Effect of Pruning Severity and Rootstock on Growth and Yield of Two Grafted, Cane-pruned Wine Grape Cultivars[1]

L. A. Lider[2], A. N. Kasimatis[3], and W. M. Kliewer[2]
University of California, Davis

Abstract. Three years of observations were made at Oakville, California, on a vineyard trial of 3 pruning severities on 2 scion grape cultivars, Chardonnay and Gamay Beaujolais, grafted onto 2 phylloxera-resistant rootstocks, 'St. George' and 'A x R #1'. There was a marked increase in crop production with decreased pruning severity. With 'Chardonnay' on 'St. George' there was nearly a 3-fold increase in yield when the pruning went from 5 retained buds/lb. (453.6g) of prunings to 15 buds/lb. With 'Gamay Beaujolais', the yield increase approached 2-fold. Vines on 'A x R #1' were markedly more fruitful than those on 'St. George', and this rootstock difference was not influenced by pruning severity over a 3-year period.

The variability in level of pruning, as estimated from a visual inspection of individual vines, was great. This could account for both low yields and high vine sizes with 'Chardonnay'. The pruning level used by an experienced pruner was about 8 retained buds/lb. of prunings on average-sized vines of 'Chardonnay' on 'St. George', and about 6 buds on the largest vines.

The most severe pruning was very restrictive on yields per vine, and vine vigor was enhanced at these low bud counts. Fruit maturity was delayed by the least-severe pruning level and, in some instances, vine size was reduced the following year. Under the conditions of the test site, the intermediate level of pruning severity, 10 buds/lb. of prunings, was appropriate for the small-clustered, cane-pruned cultivars at the intermediate vine sizes.

The study of grape rootstocks resistant to phylloxera has been one of the most actively pursued fields of viticultural research over the past 100 years. Recent observations in California indicated that a number of factors, such as soil moisture, climate, and scion markedly influence rootstock performance; and that, in selecting a stock-scion combination for a specific site, each of these factors should be carefully evaluated. In recent years, however, the wine-grape growers in the coastal valleys of California have limited their commercial use of stocks to 2 choices. These are *Vitis rupestris* 'St. George' (synonym, *Rupestris* du Lot) and 'Aramon x Rupestris Ganzin #1' (synonym Ganin 1), which will be referred to hereafter as 'St. George' and 'A x R #1'.

Jacob (2) noted both the merits and the faults of 'St. George' with certain scions. The low-yielding tendency and high vegetative vigor of scions on 'St. George' have been reported by Lider (4, 5). Earlier it was suggested by Winkler (9, 10) that less severe pruning could materially improve the carbohydrate nutrition of these vigorous vines, and thus increase crop production. Cook and Lider (1) in a study of nitrate levels in petioles of vines grafted upon 'St. George', found a generally high level induced by this stock, as compared to 'A x R #1'. The high levels were correlated inversely with crop production and directly with vegetative vigor.

In studies of 'Concord', Shaulis and Oberle (7) and Kimball and Shaulis (3) showed that the pruning level could materially affect the crop load the following summer and, through this, affect both the maturity of the fruit and the vegetative development of the vine. A subsequent effect of less severe pruning was a decrease in vegetative development. In further studies with 'Concord' grapevines Shaulis and Steel (8) showed that as large vine size was attained, up to 5 lb. of prunings per vine, whether by rootstock or by management reduced fruitfulness. They associated this with increasing foliar crowding causing low light intensity within the vine on the restricted canopy.

Our primary objective was to evaluate subsequent effects of an increased crop load on vegetative development and fruitfulness of scions on 'St. George' and 'A x R #1' rootstocks. It seemed logical that, if the more vigorous scions on 'St. George' were bearing yields below their capacity, a reduced pruning severity should increase the stress of crop on these plants and thus reduce vegetative vigor. Our second objective was to evaluate, on typical vines of a cane-pruned wine variety, the level of pruning severity used by an experienced grapevine pruner, and to illustrate the range of variability in level from vine to vine down the vineyard row. Finally, we hoped to determine a relation between number of buds retained and vine size that would provide a basis for improving the pruning practices generally used for these cultivars in this district.

