SOME FIELD EXPERIMENTS WITH CONCORD GRAPES

by

THEODORE CHRISTIAN STEBBINS

B. S., Kansas State Teachers College, Emporia, 1934;
B. S., Kansas State College
of Agriculture and Applied Science, 1936

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

KANSAS STATE COLLEGE

OF AGRICULTURE AND APPLIED SCIENCE

1937

TABLE OF CONTENTS

INTRODUCTION

The work described in this thesis is some field experiments with the Concord grape, the most extensively grown American variety throughout the grape regions of the United States.

A part of this work was a study of the effects of severity of pruning on the vigor and vegetative character of Concord vines. Although grape pruning is one of the oldest practices in fruit growing, the various methods of pruning American grapes have been developed in the last seventy-five years, for it was only after the failure of repeated attempts to grow European grapes in America that the native species were domesticated.

The grape vine since has been subjected to many methods of pruning and training by growers and investigators, to all of which it has adapted itself readily, giving constant and definite responses. In contrast to most other fruit plants, the grape soon outgrows mistakes and apparently is not easily unbalanced by considerable variation in severity of pruning. However, it is reasonable to suppose that by comparing results of several modifications, certain of these practices will be found to yield better results than others. This study includes the effect of severity of pruning on the amount of wood produced, the number of leaves to the vine, to the shoot, and to the bunch of fruit, and the effect on the size of fruit.

Location, previous weather conditions, the character of the soil, and individuality of the vines as well as many other factors, all influence the severity of pruning that will give the best results in a given vineyard. If the grower is to determine the most economical and profitable degree of pruning to practice, he must be able to recognize the responses that a grape vine makes to different treatments. He should be able to interpret the condition of a healthy vine by observing its previous season's growth and fruiting activities, if the season were normal. It is hoped that this piece of work may aid in determining the optimum number of buds to be left on the vines at pruning time to obtain the greatest yield of fruit and at the same time maintain the maximum vigor and best growth of vines from year to year.

The Concord grape possesses many qualities that make it superior to other good varieties for Kansas but it is not entirely free from undesirable features. Its outstanding fault is the uneven ripening of the fruit. This effect is present even when conditions are favorable for growth and maturity of fruit and becomes more serious during seasons of drouth and intense heat. In such abnormal seasons as that of 1934, the fruit remains green, except for individual berries on some bunches, long after the middle of August when they normally would have reached maturity. Apparently the conditions accompanying the drouth in some way hinder the metabolism of the vine and thereby delay the maturity of the fruit.

An attempt was made to determine the type and extent of injury wrought by these two conditions and to subject the vines to various methods of treatment in an effort to determine which of these two factors causes the greater injury to the vines. It may be impossible to find a practical remedy for this abnormality, but the presence of such conditions provides a good opportunity for study and observation which may lead to the discovery of the cause or causes of such abnormal behavior.

REVIEW OF LITERATURE

Although the uneven ripening of the Concord grape in the general area surrounding Kansas is very pronounced and undesirable under conditions of drouth and extreme heat, practically nothing has been done by investigators to discover the exact cause of this condition. Cross and Webster (3), however, have approached the problem from two angles: one a study of the environmental and the other of the chemical factors which might be responsible for this uneven ripening. In the environmental studies, they varied the daily period of illumination, reduced the intensity of the sunlight by partially shading with cheese cloth, changed the quality of light with nitro-cellulose glass, cooled the atmosphere and raised the relative humidity, practiced irrigation, and varied the amount of fruit and foliage on several canes. A comparison of their results indicates that all treatments which extended, protected, or conserved the leaf area per cluster of fruit gave the highest percentage of ripe fruit, while reducing the leaf area had the opposite effect. Under treatments which conserved foliage by protecting it from the hot sun and low humidity, the percentage of ripe fruit was greater than that borne by untreated plants.

Similar studies were begun by Meyer (4) during the extreme heat and drouth of 1934. His four methods of treatment included the application of 200 gallons of water to each vine once a week, the use of lath half-shades to reduce the intensity of sunlight, and the use of both shade and water. Serious leaf injury had already taken place on all vines before those treatments were started, and it continued to increase rapidly on the untreated vines and only slightly slower on the shaded vines. Leaf injury continued to increase on the watered vines but new growth replaced them with new leaves. The rate of injury to the leaves on the shaded-and-watered vines was slightly reduced by shading, and the new growth increased the final leaf area.

From this preliminary work, Meyer (4) stated that "in spite of high temperatures Concord grapes can be matured satisfactorily by supplying the vines with an adequate amount of water," and that "shading had almost no beneficial effect".

Although pruning of the Concord vine by growers is now done almost by formula, considerable experimental work is being done by various investigators to discover the effects of modifying these few well-established methods. According to Partridge (8), the Concord vine is able to protect itself against improper pruning better than almost any other variety and is therefore the favorite among most workers. The four-cane Kniffin system of training is favored as a foundation on which to practice these variations. Partridge (8) also found that a vine pruned to approximately the same number of buds every season will usually adapt itself to most types of pruning, but the quality of bunches may be poor. If too many buds are left after the first overproduction, the vine growth will be weak and the clusters and berries will be small; however, the yield will be nearly as large as that from a well-pruned vine. If too few buds are retained, shoot growth becomes more vigorous and finally may become so strong that fruit production is prevented.

The number of shoots that grow in one season are limited in proportion to the number of buds left at pruning time. However, the total vegetative growth of the vines was found by Colby and Tucker (2) to remain about constant even though the type of growth varies. On more severely pruned vines, there are fewer but longer shoots than on less severely pruned vines.

Finding the desirable number of buds to each vine may be difficult in practice for that number may be influenced by several factors. Partridge (5) found the length of canes left at pruning time may be increased as the soil becomes heavier. He states further that the optimum number of buds varies with different vineyards and from year to year in the same vineyard. He found 32 buds on each vine to be optimum in sandy soils of Michigan. On medium loam soil 36 buds were best. He found no optimum number for vigorous vines in heavy clay soils. To know that such optima exist and to know the approximate numbers should be of value in pruning and training to meet local conditions.

In similar work, Partridge (7) found growth and yield to be inter-related. The crop borne by a vine depends on the vigor of its growth the previous season. In general, the greater the cane growth, the larger the yield the following year; and the larger the crop, the smaller the cane growth that season. From another investigation, Partridge (8) found the weight of one and two year old wood pruned from a vine to be a fairly accurate measure of its vigor. In Michigan, 30 buds left for each pound of wood removed were found optimum. For each additional pound, eight more buds should be left.

Although there is some disagreement concerning the relationship between the size of canes and their fruitfulness, most investigators agree that growers should select canes thought to be the most productive and treat the vines according to their individual needs. There are both experimental proof and general agreement among growers that canes of medium length and diameter are the most fruitful. Partridge (5, 7, 8) and Schrader (9) agree that canes of "pencil size" are the most fruitful. Vines with an original length of four or five feet are more desirable according to Schrader (9) than shorter or longer canes. The length of internodes is also an index to the fruiting capacity of canes, according to Clark (1) and Partridge (6). The latter states that canes with five to eight inches between the fifth and sixth nodes are more productive than those with shorter or longer internodes.

Partridge (8) found that pruning has a greater influence on cane size than any other vineyard operation, and that the number of bunches is probably more closely correlated with the characteristics of the cane than those of the shoot. The size of the blossom cluster, however, is more closely associated with shoot characteristics, as found by Partridge (7). According to Colby and Tucker (2), the shoot vigor of strong canes, like their productiveness, tends to increase with the buds farther from the base at least to the sixteenth node. This probably explains the correlation between shoot growth and production.

The chief advantages of producing a crop on medium-size wood, as found by Partridge (8), are the use of a minimum amount of wood and thus the simplification of spraying, tying, picking, and pruning, and the production of larger and higher quality bunches. Clark (1) also favors the use of medium size canes even when the severity of pruning is varied considerably. He states further that the type of cane most productive in a heavy crop year is also most productive in a light crop year.

Although pruning of the grape vine is so done that subsequent thinning of the fruit usually is considered unnecessary as contrasted to the condition found with some tree fruits, considerable work in thinning has been done with various objects in mind.

Schrader (10, 11) practiced various degrees of thinning at different stages of growth to find the effect of fruiting on the growth of Concord vines. Results of two years' work showed that the removal of blossoms or fruit clusters early in the growing season had a definite stimulating effect on shoot growth, which is greater if done before the setting of fruit. Contrary to the results of 1930, he found in 1931 that removal of flower clusters did not stimulate growth of shoots in excess of the growth made by fruiting shoots on the same vine. Favorable growing conditions in 1931, as contrasted to a drouth in 1930, may have offset the effects of fruiting. The removal of all bunches after setting of fruit stimulated later growth, but not as much as did the removal before setting of fruit. The thinning of bunches to one on a shoot after setting resulted in very little increased shoot growth, but similar thinning before fruit set did stimulate considerable growth. From these results, Schrader reached the conclusion that fruiting has a marked "devitalizing" effect on the vine, and not a stimulating effect. Upon further observation, Schrader (10) found that individual shoots were stimulated by the removal of blossoms or clusters so he supposed that there was some individuality, or at least some independence among different shoots on the same vine.

