivars among the French Hybrids (Table 11). 'DeChaunac' performed poorly in both years of the study, although in an earlier three year evaluation in the same location it had been the highest yielding cultivar (21). 'DeChaunac' tends to over-bear, and is cluster thinned as a commercial practice. Failure to control the crop size of this cultivar can eventually result in reduced vigor and winter hardiness (13).

TABLE 12

BERRY WEIGHT OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. 1979 AND 1980

Fruit Color / Cultivar	Berry Weight (g) 1979	1980	Mean
Black			
Baco Noir	1.2f[z]	1.0e	1.1e
Cascade	1.7de	1.5cd	1.6c
DeChaunac	1.6e	1.2de	1.4d
Foch	0.9f	0.9e	0.9e
Rosette	1.6e	1.5cd	1.5cd
Rougeon	2.8b	2.1b	2.5b
White			
Aurore	1.8de	1.5cd	1.6c
GW 7	2.1c	2.5ab	2.3b
Seyval	1.8de	1.7c	1.7c
Vidal 256	1.9d	1.5cd	1.7c
Villard Blanc	3.1a	2.6a	2.9a
Mean	1.9	1.6	1.7

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Yields tended to be lower in 1980 than in 1979, although 'Rosette,' 'Rougeon,' 'Seyval,' and 'Villard Blanc' all had higher yields in 1980 (Table 11). As with the American Bunch grapes, yields tended to be linked more to the number of clusters per plant than to cluster size.

Fruit Quality

The juice soluble solid levels of many of the American Bunch were inadequate in 1979 as determined commercially (29) (Table 13). Only the two red-fruited varieties, 'Catawba' and 'Yates' had sufficiently high soluble solids in 1979, and the mean for all of the American Bunch cultivars was only slightly over 14.0%. Mean soluble solid levels in 1980 were somewhat higher, and almost half of the cultivars had soluble solid over 15%. It is interesting to note that the soluble solid levels of all of the red-fruited cultivars and the white-fruited 'Niagara' were well over 15%, but of the six black-fruited cultivars examined, only 'Bath' had soluble solid levels of 15%. Over the two year period the mean for all of the red-fruited cultivars and for the white 'Niagara' reached 15% soluble solid level, but the mean for none of the black-fruited cultivars was that high.

The pH of grape juice and wine musts tends to range from 2.7-4.0 with the majority of fruits having pH in the 3.4-3.5 range (2, 19). The pH of all of the American Bunch grapes fell within this broader range both years of the study, although pH levels were higher the second year for all cultivars examined (Table 13). This could

TABLE 13

SELECTED QUALITY PARAMETERS OF JUICE FROM AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Soluble Solids (%)			pH			Acidity (%)		
	1979	1980	Mean	1979	1980	Mean	1979	1980	Mean
Black									
Alwood	13.61bc[y]	13.2d	13.4d	3.1cd	3.4bcd	3.2cd	0.9e	0.4de	0.7e
Bath	14.0bc	15.1bc	14.5c	3.2bc	3.2de	3.2cd	1.0de	0.6bc	0.8d
Concord	14.1bc	14.4cd	14.3c	3.0d	3.4bcd	3.2cd	1.6b	0.5cd	0.9c
Fredonia	12.3de	13.0d	12.7d	3.0de	3.4cde	3.2cd	1.6b	0.7b	1.1b
Moore's Early	12.0e	13.4d	12.7d	2.8ef	3.3de	3.1e	1.9a	0.7ab	1.3a
Van Buren	13.3cd	13.3d	13.3d	3.3ab	3.4bcd	3.3bc	1.3c	0.7bc	1.0c
Red									
Catawba	17.3a	16.5a	16.9a	2.7f	3.2e	2.9f	1.6b	0.8a	1.2ab
Moored	14.6b	16.4ab	15.5b	3.2bc	3.6b	3.4b	1.1d	0.4ef	0.7de
Yates	18.0a	17.1a	17.6a	3.4a	3.9a	3.7a	0.6f	0.2f	0.4g
White									
Niagara	13.8b	16.4ab	15.1bc	3.1cd	3.6bc	3.3bc	0.8f	0.4ef	0.6f
Mean	14.3	14.9	14.6	3.1	3.4	3.3	1.2	0.5	0.9

[z]Calculated as percent tartaric acid.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

reflect differences in using fresh versus frozen fruit in the analysis method, differences in instrumentation, or seasonal variation. 'Catawba' had the lowest fruit pH reading both years and 'Yates' and 'Moore's Early' the highest readings.

The percent acidity of grape juice ranges from 0.3-4.8 although few acid levels in mature grapes would approach the higher figure (2, 19). Percent acidity is more indicative of differences in flavor of grape juice than pH since fruits can be buffered against pH changes (18, 19). The American Bunch cultivars were significantly different from one another for pervent acidity in both 1979 and 1980. 'Moore's Early,' 'Fredonia,' and 'Catawba' had relatively high percent acidity in 1979 and again in 1980. 'Moored,' 'Yates,' and 'Niagara' had the lowest levels of any of the cultivars both years.

