Influence of Irrigation, Pruning Severity, and Nitrogen on Yield and Quality of ‘Concord’ Grapes in Arkansas

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Abstract. When vines of ‘Concord’ (Vitis labrusca, L.) trained to the Geneva Double Curtain were irrigated or pruned to 60±10 nodes/vine, yield was increased with some sacrifice in juice quality, as indicated by lower % soluble solids and poorer juice color. High quality juice was obtained from fruit from 60+10 irrigated vines, the highest yielding treatment, when harvest was delayed 10 to 14 days. Level of nitrogen fertilization did not affect yield, % soluble solids, or juice color. Irrigation was the only variable affecting vine size. High yields from irrigated and 60+10 vines found in this study indicated that the fruiting potential of the ‘Concord’ grapevine in Arkansas has not been fully exploited.

The predominant training and pruning system used in Arkansas to produce ‘Concord’ grapes is the Umbrella Kniffin system with vines balance pruned using a 30±10 schedule (30 nodes retained for the first 454 g of dormant prunings and 10 more nodes left for each additional 454 g). However, other production systems may be better adapted to ‘Concord’ production in Arkansas. Studies in New York (22, 24) have indicated that higher yields can be obtained with ‘Concord’ when vines are trained to the Geneva Double Curtain (GDC) system than when trained to single-curtain type systems. Present training practices in Arkansas are based on studies conducted in other ‘Concord’ producing regions. A recent Arkansas study (8) indicated that yield increases can be obtained, while maintaining high fruit quality, when the GDC system is used in conjunction with low pruning severities.

Although high yields are desirable, high fruit loads may have a detrimental effect on vine growth and fruit maturity (15, 16, 19). Adjusting cultural practices, such as altering soil moisture (6, 9, 18, 26, 28) and rate of nitrogen fertilization (4, 19) may contribute to the maintenance of large vines even while producing higher yields of high quality fruit. Numerous studies have reported the effects of water stress or irrigation (2, 6, 7, 9, 12, 13, 18, 21, 26, 28, 29), pruning severity (5, 8, 10, 11, 14, 15, 17, 19, 23, 25), and nitrogen (1, 3, 11, 20, 25, 27) on grapevine growth. However, no research has been reported on the interactive effects of these variables on ‘Concord’ grapes.

Since ‘Concord’ grape production is the major small fruit industry in Arkansas, research is needed to determine the effects of irrigation, pruning severity, and nitrogen on the yields and quality of ‘Concord’ grapes trained to the high yielding GDC system. This study was conducted to determine the interactive effects of two irrigation levels, 2 pruning severities and 2 N levels on the yield and quality of ‘Concord’ grapes growing in Arkansas.

Materials and Methods

The study was conducted for 2 years (1975-1976) in a ‘Concord’ vineyard established in 1966. Soil was a Taloka Mounded series (land levelled) having a field capacity of 17.1% and a wilting percentage of 5.2. Vines were clonally propagated from a single parent vine in order to minimize vine variation within the vineyard. The parent vine had been selected on the basis of its large size and ability to mature fruit with a high percentage of soluble solids. Before the study began uniform cultural practices had been carried out. Vine size was not significantly different within replications and the average vine size was 1.1 kg of dormant prunings.

Vines were GDC trained and spaced 2.4 m in the row and 3.0 m between the rows. The trellis was 1.8 m high and 1.2 m wide.

Vines were either irrigated or non-irrigated. Irrigated plots were watered as needed from bloom until about 1 week prior to veraison to maintain soil moisture tension between 100-200 mb at a depth of 60 cm. Soil moisture tension in non-irrigated plots ranged from 750-800 mb at 60 cm. Tensiometers were used. Water was supplied to each vine by 2 trickle emitters placed within the row 60 cm from the trunk – one on either side. As supplemental water vines received 2.97 x 10^3 m^3 of water/ha (11.7 acre-inches) and 3.46 x 10^3 m^3 of water/ha (13.7 acre-inches) in 1975 and 1976, respectively.

Pruning schedules used in this study were the conventional 30+10 level and a 60+10 level and 6 node canes were retained. Prior to the experiment the vineyard had been uniformly pruned to 30+10.

Two nitrogen levels were established. Plots either received 0 kg/ha N for the 2 year period or 152 kg/ha (April 10, 1975) and 228 kg/ha (March 18, 1976) of actual N (NH_4NO_3). Fertilizer was broadcast between the rows and incorporated into the soil. The objective of having 2 N levels was to establish 2 distinct levels of vine size. Since there was no significant increase in vine size in 1975 as a result of N level, the rate of NH_4NO_3 applied was increased in 1976. Vetch was grown as a cover crop during the dormant period. Each year prior to the initiation of the study, 97 kg/ha N had been uniformly applied to the vineyard.