In their study of the effect of fruiting on fruit bud formation, Colby and Tucker (2) report that shoots on short canes produced fewer and smaller clusters than did shoots in corresponding regions on longer canes. The rate of fruit bud formation per node was low when severe pruning was done, and increased constantly as the severity decreased until the optimum was reached at from 55 to 65 buds to the vine. The vines pruned to this number of buds made a profitable yield and produced the largest number of flowers for the next year. These results were found, however, under conditions of fertile soil and adequate moisture.

MATERIALS AND METHODS

Severity of Pruning

Preparation of Vines. Two rows of 14-year old Concord vines were used for the experiment on severity of pruning. These vines (in rows 6 and 8) were trained to the four-cane Kniffin system and previously had been placed in groups of 30, 40, and 60 buds respectively. On March 1, 1936, these vines were pruned[1] to the designated number of buds, there being approximately an equal number of vines in each of four groups. The two groups of vines pruned to 60 buds remained identical until June 1 when the fruit on the one group[2] of vines was thinned to a maximum of two bunches on each shoot.

---

[1] Pruning was done as part of a problem by Emanuel Zoglin.

[2] Vines subjected to thinning are referred to as 60 T. B.

Collection of Data on Shoots, Leaves, and Fruit. During the week of July 13 to 18, eleven or more representative vines from each group were studied for the following information: total number of shoots, number of fruiting shoots, total number of leaves, number of bunches, and the number of leaves for each bunch.

All leaves with less than half their area injured were counted on each vine and each shoot. The number of fruiting shoots and the number of leaves on those shoots were also counted. After having counted the number of bunches, the number of leaves for each bunch was calculated.

Fruit Studies. Observations were made on the time and amount of ripening of the fruit on vines under each treatment. In order to protect the ripening fruit from birds, it was necessary to bag the best bunches with small manilla sacks. About 700 sacks were used on the fruit on the two rows of vines.

The size and specific gravity of the berries from the vines under the pruning treatments were found in an effort to determine the effects of the treatments upon those two characteristics. On September 9, following the hailstorm, some of the sound berries were collected from various clusters on vines under each treatment, placed in paper bags and thoroughly mixed. For each method of treatment, eleven samples, each containing twenty berries, were carefully weighed and placed in a graduated cylinder of distilled water to find the amount of water displaced. Thus the volume of each sample was computed, it being equal to the weight of the water displaced by the berries. By dividing the weight of the berries by their volume, their specific gravity was found.

Comparison of Cane Growth. On December 1, 1936, a number of representative vines under each treatment in rows 6 and 8 were pruned to 32 buds each. The wood removed from each vine was weighed and this weight constitutes one measure of the effect of severity of pruning on the vegetative vigor of the vines.

Effect of Heat and Drouth

Beginning the first of June, and throughout the summer of 1936, as shown in table 1, the grape vines were subjected to extreme heat and almost no rainfall, a condition which motivated the experimental work with shading and watering. By July 1, the vines were showing signs of injury from the extended period of heat and drouth. At that time four plots, each containing four Concord vines, were selected in rows 24 and 25 according to the plan in figure 1.

Figure 1. Arrangement of plots for treatment.

	Row 25 Vine	Row 24 Vine	
	1	1	
Buffer	2	2	Buffer
	3	3	
	4	4	
Shaded and watered	5	5	Watered
	6	6	
	7	7	
Buffer	8	8	Buffer
	9	9	
	10	10	
Shaded	11	11	Untreated
	12	12	
	13	13	

Table 1. Rainfall and temperature record.

June					July					August				
Day	Max.	Min.	Mean	Rain	Day	Max.	Min.	Mean	Rain	Day	Max.	Min.	Mean	Rain
1	88	68	78		1	91	64	77.5		1	90	57	73.5	
2	90	60	75		2	97	60	78.5		2	94	58	81	
3	78	47	61.5		3	99	69	84		3	99	66	82.5	
4	76	49	62.5		4	104	72	88		4	92	71	81.5	
5	77	60	68.5	0.23	5	108	70	89		5	98	65	81.5	0.05
6	73	55	64	0.45	6	102	73	87.5		6	83	61	72	
7	81	56	68.5		7	100	73	86.5		7	81	64	72.5	0.70
8	88	66	77		8	98	76	81		8	82	63	72.5	0.02
9	98	70	84		9	98	76	87		9	96	67	81.5	
10	86	55	70.5		10	102	78	90		10	108	68	88	
11	75	49	62		11	104	74	89		11	105	70	87.5	
12	81	51	66		12	103	75	86		12	105	70	87.5	
13	83	56	69.5		13	103	71	87		13	114	83	98.5	
14	92	63	77.5		14	106	71	88.5		14	117	85	101	
15	100	66	83		15	110	71	90.5		15	113	82	97.5	
16	102	69	85.5		16	110	69	89.5		16	108	82	95	
17	99	62	80.5		17	112	72	92		17	105	75	90	
18	98	61	79.5		18	112	76	94		18	108	81	93.5	
19	101	71	86		19	114	75	94.5		19	110	84	97	
20	109	67	88		20	106	72	89		20	109	70	89.5	1.09
21	103	67	85		21	101	66	83.5		21	100	71	85.5	
22	104	64	82		22	97	67	82		22	102	72	87	0.13
23	82	54	68		23	103	76	89.5		23	100	67	83.5	
24	86	50	63		24	107	65	86		24	104	70	87	
25	90	58	74		25	114	78	96		25	109	80	94.5	
26	101	73	87		26	111	81	96		26	109	70	89.5	
27	109	76	92.5		27	109	81	95		27	107	79	93	
28	104	66	85		28	109	70	89.5	1.88	28	103	68	85.5	
29	104	81	92.5		29	91	78	84.5		29	87	54	70.5	
30	106	72	89		30	91	66	78.5		30	88	55	71.5	
					31	90	57	73.5		31	95	65	80	
Average	92.0	62				101.8	69.4	87.39			94.3	70.2	85.51	

<u>Application of Treatments</u>. On July 6, lath shades were constructed and placed above the two shaded plots, as shown in figures 3 and 4. On the same day 135 gallons of water were added to each vine in the watered and the shaded-and-watered plots. The loose soil was pulled to the center between the rows and the water applied in the shallow basins surrounding the vines. This amount of water over an area of 72 square feet was equivalent to a three-inch rain, and similar applications were later made at ten-day intervals.

<u>Soil and Soil Moisture</u>. For soil moisture determinations, 50-gram samples were taken from each of the four plots to a depth of three feet at ten-day intervals, midway between the applications of water. These samples were dried at a temperature of 105° C for at least 24 hours, then weighed. The per cent moisture was then determined on a dry soil basis.

The wilting coefficient was found for the soil between rows 24 and 25 as well as for that in rows 6 and 8. The soil samples were separated at the ten-inch level in order to find any difference in wilting coefficient between the surface soil and the subsoil. The field capacity of the soil between rows 24 and 25 was found by the field method about 40 hours after a rain of 3.8 inches. Several samples were taken to a depth of ten inches and an average calculated from the individual readings.

Collection of Data on Shoots, Leaves, and Fruit. On July 10 and 11, all vines in the four plots were studied in the same manner as those in rows 6 and 8. At the end of two weeks, during which time extremely hot and dry weather prevailed, the leaves and bunches again were counted in the same manner, and a comparison was made between the two sets of data.

Leaf Studies. The increasing number of injured leaves and the manner in which this injury increased prompted various lines of study to observe the condition within the leaf which accompanied that injury; and to determine which of the two conditions, the lack of moisture or the intense heat is the greater source of that injury.

The variation in moisture content of the leaves under the four methods of treatment was studied by the punch method. Starting 40 hours after the application of water, 50 leaves from each plot were punched at 6:00 a. m. and 2:00 p. m. for three days. These samples were weighed, oven-dried at 100° C for 48 hours, then reweighed and the moisture content determined. This was done on two occasions under different temperatures.

In order to study the relationship between progressive injury of individual leaves and their loss of moisture, seven leaves ranging from apparently normal to completely dead were selected, carefully weighed, and oven-dried at 100° C for 48 hours, then reweighed.

