# Effects of Irrigation and Pruning of Shiraz Grapevines on Subsequent Red Wine Pigments

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The effect of irrigation and pruning on wine pigments was studied in experimental wines made from *Vitis vinifera* cv. Shiraz grown in the hot, arid climate of Griffith, N.S.W., Australia for four years from 1975 through 1978. Irrigation reduced wine color, the amount of pigments and the proportion of anthocyanins in the colored form. The reduced proportion of pigments in the colored form was due to the increase in wine pH. The reduction in wine color was correlated with an increase in berry size with the irrigated treatment compared to the nonirrigated treatment. In two of the four years severe pruning reduced wine color, in one year pruning had no effect, and in the other years severe pruning increased wine color. Thus, water stress will consistently increase wine color, but severe pruning had no consistent effect and often reduced wine color.

Irrigation and pruning are two vine management practices that affect productivity, but the general effects of these practices on wine quality has not been well established.

Irrigation of grapevines had no effect on subsequent wine quality in California but reduced red wine color (8,21). Irrigation indirectly reduced cluster temperatures by up to 10°C (6). Thus, if high temperature was limiting pigment production, irrigation should have increased fruit pigmentation and hence wine color (10,11).

Irrigation increased wine quality in Czechoslovakia (5) and Bulgaria (20). On the other hand, irrigation reduced red wine quality in France (2,3,22), Argentina (14), and Italy, although in Italy a single late irrigation increased wine quality (1,13). In a comparison of different regions in Australia, red wine color was lower in an irrigated region compared to a nonirrigated region (17). But this reduction in wine color may have been due to either direct or indirect effects of irrigation or higher temperatures in the irrigated region.

Light pruning (higher node numbers) increased yields and delayed maturity which resulted in poor wine color. However, severe pruning (low node numbers) reduced yields and did not necessarily result in the optimum wine quality (12).

Wine quality has been evaluated by hedonistic tasting of experimental wines (5,6,8,20,21) or inferred from grape composition (1,2,3,13,20,22). In at least one case, significant organoleptic differences which existed between wines produced from irrigated and nonirrigated vines could not be qualified due to a lack of a definite preference among the tasters, and the results also depended on the selection of the panel (6).

Recently, pigment measurements have established a basis for quantitative comparisons of red wine quality and the desirable effects of anthocyanins on wine flavor and quality have been demonstrated (9,18,19). Although the evaluation of these parameters may be as subjective as any hedonic evaluation, the measurements can be used as a basis for quantitative comparison.

This report describes an investigation which was initiated to examine the effect of grapevine irrigation on red wine quality using these quantitative methods.

Since irrigation increases vine yields, the experiment was designed to test the hypothesis that irrigation affects wine quality due to increased vine yields. The effects of irrigation and pruning on yield and grape quality have been reported previously (6,7). At the 160 node level irrigation increased yields from 10 to 22.7 tons per hectare. At the 20 and 40 node levels, irrigation had no effect on yields in most years. Thus, at the 20 node level, the effect of irrigation on subsequent red wine pigments was studied at the same yield level. This paper reports the effects of crop level and irrigation on wine pigments.

## Materials and Methods

The wines used in this study were all made from Shiraz grapes grown in the hot, arid climate (climatic region IV, [23] of Griffith, N.S.W., Australia), in four successive years, beginning in 1975. The vines were planted in 1963 and trained to a spur pruned bilateral cordon. The climatic data are presented in Table 1.

Table 1. Mean pH of wines made from irrigated and nonirrigated Shiraz vines at four levels of pruning (20, 40, 80 and 160 nodes) from 1975 to 1978 and evaporation and mean monthly temperature for the growing season.

| | Vintage year | | | |
|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 |
| Wine pH | 3.95 | 4.19 | 3.79 | 4.07 |
| Evaporation (mm) | | | | |
| Sept. to March | 1391 | 1412 | 1462 | 1668 |
| Mean temp. (°C) | | | | |
| September * | 10.9 | 13.7 | 12.4 | 11.8 |
| October | 14.8 | 14.5 | 14.3 | 18.2 |
| November | 17.5 | 19.3 | 18.0 | 19.9 |
| December | 20.6 | 24.3 | 21.2 | 22.4 |
| January | 21.7 | 22.9 | 23.8 | 23.1 |
| February | 24.3 | 24.5 | 25.6 | 24.4 |
| March | 19.8 | 21.4 | 20.0 | 21.7 |

*Sept., Oct., Nov. and Dec. are for the year previous to the vintage year.