A factorial design with 4 vine plots replicated 6 times was used. Individual vine yields and pruning wt were determined, and all treatments were imposed on the same vines each year.

Starting at veraison of the 30+10, non-irrigated plots (Aug. 8, 1975; Aug. 9, 1976), 3 representative basal clusters from each plot were taken at about 2 week intervals. Subsequent samples were obtained on Aug. 21 and Sept. 2 in 1975 and Aug. 21 and Sept. 8 in 1976. The final samples were taken during commercial harvest in the area. Each sample was placed in a polyethylene bag, sealed and frozen for later analysis.

To prepare for analysis, samples were thawed at 20°C overnight, berries were separated from stems, counted, and weighed to determine berry wt and number of berries/cluster. They were then blended for 15 sec in a laboratory blender, placed in 250 ml beakers, warmed to 20°C, and % soluble solids were determined by squeezing a drop of juice from the puree through a Kimwipe onto a Bausch and Lomb refractometer.

Beakers containing the blended samples were covered with
watch glasses, placed in a water bath at 85°C for 1 hr and allowed to cool to about 40°C. Pulp was removed by straining samples through 2 layers of grade 50 cheesecloth. Five ml of juice were diluted to 100 ml using distilled water, centrifuged for 30 min (4000 rpm) and absorbance at 520 nm read using a Bausch and Lomb spectrophotometer (model 340). Distilled water was used as a reference. Titratable acidity, expressed as % tartaric acid, was determined by titration.

Results

Environmental conditions. Since variations in weather conditions can affect quality of 'Concord' grapes grown in Arkansas (13), the 1975 and 1976 seasons have been defined in Fig. 1 by using degree-day summation and rainfall. Accumulation of heat units was begun at peak bloom (May 16 in 1975 and May 7 in 1976). Weather data were collected from a weather station adjacent to the Experiment Station vineyard. The 1975 growing season had a higher degree-day summation prior to sampling and during the entire sampling period.

Rainfall during the 1975 and 1976 growing seasons and sampling periods differed. During the sampling period, rainfall was greater in 1976 (Fig. 1). Rainfall from May 1 to August 30 was higher in 1975 (46 cm) and lower in 1976 (31 cm) than the average rainfall (37 cm) for the 10 years prior to the establishment of the study. Yield potential was reduced in 1976 by an estimated 5% hail damage to the young shoots in the spring.

Yield, fruit characteristics, and pruning wt. Between the 2 years of the study, yield, yield/node, berry wt and vine size differed (Table 1), but the no. of berries/cluster did not. Yield was about 2 MT/ha higher in 1975 than in 1976. Yield/node and berry size were lower in 1976 and vine size as indicated by pruning wt was significantly smaller in 1976.

Irrigation increased yield by 2.3 MT/ha for the 2-year average (Table 1); however, the yield response to irrigation was not the same in the 2 years as indicated by a significant interaction between irrigation × years. Yield differences between the irrigation treatments were greater in 1976 than in 1975. Irrigated plots did not significantly differ in yield between the 2 years, but yield was lower in non-irrigated plots in 1976 than in 1975.

Yield/node was greater in irrigated plots both years (Table 1). Although berry wt at harvest and the no. of berries/cluster did not differ between irrigation treatments during 1975, irrigated plots produced larger berries and had more berries/cluster than the non-irrigated plots in 1976 and for the 2-year average. Weight of dormant prunings was higher for irrigated vines than non-irrigated vines. There was a greater reduction in vine size from 1975 to 1976 in the non-irrigated plots.

Changing the pruning schedule from 30 to 60+10 increased yield by 5.0 MT/ha for the 2-year average (Table 1). However, under the higher moisture stress conditions which existed in 1976, the magnitude of the yield differences between the 2 pruning severities in 1976 was not as great as in 1975 (Figure 2). For the 2-year average, yield/node, berry wt, berries/cluster and vine size did not differ on vines of the 2 pruning severities.

Though yield/node was not significantly affected by N level in 1975 and 1976, when pooled across the 2 years it was increased by the higher N rate; however, this effect was not great enough to cause significant differences in yield/ha (Table 1). Berry size, berries/cluster and vine size were not affected by N.

Vines which were pruned to 60+10 nodes/454g of prunings and irrigated produced significantly higher yields than any of the other pruning and irrigation treatments (Fig. 3). Fig. 4 shows the 2-year average yield from each of the treatments. The highest yielding treatment (60+10 irrigated, high N) and the lowest yielding treatment (30+10 non-irrigated, low N) differed in yield by about 8.0 MT/ha (Fig. 4).

