

Concord Grapes: the Mechanical Pruning Story

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Concord grapes grown in Washington are generally mechanically harvested. Research-driven attempts to introduce mechanical pruning have resulted in more than 50% of Washington's Concord vineyard area being at least initially mechanically pruned. However, most of this area is then followed by a manual touch-up, and manual pruning remains the standard practice, although it is the most labor- and cost-intensive vineyard management operation. Grape growers fear that overcropping due to the higher bud numbers on mechanically pruned vines results in poor fruit quality, alternate bearing, and a loss in cold hardiness of these vines. Wide variations in crop production from year to year represent problems for growers, juice processors, and financial institutions. However, from an economic viewpoint, growers must maximize both the quantity and quality of the crop at sustainable levels and at the lowest possible cost. The aim of our study was to evaluate the viability of mechanical pruning under commercial conditions as an economical alternative to the standard manual pruning practice. An additional goal was to investigate the ability to mechanically adjust crop production (mechanical thinning) and thereby reduce yield variations from season to season. We conducted pruning trials in two mature commercial Concord vineyards north of Sunnyside in Washington's Yakima Valley from 1997 to 2001.

Site A was planted in 1989/90 with a 8 ft x 9 ft spacing as a single curtain on a 6 ft cordon wire. We imposed five different pruning treatments for the five years of the study: manual balance pruning (BP: 50 + 10 nodes per vine, as 5-node canes); manual fixed-node pruning (FN: 130 nodes per vine); mechanical pruning (MP: hedged with a tractor-mounted system); mechanical pruning with vine separation using vertical pruning cuts between adjacent vines to prevent canes extending beyond this point (MPVS); and mechanical pruning with vine separation and crop adjustment (MPVSCA). Crop adjustment was based on the desired crop load for Washington of 9-11 t/acre and was accomplished with a mechanical harvester from 1997 to 1999 and by hand in 2000 and 2001. Irrigation was under the control of the owner and was by furrow from 1997 to 2000 and overhead sprinkler in 2001. All pest and disease management practices were at the vineyard owner's discretion.

Site B was planted in 1980 with 7.3 ft x 11 ft spacing as a double curtain on two 6 ft cordon wires, spaced 3 ft apart. Two manual pruning treatments were imposed for the five years of the study: 130 nodes per vine (DC130) and 260 nodes per vine (DC260: hedged with hand adjustment). Irrigation (furrow) and all other vineyard management practices were performed commercially by the vineyard owner.

Weather data collected for the two vineyard sites indicated a growing degree-day (GDD, base temperature 50 °F) accumulation from 1 April through 31 October of 2508 in 1997, 2848 in 1998, 2246 in 1999, 2432 in 2000, and 2609 in 2001. The long-term average is 2445 GDD. Clearly, 1998 was the warmest growing season during the study, and 1999 the coolest. In all years the warmest temperatures occurred in July and August. Late spring frosts occurred in 1999 (8-10 May), and an early fall frost truncated the season in 2000 (23 September). Rainfall during the April to October period was 3.4 in (1997), 2.5 in (1998), 5 in (1999), 5.1 in (2000), and 1.6 in (2001), respectively. 2001 will always be remembered as the drought year. There had been very

little precipitation in the valley and the mountains during the preceding winter, so that growers in the Roza Irrigation District, where both vineyard sites are located, only received about 38% of normal irrigation water delivery. The water was turned off for three weeks early in the growing season (29 May to 18 June), which coincided with the bloom period, and shut off for the season in mid September. The earlier years of this study had more rainfall during the growing season and no restrictions on irrigation water. The winter that preceded the 2000 growing season had also registered very little precipitation, but irrigation water was available throughout the season.