Though soluble solid contents were similar, 'Yates had only one-third the acid content of 'Catawba' and would therefore taste sweeter. 'Niagara' also had relatively high soluble solids, low acidity.

Percent acidity readings were much lower in 1980, and as was the case with pH, this could reflect a variety of factors. Since soluble solids were higher and acidity lower in 1980, the differences could reflect a greater maturity at harvest in 1980.

Fruit soluble solid readings of the French Hybrids were higher than for the American Bunch. All were above the suggested 15% soluble solid level and in 1979 several cultivars were above 18%. Mean soluble solid levels fell somewhat in 1980 (Table 14).

TABLE 14

SELECTED QUALITY PARAMETERS OF JUICE FROM FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color	Soluble Solids (%)			pH			Acidity (%)[z]		
Cultivar	1979	1980	Mean	1979	1980	Mean	1979	1980	Mean
Black									
Baco Noir	19.3cd[y]	18.7n.s.	19.0abc	3.1cd	3.5e	3.3ef	1.5a	0.8a	1.2a
Cascade	19.3cd	17.7	18.5bcd	3.5a	4.0ab	3.8a	0.6e	0.4c	0.5f
DeChaunac	17.3ef	15.3	16.3e	3.3b	3.9abc	3.6b	0.9d	0.4c	0.7e
Foch	21.7a	18.7	20.2a	3.4ab	4.1a	3.7a	0.9d	0.4c	0.7e
Rosette	18.3de	17.6	17.9cd	2.9e	3.5e	3.2f	1.0cd	0.6b	0.8c
Rougeon	16.2f	18.3	17.2de	3.1cde	3.8cd	3.4ed	1.1c	0.6b	0.8bc
White									
Aurore	16.8f	17.5	17.1de	3.1c	3.8cd	3.4cd	1.3b	0.4c	0.8bc
GW 7	18.4de	17.5	17.9cd	3.3b	3.8cd	3.5bc	0.7e	0.4c	0.5f
Seyval	20.1bc	19.0	19.5ab	3.3b	3.8bc	3.5bc	0.9cd	0.4c	0.7cd
Vidal 256	21.1ab	18.1	19.6ab	3.1cd	3.5de	3.3ef	1.3b	0.6b	0.9b
Villard Blanc	18.4de	17.0	17.7cde	3.0de	3.8bc	3.4ed	1.1c	0.5b	0.8cd
Mean	18.8	17.8	18.3	3.2	3.8	3.5	1.0	0.5	0.8

[z]Calculated as percent tartaric acid.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

For the two year period, 'Seyval' (19.5%) and 'Vidal 256' (19.6%) had the highest soluble solid readings of the white-fruited cultivars. 'Foch' had the highest soluble solid readings of the black-fruited varieties with soluble solid of over 20%. 'DeChaunac' and 'Rougeon' had the lowest soluble solid of the black-fruited varieties both seasons, and 'Aurore' had the lowest of the white-fruited varieties.

Percent acidity and pH were only slightly different from the American Bunch, and pH levels rose and percentage acidity fell the second year of the study. In both years, the fruits of 'Cascade' and 'Foch' showed consistently high pH levels and the fruit of 'Rosette' showed consistently low pH levels relative to the other cultivars.

'Baco Noir' exhibited high levels of fruit acidity both years, followed by 'Vidal 256.' 'Cascade' and 'GW 7' had low levels although variation among cultivars was not as profound in 1980. Although fruit pH and acidity levels varied from one season to the next, they nevertheless seemed to reflect cultivar differences and characteristics.

Nutrient Content

Levels of nutrients in the American Bunch vines, as determined by petiole analysis, generally fell within the range of recommendations by the Cornell Grape Leaf Petiole Test (36). Comparisons of nitrogen levels with others' results was difficult to assess since ammonium nitrogen was determined and values stated in available

literature were based on either nitrate N or total N (Table 15). Nitrogen values generally were slightly less than 1% of dry matter weight for the American Bunch in 1979. 'Concord,' 'Van Buren,' and 'Moore's Early' has the highest N concentrations and 'Alwood' the lowest level of N that year. In 1980, 'Concord,' 'Moore's Early,' 'Van Buren,' and 'Catawba' had the highest and 'Alwood' the lowest N content.

In 1979, none of the petiole samples had phosphorus (P) levels as low as 0.11%, which would indicate a deficiency (36). Most of them had levels approaching the 0.30% level considered high by recommendations from Cornell. In 1980 levels were lower but still sufficient for all cultivars.

Petiole analysis for potassium (K) (Table 16) indicated that there were no deficiencies of that mineral, i.e., < 1.0% (36) for any of the cultivars for either 1979 or 1980. However, there were two-fold differences among the cultivars which could reflect differences in efficiency of absorption of that mineral. 'Van Buren' had K levels that approached the 3.0% level considered excess (36). 'Van Buren' and 'Fredonia' had high levels of K in 1980.

