Amer J Enol & Vitic, 1987, Vol. 38, #4, pp. 260-264

Effects of Cultivar, Maturity, Cluster Thinning, and Excessive Potassium Fertilization on Yield and Quality of Arkansas Wine Grapes

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A study was established on Cabernet Sauvignon and Gewurztraminer, two French-American hybrid cultivars (Seyval and de Chaunac), and a Vitis aestivalis cultivar (Cynthiana) to determine their yields and quality responses to thinning to one cluster per shoot before anthesis and a high level of potassium fertilization (2.7 kg K_2SO_4/vine). The relationships between the development of percent soluble solids and the increase in juice pH values, as well as the decrease in fruit acidity, were examined for each of these five cultivars. Gewurztraminer produced juice with the highest pH and lowest acidity, and Cynthiana produced fruit with the most acceptable pH and highest acidity values. The application of K fertilization and cluster thinning increased K and pH in fruit from some cultivars; however, these effects were not observed in all cultivars.

Optimal soluble solids, acidity, and pH of must have been established for the production of wine in California (1). Musts used for white table wines should have 19.5% to 23.0% soluble solids, acidity (expressed as tartaric acid) exceeding 7.0 g/L, and pH below 3.4. Red wines need soluble solids between 20.5% and 23.5%, acidity greater than 6.5 g/L, and pH less than 3.5. Little information is available on fruit quality of wine grapes grown in Arkansas (23,27,28).

High pH and low acidity affect wine quality of some cultivars in warm climate regions (2,8,10,16,23,25,26). The pH level influences red wine color (14,29,30), microbial spoilage (1,15,24), taste (1,3), protein stability (19), potassium bitartrate stability (3), calcium tartrate stability (4), and SO_2 efficacy (1). Wines with pH 3.6 or greater are considered to be unstable (1). Adjustments in pH are often more difficult to make than adjustments in other quality parameters, such as sugar and acid content (16).

Potassium fertilization is recommended for prevention of K deficiency (9); however, it has also caused unacceptably high pH and other quality problems in grape juice (18,20,21,22) and wine (5,13,24).

Cluster thinning is a method for stabilizing vine yields and grape quality, particularly in French-American hybrid cultivars (6,7,11,12,17), but accumulated data on cluster thinning show inconsistent effectiveness, and the practice has not been tested under Arkansas growing conditions. Therefore, additional knowledge concerning the effects of potassium fertilization and cluster thinning on fruit quality would be desirable.

The objective of this study was to measure the effects of cluster thinning and potassium fertilization on yield and quality of various species and cultivars of wine grapes grown in Arkansas. Also, the relationships between the development of percent soluble solids and changes in pH and acidity in these cultivars were observed.

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Presented at the 37th Annual Meeting of the American Society for Enology and Viticulture, Anaheim, CA (June 1986).

This research conducted at the University of Arkansas, Fayetteville, AR.

Manuscript submitted for publication 8 April 1986.

Materials and Methods

This study was initiated in 1981 in mature, commercial vineyards near Altus, Arkansas. All vines were own rooted and grown in a fine sandy loam. Data were recorded in 1981, 1982, 1983, and 1984 for the *Vitis vinifera* L. cultivar Gewurztraminer and the French-American hybrid cultivar Seyval. In 1982, 1983, and 1984, the *V. aestivalis* Michaux. cultivar Cynthiana, the *V. vinifera* L. cultivar Cabernet Sauvignon, and the French-American hybrid cultivar de Chaunac were added to the study. *Vitis vinifera* and French-American hybrid cultivars were trained to a bilateral cordon and spur pruned to 70 nodes each year. Cynthiana was trained to a six-arm Kniffin system and pruned to 70 nodes each year. All vines were spaced 1.83 m within the row and 3.66 m between rows. All other cultural, insect, and disease practices were standard and were conducted according to Arkansas Agricultural Experiment Station recommendations.

The four treatments established in this study were: (1) no additional K fertilization, not thinned (control); (2) no additional K fertilization, cluster-thinned; (3) additional K fertilization, not thinned; and (4) additional K fertilization, cluster-thinned. Cluster-thinned vines were thinned to leave the basal cluster on each shoot prior to anthesis. Vines receiving additional K fertilization were each banded with 2.7 kg K_2SO_4 before budburst in addition to that applied by the commercial producer. Plots consisted of three vines separated by guard vines. Within each cultivar, the experiment was in completely randomized blocks with three replications.

