Influence of Different Irrigation Amounts on Plant Vigor and Fruit Quality in Two California Vineyards on Contrasting Soil Types

#325-13

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ABSTRACT

Two Merlot vineyards, each containing at least two contrasting soil types, were investigated to monitor soil moisture variations and plant water stress under different irrigation regimes corresponding to 80, 66 and 50 percent of the grower's usual water supply on each soil type. One of the goals of this study was to evaluate differences in evapotranspiration (ET) of grapevines planted on two contrasting soils in a single vineyard block, using surface renewal methods, and to evaluate site-specific corrective measures. A second goal was to measure differences in fruit quality between soil sites and between irrigation treatments. Both vineyards were located in the Sacramento-San Joaquin Delta of northern California. Vineyard 1 (Thornton) contained soils with contrasting morphology. An Entisol on recent alluvium induced high vine vigor, higher grape yields and delayed fruit ripening. A nearby Alfisol with compact clayey subsoil supported less vigorous growth, lower plant water potential but higher fruit yields and earlier ripening. Vines in vineyard 1 were 5 years old, had VSP trellising with machine pre-pruning after harvest, and final cordon pruning in March. Vineyard 2 (Rancho Seco) was a 10-year old Merlot vineyard on a nearly level terrace, containing two strongly contrasting Alfisols. The first soil had loamy topsoil over very clayey, compact subsoil with minimal gravel. Vines were vigorous, plant water potential values were lower and harvest weights were higher than those recorded on the second soil. The second soil had sandy loam topsoil over sandy subsoil and contained 35 to 85% gravel and cobbles. Plants displayed lower vigor and had lower yields than those on the first soil. Plants in vineyard 2 had a VSP training system, and were cordon pruned in early January. Measured ET of vines on the four sites showed marked differences, reflecting the contrasting soil properties.

BACKGROUND

One of the biggest problems in crop management is the challenge of managing irrigation timing and amount to obtain uniformity of crop maturity and production within a single irrigation block that includes contrasting soils with different water holding characteristics. This is especially true for wine grape irrigation management, where having good-quality grapes reach maturity at the same time is crucial to optimal production. The traditional methods of assessing water-use efficiency do not apply in these situations. For optimal water use efficiency, the goal is to obtain the best marketable product per unit of water used, so optimizing irrigation of blocks with contrasting soil properties requires a non-traditional approach.

Currently, there is little information on the actual evapotranspiration (ET_a) of wine grapevines. Irrigation practices are mainly based on experience and traditional practices. The crop factor to estimate actual wine grapevine evapotranspiration (ET_a) is generally reported to be about 0.80 and growers are often encouraged to apply about 70% of well-watered crop evapotranspiration (ET_c) to achieve good production and quality. This, however, does not account for soil differences, the timing of irrigation, and it has not solved the problem of attaining uniform ripeness dates, which is important to growers. The ET_a should be estimated as $ET_a = ET_o \times K_c \times K_s$, where the well-watered evapotranspiration is $ET_c = ET_o \times K_c$ and the crop coefficient factor (K_c) corrects the ET_o estimate for water-stress effects on transpiration. Knowledge of the correct crop coefficient factor and soil surface moisture coefficient (K_s) for wine grapes could potentially improve irrigation efficiency. Information on the K_s factor, however, is unavailable at this time, so it is nearly impossible for grape growers to use the California Irrigation Management System (CIMIS) for this purpose.

This project was designed to more accurately determine ET_c, ET_a, K_c, and K_s figures and to study methods to estimate K_s from simple plant-based measurements. Evapotranspiration is being evaluated using the surface renewal (SR) method, which is calibrated using an eddy covariance sonic anemometer. The SR method was developed and tested at UC Davis, and it has many features that make it desirable for ET_a determination. There has been considerable research on use of the SR method to measure ET of wine grapes (Spano et al., 2000), and it offers a relatively simple, low-cost procedure to determine ET_a.

