V107

AMERICAN VINEYARD FOUNDATION

Final Report

JUNE 1990

PROJECT TITLE: Vineyard Canopy Management Practices for Improving Grapevine Microclimate, Fruit Composition, and Wine Quality.

PRINCIPAL INVESTIGATORS: W. M. Kliewer (916) 752-0911
A. C. Noble (916) 752-0387
Department of Viticulture and Enology
University of California
Davis, CA 95616

OBJECTIVES:

1. Determine the effect of different vineyard cultural practices (trellising, hedging, pruning level, and leaf removal) on vine microclimate, fruit composition and wine quality. Emphasis will be on studying ways to reduce must pH through modification of canopy microclimate by canopy management practices.

SUMMARY:

Viticulture

Trellis-training systems, row spacing, pruning level and leaf removal in the fruiting region were compared as a means of modifying grapevine canopy microclimate and thereby improving fruit and wine composition and crop yields of Chardonnay, Sauvignon blanc and Cabernet Sauvignon in field experiments conducted at the Oakville Station and for Chenin blanc and French Colombard grown at Davis. Trellising systems that divide grapevines into two separate canopies, such as the GDC and Lyre trellis systems, continued to show yield increase of 10 to 40% without any indication of a reduction in fruit composition or wine quality. Canopy division increased the amount of photosynthetic light, red/far red light ration and the amount of sunflects in the fruiting region compared to non-divided canopies. Canopy density, expressed as square meter of leaf area per meter of canopy length, was closely correlated with the level of photosynthetic light and red/far light in the fruit zone. Vines with canopy densities greater than 4 to 5 m^2/m canopy length generally had poor canopy microclimates, indicating that there was excessive shading in the fruiting region. Leaf removal in the fruiting region was more effective than shoot positioning in improving canopy microclimate. Row spacing had little effect on fruit composition but closer row spacing produced higher crop yield per acre. At 8, 10 and 12 foot row spacing, the average crop yield of Cabernet Sauvignon at the Oakville Station was 11.5, 10.3 and 8.9 tons/acre, respectively. Cabernet Sauvignon vines pruned to 24, 36, 48 and 60 buds/vine produced average yields of 8.0, 9.9, 10.8, and 11.5 tons/acre, respectively. With an increase in bud number per vine, there was a decrease in pH, TA, and K and an increase in malic acid in fruits at harvest. The level of anthocyanin did not differ significantly between pruning levels.

Sensory Evaluation

For the 1989 vintage, Cabernet Sauvignon wines prepared from Oakville vines on a bilateral trellis were not significantly different from those made from vines trellised on a Geneva Double Curtain. However, for both trellises, wines made from vines pruned to 24 buds were significantly different than from vines pruned to 60 buds per vine ($p<0.01$). The wines made from vines pruned to 24 buds/vine were significantly more vegetative in flavor than wine made from vines pruned to 60 buds per vine for Bilateral ($p<0.05$) and GDC Trellises ($p<0.01$). Vines pruned to 60 buds/vine yielded an average of three and a half tons more than vines pruned to 24 buds/vine.

In the comparison of the effects of different trellises on Sauvignon blanc vines (Oakville, block A), only one significant difference was found. One foot quadrilateral trellises yielded wines which differed significantly from those from four foot quadrilaterals ($p<0.01$), but only for non-shoot positioned vines. For shoot positioned vines, no significant differences in wines were produced between vines trellised on bilateral versus four foot quadrilaterals or between one foot quadrilaterals versus four foot quadrilaterals.

For Chenin blanc vines in Davis, for both shoot positioned and non-shoot positioned vines, highly significant differences were found between the bilateral trellis, lyre trellis and the GDC. However, in informal evaluation of the wines, it was felt that these differences could be attributed to enological problems, rather than to viticultural practices: the bilateral trellised wines in both cases were characterized by off-odors variously described as oxidized and sulfur, skunk, etc., whereas the GDC and Lyre trellised wines were "clean" and free of these off-odors. However, the Lyre trellised wines were perceptibly sweeter than the other wines because of higher RS and/or lower acidity.

RESEARCH ACCOMPLISHMENTS:

Objective 1: Determine the effects of different vineyard cultural practices (trellising, pruning level, leaf removal and row spacing) on vine microclimate, fruit composition, productivity and wine quality.

Under this objective, detailed data were obtained from four field experiments. Two at the Oakville Experimental Vineyard: a Cabernet Sauvignon trial at the South Oakville Experimental Vineyard N-block involving experimental variables of three row spacings (8, 10 and 12 foot) in combination with two trellis systems (single canopy bilateral and divided canopy quadrilateral) and these split again to four pruning levels [24,36, 48 and 60 buds (nodes)] per vine. The second experiment located at the North Oakville Experimental Vineyard was designed to compare a single canopy bilateral cordon with four quadrilateral cordon systems in which the distance between cordon branches are one, two, three and four feet apart. The remaining two trellising trials were conducted at U.C. Davis, one with Chenin blanc and the other with French Colombard. The Cabernet Sauvignon experiment at the South Oakville Experimental Vineyard will be discussed first.

