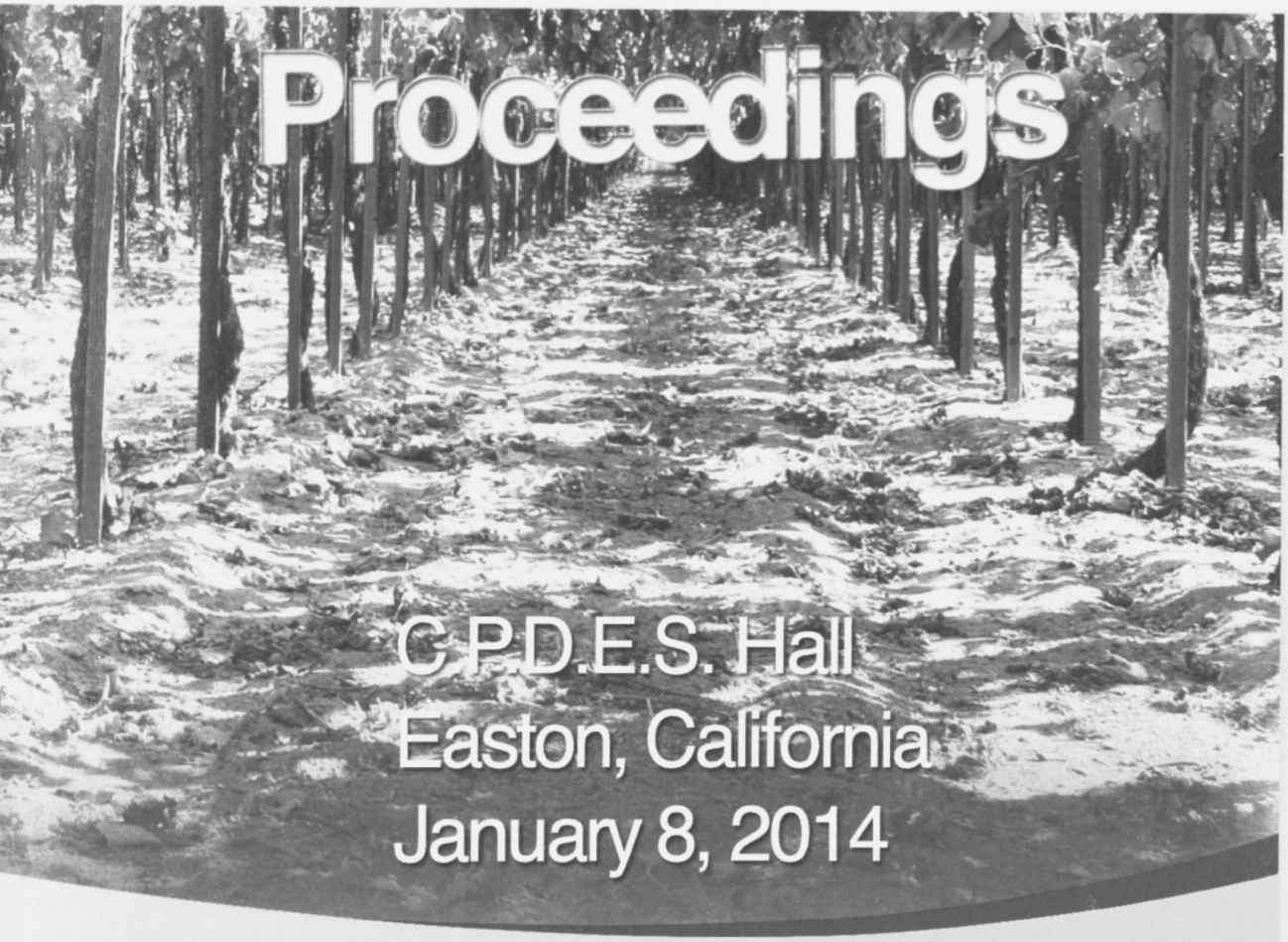
Grape Symposium



University of California
Agriculture and Natural Resources | Research and Extension Center System

Making a Difference for California

AGENDA

7:00 am **REGISTRATION**

7:45 am **MORNING WELCOME**

8:00 - 8:25 am **Research Update: Rootstocks for Raisin Production**
Sonet Van Zyl, California State University, Fresno

8:25 - 8:50 am **Research Update: Canopy Management in Dry-on-Vine (DOV) Raisin Vineyards**
Matthew Fidelibus, UC Davis & UC Kearney Ag Center, Parlier CA

8:50 - 9:30 am **Dynamics of Nitrogen Reserves in Grapevines and Vineyard Nitrogen and Potassium Requirements**
Larry Williams, UC Davis & UC Kearney Ag Center, Parlier CA

9:30 - 9:55 am **Raisin Moth Biology, Damage and Management**
Kent Daane, UC Berkeley & UC Kearney Ag Center, Parlier CA

9:55 - 10:15 am **BREAK**

10:15 - 10:45 am **Research Update: Raisin Grape Breeding Program**
Craig Ledbetter, USDA-ARS, Parlier CA

10:45 - 11:15 am **Economics of Producing Raisins**
Annette Levi, California State University, Fresno

11:15 - 12:00 pm **Research Update: Grapevine Trunk Diseases and Grower Survey**
Kendra Baumgartner, USDA ARS, Davis CA

12:00 pm **LUNCH**

Organizing Committee:

Matthew Fidelibus · UC Davis
Sonet Van Zyl · CSU Fresno
Stephen Vasquez · TKI

Evaluation of Nematode Resistant Rootstocks for Use with Early Ripening Raisin Varieties Grown for Dried on the Vine Raisin Production

Van Zyl, S[1]., Fidelibus, M., & Vasquez, S.J.

Introduction

Raisin grape production accounts for 7.59% of the world grape production with the USA in the leading position producing on average 400,000 tons annually. The USA represents 36% of the world's raisin production. California accounts for over 90% of the production, making raisins an important component of the viticulture industry in California. Raisin production is concentrated around the Fresno area with an annual farm-gate value of approximately $500 million.

Traditionally, 'Thompson Seedless' raisins are picked in late August, and tray dried between rows. The drying process typically takes two-three weeks to complete. The risk of inclement weather (cloudy skies and rain) during the drying period increases the chance of inadequate drying weather. Precipitation during the drying process can increase mold (*Alternaria*, *Aspergillus*, *Cladosporium* and *Botrytis*) growth on raisins and reduce its marketability. In addition to the risk of rain, raisin processing is labor intensive. These two factors have created interest among raisin growers in dried-on-vine (DOV) raisin production.

DOV raisin production relies on two essential components: 1) early maturing varieties and 2) new trellis systems developed specifically for DOV production. Currently two varieties are used for DOV production on high capacity systems namely Fiesta and Selma Pete. New vineyards for raisin production are being planted to one of these varieties due to their comparable production to Thompson Seedless. Both ripen earlier than Thompson Seedless and have potential for mechanical harvesting when DOV farmed. Fiesta has increased slowly since its release because it was thought to have a large seed trace. This has since been proven incorrect and plantings stand at 12,685 bearing and non-bearing acres (California Agricultural Statistics Service, 2010). Selma Pete acreage stands at 3,143 total (bearing and non-bearing) but interest is high for this variety specifically for DOV production using the open gable trellis system. In 2010, 6,716 acres of Fiesta and 1,245 acres of Selma Pete were produced using an overhead trellis system. It is conceivable that these two varieties may become the standards for DOV raisin production as older Thompson Seedless vineyards get removed.

Unlike traditional raisin production, trellis systems are vital to the success of DOV raisin production. Currently, two trellis systems are most prevalent among DOV growers, the open gable and the overhead trellis systems. The basic principle of the open gable trellis (syn: Y-trellis) maintains the fruit on both sides of the trellis after cane severing. In traditional raisin production vineyards, vines are head-trained, but for DOV production it is more desirable to train vines as bilateral, quadrilateral cordons or a split head to facilitate cane severance and pruning. The following season's fruiting wood is

maintained on both sides of the trellis or on catch wires in the trellis center. Overhead trellis systems rely on alternating middles for fruit drying zones and renewal areas for the following season's fruit-drying zone. Both these trellis systems lend themselves to high production and mechanization. As DOV raisin production increases, growers will select one of these two systems. Evaluation of rootstock, scion, and trellis system interaction is essential in deciding which combination maximizes production.

Although DOV raisin production has many benefits (less labor intensive, better crop quality), some drawbacks exist. One disadvantage is the severing of canes, which reduces the active canopy by half. This de-vigorating process can reduce the production of grapevines over time. High vigor is key to overcoming the de-vigorating process. Establishing a raisin vineyard on its own roots for DOV production subject vines to other problems. Raisin vineyards are often planted on sandy soils containing pests such as nematodes. The reduction and eventual elimination of methyl bromide in the coming years will make vineyard establishment more difficult. Development of a new broad-spectrum fumigant equivalent to methyl bromide is not likely. New vineyards will therefore have to be planted on rootstocks having resistance to root knot (*Meloidogyne* spp.), ring (*Criconemella xenoplax*), dagger (*Xiphinema* spp.) nematodes and phylloxera. High vigor rootstocks that have resistance to nematodes will be most beneficial to the longevity of DOV vineyards.

Freedom and 1103 Paulsen are rootstocks which are commercially available that have some resistance to nematodes and are considered high vigor stocks. The use of rootstocks that impart vigor and have nematode resistance will be important in DOV vineyard establishment.

Establishing a DOV vineyard is costly. Setbacks due to weak vines, which do not fill the trellis system, cost growers time and money. It is conceivable that rootstocks will play an important role in new DOV vineyards. Some of the rootstocks previously mentioned, are currently being evaluated under DOV raisin production using a south-side trellis system.

Materials and Methods

In 2009, 'Selma Pete' was planted onto six rootstocks. The layout of the block represents a random complete block design with seven replicates (seven vines per replicate). Three rootstocks represent products from the USDA-ARS, Geneva, NY breeding program. Their strong resistance to root-knot nematode and adaptability to the San Joaquin Valley conditions characterize these rootstocks. Illinois-547-1 is a rootstock developed in 1956 by Herb Barrett, a University of Illinois breeder. Little is known about this stock but its parentage suggests that it has tolerance to lime soils, nematodes and phylloxera. 1103-Paulsen is rootstock that has long been used in the wine grape industry but has shown promise in table and raisin trials. Freedom known as an industry standard is being used as the control. Table 1 outlines the rootstocks being used in this trial.

The vineyard is planted to an open gable trellis system on 7' x 12' spacing and trained to a bilateral cordon and cane pruned. The first data was collected in the 2012 growing season. Petioles were collected during bloom, at veraison and at harvest to determine plant nutritional values.

Table 1. Rootstock selections evaluated in a Selma Pete rootstock trial in Fresno County. Freedom rootstock is the industry standard and was planted as the control.

Rootstock	Origin	Parentage
Freedom	USDA, Fresno	1613 C (*V. solonis* x *V. othello*) x Dog Ridge
Matador (PC0188-151)	USDA Geneva	101-14 Mgt x 3-1A (*V. mustangensis* x *V. rupestris*)
PC00106-47	USDA Geneva	Dog Ridge x (*V. x doaniana* x *V. vulpina*)
PC001112-39	USDA Geneva	*V. rupestris* x (*V.* x *novae-angliae* x *V. mustangensis*)
Illinois 547-15	University of Illinois	*V. rupestris* 38 x B9 *V. cinerea*
1103P	Sicily, Italy	*V. berlandieri* x *V. rupestris*

Results

The data collected during the 2012 season was not statistically analyzed. Data is still being collected for the 2013 season and statistical analysis will be performed on all data once collected. Table 2 shows the fruit characteristics and pruning weights for the 2012 growing season. Representative berry samples were collected to determine the total soluble solids (Brix), pH and titratable acid (TA). Total soluble solids were consistently high for all the rootstocks with Illinois 547-1 showing the highest average TSS. There were no differences between treatments for the pH or TA. Pruning weights were lower for 1103 Paulsen and Illinois 547-1 compared to the other rootstocks, with the control (Freedom) at the highest.

Table 2. Fruit characteristics and pruning weights.

Rootstock	TSS (Brix)	pH	TA	Pruning weight (lbs)
Freedom	27.7	4.2	0.4	3.1
Matador (PC0188-151)	27.3	4.1	0.4	2.6
PC00106-47	28.4	4.2	0.4	3.3
PC001112-39	28.6	4.1	0.4	2.2
Illinois 547-15	28.9	4.2	0.4	1.3
1103P	28.8	4.2	0.4	1.7

Freedom produced the most green (fresh) fruit at 33.4 pounds (Table 3), with 1103P producing the least at 21.9 pounds. The most dried fruit was also produced by Freedom

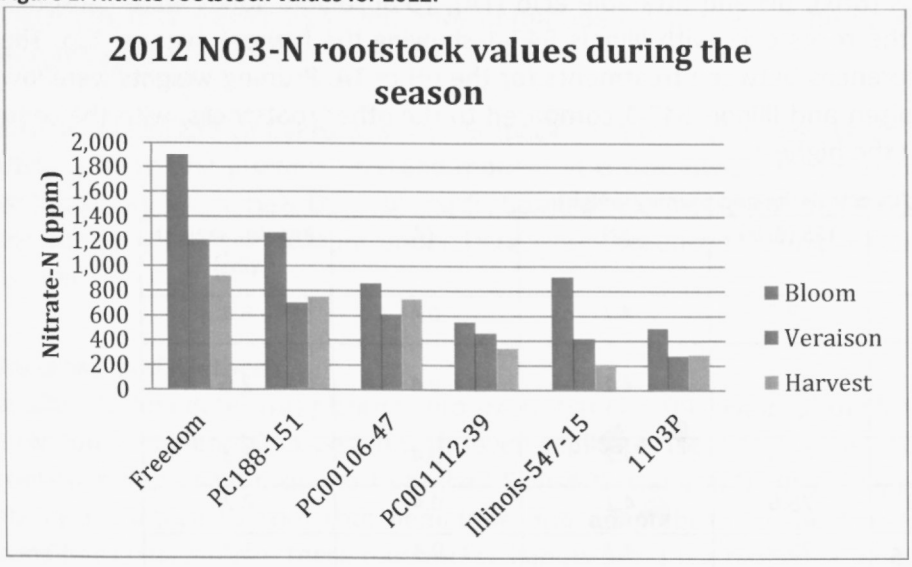
and the least was produced by PC00106-47, an unnamed cultivar from the USDA breeding program.

Table 3. Fresh and dry weights and raisin characteristics.

Rootstock	Fresh Weight (lbs)	Dry weight (lbs)	% Moisture	%SStd	%B-B
Freedom	33.4	4.25	9.81	0.14	99.06
Matador (PC0188-151)	33.4	4.21	9.86	0.10	99.8
PC00106-47	23.8	3.86	9.54	0.34	98.06
PC001112-39	29.3	4.32	9.49	1.66	91.30
Illinois 547-15	23.9	3.85	9.69	1.20	9140
1103P	21.9	3.99	9.94	0.29	95.63

Freedom is known as a good forager for nutrients and water and in this trial it stood out amongst the rootstocks as a strong performer. Figure 1 shows the seasonal values for nitrate nitrogen. All of the other rootstocks had lower nitrate nitrogen values throughout the season, with 1103P showing visual symptoms. Based on the pruning weight data, it probably would have benefited from an in-season application of nitrogen.

Figure 1. Nitrate rootstock values for 2012.



Petiole analyses are shown in Tables 4-6. Table 4 represents the nutritional values at bloom for each rootstock. Potassium levels were the highest for Freedom and Illinois 547-1. Phosphorus levels for 1103P was much higher than Freedom, Matador and PC001112-39, with the lowest values represented in PC00106-47 and Illinois 547-15.

PC00106-47 had the highest value for sulfur at 1412 ppm with Freedom having the second most at 925 ppm at bloom and the trend continued through veraison and harvest. Freedom showed the highest levels of sodium and chlorine throughout the season.

The data represented in this update is preliminary. The data from 2013 and 2014 will lead to specific conclusions and suggestions regarding the establishment of new rootstocks.

Table 4 Bloom petiole nutritional values.

Rootstock	N (Total)	P (Total)	K (Total)	S (Total)	B (Total)	Ca (Total)	Mg (Total)	Zn (Total)	NO3-N	Na (Total)	Cl (Total)
	%	%	%	ppm	ppm	%	%	ppm	ppm	ppm	%
Freedom	1.10	0.30	3.32	925.71	50.74	1.33	0.74	44.06	1901.43	197.57	0.26
Matador (PC-188-151)	1.03	0.35	2.47	878.57	47.83	1.47	0.86	46.33	1267.14	125.71	0.09
PC00106-47	0.93	0.16	2.73	1412.86	43.47	1.42	0.60	46.20	862.86	75.57	0.12
PC001112-39	0.89	0.30	2.67	798.57	44.34	1.19	0.61	49.33	551.43	177.29	0.11
Illinois 547-15	0.93	0.19	3.34	700.00	52.73	1.31	0.61	43.50	917.14	116.43	0.18
1103P	0.93	0.42	2.95	1052.86	48.13	1.68	0.73	45.80	501.43	144.57	0.13

Table 5. Veraison nutritional values.