A comparison of the conditions of "normal" and injured leaves was made by taking sets of 50 punches from the normal leaves and some at the same time from the "normal" tissue of the injured leaves in a corresponding position bordering the injured portions.

To observe the activity of vines which appeared to be suffering considerably from lack of water and extreme heat, four vines were studied for any variation in moisture content and photosynthetic activity. Three vines (A, B, and C) in close proximity in row 8 were chosen because of the wilted appearance of their leaves along with a fourth vine, D, from which the fruit had disappeared early in June. At 5:30 a. m. on August 29, punches were taken from 25 representative leaves on each of the four vines. Punches from the same leaves were taken again at 11:30 a. m. on the opposite side of the midrib. The green samples were weighed, then placed in a drying oven at 100° C for 48 hours and reweighed. In an effort to note any change of activity in these same vines when subjected to different treatments, 135 gallons of water were applied to vine A immediately following the second punching. The fruit then was removed from vine C, while vine B remained untreated as a check against vines A and C. Vine D remained untreated and served as a check against the fruiting vines. At the same hours on the third and fourth days, samples were again taken from those leaves and treated in the same manner as above.

Fruit Studies. Observations were made on the appearance of ripe berries on the vines under the four methods of treatment. It was necessary to bag all the fruit to protect it from birds. The size and specific gravity of berries from each of the vines under the different treatments were found in order to determine the effect of such treatments on those two characteristics.

Comparison of Cane Growths. All vines subjected to the different treatments were pruned at the same time and in the same manner as those in rows 6 and 8. The wood removed from each vine was weighed in order to find the effect of shading, watering, and both shading-and-watering upon the vegetative vigor of the vines.

OBSERVATIONS AND RESULTS

Severity of Pruning

Responses of Shoots, Leaves, and Fruit. As shown in tables 2 to 6, the vines with 30 buds were found to average the greatest number of leaves for each shoot as well as for each bunch of fruit, but the average number of bunches on each vine was considerably below that of the other vines. As the number of buds left on each vine at pruning time was increased, the number of leaves on each shoot decreased in contrast to an increase in number of shoots and bunches.

The vines with 30 buds were found to average a few more leaves to the vine than those with 40, 60, and 60 T. B. following in that order. Upon observation, it was found that the difference was accounted for in part by the increase in number of leaves on each shoot and also by a smaller per cent of damaged leaves on the vines with 30 buds. The shoots on those vines had more secondary shoots which contributed to the number of leaves.

Table 2. Number of shoots, leaves, and bunches of fruit on vines pruned to 30 buds. July 14 to 16, 1936.

Row 6	Total shoots	Fruiting shoots	Bunches	Total leaves	Fruiting shoot leaves	Leaves per bunch
Vine 1	37	32	64	883	850	13.3
13	24	22	40	315	294	7.4
19	29	28	48	870	863	18.0
25	34	27	52	748	631	12.1
37	38	30	51	798	718	14.0
43	31	25	38	497	425	10.7
Row 8						
Vine 1	35	30	47	630	556	11.8
19	28	23	44	924	811	18.4
25	27	24	45	240	206	4.6
31	42	37	73	924	779	10.6
37	30	27	63	480	447	7.1
43	41	31	42	943	804	19.1
49	36	35	66	612	595	9.0
55	37	33	75	777	730	9.7
Total	469	404	748	9641	8709	165.8
Average	33.5	28.9	53.6	688	622	11.84

Average number of leaves per fruiting shoot - 21.8.

Table 3. Number of shoots, leaves, and bunches of fruit on vines pruned to 40 buds. July 14 to 16, 1936.

Row 6	Total shoots	Fruiting shoots	Bunches	Total leaves	Fruiting shoot leaves	Leaves per bunch
Vine 2	28	26	64	534	818	12.8
5	45	42	82	980	963	10.5
8	47	36	62	517	462	7.5
23	39	32	76	741	611	8.0
26	55	50	60	935	896	15.0
29	34	27	91	782	644	7.0
44	53	43	52	645	567	10.9
47	27	27	62	324	324	5.2
Row 8						
Vine 2	36	31	59	501	445	7.5
5	39	32	56	546	448	8.0
29	40	35	78	920	806	10.3
35	33	32	77	759	738	9.6
38	53	50	85	1113	1068	12.5
41	40	36	84	480	423	5.0
50	43	40	85	540	518	6.1
53	38	31	50	304	255	5.1
Total	660	570	1103	10721	9966	141.0
Average	41.2	35.6	68.9	670	623	9.0

Average number of leaves per fruiting shoot - 17.5.

Table 4. Number of shoots, leaves, and bunches of fruit on vines pruned to 60 buds. Thinned to maximum of two bunches per shoot. July 14 to 16, 1936.

Row 6	Total shoots	Fruiting shoots	Bunches	Total leaves	Fruiting shoot leaves	Leaves per bunch
Vine 6	36	31	67	411	330	4.9
12	46	39	70	280	253	3.6
18	57	38	74	962	637	8.6
24	60	52	67	840	729	10.9
45	46	38	81	506	439	5.4
Row 8						
Vine 3	54	43	87	594	512	5.9
6	71	56	73	781	616	8.4
18	55	50	78	540	495	6.3
21	53	45	73	689	608	8.2
24	64	62	110	448	436	4.0
27	57	47	77	483	407	5.3
30	52	47	77	728	683	8.8
33	45	41	67	540	486	7.2
36	53	51	97	583	562	5.7
39	48	44	76	690	671	8.9
48	43	30	85	688	545	6.4
54	66	57	86	726	645	7.5
Total	906	771	1345	10489	9054	116.0
Average	53.3	45.3	79.0	617	522.6	6.60

Average number of leaves per fruiting shoot - 11.7.

Table 5. Number of shoots, leaves, and bunches of fruit on vines pruned to 60 buds. Fruit unthinned. July 14 to 16, 1936.

Row 6	Total shoots	Fruiting shoots	Bunches	Total leaves	Fruiting shoot leaves	Leaves per bunch
Vine 3	56	50	93	876	793	8.5
22	59	57	102	753	708	6.8
28	59	54	82	767	702	8.6
46	50	48	102	550	524	5.1
52	53	46	105	709	667	6.3
Row 8						
Vine 4	34	25	59	767	704	12.0
10	52	47	110	376	344	3.1
16	59	49	110	531	455	4.1
22	57	46	109	740	629	5.8
40	59	55	125	590	557	4.5
52	63	60	102	378	349	3.4
Total	602	537	1099	7037	6432	68.2
Average	54.7	48.8	99.9	643	584.7	6.2

Average number of leaves per fruiting shoot - 12.2.

Table 6. Summary of tables 2 to 5 inclusive.

Severity of pruning	Total shoots	Fruiting shoots	Bunches	Total leaves	Fruiting shoot leaves	Leaves per bunch	Leaves per fruiting shoot
30 buds	33.5	28.9	53.6	688	622	11.6	21.8
40 buds	41.2	35.6	68.9	670	623	9.0	17.5
60 buds T. B.	53.3	45.3	79.0	617	523	6.6	11.7
60 buds	54.7	48.8	99.9	643	585	6.2	12.2

__Fruit Studies.__ By August 3 some of the berries on all vines were developing some purple color. This was limited, however, to only a few berries in each bunch rather than to entire bunches. These early maturing berries apparently were normal and of fair quality, while others in the same bunch remained hard, acid, and green. No greater difference was found in the number of colored berries on vines subjected to different methods of pruning than between berries on different vines of the same treatment. These variations may have been entirely individual or due to their previous conditions and their reactions to treatments.

Soon after the first berries began to ripen, the other fruit in the vineyard became so limited that the birds began to attack them. The berries either were devoured completely or so damaged that they were destroyed by various insects. Bagging of the fruit served to protect it from the birds as well as partially protecting it from the hailstorm. The hailstorm, however, left a very small amount of undamaged fruit, and so completely defoliated the vines that all hopes of ripening were abandoned.

Upon general observation of the berries on the vines under the four pruning treatments, it appeared that there was a difference in size, at least, between those pruned to 30 buds and those pruned to 60 buds.

The results, as given in table 7, show that the samples from the vines bearing 30 buds weighed an average of 38.21 grams each and totaled 420.30 grams; while the total displacement of water was 413 cc. with an average displacement of 37.55 cc. for each sample. Thus the specific gravity was found to be 1.0177.

The samples from vines bearing 40 buds averaged 36.43 grams each and reached a total of 400.67 grams. Their average volume was 36.18 cc., the total volume being 398 cc. for the eleven samples, or 220 berries. Their specific gravity was 1.0067.

The samples from vines bearing 60 buds, and on which thinning was done, averaged 32.16 grams for each sample, or 353.80 grams total. The total volume of these samples was 346 cc. with an average of 31.45 cc. and a specific gravity of 1.0225.