Fruit samples were collected at three stages of maturity. For all cultivars except Cynthiana, these maturities represented soluble solids levels of approximately 14%, 16%, and 18%. For Cynthiana, the approximate soluble solids levels for the three sampling dates were 16%, 18%, and 20%. The samples consisted of three basal clusters, one cluster randomly selected from each vine in the plot. After the final fruit sample was collected, vines were harvested and individual yields recorded. The clusters were placed in polyethylene bags, covered with ice, and returned to the Department of Food Science, University of Arkansas, Fayetteville, where they were immediately frozen and stored at -23°C for later analysis.

Before analysis, the number of berries per cluster and individual frozen berry weight were determined. Samples were subsequently thawed overnight at 2°C, and, berries of the red grape cultivars were blended for 30 seconds in a Waring Blendor TM and placed in 250-mL beakers. A 5mL unheated portion of each sample was used to determine percent soluble solids in a Bausch and Lomb Abbe refractometer. Meanwhile, each beaker was covered with a watch glass, heated for one hour in a water bath (85°C), and cooled. Samples were then pressed by hand through four layers of coarse cheesecloth to separate pulp from juice.

Berries of the white grape cultivars were crushed in a Squeezo TM screw press and the juice collected into 250mL beakers. The percent soluble solids was determined using a Bausch and Lomb Abbe refractometer. Portions of all must samples were centrifuged for 10 minutes at 15 000 rpm to remove particulates before subsequent analysis.

For all grapes, the pH was determined with a glass electrode and a Corning (model 130) pH meter. The acidity of each sample was determined by diluting a 5-mL aliquot to ca 125 mL with deionized water and titrating to pH 8.4 with 0.1 N NaOH. The acidity is expressed as percent tartaric acid. Juice K was determined by atomic absorption with an Instrumentation Laboratories Inc. (model 251) atomic absorption/emission spectrophotometer.

Petiole samples for K analysis were collected each year at the first sampling date for fruit maturity. Samples were taken from the first healthy leaf distal to the last cluster on fruiting primary shoots. The petioles were separated from the blades, air-dried, ground in a micro Wiley mill to pass through a 40-mesh screen, and stored in tightly capped glass vials. Samples were digested using heat, H_2SO4_4 and H_2O_2, cooled to room temperature, filtered, and brought to volume with deionized water. Petiole K was determined by atomic absorption as discussed for juice K.

The data were first anaylzed using factorial analysis. Within a given year, the main effects were significant, but none of the interactions were significant. Since the most important information is the actual pH and juice K values, K analysis and the data from the final fruit sampling (harvest date) were analyzed using the treatments as individual means with each cultivar being analyzed separately. Means were separated by Duncan's multiple range test at the 5% level. The relationship between the development of soluble solids and the increase in pH and the decline in acidity were determined by linear regression analysis across all treatments and all sampling dates within each cultivar.

Table 1. Effects of potassium fertilization and cluster thinning on the yield, amount of K in petioles, and quality at harvest of five wine grape cultivars