Trellising Effects - South Oakville Station Plot

In 1989, Bilateral Cordon (BC) single canopy trellised vines averaged 9.8 tons/acre compared to 10.3 tons/acre for Quadrilateral Cordon (QC) divided canopy trellised vines when data for three row spacings and four pruning levels were combined together (Table 1). Table 2 presents the data for each of the 24 treatments separately. At 8 foot row spacing, yields of BC trellised vines ranged from 8.2 to 12.6 tons/acre and for QC vines from 9.5 to 13.4 tons/acre; at 10 foot row spacing BC vine yields ranged from 7.8 to 12.0 tons/acre and for QC vines from 9.3 to 11.3 tons/acre; and for 12 foot row spacing, BC vine yields ranged from 6.8 to 10.8 and for QC from 7.2 to 10.5 tons/acre. The data shows that at lighter pruning levels (24 and 36 buds/vine) QC vines generally yield one and a half to two tons more crop per acre than BC trellised vines, the increase in yield being mainly due to greater number of clusters per vine.

BC and QC fruits sampled on September 26, 1989, did not differ in fruit composition (Table 3). However, at harvest (September 30, 1989) QC fruits had higher fruit coloration and slightly lower malic acid and titratable acidity than BC fruits (Tables 4 and 5). The °Brix, pH and K in BC and QC fruits did not differ significantly at harvest.

Row Spacing Effects - South Oakville Station Plot

The average crop yield in tons/acre of 8, 10 and 12 foot row spacings were 11.5, 10.3 and 8.9, respectively or approximately 2.5 tons higher crop yield per acre at 8 foot row spacing than at 12 foot row spacing (Table 1). Cluster weight and number of berries per cluster were less at 8 foot row spacing than at 10 and 12 foot row spacing (Table 1). At harvest, fruits at 8 foot row spacing were higher in malic acid than 10 and 12 foot row spacing, however, °Brix, pH, TA, K and berry color of fruits from the three row spacings did not differ significantly (Tables 4 and 5).

Pruning Level Effects - South Oakville Station Plot

With increase in pruning levels from 24 to 60 buds per vine, there was an increase in average crop yield from 8 to 11.5 tons/acre (Table 1). Number of clusters per vine were directly related to bud number per vine. Vines pruned to 24 buds/vine had significantly smaller berry weight compared to vines pruned to 36, 48 and 60 buds/vine. The number of berries set per cluster was inversely related to cluster number per vine. Increase in bud number per vine from 24 to 60 resulted in about a one week delay in harvest to reach the same level of °Brix. With increase in bud number (and crop level) per vine, there was a decrease in pH, titratable acidity and K, and an increase in malic acid (Tables 4 and 5). The level of anthocyanin in fruits at harvest did not differ significantly between pruning levels.

North Oakville Station Trellis-Training Experiment

This experiment was established to compare the performance of Bilateral Cordon trellised Chardonnay, Sauvignon blanc and Cabernet Sauvignon vines with quadrilateral trellised vines of 1, 2, 3, and 4 foot widths. The 1989 data are summarized in Tables 6 to 8.

Crop yield of Chardonnay and Cabernet Sauvignon trained to 1, 2, 3, or 4 foot Quadrilateral Cordon trellis system had significantly higher yields than the Bilateral Cordon trellised vines. Yield increases ranged from 0.5 to 1.9 tons/acre for Chardonnay and 0.8 to 1.5 tons/acre for Cabernet Sauvignon (Tables 6 and 8). The level of sugar in fruits from all Quadrilateral trellised vines was higher than in Bilateral trained vines (Tables 6 - 8). The concentration of K in Quadrilateral fruits had slightly less arginine than Bilateral fruits in all three cultivars. Malic acid levels tended to vary inversely with Quadrilateral width for all three cultivars. Overall growth, as measured by pruning weights, did not differ between any of the treatments (Tables 6 - 8).

Chenin Blanc Trellising Trial, Davis, CA

Chenin blanc vines trained to divide canopy GDC and U (Lyre) trellis systems produced 20 to 30% higher yield than single canopy vertically trellised vines and at the same time had significantly higher level of sugar in fruits at harvest (Table 9). The pH and level of K in GDC and U-fruits were significantly higher than in Vertical trellised fruits measured on the same date, however, when compared at the same °Brix, there were no differences in pH and K. Titratable acidity and malic acid were lower in GDC and U-fruits than in Vertical fruits at harvest. Total phenols of GDC fruits were highest, Vertical fruits lowest and U-fruits intermediate.

The amount of primary and lateral shoot growth differed greatly between the three trellis systems. GDC-vines had the greatest number of shoots, but the length of the shoots and internodes were shorter and area per leaf, per primary shoot and per lateral shoot were considerably less compared to vertical and Lyre trellised vines. The total leaf area per shoot from GDC vines was about one-third less than in Vertical and Lyre vines. Both the GDC and Lyre trellised vines had significantly lower shoot density or number of shoots per meter of canopy length than Vertical trellised vines. Leaf area per cm of shoot length and per gram of fruit was significantly less for GDC trellised vines than Vertical and Lyre trellised vines, indicating that the former trellis had less canopy crowding and the highest efficiency of fruit production per unit leaf area.