Rootstock	N (Total)	P (Total)	K (Total)	S (Total)	B (Total)	Ca (Total)	Mg (Total)	Zn (Total)	NO3-N	Na (Total)	Cl (Total)
	%	%	%	ppm	ppm	%	%	ppm	ppm	ppm	%
Freedom	0.72	0.07	2.42	771.43	35.46	1.72	1.09	33.64	1208.57	639.86	0.38
Matador (PC-188-151)	0.64	0.11	1.74	838.57	37.41	1.71	1.36	37.53	701.43	409.43	0.13
PC00106-47	0.64	0.07	2.59	1005.71	36.11	1.59	0.89	38.69	612.86	145.14	0.18
PC001112-39	0.61	0.08	2.18	781.43	38.76	1.57	1.14	39.93	460.00	280.57	0.15
Illinois 547-15	0.59	0.09	2.05	604.29	38.69	1.87	1.11	37.60	418.57	516.86	0.30
1103P	0.58	0.12	2.03	858.57	40.30	1.97	1.28	32.29	280.00	633.71	0.27

Table 6. Harvest nutritional values

Rootstock	N (Total)	P (Total)	K (Total)	S (Total)	B (Total)	Ca (Total)	Mg (Total)	Zn (Total)	NO3-N	Na (Total)	Cl (Total)
	%	%	%	ppm	ppm	%	%	ppm	ppm	ppm	%
Freedom	0.58	0.07	2.04	705.71	33.57	2.11	1.66	30.99	921.43	2098.86	0.64
Matador (PC-188-151)	0.55	0.09	1.54	788.57	33.09	1.94	1.95	31.41	750.00	1458.86	0.19
PC00106-47	0.57	0.07	2.34	984.29	33.04	1.84	1.48	33.19	734.29	275.14	0.25
PC00111 2-39	0.51	0.07	1.84	728.57	32.87	1.87	1.75	37.84	338.57	475.71	0.23
Illinois 547-15	0.50	0.07	1.77	540.00	34.64	2.24	1.51	27.29	208.57	1876.14	0.47
1103P	0.52	0.12	1.87	812.86	35.71	2.37	1.89	25.34	287.14	1401.00	0.43

Impact of canopy management practices on the fruitfulness, yield, and quality of dry-on-vine raisin grapes on open gable trellis systems

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Introduction

Most modern dry-on-vine (DOV) raisin vineyards in California have an overhead arbor (Figure 1) or an open gable (Figure 2) trellis system. The overhead arbor has a slightly greater yield potential than the open gable, but is more costly to install and requires more specialized farming and harvest equipment than the open gable. Approximately 1/3 of Selma Pete vineyards are on an overhead trellis system (USDA NASS 2012); most of the rest are on an open gable. The original open gable DOV trellis is comprised of steel posts topped at 4.5 ft with 6 ft-wide V-shaped steel cross arm assemblies supporting six fruiting wires, three on each side (Fidelibus et al., 2008; Figure 2). The bottom two wires on each cross arm support fruiting canes. Cordon support wires are affixed immediately below the base of the cross arm assemblies, and a vertical 1 ft-tall post extension is mounted in the center of the cross arm assembly to support a foliage catch wire. In spring, moveable rake wires are pulled toward the center of the trellis, thus gathering the renewal shoots emerging from spurs and guiding them toward the center of the trellis where they can be supported by the center-mounted foliage catch wire.

Fruiting canes of vines subjected to the center-divided canopy management system are tied to both cross-arms creating a balanced crop load on the trellis, and helping to provide a physical separation of the renewal shoots from the fruiting shoots on canes. Canopy management practices such as the separation of renewal and fruiting zones may increase productivity if they promote the exposure of renewal shoots to sunlight (Shaulis and May, 1971). Christensen (1979) showed that Thompson Seedless canes originating from renewal shoots that grew under sun-exposed conditions, "sun canes", had better bud break than shade canes, and the shoots from sun canes were more vigorous and productive than shoots from shade canes. The specific benefit that center-divided canopies, or other possible canopy division practices, may have on the exposure of renewal shoots to sunlight, or on bud fruitfulness, has not been determined for Fiesta or Selma Pete on open gable DOV trellises. Such information is needed to help growers understand which elements of the original open gable design concept are critical to ensuring high yields.

Since the open gable trellis was commercialized, growers and trellis companies have significantly modified or omitted several of the original trellis design features and canopy management practices for various reasons including: to reduce the cost of trellis materials, facilitate pruning, more distinctly separate the fruiting and renewal zones, and to enable the vines to be harvested with smaller, less expensive, and more widely available, machines. Vineyard trellis systems with a narrower cross arm span have also been modified with a narrower cross arm angle, with many also having a substantially lowered cordon wire. These changes were made to make pruning easier (Anonymous, 2006). Many growers have also omitted the center

mounted foliage catch wire and rake wires, thus reducing the cost of trellis materials and installation. Without catch wires, the renewal shoots cannot be guided into the center of the trellis, but the canopy can still be separated into renewal and fruiting zones by pruning in such a way that canes and spurs are on separate cordons, a pruning style known as within-row-alternate-bearing (WRAB) or, more commonly, as the 'Peacock' method, after the person who invented this pruning style (Peacock and Swanson, Fidelibus et al. 2007; Figure 3).

Clearly, the move to DOV has inspired creative canopy management practices, but reports of disappointing or declining yields may indicate that some of the practices being implemented may be undesirable. Poor performance may be related to some of the trellis design and vine training changes described above, but the fact that multiple changes were often implemented at once makes it difficult to determine which factor or factors may be most important. Therefore, we have begun work to determine how different trellis designs and canopy management practices may affect canopy structure, light environment, and productivity of 'Selma Pete' and 'Fiesta' grapevines on open gable trellises.

Materials and methods

An experiment to determine how different canopy separation methods may affect canopy structure, light levels, and raisin yield and quality will be conducted in an open gable DOV vineyard at the Kearney Agricultural Center (KAC), Parlier, CA. The vineyard, established in 2004, consists of 'Selma Pete' grapevines on Freedom rootstock. The vines are trained to quadrilateral cordons on an open gable trellis system similar to that described in the introduction and in Fidelibus et al. (2008). In the winter of 2012, plots comprised of five adjacent vines were assigned to one of three treatments: 1) center-divided, 2) non-divided, or 3) WRAB. Vines assigned to the center-divided or non-divided treatments were cane pruned, leaving six to eight 15-node canes, and approximately 10 two-bud spurs per vine. Canes and spurs were left on any of the vines' cordons; the only difference between those two treatments was that vines assigned to the center-divided treatment made use of rake wires and a center-mounted foliage catch wire to separate renewal shoots from fruiting shoots in the spring. Vines assigned to the WRAB treatment were pruned such that the cordons between any two adjacent vines were either entirely spurs, or mostly canes, creating fruiting or renewal zones that alternated between pairs of vine trunks (Figure 3). Each treatment was replicated in eight plots in a randomized complete block design, and the entire vineyard was subjected to the same cultural practices considered normal and ordinary for DOV raisin grapes (Christensen 2000).

During the cluster initiation period, in May and June, renewal zone canopy architecture was characterized with a technique known as the point quadrat method (Smart and Robinson 2001). Briefly, a narrow steel rod with a sharp tip was passed horizontally through the canopy at 25 regular intervals along a transect parallel to the vine row and the ground surface, and about midway between the cordons and the top of the trellis. Each leaf, shoot, cluster, and canopy gap was noted, and the layers of each organ calculated. Similar measurements were also made vertically, from the top of the cordon through the canopy. Shoot light environment were estimated by measuring photosynthetically active radiation (PAR) levels with a quantum sensor at the cordon, and at node positions 4 to 6 and 8 to 10. Separate measurements were made for fruiting and renewal zones on vines with WRAB canopies. These data were used to determine how the various canopy separation treatments affected canopy development, the number of leaf layers in the renewal zone, and light environment the renewal shoots were exposed to. In WRAB plots separate measurements were made in the fruiting and renewal zones of each vine.

Fruit maturation was monitored periodically beginning in late July, and when soluble solids reach approximately 21 Brix, replicated samples of 100 berries were randomly collected from the vines in each plot. Each sample of berries was weighed, and average berry weight determined. Next, each berry sample was crushed in a blender, the juice filtered, and soluble solids determined with a digital refractometer. Juice pH and titratable acidity were determined by titration with 0.1 N NaOH to an 8.2 pH endpoint using an automatic titrator (900 A, Orion Research, Boston). The fruiting canes of each vine in every plot were then severed to initiate grape drying. The grapes were periodically inspected as they dried, and raisins were harvested from the vines when their moisture content decreased to about 14%. At harvest, clusters of raisins from the two vines in each plot were picked, counted, weighed, mixed, and a 1 kg subsample was collected, sealed in a plastic bag, and submitted to the USDA Processed Products Division, Fresno, CA, where trained inspectors will determine moisture content and grades, using standard methods. Prunings, including canes severed during the summer to initiate drying, will be collected, dried in a forced air oven until a constant weight is achieved, and their weight recorded. Data will be subjected to analysis of variance using SAS statistical software (SAS Inc., Cary, NC), or regression analyses, using SigmaPlot (SysStat Software Inc., San Jose, CA) software. Return fruitfulness will be noted in spring, after the flower clusters become visible.

Separate survey measurements were conducted in nine different commercial raisin vineyards having Fiesta and Selma Pete grapevines on open gable trellis systems. The vineyards selected represented a range of commercial trellis and canopy management systems. The physical characteristics of the trellis systems, including cordon height, cross arm length and angle, foliage wire number and orientation, and canopy separation method were noted, along with cane and spur numbers, and the number of nodes on each. The number of renewal shoots per vine was also noted. Canopy growth, structure, and light environment measurements were collected from three typical vines in each vineyard on each measurement date. Measurements were made as described for the canopy separation study. Fruit composition and raisin yield and quality data were also be collected as described, and the scion, rootstock, and characteristics of each trellis and training system were noted, and measurements of shaded area, canopy structure, and light environment were made on three typical vines in each vineyard as described in the canopy separation study. Immediately before cane severance, 100-berry samples were collected from each of the three plots in every vineyard, and Brix, pH, TA, and berry weight were calculated as previously described. Canes were then severed, grapes dried, and cluster counts, raisin yield, quality, and moisture content determined. Dry weight of prunings will be determined in winter, and return fruitfulness will be noted in spring, after the flower clusters become visible. Canopy characteristics will be regressed against each other, for example the number of leaf layers versus light levels in the renewal zone, and against crop coefficients such as return fruitfulness.

Results and discussion

Kearney canopy separation trial. Canopy separation method affected the number of leaf layers and the proportion of the leaves on the exterior of the vine canopies (Table 1). The canopies of all vines had similar numbers of horizontal leaf layers when measured in July, but vines with non-divided and center-divided canopies had fewer exterior leaves, horizontally and vertically, and more leaf layers, vertically, than vines with WRAB canopies (Table 1). Fewer leaf layers should improve light levels in the canopy, an effect that could promote bud fruitfulness and

budbreak, and having more leaves on the exterior of the canopy is also desirable as exterior leaves have the greatest photosynthetic capacity due to their better sunlight exposure.

Canopy separation practices, especially WRAB, increased light intensity in the renewal zone early in the season, but as the canopy developed over time, differences between treatments, with respect to light intensity, diminished. (Figure 4). Renewal shoots growing under better light exposure could form dormant buds with greater fruitfulness than those from renewal shoots grown under lower light intensities, and shoots exposed to high light levels generally have lower rates of bud necrosis over winter than shoots exposed to low light conditions. Increased bud fruitfulness and improved budbreak could potentially increase vine yields.

Position in the canopy and day of year also affected light intensity in the canopy regardless of canopy separation method. As expected, the highest light levels were at node positions 8 to 10, which were nearer the top of the trellis, and light levels diminished at lower node positions, with the lowest light levels at the cordon (Figure 5). Light levels were also generally higher on the south side of trellis compared to the north side. Light levels at node positions 8 to 10 generally decreased over time, whereas light levels at lower positions were relatively stable over time. The influence of node position on light levels might partly explain similar effects of node position on bud fruitfulness and budbreak, both of which tend to increase from the base to the tip of a cane (Christensen, 1986).

Raisin yield from vines with non-separated canopies, or canopies separated across the row was similar (4.75 to 5.16 tons/acre), and greater than the yield of vines whose canopies were separated down the row (3.19 tons/acre), but differences in yield are probably due to the fact that the pruning practices required to implement WRAB canopy separation limited cane selection in 2013; vines with non-separated canopies, or center-divided canopies had an average of 6 or 7 canes/ vine, whereas WRAB vines had, on average, about 5 canes per vine. Cane selection on WRAB vines will likely improve as the vines are repeatedly subjected to the same pruning practices, so a better understanding of the possible effects of canopy separation practices on yield will come with time.

Industry survey measurements. The industry survey measurements confirmed that there are a wide range of open gable trellis designs used by growers. For example, cross arm width ranged from 49.5" to 74.5", and trellis height from 60" to 71". Yields generally increase with cross arm width and trellis height, provided the vines can fill trellis they are provided with. For example, Peacock and Swanson (2005) showed that as trellis width increased from a single wire to cross arms that were 1.5 foot, 3 foot, or 4 foot wide, raisin yields increased 27%, 38%, and 73%, respectively. Thus, one should expect yield potential to increase with trellis height and width if other variables, such as row spacing, are held constant, and if the trellises do not become so large as to shade each other. All the vineyards visited had 12' row spacing, so trellis size may have a strong effect on yield. Unfortunately, it was not possible to collect yield data from all the vineyards visited, so yield data were not analyzed. However, we are planning to collect bud break and bud fruitfulness data in spring, 2014.

In addition to different trellis sizes, many growers have established the vine heads or cordons at variable heights on the trellis. We wanted to examine how cordon or head height might affect light levels in the canopy, but this was complicated due to differences in trellis heights. For illustrative purposes, we chose to measure the gap between trellis height and height of the head or cordon as a measure of "head height", with small gaps having relatively high heads, and large gaps having relatively low heads. Using this methodology, it appears that vines

with relatively low heads or cordons relative to their trellis height generally have lower light levels at most positions in their canopies than vines with relatively high heads or cordons (Figures 6-11). Christensen has noted that vines having low heads or cordons relative to trellis height tend to have less fruitful canes. This is most likely because the light environment that renewal shoots are exposed to between bloom and veraison affects the potential fruitfulness of these shoots in the following year, when they have become fruiting canes. Buds from shoots that grew out under good light conditions will have better budbreak and higher fruitfulness than buds from shoots grown under poor light conditions.

Table 1. Effect of canopy separation method on the number of leaf layers and the percent of leaves on the canopy exterior of Selma Pete grapevines on an open gable trellis, Parlier, CA.

Canopy separation method	Horizontal		Vertical	
	Leaf layers (no.)	Exterior leaves (%)	Leaf layers (no.)	Exterior leaves (%)
None	2.3[z]	29 b	3.5 a	23 b
Center divided	2.4	26 b	3.5 a	22 b
WRAB[y]	2.5	40 a	2.9 b	35 a

[z]Values are treatment means, n = 8. Means followed by a different letter, within columns, are significantly different according to Duncan's new multiple range test.

[y]WRAB = "within row alternate bearing", also known as "Peacock" pruning.

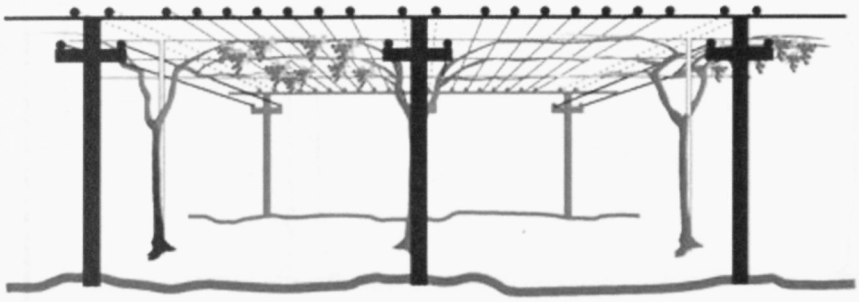

Figure 1. An overhead arbor trellis system.