Vegetative growth characteristics for the two vineyards are presented in Table 1. On site A the number of nodes retained at pruning was always lowest in the BP vines, intermediate in the FN vines, and highest in the mechanically pruned vines, which had up to three times as many nodes as the BP vines. As would be expected, node numbers in the mechanical pruning treatments fluctuated far more from year to year than did those in the manual pruning treatments. Percent budbreak in mid-April varied widely (from less than 30% to over 200%) between individual vines and also from year to year, but was generally highest for the BP vines and lowest for the MP vines. This suggests that the mechanically pruned vines operated slightly above their capacity. Following budbreak, the percentage of shoots from count positions was consistently higher for the three mechanically pruned treatments (90-95%) than for the manually pruned vines (80-85%). The total shoot number per vine remained relatively constant throughout the study period for the BP and FN treatments, but steadily increased for the machine pruned vines. Average shoot length at bloom varied considerably from year to year, but was relatively constant (about 54 in) at 1200 GDD. Hand-pruned vines usually had longer shoots with more nodes (and hence more leaves) than mechanically pruned vines, both at bloom and 1200 GDD. However, because of their greater number of shoots, the mechanically pruned vines generally had a much larger total leaf area per vine. This larger canopy was effective in intercepting and using more sunlight early in the season, but it also resulted in higher vine transpiration rates, making these vines more vulnerable to water stress.

Table 2 shows the various yield components contributing to the Concord crop each year. The average number of clusters per shoot on site A varied from 1.6 to 3.1, depending on season and pruning treatment. The mechanically pruned vines (with the obvious exception of MPVSCA) had more clusters per shoot than the manually pruned vines in the first two years of the study, but this was reversed for the three remaining years. Nevertheless, due to the effect on shoot numbers, machine pruning consistently resulted in more clusters per vine than hand pruning, and BP vines always had the least number of clusters. Crop adjustment in the MPVSCA treatment reduced cluster numbers and cluster weight in all years except 2000, where only one replicate was thinned. The higher the numbers of clusters, the lighter these clusters were, and these differences were due to differences in berry number rather than berry weight. 1997 was an exceptional year insofar as clusters across all pruning treatments had almost twice as many berries as in the other years. Conversely, late spring frosts in 1999 resulted in unusually few and small clusters from secondary shoots. Despite the differences in cluster and berry numbers, berry weights showed no consistent differences between pruning treatments, but there was a pronounced seasonal effect on berry weight. In 2000 and 2001 berries were substantially smaller than in the first three years.

Most of the yield differences between seasons was caused by the number of berries per cluster, followed by the number of nodes retained, clusters per shoot, and shoots per node, with berry weight being insignificant. However, within seasons the number of nodes retained consistently made the largest relative contribution to yield variation. The contribution of each of the other yield components varied from year to year. Thus the greater number of nodes per vine

resulted in the highest yields for the MP and MPVS vines, and the lowest for the BP vines (Table 2). However, the season had a far bigger effect on yield variability than did the pruning treatments, with 1997 producing the biggest crop and 1999 the smallest. The high yields of 1997 were caused by unusually good fruit set, while the low yields of 1999 were due to damage caused by late spring frosts. It should be noted that yields varied in parallel from year to year; BP yields were always the lowest and MP/MPVS yields always the highest. Thus, when looking at cumulative yields over the five years of the study, mechanical pruning outperformed manual balance pruning by over 20 t/acre, while fixed-node pruning and mechanical pruning with crop adjustment were similar, but still produced 10 t/acre more than balance pruning. This clearly speaks against an induction of alternate bearing by mechanical pruning. External (environmental and management) factors must have been responsible for the yield fluctuations rather than the pruning strategy. Our results also show that mechanical crop adjustment on machine-pruned vines did not reduce yield variations from year to year and that, although it may be viable alternative to hand pruning, it does not seem necessary in most seasons.