Treatment	Yield (MT/ha)	Berries per cluster	Berry wt (g)	Petiole K (%)	Juice K (mg/L)	pH	Acidity (% tartaric)	Soluble solids (%)
Gewurztraminer (4-yr means)								
No K, not thinned	9.2b[z]	69b	1.27a	3.52a	2346a	4.16a	0.45a	18.7a
No K, cluster-thinned[y]	9.8b	79ab	1.34a	4.12a	2360a	4.19a	0.43a	18.3a
2.7 kg K_2SO_4/Vine, not thinned	12.3a	73b	1.36a	4.21 a	2557a	4.16a	0.43a	18.6a
2.7 kg K_2SO_4/Vine, cluster-thinned[y]	10.7ab	93a	1.26a	4.26a	2566a	4.21 a	0.45a	18.4a
Treatment x year	ns	ns	ns	ns	ns	ns	ns	ns
Cabernet Sauvignon (3-yr means)								
No K, not thinned	12.7a[z]	86b	1.28a	4.50c	3256c	3.70c	0.65a	19.Ob
No K, cluster-thinned[y]	11.1a	99ab	1.38a	5.55b	3577c	3.76b	0.61ab	19.4ab
2.7 kg K_2SO_4/Vine, not thinned	13.5a	81 b	1.17a	6.94a	4379b	3.83a	0.62ab	19.4ab
2.7 kg K_2SO_4/Vine, cluster-thinned[y]	10.9a	111 a	1.36a	7.16a	4954a	3.83a	0.60b	19.8a
Treatment x year	t	ns	ns	ns			ns	ns
Seyval (4-yr means)								
No K, not thinned	12.9az	122b	1.46b	1.39c	1741 b	3.57b	0.52a	17.8ab
No K, cluster-thinned[y]	13.8a	147a	1.59a	1.78b	1874b	3.62b	0.53a	18.5a
2.7 kg K_2SO_4/vine, not thinned	13.Oa	104c	1.61 a	1.86b	1870b	3.74a	0.51a	16.9b
2.7 kg K_2SO_4/Vine, cluster-thinned[y]	14.Oa	156a	1.63a	2.06a	2188a	3.79a	0.51a	17.6ab
Treatment x year	ns	ns	ns	ns	ns	ns	ns	ns
de Chaunac (3 yr. means)								
No K, not thinned	9.5a[z]	42b	1.65a	2.30b	2104a	3.64b	0.80a	19.1ab
No K, cluster-thinned[y]	8.9a	53ab	1.98a	2.52b	2005a	3.65b	0.77ab	19.8a
2.7 kg K_2SO_4/Vine, not thinned	9.2a	40b	1.82a	3.22a	2200a	3.71 a	0.75ab	18.1b
2.7 kg K_2SO_4/Vine, cluster-thinned[y]	8.7a	65a	1.86a	3.99a	2545a	3.73a	0.72b	18.8ab
Treatment x year	ns	ns	ns	ns	ns	ns	ns	ns
Cynthiana (3-yr means)								
No K, not thinned	8.2ab[z]	83a	1.10b	1.93c	3733c	3.51 b	1.20b	20.9a
No K, cluster-thinned[y]	7.8ab	92a	1.25a	2.35b	4075bc	3.54b	1.25ab	21 .1a
2.7 kg K_2SO_4/Vine, not thinned	9.8a	84a	1.11b	3.19a	4502ab	3.58b	1.29a	20.1a
2.7 kg K_2SO_4/Vine, cluster-thinned[y]	6.9b	92a	1.18ab	3.72a	4718a	3.67a	1.28ab	20.1 a
Treatment x year	ns	ns	ns	ns	ns	ns	ns	ns

[y] Vines thinned to one cluster (basal) per shoot.
[z] Means within each cultivar separated by Duncan's multiple range test at the 5% level.

Results and Discussion

Gewurztraminer: Gewurztraminer vines that received excessive K fertilization and were not cluster thinned produced higher yields than vines receiving no additional K fertilization (Table 1). Cluster thinning increased the number of berries per cluster in the additional K plots but did not increase berry weight. The increased berry set from cluster thinning resulted in comparable yields for the thinned and unthinned vines within a given fertilization treatment.

There were no effects from the treatments of petiole K, fruit K, pH, percent soluble solids, or acidity of Gewurztraminer (Table 1). Gewurztraminer produced fruit that was extremely high in pH and low in acidity regardless of the fertilization or thinning treatment. Previous studies have shown that Gewurztraminer produces fruit with high pH under Arkansas growing conditions (27,28).

Cabernet Sauvignon: Cabernet Sauvignon vines did not show a significant yield response to any of the treatments. Cluster thinning increased the number of berries per cluster in the K plots (Table 1). There was no effect from any of the treatments on berry weight. A significant year × treatment interaction showed that cluster thinning reduced yields only in the second year (1983) of the study (data not shown).

Excessive K fertilization of Cabernet Sauvignon increased petiole K, fruit K, and pH, and the cluster thinned vines with additional K fertilization produced fruit with the highest K levels (Table 1). Cluster thinning of vines receiving no additional K resulted in fruit with a slightly higher pH. The significant year × treatment interaction for both fruit K and fruit pH showed that additional K fertilization did not increase K or pH values as much during the first year of the study as during the final two years (data not shown). Fruit from vines receiving additional K and cluster thinning produced fruit with slightly higher percent soluble solids and lower acidity than observed in the other treatments. Cabernet Sauvignon vines appear to be very effective users of K and responsive to conditions that would create high levels of petiole and juice K with the expected increases in juice pH.

