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DEFICIT IRRIGATION STUDIES

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Evaluation of the Effects of Two Deficit Irrigation Strategies on Grapevine Cold Acclimation, Hardiness, Growth, Yield, and Fruit Quality

Two deficit irrigation strategies, partial rootzone drying (PRD) and regulated deficit irrigation (RDI), were evaluated for two seasons (2002-2003) for their effect on grapevine yield, fruit composition, vegetative growth, cold acclimation and bud cold hardiness. All studies were conducted in a 17-year-old block of bilateral cordon-trained, own-rooted Cabernet Sauvignon vines grown on a Patricia sandy loam soil in Plains, Texas. The PRD experimental design was a randomized complete block with 3 irrigation treatments and 4 replications, each consisting of 25-vine plots. This experiment compared two deficit treatments: (PRD) a typical PRD strategy of watering alternate sides of the rootzone, and (Equal) for which a volume of water equal to the PRD treatment was delivered to the entire root system. The deficit treatments were compared to a no-deficit treatment (Double) receiving 2X volume water to the entire root system. The PRD irrigation treatment provided water to only one side of the root system for a period of approximately 7 to 10 days, prior to switching water applications to the opposite side. The PRD water application was rotated to the other side (dry side) for the next irrigation cycle whenever soil moisture deficits fell between -100 to -150 kPa. Both PRD and Equal treatments were irrigated to replace approximately 50% ET_c during July and August.

The RDI experimental design was a randomized complete block, with 2 irrigation treatments and 4 replications, each consisting of 25-vine plots. Treatments consisted of deficit irrigation during the post fruit-set to veraison period compared to a control that was well-irrigated (no-deficit) throughout the season. During 2003, one of the plots was used for more intensive measurements of leaf water potential, stomatal conductance, transpiration, and xylem sap ABA content. Xylem sap was collected weekly from the RDI deficit and no-deficit treatments by expressing sap from leaves with a pressure chamber. Samples were frozen for subsequent analysis of ABA content by ELISA using the Phytodetek immunoassay kit for abscisic acid. Plant water status was monitored by measuring leaf water potential at mid-day. Stomatal conductance and transpiration rate were measured with a LiCor Porometer on 5 healthy leaves in mid-shoot positions on both sides of the canopy for 5 vines per plot.

Fruit was harvested at maturity, weighed for total yield per plot, average cluster weight and average berry weight. Juice samples were analyzed for soluble solids, total acidity, and pH. Pruning weights for each treatment were collected during the dormant season. Periderm development was monitored as an indicator of cold acclimation. For all treatments, five randomly selected canes per plot were measured weekly for the extent of periderm development in 2002 and 2003 beginning mid- season. A final measure of total periderm development was taken after leaf-fall. Dormant bud cold hardiness was evaluated using the digital thermal analysis method. All data were analyzed by ANOVA and mean separation when main effects were significant.

PRD Results and Discussion. Deficit irrigation via the PRD strategy performed the same as deficit irrigation that applied an equal volume of water to both sides of the rootzone for all parameters measured in 2002 and 2003 (Table 1.). There were no significant differences between the two deficit treatments in yield, cluster weight, berry weight, pruning weight, fruit soluble solids, titratable acidity, and pH. The 2X water treatment, which provided 100% or more of ET_c had significantly lower sugar content and higher pruning weight than the deficit treatments in 2002. The Double water treatment exhibited a nonsignificant trend to higher yield in 2002 and mean yield significantly higher than the PRD treatment in 2003.

Table 1. Mean components of yield, pruning weight, and fruit composition of Cabernet Sauvignon vines receiving PRD, deficit with water applied to both sides (Equal), and no deficit (Double) in 2002 and 2003.