MATERIALS AND METHODS

Vineyard Management: Two Merlot vineyards, each containing contrasting soil types and located in the San Joaquin-Sacramento Delta region, were selected for this study. Both vineyards were irrigated. The Rancho Seco site was located on a terrace amid rolling hills. The vineyard contained 10-year-old Merlot vines on a nearly level terrace. Vines had VSP trellising and were cordon pruned in early January. The Thornton site contained 3-year-old Merlot vines, had VSP trellising with machine pre-pruning after harvest, and final cordon pruning in March.

Micrometeorological Stations: Surface renewal stations were set up for monitoring evapotranspiration in early July 2008. Each station was installed over one of two contrasting soil plots. Net solar radiation, wind speed and canopy temperature were recorded over the row in each of the selected soil patches. Monitoring equipment included thermocouples to measure air temperature, net radiometers to measure solar radiation, and infrared thermometers to measure vine canopy temperature. Soil temperature parameters were recorded by placing sensors and soil heat flux plates under the row and across the row.

Soil Sampling and Analysis: At the Thornton site, 38 auger holes were drilled, with 6 rows of 6 holes each, plus one additional hole at each weather station. At the Rancho Seco site, 4 soil pits were opened using a backhoe near the two surface renewal stations. A total of 16 soil samples were collected, described, and processed for further analysis. The soils at both vineyards were described following the NCSS field description manual (Soil Survey Staff, 1993). Soil pH and electrical conductivity were measured using a saturated paste. Soil solution samples were sent to the DANR analytical laboratory at UC Davis for complete analysis.

Plant Sampling and Analysis: During the first year, 40 vines were tagged and sampled near each of the four Surface Renewal stations. Mid-day plant water potentials (Ψ) were measured with a pressure bomb at veraison and harvest. At harvest, fruit yield was determined by weighing the harvest and dividing by the number of vines the first year, and then weighting the harvest for each individual vine the second year. Berry clusters were counted and weighed. The number of berries per cluster was counted. Pruning weights were recorded for all vines at both sites.

Modification of the Irrigation System: The irrigation system was modified in years two and three to apply 80%, 66% and 50% of baseline irrigation on selected patches away from the weather station. Soil moisture and water potential sensors were installed in the treated areas.

Figure 1. Surface renewal station. *Thermocouples are shown extending to the left from the station. The 3-d sonic anemometer is on the same arm as the thermocouples. The net radiometer (Rn sensor) is in the foreground. In addition, 3 soil heat flux plates are buried at 5 cm depth, one in the row and the others at 1/3 and 2/3 distance between rows. Soil temperature probes were inserted in the 5 cm soil layer at 12 locations to obtain the mean change in soil temperature over half hour periods. In conjunction with the heat flux plates, the change in soil temperature is used to estimate a mean value for soil heat flux on the ground surface.*

RESULTS

Vineyard One - Thornton

Vineyard One was located near the town of Thornton in the basin rim of the Sacramento Delta. Soils had redoximorphic features (red, gray and blue stains) caused by the presence of a shallow water table. Differences in soil type between two representative vineyard rows, 415E and 362W, are detailed in Table 1. The 415E station was associated with a deep stratified Entisol with a silty loam control section and fine sandy loam subsoil. The 362W station was set in a patch of much less vigorous vines and was associated with an Alfisol with a well-developed argillic horizon and oxidized sandy loam subsoil with evidence of silica coatings, iron banding and incipient cementation.