Seyval: Seyval vines did not show a significant yield response to any of the treatments. However, this French-American hybrid cultivar did show an increase in berries per cluster as a result of cluster thinning (Table 1). The unthinned vines without additional K produced the smallest berries. Additional K fertilization increased fruit pH, and a significant increase in petiole and fruit K occurred in the cluster-thinned plots given additional K. The percent soluble solids of the fruit appeared to be related to cluster thinning with the cluster-thinned vines tending to produce fruit with slightly higher percent soluble solids. However, only the fruit from the cluster thinned vines without additional K was significantly higher in percent soluble solids than fruit from vines that were not thinned but received additional K fertilization. None of the treatments affected fruit acidity.

de Chaunac: de Chaunac vines did not show a significant yield response to any of the treatments (Table 1), but cluster thinning increased berries per cluster. There was no effect from any of the treatments on berry weight. de Chaunac fruit from the vines receiving additional K fertilization had significantly higher petiole K levels and higher pH than fruit from vines receiving no additional K (Table 1). Cluster thinning tended to increase percent soluble solids. However, the only significant difference in percent soluble solids was between the fruit from cluster-thinned vines without additional K and the fruit from unthinned vines receiving additional K. The acidity of the fruit from unthinned vines not receiving additional K had slightly but significantly higher acidity than the fruit from cluster-thinned vines receiving additional K fertilization.

Cynthiana: Cluster thinning Cynthiana vines reduced yields in the plots receiving additional K (Table 1). Cluster thinning did not significantly increase the berries per cluster in the Cynthiana cultivar, but berry weight tended to be slightly higher in the cluster-thinned plots. Both cluster thinning and additional K fertilization tended to increase the petiole and fruit K levels, but only the cluster-thinned vines receiving additional K had significantly higher fruit K levels than those vines not receiving additional K. The combination of thinning and additional K fertilization resulted in increased fruit pH (Table 1). Cynthiana did not appear to be as effective as Cabernet Sauvignon in accumulating K in petioles, but the fruit was an active sink for K. There was no significant effect from any of the treatments on percent soluble solids, but Cynthiana had higher percent soluble solids than any of the other cultivars in this study.

Changes during maturation: Regression analysis was used across all treatments and three sampling dates on each cultivar to examine the relationships between the development of percent soluble solids and the changes in pH and acidity. These analyses show the high pH and low acidity levels that are predicted for Gewurztraminer even at extremely low levels of soluble solids (Fig. 1). In contrast, regression analysis shows that at a given level of soluble solids, Cabernet Sauvignon, the other *V. vinifera* L. cultivar, had fruit with much better pH (lower) and acidity levels (higher) than the fruit of Gewurztraminer.

The regression analysis indicated that fruit pH was excessively high (above 3.5) in the French-American hybrid Seyval after the fruit reached 16% soluble solids (Fig. 1). The de Chaunac fruit had better pH (lower) and acidity (higher) levels at a given level of soluble solids than Seyval fruit. de Chaunac maintained acceptable levels of pH (3.5 or below) and acidity (above 0.7%) until the percent soluble solids reached approximately 18% (Fig. 1).

At any given level of soluble solids, the fruit of Cynthiana (*Vitis aestivalis* Michaux.) had lower pH and higher acidity values than any other cultivar or species in this study (Fig. 1). Regression analysis indicated that Cynthiana fruit still had acceptable fruit pH (*ca* 3.5) and acidity (above 0.7%) at 20% soluble solids.

