EFFECT OF LEAF TO FRUIT RATIO ON FRUIT QUALITY AND SHOOT DEVELOPMENT IN 'CARIGNANE' AND 'ZINFANDEL' WINE GRAPES

ROBERT J. WEAVER[1]

The number of leaves required to nourish the apple (2, 3, 5) and grape (7) has been studied. Winkler (7) found that 16 leaves sufficed to mature the fruit on girdled shoots of 'Muscat of Alexandria'; with 'Malaga', 20 leaves were sufficient. In our experiments the leaf requirement for 'Carignane' and 'Zinfandel' grapes was studied; also, the degree of coloration of fruit and the percent total solids of juice were correlated with leaf number. An other objective was to relate color development with maturation as expressed by degrees Balling and percentage of acid. The effect of the growing shoot apex and laterals on maturation of fruit was also studied. Shoot growth was also followed, including effects on maturation as expressed by content of total available carbohydrates in the shoots.

MATERIALS AND METHODS

Mature 'Carignane' and 'Zinfandel' grapevines in an irrigated vineyard at the University of California at Davis were used. The vines were head-trained and spur-pruned. Aside from the experimental procedures, the vineyard care was routine. Girdles about 1/4 inch wide were made at the base of shoots. The girdles were reopened weekly; leaves developing after defoliation were removed. In the individual shoot experiments only one cluster per shoot was retained.

During the coloration period, the degree of coloring was estimated visually. At harvest the color in the juice was determined with the Klett-Summerson colorimeter, using the blue, amber, and green tristimulus filters according to the procedure outlined by Berg and Akiyoshi (1). The dominant wave length, % purity (degree of saturation), % Y (brightness), and McAdam units (minimum perciptible difference between two colors as judged by the average observer) were usually determined.

The percentage of total soluble solids in the juice was obtained with a Balling hydometer or a hand refractometer. Total acidity was determined by titration. Berry weight was determined by removing berries from clusters and weighing. All berries were weighed in the individual shoot treatments. On whole vine treatments, berries were thoroughly mixed and lots of 200 weighed in duplicate.

For carbohydrate analyses shoots were cut into small pieces, dehydrated at 65°C, and then ground in an intermediate Wiley Mill. Duplicate samples were analyzed. Extraction procedures were those of Winkler and Williams (9), modified by using Clarase for starch digestion. Carbohydrate analyses were made according to the method of Phillips (6). Data are expressed as % dry weight.

To obtain leaf area, leaves were mixed and then sections 7cm² in area were cut out at random. Total leaf area was determined by relating the weight of a sample of leaves whose area was known to the total weight of all leaves.

EXPERIMENTAL RESULTS

Number of leaves and maturation: *'Carignane' 1957*—On July 10 the fruit of 'Carignane' vines was thinned to one cluster per shoot. Each retained cluster weighed about 187 grams, and contained about 220 green berries from 11 to 12 mm in diameter. The shoots averaged 52 leaves, approximately half of them arising from lateral shoots. The degrees Balling of the juice was 6.5.

[1] Professor of Viticulture, Department of Viticulture and Enology, University of California, Davis.

On July 10 the following girdling and defoliation treatments were made, 10 shoots per treatment:

1. Shoot girdled; only the 2 basal leaves retained.
2. Shoot girdled; only the 4 basal leaves retained.
3. Shoot girdled; only the 8 basal leaves retained.
4. Shoot girdled; only the 12 basal leaves retained.
5. Shoot girdled; only the 16 basal leaves retained.
6. Shoot girdled; all leaves retained, except those on lateral shoots.
7. Shoot girdled; all leaves retained.
8. Shoot not girdled; all leaves retained.

The percentage of color was estimated three times during the season (Table 1). Coloration was the most rapid on girdled shoots when laterals were removed (Table 1; Figure 1).

The clusters were harvested on September 12. The lowest amount of color (highest % Y) as determined by the tristimulus method occurred with shoots with 2 leaves (Table 2; Figure 2). Berries on these shoots were shriveled and had a reddish-green color. Berries were larger, and reddish, on shoots with four leaves. Clusters on girdled shoots with 8 to 12 leaves also had a reddish cast, although berries were larger (Table 3).