The samples from vines bearing 60 buds averaged 32.11 grams with a total of 353.76 grams. Their volume averaged 31.90 cc. with a total of 351 cc. and a specific gravity of 1.0079.

Thus the berries from vines pruned to 30 buds were found to weigh 4.7 per cent more than those pruned to 40, and 13.4 per cent more than those pruned to 60 T. B. and 60 buds. The berries from vines pruned to 30 buds had 3.6 per cent greater volume than those pruned to 40, 16.2 per cent greater than those pruned to 60 T. B., and 15.2 per cent greater than those pruned to 60 buds.

These results show that the larger berries in both volume and weight were found on those vines pruned to the fewest number of buds, and that the size of the berries decreased as the number of buds on each vine was increased. The difference in size of these berries is not unusually large, but is significant.

The difference in specific gravity of the berries from the various vines was found to be insignificant and to vary independently of their size and weight.

Table 7. Effects of different pruning treatments on size and specific gravity of berries.

30 buds Sample	Weight gms.	Displacement cc.	Specific gravity	60 buds T. B. Sample	Weight gms.	Displacement cc.	Specific gravity
1	40.98	40		1	34.75	34	
2	41.62	42		2	33.61	33	
3	36.42	35		3	31.78	32	
4	40.29	40		4	33.59	32	
5	38.07	37		5	32.19	32	
6	39.31	38		6	31.19	31	
7	38.67	38		7	32.56	32	
8	36.81	36		8	29.78	28	
9	35.10	35		9	32.90	33	
10	37.14	37		10	30.18	29	
11	35.89	35		11	31.27	30	
Total	420.30	413	1.0177		353.80	346	1.0225
Average	38.21	37.55			32.16	31.45	

40 buds Sample	Weight gms.	Displacement cc.	Specific gravity	60 buds Sample	Weight gms.	Displacement cc.	Specific gravity
1	36.15	37		1	32.15	32	
2	36.06	36		2	32.08	32	
3	35.16	35		3	33.19	33	
4	38.29	38		4	33.04	32	
5	38.12	38		5	33.33	33	
6	35.90	36		6	31.61	32	
7	37.57	37		7	34.67	34	
8	33.26	33		8	31.88	32	
9	39.07	38		9	32.60	32	
10	36.39	36		10	29.92	30	
11	34.70	34		11	29.29	29	
Total	400.67	398	1.0067		353.76	351	1.0079
Average	36.43	36.18			32.11	31.90	

Comparative Growth of Different Vines. There was no visible difference in the appearance of the shoot growth made by the vines pruned to 30 buds and those pruned to 40 buds. Neither was there any noticeable difference between that of the vines with 60 buds with no thinning of fruit and those which were thinned. There was, however, an apparent difference in representative growth between the vines pruned to 30 buds and those pruned to 60 buds. On the vines with 30 buds, the shoots were fewer in number but larger in diameter and somewhat longer than those on vines with 60 buds. Due to uncontrolled causes, there was considerable difference in the amount and kind of growth among the vines pruned to the same number of buds. Some of the vines produced canes of considerable size and length while others in the same group produced inferior canes, none of which would be desirable bearing wood. Upon examination, it was found that very vigorous or unusually weak vines were more or less grouped together, indicating that certain conditions in the soil were responsible for such variation.

As shown in table 8, the vines pruned to 60 buds produced an average of 348.9 grams of new wood in excess of that retained for bearing. Those pruned to the same number of buds but subjected to thinning produced an average of 390.8 grams, or 12.0 per cent more than those with no thinning. The vines pruned to 40 buds produced an average of 515.6 grams of wood which amounted to a 47.8 per cent increase over those with 60 buds, while those with 30 buds produced 573.9 grams, or 64.5 per cent more than those with 60 buds. Although a variable and limited number of vines was available for the four classes, there is enough difference between them to indicate that the greatest growth occurred on the vines pruned to the fewest buds, with the least growth on vines with the most buds. It appears that the thinning of fruit to a maximum of two bunches on a shoot reduced the food requirement and permitted an increased growth over than on unthinned vines. This increase, however, is small and may not be significant on the basis of so few comparisons and such poor growth.

The canes produced on the vines with 30 buds were found superior to those with 60 buds, both in size and condition. They had reached a good state of maturity and showed less chance for winter injury, while those on the latter were less mature. Following the early frezes, these inferior canes possessed a wrinkled appearance and showed considerable injury.

The vines with 30 buds were more easily pruned than those with more buds because of their better cane growth. Also, it was found that on all canes the best shoot growth occurred from buds nearer the outer ends. This was more pronounced on the vines with 60 buds than on those with 30 buds, with the result that the most desirable canes on the former were too far from the head to save for the following year's bearing wood.

The results obtained would favor the pruning of Concord vines to 30 buds in preference to 40 or 60 in order to obtain more and better growth, thereby facilitating pruning and reducing winter injury. These results, however, were obtained under conditions of extreme drouth and heat and may not be applicable to the average year. Judging from the growth made by some of the lightly pruned vines, it would seem that under normal conditions they would produce too much vegetative growth and too little fruit. Therefore, the optimum number of buds for a normal year, following several normal years, would probably be somewhat higher than 30. However, upon comparing the appearance of the vines at present and considering the abnormal conditions of the last three years, pruning the vines to 30 buds, even at the expense of some fruit, is now to be desired above even 40 buds. By this process, the vigor of the vines may be regained thereby permitting high production during normal years.

Table 8. Comparison of the weights of canes removed from vines pruned to different numbers of buds.

30 Buds		40 Buds		60 Buds T. B.		60 Buds	
Row 6 Vine	Weight gms.	Row 6 Vine	Weight gms.	Row 6 Vine	Weight gms.	Row 6 Vine	Weight gms.
1	679.0	2	341.5	18	510.0	3	398.0
19	1089.0	5	363.0	21	200.0	22	648.0
25	610.5	8	380.5	24	374.0	28	362.5
37	641.0	14	203.5	27	392.0	40	422.0
		23	614.0	39	661.0	46	322.5
		26	1009.0	45	695.0	48	425.5
		29	627.5			52	622.0
		35	1003.0				
		38	438.5				
		41	939.0				
		44	418.5				
		47	409.0				
		53	804.0				
Row 8 Vine		Row 8 Vine		Row 8 Vine		Row 8 Vine	
1	326.0	2	216.0	3	151.5	10	68.5
13	502.0	17	453.5	6	428.5	16	213.0
19	666.5	20	354.0	12	294.5	22	310.0
25	264.5	23	434.0	15	197.0	40	278.5
31	705.5	26	490.0	18	265.5	46	117.0
37	274.5	35	364.5	21	542.5		
43	623.0	38	654.5	24	125.5		
49	505.0	41	310.0	27	173.5		
				30	494.0		
				33	278.5		
				36	427.0		
				39	231.0		
				45	958.0		
				48	417.0		
Total	6886.5		10827.5		7816.0		4187.5
Average	573.9		515 .6		390.8		348.9

Effect of Heat and Drouth

Soil and Soil Moisture. The soil of the station vineyard has a heavy red clay subsoil with varying amounts of scattered gravel. This subsoil is overlain with a darker soil which varies from six to ten inches in depth and contains a considerable amount of organic matter. There is a rather sharp break between the surface soil and subsoil.

As shown in table 9 and in figure 2, the wilting coefficient of the soil in rows 6 and 8 was found to be 16.33 per cent in the top ten inches and 16.56 in the next twenty inches. This value for the soil between rows 24 and 25 was 15.50 in the top ten inches and 15.33 in the next twenty inches.

In table 10 are recorded the amount of water applied to the different plots, the date applied, and the form in which it occurred. Results of individual soil moisture determinations are found in table 11 together with an average percentage for the period from July 10 to September 12. These data are represented graphically in figure 2 together with the wilting coefficient and field capacity.

As shown in table 11, the average per cent of moisture in the untreated soil for the two months' period was 18.1. This was 2.7 per cent above the wilting percentage and showed little fluctuation over the entire period. The shaded soil had an average of 18.6 per cent moisture, only 0.5 per cent higher than the untreated soil. The average moisture content in the watered soil was 24.1 per cent, or 8.7 per cent above the wilting coefficient, as compared with 24.8 per cent in the shaded-and-watered soil, with a difference of 0.7 per cent between the two. In both cases the soil beneath the shades had a slightly higher per cent of moisture than in the corresponding unshaded plots. These differences are not large but may be of importance when the soil moisture so nearly approaches the wilting coefficient.

These figures are averages and tend to hide any fluctuations. The individual moisture readings for the different depths of one, two, and three feet naturally were more uniform in the untreated and shaded plots than in either the watered or the shaded-and-watered.