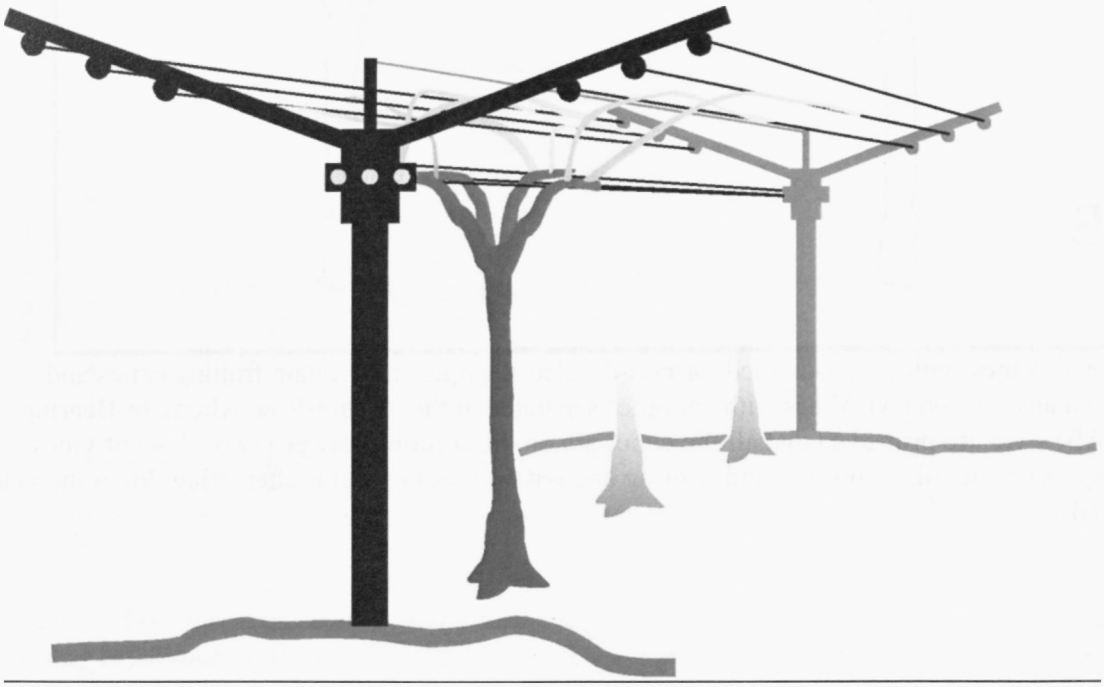

Figure 2. An open gable DOV trellis system.

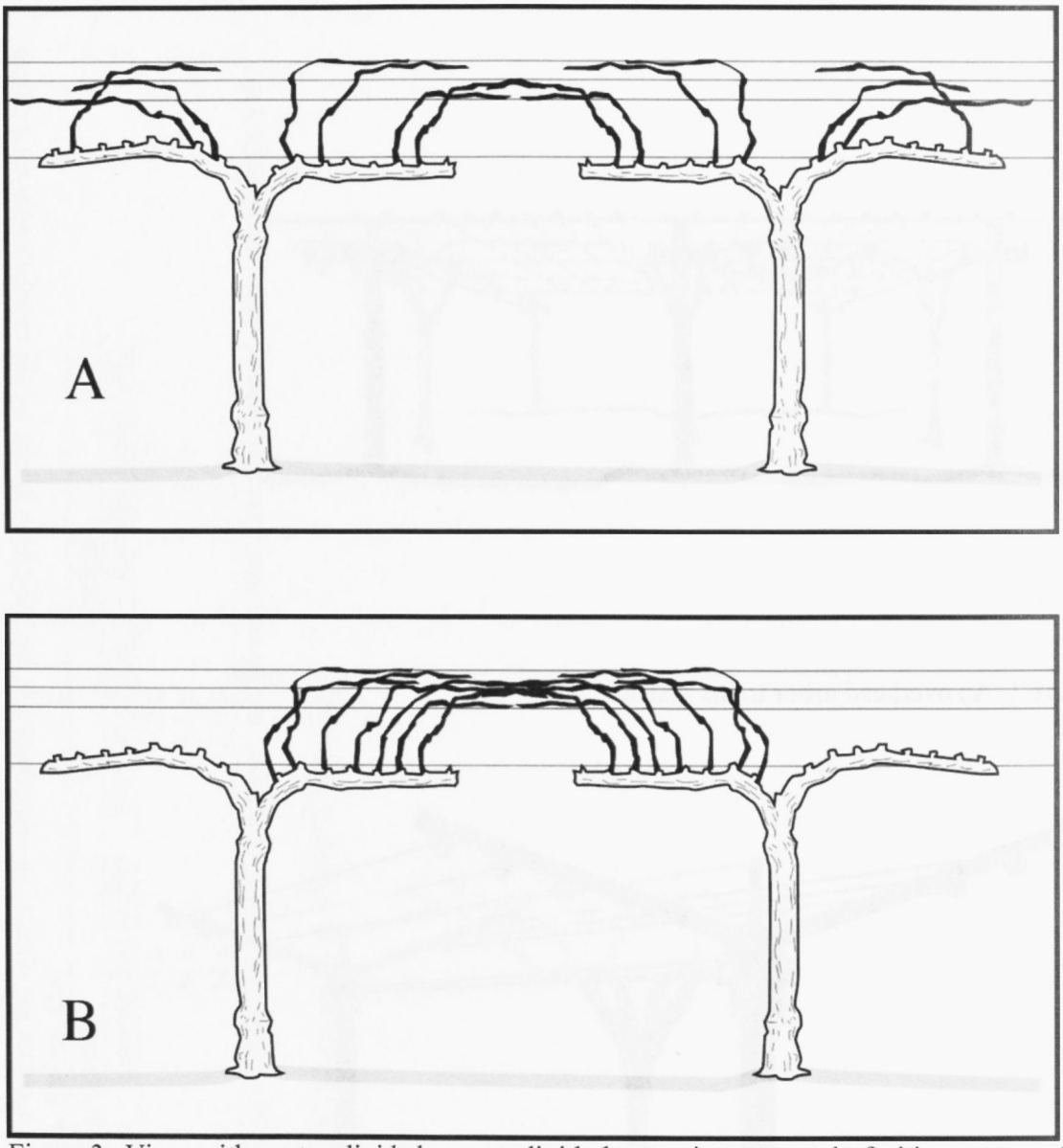

Figure 3. Vines with center-divided, or non-divided, canopies may retain fruiting canes and spurs on any cordon (A). Vines with canopies separated in the Within-Row-Alternate-Bearing (WRAB) style are pruned so that all the canes are on the cordons between two adjacent vines, with spurs on the other cordons, and fruiting and renewal sections thus alternating down the vine rows (B).

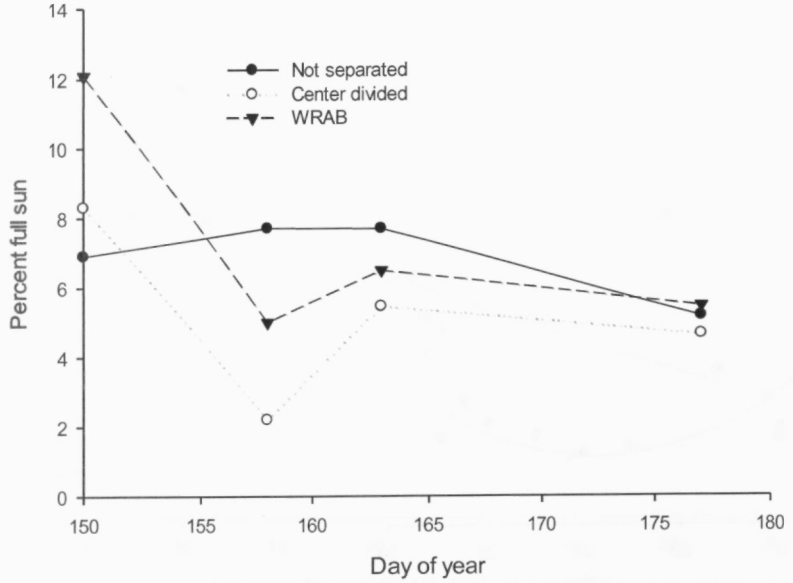

Figure 4. Canopy separation practices increased light levels in the renewal zone of Selma Pete grapevines on an open gable trellis early in the season, but as the canopy developed over time, light level differences between treatments diminished.

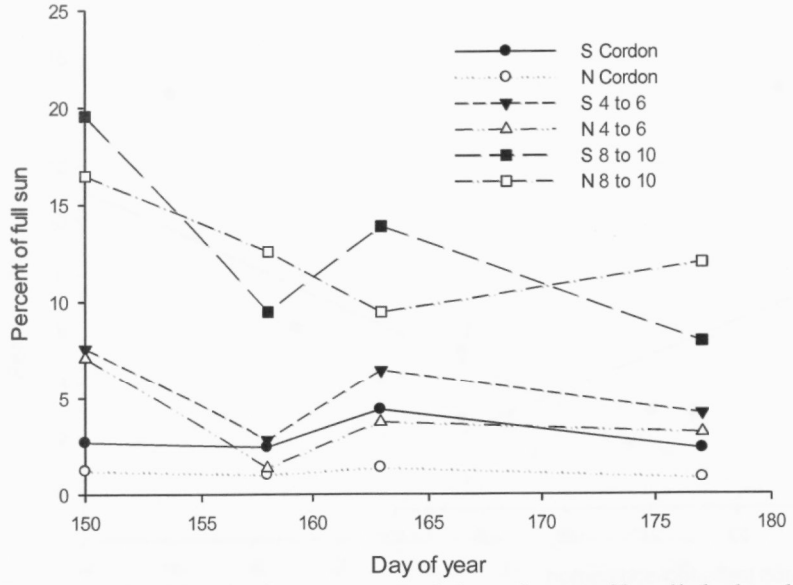

Figure 5. Position in the canopy and day of year effect light levels in the canopy regardless of canopy separation method. "S" means south, "N" means north, "cordon" means measurements made at cordon level, "4 to 6" means measurements made between nodes four and six (node number increases from base to tip) on renewal shoots, "8 to 10" means measurements made between nodes 8 and 10.

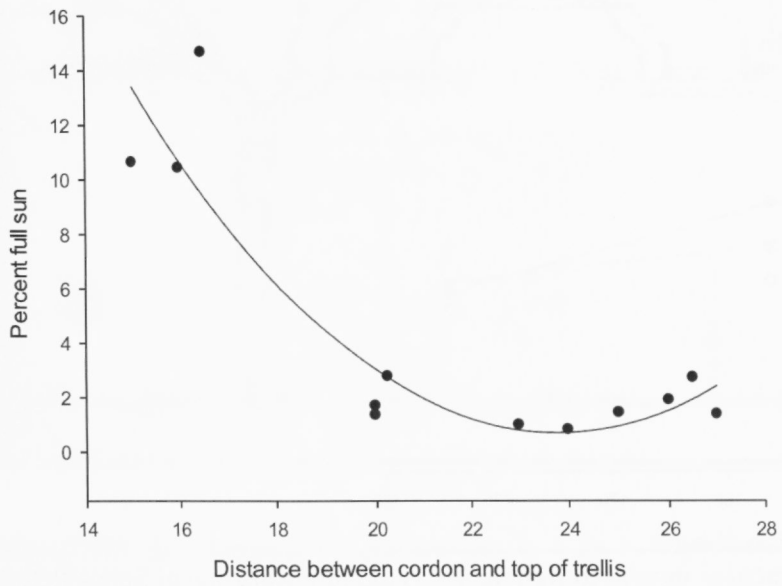

Figure 6. Effect of distance between the cordon and the top of the trellis on light levels at the cordon of Selma Pete or Fiesta grapevines with non-separated or center-divided canopies.

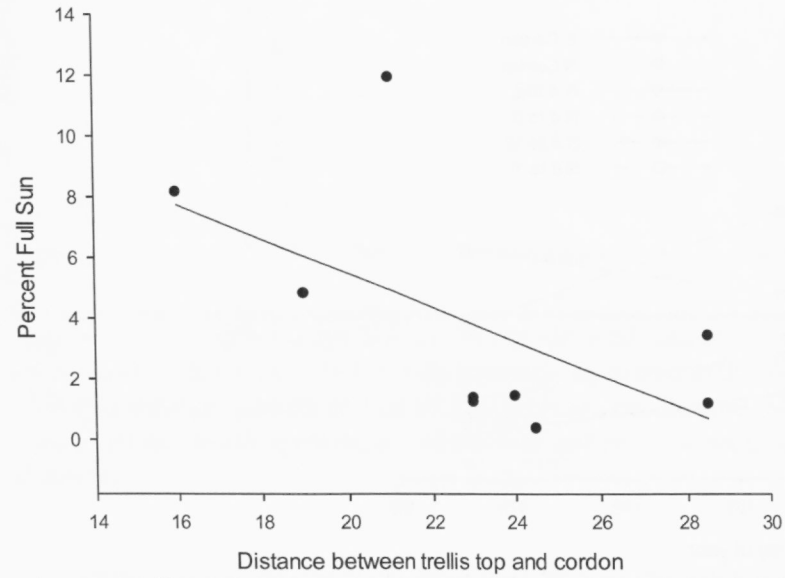

Figure 7. Effect of distance between the cordon and the top of the trellis on light levels at the cordon of Selma Pete grapevines with canopies subjected to within-row alternate-bearing (WRAB, or "Peacock") pruning.

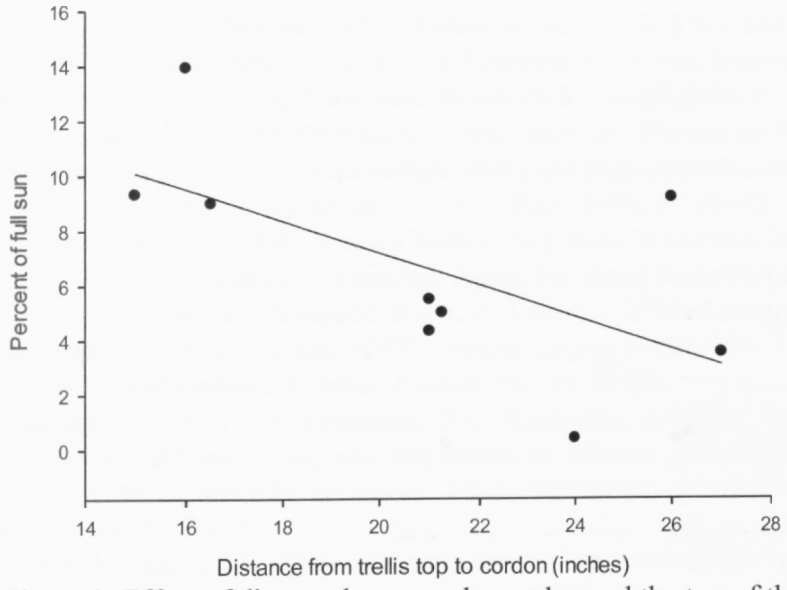

Figure 8. Effect of distance between the cordon and the top of the trellis on light levels between nodes 4 and 6 (node number increases from shoot base to tip) of Selma Pete or Fiesta grapevines with non-separated or center-divided canopies.

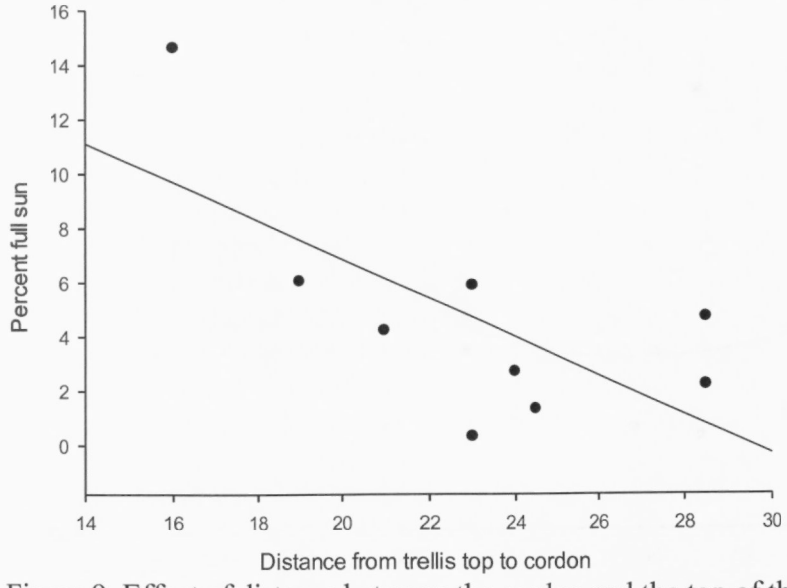

Figure 9. Effect of distance between the cordon and the top of the trellis on light levels between nodes 4 and 6 (node number increases from shoot base to tip) of Selma Pete grapevines with canopies subjected to within-row alternate-bearing (WRAB, or "Peacock") pruning.

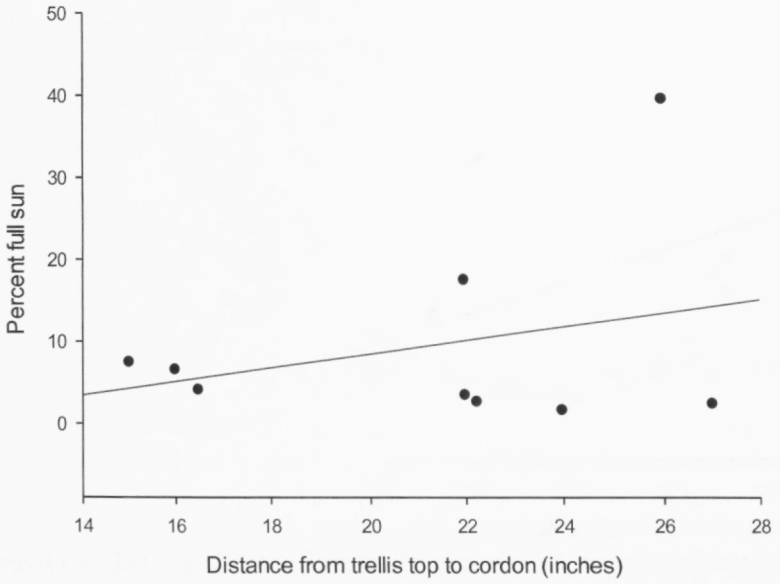

Figure 10. Effect of distance between the cordon and the top of the trellis on light levels between nodes 8 and 10 (node number increases from shoot base to tip) of Selma Pete or Fiesta grapevines with non-separated or center-divided canopies.