Materials and Methods

The study was initiated at the University's Oakville viticulture station in Napa Valley in 1966 with vines in buffer rows in a planting initially designed for fertilizer studies. We used 2 scion cultivars, each grafted upon 2 phylloxera-resistant rootstocks. Rootings of the 2 stocks were planted in the spring of 1959. These were grafted, using the field-budding technique, in August of that year to the scions 'Chardonnay' and 'Gamay Beaujolais'. These cultivars are small-clustered, early maturing types, and were generally cane-pruned, using pruning units 12 to 15 buds long.

The planting stock used to set this block of vines was obtained from the University-sponsored Foundation Plant Materials Service. At planting, each of the scions and rootstocks were judged free of known grape virus diseases. In subsequent years, a mild strain of grape leaf-roll virus was detected in the source of 'St. George' by an improved technique. The impact of this virus on vine growth and fruit maturity is currently being evaluated.

The vines were set 1.8 m (6 ft) apart in rows, 3.7 m (12 ft) apart. A 2-wire, vertical trellis system was used. The lower wire was 71 cm (28 in) from the ground to support the fruiting canes, and a second wire at 102 cm (40 in) supported foliage. The soil, a Bale gravelly loam, was deep, fertile, and relatively uniform throughout the test area.

The vineyard was not irrigated, and the vines depended entirely upon rainfall for their water supply. Mean annual precipitation was about 86 cm, and most of this fell during winter and spring. No fertilizer was applied to the vines in the buffer rows since they were planted, and cultural operations,

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[2]Department of Viticulture and Enology.
[3]Agricultural Extension Service.

typical for the area, included annual, early-spring, complete weed control.

The planting was set in rows of 50 vines each, with 25 vines grafted to each of the 2 scions. The buffer rows of the 2 rootstocks occurred as complete rows, and were randomized 3 rows apart throughout the planting. Two half rows, comprising 50 vines, of each stock-scion combination were used for the differential pruning levels. An additional 25 vines each of the 2 scions on 'St. George' were used to evaluate the pruning levels used by the experienced pruner. Prior to initiation of the study, all vines had been brought to maturity under the general practice of adjusting the dormant season pruning level to the vigor level of the individual vine, as based on visual evaluation of the past season's growth.

In January 1966, the most uniform 36 vines, based on the wt of 1-year old dormant prunings, were chosen from the 50 vines of each stock-scion combination available. Three differential pruning levels were established, with 12 vines at each level, randomized as single vines in the 2 rows. The 'Chardonnay' vines were chosen as near to equal size on both rootstocks. This was done by selecting plants at the lower end of the pruning wt distribution with 'St. George' and at the upper end with 'A x R #1'. With 'Gamay Beaujolais', the vines were selected from the intermediate size for both stocks, giving a rather large difference in initial pruning weights.

The 3 pruning levels, based upon the number of buds retained per pound of 1-year old dormant prunings, were set at 5, 10, and 15 buds/lb. for all vine sizes. The fruiting units used were 12-bud canes on 'Gamay Beaujolais' and 15-bud canes on 'Chardonnay'. In all instances, six 2-bud renewal spurs per vine were retained, and these were included in the total bud count. An estimate of the wt of the fruiting canes retained on each vine was made annually, and this was included in the final wt of prunings recorded for each vine.

Individual vine records of pruning wt, bud number, cluster number, yield, and fruit maturity were obtained each year. Fruit maturity, as degree Brix, was obtained from a randomly selected sample representing 10% of the crop on each vine at the time of harvest, and was measured with a hand refractometer. The experiment was continued for 3 growing seasons.

An evaluation of the pruning level used by an experienced pruner was made. This pruner used the technique generally accepted in the vineyards of the area, which involves a visual inspection of each vine and determination of the number of canes to be retained. Pruning wt and a count of the buds retained on each vine were obtained. A 25-vine row of each scion on 'St. George' was used for 3 years. The results were evaluated to establish an acceptable standard for the pruning level study.