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Half the vines, designated I, were trickle irrigated three times a week replacing 0.6 of Class A pan evaporation. The other half, designated NI were not irrigated at all.

Four pruning levels, 20, 40, 80, and 160 nodes per vine, designated P20, P40, P80, and P160, were imposed on each irrigation, and there were four replicates of each randomized treatment. Altogether 120 wines were made, falling into eight categories for each vintage: irrigated (I) and nonirrigated (NI) at four pruning levels. Wines were not made from P80 in 1975. The grapes were harvested as close as possible to 22° Brix soluble solids, and 12 kg grape samples were fermented in contact with their skins by a standard method (7).

A Hitachi 181 Spectrophotometer was used for all optical density measurements at 520 nm using 1, 2, or 5 mm path lengths according to wine color density. Wine color and the anthocyanin equilibria were calculated by the methods of Somers and Evans (19). Wine color (WC) was the absorbance at 520 nm after 20 $\mu$L of acetaldehyde was added to a 2 mL wine sample. Total pigment concentration (WCA) was the wine color at pH less than 1; 100 $\mu$L of wine was added to 10 mL of 1 *M* HCl and absorbance measured at 520 and a correction made for the dilution. The anthocyanin color (AC) was the difference between WC and the absorbance of a wine sample containing 0.3% sodium metabisulphite which was defined as the polymeric pigment color (PPC). The total anthocyanin color (ACA) was the difference between WCA and 5/3 of PPC. The wine chemical age (CAW) was the proportion of color due to polymeric pigment; CAW = PPC/WC. Potassium was measured with a flame photometer, but after the wines had been stored at 1°C for 30 days. All measurements were made in June 1978.

## Results

Over the four years the average pH for the I wines was 4.08 which was significantly ($p<0.05$) higher than 3.92 for the NI wines (Table 2). Irrigation had no effect on wine potassium, presumably due to the cold stabilization treatment. Only in 1977, for the NI wines the pH was in a desirable range (pH = 3.65), and irrigation increased this to 3.90. In three of the four years, all pH levels were excessively high, but in the other year irrigation increased the pH to an undesirable level.

A high wine pigment concentration in 1977 for the NI vines at P160 was associated with significant interactions

Table 2. Potassium, pH, wine color (WC), total pigment color (WCA), anthocyanin color (AC), and total anthocyanin color (ACA) of wine produced from irrigated (I) and nonirrigated (NI) Shiraz vines at four levels of pruning (20,40,80,160 nodes) from 1975 to 1978.