French Colombard Trellising Trial, Davis, CA

Crop yield of French Colombard vines trained to GDC and Lyre trellis systems produced 24.6 and 26.7 tons/acre, respectively, compared to 16.9 tons acre for the two-wire Vertical (control) vines (Table 11). The increase in crop was mainly due to increase in the number of shoots and clusters per vine. GDC vines had the smallest berry weight and Lyre vines the largest berry weight. There was no significant difference in °Brix, pH, TA and K in fruits at harvest (Table 12). The number of shoots per meter of cordon length for the two-wire Vertical, GDC and Lyre trellised vines were 27.7, 16.0 and 17.9, respectively, indicating considerable less crowding in the latter two trellis systems. The amount of photosynthetic light and sunflects in the fruiting region of GDC and Lyre vines were nearly double that of the two-wire Vertical trained vines.

RESEARCH ACCOMPLISHMENTS:

Sensory Evaluation Results

For each of the experimental treatments, the three replicate fermentations were evaluated informally. Where severe problems were detected (such as H2S or badly oxidized wines) in one of the replicate fermentation, the spoiled wine fermentation replicate was eliminated. For each treatment, the remaining replicate fermentation lots were blended for sensory evaluation.

Within each variety for each experimental treatment, duo-trio difference tests were performed to determine if significant differences could be detected between treatments. Each duo-trio test was performed in duplicate by 15 trained judges. All evaluations were performed in individual tasting booths under white light. In cases where statistically significant differences were found, the wines were compared informally to determine if further tests should be run. However, in only two cases was it demonstrated that the differences were large enough to examine by the use of pair tests. Accordingly, pair difference tests were run in duplicate for vegetative flavor for the Cabernet 24 versus 60 buds/vine treatments.

Cabernet Sauvignon

Trellising effects: In Table A1, the results of sensory difference tests are presented for comparison of the flavor of Cabernet Sauvignon wines trained on Bilateral trellis (BIL) versus a GDC trellis. AT the extreme pruning levels (24 and 60 buds) no significance difference in wine flavor was found between the two trellises did not have any detectable effect of wine flavor. (Where no significant difference in flavor is found, clearly no difference in quality occurred).

Pruning level effects: With increase in pruning levels from 24 to 60 buds/vine, significant differences in the wine sensory properties were observed for both the Bilateral trellis and for the GDC trellis (both were significant at $p<0.01$, as summarized in Table A2). From pair tests for vegetative flavor (aroma and flavor by mouth), statistically significant differences were detected between the two pruning levels: For both the GDC and the Bilateral trellis, the 24 bud per vine pruning level yielded a more vegetative flavor as summarized in Table A3. Judges comments and informal evaluation suggested that the difference primarily lay in the higher intensity of vegetative aroma in the 24 bud/vine treatment versus a higher fruitiness in the 60 bud/vine treatment.

Sauvignon blanc

As summarized in Table A4, in the comparison of the effects of different trellises on Sauvignon blanc vines (Oakville, block A), only one significant difference was found. For non-shoot positioned trials, one foot quadrilateral trellises yielded wines which differed significantly from those wines from four foot quadrilaterals ($p<0.01$). Informal evaluation of these wines showed the difference primarily to reside in the intensity of fruitiness. The four foot quadrilateral vines yielded wines which were informally described as slightly more fruity than the one foot quadrilateral. However, this difference may attributed to the presence of hydrogen sulfide or other volatile sulfur spoilage problem which occurred in the one foot quadrilateral wines. This difference was not large enough to warrant a pair test for fruitiness. For the non-shoot positioned vines, wines from Bilateral trellised grapes could not be distinguished from four foot quadrilateral wines.

For shoot positioned vines no significant differences in wines were produced between vines trellised on Bilateral versus four foot quadrilaterals or between one foot quadrilaterals versus four quadrilaterals.

Examination of the wine composition revealed that the shoot positioned one foot and two foot quadrilateral trellises had lower TA/higher pH than the corresponding shoot positioned wines. However, only a few judges commented on acidity differences.

Chenin blanc

For Chenin blanc vines in Davis, for both shoot positioned and non-shoot positioned vines, highly significant differences were found between the Bilateral trellis, the lyre trellis, and GDC, as summarized in Table A5. However, in informal evaluation of the wines, it was felt that these differences could be attributed to enological problems, rather than to viticultural practices: the Bilateral trellised wines in both cases were characterized by off-odors variously described as sulfur, skunk, etc., in contract to an absence of sulfur problems in vines trellised on Lyre or GDC. The shoot positioned lyre trellis wine had a higher residual sugar than the other wines, although both non-shoot positioned and shoot positioned lyre wines were reported to be sweeter in informal evaluations of the wines.

In comparison of a Bilateral trellis versus an exposed Bilateral trellis, no significant differences were found between the wines.

Inspection of the chemical analyses of the wines suggests that the Lyre trellis yielded wines of higher ethanol (for both shoot positioned and non-shoot positioned vines), slightly higher pH, and higher residual sugars. No comments about differences in viscosity, both, etc., indicative of ethanol differences were made during informal or formal evaluations. As well, the shoot positioned Bilateral vines yielded wine with the highest TA, but this did not appear to be detected by the judges.

In summary, by informal evaluation of these wines following the difference testing, the difference between Bilateral trellised Chenin blanc wines and the other two trellises was attributable to the presence of more oxidized and volatile sulfur odors in the Bilateral trellis wines. In comparison of the Lyre with the other wines, the higher residual sugars, accounted for the discrimination.

LE 1

INFLUENCE OF ROW SPACING, TRELLISING AND PRUNING LEVEL ON CROP YIELD AND YIELD COMPONENTS OF CABERNET SAUVIGNON, 1989, OAKVILLE, CA.