Results

The level of pruning for each of the 25 vines of the 2 scions pruned by the experienced pruner are plotted in Fig. 1. A highly significant ($P<0.01$) relationship existed between the number of buds retained per pound of prunings (Y) and pruning wt (X) for

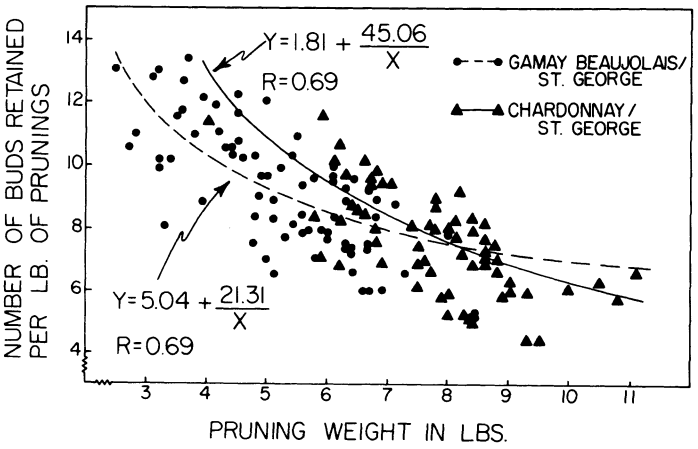

Fig. 1. Regression curves of the number of buds retained per lb. of prunings on 25 vines each of 2 scions on 'St. George' pruned for 3 years. Visual inspections were used to determine the level of pruning.

'Gamay Beaujolais' and 'Chardonnay' with regression equations $Y = 1.81 + \frac{45.06}{X}$ and $Y = 5.04 + \frac{21.31}{X}$, respectively, and correlation coefficients of 0.69 for both scions. The vertical distribution at any given vine size is a measure of pruner variability. For example, with 'Gamay Beaujolais', vines at the 5-pound size had a range from 6.2 buds retained per pound of prunings to over 12.0 buds. The 'Chardonnay' vines, as a group, were considerably larger than the 'Gamay Beaujolais' vines; and the number of buds retained per pound of prunings was generally lower on the former cultivar. It is significant to note from the regression curves that a rather constant total number of buds per vine were retained throughout the range of vine sizes. For 'Chardonnay' it was about 50. The average pruning wt was about 7.5 lb. for 'Chardonnay', and 5.0 for 'Gamay Beaujolais'. From this, 10 buds/lb. of prunings was determined as the intermediate level of pruning for the study.

The yields obtained each year on the stock 'A x R #1' were markedly higher than those on 'St. George' (Tables 1 and 2). With equal-sized vines of 'Chardonnay' on both stocks at the initiation of the study, the yields on 'A x R #1' were significantly higher. During 1966 and 1967, yields of 'Gamay Beaujolais' were approximately equal on the 2 stocks when each of the pruning levels was compared. However, when differences in vine size were considered, regardless of scion or pruning level, the performance of 'A x R #1' was much better than that of 'St. George'. This can be seen from the figures on the crop/100 buds for each year. The effect of the changes in vine size on number of buds retained from year to year are eliminated by this method of presentation, and a comparison of scion fruitfulness can be made between the 2 stocks.

With decreasing severity of pruning there was a consistent and significant delay in fruit maturity, as indicated by the reduced °Brix measurements at harvest. The small differences in 1968 can be accounted for by the relatively high fruit maturity

Table 1. Growth and crop (average of 12 vines) at 3 levels of pruning severity of 'Chardonnay' grape on 2 roostocks.