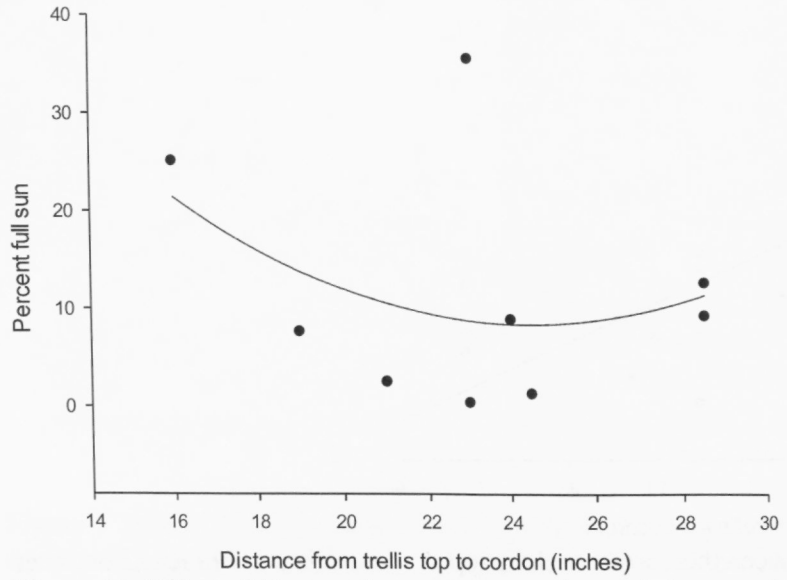

Figure 11. Effect of distance between the cordon and the top of the trellis on light levels between nodes 8 and 10 (node number increases from shoot base to tip) of Selma Pete grapevines with canopies subjected to within-row alternate-bearing (WRAB, or "Peacock") pruning.

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A Brief Review of Mineral Nutrition of grapevines and Fertilization Guidelines for California Vineyards

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Background

Commonly observed grapevine deficiencies in California include those associated with nitrogen, potassium, zinc and boron (Christensen et al., 1982). Less common deficiencies include those of iron, magnesium and manganese. Lastly, toxic effects of nitrogen, chloride and boron have been observed in California vineyards. Many locations in the San Joaquin Valley and elsewhere in California have ground water pollution problems. The pollutants include, among others, nitrates. In addition, nitrogen management in agro-ecosystems can affect the production of nitrous oxide (N_2O), a greenhouse gas (GHG). Therefore, a vineyard fertilization program should try to minimize the leaching of mineral nutrients below the root zone and the production of GHGs. Once the decision to fertilize has been made then one must determine how much and when to apply the fertilizer. Fertilizers can be costly and one can become more cost efficient if educated decisions regarding vineyard fertilizations are made.

Assessing vineyard/vine mineral nutrient status

One of the most important questions to answer in a vineyard fertilization management program is: How does one determine the need to fertilize? The observation of foliar and/or fruit mineral nutrient deficiencies on vines can be used. Unfortunately, these symptoms could indicate that the deficiency may already have caused a reduction in yield. Some grape producing countries use soil analysis to establish the need to fertilize a vineyard. However, it has been concluded that soil analysis for the determination of N, K (potassium), Mg (magnesium) and Zn (zinc) fertilization requirements in California is of no value (Christensen and Peacock, 2000). Those authors do conclude that soil and water analysis can be used to determine B (boron) toxicity levels.

Vine tissue analysis has long been used in California to assess the nutrient status of grapevines (Cook and Kishaba, 1956) and it is considered to be very reliable (Kliewer, 1991). The organ most often sampled on grapevines is the petiole; however, many growers may also sample the leaf blade. Generally, the petiole and blade will be analyzed separately and not as a single unit. In order to compare tissue analysis results from one year to the next it is advantageous to collect the samples at the same phenological growth stage. The sampling of petioles will occur most commonly at bloom.

A second sampling date chosen by some will be at veraison (berry softening). The petioles (or blades) used for the sample at bloom will be taken opposite a cluster along the shoot. The petioles sampled at veraison will be obtained from leaves that are considered mature (fully expanded) and probably on the exterior of the canopy. Research conducted in California has shown that the analysis of the fruit at harvest and canes at pruning could also be used to assess the nutrient status of grapevines (Kliewer, 1991). The most common form of nitrogen analyzed in petioles is both nitrate-N and total N while that for leaf blades is total N. The N analysis of fruit at harvest would include total N, the amino acid arginine, ammonia and total amino acids. Ammonia and total amino acids measured in the must have been referred to collectively as yeast assimilable nitrogen concentration or YANC. Lastly, the forms of N analyzed in canes would be total N and arginine.

Critical values of bloom-time petiole nitrate-N values have been established for Thompson Seedless grapevines in California (Christensen et al., 1978). It is assumed that a nitrate-N value less than 350 ppm (dry weight basis) is deficient, 350 to 500 ppm questionable and 500 to 1200 ppm adequate. Values over 2,000 are excessive. Adequate values of total N for petioles at bloom range from 0.5 to 3.0%, depending upon the country where those values were developed and cultivar (Kliewer, 1991). There is a linear correlation between bloom-time petiole nitrate-N and total N (Figure 1 and unpublished data of A.B. Iandolino and L.E. Williams). The percent total N of leaf blades will decrease as the season progresses and it is a function of degree-days (Williams, 1987), therefore, the time of leaf blade sampling will dictate the value obtained. Critical values of petiole analysis for K of Thompson Seedless in California are as follows: less than 1.0% is deficient, 1.0 to 1.5 % is questionable and over 1.5% is adequate. A bloom-time petiole K value of 0.8% or greater appeared to be adequate for Chardonnay and Cabernet Sauvignon, on different rootstocks, in a trial conducted by the author over a period of three years (unpublished data). Values for other mineral nutrients have been determined for Thompson Seedless and can be found in Christensen, et al., (1982). These critical values also appear to be adequate for other cultivars and in different vineyard situations.

It has been observed that bloom-time petiole nitrate values will differ from year to year, cultivar to cultivar and whether the vines are on their own-roots or on rootstocks. Therefore, many feel that the critical values established for Thompson Seedless grapevines may not be appropriate in other vineyard situations. For example, the table grape cultivars Perlette and Flame Seedless will generally have lower values of petiole nitrate-N values at bloom than Thompson Seedless when grown at the same location and soil type (Table 1). The values in Table 1 also demonstrate yearly variation in petiole nitrate-N values. It should be pointed out that the cultivars used to obtain that data never showed any foliar N deficiency symptoms. Irrigation type (drip vs. furrow irrigation) and whether the vines had been irrigated prior to the sample date also will influence petiole nitrate-N values when sampled at bloom. It was demonstrated that drip irrigated Thompson Seedless vines generally had lower petiole nitrate-N values (mean of four years was 345 ppm) than furrow irrigated vines (mean was 1176 ppm) and that non-

irrigated vines also had lower petiole nitrate-N values than irrigated vines (L.E. Williams, unpublished data).

A study was conducted to determine if time of day or leaf location would influence petiole nitrate values of Thompson Seedless at bloom (Table 2). The highest nitrate-N values were for leaves collected at 4 pm and for leaves exposed to direct sunlight. At veraison, only leaf location had a significant effect on petiole nitrate-N (Table 3). Petioles from leaves in the shade had significantly greater nitrate-N than leaves in direct sunlight at veraison. Nitrate-N of Chardonnay petioles collected at bloom was not significantly affected by either time of day or leaf location (Table 4) while that of Cabernet Sauvignon was only affected by leaf location (Table 5).

Petioles were collected from Perlette and Flame Seedless grown in the Coachella Valley at bloom, veraison and harvest in 2002. Petioles were sampled on a diurnal basis for both cultivars at bloom. At bloom a composite of leaves exposed to direct sunlight and growing in the shade were used, they were not separated into sun and shade petioles. Petioles of both cultivars more than doubled their dry weight when measured between bloom and veraison and gained another 17% between veraison and harvest (Table 6). This may be the primary reason that the concentration of mineral nutrients within petioles decreases during the growing season (i.e. a dilution effect). It may also explain why petiole NO_3-N values differ among cultivars and/or the same cultivar grafted onto different rootstocks. Cultivars with larger leaf blades and petioles may experience more of a dilution effect than those will smaller blades and petioles (i.e. more dry biomass per petiole but the same amount of a mineral nutrient within its tissue). Time of day significantly affected petiole nitrate-N of Perlette and nitrate-N and K of Flame Seedless at bloom (Table 7). Petiole nitrate-N was greatest at the 4 pm sampling time for both cultivars while K was greatest at midday for Flame Seedless.

During the Spring of 2002, clusters were counted on vines that were part of the fertilizer treatments imposed in the Thompson Seedless, Chardonnay and Cabernet Sauvignon vineyards prior to bloom in 2001. Cluster numbers of Thompson Seedless grapevines receiving either 50 or 100 lbs N per acre were significantly greater than vines receiving no applied N (Table 8). Petiole nitrate-N for the non-fertilized vines was less than 65 ppm while those of the fertilized vines were greater than 2400 ppm. The fertilizer treatments imposed in 2001 in the Cabernet vineyard had no effects on return fruitfulness in 2002 (Table 9). The non-irrigated vines in the Chardonnay vineyard had the lowest number of clusters, probably due to a lack of adequate water during the 2001 growing season.

Several generalizations can be drawn regarding what may influence the nutrient values of petioles. 1.) The type of leaf chosen to sample, whether it is in the sun, shade or opposite the cluster, may influence the values of nitrate-N and K. Sunlit leaves at bloom generally had higher values of petiole nitrate-N than either shaded leaves or leaves opposite the cluster. At veraison and prior to harvest, shaded leaves had greater values of petiole nitrate-N and K than sunlit leaves. However, it has been found that NO_3-N and total N and K values of petioles from leaves located at those three positions (sun, shade

or opposite a cluster) are all highly correlated with one another. The author is of the opinion that the choice of leaf location to sample petioles is of little consequence as long as one chooses petioles from the same location year after year. 2.) Irrigation amount (when comparisons between the Irrigated and Non-irrigated treatments were made) had an effect on petiole nitrate-N and K late in the growing season. The irrigated treatment generally had lower values of nitrate-N and K when compared to the non-irrigated treatment. It is unknown at this time whether the water status of the vine is responsible for this effect. 3.) The three cultivars (Chardonnay, Cabernet Sauvignon and Thompson Seedless) used in this study (starting in 2001) generally responded to the treatments and sampling differences similarly. 4.) Values of bloom petiole nitrate-N below 100 ppm in 2001 were associated with fewer cluster numbers in 2002. The number of clusters on vines with petiole nitrate-N values above 100 ppm was not different from the fertilized vines.

A recent study was conducted in California by the author to determine if rootstock had an effect on N fertilizer use efficiency of Chardonnay and Cabernet Sauvignon scions. In that study, bloom-time petiole nitrate values were correlated with total N in the fruit at harvest, leaves at the end of the season (as they fell from the vine) and canes when the vines were pruned. The results indicated that the concentration of N generally increases in the fruit, leaves and canes as petiole nitrate-N increased from a low of 50 ppm to approximately 200 ppm (Figure 2). As the nitrate-N values at bloom in the petioles increased from 200 ppm to 10,000 ppm there was no further increase in the percent total N in the fruit, leaves or canes. These results indicate that a critical value of approximately 200-ppm (dry wt. basis) in the petioles at bloom may be sufficient under most vineyard conditions. The 200-ppm nitrate-N value, found in that study, may explain why the low values of nitrate-N in some cultivars and/or cultivar-rootstock combinations don't express deficiency symptoms at the 'less than adequate' values originally established for Thompson Seedless. Therefore, establishing new critical values of nitrate-N for each cultivar and/or rootstock used may be unnecessary. In support of these findings, a study by Spayd et al. (1993) found that yield of White Riesling increased almost five-fold when petiole nitrate-N values increased from 7 to approximately 200 ppm but yield then leveled off at higher concentrations of nitrate-N values in the petioles.

Determination of N fertilizer amounts

Once the decision has been made to fertilize the vineyard, the appropriate amount of fertilizer should be applied. Mineral nutrient budgets (i.e. the amount of nutrients the vine needs for proper growth and development) have been established in various studies around the world. It was determined that Thompson Seedless grapevines needed approximately 39 kg N ha^{-1} (~ 35 lbs N $acre^{-1}$) for the leaves, 11 kg N ha^{-1} (10.7 lbs N $acre^{-1}$) for the stems (main axis of the shoot) and 34 kg N ha^{-1} (~ 30 lbs N $acre^{-1}$) for the fruit (Williams, 1987). The vineyard density in that study was 1120 vines per hectare (454 vines per acre; 12' rows x 8' vine spacings) and the trellis system was a 0.45 m crossarm. The total N (found in the fruit at harvest, leaves as they fell from the vine and pruning wood) in wine grape vineyards using a VSP trellis system varied from 24 to 65 kg N ha^{-1} (21 - 58 lbs N $acre^{-1}$) over a three year period (L.E. Williams, unpublished

data). The differences in N per hectare (acre) in that study were primarily due to differences in row spacing and final yield.

In another study (Williams, 1991) it was determined that Thompsons Seedless leaves contained greater than 22 kg N ha^{-1} (~ 19 lbs N $acre^{-1}$) after they fell from the vine and the canes at pruning contained approximately 17 kg N ha^{-1} (~ 15 lbs N $acre^{-1}$). These values are comparable to other studies using Thompson Seedless. The results from both studies mentioned above (Williams, 1987; 1991) would indicate that there is a considerable amount of N in both the leaves and canes of a vine and that when both are incorporated into the soil after leaf fall and pruning would contribute to the soil's organic matter and the availability of N in subsequent years. The author has found that N from both leaves that fell from the vine after harvest and prunings incorporated into the soil is taken up the following growing season (unpublished data). Another interesting aspect of those two studies would be the difference in N within the leaves of the vines at harvest (39 kg N ha^{-1}) and leaves after they've fallen from the vine (22 kg N ha^{-1}). The difference in the amount of N in the leaves between the two (~ 15 lbs N/acre) would theoretically be the amount of N remobilized out the leaves during senescence after harvest and put into the vine's N storage pool (~20% of the seasonal total N demand by the vine) indicating the importance of leaves as a source of N for recycling within the vine. A study is currently underway by the author (funding provided by the American Vineyard Foundation, California Table Grape Commission and California Raisin Marketing Board) to provide better metrics for the remobilization of N out of the leaves after harvest and back into the permanent structures of the vine (N storage reserves). Data should be finalized by the Spring of 2014.

The amount of K needed for growth of grapevines also has been determined. In the same vineyard used above to develop a N budget for Thompson Seedless grapevines, a K budget was developed (Williams et al., 1987). Leaves, stems and fruit needed approximately 13, 29 and 50 kg K ha^{-1} (~ 11, 26 and 44 lbs K $acre^{-1}$), respectively, during the growing season. The amount of K in the leaves and canes at the end of the season were equivalent to 9 and 12 kg K ha^{-1}. The amount of K found in the fruit at harvest, leaves as they fell from the vine and canes at pruning for two wine grape cultivars, on different rootstocks and at different locations ranged from 25 to 67 kg K ha^{-1} (22 - 60 lbs K $acre^{-1}$) over a three year period (L.E. Williams, unpublished data). Differences among K per unit land area were due to same factors as discussed in the preceding paragraph for N in that study.

The above information in this section illustrates that there can be significant variation in the requirements of N and K per vineyard. This is due to differences in row spacings, trellis types, yield and overall growth of individual vines. Much of the N and K in the leaves and canes are returned to the soil for possible future use. Therefore, a better way in determining the fertilizer demands of a vineyard would be to calculate the amount of that nutrient removed in the fruit at harvest. Based upon several different studies it was determined that the average amount of N, P, K, Ca and Mg in one ton of grapes at harvest was approximately 1.5, 0.3, 2.5, 0.5 and 0.1 kg (~3.0 lbs N and 5 lbs K per ton of fruit), respectively (Mullins et al., 1992). In a recent study with Chardonnay and

Cabernet Sauvignon on different rootstocks in California the amount of N in one ton of grapes ranged from 0.98 to 1.58 kg (1.96 to 3.26 lbs per ton) while that for K ranged from 1.8 to 2.9 kg (3.6 to 5.8 lbs per ton) (L.E. Williams, unpublished data). Thus, if 10 tons of grapes were harvested per acre, the average amount of N and K removed would be equivalent to 30 lbs of N and 50 lbs of K using the mean values of N and K per ton, respectively. This would be the baseline amount of these two nutrients that one would want to replace with fertilizers in a maintenance fertilization program.