As shown in table 12, the average field capacity of the six samples taken to a depth of ten inches was found to be 31.6 per cent.

Table 9. Wilting coefficient of vineyard soil at different locations.

Row	Depth inches	Weight wet sample gms.	Weight dry sample gms.	Per cent water	Wilting coefficient
24	0-10	25.0	19.45	28.54	15.50
24	11-30	25.0	19.50	28.21	15.33
6	0-10	25.0	19.20	30.04	16.33
6	11-30	25.0	19.15	30.47	16.56

Table 10. Inches of water supplied from June 1 to September 10, 1936.

Date	Form	Watered plots	Shaded and untreated plots
June 5	Rain	0.23	0.23
June 6	Rain	0.45	0.45
July 6	Irrigation	3.00	
July 16	Irrigation	3.00	
July 27	Irrigation	3.00	
July 28	Rain	1.88	1.88
August 6	Irrigation	3.00	
August 7	Rain	0.70	0.70
August 17	Irrigation	3.00	
August 20	Rain	1.09	1.09
August 22	Rain	0.13	0.13
August 27	Irrigation	3.00	
Sept. 8	Rain	3.80	3.80
Total		26.28	8.28

Table 11. Per cent of moisture in soil on dry weight basis.

Treatment	Depth feet	July 10	July 21	July 31	August 10	August 22	August 31	Sept. 12	Average
	1	21.0	13.9	18.3	16.5	19.3	17.3	22.5	18.40
Untreated	2	20.2	17.9	18.8	19.3	19.5	18.0	17.4	18.73
	3	18.5	18.5	16.4	17.0	16.7	16.8	16.7	17.23
Averages		19.9	16.8	17.8	17.6	18.5	17.4	18.9	18.12
	1	20.5	17.1	19.0	16.5	19.9	17.8	23.1	19.13
Shaded	2	20.4	17.9	19.5	19.7	20.3	18.3	17.2	19.04
	3	19.5	17.8	17.1	17.1	17.3	17.3	17.3	17.63
Averages		20.1	17.6	18.5	17.8	19.2	17.8	19.2	18.60
	1	23.5	22.2	26.7	25.3	26.8	24.2	26.8	25.07
Watered	2	22.9	25.0	25.0	26.3	25.4	25.0	25.2	24.97
	3	21.0	20.8	23.5	24.7	22.3	23.0	20.6	22.30
Averages		22.5	22.7	25.1	25.4	24.8	24.1	24.2	24.11
Shaded-	1	23.8	24.6	27.6	26.0	26.4	24.8	27.9	25.89
and-	2	21.9	23.5	27.7	27.4	26.3	26.0	25.5	25.49
watered	3	22.8	21.1	24.0	25.1	24.2	23.4	21.3	23.13
Averages		22.8	23.1	26.4	26.2	25.6	24.7	24.9	24.83

Table 12. Field capacity of vineyard soil as found by field method.

Sample number	Wet soil gms.	Dry soil gms.	Water gms.	Field capacity per cent
1	50	37.4	12.6	33.4
2	50	39.3	10.7	29.9
3	50	37.7	12.3	32.3
4	50	38.0	12.0	31.4
5	50	38.2	11.8	30.8
6	50	37.8	12.2	32.0
Averages		38.0	11.9	31.6

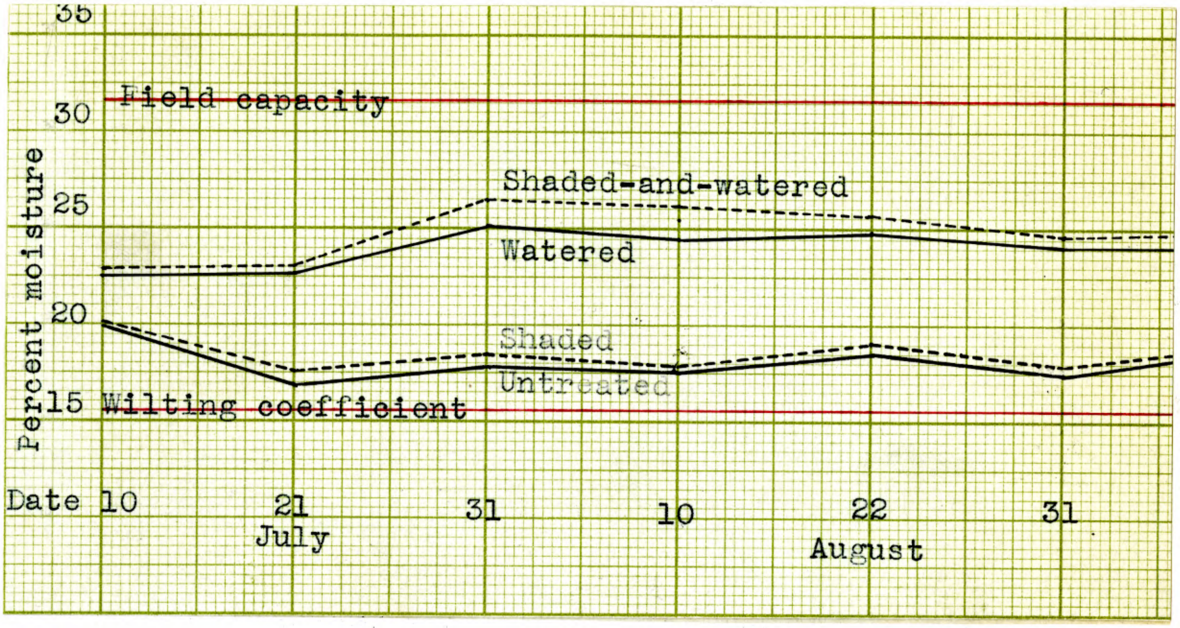

Figure 2. Per cent moisture in the four plots in relation to field capacity and wilting coefficient.

Responses of Shoots, Leaves, and Fruit. At the time this work was begun, there were some injured leaves present on all vines but there was no noticeable difference in the amount of injury in the different plots, as an attempt was made to select only vines of equal standing for the different treatments. The original amount of fruit on the vines was rather limited and was being further reduced by attacking grasshoppers.

The data in table 13 represent the conditions as found on July 10 and 11, while those in table 14 represent those found from similar observations two weeks later. A comparison of these two sets of data shows a reduction of only 10 bunches of grapes on the four vines in the untreated plot, as compared with 26 in the shaded, 35 in the watered, and 52 in the shaded-and-watered plots. Almost without exception the loss of bunches was caused by grasshoppers partially or completely detaching them from the shoots. As indicated in table 14, their damage was greatest on shaded-and-watered vines and least on the untreated vines. From this, it appears that they favored the watered and the shaded-and-watered plots possibly because of the shade and dampness or because of the difference in condition of the leaves.

Within one week after the application of the different treatments, a difference was noticed in the number of injured leaves. At the end of two weeks the injured leaves on the shaded-and-watered vines showed an increase of only 23 per cent as compared with an increase of 119 per cent on the watered, 120 per cent on the shaded, and 235 per cent on the untreated vines. The great increase in number of damaged leaves on the untreated vines reduced the average number of leaves on each fruiting shoot from 18.1 on July 10 to 9.4 on July 25. The average number of leaves for each bunch increased in the other three plots because of the loss of a considerable number of bunches. In the watered plot, the number of fruiting shoots was so reduced that the average number of leaves for each fruiting shoot increased from 19.0 to 21.2, and the number of leaves for each bunch increased from 10.8 to 13.8. The shaded-and-watered plot showed the greatest response to treatment with a 6.6 per cent increase in total number of leaves over and above the 23 per cent increase in number of damaged leaves, due to new growth of the shoots. The average number of leaves on each fruiting shoot increased from 26.7 to 27.6 and the average number of leaves for each bunch increased from 11.4 to 16.4. This great increase, however, was not due entirely to the relative reduction in number of damaged leaves or to the additional growth, but also to the reduction in the number of bunches by nearly 50 per cent.

The plot receiving no treatment suffered serious leaf injury and produced no new growth after July 1 which indicates that both the intense heat and the lack of moisture were hindering normal activity. In actual counts, the average increase in the number of damaged leaves on the four watered vines in the two weeks was 98.5 as compared with 67.5 on the shaded vines. However, this difference is due only to the fact that more leaves were found on the watered vines, the actual increase in per cent being 119 for the watered and 120 for the shaded vines. The difference does lie, however, in the fact that new leaves were being produced on the watered vines to replace in part the injured leaves. On the basis of the total number of leaves in each plot, the per cent of injured leaves found on the watered vines was 23.9, while that on the shaded vines was 22.9, a difference of only one per cent in favor of the shaded vines. Such a small difference is insignificant and shows no difference in the amount of injury resulting from extreme heat and that resulting from lack of moisture. The fact that shading-and-watering resulted in a significant reduction in injury as compared with that of either shading or watering indicates that the two conditions are interrelated. The situation may be so complicated that the same leaves exposed to extreme heat may be more severely injured when water is also limited than when sufficient water is present.