The weight and area of leaves became progressively greater on girdled shoots as the number of leaves increased (Table 3). The lowest shoot weight was in girdled shoots with four leaves. Weight per cluster increased up to shoots with 12 leaves,

TABLE 1

Percentage of Total Surface of 'Carignane' and 'Zinfandel' Grapes That Colored on Vines Subjected to Different Treatments on July 10, 1957[a]

	Date of Readings		
	'Carignane'		
Treatment	July 29	August 7	August 22
1. Girdled; 2 leaves retained	trace	trace	30
2. Girdled; 4 leaves retained	trace	5	51
3. Girdled; 8 leaves retained	2	60	82
4. Girdled; 12 leaves retained	3	65	87
5. Girdled; 16 leaves retained	33	92	89
6. Girdled; all leaves except on lateral shoots retained	41	92	92
7. Girdled; all leaves retained	24	90	89
8. Not girdled; all leaves retained	trace	27	86
	'Zinfandel'		
	July 23	August 7	August 16
1. Girdled; 2 leaves retained	trace	9	30
2. Girdled; 4 leaves retained	1	20	40
3. Girdled: 8 leaves retained	6	66	75
4. Girdled; 12 leaves retained	4	89	90
5. Girdled; 16 leaves retained	3	89	88
6. Girdled; all leaves except on lateral shoots retained	5	92	97
7. Girdled; all leaves retained	5	98	100
8. Not girdled; all leaves retained	7	94	95

[a]Each figure is average estimate of 10 replicate clusters.

carbohydrate accumulation. Browning begins at the base of the cane and proceeds acropetally. Shoots that remain green have a low accumulation of food reserves. Such canes are subject to sunburning and to frost damage. Shoots with two leaves were about 3 feet long, and only the basal foot was browned. There were blackened streaks along the shoots as a result of sunburn. Shoots with more than two leaves were 6 feet or more in length. The basal one-third of shoots with four leaves was browned, but in some cases portions of the stems were blackened. Shoots with eight leaves were browned about two-thirds the way up the stem. However, these shoots appeared weak, and the immature portions had black streaks. Shoots in treatments 4 to 8 (Table 3) were well browned and mature except at the apices.

Carbohydrate analyses showed that the percentage of sugar usually increased progressively from shoots with two leaves to girdled shoots with all leaves (Table 4). Girdled shoots with all leaves produced the maximum percentage total available carbohydrates. Ungirdled shoots with all leaves had a lower carbohydrate percentage than the corresponding girdled shoots. This was probably a result of movement of carbohydrate into the parent vine. Differences in quantity of carbohydrate would be magnified if they were put on an absolute or a per shoot basis, since the shoots with low carbohydrate also weighed less.

'Zinfandel' 1957 — The experiment with 'Carignane' was repeated with 'Zinfandel' on July 15, 1957. Visual estimates showed that very rapid coloration of fruit occurred on girdled shoots with all leaves and usually that progressively fewer leaves progressively delayed coloration (Table 1, Figure 3). The amount of color at harvest as expressed by % Y increased as the leaf number increased on girdled shoots (Table 2). There was less color on ungirdled shoots with all leaves than on corresponding girdled shoots. The high value for McAdam units in the shoots with 12 leaves resulted from a low degree of color purity in this treatment.

Since many clusters showed signs of rotting, clusters and shoots were harvested on August 16, somewhat earlier than normal (Table 3). The larger the leaf number, the greater was the leaf area. Weight of girdled shoots with no laterals reached a maximum when there were eight leaves per shoot, but weight per cluster reached a maximum when all leaves except those on lateral shoots were retained. Eight leaves per shoot produced a maximum size berry; but all leaves, including those on laterals, were needed to produce the highest de-

TABLE 2

Percent Y (Brightness) and McAdam Units for Juice of 'Carignane' and 'Zinfandel' Grapes at Harvest (September 12, 1957) from Shoots Subjected to Various Treatments.