| Year | Treatment | | Potassium | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrigation | Pruning* | (mM) | pH | WC | WCA | AC | ACA |
| 1975 | I | 20 | 46 | 3.95 | 2.52 | 9.75 | 0.13 | 1.46 |
| | | 40 | 52 | 3.96 | 3.00 | 10.50 | 0.14 | 1.53 |
| | | 160 | 49 | 3.98 | 3.25 | 14.37 | 0.16 | 2.28 |
| | NI | 20 | 47 | 4.00 | 4.63 | 17.50 | 0.25 | 2.73 |
| | | 40 | 51 | 3.93 | 5.90 | 20.62 | 0.36 | 3.10 |
| | | 160 | 42 | 3.90 | 6.25 | 20.88 | 0.34 | 3.21 |
| | LSD | — | n.s. | n.s. | 0.40 | 5.93 | 0.13 | 1.08 |
| 1976 | I | 20 | 70 | 4.33 | 3.96 | 15.62 | 0.19 | 2.33 |
| | | 40 | 68 | 4.33 | 3.65 | 17.25 | 0.16 | 2.79 |
| | | 80 | 63 | 4.28 | 3.54 | 16.25 | 0.16 | 2.64 |
| | | 160 | 58 | 4.26 | 3.05 | 14.75 | 0.12 | 2.38 |
| | NI | 20 | 61 | 4.18 | 5.40 | 23.12 | 0.29 | 3.72 |
| | | 40 | 57 | 4.13 | 4.89 | 22.25 | 0.25 | 3.71 |
| | | 80 | 53 | 4.05 | 4.63 | 20.37 | 0.24 | 3.40 |
| | | 160 | 50 | 3.96 | 4.31 | 18.75 | 0.22 | 3.01 |
| | LSD | — | n.s. | 0.20 | 0.62 | 4.91 | 0.11 | 0.61 |
| 1977 | | 20 | 54 | 3.98 | 2.85 | 14.37 | 0.21 | 2.39 |
| | | 40 | 51 | 3.95 | 2.81 | 14.50 | 0.21 | 2.54 |
| | | 80 | 47 | 3.88 | 3.07 | 12.00 | 0.21 | 1.96 |
| | | 160 | 43 | 3.80 | 2.92 | 10.87 | 0.22 | 1.77 |
| | NI | 20 | 45 | 3.76 | 5.75 | 19.50 | 0.50 | 3.26 |
| | | 40 | 44 | 3.67 | 6.70 | 19.75 | 0.49 | 3.32 |
| | | 80 | 40 | 3.60 | 6.50 | 18.25 | 0.47 | 3.07 |
| | | 160 | 41 | 3.64 | 8.82 | 24.25 | 0.86 | 3.93 |
| | LSD | — | n.s. | 0.18 | 0.93 | 3.41 | 0.14 | 0.80 |
| 1978 | I | 20 | 50 | 4.21 | 4.04 | 23.20 | 0.39 | 4.18 |
| | | 40 | 55 | 4.20 | 3.17 | 19.50 | 0.30 | 3.53 |
| | | 80 | 50 | 4.10 | 2.40 | 15.13 | 0.23 | 2.74 |
| | | 160 | 47 | 4.10 | 2.84 | 17.00 | 0.27 | 3.08 |
| | NI | 20 | 53 | 4.10 | 5.23 | 26.41 | 0.38 | 4.97 |
| | | 40 | 51 | 3.98 | 4.46 | 20.03 | 0.40 | 3.73 |
| | | 80 | 52 | 3.95 | 4.49 | 18.89 | 0.44 | 3.43 |
| | | 160 | 49 | 3.95 | 5.04 | 21.54 | 0.37 | 4.05 |
| | LSD | — | n.s. | 0.14 | 1.12 | 8.21 | 0.13 | 0.98 |

*Wine was not made from P80 in 1975.

Table 3. Relationship between berry weight and wine potassium, pH, color (WC), total pigment color (WCA), anthocyanin color (AC) and total anthocyanin color (ACA) for combined results from irrigation and pruning level treatments in 1975 and 1977.

| Year | Correlation Coefficient | | | | | |
|---|---|---|---|---|---|---|
| | pH | K | WC | WCA | AC | ACA |
| 1975 | n.s. | n.s. | −0.8909*** | −0.8680*** | −0.8752*** | −0.8413*** |
| 1977 | 0.5339* | n.s. | −0.6631* | n.s. | n.s. | n.s. |

*, *** represent significance at P = 0.05 and 0.001 levels, respectively.

between irrigation, pruning, and vintage for color density and derived variables. The grape sugar was not different from other treatments, so the result was not due to differences in grape maturity. Wine pH, alcohol, and $SO_2$ were not different from the other pruning levels, and the high values for NI P160 is unlikely an artifact of winemaking as replicate two was harvested and processed three weeks after the other replicates and the results were similar. Berry weight of the NI vines decreased 37.5% between P20 and P160 in 1977. This could be a reason for the intense wine color at P160 (16).

**Irrigation effect on wine pigments:** Irrigation reduced wine color (WC) by an average of 40%, but this ranged from 58% in 1977 to 26% in 1976 (Table 2). The differences in WC can be due to differences in total pigment color (wine color at pH $< 1.0$), WCA or the proportion of pigment in the colored form, WC/WCA. Irrigation reduced WCA by 29%, so this does not account for all the difference in WC. The highest WC occurred in 1977, but WCA was lower in 1977 than in 1976 or 1978. Thus, it would appear that the proportion of pigments in the colored form is more important in determining WC than WCA.

The treatment with the only acceptable pH (NI in 1977) had the highest WC but not the highest total pigment content. Thus, it would appear that pH is more important than pigment content.

Irrigation increased wine pH which reduced the ratio of colored anthocyanins to total anthocyanins from 20.2% to 13.4% for the average over the four years.

