Canopy Separation Did Not Improve Dry-on-Vine Raisin Yield or Quality from Selma Pete Grapevines on Open Gable Trellises

Matthew W. Fidelibus

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Summary

Goals: Dry-on-vine (DOV) raisin growers with open gable trellises can use selective cane-pruning and shoot positioning to separate grapevine canopies into distinct fruiting and renewal zones. This practice is thought to improve canopy structure and microenvironment, increasing raisin yield and quality. However, these assumptions have not yet been confirmed by research. Therefore, an experiment was conducted in which Selma Pete grapevines (Vitis vinifera) on open-gable trellises were subjected to one of three canopy separation treatments: non-separated; center-divided, where renewal shoots were gathered in the trellis center and supported by a foliage catch wire; or within-row alternate-bearing (WRAB), where selective pruning left canes and spurs on opposite cordons. The effects of canopy separation treatments on canopy structure, microenvironment and raisin yield, and quality were followed for three years.

Key Findings:

• The WRAB canopy separation method generally reduced the number of leaf layers and increased the proportion of leaves on the canopy exterior in renewal shoot zones.
• In spring, renewal shoots in WRAB canopies had more direct sun exposure than renewal shoots in other canopy types, but light levels in WRAB canopies diminished thereafter, becoming similar to those in other canopies.
• Despite effects on canopy structure and microenvironment, no canopy separation method tested affected raisin yield or quality consistently.

Impact and Significance: The WRAB canopy separation method affected canopy structure and microenvironment, but insufficiently to increase the yield or quality of DOV raisins on an open gable trellis. Moreover, the selective pruning required to establish WRAB canopies may reduce yield in the season following establishment, and possibly have negative effects on the fruiting zone microclimate, hindering fruit ripening or drying.

Key words: canopy management, microclimate, pruning, training system, trellising system, viticultural practice

Overview

For more than a century, most California raisins have been made by hand-harvesting clusters of ripe grapes onto trays that are left in the vineyard to dry. Raisins made this way are among the most labor-intensive agricultural commodities in North America. With farm labor becoming less available and more costly, many raisin growers have adopted mechanized grape picking, tray-laying, and raisin pickup procedures. Mechanization has helped minimize the cost to produce tray-dried raisins, but prices for other farm inputs have also increased in recent decades, further reducing the profit margins of raisins and other agricultural commodities. Higher non-labor production costs could be
countered by adopting practices that increase yields; but all tray-dried raisin vineyards require sunlit drying areas between vine rows, which constrains trellis dimensions and necessitates relatively wide row spacing, both of which limit the yield potential of tray-dried raisin vineyards.4

In contrast, dry-on-vine (DOV) raisin production systems provide opportunities to minimize labor and maximize yield.5 In DOV vineyards, canes bearing clusters of mature fruit are severed to initiate the DOV process.6 Grapes are left on the trellises to dry, and raisins are machine-harvested directly from the trellised vines. Thus, between-row drying areas are omitted, enabling the use of larger, more expansive trellises that may greatly increase yield potential.7 However, the DOV process proceeds less quickly than tray-drying because canopy temperatures are generally lower than those at the soil surface.8 Therefore, varieties that ripen earlier than Thompson Seedless, such as Selma Pete, are preferred for DOV, as their earliness shifts the drying period toward a hotter part of the summer and allows more time for berries to dry before the onset of the cooler, wetter weather of fall.9

The most widely used DOV trellis system in California is the overhead arbor.10 Overhead arbor systems feature distinct fruiting and renewal zones established by pruning the vines and tying their canes in such a way that trellis wires spanning the space between adjacent rows support either fruiting canes or renewal shoots11 (Figure 1). Canopy separation on such systems may serve a number of functions. Renewal shoots should grow under conditions of good sunlight exposure, thereby helping to optimize bud fruitfulness and minimize bud necrosis.12 Pruning, cane severance, harvest, and spent cane removal are also facilitated, and the clear division between fruiting and renewal sections keeps the green leaves on renewal shoots from shading grapes, providing a better microenvironment for grape drying.13 The success of the overhead arbor system has inspired attempts to adapt canopy separation to other trellis systems in hopes of achieving similar benefits.14

Within-row alternate-bearing (WRAB) is an example of canopy separation technology-transfer to a traditional T-trellis.15 Vines subjected to the WRAB system are pruned so that fruiting canes and renewal shoots are left on arms or cordons on opposite sides of vine trunks and adjacent to similar structures of neighboring vines, resulting in fruiting and renewal zones that alternate between vine trunks down a row (Figure 2). Training vines in this way is expected to increase the exposure of renewal shoots to sunlight, which could improve bud fruitfulness and reduce bud necrosis.15 However, several years of testing failed to show that the WRAB method per se increased yield, as vines subjected to WRAB had similar yields as vines with non-divided canopies whose fruit were tray-dried.16 Raisins from WRAB DOV vines graded higher than tray-dried raisins, but this was likely more an effect of drying method rather than canopy separation, as similar results were found in a different study comparing the effect of drying method on raisin quality.17 A subsequent study that specifically tested the effect of canopy separation on Thompson Seedless DOV performance showed no consistent benefit of canopy separation on traditional trellises,18 and the use of WRAB techniques on traditional T-trellises is now uncommon.

