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TISSUE ANALYSIS AS AN INDEX OF THE NUTRITIONAL STATUS OF ARIZONA VINEYARDS

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A DIGEST-SUMMARY FOR THE GRAPE GROWER

Because plant tissue analysis is employed as an indication of the nutrient status of a crop, a study of this type was conducted on grape vineyards in Maricopa, Pima, and Yuma counties. One particular reason for conducting the study was to compare Arizona and California vineyards.

This report shows that the grape vine is a rather self-sufficient plant. The vineyards in the Salt River Valley show a high percentage of nitrogen, phosphorus, and potassium in the plant tissue even where no commercial fertilizer has been used. This is not true for the Yuma mesa area where the plant tissue from the vineyards is much lower in nitrogen and phosphorus. On the Yuma mesa, the tissue analyses indicate a need for nitrogen and phosphorus fertilizers.

It was not possible to get yield data on vines from which the plant tissue samples were taken. Therefore there is a possibility that fruit quality, maturity, or yield may be improved by use of commercial fertilizer despite the high nutrient level of the vineyards in the Salt River Valley.

TISSUE ANALYSIS AS AN INDEX OF THE NUTRITIONAL STATUS OF ARIZONA VINEYARDS

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INTRODUCTION

There are several methods for determining the nutritional requirements and nutritional status of a crop among which plant tissue analysis is important. Plant tissue tests may be used quantitatively in the laboratory or qualitatively in the field. There is a wide variation in the chemical composition, or nutrient content, of different plant tissues so obviously the whole plant is not suited for a foliar diagnosis. The greatest concentration of nitrogen, potassium, and phosphorus is in the youngest leaves and the actively growing terminus of the stem; and inasmuch as the nutrient percentages vary with the age of the leaf, the first step in a foliar diagnosis is to determine where the sample should be taken to give the most useful information.

NUTRIENT REQUIREMENT OF GRAPES

The quantity of nitrogen, phosphorus, and potassium needed for average grape production, that is, the quantity sold from the land in fruit, is very small in comparison with most other crops. This is illustrated in table 1 where the nutrient content of several fruit crops is given (5). Higher or lower yields will remove nutrients roughly in proportion to the variation in yield from that given in the table.

The data show that if the leaves and prunings are returned to the soil the nitrogen, phosphorus, and potassium required to produce a grape crop is less than for the other fruit crops. In other words the grape crop does not demand heavy fertilization. There is evidence of this in the fact that many profitable vineyards are located on hillsides and on soils with a low productivity rating.

Table 1. Nutrient content of some fruit crops

Crop	Yield per acre	Part of crop	Nitrogen lbs. N	Phos. acid lbs. P_2O_5	Potash lbs. K_2O
Grape	4 tons	fruit	10	6	20
		leaves	15	4	15
Oranges	600 boxes	fruit	65	23	105
		leaves	25	7	25
Apples	400 bu.	fruit	20	7	57
		leaves, wood	10	3	18
Peaches	500 bu.	fruit	30	15	55
		leaves, wood	55	10	45

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There is only a limited amount of information available in the literature on the fertilization of grapes. Alderfer and Fleming (1) state that nitrogen has been the factor of prime importance in the fertilization of grapes in Pennsylvania. Faurot (2) found that the general trend, in Missouri, is for nitrate of soda to increase both yield of fruit and weight of prunings. Jacob and Winkler (12) state that nitrogen is the best, perhaps the only, fertilizer needed for most California vineyards. Economically favorable responses to phosphorus and potassium are rare in California. Jacob and Winkler recommend 40 to 80 pounds nitrogen per acre if a test shows that nitrogen is needed.

Ulrich (8) obtained a potash response in a vineyard located in a gravelly loam soil in northern California on application of potash sulfate at the rate of one pound per vine. A phosphate test in another vineyard failed to show any increase in yield of fruit. In this experiment radiophosphorus was used (9) and the tagged phosphate was detected in the leaves within 40 hours after application.

On a sandy soil in Southwest Michigan, Partridge and Veatch (4) obtained a response in vine growth and yield of fruit from nitrogen fertilization and a small additional response in yield from phosphorus and potassium. They made one observation which may be significant; the yield was notably influenced by the initial vigor of the vines.

This review of the literature indicates that nitrogen fertilizers are the most profitable in practically all grape growing areas. In view of the growing importance of the grape industry in Arizona, this study was conducted to determine the nutrient level of vines in Arizona vineyards.

SELECTION OF TISSUE SAMPLE

Nutrient level studies conducted in California vineyards by Ulrich (8,9,10,11) have shown that it is desirable to select the fifth or sixth leaf, namely the first dark green leaf from the tip of the cane, for nutrient tests. He refers to this leaf as the most recently matured. In order that our results might be comparable with analyses of grape leaves from California vineyards, this method of selecting leaf samples for our study was adopted. Each sample consisted of 100 leaves from approximately 100 vines and in taking the succession of samples they were taken from the same vines each time. The blades were separated from the petioles in the field. The leaves were washed with water, and dried in a forced draft oven at 70° before grinding. The blades and petioles were analyzed separately.

Time of sampling. If a single foliar analysis is to be useful in a nutrient diagnosis it is necessary to have data on leaf analysis for several periods during the growing season and to select the most indicative sampling date. Ulrich (11) suggests the mid-period of berry development for the late maturing varieties in California--that is, in late June or early July. If any deficiencies are in evidence at this time, there will still be time to make a fertilizer application. Both the varieties grown in Arizona are early maturing grapes and are harvested in late June or early July.

Chemical analysis. The leaf samples were analyzed for total nitrogen, nitrate nitrogen, phosphorus, potassium, calcium, and ash. The unit dry weight of leaves was also determined.

STUDIES CONDUCTED IN 1950

For 1950 the study was limited to a single vineyard as several of the recently planted Cardinal vineyards were not sufficiently advanced at this time. Leaf samples were taken on April 20, May 18, May 31, June 14, and July 14 from 6 blocks of Thompson seedless and 4 blocks of Cardinals. Each series of samples was taken from the same vines and from both sides of the trellis. The analyses of these samples are given in table 2.

In considering analyses made at successive periods during the growing season there are several things that must be recognized. The number of leaves per vine and per cane increase at a very rapid rate from early emergence to fruit harvest - April to late June or early July. Therefore the quantity of nutrient is actually greater per vine even though the analysis of the recently matured leaf may show a reduction percentagewise at successive dates. The location of the most recently matured leaf which represents the April sample is not the same as those taken on later dates. The distance from the apical tip may be the same but that from the trunk of the vine increases with each successive sample.

Total nitrogen. Of the three major plant nutrients, nitrogen is most often deficient in Arizona soils and nitrogen fertilizers usually give a profitable response for most crops. A high nitrogen percentage in the vegetative part of the plant, during the flowering stage, is essential for a maximum set of fruit. All the analyses given in table 2 show a high nitrogen level. For both the blades and the petioles there is a percentage decrease between April 20 and May 16. Between May 16 and June 14 the percentages are somewhat irregular but there is a significant drop between June 14 and July 14. This period represents the final period of fruit maturity as the grapes had been harvested when the leaf samples were taken on July 14.

The total nitrogen percentage is considerably higher in the blades than in the petioles. It is of interest that the average nitrogen percentage is higher in the Thompson seedless variety than in the cardinal for both the petioles and the blades. There is some evidence in the leaf analyses that the nitrogen percentage in both the blades and the petioles, for the cardinal variety, was increased by fertilization but there was no increase for the Thompson seedless.

A comparison of the nitrogen percentage in the petioles and blades from this Arizona vineyard, with those of Ulrich (10) for a California vineyard is of interest. Ulrich analyzed leaf samples from a fertilizer experiment in which both yield and sugar content of the fruit were increased by nitrogen fertilization. The variety was Mataro, a late maturing variety, and the experiment was conducted in southern California. The nitrogen percentages in both blades and petioles are higher for the leaves from the Arizona vineyard than for the leaves from the Mataro variety which had been fertilized with nitrogen.