		1966				1967				1968				1969
Root-stock	Pruning level	Pruning wt., lb./vine	Crop/ vine, lb.	Fruit maturity, °Brix	Crop/100 buds, lb.	Pruning wt., lb./vine	Crop/ vine, lb.	Fruit maturity, °Brix	Crop/100 buds, lb.	Pruning wt., lb./vine	Crop/ vine, lb.	Fruit maturity, °Brix	Crop/100 buds, lb.	Pruning wt., lb./vine
AxR#1	5 buds/lb.	5.25	11.9	22.7	43.8	4.85	9.0	21.9	35.9	5.63	14.0	22.6	48.8	5.86
	10 buds/lb.	5.07	21.4	21.4	43.0	4.46	13.9	21.6	31.3	5.38	20.7	22.3	38.7	5.49
	15 buds/lb.	5.07	24.3	20.7	34.1	4.35	17.4	21.4	26.7	4.58	22.4	22.3	33.7	5.08
	L.S.D. .05	N.S.	5.16	0.92	8.28	N.S.	4.04	N.S.	6.57	N.S.	3.90	N.S.	7.40	N.S.
	L.S.D. .01	N.S.	6.83	1.21	N.S.	N.S.	5.44	N.S.	N.S.	N.S.	5.25	N.S.	9.98	N.S.
St. George	5 buds/lb.	5.56	5.2	24.1	18.5	5.78	5.9	23.6	20.0	5.67	5.8	24.7	21.3	6.44
	10 buds/lb.	5.61	11.8	23.7	21.2	5.41	11.6	22.5	21.5	5.31	10.8	24.5	20.7	5.83
	15 buds/lb.	5.63	14.9	22.9	18.0	5.32	14.8	21.9	18.5	4.26	11.1	24.1	17.7	5.14
	L.S.D. .05	N.S.	2.13	0.55	N.S.	N.S.	2.88	0.53	N.S.	1.02	1.90	N.S.	N.S.	0.99
	L.S.D. .01	N.S.	2.88	0.74	N.S.	N.S.	3.88	0.71	N.S.	N.S.	2.57	N.S.	N.S.	1.33

Table 2. Growth and crop (average of 12 vines) at 3 levels of pruning severity on 'Gamay Beaujolais' grape on 2 rootstocks.

Root-stock	Pruning level	1966 Pruning wt., lb./vine	1966 Crop/ vine, lb.	1966 Fruit maturity, °Brix	1966 Crop/100 buds, lb.	1967 Pruning wt., lb./vine	1967 Crop/ vine, lb.	1967 Fruit maturity, °Brix	1967 Crop/100 buds, lb.	1968 Pruning wt., lb./vine	1968 Crop/ vine, lb.	1968 Fruit maturity, °Brix	1968 Crop/100 buds, lb.	1969 Pruning wt., lb./vine
AxR#1	5 buds/lb.	3.28	12.6	22.6	75.8	3.38	13.0	22.5	75.4	3.89	14.6	25.3	73.1	4.20
	10 buds/lb.	3.25	20.0	21.0	63.0	3.27	16.8	21.0	53.0	3.76	20.8	24.0	57.0	3.60
	15 buds/lb.	3.19	24.4	19.4	51.5	2.90	19.5	20.6	44.5	3.24	22.3	24.0	47.1	3.33
	L.S.D. .05	N.S.	3.55	0.97	6.77	N.S.	3.20	1.27	8.51	N.S.	3.65	N.S.	8.32	0.60
	L.S.D. .01	N.S.	4.78	1.30	9.13	N.S.	4.32	1.72	11.47	N.S.	4.92	N.S.	11.21	N.S.
St. George	5 buds/lb.	5.14	11.1	23.6	42.0	5.44	13.9	22.5	51.0	4.44	10.2	26.3	45.9	5.01
	10 buds/lb.	5.23	22.7	21.2	43.4	4.66	18.1	22.1	39.0	3.73	13.5	26.3	36.2	4.29
	15 buds/lb.	4.90	26.6	20.0	37.2	4.18	19.7	20.9	31.7	3.08	14.9	26.3	32.0	3.55
	L.S.D. .05	N.S.	N.S.	4.51	1.21	N.S.	0.88	3.92	5.06	0.75	3.04	N.S.	4.61	0.70
	L.S.D. .01	N.S.	6.08	1.63	N.S.	N.S.	N.S.	1.37	6.82	1.01	N.S.	N.S.	6.21	0.95

Table 3. Relationship of vine size to crop production, growth, and maturity of 'Gamay Beaujolais' vines on 2 rootstocks pruned to 10 buds per pound of prunings (4 vines per size class).