Treatment	'Carignane'		'Zinfandel'	
	% Y[a] (brightness)	McAdam Units	% Y[a] (brightness)	McAdam Units
1. Girdled; 2 leaves retained	84.4	13.0	95.4	15.5
2. Girdled; 4 leaves retained	86.6	11.0	90.6	14.5
3. Girdled; 8 leaves retained	78.9	9.5	89.6	15.0
4. Girdled; 12 leaves retained	67.7	2.0	88.0	21.0
5. Girdled; 16 leaves retained	72.7	6.5	81.7	14.0
6. Girdled; all leaves except on laterals retained	71.7	5.5	81.1	10.0
7. Girdled; all leaves retained	65.2	7.5	70.0	5.0
8. Not girdled; all leaves retained	69.3	0	77.8	0

[a] The lower the % Y, the greater the amount of color. Fruit of treatments No. 8 were used as the standards.

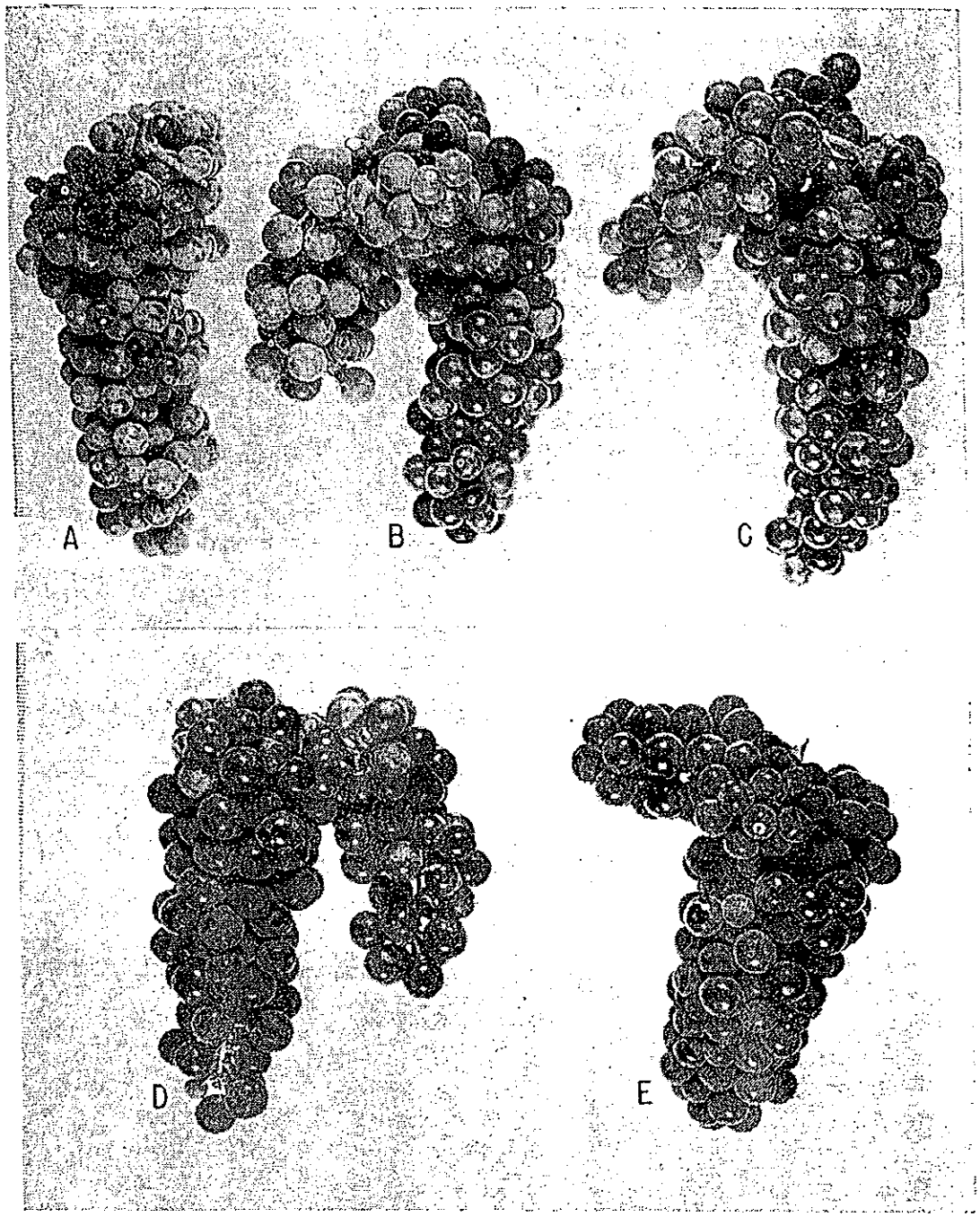

Figure 3. 'Zinfandel' clusters at harvest in 1957 after receiving various treatments on July 15: A, girdled, 2 leaves retained; B, girdled, 4 leaves retained; C, girdled, 8 leaves retained; D, girdled, 12 leaves retained, and E, not girdled, all leaves retained. Note that the greater the number of leaves retained, the greater the percentage of color. (Photographed August 16, 1957).

Leaves in Treatment 8 were removed so that the growing shoot apex with leaves was kept to about 6 inches in length.

On August 12 the clusters of all treatments were about 90% colored, except the color of fruit on girdled shoots with all leaves varied from 95 to 100%. Fruit was harvested on October 6 (Table 5). A comparison between Treatments 3 and 4 (Table 5) shows there was no significant difference in shoot weight, cluster weight, degrees Balling or percentage of acid regardless whether leaves were