Table 2. Percent total nitrogen and nitrate nitrogen in blades and petioles, air-dry material, 1950**

Block No. and variety*	Apr. 20	May 16	May 31	June 14	July 14	Apr. 20	May 16	May 31	June 14	July 14
	Percent Nitrogen in blades					Percent Nitrate nitrogen in petioles				
2T	5.06	3.30	3.52	3.74	3.04	.735	.267		.200	.100
3T	4.98	3.35	4.05	2.18	3.00	.615	.250		.050	.167
4T	4.68	3.48	3.79	3.27	3.01	.600	.217		.230	.100
6T	5.10	2.80	3.80	3.47	2.21		.233		.133	.057
9T		2.20	2.68	3.67	3.06		.250		.133	.060
10T		3.50	3.64	3.23	2.67		.280		.133	
1C	5.14	3.36	3.80	3.19	1.59	.484	.167		.082	.133
5C	4.54	3.22	3.73	3.42	2.36		.117		.170	.233
8C	3.82	2.99	3.19	3.19	2.73	.133	.072		.150	.050
7C	4.40	2.50	3.10	3.04	1.53	.234	.073		.047	.200
	Percent Nitrogen in petioles									
2T	2.30	0.94	1.32	1.14	0.96					
3T	2.12	1.20	1.50	1.85	1.19					
4T	2.07	1.10	1.71	1.64	0.83					
6T	2.27	1.12	1.62	1.46	1.22					
9T		1.26	1.13	1.75	0.83					
10T		1.26	1.83	1.08	1.18					
1C	1.89	1.19	1.43	1.05	0.87					
5C	1.48	1.16	1.55	1.27	0.73					
7C	1.43	0.70	1.21	1.46	0.86					
8C	1.85	1.08	1.85	1.26	0.67					

* Letters refer to variety, T for Thompson seedless, C for cardinal

** Fertilizer treatments as follows: 2, no fertilizer; 3, 90 lbs. P_2O_5 per acre; 4, 82 lbs. N and 90 lbs. P_2O_5 per acre; 5, no fertilizer; 6, 300 lbs. 14-7-0 per acre; 7, no fertilizer; 8, no fertilizer; 9, no fertilizer; 10, 100 lbs. potash sulfate per acre.

It seems fair to conclude that the vines in this Arizona vineyard were well supplied with nitrogen. The irrigation water used here contains 21 pounds nitrate nitrogen per acre-foot of water.

Nitrate nitrogen. For the cardinal variety the nitrate was higher at the first two sampling dates where the vines were fertilized with 300 pounds of 14-7-0 per acre. This may be evidence of a difference in nitrogen requirement or uptake between the cardinal and Thompson seedless varieties.

The nitrate nitrogen percentage is considerably higher in the petioles than in the blades particularly during the early part of the season. At no time was there any evidence of nitrate accumulation in the blades and the quantity present was quite consistent and low throughout the season. In agreement with the total nitrogen percentage there is a rapid decrease in the nitrate percentage in the petioles between April 20 and May 16. After this date the changes are variable and of less magnitude.

At all sampling dates the nitrate percentages in the Arizona leaf samples were greater than for the leaf samples representing the Mataro variety referred to above. This was true even for the Mataro vines which had been fertilized with nitrogen.

The Thompson seedless leaf samples have a higher nitrate percentage than the cardinal leaves.

Potassium. The leaf analyses given in table 3 show that the higher percentage of potassium is in the petiole and the change, as the season advanced, was largely in the petiole. There was a rapid decrease in potassium percentage, in the petioles, from early leaf emergence to July 14 when the fruit had been harvested. During the same period there was only a minor change in the potassium percentage of the blades where it was initially lower. The demand and transport of potassium continued throughout the period of fruit development and after the fruit had been harvested the demand leveled off.

There is no material difference between the potassium percentages for the cardinal and Thompson seedless varieties.

For a comparison with the potassium values given in table 3 there are leaf analyses from two California vineyards available in the literature (8). These are the late maturing varieties Petite Sirah, grown in northern California, and the Mataro, grown in southern California under conditions somewhat similar to Arizona.

In the Petite Sirah there was a significant increase in yield of fruit from an application of one pound potash sulfate per vine and also an increase in the potassium percentage of the petioles. For the Mataro variety there was no increase in yield of fruit and only a minor increase in potassium percentage of the petioles. Compared to petioles and blades of leaves from the Arizona vineyard, the potassium percentages are considerably lower for both the Petite Sirah and Mataro varieties, and about equal to the potassium percentage of the Petite Sirah leaves from potassium-fertilized vines.

Table 3. Percent total phosphorus and potassium in blades and petioles, air-dry material, 1950**

Block No. and variety*	Apr. 20	May 16	May 31	June 14	July 14	Apr. 20	May 16	May 31	June 14	July 14
	Percent Phosphorus in blades					Percent Potassium in blades				
2T	.47	.34	.41	.40	.30	1.70	1.81	1.49	1.09	0.94
3T	.47	.34	.43	.40	.29	1.53	1.34	1.35	1.42	0.99
4T	.43	.30	.39	.34	.26	1.50	1.24	1.12	1.37	0.99
6T	.48	.33	.39	.33	.23	1.42	1.28	1.32	1.18	0.87
9T		.27	.39	.36	.30		1.32	1.24	1.16	0.69
10T		.39	.30	.39	.30		1.32	1.44	1.17	0.96
1C	.48	.37	.33	.28		1.53	1.50	1.24	1.15	1.88
5C	.36	.22	.20	.30	.18	1.71	1.37	1.33	1.44	0.89
8C	.40	.26	.30	.27	.18	2.10	1.30	1.35	1.22	1.01
7C	.44	.26	.28	.27	.17	1.50	1.39	1.47	1.48	1.14
	Percent Phosphorus in petioles					Percent Potassium in petioles				
2T	.58	.37	.50	.52	.45		3.66	2.59	2.31	2.38
3T	.57	.44	.55	.44	.40	3.80	3.67	3.02	3.16	2.06
4T	.46	.34	.41	.27	.27	3.48	3.25	2.85	3.09	1.56
6T	.56	.38	.55	.29	.38		3.32	3.02	3.44	2.10
9T		.46	.52	.47	.54		3.86	2.88	2.53	1.39
10T		.50	.61	.54	.36		3.93	3.06	2.59	1.70
1C	.49	.32	.35	.26	.22	4.24	3.92	3.55	2.63	
5C	.31	.30	.36	.39	.20	3.85	3.46	3.64	3.34	1.70
7C	.41	.31	.31	.28	.22	4.26	3.84	2.88	1.99	1.39
8C	.51	.30	.29	.23	.19	3.70	3.46	3.09	3.09	1.85

* Letters refer to variety, T for Thompson seedless, C for cardinal

** Fertilizer treatments as follows: 2, no fertilizer; 3, 90 lbs. P_2O_5 per acre; 4, 82 lbs. N and 90 lbs. P_2O_5 per acre; 5, no fertilizer; 6, 300 lbs. 14-7-0 per acre; 7, no fertilizer; 8, no fertilizer; 9, no fertilizer; 10, 100 lbs. potash sulfate per acre.

The leaf samples from the Arizona vineyard which had been fertilized with 100 pounds potash sulfate per acre showed a slight increase in potassium percentage in the petioles.

Phosphorus. The phosphorus percentages in the blades and petioles (table 3) decreased very rapidly between April 20 and May 16. Between May 16 and June 14 there was little change. The phosphorus percentages did not show the great differences noted for nitrogen and potassium. It is of interest that the phosphorus percentages of both the blade and petiole are higher for the leaves from the Thompson seedless vines than of the cardinal vines. Also, the difference between the blade and petiole of the Thompson seedless variety is greater.

For comparison of the phosphorus level with leaves from California vineyards data are available for the Burgher variety (9). The analyses are of leaves from a phosphate fertilizer test in which there was a slight increase in phosphorus percentage of the petioles but no increase in yield of fruit. The phosphorus percentages of California-grown leaves are all lower than the percentages in leaves from the Arizona vines; that is, the phosphorus percentage of petioles from unfertilized vines in Arizona is higher than the phosphorus percentage in the petioles of leaves from the Burgher vines which had been fertilized with 400 pounds P_2O_5 per acre.

In this Arizona vineyard there were vines that had been fertilized with superphosphate and others which had been fertilized with 14-7-0 commercial fertilizer, as well as unfertilized vines. The data in table 3 do not show any appreciable difference in phosphorus percentage of blades or petioles between fertilized and unfertilized vines.

1941 samples. In connection with the high nutrient level shown by the analyses given in tables 2 and 3, it is of interest to present the analyses of samples taken from this same vineyard in 1941. The data are given in table 4 and represent the average of 14 samples of Thompson seedless leaves. This analysis represents the whole leaf: blade and petiole.