Table 13. Data for vines in rows 24 and 25 as found at beginning of treatments. July 10-11, 1936.

Treatment	Row	Vines	Bunches	Total shoots	Fruiting shoots	Total leaves	Fruiting shoot leaves	Damaged leaves	Leaves per fruiting shoot	Leaves per bunch
Untreated	24	10	46	26	19	557	418	72	22.0	9.1
		11	29	20	17	374	323	47	19.0	11.1
		12	27	26	16	406	254	85	15.9	9.4
		13	24	32	14	494	217	50	15.5	9.0
Total			126	104	66	1831	1212	254	72.4	38.6
Average			31.5	26	16.5	458	303	63.5	18.1	9.6
Shaded	25	10	39	29	26	463	391	67	15.0	10.0
		11	25	31	14	475	170	49	12.1	6.8
		12	21	32	12	610	228	60	19.0	10.8
		13	33	27	16	437	262	38	16.7	7.9
Total			118	119	68	1985	1051	214	62.8	35.5
Average			29.5	29.8	17	496	263	53.5	15.7	8.9
Watered	24	4	26	27	15	634	372	89	16.8	14.3
		5	23	34	10	677	190	76	19.0	3.9
		6	27	35	12	739	216	97	18.0	8.8
		7	19	22	14	612	311	69	22.2	16.4
Total			95	118	51	2662	1089	331	76.0	43.4
Average			24	29.5	12.7	665	272	82.5	19.0	10.8
Shaded-and-watered	25	4	35	21	19	609	463	49	24.4	13.2
		5	32	25	15	377	257	60	17.1	8.0
		6	25	23	13	629	385	41	29.4	15.4
		7	27	32	15	512	240	53	16.0	8.9
Total			119	101	62	2127	1345	203	86.9	45.5
Average			29.8	25.2	15.5	532	336	51	26.7	11.4

Table 14. Data for vines in rows 24 and 25 as found after two weeks' treatments. July 24-25, 1936.

Treatment	Row	Vines	Bunches	Total shoots	Fruiting shoots	Total leaves	Fruiting shoot leaves	Damaged leaves	Leaves per fruiting shoot	Leaves per bunch
Untreated	24	10	42	25	18	257	184	219	10.2	4.4
		11	35	20	18	162	155	211	8.6	4.4
		12	25	26	15	174	111	226	7.4	4.4
		13	14	32	11	320	127	195	11.5	9.0
Total			116	104	62	913	577	851	37.7	22.2
Average			29	26	15.5	228	144	213	9.4	5.5
Shaded	25	10	36	29	23	337	301	153	13.1	8.4
		11	14	31	10	409	134	109	13.4	8.9
		12	12	32	12	529	211	126	17.8	17.8
		13	30	27	15	353	225	97	15.0	7.5
Total			92	119	60	1628	871	485	59.3	42.6
Average			23	29.8	15	407	218	121	14.8	10.6
Watered	24	4	20	27	14	560	348	183	24.9	17.4
		5	11	34	7	612	137	160	19.6	12.5
		6	12	35	8	644	144	206	18.0	12.0
		7	17	22	10	527	223	175	22.3	13.1
Total			60	118	39	2343	852	724	84.8	55.0
Average			15	29.5	9.8	586	213	181	21.2	13.8
Shaded-and-watered	25	4	6	21	5	630	150	45	30	25.0
		5	14	25	8	408	323	72	40.4	13.1
		6	22	23	12	667	348	57	20.9	15.8
		7	25	32	15	563	289	87	19.3	11.6
Total			67	101	50	2268	1110	261	110.6	65.5
Average			16.7	25.2	12.5	567	227.5	65.2	27.6	16.4

Leaf studies. From observation it appeared that individual grape leaves did not become flaccid and then regain their turgidity as apple leaves may do for several days during extremely hot weather. In contrast with the apple, grape leaves usually become functionless as a result of a completely dead area which may begin as only a spot and spread over the entire leaf in the course of a few days. While this injured area is spreading, the dead portion may be separated from the rest of the leaf without any noticeable effect on the functioning of the living portion. This behavior is discussed more fully in another part of this thesis.

The moisture content of the leaves under the four methods of treatment, as shown in table 15, remained fairly constant throughout, but varied more from day to day within a given plot than between plots on the same day. This indicates that the moisture content is influenced more by daily fluctuations in temperature and air humidity than by different treatments.

The average daily decrease in moisture content of leaves on the untreated vines was 1.88 per cent as compared with 2.08 on the shaded, 2.74 on the watered, and 2.87 on the shaded-and-watered vines. Leaves on the untreated and shaded vines received very little moisture from the soil but still retained their moisture rather uniformly. No growth was taking place to require water and apparently the vines set up considerable resistance to the force of transpiration.

Leaves on the watered and the shaded-and-watered vines, on the other hand, were supplied with considerable amounts of water but still showed no noticeable increase in moisture content. Judging by the new growth on these vines a considerable amount of water was used directly for that purpose. However, the greater part of this water was lost from the leaves by transpiration. Apparently the rate of transpiration from the vines supplied with water was sufficiently greater than that from unwatered vines to prevent a noticeable increase in moisture content of the leaves under such extreme weather conditions. The results also show that under such conditions the grape leaves function within a rather narrow range of variation in moisture. If a greater amount of water be supplied to the leaves than is necessary to maintain this normal water content, then growth results and the rate of transpiration increases until a balance is reached with the upward movement of the water from the soil. If, on the other hand, the moisture content of the soil is so low, as was the case in the unwatered plots, the upward movement of water is reduced to almost zero; then no growth results and transpiration is reduced. When the transpiring power of the air becomes so great that the moisture content of the leaves is reduced below the lower limits of this narrow range or below the critical point, then injury results and they have a burned appearance. As a result of this decrease in leaf area the vines are still less subject to transpiration and may be in better condition than they appear to be. Such a complete state of dormancy in the middle of the summer, however, is undesirable because of the late fall growth which follows fall rains and uses stored food. Such growth is also subject to winter injury.

As the injury progressed on individual leaves, the per cent of moisture, as shown by table 16, had a general tendency to decrease but slightly until the leaf was greatly injured, then a rapid decrease resulted as the leaf died. This behavior might be attributed to a dehydration process whereby the leaf continues to hold a large part of its moisture until nearly all activity ceases, then loses it rapidly as soon as the individual cells die and the leaf completely loses control over it.

Table 15. Daily variation in moisture content of Concord grape leaves - 1936.

Date	Time	Temperature degrees F	Relative humidity	Per cent water on dry weight basis: Untreated	Shaded	Watered	Watered-and-shaded
July 23	6:00 a. m.	78	43	60.40	61.80	59.87	61.14
July 23	2:00 p. m.	105	14	59.84	59.97	58.30	57.44
July 24	6:00 a. m.	69	47	62.73	61.67	63.04	62.79
July 24	2:00 p. m.	110	17	60.09	58.97	58.61	60.15
July 25	6:00 a. m.	76	48	62.54	60.91	63.00	62.16
July 25	2:00 p. m.	106	19	62.14	60.30	60.97	61.26
July 29	6:00 a. m.	73	61	63.04	62.30	63.04	62.37
July 29	2:00 p. m.	92	39	59.87	57.90	60.09	58.90
July 30	6:00 a. m.	70	64	62.78	62.26	63.48	64.74
July 30	2:00 p. m.	90	36	61.16	61.19	60.97	61.12
July 31	6:00 a. m.	62	64	62.08	61.19	62.76	63.01
July 31	2:00 p. m.	92	23	59.17	59.34	59.77	60.09
Average high				62.26	61.69	62.53	62.70
Average low				60.38	59.61	59.79	59.83
Average difference				1.88	2.08	2.74	2.87

From all observations, the "normal" part of the leaf apparently functions normally and quite independently of any injury which may exist and be progressing in any other part of the leaf. This condition, however, may be governed largely by the location of the injured area with respect to the normal tissue, that is, whether or not it be between the midrib and the normal tissue. The foregoing statement is based upon the results of taking punches from normal and injured leaves. From the results of that work, and according to table 17, the tissue from the "normal" side of an injured leaf contained slightly over two per cent more moisture than that from apparently normal leaves, while that tissue bordering the injured areas had five per cent less moisture than tissue from normal leaves. Upon repeating this, a difference of less than one per cent was found instead of five per cent. This difference may be too small to be significant, especially in face of the fact that a greater variation occurred between two sets of punches from normal leaves than occurred between punches from normal and injured areas.