Levels of calcium (Ca) for all cultivars fell below the recommended range of 1.25-1.5% dry weight both years of the study (36). The analysis procedure used had originally been designed for sodium and adapted to calcium. Grape vines were free of Ca deficiency both years of the study and it was therefore considered that the low readings were a result of problems associated with the analysis and did not reflect real deficiencies.

TABLE 15

PETIOLE N AND P CONTENT OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Mineral (% Dry Weight)					
	Nitrogen			Phosphorus		
	1979	1980	Mean	1979	1980	Mean
Black						
Alwood	0.62c[z]	0.58e	0.60d	0.33bc	0.18bc	0.25c
Bath	0.85ab	0.76bcd	0.80bc	0.49a	0.18c	0.34a
Concord	1.00a	0.88ab	0.94a	0.31bc	0.22a	0.26bc
Fredonia	0.83ab	0.72cd	0.77bc	0.31bc	0.23a	0.27bc
Moore's Early	0.99a	0.93a	0.96a	0.30c	0.21abc	0.25c
Van Buren	1.00a	0.94a	0.97a	0.38b	0.23a	0.30ab
Red						
Catawba	____	0.82abc	____	____	0.21abc	____
Moored	0.92ab	0.76bcd	0.84ab	0.35bc	0.20abc	0.28bc
Yates	0.76bc	0.69cde	0.72bcd	0.34bc	0.22ab	0.28bc
White						
Niagara	0.78bc	0.64de	0.71cd	0.38b	0.20abc	0.29bc
Mean	0.86	0.77	0.81	0.35	0.21	0.28

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

TABLE 16

PETIOLE K, Ca, AND Mg CONTENT OF AMERICAN BUNCH GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Mineral (% Dry Weight)								
	Potassium			Calcium			Magnesium		
	1979	1980	Mean	1979	1980	Mean	1979	1980	Mean
Black									
Alwood	1.69c	1.32d	1.50c	0.89ab	0.92ab	0.90ab	0.32n.s.	0.44ab	0.38abc
Bath	1.91c	1.28d	1.59c	0.85bc	0.95a	0.90ab	0.32	0.49a	0.41ab
Concord	2.08c	1.67cd	1.87c	0.79bc	0.76cd	0.78cd	0.32	0.40abc	0.36bc
Fredonia	2.75ab	2.28ab	2.51ab	0.80bc	0.77cd	0.78cd	0.31	0.35bc	0.33c
Moore's Early	1.92c	1.76bcd	1.84c	0.82bc	0.79cd	0.80c	0.34	0.42abc	0.38abc
Van Buren	2.92a	2.44a	2.68a	0.74c	0.70d	0.72d	0.33	0.33c	0.33c
Red									
Catawba		1.69cd			0.80cd			0.42abc	
Moored	1.92c	1.34d	1.63c	0.85bc	0.79cd	0.82c	0.32	0.49a	0.41ab
Yates	2.17bc	2.00abc	2.08bc	0.97a	0.90ab	0.94a	0.32	0.46a	0.39abc
White									
Niagara	1.85c	1.41cd	1.63c	0.87ab	0.83bc	0.85bc	0.39	0.49a	0.44a
Mean	2.13	1.72	1.93	0.84	0.82	0.83	0.33	0.43	0.38

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Magnesium (Mg) levels were acceptable for all cultivars in 1979 and 1980, falling within the sufficient-high range of 0.3-0.5% (36).

Levels of all nutrients except Mg were generally lower in the second year (Tables 15, 16). Phosphorus was still within an acceptable range for all cultivars, and only 'Alwood,' 'Bath,' and 'Moored' had potassium levels low enough to indicate possible deficiencies, although no physical symptoms of K deficiency were detected in any vines. Magnesium content was slightly lower in 1980, and in view of the fact that Mg and K have been found to be significantly negatively correlated, this result would be expected within the decrease in K that occurred the second year (17, 29). Additionally, N, P, and K levels have been shown to decrease, and Mg and Ca levels to increase as the season progressed (1). Therefore differences in the nutritional data for the two years could be the result of differences in sampling procedure since samples were collected one week later the second year. Differences in climate could have resulted in even more discrepancy in vine maturity between the two seasons. Temperatures were higher and precipitation lower in May-July of 1980 versus 1979 (Tables A-1, A-2) possibly resulting in even more advanced vine maturity when samples were collected in 1980.