Table 4. Analysis of leaf samples from one vineyard of Thompson Seedless Grapes. Average of 14 Samples. Taken in 1941. Percent dry weight

Ash	7.28	Nitrogen (Total)	4.78	Calcium	0.81	Manganese	.018
Phosphorus	0.58	Potassium	1.36	Magnesium	0.22	Iron	.031

It is evident from a comparison of these data with the 1950 analyses in tables 2 and 3 that the nutrient level in this vineyard has continued high over an extended period.

STUDIES CONDUCTED IN 1951

For the 1951 season the study was extended to include one vineyard in Pima County, six in Maricopa County, and four on the Yuma mesa. The analyses of the blades and petioles are given in tables 5 and 6 as percentage air-dry material. The fertilizer program followed by most of the growers was obtained and are given as a footnote to the table.

Nitrogen. In general the total nitrogen values for all the vineyards in Maricopa County are in agreement with those obtained for a single vineyard in 1950. The Pima County vineyard shows the highest early season nitrogen percentage for both blades and petioles.

The leaves from the Yuma mesa vineyards are the lowest and show evidence of a nitrogen deficiency. The soil there is a very sandy type and the leaf analyses indicate that some emphasis on amount and method of nitrogen fertilization will be necessary for adapting the best fertilizer program. Despite the fact that all the vineyards on the Yuma mesa were fertilized with some nitrogen the values obtained from the leaf analyses are definitely the lowest of the three areas in the State where grapes are grown commercially.

Reference to the fertilizer applied to the various vineyards, as shown in table 5, most of them were fertilized with both nitrogen and phosphorus. For the vineyards in the Salt River Valley there is no evidence that nitrogen fertilizer affected the nitrogen percentage in the leaves. The data show an early reduction in nitrogen percentage of the blades during the period between early emergence and fruit maturity. Changes in nitrogen percentage in the blades, for the two varieties, are similar. The significant data are those showing the difference in nitrogen percentage of the petioles, namely low early nitrogen and little change in the petioles of the Thompson seedless variety. This is the same vineyard from which the 1950 leaf samples were taken.

Nitrate nitrogen. The nitrate values for both blades and petioles, for the 1951 samples are shown in table 5. They show a widely variable nitrate percentage between the different vineyards. Whether this is due to a rapid fluctuation in the nitrate in the petiole, to environment, or to available nitrogen in the soil, cannot be stated at this time. The nitrate percentages in the blades are apparently of little or no value but are presented in the table to show the low nitrate level in the blades at all stages of growth.

The low nitrate percentage in the petioles from the Yuma vineyards is of special interest and more so than the total nitrogen percentages. It is equal to the nitrate nitrogen percentage of the blades. This is further evidence of the need for emphasis on nitrogen fertilization of grapes grown on this sandy soil.

The nitrate analyses indicate that the need for nitrate nitrogen exists during the early stages of fruit development. After the fruit had been harvested the nitrate percentage dropped to a minimum in the blades which is equivalent to the low nitrate in the blades.

Table 5. Percent total nitrogen and nitrate nitrogen in blades and petioles, 1951, air-dry basis

Vineyard No. Location*	Apr.24	June 1	July 20	Sept.25	Apr.24	June 1	July 20	Sept.25
	Nitrate(N) cardinal blades				Total nitrogen(N) cardinal blades			
1-P	.017	.017	.056	.022	4.45	3.84	3.19	2.89
1-P	.017	.017	.030	.022	4.95	3.93	3.40	2.48
2-M	.020	.043	.027	.024	3.88	3.32	3.03	----
2-M	.027	.033	.033	.028	4.02	3.06	3.25	2.59
2-M	.022	.047	.023	.024	4.04	3.50	3.18	3.06
3-M	.020	.030	.017	.022	3.02	2.56	3.07	3.39
3-M	.042	.030	.034	.022	4.06	3.85	3.45	3.00
4-M	.025	.033	.022	.022	3.28	3.68	3.10	3.50
5-M	.042	.027	.017	.030	4.04	2.86	3.42	3.16
6-M	.017	.023	.022	.020	4.06	3.44	2.74	3.08
6-M-A	.033	.030	.020	.018	3.34	3.00	3.15	3.08
7-M	---	.023	.020	.018	---	2.50	3.40	3.08
8-Y	---	.040	.021	----	---	2.48	2.65	1.92
	Nitrate(N) cardinal petioles				Total nitrogen(N) cardinal pets			
1-P	.500	.508	.120	.080	2.02	1.32	0.84	1.10
1-P	.433	.434	.133	.076	2.32	1.85	0.84	1.20
2-M	.300	.067	.056	---	1.76	0.97	0.96	----
2-M	.250	.087	.076	.018	1.64	0.91	0.95	0.92
2-M	.257	.150	.056	.048	1.75	1.15	0.99	0.83
3-M	.183	.067	.034	.092	1.50	1.05	0.96	1.20
3-M	.300	.175	.073	.076	1.43	1.22	0.92	1.15
4-M	.350	.047	.100	.028	1.78	1.12	0.95	1.04
5-M	.132	.167	.133	.064	1.48	1.57	0.96	0.93
6-M	.250	.040	.048	.044	2.14	0.91	0.87	0.83
6-M-A	.217	.030	.060	.042	1.58	0.75	1.40	0.96
7-M	.100	.167	.035	.032	1.73	1.28	0.98	1.10
8-Y		.060	.031	.022	----	0.91	0.80	0.84
	Nitrate(N) Thomp. blades				Total nitrogen(N) Thomp. blades			
2-M	.012	.027	.066	.024	4.15	3.65	3.43	2.79
2-M	.047	.027	.043	.026	4.16	3.16	3.03	3.08
9-Y	----	.023	.018	.017	----	2.88	2.06	2.32
10-Y	----	.032	.019	.024	----	2.79	2.18	1.27
11-Y	----	.027	.020	.020	----	2.70	1.85	3.18
	Nitrate(N) Thomp. Petioles				Total nitrogen(N) Thomp. Petioles			
2-M	.283	.150	.232	.084	1.39	1.36	1.31	1.22
2-M	.317	.070	.232	.088	1.39	1.08	1.12	1.22
9-Y	---	.016	.029	.026	---	0.97	0.87	1.00
10-Y	---	.040	.030	.022	---	0.94	0.87	1.14
11-Y	---	.023	.029	.028	---	0.98	0.70	0.83

* M refers to Maricopa County, Y to Yuma, and P to Pima. Fertilizer applied to 1 one lb. amm. sulp. per vine, 2 - 200 lbs. 14-7 to cardinals and 300 lbs. per acre to Thompsons, 3 - 200 lbs. per acre 14-7, 5 - 300 lbs. 16-20 per acre, 6 - 300 lbs. 10-11 per acre, 6A - 200 lbs. 27-8 per acre, 8 - 200 lbs. ammonia gas per acre, 9 - 16 tons manure and 200 lbs. amm. gas per acre, 10 - 40 lbs. nitrogen and 25 lbs. phos. acid per acre, 11 - one lb. amm. nit. per acre.

Phosphorus. The phosphorus data obtained from the analyses of the 1951 samples from the Salt River Valley are in close agreement with the values which were obtained from the study of the single vineyard in 1950. They show a rapid increase in phosphorus percentage for both the blades and the petioles during the period of fruit development. The leaf samples from the vineyards on the Yuma mesa are definitely the lowest in phosphorus. This is true for both blades and petioles. In the Salt River Valley there is a higher percentage of phosphorus in the Thompson seedless than in the cardinal.

Potassium. It is interesting to note that the potassium percentage in the leaves from the Yuma mesa vineyards is in rather close agreement with the values obtained for leaves from the Salt River Valley vineyards. This is true for both blades and petioles. The potassium percentage for the Thompson seedless variety is less than for the cardinal variety particularly in the petioles. An important observation is the lesser variation in potassium percentage in the blades than in the petioles, for both varieties. This shows that petiole analysis is more informative of potassium level in grapes than blade analysis.

Relation to maturity. Maturity studies were conducted in six cardinal vineyards in the Salt River Valley in 1951 (3). In this study, vineyards 4 and 6 matured first and 3 and 7 last as measured by the percentage soluble solids in the fruit. The tissue analyses do not show any correlation between these data and early or late maturity.