Harvest date was determined by the time when fruit soluble solids reached a target level of 16 °Brix. This was dependent on weather conditions and crop load, and thus the date varied considerably from year to year and between pruning treatments. The hand-pruned vines generally reached our target soluble solids level earlier than machine-pruned vines. The highest cropping year (1997) resulted in the latest harvest. This was the only year in which mechanically pruned vines failed to achieve the target sugar level and could have benefited from crop adjustment. The warm season of 1998 resulted in the earliest harvest, but the cool season of 1999, which led to the highest titratable acidity levels, delayed harvest only for the mechanically pruned vines. However, in 1999 the BP vines were the only ones harvested at below-target °Brix and also had poor color. 2001 was a season with extremely low acidity and very poor color, as shown in Table 3. This was probably because the conversion to sprinkler irrigation led to excessive soil moisture in the top 3 ft and changed the canopy microclimate (more shading). Because of the adjustment of harvest date, pruning treatments generally had no effect on fruit soluble solids, titratable acidity, or pH, and in only two out of five years color was slightly better in fruit from hand-pruned vines compared with machine pruning. Regardless of pruning strategy, soluble solids and color generally decreased with increasing yield. However, the large differences in shoot numbers and yields per vine did not lead to significant differences in the vines' cold acclimation (Table 1). Only in the cool year of 1999 did higher crop loads reduce the number of lignified nodes after harvest, but in that season there were on average 13 lignified nodes/shoot, compared with 6-7/shoot in the other four years. Even though the BP and FN vines generally had slightly more lignified nodes per shoot, the mean number was always higher than 5/shoot in every pruning treatment.

As can be seen in Table 1, vine performance on site B was relatively consistent from year to year, with the exception of 1997, in which a severe click beetle infestation led to widespread bud damage. Attaining a pruning level of 260 nodes per vine proved impossible in this vineyard; a maximum mean node number of 250 was reached in 1999 and 2000. Average budbreak usually varied between 80 and 102%. Except in 1997, where the DC260 treatment had extremely low budbreak (35%), there was no effect of the pruning treatment on budbreak. Vines pruned to 260 nodes had significantly more shoots than the DC130 vines, except in 1997, when both treatments only had 80 to 90 shoots. Shoot length at bloom was similar to site A, with a large range of 8-57 in. Shoots of DC130 vines were on average 25% longer than those of DC260 vines. Nevertheless, the greater shoot numbers of DC260 vines resulted in 57% larger total leaf area than DC130 vines at bloom and 50% at 1200 GDD. The larger canopy of the DC260 vines could

have been a disadvantage in 2001 with reduced availability of irrigation water on site B. A larger canopy would require more water and if stressed (as it was during the bloom period of 2001) the clusters could suffer. In previous years of the study irrigation water was not a limiting factor, so DC260 vines were able to support the larger canopy without affecting the clusters.

The yield components for site B are shown in Table 2. There was no consistent effect of the pruning treatment on the number of clusters per shoot, but the growing season had a pronounced influence. The drought year of 2001 was the only year in which the DC260 vines had fewer clusters/shoot than the DC130 vines. However, due to their increased shoot numbers the DC260 vines generally had about 73% more clusters than the DC130 vines, except in 1997, when there was no difference in cluster numbers. The increased cluster number of the DC260 vines resulted in a concomitant decrease in mean cluster weight. The differences in cluster size between years were due approximately equally to differences in berry number and berry weight, while the influence of berry weight dominated within seasons. There were on average 44 berries per cluster in 1997, and 31 berries in the other four years. Except in 1997, clusters on the DC130 vines had about 21% more berries than those on DC260 vines. DC130 berries were always significantly larger than DC260 berries, and berries were largest in 1998 and smallest in 2001.

Yields on site B were comparable to those on site A (Table 2) but, in contrast to site A, yield variation between seasons was almost equally due to variation in all yield components: retained nodes/vine, shoots/node, clusters/shoot, berries/cluster, and berry weight. The same was true within seasons, although the relative contribution of each yield component varied slightly from year to year. In the first four years DC130 vines yielded considerably less than DC260 vines, but yields were similar for the two pruning treatments in 2001. The loss of potential yield of DC260 vines in 2001 was probably due to abortion of clusters and reduced fruit set and confirms that a large canopy combined with drought early in the season can lead to water stress with a negative effect on vine fruitfulness. However, yields did not fluctuate in a cyclic pattern from year to year.