The French Hybrid cultivars varied significantly from one another in N content in both 1979 and 1980. 'Seyval,' 'Vidal 256,' and 'Villard Blanc' had the highest petiole N content and 'Rosette' the lowest N levels in 1979 (Table 17). Nitrogen content for all cultivars was considerably less in 1980 with cultivars averaging

TABLE 17

PETIOLE N AND P CONTENT OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color	Mineral (% Dry Weight)					
	Nitrogen			Phosphorus		
Cultivar	1979	1980	Mean	1979	1980	Mean
Black						
Baco Noir	1.15ab[z]			0.38ab		
Cascade	1.17ab	0.83bc	1.00ab	0.41a	0.19abc	0.30a
DeChaunac	1.22ab	1.02a	1.12a	0.33abc	0.21ab	0.27abc
Foch	1.20ab	0.87b	1.03ab	0.34ab	0.17c	0.25abcd
Rosette	0.79d	0.53e	0.66d	0.34ab	0.16c	0.25bcd
Rougeon	1.07bc	0.57de	0.82c	0.36ab	0.21ab	0.28abc
White						
Aurore	0.93cd	0.48e	0.71d	0.25c	0.18bc	0.22d
GW 7	1.26ab	0.69cd	0.97b	0.34ab	0.18bc	0.26abcd
Seyval	1.31a	0.71cd	1.11ab	0.31bc	0.17c	0.24bcd
Vidal 256	1.31a	0.68cd	0.99b	0.36ab	0.20abc	0.28abc
Villard Blanc	1.31a	0.78bc	0.96b	0.37ab	0.23a	0.30ab
Mean	1.16	0.72	0.94	0.35	0.19	0.26

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

16-49% less than in 1979. Seven of the ten cultivars had N levels less than the levels considered low-sufficient (0.8-1.0) (36). 'DeChaunac' had the highest N content in 1980, and 'Aurore' the lowest. 'Cascade,' 'Foch,' and 'Seyval' had the highest N concentration for the two year mean.

Petiole phosphorus levels tended to be greater in 1979 than the 0.30% level considered high by recommendation (36). 'Cascade' exhibited particularly high levels of phosphorus (0.41%). Only 'Aurore,' with a P concentration of 0.25%, fell within the sufficient-high range. Petiole P content was less in 1980. Several cultivars showed decreases of 50% or more, with concentrations in the low-mid range of sufficiency level.

The 1979 potassium concentration was relatively high in many of the cultivars with most falling within the high-excess range of 2.0-3.0% (36). 'Villard Blanc' (3.76%) and 'Baco Noir' (3.0%) had levels above excess, although these did not vary significantly from cultivars with levels slightly lower (Table 18). Potassium in 1980 declined from the high-excess levels of 1979 to levels falling mostly within the sufficient-high range. 'Rosette' had K levels (1.23%) that were within the low-sufficient range in 1980. 'Villard Blanc' accumulated significantly higher concentrations of K in the petioles compared to all French Hybrid cultivars in both 1979 and 1980.

The 1979 concentrations of Ca were within the low-sufficient range with the exception of 'Aurore' and 'Villard Blanc' which had levels below the low-sufficient range (1.00-2.50%) (36). Calcium

TABLE 18

PETIOLE K, Ca AND Mg CONTENT OF FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. IN 1979 AND 1980

Fruit Color / Cultivar	Mineral (% Dry Weight)								
	Potassium			Calcium			Magnesium		
	1979	1980	Mean	1979	1980	Mean	1979	1980	Mean
Black									
Baco Noir	3.01ab[z]			1.30a			0.33n.s.		
Cascade	2.24bc	1.58b	1.91bc	1.15bc	0.94bc	1.04ab	0.36	0.48ab	0.42n.s.
DeChaunac	2.88ab	2.25ab	2.56b	1.15bc	1.08a	1.11a	0.32	0.53a	0.43
Foch	2.75abc	1.88b	2.31bc	1.07bc	0.98ab	1.03abc	0.33	0.39abc	0.36
Rosette	1.74c	1.23b	1.48c	1.17b	0.91bc	1.04ab	0.31	0.46abc	0.39
Rougeon	2.68bc	2.30ab	2.49b	1.03bc	0.82cd	0.92de	0.33	0.36bc	0.34
White									
Aurore	2.10bc	1.53b	1.81bc	0.79d	0.76d	0.78f	0.33	0.46abc	0.40
GW 7	2.63bc	1.68b	2.15bc	1.02c	0.85cd	0.94cd	0.33	0.46abc	0.39
Seyval	2.93ab	1.64b	2.28bc	1.10bc	0.94bc	1.02abcd	0.33	0.53a	0.43
Vidal 256	2.77abc	1.78b	2.28bc	1.06bc	0.93bc	0.99bcd	0.32	0.44abc	0.38
Villard Blanc	3.76a	3.23a	3.49a	0.85d	0.83cd	0.84ef	0.34	0.33c	0.34
Mean	2.68	1.91	2.28	1.06	0.90	0.97	0.33	0.44	0.39

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

levels were deficient in most cultivars in 1980. Only 'DeChaunac' (1.08%) had Ca concentrations above the low range.