located on the apical or basal part of the shoot. When the shoot tip and laterals were allowed to grow (Treatment 5), the degrees Balling was higher than when they were removed (Treatment 4). Evidently the slow-growing shoot tip and laterals were exporting carbohydrate.

Topping the shoot above the eighth leaf (Treatment 6) caused no change in degrees Balling from Treatment 5 where the shoot tip was retained. Treatment 8 where the shoot tip was isolated from the eight basal leaves by a girdle resulted in about the same degree of ripening as where the shoot tip was removed by topping (Treatment 8).

Degree Balling and color: The objective of this experiment, done in 1957, was to determine correlation of degrees Balling with amount of color. 'Carignane' vines were used in a randomized block design; there were five replicate vines at each harvest. At the second sampling on September 2 the fruit was almost completely colored (Table 6). By September 23 there was slight shriveling of berries, which increased some by September 30. Considerable shriveling was evident by October 7; at the final harvest on October 14 fruit was beginning to rot.

After August 26 both amount of color (% Y) and degrees Balling rapidly increased (Table 6, Figure 4). Amount of color increased steadily up to approximately September 16. This level was maintained until September 30, after which a gradual rise occurred until harvest on October 14. The amount of color (% Y) increased steadily up until October 7 at which time a sharp decrease occurred. In general, color rose