TREATMENT	HARVEST DATE	CROP YIELD KG/ VINE	CROP YIELD TONS/ ACRE	NUMBER CLUSTER/ VINE	CLUSTER WEIGHT (g)	BERRY WEIGHT (g)	NUMBER BERRIES/ CLUSTER
ROW SPACING							
8 ft	10/1	13.4	11.50	113	119	1.32	91
10 ft	9/29	15.1	10.30	117	130	1.31	100
12 ft	9/29	15.7	8.96	120	132	1.29	103
Significant Level		0.002	0.002	NS	0.002	NS	0.002
TRELLIS SYSTEM							
Bilat.	9/30	14.38	9.8	114	127	1.30	98
Quad.	9/30	15.09	10.3	120	127	1.31	98
Significant Level		NS		NS	NS	NS	NS
PRUNING LEVEL							
24 buds/vine	9/26	11.79	8.06	96	124	1.22	102
36 buds/vine	9/28	14.45	9.88	108	135	1.30	104
48 buds/vine	10/3	15.87	10.86	129	124	1.36	92
60 buds/vine	10/3	16.83	11.50	134	126	1.34	94
Significant Level		0.001	0.001	0.001	0.006	0.001	0.001

TAB 2

EFFECTS OF THREE ROW SPACINGS IN COMBINATION WITH TWO TRELLIS SYSTEMS AND FOUR PRUNING LEVELS ON CROP YIELD AND YIELD COMPONENTS OF CABERNET SAUVIGNON AT HARVEST, 1989, OAKVILLE, CALIFORNIA

TREATMENT			HARVEST DATE	CROP YIELD		NUMBER CLUSTER/ VINE	CLUSTER WEIGHT (g)	BERRY WEIGHT (g)	NUMBER BERRIES/ CLUSTER
ROW SPACING	TRELLIS SYSTEM	PRUNING LEVEL		KG/ VINE	TONS/ ACRE				
8 ft	Bilat.	24 buds/vine	9/26	9.62	8.24	87	111	1.20	93
8 ft	Bilat.	36	10/3	12.68	9.82	110	117	1.35	87
8 ft	bilat.	48	10/3	14.83	12.69	121	122	1.33	92
8 ft	Bilat.	60	10/3	14.70	12.58	128	115	1.31	89
8 ft	Quad.	24	9/26	11.16	9.55	97	118	1.27	94
8 ft	Quad.	36	10/3	14.23	12.18	113	127	1.35	94
8 ft	Quad.	48	10/3	14.50	12.41	125	117	1.35	87
8 ft	Quad	60	10/3	15.70	13.44	128	124	1.36	91
10 ft	Bilat.	24 buds/vine	9/26	11.46	7.84	88	132	1.26	105
10 ft	Bilat.	36	9/26	13.81	9.44	104	136	1.25	109
10 ft	Bilat.	48	10/3	15.87	10.85	132	121	1.38	89
10 ft	Bilat.	60	10/3	17.59	12.02	134	132	1.38	96
10 ft	Quad.	24	9/26	13.67	9.35	109	126	1.22	104
10 ft	Quad.	36	9/26	15.48	10.59	113	138	1.26	110
10 ft	Quad.	48	10/3	16.11	11.02	127	128	1.40	91
10 ft	Quad.	60	10/3	16.52	11.30	130	129	1.35	96
12 ft	Bilat.	24 buds/vine	9/26	11.98	6.82	91	133	1.21	110
12 ft.	Bilat.	36	9/26	15.59	8.88	105	150	1.27	119
12 ft.	Bilat.	48	10/3	15.48	8.82	126	123	1.36	91
12 ft.	Bilat.	60	10/3	18.97	10.81	145	132	1.32	100
12 ft.	Quad.	24	9/26	12.88	7.24	107	121	1.17	104
12 ft.	Quad.	36	9/26	14.92	8.50	106	142	1.34	106
12 ft.	Quad.	48	10/3	18.44	10.51	142	133	1.32	101
12 ft.	Quad.	60	10/3	17.52	9.99	140	125	1.34	93
Row spacing X Trellis X Pruning Interaction				NS	NS	NS	NS	NS	NS

TABLE 3

INFLUENCE OF ROW SPACING, TRELLISING, AND PRUNING LEVEL ON FRUIT COMPOSITON OF CABERNET SAUVIGNON SAMPLED ON SEPTEMBER 26, 1989, OAKVILLE, CALIFORNIA

TREATMENT	BERRY WEIGHT (g)	°BRIX	pH	TA (g/L)	MALIC ACID (g/L)	K (ppm)	ANTHOCYANIN (μg/g)
Row Spacing							
8 Ft	1.28	22.2	3.32	6.76	1.36	1542	448
10 Ft	1.26	22.3	3.31	6.78	1.38	1498	448
12 Ft	1.26	22.4	3.32	6.81	1.32	1491	449
Significant Level	NS	NS	NS	NS	NS	NS	NS
Trellis System							
Bilat	1.26	22.2	3.31	6.81	1.36	1499	424
Quad	1.27	22.4	3.32	6.76	1.35	1521	472
Significant Level	NS	NS	NS	NS	NS	NS	NS
Pruning Level buds/vine							
24	1.22	22.8	3.36	6.81	1.43	1553	464
36	1.29	22.4	3.30	7.08	1.36	1631	453
48	1.27	22.1	3.30	6.68	1.35	1442	446
60	1.28	22.0	3.30	6.56	1.28	1413	429
Significant Level	0.0003	0.0001	0.0001	0.0001	0.03	0.0001	0.001