Vine Size	1966 Pruning wt., lb.	1966 Crop wt., lb.	1966 Crop/ 100 buds, lb.	1966 Fruit maturity, °Brix	1967 Pruning wt., lb.	1967 Crop wt., lb.	1967 Crop/ 100 buds, lb.	1967 Fruit maturity, °Brix	1968 Pruning wt., lb.	1968 Crop wt., lb.	1968 Crop/ 100 buds, lb.	1968 Fruit maturity, °Brix	1969 Pruning wt., lb.
'Gamay Beaujolais' on 'St. George'													
Large	6.60	28.8	43.6	20.7	5.45	21.4	39.3	22.0	4.48	16.1	35.9	26.0	5.10
Medium	4.80	19.6	40.8	21.1	4.40	17.4	39.5	21.8	3.40	12.4	36.5	26.0	3.92
Small	3.97	18.8	47.4	22.1	3.97	14.7	37.0	22.6	3.17	11.5	36.3	27.0	3.70
12-Vine avg	5.23	22.7	43.4	21.2	4.66	18.1	38.8	22.1	3.73	13.5	36.2	26.3	4.29
'Gamay Beaujolais' on 'A x R #1'													
Large	4.22	24.0	56.9	20.2	3.88	17.4	44.8	21.5	4.62	22.8	49.4	24.1	4.35
Medium	3.05	19.4	63.6	20.5	3.25	15.9	48.9	20.6	4.00	21.4	53.5	23.2	3.62
Small	2.48	16.4	66.1	22.2	2.68	17.2	64.2	20.8	2.70	18.2	67.4	24.8	2.82
12-Vine avg	3.25	20.0	61.5	21.0	3.27	16.8	51.4	21.0	3.76	20.8	55.3	24.0	3.60

that year, which resulted from a sudden very warm, dry period just before harvest. The effect of bud count on maturity, however, was not consistently related to changes in vine wt, as indicated by vine sizes the following winter. For example, in 1966, when comparing the 10- and 15-bud levels of 'Chardonnay' on both stocks, there was significantly low maturity with only 0.1 lb. greater pruning-wt change at the 15-bud level. Further, with the stock 'A x R #1' at the 10-bud level in 1967, there was a marked increase in pruning wt when compared with the 15-bud level, but only slightly higher maturity. The vines of 'Gamay Beaujolais' were more productive than those of 'Chardonnay', and the influence of crop production on both maturity and subsequent vine pruning weights were striking.

The effect of rootstock on crop was consistent. At the beginning of the 1968 season, the vines of 'Gamay Beaujolais' on 'St. George' had been reduced from the 50% larger size at the initiation of the study to near equal the size of those on 'A x R #1', at all pruning levels; however, the crop/100 buds values stayed low on 'St. George'. The trend for increasing crop/100 buds, can be accounted for by the increased tendency for latent buds to grow and bear fruits when the vine was pruned severely.

The overall averages of the 4 stock-scion combinations reveal a rapid decrease in size from the severe, 15-bud treatment, and a continued increase at the 5-bud level (Fig. 2). In addition to a seasonal influence which caused all 3 levels to rise in 1969, those vines at the 15-bud level had become reduced in size to the point where total bud count per vine was nearly equal to the count retained at the 10-bud level.

To examine the possibility of an initial effect of vine size on response to pruning, the data on the 2 stocks with 'Gamay Beaujolais' at the 10-bud pruning level were arranged in Table 3. The 12 replicated vines were placed in 3 classes of 4 vines each, based on their pruning weights at the initiation of the study. With 'A x R #1', there was a striking increase in fruitfulness as vine size decreased, and a trend toward high maturity on small vines. In addition, there was a great increase in pruning weights of the small vines in 1969. This difference in fruitfulness did not occur with 'St. George'. There was a strong trend toward