The next requirement for determining the amount of fertilizer one needs is to estimate the efficiency with which the fertilizer is acquired by the vine. The author has conducted several N fertilizer use efficiency (FUE) trials in the San Joaquin Valley and in the coastal areas of California. These studies utilized fertilizers labeled with a non-radioactive isotope of N (^{15}N). As expected, FUE in a Thompson Seedless vineyard was more efficient under drip irrigation than furrow (surface) irrigation (Williams, 1991). The FUE (defined as the amount of ^{15}N found in the vine divided by the ^{15}N applied) was greater than 40% for the drip treatment compared to approximately 12% for the furrow irrigated treatment (Williams, 1991). The FUE for the drip treatment was similar regardless whether the vines were fertilized with a single application (28 kg N per ha; [25 lbs N per acre]) at berry set or whether the vines were given 5.6 kg N per ha (5 lbs N per acre) every two weeks for a 10 week period. The lack of difference between the single and multiple applications on FUE could have been due to the fact that the vineyard had a clay pan at a depth of 1.5 m below the surface of the soil. The slug application of N may have remained in the rootzone due the clay pan. The FUE increased to greater than 50% when the treated vines were harvested the following year, indicating that the N fertilizer was present in the soil profile the second year after application. Therefore, the N fertilizer was not leached below the root zone after the winter rainfall due to the presence of the clay pan.

The second nitrogen FUE study was conducted to determine the effect of rootstock on N uptake by Chardonnay and Cabernet Sauvignon grapevines grown in the Napa and Salinas Valleys and at a vineyard in Paso Robles, along the central coast of California. The vines were drip irrigated at 100% of estimated vineyard ET (ET_c) and the labeled fertilizer was applied at berry set. Under the conditions of the study, rootstock had little effect on FUE at any of the four vineyard sites. As with my irrigation studies in these vineyards, the use of a VSP trellis system could have minimized any effect rootstock had on the vegetative growth of the vines. Therefore, the growth of all scions on the different rootstocks was similar as the vines were hedged to maintain proper shape. FUE varied considerably from one location to another. The greatest FUE (approximately 15%) was obtained in the vineyard with the lowest bloom-time petiole nitrate-N values. The low FUE in this study, compared with that of Thompson Seedless in the San Joaquin Valley, may indicate the inherent fertility of the soils at these vineyard sites. Other studies have shown that soil type will affect N FUE within a vineyard. It was found that the FUE of a N fertilizer was greater on a sandy soil compared to a clay type soil (Conradie, 1986). The study by Conradie (1986), in addition to a study conducted by my graduate student at the University of California-Davis (Alberto Iandolino) in 1999 also proved that the timing of application affects FUE. Lastly, it

should be pointed out that the FUE of vines irrigated at 50% of full ET was double that of vines irrigated at 100% of ET_c (L.E. Williams, unpublished data).

Using the information from the preceding paragraphs one would calculate the amount of N removed from the vineyard in the harvested grapes and then divide that number by the N FUE to obtain the amount of fertilizer to apply. Therefore, if one removed 30 kg of N per ha (26 lbs N per acre) in the fruit and the FUE was 50% (or 0.5) then one would need to apply 60 kg N per ha (52 lbs N per acre). The same type of calculation would be used to determine fertilizer amounts for the other macronutrients such as potassium and magnesium. From a practical standpoint, the author is of the opinion that in a non-deficient vineyard (i.e. tissue analysis does not indicate a deficiency) the actual amount of N or K applied should only be the amount of that nutrient removed in the fruit without taking into consideration FUE. This is due to the uncertainty in obtaining reliable estimates of FUE for different mineral nutrients. As mentioned in my studies using ^{15}N, FUE can vary due to numerous factors including several different vineyard management techniques and soil type.

Kinds of fertilizers

The choice of N fertilizers for raisin vineyards in California can be based mostly upon cost (Christensen and Peacock, 2000). The same may apply for table grape and wine grape growers. The nitrate form of N allows the fertilizer to be available to the vines shortly after an application while the ammonium and urea forms require their transformation to nitrate in the soil profile. The liquid forms of N fertilizers are gaining in popularity due to their ease of handling and application via drip irrigation (fertigation). Many raisin and table grape growers will use farm manure as a source of N, with its application occurring during the dormant portion of the growing season. Lastly, the acidification potential of N fertilizers should be considered in a management program particularly in acid soils. This characteristic of N fertilizers has been outlined (Christensen and Peacock, 2000).

It has been concluded that one form of K fertilizer offers no advantage over the other forms (Christensen and Peacock, 2000). Thus cost may play a major role in determining which kind to use in California and whether it is to be used in a fertigation program. For vineyards with Mg deficiencies the choice of a fertilizer would probably be magnesium sulfate. The two micronutrients mostly commonly needed in California vineyards are zinc and boron. Foliar and soil applications of the two fertilizers have been used in California (Christensen et al., 1982). Soil applications of Zn are more effective under drip than furrow irrigation. Research has shown that neutral- or basic-Zn products are the most effective Zn fertilizers (Christensen and Peacock, 2000).

Timing of fertilization events

Nitrogen and potassium are required by the grapevine throughout its growth cycle. It has been shown that the major sink (the organ that requires the most of a particular mineral nutrient) for N is the leaves while the fruit is the major sink for K (Williams, 1987; Williams et al., 1987; Williams and Biscay, 1991). Approximately,

two-thirds of the vine's annual requirement for N occurs between budbreak and several weeks after berry set. This is the period when the canopy is formed by the vine. The remaining third of the vine's annual requirement of N goes to the fruit after berry set. It should be pointed out that a portion of the N requirements of a grapevine could be derived from N reserves in the roots and other permanent structures of the vine. Anywhere from 15 to 25% of the N in the currents season's above ground growth may come from those reserves (Williams, 1991). The timing of the application of a N fertilizer should correspond to the demands of the vine. Using fertigation, one could apply the approximate amount of N needed by the vine on a weekly or bi-weekly schedule. I am of the opinion if one does not have drip irrigation, one-half the total N fertilizer, to be use for the season, could be applied four weeks after budbreak and the other half applied shortly after berry set. It is not recommended that a N fertilizer be applied at bloom since it may decrease the number of flowers that set. A few table grape growers want high values of petiole nitrate-N at bloom as they contend a high vine nitrogen status at that time assists in thinning the grape clusters (i.e. decreases berry set). The author does not recommend a N fertilizer application post-harvest, which is contrary to what others may recommend (Christensen and Peacock, 2000). The author has determined that the uptake of N by grapevines is a function of biomass accumulation and/or water use (unpublished data). Therefore, the application of a N fertilizer post-harvest assumes that the uptake of N is driven by something other than growth. It also assumes that the remobilization of N from the leaves during senescence only contributes marginally to the replenishment of N reserves. Therefore if only a small amount of N is actually taken up by the vine subsequent to harvest after a N fertilization event the N that remains in the soil from such an application could be leached during the dormant portion of the growing season.

The uptake of K by the vine is a function of vine water use throughout the course of the growing season (L.E. Williams, unpublished data). This is due to the linear relationship between vine water use and the production of vine biomass during that time frame. It also indicates that the K within the vine is derived mostly from sources in the soil and very little remobilization of K from the permanent structures of the vine. This is unlike N where some of the current season's demand for N may be obtained from N reserves in the roots and trunk of the vine. These results would indicate that the timing of an application of a K fertilizer could occur at anytime throughout the growing season, especially if one used fertigation and applied a K fertilizer every year. However, it is recommended that vineyards deficient in K should receive a slug application of a K fertilizer during fall or winter such that precipitation can move the fertilizer into the root zone (Christensen and Peacock, 2000).

Both Zn and B deficiencies affect yields by reducing berry set and the formation of berries that fail to develop. A foliar application of a Zn fertilizer before or at anthesis (bloom) can be used. The application could coincide with a "stretch" or "bloom" application of GA_3 in seedless table grape vineyards where it may be used. A B fertilizer can be applied via a soil broadcast, soil spray, or foliar application or in the drip system. The B fertilizer can be applied at any time.

The use of phosphorus (P), iron (Fe), manganese (Mn) and calcium (Ca) fertilizers and the appropriate time of their application have received little attention in California due to the low acreage where such deficiencies may occur. In many instances, only a small portion of the vineyard may express deficiency symptoms for such mineral nutrients as Fe and Mn. In those cases, a spot application of the fertilizer is sufficient. The expansion of new vineyards in the foothills of the Sierra Nevada and Pacific coast mountain ranges has occurred in areas with low soil pH. This has required the application of P fertilizers to those vineyards.

In addition of the application of the above-mentioned fertilizers, many table grape growers in California apply various foliar applications in order to enhance berry quality. Those foliar applications may contain urea, P, K, Ca, Fe, B, Mn and possibly organic material. These foliar fertilizers will be applied in conjunction with fungicides and/or GA_3 applications. Recent research indicates that a foliar and/or cluster directed application of K may increase the accumulation rate of sugar in the berries of raisin grapes (data of W.L. Peacock) and sugar and color of red or black table grapes (Dr. J.L. Smilanick, USDA-ARS).

Effects of vineyard fertilization on vegetative and reproductive growth

It is desirable to apply fertilizers in order to correct mineral nutrient deficiencies in the vineyard. The application of a N fertilizer in a deficient situation will increase vine growth and productivity. For wine grape vineyards the addition of a N fertilizer may minimize 'stuck' or 'sluggish' fermentations at the winery. However, many studies in California have demonstrated that the application of a N fertilizer in a non-deficient situation will have no effect on growth or productivity. In addition, the application of too much N may stimulate vegetative growth resulting in the shading of buds, reducing fruitfulness and lowering yields. For wine grapes, juice and/or wine pH may be a function of the K concentration. The application of too much K fertilizer may therefore decrease wine quality. The above comments would indicate the importance of being able to assess vine nutrient status prior to the application of any vineyard fertilizer.

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Table 1. The effects of cultivar and year on petiole nitrate-N when sampled at bloom. The petioles were sampled from opposite a cluster when the individual cultivar was at approximately 70% bloom. The values are expressed on a dry weight basis. Data was not collected for Thompson Seedless in 1993.

	Year			
Cultivar	1990	1991	1992	1993
	(nitrate N; ppm)			
Flame Seedless	74	274	187	926
Perlette	66	215	49	703
Ruby Seedless	132	949	1088	1029
Thompson Seedless	316	1244	787	-----

Table 2. The effects of time of day and location of leaves on nitrate-N of Thompson Seedless petioles sampled at bloom in 2001. Vines had been fertilized with 100 lbs of N per acre (112 kg N/ha) prior to bloom. Nitrate-N is expressed in ppm (dry weight basis). There was no significant interaction between time of day and location. Leaf blades were exposed to direct sunlight (sun), shaded (shade) or located opposite a cluster at the time of sample.

	Location of Leaves			Ave. Effect of
Time of Day	Sun	Shade	Opposite Cluster	Time of Day
0800 h	3746	3358	3313	3506 b
1200 h	4008	3103	3392	3501 b
1600 h	4341	3571	3816	3910 a
Ave. Eff. Loc.	4065 a	3344 b	3507 b	

Table 3. The effects of time of day and petiole location of leaves on nitrate-N of Thompson Seedless petioles sampled at veraison in 2001. Vines had been fertilized with 100 lbs of N per acre (112 kg N/ha) prior to bloom. Nitrate-N is expressed in ppm (dry weight basis). There was no significant interaction between time of day and location. Leaf blades were exposed to direct sunlight (sun), shaded (shade) or located opposite a cluster at the time of sample.

	Location of Leaves		Ave. Effect of
Time of Day	Sun	Shade	Time of Day
0800 h	638	1568	1103
1200 h	980	1206	1093
1600 h	865	1444	1154
Ave. Eff. Loc.	827 b	1406 a	

Table 4. The effects of time of day and petiole location of leaves on nitrate-N of Chardonnay petioles sampled at bloom in 2001. Vines had been fertilized with 80 lbs of N per acre (90 kg N/ha) prior to bloom. Nitrate-N is expressed in ppm (dry weight basis). There was no significant interaction between time of day and location. Leaf blades were exposed to direct sunlight (sun), shaded (shade) or located opposite a cluster at the time of sample.

	Location of Leaves			Ave. Effect of
Time of Day	Sun	Shade	Opposite Cluster	Time of Day
0800 h	1847	2411	1935	2064
1200 h	2121	2395	1893	2136
1600 h	1970	2348	2135	2151
Ave. Eff. Loc.	1979	2384	1988	

Table 5. The effects of time of day and petiole location of leaves on nitrate-N of Cabernet Sauvignon petioles sampled at bloom in 2001. The vineyard was located near Oakville in Napa Valley. The vines had not been fertilized but they had been irrigated prior to bloom. Nitrate-N is expressed in ppm (dry weight basis). There was no significant interaction between time of day and location. Leaf blades were exposed to direct sunlight (sun), shaded (shade) or located opposite a cluster at the time of sample.

	Location of Leaves			Ave. Effect of
Time of Day	Sun	Shade	Opposite Cluster	Time of Day
0800 h	371	429	184	328
1200 h	358	392	194	315
1600 h	312	435	235	327
Ave. Eff. Loc.	347 a	419 a	204 b	

Table 6. Dry weight of petioles sampled at bloom, veraison and harvest of Perlette and Flame Seedless grapevines grown in the Coachella Valley. Samples were collected during the 2002-growing season. Samples collected at bloom were a composite (50/50) of leaves exposed to direct sunlight and leaves in the shade. Petioles at bloom also were collected at three times during the day (0800, 1200 and 1600 hours).

		------- Bloom (3/21) -------			Veraison (5/6)		Harvest (6/16)	
Cultivar	Replicate	0800 h	1200 h	1600 h	Sun	Shade	Sun	Shade
		---------- (g 75 petioles^{-1}) ----------						
Perlette	I	9.0	8.1	7.7	16.5	18.0	19.5	19.1
	II	8.3	8.9	7.2	19.8	18.3	20.5	22.6
	III	8.0	7.7	7.7	18.6	16.8	23.2	22.3
	IV	7.7	7.7	6.9	19.5	17.0	24.1	20.6
Flame	I	8.4	7.5	7.1	15.6	16.4	18.4	17.6
	II	8.0	7.5	7.8	14.7	15.5	17.7	18.2
	III	8.0	7.5	7.2	15.0	14.7	17.7	17.0
	IV	8.0	7.7	7.8	15.5	15.0	17.6	17.3

Table 7. The effect of time of day on nitrate-N of Perlette and nitrate-N and K of Flame Seedless petioles sampled at bloom, March 21 2002, in the Coachella Valley. Values of nitrate-N are expressed in ppm (dry weight basis) and K in percent (dry weight basis). Means in a column followed by a different letter are significantly different at $P < 0.05$.

	Perlette	---------- Flame Seedless ----------	
Time of Day	Nitrate-N	Nitrate-N	K
0800 h	890 b	825 b	2.51 b
1200 h	985 ab	968 ab	2.74 a
1600 h	1083 a	1025 a	2.65 ab

Table 8. Bloom petiole nitrate-N and total N from 2001 and shoot and cluster number per four vines of Thompson Seedless in 2002. Treatments included vines that in 2001 received no applied water before bloom nor were fertilized, vines that had been irrigated prior to bloom but were not fertilized and vines that were irrigated prior to bloom and were fertilized with either 50 or 100 lbs of N per acre (56 or 112 kg N/ha, respectively) before bloom. Means within a column followed by a different letter are significantly different at $P < 0.05$.

Treatment in 2001	Bloom 2001 Nitrate-N	Bloom 2001 Total N	Shoot # 2002	Cluster # 2002
	(ppm dry wt.)	(% dry wt.)	(# 4 vines^{-1})	(# 4 vines^{-1})
No Irr./No N	64	0.72	365	159 b
Irrigated/No N	42	0.70	333	157 b
Irrigated/50 lbs	2450	1.33	359	200 a
Irrigated/100 lbs	2804	1.39	380	215 a

Table 9. Bloom petiole nitrate-N and total N from 2001 and cluster number per six vines of Chardonnay (grown in Carneros) and Cabernet Sauvignon (grown near Oakville in Napa Valley). Treatments included vines that were not irrigated prior to bloom, vines irrigated prior to bloom in 2001 and vines irrigated prior to bloom and fertilized with either no or 80 lbs of N per acre (90 kg N/ha), prior to bloom. Petioles for the 40 lbs N per acre treatment at Oakville were not analyzed.