	Horizon	Depth, cm	%SP	pH	EC	%BS	Texture
Thornton 415E	Ap	0-36	54	5.6	0.77	70.3	Silty Clay Loam
	AC	36-66	71	6.1	0.37	67.8	Silty Clay Loam
	2Ab/C	66-102	70	6.5	0.19	67.2	Silty Clay Loam
	C1	102-122	57	6.6	0.20	71.4	Loam
	C2	122-152	54	6.8	0.22	74.0	Sandy Loam
Thornton 362W	Ap	0-30	54	6.8	0.57	75.3	Clay Loam
	BA	30-56	35	7.1	0.33	81.4	Loam
	Bt	56-102	46	7.7	0.56	121.7	Clay Loam
	Bt2	102-117	43	7.6	0.51	136.3	Clay Loam
	BCt	117-152	40	7.5	0.39	90.3	Sandy Clay Loam

SP, Water content at saturation; EC, electrical conductivity (dS/M); %BS, percent base saturation

Table 1. Contrasting soils in the Thornton vineyard. *Differences were noted between soils 1.1 (row 415E) and 1.2 (row 362W) in soil morphology, water content at saturation, pH, electrical conductivity, base saturation, and texture.*

Vineyard Two - Rancho Seco

Vineyard Two was located near Rancho Seco, and the vineyard site was set on a dissected old alluvial fan of the Laguna formation. The two soils at this site were situated on a level terrace and had a strong contrast in gravel content and soil texture (Figure 2). The Eastern station was set on a gravelly to extremely gravelly, weakly developed Alfisol with gravelly sandy loam textures above and a coarse loamy sand subsoil with over 75 to 83% coarse fragments (gravels and small cobbles) in some parts of the subsoil, within the root zone. The Western station was set on an Alfisol with a strongly developed argillic horizon lacking coarse fragments, over a loamy subsoil. This soil belonged to the Corning series. Vines on the coarse textured soil were smaller and less vigorous than those on the Corning soil.

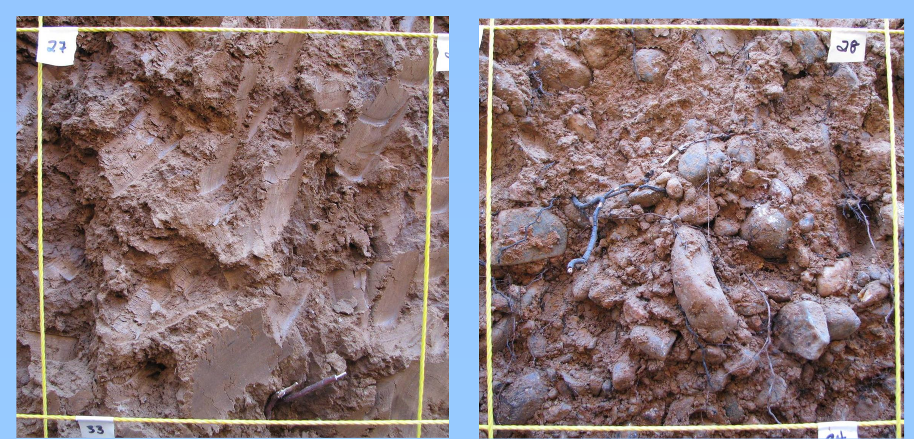

Figure 2. Contrasting soils in the Rancho Seco vineyard. ***Left:*** *Soil 2.1, loamy topsoil over very clayey, compact subsoil with few gravels.* ***Right:*** *Soil 2.2, gravelly sandy loam with 75-83% coarse fragments.*

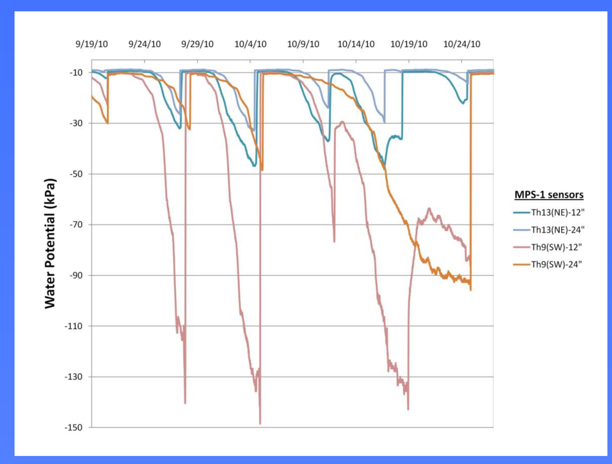

Figure 3. Soil water potential data from contrasting soils, Thornton. *Decagon dielectric water potential sensors (MPS1) were placed at depths of 12" and 24". These probes provide a continuous record of soil water potential. Blue lines show sensor readings from the Thornton NE site (Entisol). Orange lines show sensor readings from the Thornton SW site (Alfisol).*