TABLE 4

INFLUENCE OF ROW SPACING, TRELLISING, AND PRUNING LEVEL ON FRUIT COMPOSITON OF CABERNET SAUVIGNON AT HARVEST, 1989, OAKVILLE, CALIFORNIA

TREATMENT	MEAN HARVEST DATE	BERRY WEIGHT (g)	°BRIX	pH	TA (g/L)	MALIC ACID (g/L)	K (ppm)	ANTHO-CYANIN (μg/g fruit)
Row Spacing								
8 Ft	10/1	1.32	22.8	3.32	6.90	2.15	1496	501
10 Ft	9/29	1.31	22.7	3.32	6.86	1.83	1516	486
12 Ft	9/29	1.29	22.7	3.31	6.93	1.79	1494	481
Significant Level		NS	NS	NS	NS	0.002	NS	NS
Trellis System								
Bilat	9/30	1.30	22.7	3.31	7.02	1.98	1490	474
Quad	9/30	1.31	22.8	3.32	6.77	1.88	1514	505
Significant Level		NS	NS	NS	0.01	0.01	NS	0.05
Pruning Level buds/vine								
24	9/26	1.22	22.8	3.36	6.81	1.43	1553	464
36	9/28	1.30	22.7	3.31	7.10	1.74	1590	462
48	10/3	1.36	22.7	3.31	6.91	2.31	1438	528
60	10/3	1.34	22.7	3.29	6.76	2.22	1432	503
Significant Level		0.0001	NS	0.001	0.04	0.001	0.001	NS

TABLE

EFFECTS OF THREE ROW SPACINGS IN COMBINATION WITH TWO TRELLIS SYSTEMS AND FOUR PRUNING LEVELS ON FRUIT COMPOSITION OF CABERNET SAUVIGNON AT HARVEST, 1989, OAKVILLE, CALIFORNIA

TREATMENT									
ROW SPACING	TRELLIS SYSTEM	PRUNING LEVEL	HARVEST DATE	TSS °BRIX	pH	TA (g/L)	MALIC ACID (g/L)	K (ppm) (g)	ANTHO-CYANIN (µg/g)
8 ft	Bilat.	24 buds/vine	9/26	23.1	3.39	6.91	1.43	1618	469
8 ft	Bilat.	36	10/3	23.2	3.32	7.32	2.50	1517	492
8 ft	bilat.	48	10/3	22.4	3.30	7.13	2.70	1430	497
8 ft	Bilat.	60	10/3	22.8	3.29	6.98	2.16	1432	505
8 ft	Quad.	24	9/26	22.8	3.37	6.61	1.41	1576	478
8 ft	Quad.	36	10/3	22.6	3.31	6.69	2.40	1505	508
8 ft	Quad.	48	10/3	22.6	3.31	6.89	2.30	1441	572
8 ft	Quad	60	10/3	22.8	3.29	6.62	2.29	1468	489
10 ft	Bilat.	24 buds/vine	9/26	22.9	3.37	6.74	1.39	1571	435
10 ft	Bilat.	36	9/26	22.7	3.31	7.04	1.40	1655	450
10 ft	Bilat.	48	10/3	22.9	3.30	7.08	2.49	1450	557
10 ft	Bilat.	60	10/3	22.7	3.29	6.89	2.33	1446	493
10 ft	Quad.	24	9/26	22.3	3.35	6.67	1.35	1476	457
10 ft	Quad.	36	9/26	22.6	3.29	7.27	1.50	1662	438
10 ft	Quad.	48	10/3	22.9	3.35	6.62	2.03	1452	521
10 ft	Quad.	60	10/3	22.5	3.30	6.57	2.19	1420	535
12 ft	Bilat.	24 buds/vine	9/26	22.3	3.35	7.16	1.63	1547	409
12 ft.	Bilat.	36	9/26	21.9	3.29	7.13	1.24	1494	381
12 ft.	Bilat.	48	10/3	22.8	3.29	6.93	2.14	1378	503
12 ft.	Bilat.	60	10/3	22.4	3.27	6.94	2.29	1374	494
12 ft.	Quad.	24	9/26	23.3	3.35	6.75	1.36	1534	535
12 ft.	Quad.	36	9/26	23.2	3.32	7.14	1.40	1705	501
12 ft.	Quad.	48	10/3	22.8	3.30	6.81	2.21	1479	520
12 ft.	Quad.	60	10/3	23.2	3.28	6.55	2.07	1455	503
Row spacing X Trellis X Pruning Interaction				NS	NS	NS	NS	NS	NS

TABLE 6

INFLUENCE OF TRELLIS WIDTH ON YIELD, VINE GROWTH AND FRUIT COMPOSITION OF CHARDONNAY GRAPEVINES AT HARVEST, 1989, OAKVILLE, CALIFORNIA