Treatment in 2001	Bloom 2001 Nitrate-N	Bloom 2001 Total N	Cluster # 2002
	(ppm dry wt.)	(% dry wt.)	(# 6vines^{-1})
Chardonnay			
No Irr./No N	262	0.94	123
Irrigated/No N	152	1.02	171
Irrigated/80 lbs	1979	1.32	151
Cabernet Sauvignon			
No Irr./No N	145	0.73	144
Irrigated/No N	299	0.76	142
Irrigated/40 lbs	--	--	148
Irrigated/80 lbs	3215	1.30	144

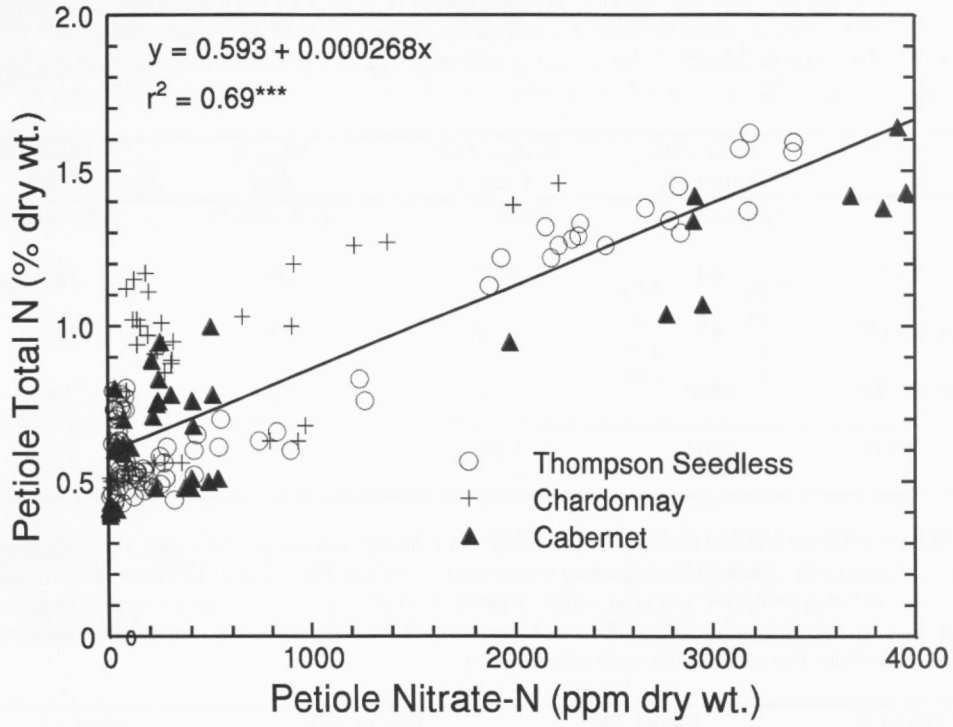

Figure 1. The relationship between nitrate-N and total N measured in petioles at bloom for three grapevine cultivars.

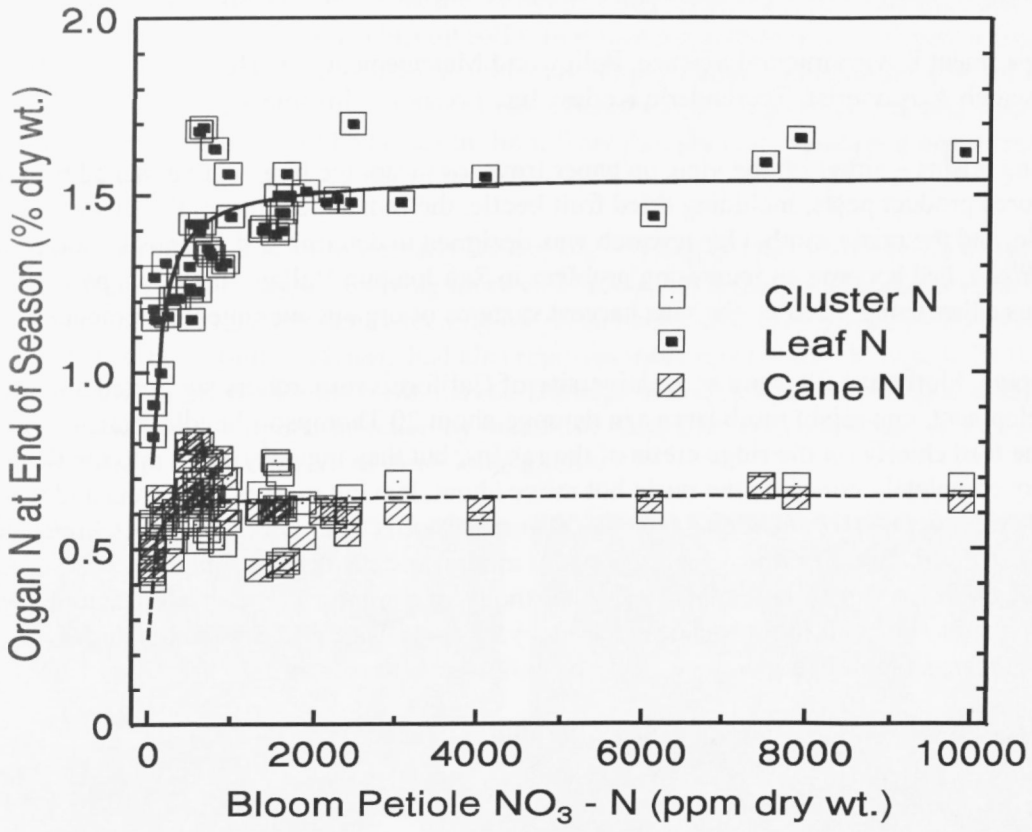

Figure 2. The relationship between petiole nitrate nitrogen (NO_3 – N) at bloom and the concentration of N in clusters at harvest, leaves as they fell from the vine and stems of shoots (canes) at pruning. Data were collected in two Cabernet Sauvignon and two Chardonnay vineyards in Napa and along the central coast of California. Vines had been grafted onto different rootstocks at each location.

Raisin Moth Biology, Damage and Management

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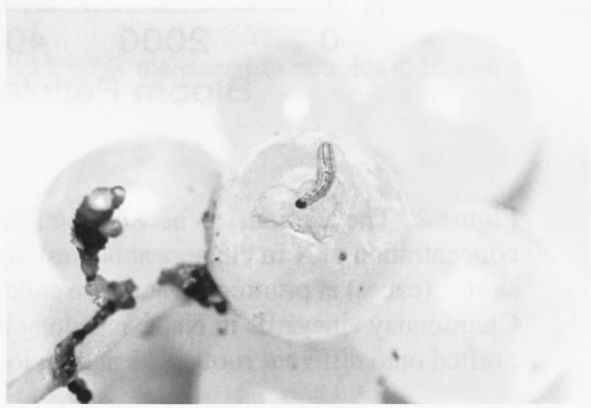
Drying raisins – either on the vine, on paper trays, or in storage bins – are attacked by a number of stored product pests, including dried fruit beetle, the Indianmeal moth, the sawtoothed grain beetle, and the raisin moth. Our research was designed to determine if the raisin moth, *Cadra figulilella*, had become an increasing problem in San Joaquin Valley vineyards, particularly for raisins either using dried on the vine harvest systems or organic management practices.

Damage. More than 30 years ago, University of California researchers suggested that, during its development, one raisin moth larva can damage about 20 Thompson Seedless raisins. Young larvae feed chiefly on the ridge crests of the raisins, but they may also bore into the flesh. They do not completely consume the raisin but move about, leaving masses of excreta and webbing. Traditionally, raisin moth begins feeding on grapes shortly after veraison and continues its life cycle on dried fruit. For this reason, the raisin moth was considered primarily a pest of raisins drying on trays or in storage bins. Therefore, the most common avenue for infestations was considered to be adult moths entering the vineyard from August to September and laying eggs on drying raisins laying on open paper trays or collected in harvest bins.

Raisin moth adult, a gray to light brown moth with little distinctive color patterns.

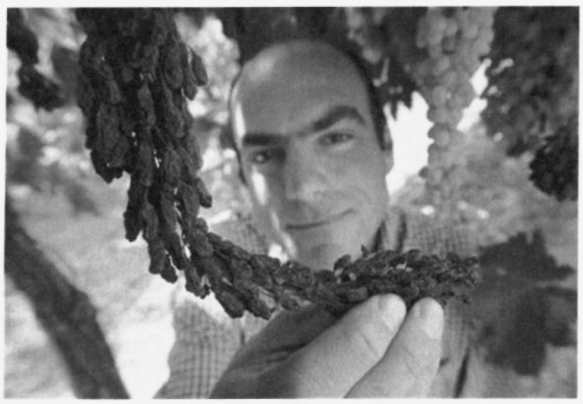

Late-instar raisin moth larvae feeding on a grape cluster.

Control. Raisin moths overwinter as late-stage larvae in cocoons often located in the top layer of soil or under the bark of trees and vines. In early spring, they complete maturation, pupate, and adults begin to emerge in late March and early April. There will typically be three generations per year. Because the larvae are primarily 'garbage feeders,' the adult moths from this overwintering generation will search for drying or decaying fruit (such as damaged stone fruit or mulberries) or mummified overwintered fruit (such as old figs or raisins).

Given this biology, since the 1970s (Coviello 1992 *Grape Pest Management*) the suggested control practices included a well-timed insecticide application to kill larvae from moths entering

the field as the raisins become susceptible (typically applied in July and targeting both omnivorous leafroller and the raisin moth), rolling the trays in the late afternoon to expose immature moths to the afternoon sun and the associated high September temperatures that cause egg and larval mortality, and using a biscuit roll rather than a cigarette roll to prevent acess to the raisins. Sanitation is also important to reduce raisin moth populations. Grapes are infested later in the season when fruit begin to soften, rot or raisin. Therefore, plowing under dropped stone fruit in early summer or destroying old bunches in the fall are thought to be sanitation measures that reduce the population size of the raisin moth.

Current research (2009-2013). In the early 2000s, Steve Vasquez (formerly Fresno County Viticulture Farm Advisor) began receiving more calls about raisin moth infestations, especially damaging populations more frequently feeding on green berries and drying fruit in dried-on-vine (DOV) vineyards. Pest control advisers had also reported more raisin moth damage in DOV vineyards and grapes grown for the fresh market. Damage to grapes was marked by a small hole in the berry, which then supports infection by bunch rot fungi (*Botrytis*, *Rhizopus*, etc). In fact, bunch rot was the primary concern of these infestations.



Raisin moth populations were studied in Fresno County vineyards with different harvest practices, from those using standard paper trays to different dried-on-the vine systems.

This increased occurrence of damage prior to or near veraison that prompted this research, beginning in 2009-2012 by Steve Vasquez and continuing in 2013 by Glenn Yokota and Kent Daane. Our goals were to better understand the life cycle of raisin moth as it relates to the newer raisin production systems that may expose fruit to damage for a longer period of time. The research also sought to identify when raisin moth begins to appear in the vineyard, the amount of damage it causes in different raisin production systems, and if there are major difference between populations in 'conventional' (synthetic insecticides) and organic raisin vineyards.

Vineyard cultural practices. In the 2009-2012 seasons, vineyards were monitored with pheromone traps and data loggers (recording temperature and relative humidity) to follow raisin moth flight and compare microclimate in different vineyard systems. As an initial attempt to decipher the effects of raisin trellis and harvesting practices, of the 12 vineyards sampled in 2010, four vineyards had conventional tray drying methods, four were overhead DOV, three had continuous tray drying, and one had an open gable.

At each vineyard location, three pheromone traps were used to record adult male raisin moth flights and two data loggers were used to record temperature and relative humidity. Traps were collected at least once a week and moths were counted and averaged for each site and date (Fig 1). The pheromone dispensers were changed every four weeks. The first traps were placed in the vineyards beginning in April.

The results show three distinct peaks, regardless of the management systems. In the beginning of the season (first flight), more moths were caught in the two overhead vineyards. Towards the end of the season (third flight), more moths were caught in the continuous tray vineyards and the one DOV open gable system. The season-endings peaks found in the continuous tray vineyards were surprising, because this system would, we suspect, dry the raisins most quickly, thereby reducing the exposure of the raisins to the moths. In fact, the high counts miught be explained by the early harvesting of fruit resulting – before the October peaks, but the traps captures males rather than female moths.

Raisin moth traps averaged 125 moths/trap at this site near the cane cutting date. Similarly, both continuous tray vineyards displayed increased trap counts shortly after canes were cut and while fruit lay on the continuous paper tray (Fig.1). Traps at the continuous tray vineyards averaged more than 200 moths per trap during this last flight (Fig. 1).

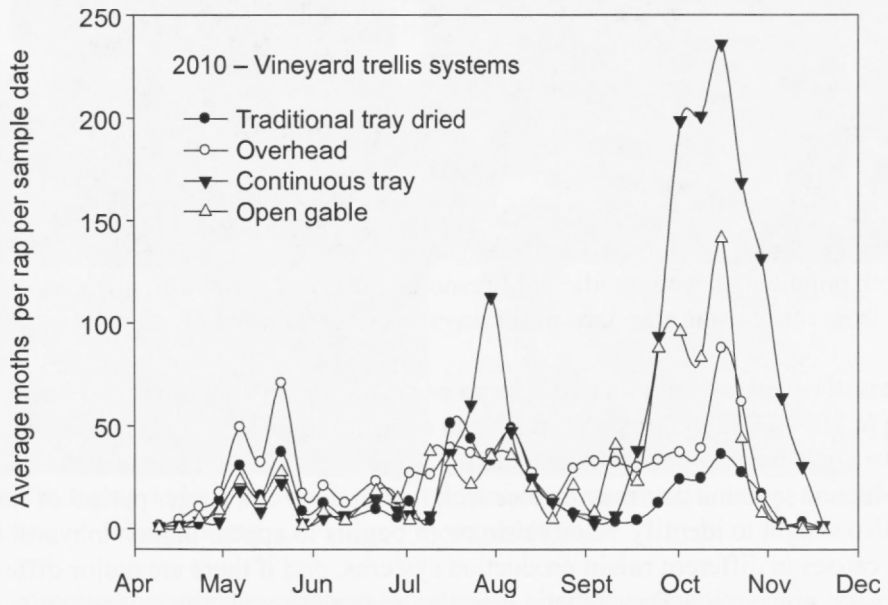


Figure 1 shows the entire season trap counts (male flights) for all vineyards, grouped by trellis and/or raisin drying type. Three distinct male flight peaks can be seen, showing the adult emergence from overwintered moths (May-June), first summer flight (July-August) and a large third flight (September-November). The larvae from this last flight form the next overwintering population.

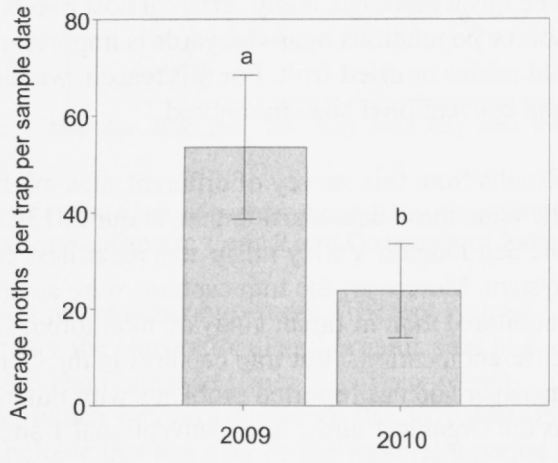
As for pest management decisions, the first flight does not represent a concern for vineyard managers as the green berries present in May and June are not believed to be a food target. However, a large first flight does indicate the potential population size in the second flight,

which began in July at berry softening. The second flight represents the treatment decision period for insecticide applications. The third was the largest of the three flights becaue of the high counts in the continuous tray sites (again, this may be site specific rather than a result of the harvesting practice). This October increase in adult males in the continuouis tray vineyards took place largely when the fruit had already been removed from the field and so does not represent the fruit-damaging population but instead the ovewtinering population. In contrast, in the DOV overhead vineyard, the increase in moth trap counts was observed at the time when canes were cut (≈Aug. 14) and grapes in this vineyard were vulnerable to infestations until the end of September, when they were being collected.

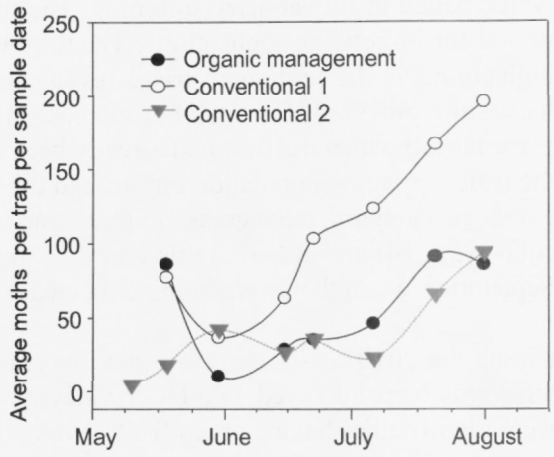
During the 2010 season, fruit was also surveyed beginning at veraison in June. Of those vineyards were surveyed, two DOV vineyards and one traditional Thompson Seedless vineyard were identified as having green fruit damage. In 2010, approximately 8% of the green fruit surveyed from the DOV vineyards and < 1% of the Thompson Seedless fruit displayed feeding damage. As in 2009, raisin moth damage was fairly easy to identify since the larvae were always found feeding on fruit along with frass and webbing.