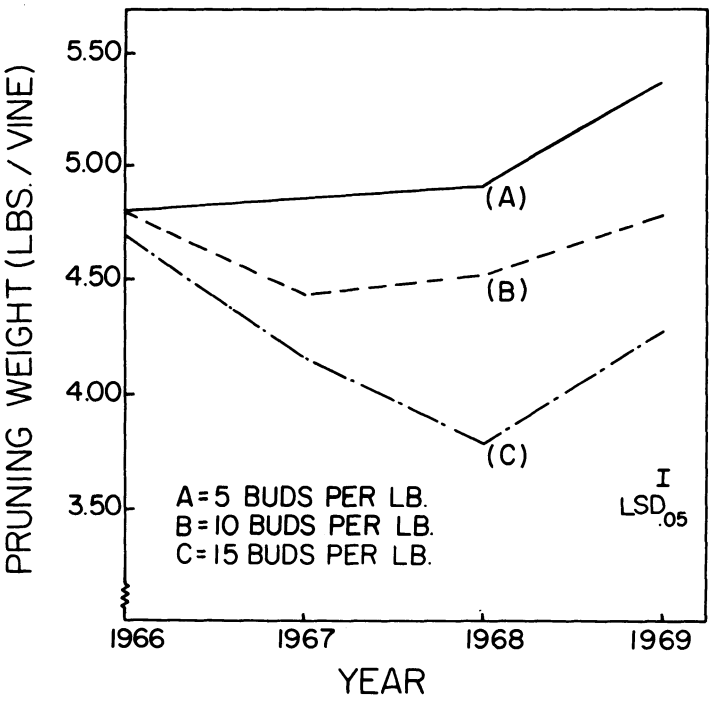

Fig. 2. Effect of pruning severity on vine size with pooled measurements of the 4 rootstock-scion combinations for 4 years.

increased maturity, however, on the small vines; and, again, there was a great reduction in pruning weights of the large vines at the end of the study.

A comparison of yields and subsequent pruning wt can be made between the large vines on 'A x R #1' and the small vines on 'St. George', where the pruning weights in 1966 were nearly equal. The influence of stock on crop/100 buds and on maturity still existed; and the final pruning wt of the vines on 'A x R #1' rose slightly, whereas that of the vines on 'St. George' dropped.

Discussion

There is a great amount of variability, from vine to vine, inherent in the technique used by wine-grape growers in California to establish the general pruning level. The practice of visual vine inspection prior to pruning can lead to variations in bud counts of up to 100% with vines of equal size. It is obvious that this is not acceptable when considering the proper balance between vegetative growth and crop potential of the individual vines.

Despite a great difference in both vine size and fruitfulness between the scion cultivars in this study, it appears that 10 buds/lb. of prunings was satisfactory for the intermediate vine sizes of all the stock-scion combinations studied. Although small vines did behave somewhat differently from large vines, it does not seem plausible to hypothesize a scale of pruning based on increasing severity with increasing pruning wt. The 30+10 pruning scale used effectively in 'Concord' vineyards (3, 6) is not applicable to these large vine sizes. In those studies vine sizes were from 1 to 4 lb. of prunings with an 8 ft vine spacing, whereas, in our study the range of vine sizes varied from no less than 3 to over 8 lb. on 'Gamay Beaujolais' and from 4 to 11 lb. on 'Chardonnay' with a vine spacing of 6 ft. Additional studies under less restrictive trellising with these cultivars could change this, however. Shaulis et al. (6) have shown that reduced exposure of leaves occurs as vine vigor increases, and that this places an upper limit on the effective use of pruning levels to regulate vine growth and fruitfulness.

The low-yielding characteristic of 'Chardonnay' could account in part, for the low response of the vines to variations in pruning. Also, the presence of the mild leaf-roll virus in the 'St. George' stock could account for its sensitivity to less severe pruning. The primary goal of our study, which was to improve the fruitfulness of vines grafted upon 'St. George', was not achieved, even though a strong influence of pruning level on vine size was exerted. Although trellis limitations could account for the difference in performance between the 2 scion cultivars, they cannot account for the strong rootstock effect on 'Chardonnay', as equal-sized vines were used. An answer can be posed to the question of why, with 'Gamay Beaujolais', the smaller vines on 'A x R #1' were not reduced in size at any pruning level, although bearing heavier crops than the vines on 'St. George'; while, in contrast, those vines on 'St. George' had depressed growth at the end of the third year. The vines on 'St. George', with their relatively large size, likely had attained maximum trellis fill at the close, 1.8 m vine spacing. If so, they would not respond by either a crop or vine size increase to an additional increase in buds retained at pruning (8). Also, with the low yielding 'Chardonnay', even the 15 buds/lb. of pruning treatment might not have been great enough to create an over-crop effect on the vigorous vines. It can be concluded, then, that both the crop and vine growth responses induced by the pruning level variables we used were influenced by the close vine spacing and the restrictive trellis system. The nutritional influence exerted by the rootstock (1) is a factor which must also be considered in the final evaluation, and this is related to management practices used with the array of vine sizes.

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