No differences were found among cultivars for Mg in 1979. The petiole content of this nutrient was in sufficiency range for all cultivars. In 1980 there were significant differences among the cultivars in Mg content. 'DeChaunac' (0.53%) and 'Seyval' (0.53%) had the highest Mg content, and 'Villard Blanc' (0.33%) the lowest, although levels for all cultivars fell within the sufficient-high range (36).

Mean N, K, and Ca nutrient concentrations for the French Hybrids were higher than for the American Bunch (Tables 15, 16, 17, 18). Mean P and Mg levels were approximately the same. The seasonal trends in nutrient levels exhibited by the French Hybrids were similar to those exhibited by the American Bunch. It was therefore felt that these trends also possibly represented differences in vine maturity at time of sampling.

Correlations

Petiole content of N, P, and K were correlated with vine growth, yield, juice soluble solids, and percentage acidity for both the French Hybrid and American Bunch grapes (combined years data) (Table 19). Shoot growth correlated positively with petiole N ($r=.55$) for the American Bunch grapes as was expected. It was also shown that high levels of N, P, and K were significantly correlated with high levels of fruit acidity ($r=+.68, .58, .49$ respectively).

TABLE 19

COEFFICIENTS OF CORRELATION (r) OF VINE GROWTH, YIELD, AND JUICE SOLUBLE SOLIDS AND ACIDITY WITH PETIOLE N, P AND K OF AMERICAN BUNCH GRAPES AND FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN. 1979-80

Grape Type / Growth Parameter	Mineral Composition (% Dry Weight) N	P	K
American Bunch			
Shoot Growth	.55*	-.03	.12
Yield	.10	.28	-.23
Soluable Solids	-.21	-.18	-.33
% Acidity	.68***	.50*	.49*
French Hybrid			
Shoot Growth	-.56**	-.25	-.19
Yield	-.21	.03	-.23
Soluable Solids	.40	.37	.21
% Acidity	.59**	.71***	.54**

*Significant at 5% level.

**Significant at 1% level.

***Significant at 0.1% level.

For the French Hybrids an unexpected negative correlation between shoot growth and nitrogen level was found. A significant positive correlation between percent acidity and percentage N, P, and K was shown (r=+.59, .71, .49 respectively). Thus, N, P, and K seemed to be related to fruit acidity to a greater degree than soluble solids.

Shoot growth measurements, yield, and petiole N concentrations from 1979 were correlated with plant mortality and budbreak percentages of 1980 to determine if these factors were related to cold hardiness (Table 20). There were no significant correlations found among the parameters for the American Bunch grapes. For the French Hybrid, 1979 yield was found to be significantly negatively correlated with plant mortality. Low yield and high percentage plant mortality apparently reflect the poorer acclimation of the French Hybrids to the severe climate of the Plateau.

Climate

It is helpful in the discussion of the seasonal effects of rainfall and temperature to examine the climatological data for the two growing seasons (Tables A-1, A-2). The 16-month period from budbreak to the following years harvest was included because buds and carbohydrate and nutrient reserves for the following season are being formed during the prior season's growth.

Although the respective seasonal means for the two growing seasons were similar (13.9^{o}C in 1978-79 and 14.1^{o}C in 1979-80), the average maximum and minimum temperatures showed greater fluctuation

TABLE 20

COEFFICIENTS OF CORRELATION (r) OF 1979 INDICES OF VINE VIGOR WITH 1980 INDICES OF PLANT HARDINESS OF AMERICAN BUNCH AND FRENCH HYBRID GRAPES GROWN ON THE CUMBERLAND PLATEAU AT CROSSVILLE, TN.

Grape Type	Vine Hardiness Indices (1980)	
Vine Vigor Indices (1979)	Plant Mortality (%)	Bud Break (%)
American Bunch		
Shoot Growth	-.52	.23
Yield	-.44	.33
% Nitrogen	-.42	-.21
French Hybrid		
Shoot Growth	-.29	.44
Yield	-.66*	-.13
% Nitrogen	.26	-.49

*Significant at 5% level.

in the 1979-80 growing season. Mean maximum temperature was 17.1°C in 1978-79 and 20.5°C in 1979-80. Mean minimum temperature was 7.8°C in 1978-79 and 7.7°C in 1979-80. Both seasons showed total average temperatures that were cooler than normal.

The 1978-79 climatological data indicated a warming trend in March followed by colder weather in April and May that could have resulted in the lower percentage bud break that occurred in 1979. Temperatures remained cool throughout early spring 1980, so buds were less likely to have lost hardiness early.

The 1979 June-September ripening period was relatively mild. Maximum temperatures never reached above 32°C and rainfall for the period was above average. The 1980 summer season had 44 days with maximum temperatures above 32°C in addition to a rainfall deficit of almost 25.4 cm below normal for the period. It was felt that the stress of the relatively high temperatures combined with low precipitation partially accounted for the reduced yields and lower nutrient levels encountered in 1980.