Table 16. Moisture content of leaves at various stages of injury, August 19, 1936.

Time	Stages of injury	Green weight of entire leaf - gms.	Dry weight of entire leaf - gms.	Water gms.	Water per cent
3:00 p. m.	(Normal) 1	4.2126	1.5594	2.6532	62.98
3:00 p. m.	2	3.0163	1.1190	1.8973	62.91
3:00 p. m.	3	3.4360	1.4117	2.0243	58.91
3:00 p. m.	4	4.0086	1.5533	2.4553	61.24
3:00 p. m.	5	3.3397	1.2889	2.0508	61.37
3:00 p. m.	6	2.8482	1.1875	1.6607	58.34
3:00 p. m.	(Dead) 7	2.0416	1.8681	0.1735	8.49

Table 17. Comparison of moisture in normal tissue and that bordering injured tissue, August 21, 1936.

Time	Sample	Green weight per square meter leaf area - gms.	Dry weight per square meter leaf area - gms.	Water per cent
9:00 a. m.	Normal leaves			
	Number 1	180.160	73.280	59.34
	Number 2	190.180	78.300	58.83
	Injured leaves			
	"Normal" side	162.820	62.140	61.71
	Injured side	127.720	58.740	54.00
11: 00 a. m.	Normal leaves			
	Number 1	164.060	61.340	57.72
	Number 2	180.540	82.700	54.34
	Injured leaves			
	"Normal" side	162.140	71.140	56.12
	Injured side	152.360	67.080	55.99

The three vines (in row 8), to which previous reference has been made and which exhibited a wilted appearance on August 28, were the only vines in the vineyard that reached that condition although many of them were suffering badly. The leaves on these three vines (A, B, C) were pale green and limited in number. The leaves on the fruitless vine were very dark green, many in number, and apparently not suffering from adverse weather conditions.

As found by the punch method, and as shown in table 18, the per cent of moisture in all except two cases was less at 11:30 a. m. than at 5:30 a. m. On the second day, a high humidity at 11:30 accompanied by a few drops of rain probably accounted for the reverse action and for the smaller decrease in moisture content. Vine A showed a loss in carbohydrates from 5:30 to 11:30 before any water was added and continued to show a periodic loss the third and fourth days after it was watered. In contrast to this, vine B, with no treatment, showed a periodic gain each day, the greatest gain occurring the first day and considerably smaller gains on both the second and third days. Vine C, before its fruit was removed, showed a gain similar to that of vine B from 5:30 to 11:30 a. m. on the first and again on the second day, but a relatively far greater gain than that of vine B was produced on the third day. Vine D under each test showed a slightly higher per cent of moisture and a greater green weight than the other vines but behaved indifferently in regard to carbohydrate accumulation. On the first day a slight gain was found from 5:30 to 11:30 a. m. while on the second and third days considerable loss in weight was found over like periods. No increase in moisture content was found in the leaves as a result of the application of water. Vine C showed no change as a result of having the fruit removed.

The wilted appearance of those vines probably was due to the fact that for the nineteen days previous to August 29 the average maximum temperature was 107° F with no precipitation. Following the day of the first punches and first treatments the maximum temperature fell to 87° F and continued relatively low during the time of treatment and study. During this period the wilted leaves regained their turgidity at least to the point where they appeared no different from those on surrounding vines. In every case the per cent of water in the samples was greater at 11:30 a.m. on the third and fourth days following the decrease in temperature than at the same time on the first day. As shown by table 18, the increase in moisture content averaged about two per cent, probably because of a decreased transpiration rate. This difference does not appear great but may be very near the critical point for grape leaves.

From this it appears that grape leaves may become flaccid and still regain their turgidity at least once, although this wilted condition might have continued to the point of death if such extremely high temperature had continued. Apparently the same factor causing injury to individual leaves on normal vines is different from that causing entire vines to become wilted. In the case of the latter, transpiration merely exceeds the passage of water from the soil to the leaves, but the turgidity is regained when transpiration is reduced. From previous observation it was found that dead areas on individual leaves may increase in size until the entire leaf is dead, while many leaves on that vine are apparently normal. This type of injury probably is due directly to extremely high temperatures burning the tissue when the moisture content of the leaf drops to the critical point. The occurrence of leaf injury on a given leaf may be due to more or less independence between the activities of different portions of the leaf. Or this difference in behavior may be due to a difference in the structure of grape and apple leaves. For example, the network of veins may be more complete in the grape leaf and thus more nearly serve each cell as an individual, thereby eliminating in part the interdependence between cells.

Table 18. Variations in photosynthetic activity and moisture content of Concord grape leaves.

Date	Time	Vine	Green weight per square meter area - gms.	Dry weight per square meter area - gms.	Gain or loss per square meter area - gms.	Water per cent
August 29	5:30 a. m.	A	177.040	76.040		56.85
		B	166.220	69.520		58.20
		C	171.400	74.440		56.57
		D	194.320	79.520		59.08
	11:30 a. m.	A	161.400	74.960	-1.440	53.56
		B	159.480	72.080	+2.560	54.81
		C	158.480	76.520	+2.020	51.72
		D	183.520	80.240	+0.720	56.28
Sept. 1	5:30 a. m.	A	170.400	76.320		55.21
		B	157.240	67.720		56.67
		C	165.280	73.840		55.27
		D	187.760	80.080		57.35
	11:30 a. m.	A	164.560	73.960	-2.360	55.56
		B	158.080	68.880	+1.160	56.42
		C	166.720	75.440	+1.600	54.75
		D	186.080	76.960	-3.220	58.64
Sept. 2	5:30 a. m.	A	184.280	76.880		58.28
		B	170.040	70.560		58.56
		C	173.600	74.880		56.87
		D	196.760	81.000		58.83
	11:30 a. m.	A	164.560	76.040	-0.840	53.79
		B	159.960	70.640	+0.080	55.84
		C	166.720	77.920	+3.040	53.26
		D	182.480	77.880	-3.120	57.32

Fruit Studies. Due to the limited leaf area on the untreated vines, many of the berries were exposed to the direct rays of the sun and received considerable sunburn injury. All of the fruit on these vines was a pale greenish-yellow color, while that on all watered vines possessed a healthy, green color. The berries on the shaded vines were not sunburned but otherwise resembled those on untreated vines.

By August 3, some of the berries on the untreated vines, as on all untreated vines, were developing some purple color. Again this color was limited to only a few berries in each bunch rather than to entire bunches. The first ripe berries on the shaded vines appeared on August 6, three days later than on the untreated vines. On August 11, the watered vines produced the first ripe berries, and two days later the shaded-and-watered vines had done the same. The ripening of these few berries was not followed by a normal ripening of the remaining fruit on any of the vines; so this difference probably would be secondary to any differences in uniformity and time of ripening of the remaining fruit. However, this difference of only a few days might be an indication of the chronological order of ripening of the remaining fruit of the four plots.

The vines in the shaded-and-watered plot had produced such new growth that many of the secondary shoots produced unseasonable but otherwise normal flowers which blossomed by August 10. This condition probably resulted from the vines' having broken a dormant or semi-rest period which had developed due to the drouth conditions previous to the first application of water. These blossoms remained on the shoots for some time but made no further development, probably because they were not fertilized.

Although some of the berries began to ripen as early as August 3, a large per cent of the fruit on all vines remained green and showed no further signs of ripening by September 8. On the night of September 8, a severe hailstorm caused such damage that all leaves on the unprotected vines were shattered and torn until the vines were almost completely defoliated. Considerable injury also was found on the canes, and all unbagged fruit was bruised or knocked to the ground. In nearly every case the bags were torn and much of the fruit within was bruised and split. The bags had provided some protection for the fruit and some of it still might have been used had not the vines been defoliated. With the leaf area reduced to practically nothing and the tendency of the fruit to remain green beyond the time of normal ripening, all further work with the fruit was discontinued.

The vines beneath the lath shades had been so protected that, although the leaves were considerably torn and damaged, a large per cent of them were still intact and might continue to function and thereby permit the ripening of the fruit. Practically no injury was found on those canes and most of the bags and fruit were not injured. The shades had so deflected the hailstones and reduced their velocity and the thick canopy of leaves on shaded-and-watered vines had so protected the underlying leaves and fruit that the injury was considerably less than that on the unprotected vines. Although some new growth had occurred between the time of the hailstorm and the time the photographs were made, the same relative differences between the plots may be seen by comparing the conditions found in figures 9 to 11 inclusive.