As shown in Table 3, both season and pruning treatment influenced fruit ripening on site B, but the seasonal effect was much larger than the pruning effect. Soluble solids were highest in 2001 but, like in site A, titratable acidity and color were poor. This was also the only year with no differences between pruning treatments in terms of fruit quality. In all preceding years, fruit of the DC130 vines came in at approximately 1 °Brix higher and substantially better color, but the same titratable acidity and pH as DC260 fruit. The pronounced effect of pruning strategy on fruit color could be due to differences in vegetative growth and concomitant fruit shading, which is a well-known phenomenon in wine grapes. However, fruit maturity in site B was generally ahead of site A, so that in three out of five years both the DC130 and DC260 vines were harvested over the 16 °Brix target, because the processing plant was not yet open to process the harvested fruit. Similar to site A, there was only a minor treatment effect on cane maturation (Table 1). Although the shoots of DC130 vines usually had slightly more lignified nodes after harvest, the mean number of lignified nodes on the DC260 vines was never less than 7/shoot.

Conclusions

- Over five years two Concord vineyard sites in Washington's Yakima Valley produced comparable yields at high levels, and light pruning (high number of retained nodes) increased the vines' yield potential.
- Yields of severely pruned vines varied in parallel with yields of lightly pruned vines, and crop adjustment on mechanically pruned vines did not improve yield variation, but there was no cyclic pattern in yields over the five-year period.

- Severe pruning and crop adjustment on mechanically pruned vines improved fruit quality only marginally. Mechanically pruned or double-curtain trained vines consistently produced heavy crops of satisfactory fruit quality and good cold acclimation even in cool seasons.
- The growing season had a much larger influence on vine growth, yield, and fruit quality than the pruning strategy, and crop adjustment was not necessary in most seasons.
- The balance pruning concept developed in New York does not suit Washington conditions; vines can sustain considerably higher yields of good quality fruit than can be achieved using the 50 + 10 formula.
- Water deficit reduced the yield potential of big vines, but over-irrigation decreased fruit quality. Closer attention needs to be paid to proper irrigation management in order to alleviate drought periods, maintain Concord vine fruitfulness, and maximize fruit quality.

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Table 1. Effect of vineyard site, pruning treatment, and growing season on vegetative growth of Concord grapevines in Washington's Yakima Valley.

	Retained nodes/vine	Budbreak (%)	Shoots/vine	Shoot length at bloom (in)	Leaf are/vine at bloom (sq ft)	Lignified nodes/shoot after harvest
Vineyard site A						
Pruning treatment						
Balanced (50+10)	88 d*	95 a	83 c	33 a	94 d	8.5 a
Fixed node (130)	126 c	83 b	103 b	32 a	114 c	8.5 a
Mechanical (MP)	203 a	72 c	140 a	30 b	150 a	7.2 b
MP + side cuts	181 b	81 b	143 a	30 b	147 ab	7.7 b
MP + side cuts + crop adjustment	181 b	81 b	141 a	30 b	142 b	7.5 b
Growing season						
1997	154 b	78 b	109 c	36 a	140 b	7.2 b
1998	138 c	85 a	112 c	29 c	88 d	6.6 bc
1999	172 a	76 b	124 b	23 d	123 c	13.0 a
2000	142 c	87 a	122 b	35 a	152 a	6.3 c
2001	173 a	85 a	141 a	31 b	145 b	6.3 c
Vineyard site B						
Pruning treatment						
Fixed node (130)	129 b	82 a	106 b	31 a	97 b	10.1 a
Fixed node (260)	228 a	80 a	176 a	27 b	138 a	8.3 b
Growing season						
1997	185 a	53 d	87 c	32 ab	94 c	11.6 a
1998	165 b	97 a	156 ab	32 ab	133 a	8.1 b
1999	191 a	85 bc	166 a	30 bc	138 a	9.6 ab
2000	191 a	81 c	151 ab	25 d	103 bc	8.4 b
2001	165 b	91 ab	146 b	27 c	117 b	8.3 b

* Means within columns followed by the same letter are not significantly different at the 5% level by Fisher's LSD test.