Crop Evapotranspiration Values on Contrasting Soil Types

At the Thornton site, crop ET values (ET_c) were similar on the Alfisol and Entisol early in the season. However, beginning in mid-June, crop ET values on the Alfisol dropped below those on the Entisol and remained lower until mid-August (Figure 4a).

At the Rancho Seco site, similar trends were observed: crop ET values were similar on both soils early in the season. However, beginning in June, crop ET values on the gravelly soil dropped below those on the heavier textured soil (Figure 4b).

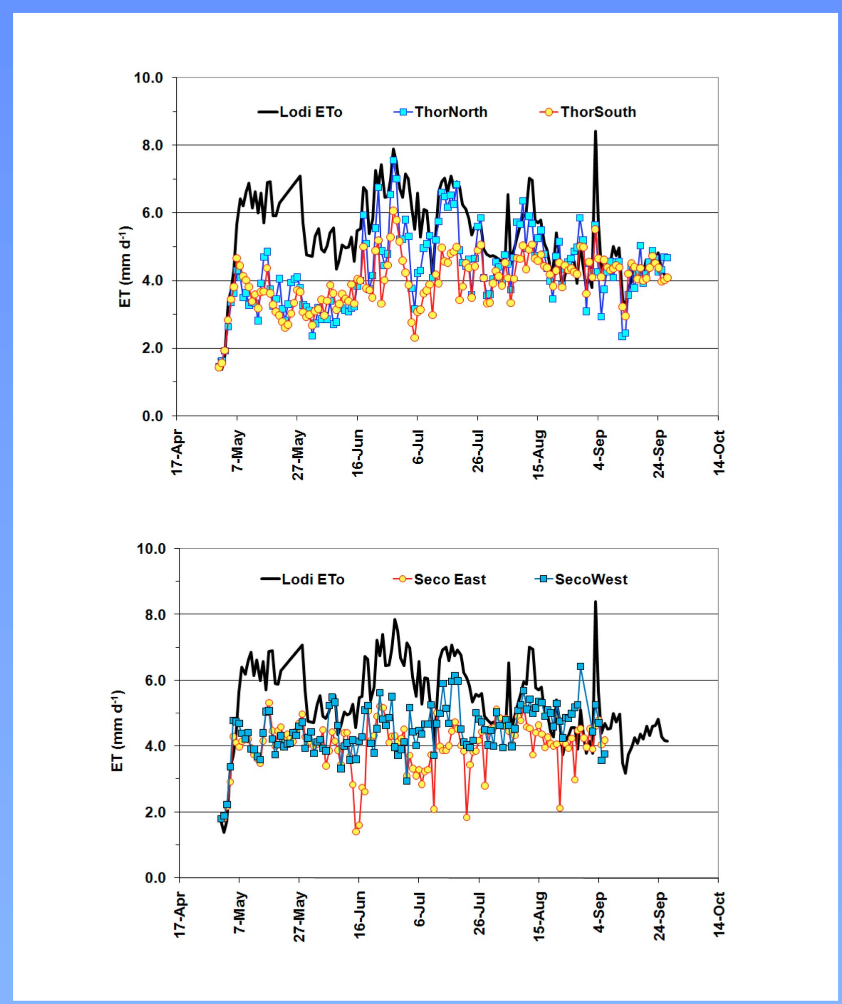

Figure 4. Evapotranspiration at contrasting sites in Thornton (4a, top) and Rancho Seco (4b, bottom). *Reference evapotranspiration values from a CIMIS station in Lodi, CA are shown for comparison.*