Analysis, per leaf basis. All the leaf analyses given in table 4 were calculated to a per-leaf basis. On this basis the changes during the season were very similar to the percentage basis. The greatest change in unit leaf weight, that is the fifth leaf which was taken for analytical samples, is during the first two months following emergence.

STUDIES CONDUCTED IN 1952

At the request of one of the growers the study was continued another season in order to make a comparison with two Thompson seedless vineyards in southern California. The Arizona vineyards included in the study for 1952 were one cardinal vineyard in Pima County, six cardinal and one Thompson seedless vineyards in Maricopa County, one cardinal and one Thompson seedless vineyard on the Yuma mesa, and two Thompson seedless vineyards in the Coachella Valley in California.

The analyses of the leaf samples taken in 1952 are given in figures 1, 2, 3, 4, and 5 together with dates on which the samples were taken. No commercial fertilizer was used on the vines from which the samples were taken in Maricopa County. The curves for these represent averages of all vineyards. On the Yuma mesa the cardinal vineyard was fertilized with 30 pounds of nitrogen per acre and the Thompson seedless vineyard with one pound of 16-20 ammonium phosphate per vine. For the vineyards in the Coachella Valley one vineyard was fertilized with $1\frac{1}{2}$ pounds of 4-10-10 per vine, in January, and the other was not fertilized. The Yuma vineyard is located on a sandy soil and the Coachella Valley one on a heavy soil.

Table 6. Percent total potassium and phosphorus in blades and petioles, 1951, air-dry basis

Vineyard No. Location*	Apr.24	June 1	July 20	Sept.25	Apr.24	June 1	July 20	Sept.25
	Phosphorus(P) cardinal blades				Potassium(K) cardinal blades			
1-P	.52	.40	.27	.30	1.52	1.49	1.35	1.44
1-P	.65	.40	.33	.27	1.72	1.63	1.32	1.31
2-M	.37	.29	.29	---	1.14	1.42	1.00	---
2-M	.37	.35	.29	.23	1.33	1.49	1.28	1.07
2-M	.42	.37	.29	.26	1.10	1.46	1.28	1.62
3-M	.36	.35	.26	.31	1.05	1.17	1.10	1.07
3-M	.42	.35	.37	.34	0.89	1.70	1.49	1.33
4-M	.40	.32	.25	.28	1.29	1.45	1.25	1.21
5-M	.44	.26	.31	.26	1.58	1.42	1.38	1.37
6-M	.46	.24	.21	.21	1.37	1.10	1.28	1.27
6-M-A	.41	.29	.29	.21	1.39	1.10	1.00	1.41
7-M	---	.38	.34	.26	---	1.45	1.67	1.26
8-Y	---	.17	.19	.16	---	1.56	1.21	1.08
	Phosphorus(P) cardinal pets				Potassium(K) cardinal pets			
1-P	.57	.32	.22	.25	4.48	4.47	2.92	3.70
1-P	.72	.58	.28	.28	4.20	4.20	2.98	2.92
2-M	.32	.23	.22	---	4.14	2.77	2.92	----
2-M	.32	.26	.25	.34	4.95	3.30	2.78	2.69
2-M	.50	.32	.29	.28	2.92	3.52	3.62	3.14
3-M	.32	.25	.15	.36	3.45	2.98	2.35	3.04
3-M	.37	.28	.35	.41	3.62	4.15	3.73	3.36
4-M	.38	.23	.20	.37	4.23	3.74	2.98	2.89
5-M	.35	.23	.24	.31	3.42	3.58	3.70	3.65
6-M	.40	.17	.15	.41	4.20	2.06	2.06	3.21
6-M-A	.37	.20	.23	.25	3.97	1.77	2.38	3.46
7-M	.40	.33	.33	.39	5.75	3.90	3.30	3.18
8-Y	---	.19	.17	.16	----	4.30	3.62	2.42
	Phosphorus(P) Thomp. blades				Potassium(K) Thomp. blades			
2-M	.44	.46	.35	.30	1.26	1.46	1.10	0.93
2-M	.44	.39	.35	.34	1.05	1.39	1.00	1.03
9-Y	.27	.27	.20	.27	----	1.52	0.57	0.75
10-Y	---	.35	.28	.26	----	1.35	1.10	1.07
11-Y	---	.27	.17	.10	----	1.60	0.60	1.17
	Phosphorus(P) Thomp. petioles				Potassium(K) Thomp. petioles			
2-M	.57	.57	.44	.39	2.95	2.38	2.17	1.29
2-M	.54	.48	.44	.41	3.13	2.63	1.50	1.84
9-Y	---	.21	.20	.29	----	2.13	0.80	1.07
10-Y	---	.29	.24	.37	----	2.56	1.53	1.49
11-Y	---	.21	.16	.31	----	3.09	0.80	1.42

* M refers to Maricopa County, Y to Yuma, and P to Pima. Fertilizer applied to 1 one lb. amm. sulp. per vine, 2 - 200 lbs. 14-7 to cardinals and 300 lbs. per acre to Thompsons, 3 - 200 lbs. per acre 14-7, 5 - 300 lbs. 16-20 per acre, 6 - 300 lbs. 10-11 per acre, 6A - 200 lbs. 27-8 per acre, 8 - 200 lbs. ammonia gas per acre, 9 - 16 tons manure and 200 lbs. amm. gas per acre, 10 - 40 lbs. nitrogen and 25 lbs. phos. acid per acre, 11 - one lb. amm. nit. per acre.

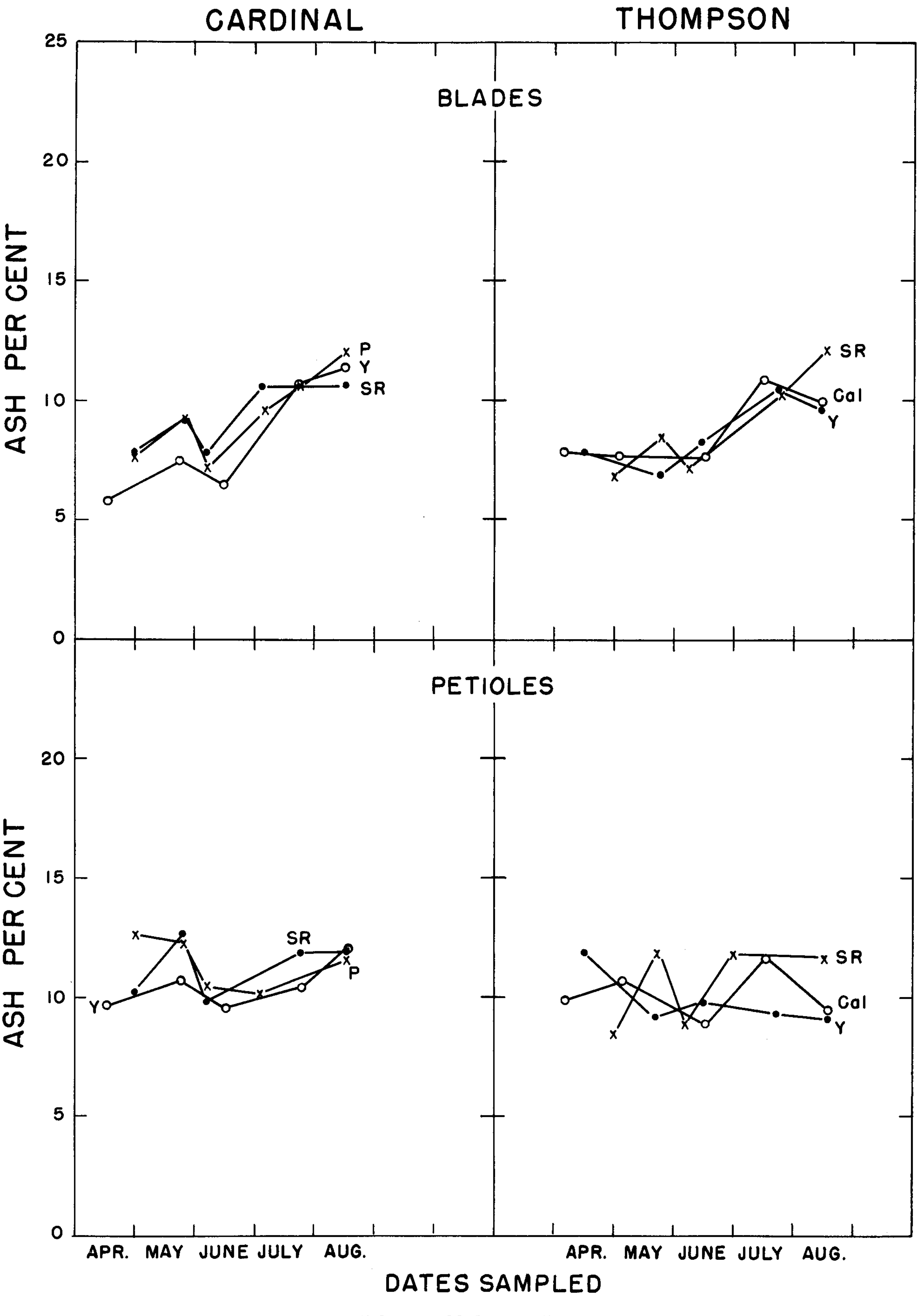

Figure 1. Percent ash in grape petioles and blades, cardinal and Thompson seedless varieties, 1952. SR, Salt River Valley; P, Pima County, Y, Yuma mesa; Cal., Coachella Valley.