The months of December-February 1979-80 had 74 days with minimum temperatures of 0°C or below and a precipitation deficit of 16.3 cm from normal for the period. In 1978-79 for the three month period there were 80 days with minimum daily temperatures of 0°C or less, plus eight days with minimum daily temperatures less than -18°C. However, there was a departure from normal precipitation of +12.4 cm for the period. It is probable that the dessicating effect of limited precipitation contributed to the higher percentage plant mortality that occurred in 1980.

CHAPTER V

SUMMARY AND CONCLUSION

Field tests were conducted at The University of Tennessee Plateau Experiment Station, Crossville, TN, to evaluate ten American Bunch and eleven French Hybrid cultivars and to assess their potential for commercial production of quality fruits.

The American Bunch cultivars tended to have greater vegetative growth, higher percentage budbreak, and a lower incidence of plant mortality than the French Hybrid cultivars, indicating a greater overall hardiness for the American Bunch cultivars. Probably as a result of the less vigorous growth and higher plant mortality from winter damage, the French Hybrid cultivars also produced lower yields than the American Bunch cultivars.

Fruit quality in terms of relative amounts of soluble solids and titratible acidity was better for the French Hybrid grapes. They had higher soluble solid content than the American Bunch graps, but similar acidity. The higher soluble solids content of the French Hybrid fruit was possibly a combined result of the lighter cropping and of more advanced fruit maturity at harvest.

The second year of the study the American Bunch showed signs of increased environmental stress as exhibited by increased plant mortality, less shoot growth, decreased nutrient levels, and lower yields as a result of fewer and smaller clusters per plant and decreased berry size. Percentage budbreak was the only growth

parameter to be larger in the second year. Soluble solids were higher and the titratible acidity was lower, perhaps as a result of the influence of lower cropload on fruit maturity.

The French Hybrid cultivars showed increased plant mortality, lower yields, decreased nutrient levels, and higher percentage budbreak in 1980 than 1979.

The 1979-80 growing season showed a greater fluctuation in temperature than the 1978-79 season. The 1980 summer was hot with a precipitation deficit of 25.4 cm. It was felt that the combination of these factors resulted in the lower yields and decreased nutrient levels found that year.

Percentage budbreak may have been lower in 1979 as a result of an early warming trend followed by frost.

When yield and quality are both considered, vines of 'Concord,' 'Moored,' and 'Niagara' performed best among the American Bunch cultivars. 'Concord' and 'Moored' exhibited high percenage budbreak, high N levels, and the fruit contained moderate levels of soluble solids and moderate-to-low levels of acids. 'Niagara' showed similar patterns, but with higher fruit soluble solid and lower vine N levels.

'Rosette' and 'Rougeon' showed the most vigor of the French Hybrid but both cultivars had fruits low in sugar and acids. The white-fruited French Hybrid cultivars, 'Seyval' and 'Vidal 256' showed only a slight loss to winter damage and had moderate yields. The fruits of both cultivars had high percentage soluble solids and

moderate-to-high acid levels. The two cultivars, therefore, exhibited potentially high quality fruits and, despite some reduction in yield potential, are worthy of commercial consideration.

LITERATURE CITED

LITERATURE CITED

1. Abdalla, D. A., and H. J. Sefick. 1965. Influence of nitrogen, phosphorus and potassium levels on yield, petiole nutrient composition and juice quality of newly established 'Concord' grapes in South Carolina. Proc. Amer. Soc. Hort. Sci. 87: 253-258.

2. Amerine, M. A., and A. J. Winkler. 1942. Maturity studies with California grapes. II. The titratable acidity, pH and organic acid content. Proc. Amer. Soc. Hort. Sci. 40: 313-323.

3. Beattie, J. M. 1954. A survey of the nutrient element status of 'Concord' grapes in Ohio. Proc. Amer. Soc. Hort. Sci. 64: 21-28.

4. Beattie, J. M., and M. P. Bauldauf. 1960. The effect of soil management system and differential nitrogen fertilization on yield and on the quality of 'Concord' grape juice. Ohio Agri. Expt. Sta. Res. Bul. 868.

5. Benson, N. R., R. M. Bullock, and I. C. Chmelir. 1956. Response of 'Concord' grapes to cultural treatments and fertilizers. Proc. Amer. Soc. Hort. Sci. 69: 235-239.

6. Boynton, D. 1946. Potassium deficiency in a New York grape vineyard. Proc. Amer. Soc. Hort. Sci. 46: 246-248.

7. Bryant, L. R., W. J. Clore and C. G. Woodbridge. 1958. Factors affecting yields of 'Concord' grapes and petiole composition in some vineyards in the Yakima Valley. Proc. Amer. Soc. Hort. Sci. 73: 151-155.

8. Clore, W. J., M. A. Wallace and R. D. Fay. 1974. Bud survival of grape varieties at sub-zero temperatures in Washington. Amer. J. Enol. Vitic. 25(1): 24-29.

9. Cook, J. A., and T. Kishaba. 1956. Petiole nitrate analysis as a criterion of nitrogen needs in California vineyards. Proc. Amer. Soc. Hort. Sci. 68: 131-140.