Differences in berry cluster weights correlated with soil characteristics

Differences in grape cluster weights correlated with soil characteristics over two successive years (2009 and 2010) in both vineyards. At the Rancho Seco site (Figure 5a), vines grown on the Corning soil with low coarse fragment content showed little variation in response to different irrigation levels. Cluster weights at 80%, 66% and 50% of baseline irrigation were strikingly similar. In contrast, vines grown on the coarser, gravelly soil showed significant variation between irrigation conditions. Data at Rancho Seco showed a similar pattern in 2010 (data not shown).

At the Thornton site (Figure 5b), vines grown on the Entisol (northeast plot), regardless of irrigation conditions, showed little variation in cluster weight. In contrast, vines grown on the Alfisol (southwest plot) showed lower vigor overall, and greater variation in grape cluster weights in response to different irrigation conditions. The lowest cluster weights were associated with vines grown on the Alfisol irrigated at 66% of baseline levels.

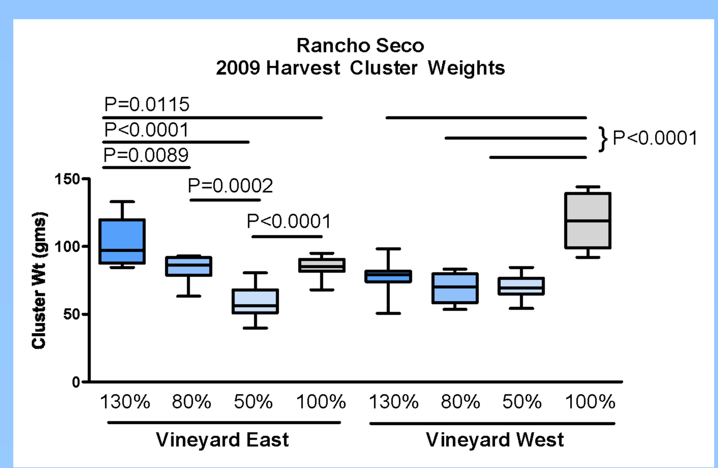

Figure 5a. Berry cluster weights at harvest at Rancho Seco (2009). *Cluster weights are shown on the y-axis. Irrigation levels, relative to baseline, are shown on the x-axis. Box plots indicate the 25th and 75th percentiles, with horizontal lines indicating the medians. Whiskers indicate 10th and 90th percentiles. All P values calculated using Mann-Whitney test.*