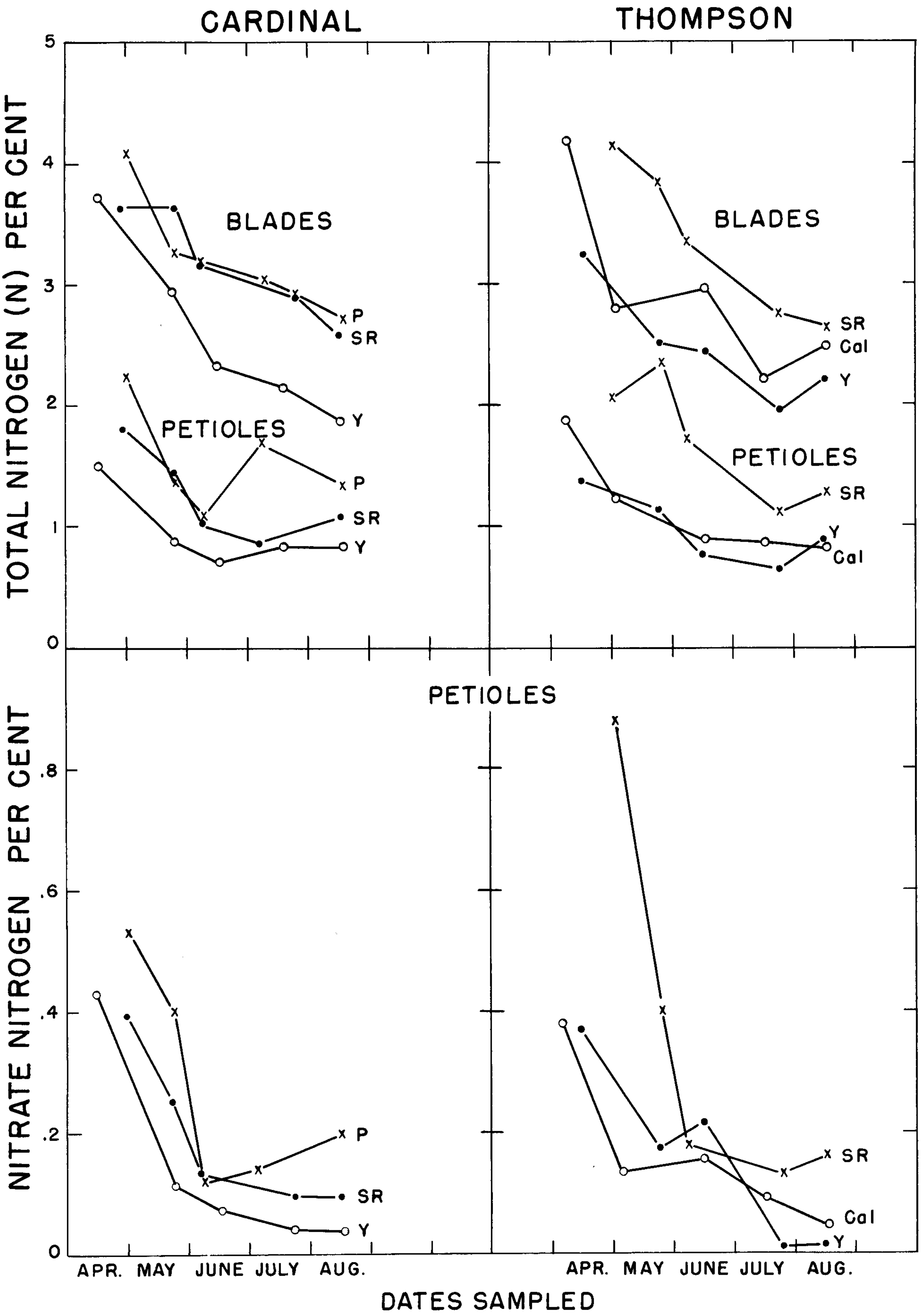

Figure 2. Percent total nitrogen and nitrate nitrogen in grape petioles and blades, cardinal and Thompson seedless varieties, 1952. SR, Salt River Valley; P, Pima County; Y, Yuma mesa; Cal., Coachella Valley.

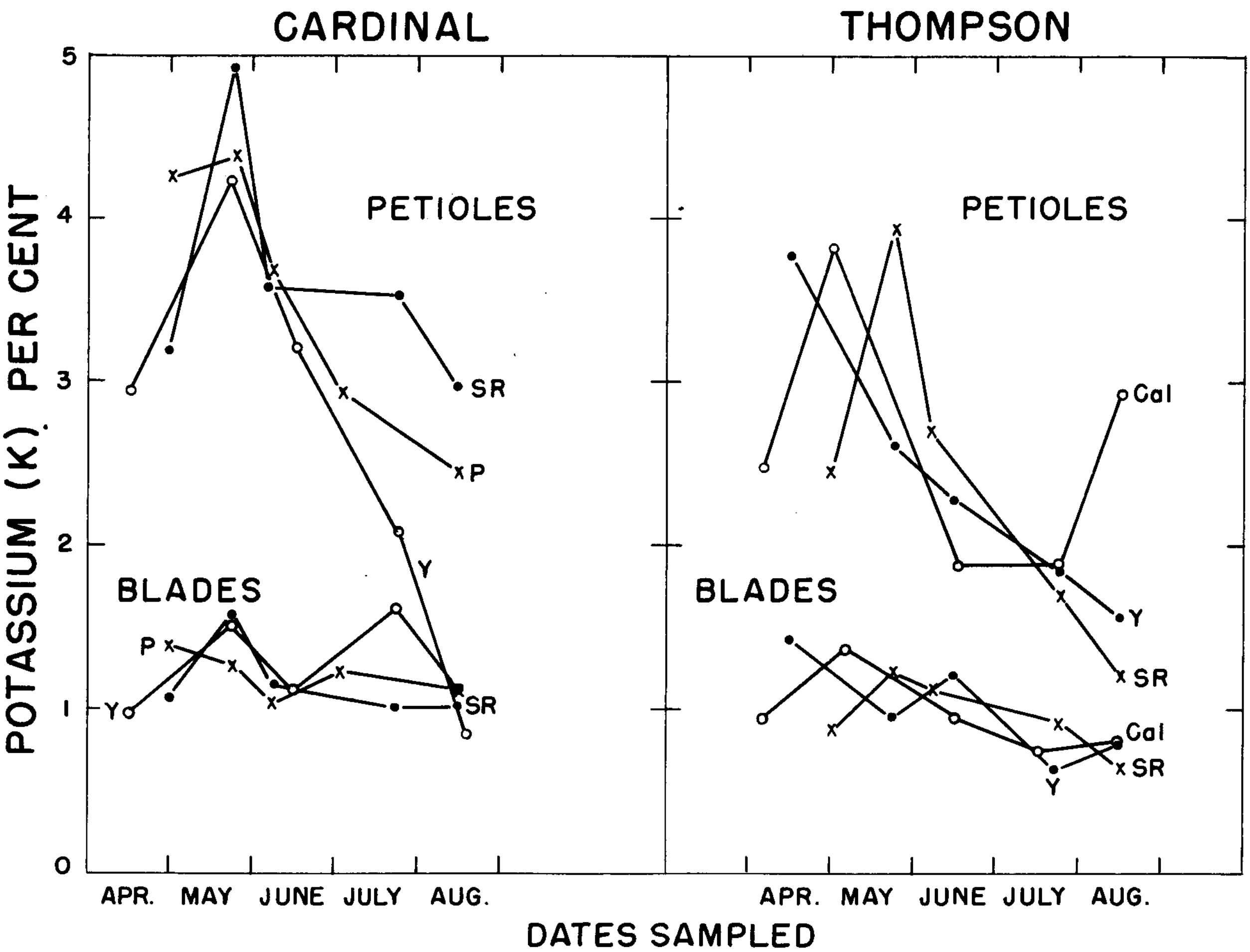

Figure 3. Percent potassium in grape petioles and blades, cardinal and Thompson seedless varieties, 1952. SR, Salt River Valley; P, Pima County; Y, Yuma mesa; Cal., Coachella Valley.