One conclusion from this initial 2009-2010 study is that differences in raisin moth damage may exist among different raisin harvesting methods. Admittedly, the vineyards sampled were separate blocks, each with different management practices, rather than replicates within a large block with similar initial raisin moth populations. Still, Figure 1 shows that the different systems had similar initial (first flight) and relatively similary mid-season (second flight) raisin moth densities in or near vineyards with the standard (paper trays), continuous tray, and DOV (overhead and open gable) systems. At this time, we hypothesize that there will be less damage in the traditional paper trays or continuous paper trays because the fruit harvested more quickly (after the petiole of canes are cut) and fruit are placed on the paper trays where the hot sun dries the fruit more quickly and kills any raisin moth eggs and larvae. In contrast, the DOV fruit dries more slowly because of the cane cutting, and had a considerable time drying inside the vine canopy, which provides a longer window of time for the fruit to be susceptible to raisin moth.

Another observation from the first years' of study is the variation in pheromone trap catches between sesaons as well as vineyards. For example, figure 2 shows the average catch form May through July in the same eight vineyards sampled in 2009 and 2010. During this period, there were more moths caught in 2009 than 2010, even though the control practices were largely the same each year. We suspect seasonal variations in temperature and the availability of other food (e.g., old peaches), influence each year's population size.



Vineyard insecticide use. In 2012, Steve Vasquez moved the study's focus from raisin moth densities under different trellis systems (traditional versus DOV) to different insect management practices (organic versus conventional). This work again stemmed from a grower-driven research question as some organic raisin farmers in Fresno County were experiencing high raisin moth damage. In the 2012 study, monitored sites included an organic site (Organic 1), and conventionally managed sites nearby (Conventional 1) and quite a distance away (Conventional 2).



All vineyards surveyed used traditional paper trays to dry the fruit. All vineyards received insecticides for moth pests (raisin moth, omnivorous leafroller and Mediterranean flour moth) but the organic site typically received spinosad (e.g., Entrust, DOW AgroSciences), whereas the conventionally managed sites received synthetic materials . Figure 3 shows a surprise in that there were more adult male captures, during the critical May to August period of berry softening, in the Conventional site (Conventional 1, which neighbored the organic site) than in the organic site. The organic site trap captures were more comparable to the more distant conventionally managed site (Conventional 2, highlighted in red). At both the organic and the conventional (1) site, there was bunch rot in 2012.

Movement of the raisin moth. In 2013, Kent Daane and Glenn Yokota began working with Steve Vasquez at the organic versus conventional interface sites in Fresno County. Our goals were to determine the movement of raisin moth among sites, which was prompted from Steve's 2012 findings. We sampled numerous organic and conventional blocks, all within the same Fresno County area. We also sampled conventional raisin blocks near Kingsburg, California.

The raisin moth has many different host plants and, for this reason, a better understanding of source populations near vineyards is important– be it another crop system or storage bins with old raisins or dried fruit. For this reason, we also sampled almonds and peaches near the organic and conventional sites monitored.

Results from this survey of different sites might be best represented by the seasonal average (Fig. 4). What these data show is that, in our 2013 samples, the raisin moth appears to be common in the San Joaquin Valley raisin area regardless of the vineyard management practices or crop system. Moreover, the trap captures were as high or higher in the almond and peach orchards monitored than in raisin vineyard monitored. Obviously, this is a small survey in terms of different locations, but trap captures in the Conventional 2 raisin blocks, where the vineyard manager had not reported problems with raisin moth damage in previous years, were just as high as the Organic 1 and 2 and Conventional 1 sites where thre was a concern about raisin moth.

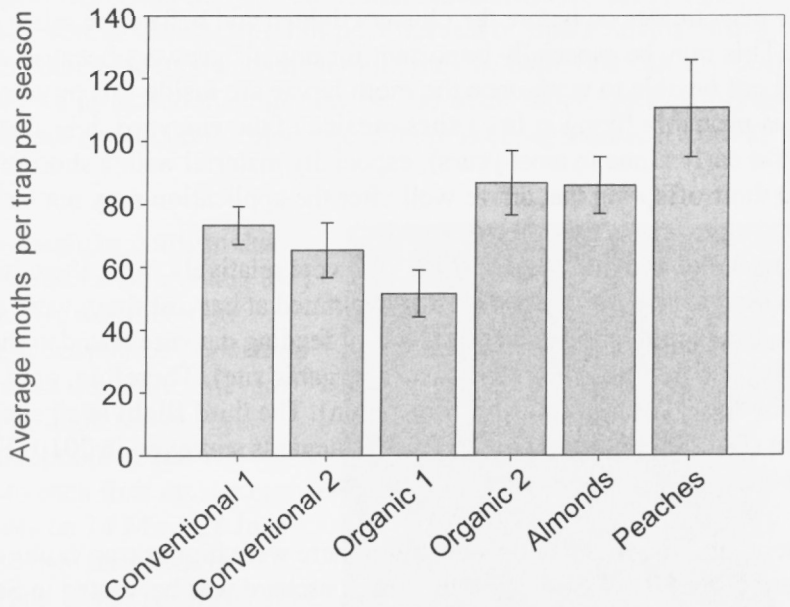


Figure 4. Seasonal average of adult male trap captures (April through October) from two nearby raisin vineyards in Fresno County (Conventional 1) and two in Tulare County (Conventional 2), two organic raisin vineyards in Fresno County (Organic 1 and 2), and two almond blocks (Almond 1) and a peach block (Peach 1) near the Fresno County vineyards.

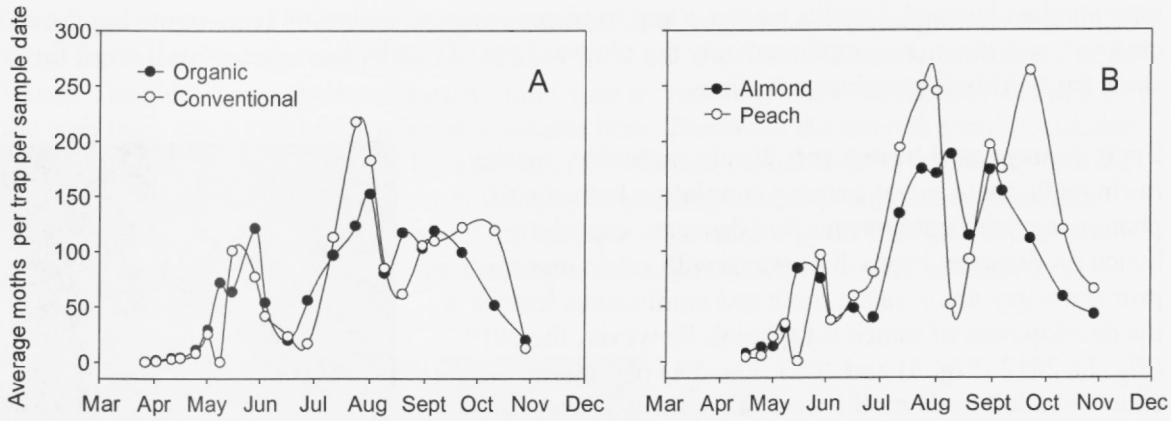


Figure 5 shows the entire season trap counts (male flights) for (A) all vineyards, grouped by management practices and (B) a peach and an almond block that were near Organic 1 and 2 and Conventional 2 sites.

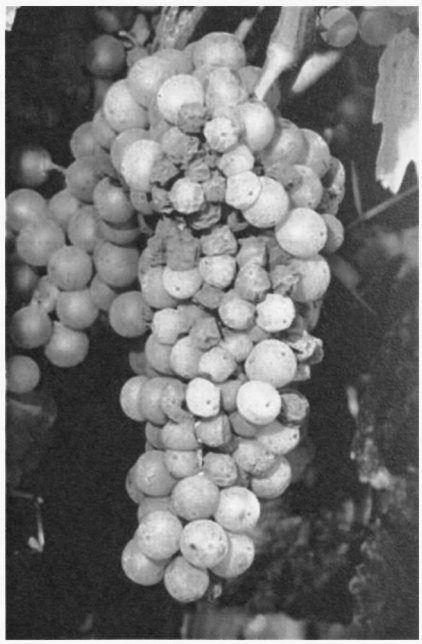
There is a slight difference in the weekly population patterns amongst these different systems. Grouping the raisin vineyards by insecticide practices, the conventional and organic sites had very similar seasonal raisin moth patterns (Fig. 5A). The first flight (from the overwintered moths) began in late April and ended in early June, which was very similar to the 2010 data (Fig. 1). The second flight began in July (Fig. 5A); we believe that this may be the important period to monitor and determine the needed control practices. In both the conventional and organic sites, the growers applied insecticide during this second flight period (July). Post-veraison berries

begin to develop sugars and soften – making them more vulnerable to moth pests. Also, it is important to get insecticides on before the clusters tighten and before the raisin moth larvae get inside the fruit. This may be especially important for organic growers because contact insecticides will not be able to work once the moth larvae are inside this protected area. Because the raisin moth is probably flying in from sites outside of the vineyard, it is also important not to apply material too early (June in most years), especially material with a short residual, because adult moths and their offspring that arrive well after the application may not be killed.

Even though the second and third flights (Fig. 5A) were relatively high, there was nearly no damage to the clusters. From 2400 fruit cluster examined at harvest there were only three fruit found with an indication of larval presence (frass or feeding damage found at the conventional sites) and only one larvae found in a fruit cluster (organic site). Therefore, only 4 of 2400 fruit examined had any moth damage (0.167% infestation). The third flight at all sites was lower than the second flight (Fig. 5A); note that in the DOV vineyards surveyed in 2010 (Fig. 1) the third flight showed a sharp increase in male moth captures.

In both the almond and peach orchards monitored there were higher trap captures, especially in the peach orchard (Fig. 5B). We note that the peach orchard was harvested in September and the captures in the second and third flight periods (July through October) may represent raisin moth populations feeding on damaged stone fruit in the trees or culls on the ground. Therefore, controlling a pest population in the vineyard does not preclude possible infestation from old stone fruit left on the tree or ground after harvest. In fact, the raisin moth will have three generations per year, but some of the population will likely feed on different host plants before entering the vineyard. For this reason, a key to management is sanitation (e.g., removing the old clusters), and this may include not only the vineyard but of nearby host sites as well (e.g., figs, stone fruit). This is not always feasible.

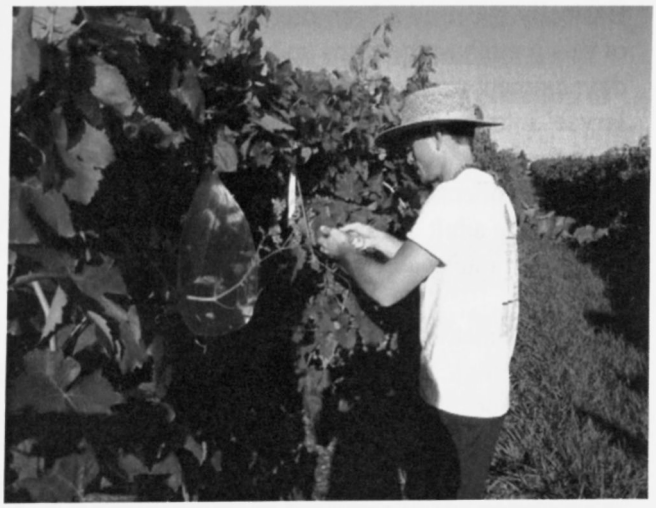
Fruit damage and bunch rot. We also note that, for the raisin moth, there is not a strong correlation between the pheromone trap captures and fruit damage –especially bunch rot damage. From discussions with raisin managers, a primary worry about raisin moth and omnivorous leafroll is the development of bunch rot (photo). However, the 2010 (Fig. 1), 2012 (Fig. 3) and 2013 (Fig. 5A) pheromone trap counts of adult male moths were fairly similar, and yet there were higher levels of bunch rot in 2010 and 2012 than 2013.



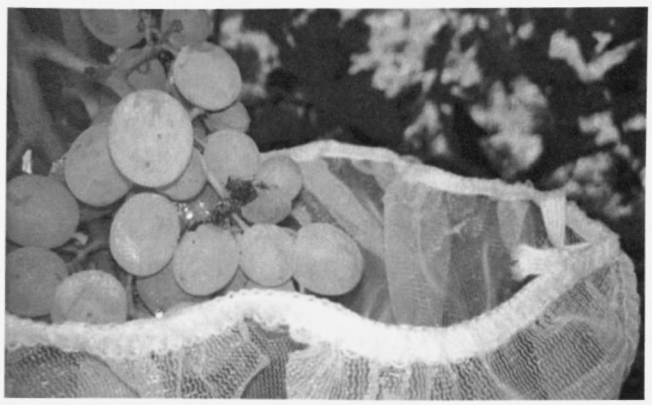
The seasonal variation may be due to better timing of insecticide applications in 2013 that reduced the number of raisin moth infested fruit (and therefore bunch rot); but it is just as feasible that other conditions – such as weather or the amount of fungal spores in the vineyard – may be more important. Many vineyard managers with high bunch rot damage in 2010 assumed that there was a correlation with cluster damage and high raisin moth counts and this needs to be better understood.

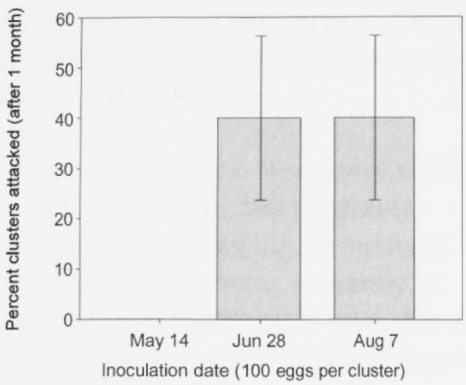
Seasonal susceptibility. University of California researchers reported in the 1960s-1970s that raisin moth larvae were primarily a pest of post-harvest or stored raisins. Steve Vasquez's studies in 2010 provided some evidence that raisin moth may be more of a concern with DOV harvest systems, and here we proposed that this may be due to the longer period of time that the fruit are susceptible (soft) and drying on the vine where there is enough shade to reduce larval mortality from the heat.

In this study we sought to confirm that the moth larvae cannot attack young fruit or leaves – basically, we wanted to confirm that the overwintered population in the vineyard must leave the vineyard after the first adult flight to lay eggs elsewhere on susceptible hosts. We added 100 eggs to each fruit cluster or clumping of leaves on 14 May, 28 June and 7 August and then checked for feeding damage and larvae (or frass) after 4 and 6 weeks (basically the time the eggs to hatch and pupate).

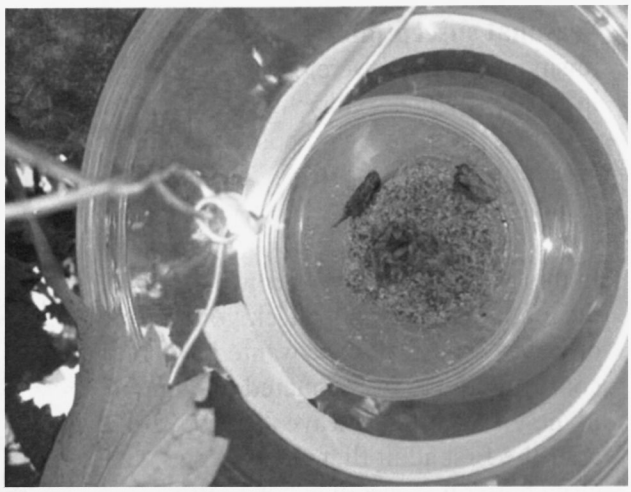


Results showed that raisin moth larvae never survived on leaves. In contrast, 40% of the inoculated clusters had feeding damage in the June and August inoculation periods (Fig. 6). On those fruit with feeding damage, an average of 7.7 ± 6.4 and 5.2 ± 0.8 larvae per cluster were found. The study suggests that the early fruit (prior to veraison) is not susceptible and that only the fruit (e.g., not leaves) will serve as a suitable host. Therefore, the overwintered population probably leaves the vineyard in May and June (first flight); populations return in July (second flight) and September and October (third flight) even though the trap captures suggest that a population has been present throughout the summer. Of course any old fruit still found in the vineyard could serve as a host during the May to June period, which is why sanitation is important.





Natural enemies. A number of natural enemies that attack these moth pests. For raisin moth, the braconid wasps *Habrobracon (Bracon) hebetor* is the best known natural enemy. In 2013, we used 'sentinel larvae' in a number of fields to determine if there were active parasitoids. Basically, we used a bran diet to rear 100s of raisin moth to the third and fourth development stages, placed these 'sentinel larvae' into the field with raisins as proper food for 2 weeks (before they pupated), and then collected the larvae and reared them to the adult stage to determine parasitism rates.



Using this method we collected *Bracon hebetor* from all sites monitored. In fact, parasitism rates were very high, but this may be an artifact of the collection systems – once a single female wasps finds the bucket continuing the raisin moth, she might parasitize 80% of the moths in that bucket.

Outreach and Education. Results are being presented to the grape industry and UC Cooperative Extension personnel through grower reports and seminars. We will continue some of the studies in the 2014 season to complete this project. What remains to be shown is the connection between raisin moth feeding and bunch rot, and a correlation (if one exists) between raisin moth trap captures and fruit infestation or bunch rot.