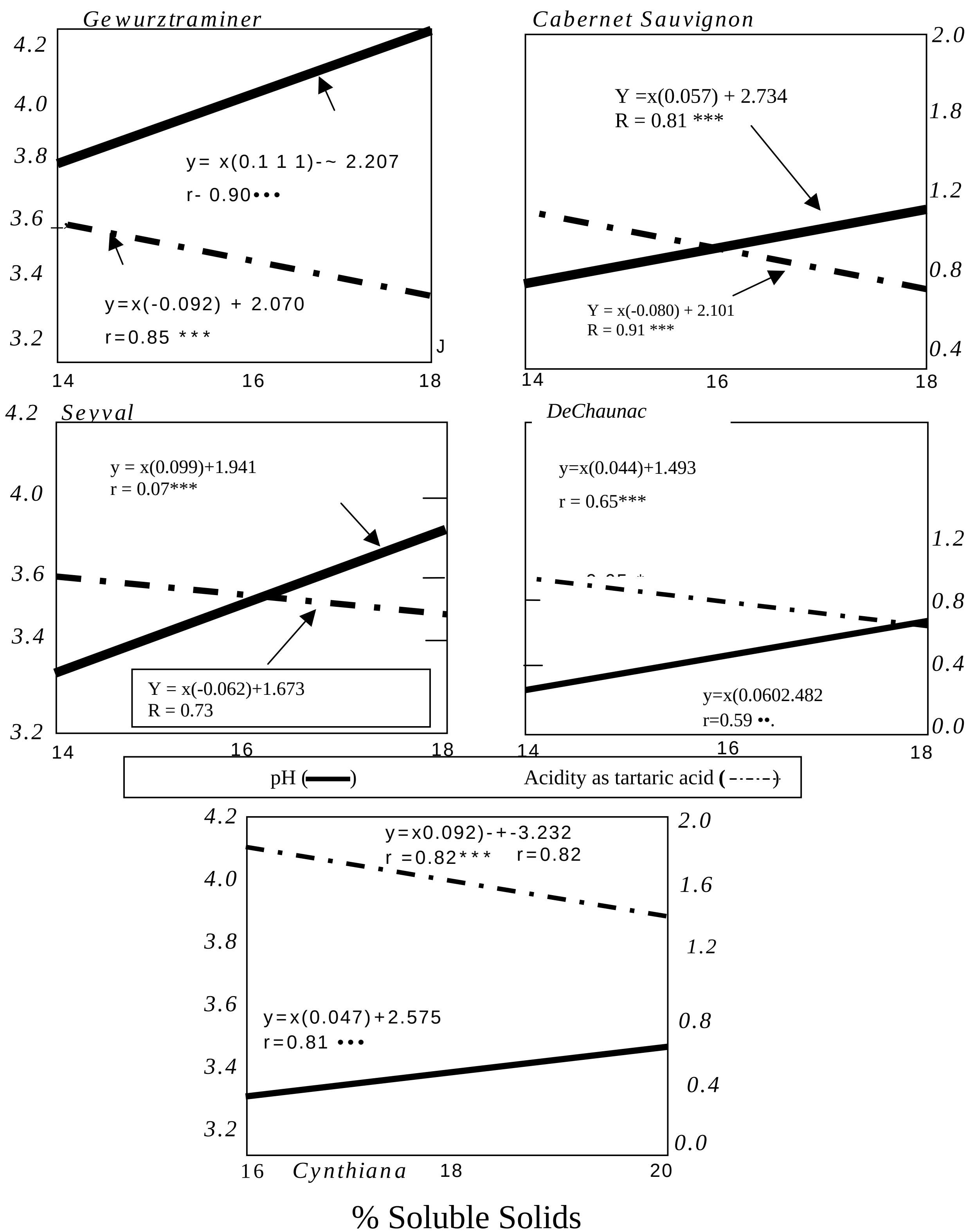

Fig. 1. Relationship between percent soluble solids, pH, and acidity in the juices of five wine grape cultivars.

Conclusions

Application of K fertilizer in addition to that already recommended for the vineyard did not affect yield except for the Gewurztraminer cultivar, which showed a yield response to additional K fertilizer. Gewurztraminer did not show a significant change in either juice K or pH with any of the treatments. The combination of increased berry set and berry size on the cluster-thinned vines apparently resulted in yields comparable to yields from unthinned vines in all cultivars except Cynthiana.

Excessive K fertilization and cluster thinning tended to increase petiole and fruit K and fruit pH in most cultivars. Within a given cultivar, there were only minor effects on fruit acidity from any one of the variables. The percent soluble solids showed little response to the treatments except in the tendency for cluster thinning to slightly improve soluble solids in Cabernet Sauvignon and the two French-American hybrid cultivars.

The Gewurztraminer cultivar did not produce fruit with an acceptable pH level at any soluble solids level sampled. The Cynthiana cultivar produced the most acceptable fruit pH and acidity levels of any cultivar or species at high levels of soluble solids.

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