![Figure 1](image1.png) **Figure 1** An overhead arbor dry-on-vine raisin grape vineyard during the drying period following cane severance. Coordinated pruning and tying of canes separates the vine’s canopies into alternating fruiting (center) and renewal (either side) zones. In this picture, the fruiting canes have been severed to initiate fruit drying.

![Figure 2](image2.png) **Figure 2** Thompson Seedless grapevines trained to the within-row alternate-bearing system a few weeks after cane severance to initiate grape drying. Fructing canes and renewal shoots were left on arms on opposite sides of vine trunks and adjacent to similar structures of neighboring vines, resulting in alternating fruiting and renewal zones between vine trunks down a row.
Even though no clear benefit of the WRAB DOV system has been shown for Thompson Seedless vines on traditional trellises, many growers have implemented WRAB on open gable systems, assuming it will improve fruitfulness, and thereby, yield. The term "open gable" can refer to a relatively wide range of free-standing, Y-shaped trellis systems consisting of steel posts to which V-shaped steel cross arm assemblies supporting six fruiting wires, three on each side, are attached. The original open gable DOV trellis is comprised of steel posts topped at 1.37 m (4.5 ft) with 1.83 m (6 ft)-wide cross arm assemblies19 (Figure 3). 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, .30 m (1 ft)-tall post extension is mounted in the center of the cross arm assembly topped by a foliage support wire. As originally conceived, the canopy of vines on this type of trellis was to be physically separated into renewal and fruiting zones by using moveable rake wires to gather the renewal shoots emerging from spurs and guide them toward the support wire in the center of the trellis (center-divided). However, many growers have omitted the rake wires and center support wire to reduce the cost of trellis materials and eliminate the need for a labor crew to position shoots with rake wires. In such vineyards, the canopies are left unseparated (Figure 3B) or vines are subjected to WRAB by pruning so that canes and spurs are on separate cordons, on either side of the vine trunk (Figure 3C). Canopies separated in this manner do not need rake wires or a center-mounted support wire. The specific benefit that center-divided or WRAB 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 Selma Pete on open gable DOV trellises. Therefore, a multi-year experiment at the Kearney Agricultural Center in Parlier, CA, was conducted to determine how different canopy management practices, including center-divided, WRAB, and non-divided, may affect canopy structure, light environment, and productivity of Selma Pete raisin grapes on open gable trellises.

**Major Observations and Interpretations**

**Canopy structure.** The canopies of all vines had a similar number of horizontal leaf layers (between 2.1 and 2.6), but in 2013, vines with non-divided and center-divided canopies had a smaller proportion of exterior leaves, horizontally and vertically, and more leaf layers, vertically, than vines with WRAB canopies (Table 1). Similar results were observed in 2014, when vines with WRAB canopies had a greater proportion of exterior leaves than vines subjected to other canopy separation methods. Vines with fewer leaf layers should allow more light into the renewal zone of the canopy, which could promote bud fruitfulness and budbreak.20 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.21

**Canopy light environment.** WRAB canopy separation increased photosynthetically active radiation (PAR) in the renewal zone early in the 2013 season, but as the canopy developed over time, the differences in PAR among treatments diminished (Figure 4). Position in the canopy and day of year also affected light intensity in the canopy, regardless of canopy separation method. As

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**Figure 3** An open-gable dry-on-vine trellis system. (A) Canopy separation was originally intended to be accomplished with rake wires (RW) brought to a central position in spring, thereby guiding renewal shoots (RS) to a support wire (SW) on a central mast, thus dividing the canopy horizontally (center divided). Also shown in A are positions of quadrilateral cordons (QC) and fruiting canes (FC). (B) Omitting the SW and RWs without selective pruning results in an unseparated canopy, where two adjacent vines in a row have non-separated canopies. (C) In contrast, selective pruning may be employed to separate the canopy of vines in a row in the within-row alternate-bearing style. Fruiting canes are drawn in black; renewal shoots (shown only in A), are in grey.
expected, the highest PAR was at node positions eight to 10, which were closer to the top of the trellis, and PAR diminished at lower node positions, with the lowest light levels found at the cordon (Figure 5). For a given position in the canopy, PAR was generally higher on the south side of the trellis than on the north side (Figure 5). PAR at node positions eight to 10 generally decreased as the canopy developed, while PAR at lower positions was relatively stable during the course of the study. The influence of node position on PAR may 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.22