10. Gloor, R. L. 1981. A Guide to American and French Hybrid Grape Varieties. Foster Nursery Co., Inc., Fredonia, NY.

11. Howell, G. S. 1980. Cold climate cultural practices. Vinif. Wine Growers J. 7(4): 239-240.

12. Howell, G. S., B. G. Stergios and S. S. Stackhouse. 1978. Interrelation of productivity and cold hardiness of 'Concord' grapevines. Amer. J. Enol. Vitic. 29(3): 187-191.

13. Jordan, T. D., R. M. Pool, T. J. Zabadal and J. P. Tomkins. 1981. Cultural practices for commercial vineyards. Cornell Ext. Bul. 111.

14. Kenworthy, A. L. 1964. Fruit, nut, and plantation crops, deciduous and evergreen. A guide for collecting foliar samples for nutrient element analysis. Hort. Dept., Michigan State Univ., East Lansing, Michigan.

15. Kliewer, W. M. 1964. Influence of environment on metabolism of organic acids and carbohydrates in Vitis vinifera. II. Temperature. Plant Phys. 39(6): 869-879.

16. Larson, R. P., A. L. Kenworthy, H. K. Bell, E. J. Benne and S. T. Bass. 1959. Effect of nitrogen, phosphorus, potassium and magnesium fertilizers on yield and petiole nutrient content of a 'Concord' grape vineyard. Michigan Quart. Bul. 41(4): 812-819.

17. Larson, R. P., A. L. Kenworthy, H. K. Bell, S. T. Bass and E. J. Benne. 1955. Nutritional conditions of 'Concord' vineyards in Michigan. I. Nutrient element content of petioles in relation to production. Michigan Quart. Bul. 39(1): 63-70.

18. Lott, R. V. 1967. Changes in the composition of 'Concord' grapes during maturation and ripening. Hort. Res. 7: 126-134.

19. Lott, R. V., and H. C. Barrett. 1967. The dextrose, levulose, sucrose and acid content of the juice from 39 grape clones. Vitis. 6: 257-268.

20. Morris, J. R., and D. L. Cawthon. 1982. Effect of irrigation, fruit load and potassium fertilization on yield, quality and petiole analysis of 'Concord' (Vitis labrusca L.) grapes. Amer. J. Enol. Vitic. 33(3): 145-148.

21. Mullins, C. A., D. W. Lockwood, D. L. Coffey and J. L. Collins. 1979. Evaluation of grape cultivars in Tennessee. Tennessee Agri. Expt. Sta. Bul. 586.

22. Nagel, C. W., J. L. Amistoso and R. B. Bendel. 1982. The effect of pH and titratable acidity on the quality of dry white wines. Amer. J. Enol. and Vitic. 33(2): 75-79.

23. Paroschy, J. H., A. G. Meiering, R. L. Peterson, G. Hostetter and A. Neff. 1980. Mechanical winter injury in grapevine trunks. Amer. J. Enol. Vitic. 31(3): 227-232.

24. Partridge, N. L. 1925. Growth and yield of 'Concord' grape vines. Proc. Amer. Soc. Hort. Sci. 22: 84-87.

25. Partridge, N. L. 1931. The effect of fruit production and fertilizer treatments on the maturity of 'Concord' grapes. Proc. Amer. Soc. Hort. Sci. 28: 147-150.

26. Reynolds, H., and J. E. Vaile. 1942. Chemical composition of Arkansas grown American grapes. Arkansas Exp. Sta. Bul. 420.

27. Shaulis, N., and K. Kimball. 1956. The association of nutrient composition of 'Concord' grape petioles with deficiency symptoms, growth and yield. Proc. Amer. Soc. Hort. Sci. 68: 141-156.

28. Shoemaker, J. S. 1978. Small Fruit Culture. Avi Publishing Co., Inc., Westport, CT.

29. Smith, C. B., H. K. Fleming and H. P. Poorbaugh. 1957. The nutritional status of 'Concord' grape vines in Erie County, Pennsylvania as indicated by petiole and soil analysis. Proc. Amer. Soc. Hort. Sci. 70: 189-196.

30. Stergios, B. G., and G. S. Howell. 1977. Effects of defoliation, trellis height and cropping stress on the cold hardiness of 'Concord' grapevines. Amer. J. Enol. Vitic. 28(I): 34-41.

31. Thomas, R. L., R. W. Sheard, and J. R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus, and potassium analysis of plant material using a single digestion. Agron. J. 59: 240-243.

32. Ulrich, A. 1942. Nitrate content of grape leaf petioles as an indicator of the nitrogen status of the plant. Proc. Amer. Soc. Hort. Sci. 41: 213-218.

33. Ulrich, A. 1942. Potassium content of grape leaf petioles and blades contrasted with soil analysis as an indicator of the potassium status of the plant. Proc. Amer. Soc. Hort. Sci. 41: 204-212.