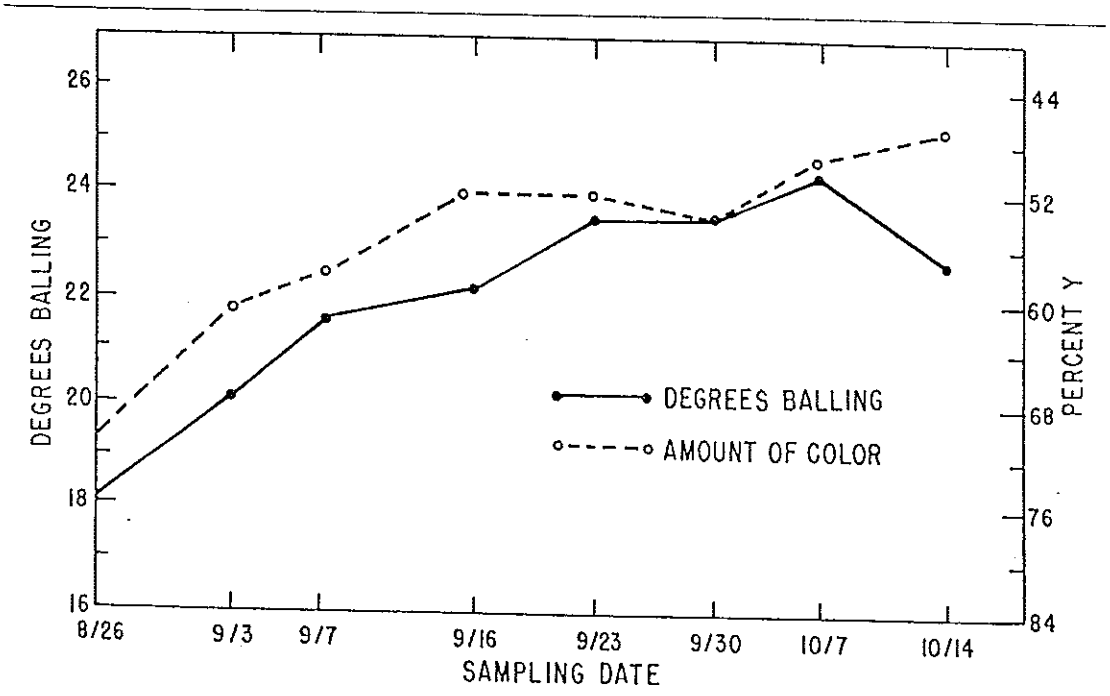

Figure 4. Graph showing change in amount of color (% Y) and degrees Balling in 'Carignane' grapes during ripening in 1957. Note increases in color and degrees Balling are similar except late in season.

TABLE 6

Data at Various Harvest Dates for 'Carignane' Grapes in 1957 at Davis, California

Date of Sampling	Crop weight (lb/vine)	Balling (degree)	Acid, (% tartaric)	Visual Est. of Color (%)	% Y[a] (brightness)	% Purity (Degree of Saturation)	Dominant Wave Length	McAdam[a] Units
8/26/57	26.2	18.1	1.50	84	71.5	7.0	502	8.0
9/3/57	23.0	20.0	1.30	84	60.9	13.0	502	22.0
9/7/57	23.8	21.5	1.13	95	57.3	14.2	501	25.5
9/16/57	27.4	22.2	0.78	100	52.0	13.0	499	23.0
9/23/57	24.2	23.4	0.73	100	52.0	7.5	494	7.0
9/30/57	25.2	23.6	0.59	100	54.0	6.0	700	0
10/7/57	22.8	24.4	0.63	100	49.2	6.7	630	3
10/14/57	28.6	22.7	0.79	100	47.2	17.3	510	31.0
d.05	N.S.	1.3	0.41	....	....	....	....	....

[a] The lower the % Y, the greater the amount of color. Fruit harvested on September 30 was used as the standard.

color in a given variety develops in relatively cool climates (8). Under climatic conditions different from those at Davis the degrees Balling and color development might present an entirely different relationship.

It is interesting that the number of leaves required for a high Balling reading of fruit is the same as the number required for proper maturation of canes, as expressed by carbohydrate analyses and color of the canes. In girdled 'Zinfandel' shoots, however, degrees Balling decreased with fewer leaves more rapidly than did berry size. In 'Zinfandel' degrees Balling was higher on girdled shoots with all leaves including laterals than on corresponding shoots without laterals. With 'Carignane' there was no significant differences. The reason for this difference is not known.

SUMMARY

1. 'Carignane' shoots were girdled and defoliated to varying degrees. The most rapid coloration of fruit occurred on shoots with 16 or more leaves. The lowest amount of color at harvest occurred with shoots with 2 leaves. The lowest shoot weight was in girdled shoots with 4 leaves. The weight per cluster increased up to shoots with 12 leaves. Degrees Balling was sharply reduced by fewer number of leaves per shoot. Sixteen or more leaves per shoot produced high percentages of starch and total available carbohydrates in the shoots.

2. The experiment was repeated with 'Zinfandel' with similar results. Shoot weight reached a maximum when there were 8 leaves, but weight per cluster reached a maximum when all leaves except those on lateral shoots were retained. Eight leaves produced a maximum size berry; but all leaves, including those on laterals, were needed to produce the highest degrees Balling reading. The leaf area produced by lateral shoots was greater than that produced by the primary shoot.

3. An experiment with 'Carignane' showed there is no significant difference in shoot weight, cluster weight, degrees Balling or percentage of acid whether leaves are located on the apical or basal part of the shoot. When shoot tips and lateral shoots were allowed to grow, the Balling