**Berry and raisin quality and yield.** Canopy separation treatments generally had few and small effects on fruit quality and yield. Vines with center-divided canopies had berries with slightly lighter fresh weights (~6%) at cane severance than vines with WRAB canopies (Table 2). Though statistically significant, such a small difference in berry weight is unlikely to be of practical significance. Treatment effects on berry soluble solids content depended on the year (Table 3). In the first two years of the study, berries from vines of all treatments

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**Table 1** Effect of canopy separation method on the number of leaf layers and the percent of leaves on the canopy exterior in the renewal zone of Selma Pete grapevines subjected to different canopy separation methods on an open gable trellis in 2013 and 2014 at Parlier, CA.

| Canopy separation method | Horizontal | Vertical |
|--------------------------|------------|----------|
|                          | Leaf layers (n) | Exterior leaves (%) | Leaf layers (n) | Exterior leaves (%) |
| 2013                     |              |                   |              |                   |
| None                     | 2.3 <sup>a</sup> | 29 <sup>b</sup> | 3.5 <sup>a</sup> | 23 <sup>b</sup> |
| Center-divided           | 2.4         | 26 <sup>b</sup> | 3.5 <sup>a</sup> | 22 <sup>b</sup> |
| WRAB<sup>b</sup>         | 2.5         | 40 <sup>a</sup> | 2.9         | 35 <sup>a</sup> |
| 2014                     |              |                   |              |                   |
| None                     | 2.6         | 27 <sup>b</sup> | 2.9         | 28                |
| Center-divided           | 2.6         | 26 <sup>b</sup> | 2.9         | 29                |
| WRAB                     | 2.1         | 41 <sup>a</sup> | 2.9         | 31                |

<sup>a</sup>Values are treatment means with n = 8. Means followed by a different letter, within columns, are significantly different according to the Tukey-Kramer adjustment method.

<sup>b</sup>WRAB: within-row alternate-bearing.

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**Table 2** Berry fresh weight as a function of canopy management treatment in 2013, 2014, and 2015 at Parlier, CA.

| Canopy management treatment | Berry fresh wt (g) |
|-----------------------------|--------------------|
| Non-divided                 | 1.95 ab<sup>a</sup> |
| Center-divided              | 1.89 b             |
| WRAB<sup>b</sup>            | 2.01 a             |

**Significance**

|                      | <sup>a</sup>  |
|----------------------|--------------|
| Year                 | <0.001       |
| Treatment            | 0.02         |
| Year x Treatment     | 0.19         |

<sup>a</sup>Values are treatment means with n = 24. Means followed by a different letter, within columns, are significantly different according to the Tukey-Kramer adjustment method.

<sup>b</sup>WRAB: within-row alternate-bearing.
amassed soluble solids of ≥20 Brix by mid-August, which is generally considered adequate for DOV raisin-making, and there were no treatment effects on soluble solids. However, in 2015, berries from vines subjected to WRAB had less soluble solids than berries from vines with non-divided canopies. Delayed ripening is undesirable because raisin grades and yields generally correlate positively with soluble solids. Treatments did not affect raisin grade (Table 4) or yield in the last two years of the study (Table 5), probably because soluble solids contents of berries from all treatments were >20 Brix, which may be sufficient to attain optimal yield and quality for Selma Pete DOV raisins. However, delayed ripening is still undesirable, as it may force cane severance to be delayed, which could impede drying in some years, depending on weather conditions during the drying period. Raisins from WRAB vines had higher raisin moisture content in 2013 (Table 6). Similar results were observed in a previous study, where raisins from WRAB vines were occasionally moister than raisins from other vines, possibly because the WRAB method only makes use of half the trellis for vine drying, concentrating fruit in a way that may inhibit drying. Vines subjected to WRAB had lower yields than vines subjected to other treatments in 2013, the first year of the study. Reduced cluster numbers in the year following implementation of WRAB also were observed in an earlier study of Thompson Seedless on a traditional T-trellis and was probably due to pruning practices required to implement WRAB canopy separation, which limited cane selection in 2013. Vines with non-separated canopies, or center-divided canopies, averaged six or seven 15-node canes/vine, while WRAB vines averaged about five canes per vine that year (data not shown). Cane selection on WRAB vines improved in winter 2014, and yield and fruit and raisin quality were similar thereafter, regardless of treatment (Table 5).

### Broader Impact

Cane pruning enables vine canopies to be separated into distinct fruiting and renewal sections. The potential benefits that canopy separation may have on yield and quality may depend on trellis and canopy structure, but this and previous studies suggest there may be no benefit in the WRAB method of canopy separation for traditional T or open-gable trellises.