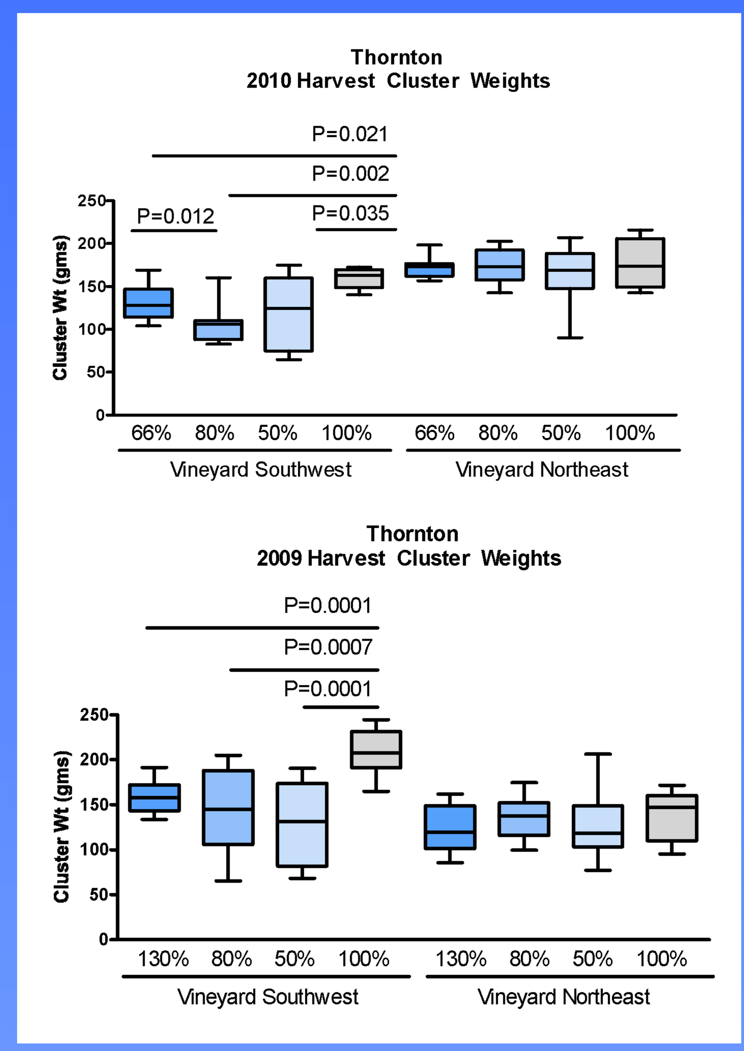

Figure 5b. Grape cluster weights at harvest over two successive years, Thornton vineyard. *Cluster weights are shown on the y-axis. Irrigation levels, relative to baseline, are shown on the x-axis. Box plots indicate the 25th and 75th percentiles, with horizontal lines indicating the medians. Whiskers indicate 10th and 90th percentiles. All P values calculated using Mann-Whitney test.*

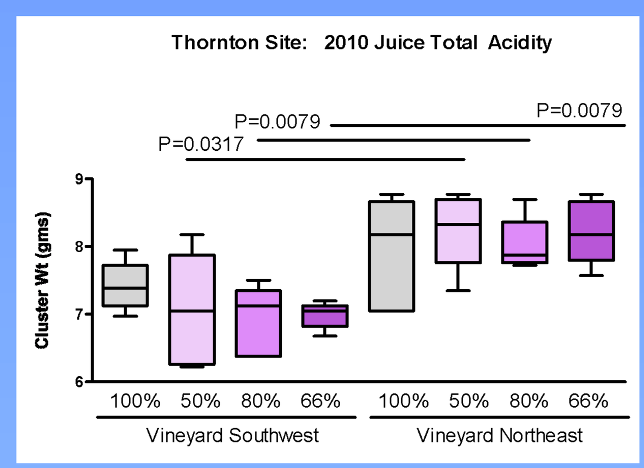

Figure 6. Juice total acidity, 2010 harvest, Thornton vineyard. *Significant differences were measured in total acidity when comparing grapes grown under the same irrigation conditions but on two different soil types within the same vineyard. TA was generally lower at the Southwest (Alfisol) site as compared to the Northeast (Entisol) site.*

SUMMARY AND DISCUSSION:

These two ongoing studies illustrate the concept that soil type may have a direct impact on vine water balance in single vineyard blocks. Contrasting soils can induce differences in crop coefficients and actual evapotranspiration, significantly affecting vine vigor, crop load and fruit quality.

In summary:

- Vines grown on contrasting soils exhibited differences in canopy size, overall crop load, and berry cluster weights.
- Evapotranspiration (ET) differences appeared later in the season, when plants experienced the most stress. ET differences correlated with differences in soil water holding capacity.
- Juice total acidity (TA) was higher on soils with a higher water holding capacity, and ripening was delayed.
- These findings appear to be consistent over the first two years of this ongoing study.

ACKNOWLEDGMENTS

The authors thank the vineyard owners, M. Bokisch and M. Olagaray, for providing access to their vineyard sites. This project was funded by the California Department of Water Resources (DWR).

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