Fruit maturation and juice quality. As maturity progressed, % soluble solids and color increased, while acidity decreased. Despite the smaller crop load, fruit maturity was not as advanced in 1976 on the initial sampling date as in 1975. However,
Table 1. Main effects of irrigation, pruning severity, N, and year on yield, fruit characteristics and pruning wt of 'Concord' grapes, 1975-1976.2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Irrigation</th>
<th>Pruning severity</th>
<th>Nitrogen</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Not Irr.</td>
<td>30+10</td>
<td>60+10</td>
</tr>
<tr>
<td><strong>Yield (MT/ha)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>12.6a</td>
<td>10.9a</td>
<td>8.6b</td>
<td>15.0a</td>
</tr>
<tr>
<td>1976</td>
<td>11.1a</td>
<td>8.2b</td>
<td>7.9b</td>
<td>11.5a</td>
</tr>
<tr>
<td>Mean</td>
<td>11.9a</td>
<td>9.6b</td>
<td>8.2b</td>
<td>13.2a</td>
</tr>
<tr>
<td><strong>Yield (g/node)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>163a</td>
<td>139b</td>
<td>152ab</td>
<td>150a</td>
</tr>
<tr>
<td>1976</td>
<td>134a</td>
<td>110b</td>
<td>126a</td>
<td>119a</td>
</tr>
<tr>
<td>Mean</td>
<td>149a</td>
<td>125b</td>
<td>139a</td>
<td>135a</td>
</tr>
<tr>
<td><strong>Berry wt (g)</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>3.22a</td>
<td>3.04a</td>
<td>3.11a</td>
<td>3.15a</td>
</tr>
<tr>
<td>1976</td>
<td>2.96a</td>
<td>2.74b</td>
<td>2.94a</td>
<td>2.76b</td>
</tr>
<tr>
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<td>3.09a</td>
<td>2.89b</td>
<td>3.03a</td>
<td>2.95a</td>
</tr>
<tr>
<td><strong>No. berries/cluster</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>39a</td>
<td>38a</td>
<td>37a</td>
<td>39a</td>
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<td>1976</td>
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<td>37a</td>
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<tr>
<td>Mean</td>
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<td>35b</td>
<td>37a</td>
<td>38a</td>
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<td><strong>Pruning wt (kg/vine)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>1.3a</td>
<td>1.0b</td>
<td>1.2a</td>
<td>1.1a</td>
</tr>
<tr>
<td>1976</td>
<td>1.1a</td>
<td>0.7b</td>
<td>0.9a</td>
<td>0.9a</td>
</tr>
<tr>
<td>Mean</td>
<td>1.2a</td>
<td>0.8b</td>
<td>1.1a</td>
<td>1.0a</td>
</tr>
</tbody>
</table>

Footnotes:
2Mean separation between treatments within rows by Duncan's multiple range test, 5% level.
3Means within years within main effect blocks are pooled over 6 replications and all other variables in table.

Fig. 3. Interactive effects of irrigation x pruning severity on yield of 'Concord' grapes (means pooled across 2 N levels, 2 years, and 6 replications).

Fig. 4. Effects of irrigation, pruning severity and nitrogen on yield of 'Concord' grapes (means pooled across 2 years and 6 replications).
the final sample in 1976 had a higher % soluble solids and lower acidity than the corresponding sample in 1975 (Table 2).

Fruit maturity was delayed by irrigation as indicated by lower % soluble solids, higher acidity, and poorer color of the juice (Fig. 5). Differences between irrigated and non-irrigated vines in soluble solids, acidity, and color were established by veraison. Differences in % soluble solids and juice color of fruit from the 2 irrigation treatments tended to remain through harvest, but differences in juice acidity decreased with time (Fig. 5, Table 2). Although juice from irrigated vines was lower in % soluble solids at harvest, the yield of soluble solids/node of and of soluble solids/vine was higher due to the increase in fruit yield (Table 1, 2).

Reduced pruning severity tended to delay fruit maturity in 1975 and for the 2-year average as indicated by lower % soluble solids and poorer color (Table 2). However, in 1976 % soluble solids and color did not differ in response to pruning severity. The yield of soluble solids/node was not affected by pruning severity; but, the yield of soluble solids/node and of soluble solids/vine was significantly higher from 60+10 vines than 30+10 vines. Juice acidity was not affected by pruning severity (Table 2).