### Experimental Design

An experiment to determine how different canopy separation methods may affect canopy structure, light levels, and raisin yield and quality was conducted at the Kearney Agricultural Center in Parlier, CA, from 2013 to 2015.

### Table 3

| Treatment  | Soluble solids (Brix) |
|------------|-----------------------|
|            | 2013 | 2014 | 2015 |
| Non-divided | 22 a | 20   | 23.0 a |
| Center-divided | 22 | 20   | 22.1 ab |
| WRAB       | 23   | 20   | 20.8 b |

Values are treatment means with n = 8. Means followed by a different letter, within columns, are significantly different according to the Tukey-Kramer adjustment method.

WRAB: within-row alternate-bearing.

### Table 4

| Canopy management treatment | Quality (%) |
|-----------------------------|-------------|
|                            | % B or better | % Substandard |
| Non-divided                 | 69 a         | 11.2          |
| Center-divided              | 78           | 5.8           |
| WRAB                        | 76           | 6.4           |

Year | Treatment | <0.001 | <0.01 |
|-----|-----------|--------|-------|
|     | Year x Treatment | 0.08   | 0.21  |

Values are treatment means with n = 8. WRAB: within-row alternate-bearing.

### Table 5

| Treatment  | Yield (ton/ha) |
|------------|----------------|
|            | 2013 | 2014 | 2015 |
| Non-divided | 12.25 a | 14.2 | 9.3 |
| Center-divided | 11.60 a | 14.3 | 10.9 |
| WRAB       | 7.74 b | 12.7 | 11.4 |

Values are treatment means with n = 8. Means followed by a different letter, within columns, are significantly different according to the Tukey-Kramer adjustment method.

WRAB: within-row alternate-bearing.

### Table 6

| Treatment  | Raisin moisture (%) |
|------------|---------------------|
|            | 2013 | 2014 | 2015 |
| Non-divided | 12.75 b | 12 | 11 |
| Center-divided | 12.68 b | 12 | 11 |
| WRAB       | 13.87 a | 12 | 11 |

Values are treatment means with n = 8. Means followed by a different letter, within columns, are significantly different according to the Tukey-Kramer adjustment method.

WRAB: within-row alternate-bearing.
through 2015. The vineyard, established in 2004, consists of Selma Pete grapevines on Freedom rootstock in rows oriented east to west. Vines were spaced 1.8 m apart in row and 3.3 m between rows. The vines were trained to quadrilateral cordons on an open gable trellis system similar to that described in the introduction and in another publication. In winter 2012, plots comprised of five adjacent vines were assigned to one of three treatments: A) center-divided, B) non-divided, or C) WRAB (Figure 3). Vines assigned to the center-divided or non-divided treatments were cane-pruned, leaving six to eight 15-node canes and ~10 two-bud spurs per vine. Canes and spurs were left on any of the vines’ cordons; the only difference between center-divided and non-divided vines was that vines assigned to the center-divided treatment made use of rake wires and a center-mounted foliage catch wire to help 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 in another publication. In July 2013 and 2014, renewal zone canopy architecture was periodically characterized with the point quadrat method. PAR was also measured periodically as they dried, and raisins were harvested from the vines when their moisture content decreased to ≤14%. At harvest, clusters of raisins from the two vines in each plot were picked, counted, weighed, and mixed, and a 1 kg subsample was collected, sealed in a plastic bag, and submitted to the USDA Processed Products Division in Fresno, CA, where trained inspectors determined moisture content and grades using standard methods.

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26. 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; Smart R and Robinson M. 2001. Sunlight into Wine. Winetitles, Adelaide.

27. Measurements were made with a ceptometer (Sunfleck PAR Ceptometer, Decagon) that was held level and positioned parallel to the vine row at the cordon, at several heights that corresponded approximately to node positions four to six and eight to 10 on renewal shoots. Average light data showing the main effects of canopy separation and position in the canopy were determined with SAS statistical software (SAS, Inc.), and plotted using SigmaPlot (SysStat Software, Inc.) software.

28. Each berry sample was weighed and average berry weight was determined. Next, each berry sample was crushed in a blender, the juice was filtered, and soluble solids was determined with a digital refractometer (PAL-1; Atago-USA). Juice pH and titratable acidity were determined by titration with 0.1 N NaOH to an 8.2 pH endpoint using an automatic titrator (DL 50, Mettler Toledo).

29. Data were subjected to analysis of variance using the mixed procedure of SAS statistical software. When interaction effects between year and treatment were noted, effects of treatments in different years were determined. Otherwise, only the main effects of treatment were considered. Post-hoc pairwise comparisons of least square means were made using the Tukey-Kramer adjustment method.