Raisin Breeding at the Agricultural Research Service in Central California

Craig A. Ledbetter, USDA/Agricultural Research Service
San Joaquin Valley Agricultural Sciences Center
Parlier, CA

The Agricultural Research Service has a long history of raisin grape evaluation and breeding in California's San Joaquin Valley. In the 1920s, ARS scientists evaluated dozens of grape accessions from around the world to identify superior varieties for raisin production in the California environment. The former ARS station in Southeast Fresno is where 'Fiesta' raisin was bred and evaluated by Dr. John Weinberger during the early 1970s.

Raisin grape breeding continued under the direction of Dr. David Ramming after Dr. Weinberger's retirement. Initially, emphasis was placed on identifying earlier ripening cultivars that would better avoid late season rain damage. Cultivars 'DOVine' (1995) and 'Selma Pete' (2001) were introduced as being 14 and 21 days earlier to harvest, respectively, than 'Thompson Seedless.' Both new cultivars were capable of being harvested 'on the vine' after a cane-cutting treatment, saving labor during the harvest operation.

Further labor-savings would be achieved if raisins could be bred that dried naturally on the vine without a cane-cutting treatment. With this in mind, several selections were identified in raisin grape populations where berries wilted naturally on the vine. Hybridization amongst these elite types led to further selections with enhanced wilting/drying ability, and presently several hundred natural dry on the vine raisin selections are being evaluated for harvest timing and raisin quality at our San Joaquin Valley Agricultural Sciences Center in Parlier, CA.

The development of raisin cultivars with resistance to powdery mildew (PM) has been a breeding objective since the mid-1990s. Numerous *Vitis* accessions from around the world with reported PM resistance were assembled in breeding plots and evaluated under no spray conditions for several years. After demonstrating PM resistance in the field, these accessions were bred with high quality raisin accessions to introgress resistance into the next generation of seedlings. Several distinct PM resistance sources were utilized in the breeding plan. These sources are being combined through directed breeding efforts with the future goal being raisin cultivars with high product quality and multiple or pyramided PM resistance.

Pierce's Disease (PD) resistance is also being bred into raisin grapes. Resistance to PD has been identified in both *Vitis arizonica* and in specific *Vitis* hybrids from the Southeast United States (SEUS). Both sources of resistance have been used in developing PD resistant raisins, and a molecular marker is tightly linked to resistance in *Vitis arizonica*. Currently, a large segregating population from the SEUS source is being screened for PD resistance. Results will be used in developing a molecular marker linked to PD resistance in the SEUS germplasm to facilitate future breeding efforts.

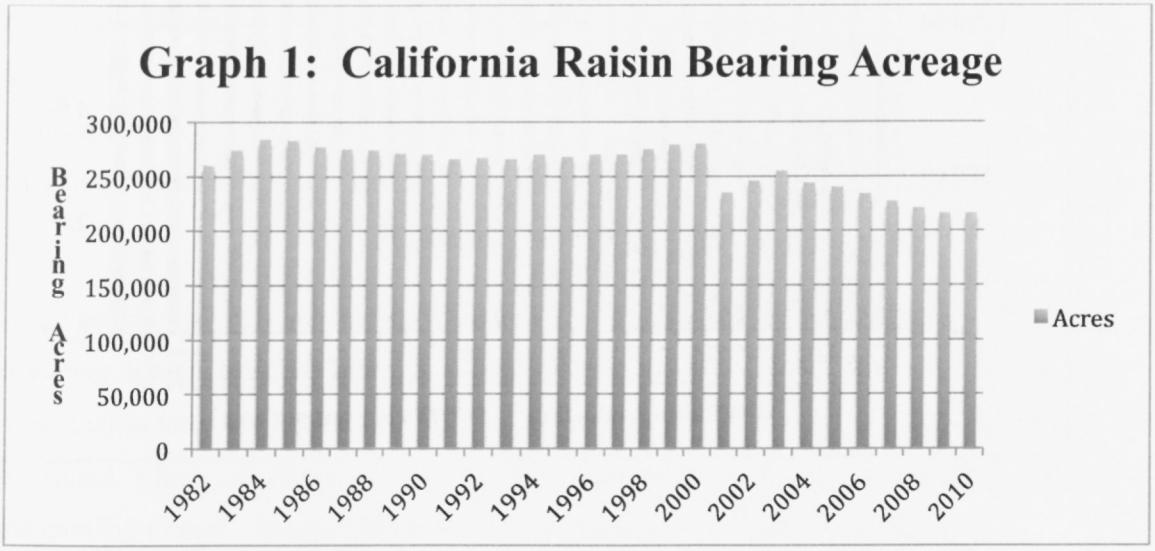
As might be imagined, the most recent hybridizations in raisin grapes have focused on combining the important natural dry on the vine trait with both PM and PD resistances. Both resistance traits have been established into raisin germplasm capable of natural dry on the vine, but product quality and yield are as yet insufficient to warrant large scale trials of individual accessions. We continue to select new material and evaluate raisin quality and quantity. Hybridizations will continue in developing new raisin cultivars capable of an economic yield of high quality raisins that dry naturally on the vine, and with resistances to both powdery mildew and Pierce's Disease.

ECONOMIC TRENDS OF THE CALIFORNIA RAISIN INDUSTRY

Annette E. Levi[1]

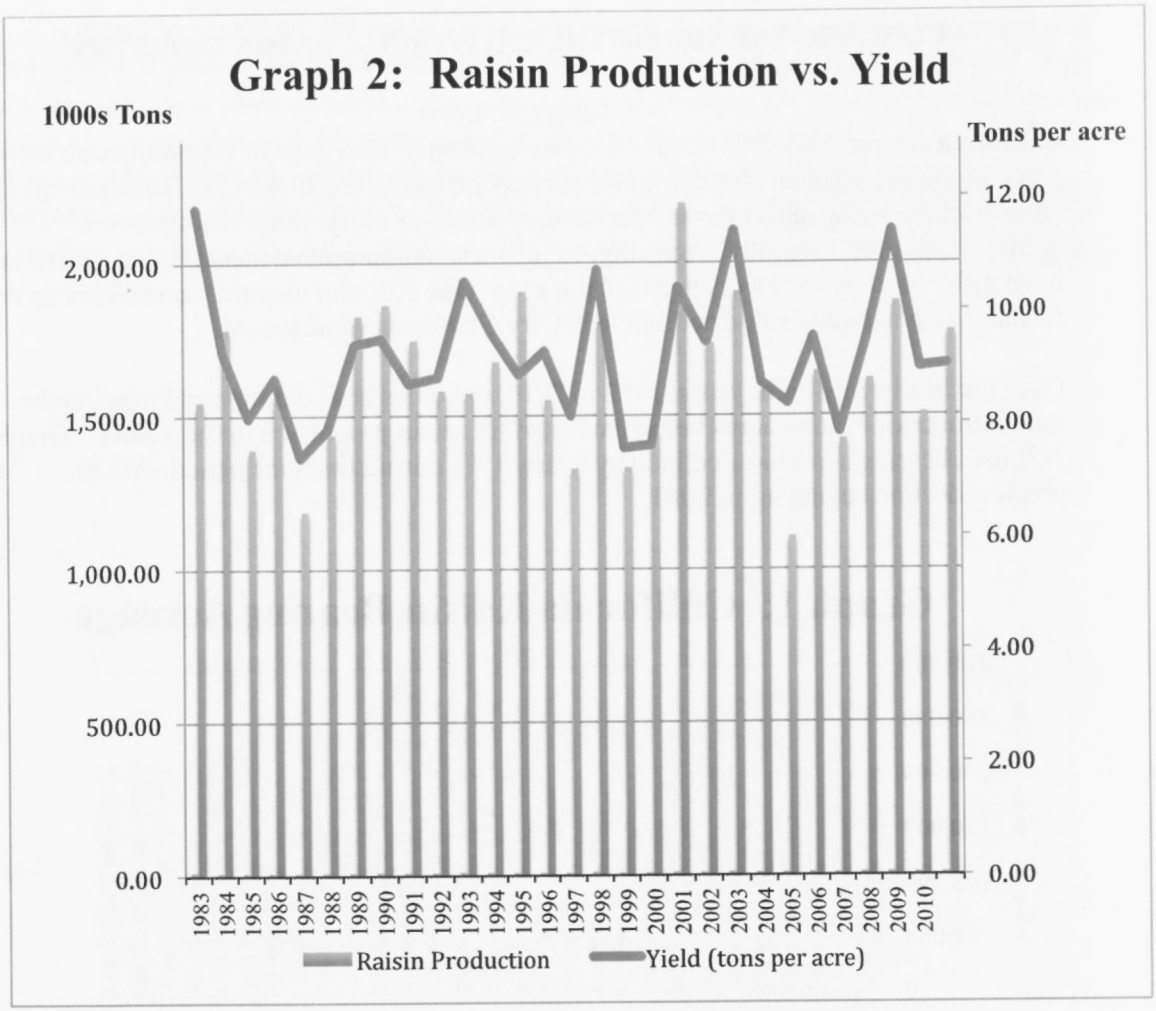
California accounts for 99% of the U.S. raisin industry with most of the production taking place in the San Joaquin Valley. Raisin production has a long history in California which dates back to the Spanish missionaries to the mid18th century. Since that time new seedless varieties, innovative irrigation techniques, and improved management practices have influenced how growers produce this crop. One constant over the years has been the raisins being naturally sun-dried in the hot dry California summer sun.

Over the last twenty-eight years, 1982 to 2010, there has been a downward trend in the total number of bearing acres being harvested for raisin production in California – Graph 1. Raisin bearing acres has declined by nearly 17% during that time period with the greatest decline beginning in 2001.



Production has declined by an average of 15% during the same 28-year time period. Please see Graph 2. Production fluctuations tend to follow changes in weather and environmental conditions, prices received by growers for raisins, prices received by growers for alternative crops, increasing land values, among other issues. Even while total acreage and production is declining, raisin grape yields have indicated a slow upward trend. Please see graph 2.

Over the last 28 years raisin grape yields have averaged 9.18 tons per acre. From 1980 to 1989 average yields were 9.01 tons per acre, through the 1990s there was a slight decline in yields to 8.97 tons per acre. Since the 2000s raisin yields have averaged 9.50 tons per acre. This increase in yield is an indicator of efficiency gains of the industry. Between 2000 and 2010 only four years (2003, 2004, 2006 and 2009) that were below or equal to the same yield levels as the 1990s.



Sources and More Information

California Raisin Marketing Board
http://calraisins.org/about/the-raisin-industry/

U.S.D.A. Rural Development and Agricultural Marketing Resource Center
http://www.agmrc.org/commodities__products/fruits/raisin-profile/

1. Chair and Professor, Department of Agricultural Business, California State University, Fresno.

Management of Trunk Diseases in California

Trunk diseases, also referred to as wood-canker diseases, pose a risk to all California vineyards, due to the widespread distribution of the fungal pathogens throughout the state. Trunk diseases take a long time to develop and often the symptoms do not appear until one or more years after a vine is infected. The infections are chronic and re-occur each year. Trunk diseases in older vineyards reduce yields and increase management costs to the point at which the entire vineyard must be replanted. In this way, trunk diseases significantly limit vineyard longevity. The main grapevine trunk diseases in California, which vary in their presence/ prevalence depending on geography and cultivar, are as follows:

Botryosphaeria dieback
Esca
Eutypa dieback
Phomopsis dieback

Do you have a trunk disease?

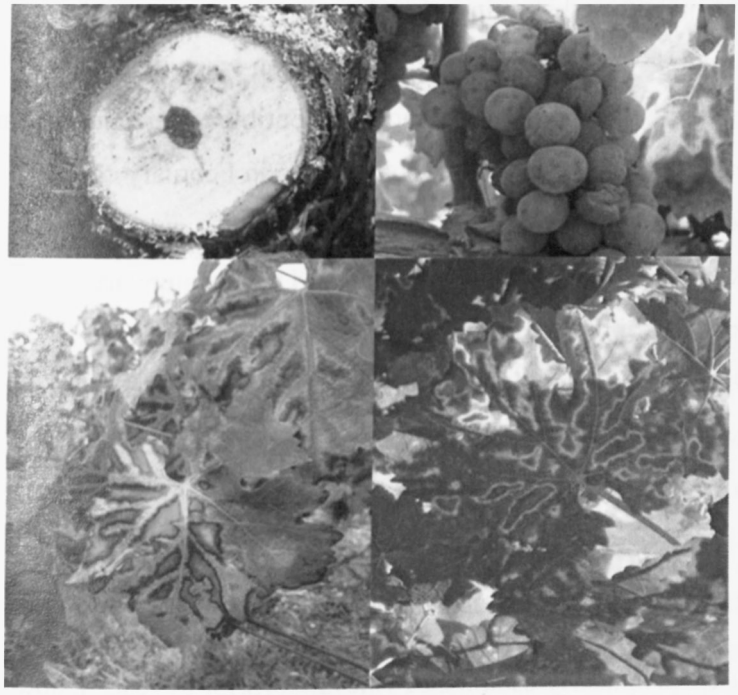
The most common symptom, which is typical of all trunk diseases, is a dead spur (at left below). After cutting through the dead spur, a wood canker is revealed (at right). The trunk pathogen, in this case *Eutypa lata*, has infected this spur and decomposed a portion of the wood, which is visibly rotted. Likely, this dead spur was living in the previous year, but had noticeably stunted shoots growing from it. Stunted shoots are also a symptom typical of all trunk diseases.

Eutypa dieback

Symptoms that are diagnostic of Eutypa dieback include stunted shoots with shortened internodes and dwarfed leaves. Leaves are mishapen; they are elongate and have tattered edges.

Esca

Symptoms that are diagnostic of Esca include an interveinal necrosis, fruit spots on a white cultivar, and concentric rings of black spots, as viewed in a cross-section of a cordon.



Botryosphaeria dieback and Phomopsis dieback do not have diagnostic canopy symptoms. Instead, they are best characterized by the presence of one or more of the general symptoms shown previously.

Prevent Trunk Diseases

Trunk diseases are preventable, and there are effective management practices. A critical practice is to start managing trunk diseases even in the absence of symptoms and in newly-established vineyards. Prevent trunk diseases BEFORE symptoms appear. Prevention depends on protecting pruning wounds, which are infected by rain-induced spore release, during the dormant season in California. Susceptibility to infection depends in part on when the pruning cuts are made. Pruning wounds made early in December are more susceptible to infection in part because they can take weeks to 'heal'. In contrast, pruning wounds made in February can heal within days, and thus can resist infection soon after pruning. There are no exact models to predict high versus low disease risk periods, mainly because rainfall and temperature are variable. Furthermore, year to year variability in weather patterns affects not only the healing process of a pruning wound, but also spore release of the fungal pathogens. Regardless, the susceptibility period of a pruning wound is longest during the cold winter months and shortest under warmer conditions, as the growing season approaches in late winter.

What to do in Newly-Established Vineyards

Utilize practices to prevent trunk diseases in newly established vineyards (prior to year 5), and continue every year. The infections are permanent and there are no curative practices. Once you see symptoms, there is an infection and it is too late for prevention.

There are two approaches for preventing trunk diseases:

1) **Delay pruning until February**. If you prune either by hand or mechanically, schedule pruning in February or later and not in December. Double pruning is a modification of delayed pruning for cordon-trained, spur-pruned vineyards. It involves a 1st pruning pass (usually mechanical) in December, leaving canes approx. 10-12 inches above last year's spurs and making no cuts down to the cordon. This is followed by a 2nd and final pruning pass in February, which leaves the 2-bud spurs. Pruning away the 10 to 12-inch canes in February will ensure the removal of any pathogens that infected the pruning wounds after the 1st pruning pass.

2) **Protect pruning wounds**. Pruning-wound protectants that have both been shown to be effective in published studies and are labeled for dormant-season use against trunk diseases are

thiophanate-methyl (Topsin® M WSB, United Phosphorus, Inc.) and myclobutanil (Rally® 40WSP, Dow AgroSciences). Other pruning-wound protectants (e.g., Vitiseal) are currently under investigation. Materials must remain continuously active from the day of pruning to 1 month after pruning, if you are pruning in December. Because the currently labeled pruning-wound protectants are not active for 1 month, more than one application is required. Also, they must be reapplied after rain: a little over 1/16 inch of rain triggers spore production.

Trunk Disease Survey

To determine trends in usage of the two management approaches listed above, we are conducting surveys of grape growers at meetings organized by UC Cooperative Extension Specialists and Farm Advisors. We use Turning Point, an electronic audience response system, to conduct the survey, which was designed with the help of UCCE Extension and industry representatives. We are also conducting economic analyses to determine the long-term costs and benefits of the management approaches listed above. The goal of the survey and the combined economic analyses is to develop management guidelines that are concise and reflect the perceptions and experiences of growers. We do not want to recommend practices that are not considered effective according to growers or practices that are not economically feasible in certain counties.

To see preliminary results of the survey of wine-grape growers in San Joaquin County, go to http://www.lodigrowers.com/trunk-disease-survey-results-part-iii-of-iii/

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The following continuing education PCA and CCA hours have been approved:

CCA: 50325
IPM - 1.5
Crop Management - 1.5
Prof. Development - 0.5

PCA: M-0066 -14
Other - 1.5