Irrigation × pruning severity interacted in that the decrease in % soluble solids and color shown by the main effect of irrigation (Table 2) was the result of irrigating 30+10 vines (Fig. 6). Quality parameters responded to the irrigation × pruning severity treatments in a similar manner both years of the study (data not presented). For the 2-year average, non-irrigated, 30+10 fruit produced juice of higher soluble solids and better color (higher optical density) than any other treatment on a given sampling date (Fig. 7). Titratable acidity was not affected by the interaction of irrigation × pruning severity × sampling date, although there were differences in acidity early in the season due to irrigation.

During 1975 the 2 N rates did not affect any of the juice quality parameters measured (Table 2). No differences were observed in % soluble solids, yield of soluble solids/node or color in 1976. Acidity was slightly, but significantly, lower in juice from the high N treatment in 1976 and for the 2-year average. Although N did not significantly affect yield (Table 1) or % soluble solids (Table 2), the yield of soluble solids/vine was greater at the high N level than at the low level in 1976.

Discussion

Yield, yield components, and pruning wt. Other researchers (2, 7, 12, 18, 26, 28) have reported that moisture stress can reduce the fruitfulness of grapevines. Therefore, the differences in yield and yield/node observed in this study seemed to indicate that the vines which did not receive irrigation were under moisture stress at some time. Yield differences between irrigation treatments in 1976 were also due to a decrease in vine size of vines in the non-irrigated plots; therefore, more nodes/vine were left on irrigated vines than non-irrigated vines. Differences in vine size which resulted from the different moisture levels were visible in the field, with irrigated plots having more apparent vegetative growth than vines which were not irrigated. Vaadia and Kasimatis (28), working with 'Chenin blanc' grapes, observed visible differences in vegetative growth and reported significant differences in vine size due to irrigation treatment.

Yield increases due to decreased pruning severity were expected, since other researchers (5, 8, 11, 14, 15, 16, 17, 19, 23) had reported higher yields as a result of less severe pruning levels. Vine size was not reduced by the high crop loads obtained at the 60+10 pruning level. Kimball and Shaulis (14) reported similar results in a New York study. They concluded...
that the vineyard site played an important role in the results which were obtained, since serious vine size reductions were observed at other locations when pruning severity was less than 30+10.

Vines utilized in this study did not respond to high levels of N fertilizer. Fleming (11) reported similar findings from a study conducted in a vineyard with similar cultural practices and soil type as the vineyard used in this study. Though fruit yield/ha (Table 1) was not significantly affected by N at the 5% level of significance, it did differ at the 8% level. Berry wt, berries/cluster, and pruning wt did not differ between the 2 N levels. Differences in node fruitfulness between the N levels might have been due to an increase in the no. of clusters/vine.

A majority of the ‘Concord’ grapes in Arkansas are pruned to 30+10. Irrigation is not a practice which is common to ‘Concord’ production in Arkansas. Yield increases, as a result of irrigation and less severe pruning, found in this study indicate that the yield potential of ‘Concord’ vineyards in Arkansas may not have been fully exploited. The results of this study only reflect 2 years of research and failure of vine size to stabilize may be reason for caution in making any recommendations at this time.

**Fruit maturation and juice quality.** Fruit maturation and raw product quality are important to the grape juice industry. Juice soluble solids concn is the index of fruit maturity for the grape juice industry. Most processors set a minimum standard of 15% soluble solids for the raw juice. Higher price for fruit of higher soluble solids encourages ‘Concord’ grape producers to delay harvest, so as to increase the soluble solids concn. Juice color and acidity are also important quality factors.

Experimental variables which had a significant effect on fruit yield (irrigation and pruning severity) tended to adversely affect fruit maturation. Kattan et al. (13) reported that irrigation caused a delay in ‘Concord’ fruit maturity. Other researchers have reported delays in ‘Concord’ fruit maturity and/or lower soluble solids at harvest when pruning severity was reduced (8, 14, 17, 19). It may be possible to utilize both irrigation and a less severe pruning level even though fruit maturity may be delayed 10-14 days. Favorable climatic conditions for fruit maturation which exist after the harvest season of early Sept, in Arkansas might allow fruit to mature in spite of use of cultural factors which result in delayed fruit maturity. Delays in maturity may be more critical in more northern ‘Concord’ producing areas where maturity of the fruit and the first killing frost occur nearly simultaneously.

A decrease in titratable acidity was the only significant
change in juice quality due to high N fertilization. Abdalla and Sefick (1) reported that in 1 year of their study the application of 52 lb. of actual N per acre (58 kg/ha) resulted in a 0.02% decrease in acidity (reported as tartaric) of 'Concord' grape juice. Other researchers (1, 3, 27) have reported similar results to those obtained in this study with regard to lack of effect of N on the soluble solids content of 'Concord'. However, Partridge (20) reported a tendency for high N to delay 'Concord' fruit maturity.

**Literature Cited**