Table 2. Effect of vineyard site, pruning treatment, and growing season on yield and its components of Concord grapevines in Washington's Yakima Valley.

	Yield (t/acre)	Yield (lbs/vine)	Clusters/shoot	Clusters/vine	Cluster weight (oz)	Berries/cluster	Berry weight (g)
Vineyard site A							
Pruning treatment							
Balanced (50+10)	11.0 d*	36 d ^z	2.4 b	192 d	3.1 a	37 a	2.74 a
Fixed node (130)	13.4 b	44 b	2.5 a	254 c	2.9 b	38 a	2.71 a
Mechanical (MP)	14.6 a	48 a	2.5 ab	333 a	2.5 c	37 a	2.67 a
MP + side cuts	14.4 a	48 a	2.4 b	332 a	2.4 c	35 ab	2.59 a
MP + side cuts + crop adjustment	12.8 c	42 c	2.2 c	304 b	2.3 d	33 b	2.62 a
Growing season							
1997	19.7 a	65 a	2.6 b	266 d	4.1 a	59 a	2.83 a
1998	11.3 c	37 c	2.8 a	305 b	2.0 d	29 d	2.74 a
1999	9.1 d	30 d	2.0 d	237 e	2.1 d	25 e	2.78 a
2000	13.4 b	44 b	2.3 c	278 c	2.6 b	36 b	2.51 b
2001	13.4 b	44 b	2.3 c	320 a	2.4 c	32 c	2.49 b
Vineyard site B							
Pruning treatment							
Fixed node (130)	9.6 b	35 b	2.2 a	224 b	2.6 a	35 a	2.11 a
Fixed node (260)	12.0 a	44 a	2.4 a	364 a	2.0 b	31 b	1.85 b
Growing season							
1997	8.2 c	30 c	2.0 bc	169 d	2.9 a	44 a	1.90 c
1998	12.3 a	45 a	2.6 a	394 a	1.9 c	27 c	1.94 c
1999	11.7 a	43 a	2.4 ab	242 c	2.9 a	32 bc	2.32 ab
2000	11.8 a	44 a	2.4 a	333 b	2.2 b	32 bc	2.03 bc
2001	9.8 b	36 b	2.0 c	274 c	2.2 b	31 b	1.93 c

* Means within columns followed by the same letter are not significantly different at the 5% level by Fisher's LSD test.

Table 3. Effect of vineyard site, pruning treatment, and growing season on fruit quality of Concord grapevines in Washington's Yakima Valley.

	Soluble solids (°Brix)	Titratable acidity (% w/v)	pH	Color (A ₅₂₀)
Vineyard site A				
Pruning treatment				
Balanced (50+10)	16.6 a*	1.06 a	3.49 a	8.26 a
Fixed node (130)	16.6 a	1.03 ab	3.49 a	8.28 a
Mechanical (MP)	16.3 a	1.02 b	3.46 a	7.76 a
MP + side cuts	16.4 a	1.01 b	3.48 a	7.62 a
MP + side cuts + crop adjustment	16.4 a	1.01 b	3.49 a	8.00 a
Growing season				
1997	16.1 b	0.97 d	3.48 bc	7.57 b
1998	17.2 a	1.02 c	3.51 b	9.60 a
1999	16.4 b	1.32 a	3.35 d	8.87 a
2000	16.4 b	1.07 b	3.58 a	9.44 a
2001	16.2 b	0.74 e	3.47 c	4.43 c
Vineyard site B				
Pruning treatment				
Fixed node (130)	17.1 a	1.03 a	3.41 a	7.38 a
Fixed node (260)	16.5 b	1.02 a	3.40 a	6.34 b
Growing season				
1997	n/a	n/a	n/a	n/a
1998	16.6 b	1.07 c	3.42 bc	6.36 b
1999	15.6 c	1.23 a	3.36 d	6.97 b
2000	16.6 b	1.12 b	3.47 a	9.29 a
2001	18.5 a	0.67 d	3.39 cd	4.83 c

* Means within columns followed by the same letter are not significantly different at the 5% level by Fisher's LSD test.