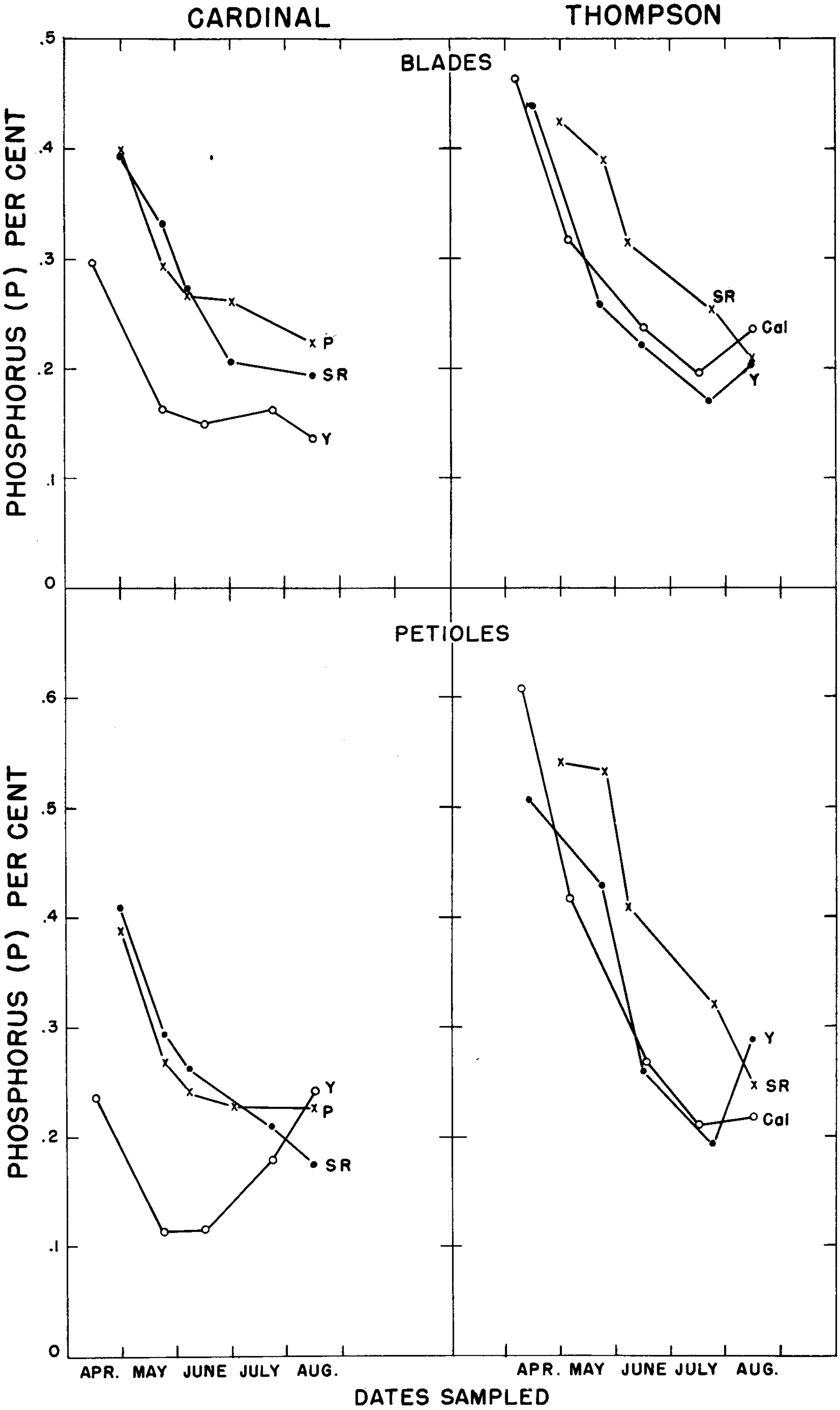

Figure 4. Percent phosphorus in grape petioles and blades, cardinal and Thompson seedless varieties, 1952. SR, Salt River Valley; P, Pima County; Y, Yuma mesa; Cal., Coachella Valley.

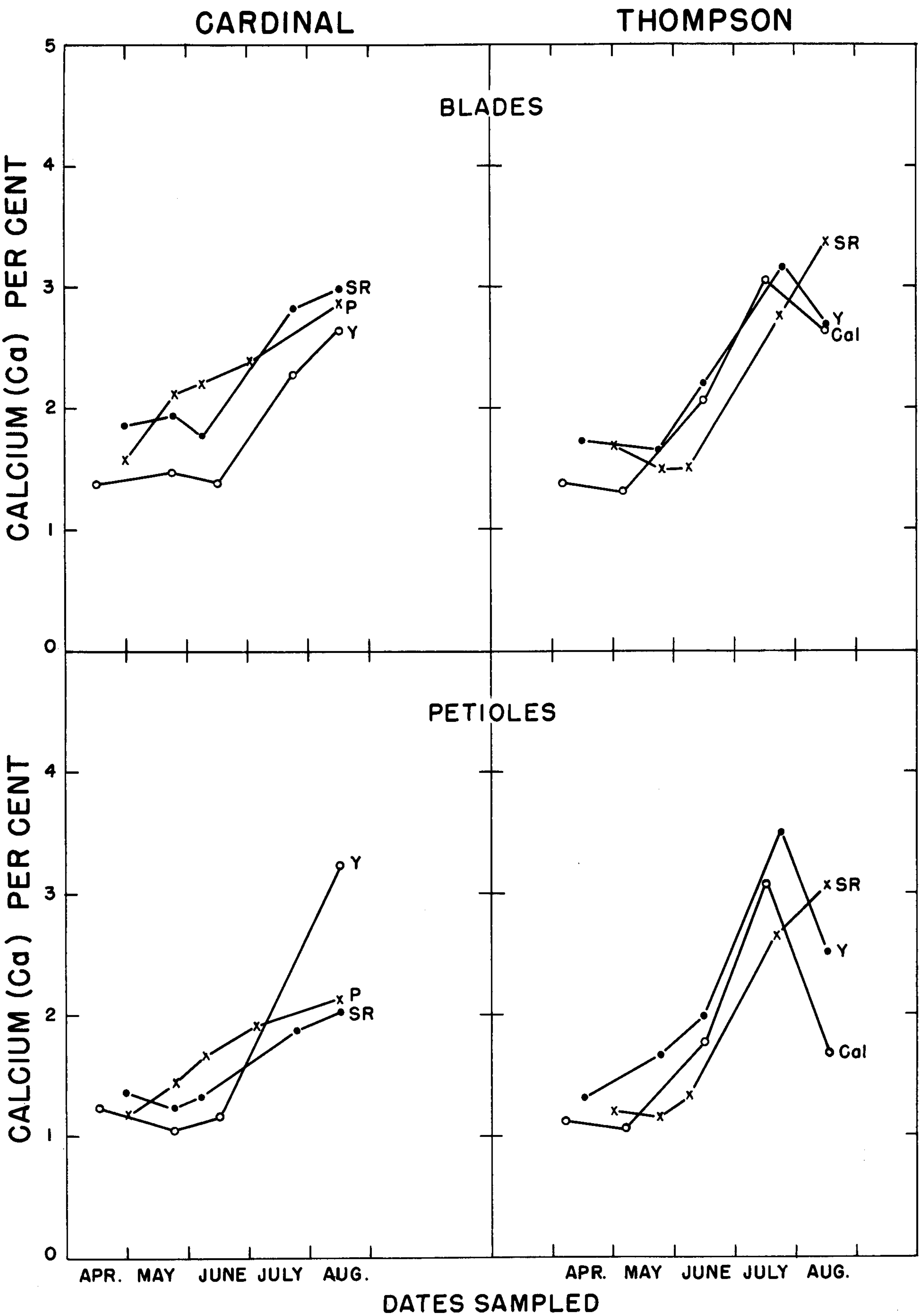

Figure 5. Percent calcium in grape petioles and blades, cardinal and Thompson seedless varieties, 1952. SR, Salt River Valley; P, Pima County; Y, Yuma mesa; Cal., Coachella Valley.