The limited amount of fruit remaining on the shaded-and-watered vines remained green until the week of October 1 when it showed definite signs of ripening. Although the assumption is on a very small amount of material, it appears that shading-and-watering permitted the fruit to ripen but delayed it for at least a month. The fruit on the shaded vines had only a slight tendency to ripen during the latter part of September. At the time of the hailstorm, the fruit on untreated vines showed no further signs of ripening and, judging by results in other vineyards, it would have remained green.

Although these observations are from very limited sources, it appears that any practice which tends to prevent a reduction in leaf area tends to increase the chances for ripening.

As shown in table 19, the average weight of 20 berries from untreated vines was 34.98 grams as compared with 39.42 for berries from shaded vines, 38.35 for those from shaded-and-watered vines, and 40.04 from watered vines. The specific gravity varied so little that it was insignificant; so the berries from shaded vines were 12.69 per cent larger than those from untreated vines. The berries from watered vines were 17.35 per cent larger, while those from shaded-and-watered vines were only 9.34 per cent larger than berries from untreated vines. It may be supposed from these results that the berries on the untreated vines remained somewhat small due to a limited and decreasing leaf area and supply of water. The berries on shaded vines may have grown larger because the leaves were protected somewhat. The berries on watered vines may have been the largest because of the new growth of leaves which offset the loss by injury. The berries on shaded-and-watered vines showed the least increase in size over the untreated in spite of the outstanding increase in leaf area and decrease in injury. It may be possible that such excessive growth occurred on these vines that the fruit was in part deprived of nutrients.

Table 19. Effects of different treatments on size and specific gravity of berries.

Treatment	Average weight of 20 berries gms.	Average displacement	Specific gravity	Percentage increase in size over untreated
Untreated	34.98	34.3	1.028	
Shaded-and-watered	38.35	37.8	1.015	9.34
Shaded	39.42	38.9	1.011	12.69
Watered	40.04	39.50	1.014	17.35

Comparative Growth of Vines. As shown in table 20, the untreated vines produced an average of 567.0 grams of new wood while the shaded vines produced an average of 715.9 grams. This represents an increase of 26.3 per cent over that of the untreated vines, but because of such variation in growth of the vines under the same treatment, this was found to be not significant statistically. Since no shoot growth occurred on the shaded vines after the shades were erected, the difference in growth is due to factors other than shading. The watered vines produced an average of 1083.8 grams for an increase of 91.2 per cent over that of untreated vines. The shaded-and-watered vines produced the greatest growth with an average of 1300.2 grams or a 129.3 per cent increase over that of the untreated vines. There was a significant increase in growth on all watered vines over the unwatered, due directly to the application of water. It is doubtful whether the shade above the one watered plot caused any significant increase in growth over that of the watered vines.

All unwatered vines in this experiment produced a sufficient number of desirable canes to permit the usual method of pruning with little difficulty. A large per cent of the canes on all watered vines, on the other hand, were undesirable because of their excessive growth. These "bull" canes had many lateral branches and were much too long and too large to be of optimum size. This condition made pruning more difficult and no doubt would cause undesirable conditions for fruiting the following year.

Table 20. Weight of pruning wood on treated vines.

Plot	Vine	Weight of new wood gms.	Average to vine gms.
Untreated	10	602	
	11	369	
	12	606	
	13	691	
Total		2268	567.0 ±119.7
Shaded	10	603	
	11	695	
	12	649	
	13	916.5	
Total		2863.5	715.9 ±127.9
Watered	4	1080	
	5	1137	
	6	993.5	
	7	1125	
Total		4335	1083.8 ±53.6
Shaded-and-watered	4	1473	
	5	1308	
	6	1231	
	7	1189	
Total		5201	1300.2 ±108.6

CONCLUSIONS

The number of shoots and bunches of fruit were limited in proportion to the number of buds left at pruning time. On vines pruned to 30 buds, there were fewer but larger shoots than on vines with 40 or 60 buds. Thus on severely pruned vines the total vegetative growth was greater in proportion to the number of buds than that on less severely pruned vines. Larger berries were found on the more severely pruned vines but they were not sufficiently larger to offset the decrease in number of bunches. Thus at the expense of some fruit, greater vegetative growth and consequently greater vigor is obtained by more severe pruning. Following and during unfavorable seasons, this practice is advisable in order that vines may recover and be prepared for high production during favorable years. Thirty buds were more nearly optimum than 40 or 60 during extremely hot dry years, but this number should be increased somewhat during normal years in order to maintain a balance between vegetative growth and fruit production.

The intense heat and drouth produced certain undesirable results on Concord vines. Growth was stopped, severe leaf injury resulted, and the fruit failed to ripen. A partial shading of the vines reduced the leaf injury, but did not cause any new growth or any visible change in the green fruit. The application of three inches of water to vines at ten-day intervals resulted in a significant increase in growth as well as a reduction in leaf injury equal to that by shading, but did not affect the ripening of the fruit. The use of both shade and water resulted in increased growth, and a greater reduction in leaf injury than either shading or watering alone. Indications of complete ripening occurred about six weeks after the normal date for Concord.

The moisture in untreated soil was only slightly above the wilting coefficient. Watering resulted in a considerable increase in soil moisture. Each shaded plot contained only slightly more moisture than the corresponding unshaded plot.

Leaf injury was peculiar in that small dead areas appeared on individual leaves and increased in size until entire leaves were dead. Increasing injury resulted in only a slight decrease in moisture until the leaf was practically dead. The comparative moisture contents of the leaves from day to day remained fairly constant regardless of treatment and temperature fluctuations. Apparently the increased rate of transpiration, in addition to growth, prevents the increase in moisture content of the leaves supplied with water.

The fact that either shading or watering reduces the amount of leaf injury indicates that both the intense heat and sunshine and the lack of moisture cause injury to Concord leaves. It was impossible, however, to isolate their effects and thereby determine which of the two conditions is responsible for the greater injury.

ACKNOWLEDGMENT

The writer wishes to express his appreciation for the valuable suggestions and kind assistance of Prof. R. J. Barnett, under whose direction these investigations were made. Credit also is due Dr. Wm. F. Pickett and Dr. G. A. Filinger for their helpful suggestions and advice in the preparation of this thesis.

Figure 3. Lower view of lath shade placed to obstruct hottest rays of sun.

Figure 4. Lath shade as viewed from above.

Figure 5. Untreated vine with increasing leaf injury - July 27, 1936.

Figure 6. Shaded vines as they appeared three weeks after beginning of treatment.

Figure 7. Watered vine showing less defoliation than untreated vines three weeks after beginning of treatment.

Figure 8. Shaded-and-watered vines showing dense foliage due to reduced leaf injury and new growth, July 27, 1936.

Figure 9. Defoliated condition of untreated vines three weeks after severe hailstorm of September 8, 1936. Meager new growth has appeared.

Figure 10. Shaded vines in foreground showing less defoliation by hail than unprotected vines, background.

Figure 11. Difference in shaded-and-watered vines, front, and untreated, background, due to protection by shade and by thick canopy of leaves resulting from treatment.

LITERATURE CITED

1. Clark, J. H.
Some effects of pruning on grape production. Proc. Amer. Soc. Hort. Sci. 22: 80. 1925.

2. Colby, A. S. and Tucker, L. R.
Some effects of severity of pruning on growth and production in the Concord grape. Ill. Agri. Exp. Sta. Bul. 393: 179-206. 1933.

3. Cross, Frank B. and Webster, James E.
Physiological studies of uneven ripening of Concord grapes. Proc. Amer. Soc. Hort. Sci. 32: 361-364. 1935.

4. Meyer, Arthur.
Notes on the ripening of Concord grapes under drouth conditions. Unpublished manuscript, Hort. Dept. library, Kansas State College. 7 p. 1934.

5. Partridge, N. L.
Further observations on the fruiting habits of the Concord grape. Proc. Amer. Soc. Hort. Sci. 19: 180-183. 1922.

6. Partridge, N. L.
Profitable pruning of the Concord grape. Mich. Spec. Bul. 141. 12 p. 1925.

7. Partridge, N. L.
Relation of blossom formation in the Concord grape to current season conditions. Proc. Amer. Soc. Hort. Sci. 26: 261. 1929.

8. Partridge, N. L.
How to grow the best type of fruiting canes on Concord grape vines. Del. State Agri. Bd. Quar. Bul. 22(5): 60-66. 1932.

9. Schrader, A. L.
Growth studies of the Concord grape.
Proc. Amer. Soc. Hort. Sci. 20: 116-127. 1923.

10. Schrader, A. L.
The effect of fruiting on the shoot growth of the Concord grape. Proc. Amer. Soc. Hort. Sci. 27: 170. 1930.

11. Schrader, A. L.
Further studies on the effect of fruiting on the shoot growth of the Concord grape. Proc. Amer. Soc. Hort. Sci. 28: 137-142. 1931.