PARAMETER MEASURED	TRELLIS-TRAINING TREATMENTS[z]					SIGNIFICANT LEVEL	
	BILAT.	0.3m QUAD	0.6m QUAD	0.9m QUAD	1.2m QUAD	BILAT. VS. QUAD	QUAD WIDTH
Date Harvested	9/15	9/15	9/15	9/15	9/13		
Crop Yield (kg/vine)	18.6	20.2	20.5	20.5	19.1	0.05	NS
Crop Yield (tons/ac)	9.3	10.1	10.2	10.2	9.6	0.05	NS
Number clusters/vine	114	122	123	125	121	NS	NS
Cluster weight (g)	164	169	168	165	159	NS	NS
Berry weight (g)	1.36	1.40	1.41	1.41	1.36	0.06	NS
Number berries/cluster	120	121	120	117	117	NS	NS
Pruning weight (kg)	2.42	2.56	2.47	2.51	2.38	NS	NS
Yield/Pruning weight	7.68	7.89	8.30	8.17	8.02	NS	NS
TSS (°Brix)	22.7	22.9	22.7	23.2	23.4	NS	0.09
pH	3.21	3.24	3.20	3.23	3.21	NS	NS
Titratable acidity (g/L)	5.87	5.64	5.74	5.83	5.55	NS	0.06
Malic acid (g/L)	1.19	1.09	1.19	1.22	1.08	NS	NS
Potassium (ppm)	1229	1269	1270	1279	1303	0.04	NS
Arginine (μg/ml)	112	101	110	94	88	NS	NS

[z] Trellis-trianing data have been combined for shoot positioned and not shoot positioned vines.

TABLE 7

INFLUENCE OF TRELLIS WIDTH ON YIELD, VINE GROWTH AND FRUIT COMPOSITION OF SAUVIGNON BLANC GRAPEVINES AT HARVEST, 1989, OAKVILLE, CALIFORNIA

PARAMETER MEASURED	TRELLIS-TRAINING TREATMENTS[z]					SIGNIFICANT LEVEL	
	BILAT.	0.3m QUAD	0.6m QUAD	0.9m QUAD	1.2m QUAD	BILAT. VS. QUAD	QUAD WIDTH
Date Harvested	9/13	9/8	9/5	9/3	8/30		
Crop Yield (kg/vine)	17.9	17.2	18.5	17.0	15.4	NS	NS
Crop Yield (tons/ac)	8.9	8.6	9.2	8.5	7.7	NS	NS
Number clusters/vine	133	131	144	136	130	NS	0.05
Cluster weight (g)	135	130	129	124	118	0.04	0.03
Berry weight (g)	1.72	1.74	1.75	1.60	1.69	NS	NS
Number berries/cluster	79	75	74	78	70	NS	NS
Pruning weight (kg)	2.80	2.99	3.23	2.88	3.05	NS	NS
Yield/Pruning weight	6.39	5.75	5.73	5.90	5.04	NS	NS
TSS (°Brix)	21.9	22.2	22.6	23.1	23.2	0.02	0.03
pH	3.15	3.15	3.09	3.13	3.12	NS	NS
Titratable acidity (g/L)	6.69	7.14	7.83	7.15	7.36	0.002	NS
Malic acid (g/L)	1.60	1.97	1.91	1.27	1.42	NS	0.004
Potassium (ppm)	1179	1162	1331	1222	1264	0.05	0.04
Arginine (μg/ml)	256	249	185	206	180	0.05	0.08

[z] Trellis-trianing data have been combined for shoot positioned and not shoot positioned vines.

TABLE 8

INFLUENCE OF TRELLIS WIDTH ON YIELD, VINE GROWTH AND FRUIT COMPOSITION OF CABERNET SAUVIGNON GRAPEVINES AT HARVEST, 1989, OAKVILLE, CALIFORNIA

PARAMETER MEASURED	TRELLIS-TRAINING TREATMENTS[z]					SIGNIFICANT LEVEL	
	BILAT.	0.3m QUAD	0.6m QUAD	0.9m QUAD	1.2m QUAD	BILAT. VS. QUAD	QUAD WIDTH
Date Harvested	10/3	10/3	10/3	10/3	10/3		
Crop Yield (kg/vine)	14.8	15.6	16.3	16.3	16.3	0.002	NS
Crop Yield (tons/ac)	7.4	7.8	8.15	8.15	8.15	0.002	NS
Number clusters/vine	129	134	138	138	141	0.03	NS
Cluster weight (g)	115	116	119	118	116	NS	NS
Berry weight (g)	1.19	1.20	1.22	1.21	1.24	NS	NS
Number berries/cluster	97	98	97	98	94	NS	NS
Pruning weight (kg)	2.39	2.43	2.68	2.30	2.77	NS	NS
Yield/Pruning weight	6.19	6.42	6.08	7.09	5.88	NS	NS
TSS (°Brix)	21.7	22.1	22.3	22.4	23.0	0.007	0.01
pH	3.21	3.19	3.21	3.21	3.20	NS	NS
Titratable acidity (g/L)	6.46	6.32	6.42	6.24	6.38	NS	NS
Malic acid (g/L)	1.21	1.07	1.18	1.01	1.03	NS	NS
Potassium (ppm)	1202	1237	1240	1261	1318	0.06	0.05
Anthocyanin (mg/g fruit)	0.67	0.72	0.67	0.73	0.69	NS	NS

[z] Trellis-trianing data have been combined for shoot positioned and not shoot positioned vines.