34. Van Slyke, D. D., and A. Hiller. 1933. Determination of ammonia in blood. J. Biol. Chem. 102: 499-504.

35. Winkler, A. J., J. A. Cook, W. M. Kliewer and L. A. Lider. 1974. General Viticulture. University of California Press, Berkeley and Los Angeles.

36. Zabadal, T. J. 1979. Grape petiole analysis. Best way to determine vine nutrition. Vinif. Wine Growers J. 6(1): 23-26.

APPENDIX

TABLE A-1

MONTHLY TEMPERATURE AND PRECIPITATION FOR JUNE 1978-SEPTEMBER 1979 AT THE PLATEAU EXPERIMENT STATION, CROSSVILLE, TN.

	Daily Temperature (°C)				# Days				Precipitation (cm)	
Month	Max.	Min.	Mean	Departure from Norm.	Max. Temp. =>32°	Min. Temp. =<0°	Min. Temp. =<-18°		Total	Departure from Norm.
June	27.0	14.6	20.9	-0.2	3	0	0	0	18.3	+7.0
July	28.7	16.9	22.8	+0.1	0	0	0	0	16.6	+3.6
August	28.1	16.7	22.4	+0.1	0	0	0	0	13.6	+3.3
September	26.6	14.1	20.4	+1.2	0	0	0	0	2.9	-7.2
October	19.5	3.9	11.7	-1.6	0	0	5	0	3.9	-3.0
November	16.3	4.6	10.5	+3.4	0	0	5	0	14.0	-2.9
December	9.2	-4.4	2.4	+0.2	0	2	26	0	20.5	+6.2
January	2.4	-9.1	-3.3	-4.6	0	12	30	6	23.3	+9.0
February	4.7	-7.2	-1.2	-3.6	0	8	24	2	11.1	-2.9
March	13.6	1.4	7.5	+0.8	0	1	15	0	11.7	-3.7
April	18.2	6.1	12.2	-0.7	0	0	3	0	15.3	+2.4
May	22.1	10.0	16.1	-1.3	0	0	1	0	19.2	+8.6
June	25.9	13.5	19.7	-1.4	0	0	0	0	7.7	-3.7
July	25.7	16.7	21.2	-1.5	0	0	0	0	24.0	+11.0
August	27.7	14.7	21.2	-1.0	0	0	0	0	6.5	-3.8
September	24.0	12.0	18.0	-1.2	0	0	0	0	16.0	+5.8
Season Mean	17.1	7.8	13.9						14.0	
Season Total				-11.4	3	23	109	8		+35.4

Source: Climatological Data, Tennessee, Volume 83-84, 1978-79. National Oceanic and Atmospheric Administration Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina.

TABLE A-2

MONTHLY TEMPERATURE AND PRECIPITATION FOR JUNE 1979-SEPTEMBER 1980 AT THE PLATEAU EXPERIMENT STATION, CROSSVILLE, TN.

	Daily Temperature (°C)				# Days				Precipitation (cm)	
Month	Max.	Min.	Mean	Departure from Norm.	Max. Temp. =>32°	Min. Temp. =<0°	Min. Temp. =<0°	Min. Temp. =<-18°	Total	Departure from Norm.
June	25.9	13.5	19.7	-1.4	0	0	0	0	7.7	-3.7
July	25.7	16.7	21.2	-1.5	0	0	0	0	24.0	+11.1
August	27.7	14.7	21.2	-1.1	0	0	0	0	6.6	-3.8
September	24.0	12.0	18.0	-1.2	0	0	0	0	16.0	+5.8
October	18.6	4.5	11.6	-1.8	0	0	6	0	9.6	+2.6
November	13.5	1.2	7.4	+0.4	0	1	14	0	12.3	+1.2
December	9.1	-3.5	2.8	+0.6	0	2	24	0	8.5	-5.7
January	6.8	-3.6	1.7	+0.3	0	4	26	0	13.3	-0.9
February	4.9	-8.1	-1.6	-3.9	0	11	24	0	4.4	-9.6
March	11.0	-1.8	4.6	-2.1	0	2	20	1	29.5	+14.1
April	17.8	4.7	11.3	-1.5	0	0	5	0	9.88	-3.0
May	22.8	10.9	16.8	-0.5	0	0	0	0	11.2	+0.6
June	27.1	14.1	20.6	-0.4	2	0	0	0	2.9	-8.5
July	32.3	17.5	24.9	+2.1	19	0	0	0	7.5	-5.5
August	31.6	16.6	24.1	+1.8	14	0	0	0	6.8	-3.6
September	28.4	13.6	21.0	+1.7	9	0	0	0	2.3	-7.8
Season Mean	20.5	7.7	14.1						10.8	
Season Total				-8.5	44	20	119	1		-16.7

Source: Climatological Data, Tennessee, Volume 84-85, 1979-80. National Oceanic and Atmospheric Administration Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina.

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