The curves in figures 1, 2, 3, 4, and 5 represent average values for each variety and each district. The 1952 analyses were more complete than for the other two seasons and included ash, total nitrogen, nitrate nitrogen, phosphorus, potassium, and calcium.

Ash. The percentage mineral matter (ash) in leaves and petioles is given in figure 1. The ash is definitely higher in the petioles than in the blades during the early period of fruit production - early April to mid-June. The percentage of ash in the blades increases consistently as the season advances and at the end of the season the percentage is about equal in blades and petioles. The values for the petioles vary somewhat during the season but on the whole are quite constant throughout the period of fruit development.

The seasonal changes in ash percentage of both blades and petioles is very different from the changes in nitrogen, phosphorus, and potassium for the fifth leaf from the tip of the cane which was sampled for this study. There is no particular difference between the percentage of ash in leaves from Arizona and Coachella vineyards.

Total nitrogen. The total nitrogen percentage for the cardinal variety is about the same for the 1952 Pima and Maricopa County samples while the leaves from the Yuma mesa vineyard were the lowest, for both blades and petioles.

The data for the Thompson seedless variety give a comparison between Coachella Valley and two areas in Arizona. The Yuma leaf samples, both blades and petioles, are again the lowest in nitrogen percentage and at all sampling periods the samples from Maricopa County are the highest. This is significant because all the 1952 samples from Maricopa County were from unfertilized vines while one of the Coachella Valley samples and both Yuma mesa samples were from vines that had been fertilized with nitrogen. The leaf samples from the Coachella vineyard, located on the heavy soil and not fertilized with nitrogen, were consistently higher in nitrogen percentage than the samples from the vineyard which had been fertilized with 1½ pounds 4-10-10 per vine. It is of interest in this connection that the latter vineyard is consistently one of the first to attain maturity in the southwest.

Nitrate nitrogen. The nitrate values show the characteristic rapid reduction as the season advances with most of the decrease occurring in April and May. Again the leaves from the Yuma mesa vineyards are materially lower in nitrate than those from the vineyards in Pima or Maricopa Counties. This is particularly true for the Thompson seedless samples during the early part of the season. The data of particular interest to Arizona growers is the fact that the nitrate percentage for the Coachella vineyard drops to a minimum most quickly and continues to remain very low for the rest of the period of fruit production.

Potassium. In the petiole samples, where the higher potassium percentage exists, the tendency was for a rise between early April and early May after which there was a decrease. This indicates that withdrawal of potassium for fruit development begins at a later date than the demand for nitrogen. The data show that the petiole analysis is preferable to the blade analysis for diagnosing the potassium nutrient level. The potassium level in the cardinal variety is higher than for the Thompson seedless. There is also some difference in the potassium percentages in the blades of the two varieties. It is quite constant throughout the season for the cardinal but there is a slight decrease for the Thompson seedless as the season advances.

Phosphorus. There is a very definite difference between cardinal and Thompson seedless varieties, with respect to phosphorus percentage, in that the blades and petioles of the latter are higher. Again the leaf samples from the Yuma mesa are the lowest, particularly for the cardinal variety. The samples from the Coachella vineyards are the highest in initial, or early season, phosphorus percentage and the decrease during the period of fruit development is greater.

The difference between the cardinal and Thompson seedless varieties grown on the Yuma mesa is of special interest. The cardinal vineyard was fertilized with nitrogen only while the Thompson seedless vineyard was fertilized with 16-20 ammonium phosphate. The higher phosphate level in both the blades and the petioles of the latter clearly show the need for phosphorus fertilization on this soil.

Calcium. The data obtained from the analysis of the leaves for calcium content are given in figure 5. These data show that calcium percentage increases as the season advances through the period of fruit development. In this way the grape leaves are similar to citrus leaves. This increase in calcium percentage with age of leaf holds for both the blades and the petioles. There is no great difference in the calcium levels for leaves from the several districts from which samples were taken. Neither is there any great difference in the calcium percentages of the blades and petioles of the two grape varieties.

Maturity. The data, compared to that of maturity studies for 1952 (6), failed to show any correlation between leaf analyses and date at which soluble solids in the fruit indicated maturity.

Leaf size. There is a difference between the leaf size of the Coachella Valley samples and those from the Arizona Thompson seedless vineyards (table 7). The recently matured fifth leaf for the Salt River Valley vineyards decreases in size during the early part of the season but begins to increase at about the mid-period of berry production. In contrast the leaves from the Coachella vineyards decrease quite consistently from early emergence to maturity in mid-June. In other words the Arizona vineyards are more vegetative at the mid-period of berry production. Judging maturity on the basis of leaf size the leaves from the Salt River Valley vineyards do not begin to show maturity until about August 1 while the Coachella valley vineyards show a much earlier and more rapid progress toward the leaf size which indicates maturity.

Analysis per leaf basis. The chemical analyses of both blades and petioles were calculated to a per leaf basis to determine whether leaf size might change the interpretations made from the data on a percentage basis. On this basis the data show a lower nitrate nitrogen, total nitrogen, and potassium content for the leaves from the Coachella valley vineyards. The phosphorus is higher at early emergence but lower for the latter part of the period of fruit production.

Table 7. Air dry weight of blades and petioles as grams per 100 leaves, 1952

Location	Variety	Weight of blades in grams				
Pima Co.	Cardinal	61(May 1)	74(May 21)	60(June 9)	43(July 3)	30(Aug. 15)
Maricopa Co.	Cardinal	66(May 1)	88(May 21)	73(June 9)	62(July 21)	52(Aug. 15)
Maricopa Co.	Thompson	73 "	74 "	90 "	84 "	39 "
Yuma mesa	Cardinal	69(Apr. 17)	63(May 22)	47(June 16)	37(July 24)	42(Aug. 15)
Yuma mesa	Thompson	73 "	51 "	69 "	84 "	53 "
Coachella	Thompson	78(Apr. 7)	57(May 7)	52(June 18)	55(July 14)	40(Aug. 15)
		Weight of petioles (dates same as above)				
Pima Co.	Cardinal	8.1	9.4	9.2	5.6	2.9
Maricopa Co.	Cardinal	13.6	11.2	9.5	7.2	7.0
Maricopa Co.	Thompson	9.6	7.6	8.2	6.7	3.7
Yuma mesa	Cardinal	10.0	7.1	3.9	2.6	5.5
Yuma mesa	Thompson	7.8	2.4	4.2	6.0	3.7
Coachella	Thompson	9.6	5.3	3.9	3.5	2.0

SUMMARY

The research presented in this bulletin represents a three year study of the nutrient level in Arizona grape vineyards as measured by leaf-tissue analysis. For the third year, leaf samples from two vineyards in the Coachella Valley, California, were also analyzed. The leaf samples were taken at several dates, beginning at the time of early leaf emergence and continuing until after the fruit had been harvested, in order to learn the seasonal changes in nutrient level. Similar studies on grapes and on other crops have shown a significant difference between the nutrient level in blades and petioles. In this investigation all the leaf samples were separated into blades and petioles and they were analyzed separately.

The results indicate that the petiole analysis is more indicative of the nutrient status despite the fact that the blade constitutes the bulk of the leaf. For the grape leaf samples collected in 1952 from six vineyards in the Salt River Valley the blades represented 83 percent, by dry weight, of the whole leaf. Furthermore the changes which take place in nutrient percentages, in the petioles during the period of fruit development, are of greater magnitude. This is particularly true for potassium and nitrate nitrogen. A major seasonal change in phosphorus occurs in both the blade and the petiole but the latter is slightly greater. The change in calcium percentage is about the same for both blade and petiole while the change in ash percentage is largely in the blade.

In making a foliar diagnosis of the nutrient level of a crop it is important to know the time or the stage of growth at which tissue samples are most indicative. The information gathered in this three year study of Arizona vineyards indicates that if a single sample is to be used it should be taken about May 15 and that the petiole analysis will yield more reliable information than the blade.