TABLE 9

INFLUENCE OF TRELLIS, SHOOT POSITIONING AND LEAF REMOVAL IN FRUITING REGION ON FRUIT COMPOSITION OF CHENIN BLANC AT HARVEST, 1989, DAVIS, CALIFORNIA

Treatment	Crop Yield (kg/vine)	Total Soluble solids (°B)	pH	TA (g/L)	Malic acid (g/L)	K (ppm)	Arginine (μg/ml)	Total Phenols (μg/cm²)
Trellis System								
Vertical	32.8	19.8	3.26	6.44	2.57	1132	134	27.9
GDC	39.2	20.1	3.29	6.03	2.39	1140	121	30.3
U	41.3	21.4	3.34	5.86	2.34	1198	118	28.5
Signif. level	0.0001	0.0001	0.0001	0.0001	0.009	0.0002	0.009	0.001
Shoot Positioning (SP)								
Not SP	40.2	20.7	3.32	6.08	2.51	1197	122	28.5
SP	35.6	20.3	3.28	6.14	2.36	1116	126	29.3
Signif. level	0.001	0.02	0.001	NS	0.02	0.0001	NS	NS
Leaf Removal								
None	36.8	20.7	3.30	6.11	2.51	1176	127	27.9
Northside	38.6	20.3	3.28	6.25	2.46	1140	122	29.9
North and South side	38.3	20.4	3.31	5.97	2.32	1155	123	28.8
Signif. level	NS	NS	NS	0.07	NS	NS	NS	NS

TABLE 10

CANOPY CHARACTERISTICS OF VERTICAL, LYRE, AND GDC TRELLISED CHENIN BLANC GRAPEVINES, 1989, DAVIS, CALIFORNIA

PARAMETER	TRELLIS SYSTEM VERTICAL	LYRE	GDC	SIGNIFICANT LEVEL
Total number shoots/vine	62.2a	68.1a	77.1b	0.0007
Average number primary leaves/shoot	14.7a	16.5b	16.9b	0.037
Average primary shoot length (cm)	109.8	120.8	108.1	NS
Average internode length (cm)	7.4a	7.2a	6.3b	0.001
Area/primary leaf (cm^2)	123.0a	102.2b	73.9c	0.001
Leaf area/primary shoot (cm^2)	1710a	1570a	1210b	0.01
Number laterals/primary shoot	7.2	6.9	5.1	NS
Average number nodes/lateral	4.1	3.8	4.2	NS
Average length/lateral (cm)	10.9	9.8	10.8	NS
Average area/lateral leaf (cm^2)	35.3a	25.0b	23.0b	0.01
Total lateral leaf area/ shoot (cm^2)	1300a	1620a	840b	0.05
Total leaf area/shoot (cm^2)	3020a	3160a	1970b	0.05
Total leaf area/vine (m^2)	18.76a	21.43a	15.06b	0.05
Lateral leaf area as percent of total leaf area	43.0%	51.3%	42.6%	NS
Shoot number/m canopy length	28.3a	15.5b	17.5b	0.01
γ (leaf area (cm^2) /cm shoot length)	27.5a	26.1a	18.2b	0.05
Canopy surface area (m^2)	12.5a	17.7b	16.1b	0.05
Total leaf area/canopy surface area	1.50a	1.21b	0.93c	0.05
Total leaf area/fruit weight ratio (cm^2/g)	5.7a	5.3a	3.9b	0.05

TABLE 11

INFLUENCE OF TRELLIS SYSTEM ON CROP YIELD AND YIELD COMPONENTS OF FRENCH COLOMBARD IN 1989, DAVIS, CA (HARVESTED OCTOBER 2, 1989)

Trellis System	Crop Yield kg/vine	Crop Yield tons/ac	No. Clusters Per vine	Cluster Wt (g)	Berry Wt (g)	No. of Berries Per cluster
2-wire vertical	33.8	16.9	145	238	2.11	113
GDC	49.2	24.6	198	252	1.94	129
Lyre	53.5	26.7	190	294	2.21	133
Signif. Level	0.007	0.007	0.03	NS	0.007	NS

TABLE 12

INFLUENCE OF TRELLIS SYSTEM ON FRUIT COMPOSITION OF FRENCH COLOMBARD AT HARVEST IN 1989, DAVIS, CA. (HARVESTED OCTOBER 2, 1989)

System	Total Soluble Solids (°Brix)	pH	Titratable Acidity (g/L)	K ppm
2-Wire vertical	19.8	3.28	9.03	1798
GDC	19.3	3.21	9.12	1620
Lyre	19.9	3.25	8.76	1643
Signif. Level	NS	NS	NS	NS

TABLE 13

INFLUENCE OF TRELLIS SYSTEM ON SHOOT DENSITY AND CANOPY LIGHT MICROCLIMATE IN THE FRUITING REGION OF FRENCH COLOMBARD GRAPEVINES, 1989 SEASON.

	Trellis System[x]			
	2-wire Vertical (Bilateral Cordon)	GDC	Lyre	Signif. Level
No. Shoots/vine	66.5	77.0	86.0	0.0001
No. Shoots/m cordon length	27.7	16.0	17.9	0.0001
PPFD in Fruiting Region ($\mu Em^{-2}s^{-1}$)[z]	186	437	348	0.01
% Sun Flecks in Fruiting Region[y]	7.5	17.8	13.9	0.03

[z] PPFD = photosynthetic photon flux density and is an expression of light quantity.