| Irrigation Treatment | Yield (kg/vine) | Cluster Wt. (g) | Berry Wt. (g) | Pruning Wt. (kg/vine) | Soluble Solids (Brix) | Titrateable Acidity (g/L) | pH |
|-----------------------------|-----------------|-----------------|---------------|-----------------------|-----------------------|---------------------------|------|
| 2002 | | | | | | | |
| PRD | 5.15 | 102.56 | 1.28 | 0.52b | 24.78a | 4.23 | 3.83 |
| Equal | 5.12 | 100.26 | 1.25 | 0.73b | 24.50a | 4.05 | 3.85 |
| Double | 5.93 | 119.43 | 1.33 | 1.11a | 23.12b | 4.95 | 3.82 |
| 2003 | | | | | | | |
| PRD | 2.96b | 43.44 | 1.06 | 0.46b | 26.50 | 4.01 | 3.63 |
| Equal | 3.00ab | 42.07 | 1.10 | 0.63ab | 25.77 | 3.90 | 3.63 |
| Double | 3.89a | 44.19 | 1.32 | 0.75a | 25.50 | 4.01 | 3.66 |

Means within columns and years followed by the same letter are not significantly different at $P > 0.05$.

The deficit irrigation treatments (PRD and Equal) both induced significantly earlier periderm development than the 2X treatment in 2002 and 2003. During the first month of acclimation in 2002, deficit treatments exhibited 2 to 3 times greater percentage of nodes with periderm compared to the no-deficit treatment (Double). Bud cold hardiness evaluations exhibited no significant differences between treatments in 2002. However, 2003 treatments resulted in significantly greater bud cold hardiness for both deficit treatments compared to the 2X treatment for four sampling dates in the dormant season. It is difficult to discern whether the deficit treatments actually improved bud cold hardiness or that the Double water treatment may have been excessive, thereby reducing hardiness in these vines.

RDI Results and Discussion. Deficit irrigation during the fruit-set to veraison period had significantly higher fruit soluble solids and significantly reduced pruning weight compared to the no-deficit control (Table 2.). The deficit treatment had a nonsignificant trend to lower yields in both years, suggesting that imposition of a water deficit greater than that used in this experiment could result in reduced yields.

Pre-veraison deficit had a similar effect on shoot acclimation as PRD deficit. In both years, pre-veraison deficit vines began acclimation significantly earlier than the no-deficit treatment. By the end of the deficit treatment period (veraison), 42% of the nodes per shoot displayed periderm development compared to only 14% of the nodes

for the no-deficit control. Earlier periderm development, however, did not result in greater bud cold hardiness in either 2002 or 2003. There was a general trend to greater bud cold hardiness for pre-veraison deficit vines on several sampling dates, but the data were not significantly different.

Table 2. Mean components of yield, pruning weight, and fruit composition of Cabernet Sauvignon vines receiving pre-veraison water deficit or no deficit in 2002 and 2003.

| Irrigation Treatment | Yield (kg/vine) | Cluster Wt. (g) | Berry Wt. (g) | Pruning Wt. (kg/vine) | Soluble Solids (Brix) | Titrateable Acidity (g/L) | pH |
|-----------------------------|--------------------|-----------------------|---------------------|-----------------------------|-----------------------------|---------------------------------|------|
| 2002 | | | | | | | |
| Pre-Veraison Deficit | 4.53 | 88.43 | 1.17 | 0.58a | 24.55a | 4.01 | 3.88 |
| No Deficit | 5.43 | 97.76 | 1.25 | 0.99b | 23.60b | 4.50 | 3.86 |
| 2003 | | | | | | | |
| Pre-Veraison Deficit | 2.76 | 41.10 | - | 0.39 | 23.54 | 5.14 | 3.59 |
| No Deficit | 3.26 | 46.96 | - | 0.49 | 23.63 | 4.35 | 3.65 |

Means within columns and years followed by the same letter are not significantly different at $P > 0.05$.

Analysis of xylem sap ABA content revealed a rapid increase and peak in ABA concentration during the early period of the pre-veraison deficit treatment. Xylem sap ABA concentration was significantly higher in the deficit irrigation treatment for two consecutive sampling dates. The peak in ABA occurred six days prior to a rapid increase in periderm development in pre-veraison vines, suggesting that ABA may be a factor triggering or enhancing the acclimation process. Further studies are necessary to elucidate this relationship. ABA content rapidly decreased in pre-veraison deficit vines following the peak, which may be attributable to increased sensitivity to ABA of water-stressed vines and subsequent reduced ABA production.