The most important information derived from this investigation is that which shows the present nutrient status of Arizona vineyards. Most of this information is favorable. The data of special interest are those which compare the analyses of leaves from the Yuma mesa vineyards and those in Pima and Maricopa counties.

The total nitrogen analyses, for the three years, are in good agreement for nitrogen percentage in both blades and petioles, although there is some difference in the ratio between blade and petiole percentages. The decrease in nitrogen percentage during the period of fruit development also shows a consistent trend for all three years.

The analyses of the leaf samples from Pima and Maricopa counties, for the entire three year period, show that the vines are very well supplied with nitrogen even where no nitrogen was applied as fertilizer. There is no evidence of a deficiency at any period during the season: in cases where it was possible to make comparisons between fertilized and unfertilized vines, there was little or no difference in nitrogen percentage in the leaves.

For the Yuma mesa vineyards a different situation exists, namely the nitrogen percentages are very much lower than for the other vineyards. In fact the data show a nitrogen deficiency in these vineyards and indicate that in the sandy soil existing there, split applications of nitrogen may be necessary. This conclusion is based on the fact that the nitrogen percentage in leaves was lower than for the other two areas in the State despite the fact that the vines had been fertilized with nitrogen.

The nitrate data for the three year period are in good agreement considering the rapid change that takes place in the nitrate content of the petioles. The principal agreement is in the rate at which nitrate decreases and the period at which this rapid decline takes place. There is evidence that the demand for nitrate, for the period following June 1, does not permit a nitrate accumulation in the petioles. In some cases there was an increase in nitrate percentage late in the season. This indicates an accumulation in the petiole after the fruit had been removed from the vine. The nitrate values for the leaves from the Yuma mesa vineyards give further evidence of the low nitrogen level there.

Throughout the three-year period the potassium percentages were quite consistent in the blades. There is a trend toward a slight decrease as the season advances. The major change took place in the petioles, where potassium percentages were somewhat irregular during the early period of leaf emergence; but after June 1 the percentages decreased rapidly. Apparently the period following June 1 represents the greatest demand for potassium for fruit development. The potassium level appears to be favorable in the Yuma mesa vineyards in contrast to the nitrogen and phosphorus levels.

The distribution of phosphorus between blades and petioles did not show so wide a variation as for potassium, total nitrogen, and nitrate nitrogen. In other words the demand for phosphorus during the fruiting period is reflected in both the blades and petioles. For the three-year period over which leaf samples were taken in Maricopa County vineyards both petioles and blades were higher in phosphorus percentage in the Thompson seedless than in the cardinal variety. There was a major difference between phosphorus percentage of leaves from the Yuma vineyards and those from the other two areas. Also there is less difference between the petioles and the blades. There is quite conclusive evidence in this study that phosphorus fertilizer should be used in the fertilizer program on the Yuma mesa. It is shown in figure 4 that the cardinal variety, which was not fertilized with phosphate, is very low in phosphorus percentage while the Thompson seedless vineyard, which was fertilized with phosphate, is about the same as for the samples from the Thompson seedless vineyard in Maricopa County.

In presenting the leaf tissue analyses for 1950 a comparison was made between the analyses of leaves from the Arizona vineyard and the analyses of leaves from some California vineyards which were available in the literature. This comparison showed that the nutrient level, as measured by leaf analysis, was much higher for the Arizona vines. However the data available in the literature for the California vineyards were for late maturing varieties.

The question arose regarding a comparison between the same varieties grown in both states. On request of one of the growers, arrangements were made to collect leaf samples from two Thompson seedless vineyards in the Coachella Valley in California during the 1952 season. The conditions in this valley are somewhat similar to those in Arizona. Also the vineyards there are of particular interest to the Arizona growers who compete with the Coachella Valley growers in the sale of their grapes.

On the whole the blade and petiole analyses shown in figures 1, 2, 3, 4, and 5 are in good agreement with the leaves from Arizona vineyards. There are some differences which may be of interest. The initial decrease in nitrogen and phosphorus percentages, for blades and petioles, and for nitrate in the petioles, is definitely more rapid for the samples from the California vineyards. Also the phosphorus percentage was initially higher.

There is some evidence in the data for the several grape growing areas, that plant vigor at the early leaf emergence period may be an important factor in early maturity and quality. One of the vineyards in the Coachella valley from which leaf samples were analyzed has a consistant record for early maturity and quality. In this vineyard the fertilizer is applied in January although leaf emergence does not start until about mid-March or the first of April. As shown by our data on analysis and dry weight of leaves, this practice was reflected in large early leaves and higher initial nitrogen and phosphorus percentages.

In general it can be stated that plant tissue tests on Arizona vineyards show a high nutrient level for all the vineyards except those growing on the Yuma mesa. In this area there is quite positive evidence of a need for both nitrogen and phosphate fertilizers. Since quality, earliness, or other factors are often sought in a crop like grapes the point should be stressed that while the plant tissue studies do show a high nutrient level it is entirely possible that fertilizer should be used, particularly nitrogen, in many of the vineyards of the State, for obtaining such effects as are represented in better quality.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the cooperation of the growers, the help of C. W. Van Horn who took most of the samples in the Yuma area, and J. R. Furr, U. S. Date Station, Indio, Calif. who samples the vineyards in the Coachella Valley.

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APPENDIX

In response to a request from the growers a number of soil samples from California and Arizona vineyards were analyzed and also a number of water samples representing the water used for irrigation. The soil samples were taken in 1952 and for the Arizona vineyards two samples were taken. One of these was taken in April and the other in August after the fruit had been harvested. The soil analyses are given in table 8 and the water analyses in table 9.

Table 8. Analyses of soils from Arizona and California vineyards

Location or vineyard no.	pH	p.p.m. Sol. Salts	Phosphate p.p.m. PO_4	Nitrate p.p.m.N
		CALIFORNIA		
Coachella	7.5	560	32	48
Acampo	7.6	275	42	13
DiGeorgio 1	8.1	220	28	8
DiGeorgio 36D	8.1	195	26	11
Youngstown	6.6	130	48	11
Woodbridge	7.2	240	35	12
Victor	6.8	145	26	10
Borrego 1	8.0	340	28	14
Borrego 2	8.3	125	39	12
		ARIZONA		
1, April	7.5	2075	8	30
1, August	7.5	2180	8	40
2, April	7.8	170	5	14
2, August	7.8	180	4	10
3, April	8.2	565	6	8
3, August	8.2	450	5	5
4, April	8.1	465	5	11
4, August	8.0	490	7	10
5, April	8.2	360	4	6
5, August	8.1	465	6	5
6, April	8.2	525	5	8
6, August	8.2	535	5	8
7, April	8.4	530	10	5
7, August	8.5	575	5	8
8, April	7.7	495	10	10
8, August	7.8	510	11	11
10, April	7.8	430	11	10
10, August	7.9	480	10	12

There is a very pronounced difference in these soil analyses. On the whole the Arizona soils are higher in salinity. The principal difference is in the available phosphate content which is considerably higher in the California soils. Perhaps we should limit the comparison to the single soil from Coachella Valley. This was taken from the vineyard which was previously mentioned as one which has a good record for quality and earliness. In this connection the higher available nitrogen and phosphate, as compared to the Arizona soils may be significant.

Table 9. Chemical analyses of irrigation waters used on California and Arizona vineyards

Location or vineyard no.	Bicarb. HCO_3	Chloride Cl	Sulfate SO_4	Calcium Ca	Magnesium Mg	Sodium Na	Total salts
			CALIFORNIA				
			Parts per million				
Coachella	110	70	71	53	4	57	376
All. Amer. Canal	161	104	308	158	11	74	816
DiGeorgio 1	266	52	107	75	11	94	644
DiGeorgio 36D	276	48	117	83	8	104	690
Woodbridge	159	18	tr.	30	4	33	252
Victor	173	32	10	53	8	22	312
Youngstown	98	20	tr.	23	8	13	171
Acampo	237	32	35	53	15	43	427
Borrego 1	142	122	805	218	19	307	1749
Borrego 2	151	114	598	233	11	173	1402
			ARIZONA				
2	190	88	tr.	60	4	56	405
3	194	28	tr.	60	11	10	326
5	149	32	20	15	4	65	588
8 and 10	188	98	350	90	30	142	898

Except for the water in the Borrego Valley there is no great difference in the quality of the waters being used in the two states.