**Pruning effect on wine pigments:** In 1978 pruning had no effect on WC, but in 1975 and 1977 P160 increased WC compared to P20. In 1976, P160 reduced WC compared to P20 (Table 2). In 1976, 1977 and 1978 WCA was not affected by pruning and in 1975 P160 increased WCA.

In 1976 and 1977, pruning level had no effect on ACA; in 1978, P20 with an ACA of 4.57 was significantly greater than all other pruning levels; but in 1975, P160 with an ACA of 2.75 was significantly greater than P20 and P40. Over the four years, P20 produced wines with 15.6% of the anthocyanins in the colored form which was significantly lower than P80 at 18.1% and P160 at 17.9%.

**Relationship between berry weight and wine pigments:** In 1975 and 1977, berry weight was recorded for the harvested fruit. In 1975, berry weight was negatively correlated with WC, WCA, AC and ACA (Table 3). The increase in berry weight due to irrigation and low node number pruning levels was associated with the reduced wine pigments. In 1977, berry weight was negatively correlated with WC, but no significant correlation was detected between berry weight and WCA, AC and ACA. A significant, positive correlation existed between berry weight and wine pH (Table 3).

**Vintage effects on wine pigments:** Wines made in 1976 and 1978 had higher pH values for both I and NI treatments than 1975 and 1977 (Table 4). Wine color also varied with vintage, the lowest WC for the I treatments occurred in 1977 which was the year of the highest WC for the NI wines.

The wines were measured at 39, 27, 15 and 3 months after fermentation for 1975, 76, 77 and 78 vintages, respectively, but on a chemical wine age basis (CAW), the wines were all aged to the same degree. It appears that the wines were fully aged within the first 3 months. The 1978 wines at 3 months (Table 4) were equivalent to the 15 year old wines in another study (19).

## Discussion

Wine quality can be assessed in terms of color density (18), total pigment color (9), total anthocyanins (9) and colored anthocyanins (9,18). Irrigation reduced wine quality on the basis of these parameters. The reduction in wine quality was not due to the increase in yield that occurred with irrigation because severe pruning reduced irrigated vine yields to the level of the nonirrigated vines. The quality of the severely pruned vines was similar to that of the other irrigated treatments and lower than the nonirrigated vines.

Contrary to popular belief, increasing the pruning level, hence yield, generally increased these quality parameters. The increase in pigment color with the increase in yield was associated with a reduction in berry size. A

Table 4. Vintage effects on pH, wine color (WC) and chemical age (CAW) of wines produced from irrigated (I) and nonirrigated (NI) Shiraz vines at four levels of pruning from 1975 to 1978.

| | pH | | WC | | CAW | |
|---|---|---|---|---|---|---|
| Vintage | I | NI | I | NI | I | NI |
| 1975 | 3.96 | 3.94 | 2.49 | 5.59 | 0.95 | 0.94 |
| 1976 | 4.30 | 4.08 | 3.55 | 4.81 | 0.95 | 0.95 |
| 1977 | 3.90 | 3.67 | 2.91 | 6.94 | 0.93 | 0.92 |
| 1978 | 4.20 | 4.00 | 3.11 | 4.81 | 0.90 | 0.92 |

simulated reduction in berry size of 10% was shown to significantly improve wine quality (16).

Seasonal evaporation which controls vine water use did not appear to have any relationship with wine pH (Table 1). Seasonal temperatures did appear to have a relationship with wine pH (Table 1); lower temperatures for the 1975 vintage resulted in lower pH values. Higher temperature over all the growing season in 1976 and 1978 resulted in higher wine pH values.

In 1977, low temperatures for the first part of the growing season, but followed by high temperatures during grape maturation, resulted in the lowest wine pH values (Table 1).

Thus, temperatures for the first part of the growing season are thought to be more important in affecting wine pH than temperatures in the latter part of the season.

## Conclusions

Irrigation reduced wine color by reducing the amount of pigments, but more importantly by reducing the proportion of the pigments in the colored form. The reduced proportion of colored pigments was due to an increase in wine pH due to irrigation which was associated with larger berries compared to the berries from the nonirrigated vines.

The irrigation effect was due to irrigation *per se* and not due to the reduced yield associated with the nonirrigated vines.

Increasing the yield by increasing the pruning levels for the average over the four years increased wine pigments. The increased wine pigment was associated with a reduction in berry size.

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