[y] % Sun Flecks was measured with a ceptometer between 11:00 a.m. and 1:00 p.m. held horizontally facing upward immediately above the fruiting region.

[x] The 2-wire vertical is a single canopy and GDC and Lyre are divided canopy type trellis systems.

TABLE A1.. **EFFECT OF TRELLISING ON 1989 CABERNET SAUVIGNON WINES** (OAKVILLE BLOCK N). NUMBER OF CORRECT RESPONSES & SIGNIFICANCE FOR DUO-TRIO COMPARISONS OF AROMA & FLAVOR (n = 15 Judges x 2 reps).

COMPARISON TESTED	NO. CORRECT	SIG
BILATERAL TRELLIS (bil) vs. GDC TRELLIS (GDC)		
24 BUDS PRUNING LEVEL		
wine # 25325B(bil) vs. wine # 25328B(GDC)	19	NS
60 BUDS PRUNING LEVEL		
wine # 25457B(bil) vs. wine # 25463B(GDC)	17	NS

TABLE A2.. **EFFECT OF PRUNING LEVEL ON 1989 CABERNET SAUVIGNON WINES** (OAKVILLE BLOCK N). NUMBER OF CORRECT RESPONSES & SIGNIFICANCE FOR DUO-TRIO COMPARISONS OF AROMA & FLAVOR (n = 15 Judges x 2 reps).

COMPARISON TESTED	NO. CORRECT	SIG
BILATERAL TRELLIS		
24 BUDS vs. 60 BUDS		
wine # 25325B(bil) vs. wine # 25457B(bil)	23	**
GDC TRELLIS		
24 BUDS vs. 60 BUDS		
wine # 25328B(bil) vs. wine # 25463B(bil)	23	**

TABLE A3. SUMMARY OF PAIR TESTS FOR VEGETATIVE FLAVOR.
Number of responses selecting each sample as more vegetative(n=13jx2r)

VARIETY	COMPARISON		Significance
CABERNET SAUVIGNON	60 Buds	24 Buds	
Bilateral Trellis	7	19	*
GDC Trellis	6	20	**

NS, *, ** Respectively, denote No significant difference or significance at $p<0.05$ and 0.01.

TABLE A4 **EFFECT OF TRELLISING ON 1989 SAUVIGNON BLANC WINES** (OAKVILLE BLOCK A) NUMBER OF CORRECT RESPONSES & SIGNIFICANCE FOR DUO-TRIO COMPARISONS OF AROMA AND FLAVOR. (n = 15 Judges x 2 reps).

COMPARISION TESTED	NO. CORRECT	SIG
SHOOT POSITIONED: DIFFERENT TELLISING TREATMENTS		
BILATERAL vs. 4' QUADRILATERAL wine # 25207B (BIL) vs. wine # 25086B (4' Q)	16	NS
1' QUADRILATERAL vs. 4' QUADRILATERAL wine # 25210B (1' Q) vs. wine # 25086B (4' Q)	14	NS
NON SHOOT POSITIONED: DIFFERENT TRELLISING TREATMENTS		
BILATERAL vs. 4' QUADRILATERAL wine # 25091B (BIL) vs. wine # 25013B (4' Q)	17	NS
1' QUADRILATERAL vs. 4' QUADRILATERAL wine # 25019B (1'Q) vs. wine # 25013B (4'Q)	22	**

NS = NOT SIGNIFICANT; *, **, *** denote p < 0.05, 0.01, 0.001 respectively

TABLE A5. **EFFECT OF TRELLISING ON 1989 CHENIN BLANC WINES** (TYREE BLOCK B, D) NUMBER OF CORRECT RESPONSES & SIGNIFICANCE FOR DUO-TRIO COMPARISONS OF AROMA AND FLAVOR. (n = 15 Judges x 2 reps).

COMPARISION TESTED	NO. CORRECT	SIG
SHOOT POSITIONED: DIFFERENT TELLISING TREATMENTS		
SP BILATERAL vs. SP LYRE wine # 25237B (BIL) vs. wine # 25243B (lyre)	25	***
SP BILATERAL vs. SP GDC wine # 25237B (BIL) vs wine # 25236B (GDC)	27	***
SP LYRE vs. SP GDC wine # 25243(lyre) vs wine # 25236B (GDC)	26	***
SP BILATERAL vs. SP EXPOSED BILATERAL wine # 25237B(BIL) vs wine # 25225B (exp BIL)	18	NS
NON SHOOT POSITIONED: DIFFERENT TRELLISING TREATMENTS		
NSP BILATERAL vs. NSP LYRE wine # 25229B (BIL) vs. wine # 25231B (lyre)	24	***
NSP BILATERAL vs. NSP GDC wine # 25229B (BIL) vs. wine # 25240B (GDC)	24	***
NSP LYRE vs. SP GDC wine # 25231(Lyre) vs wine # 25236B (GDC)	25	***
NSP BILATERAL vs. NSP EXPOSED BILATERAL	NOT TESTED[a]	

NS = NOT SIGNIFICANT; *** denotes p < 0.001.

[a]NOTE: Wines made from NON-SHOOT POSITIONED, EXPOSED BILATERAL TRELLIS were badly OXIDIZED. These wines were not included in further testing.