

Total Vineyard Mechanization to Optimize Yield and Quality of Concord Grape Production
Cornell University, NYSAES, Fredonia Vineyard Laboratory
Final Report to Viticulture Consortium and the New York Wine and Grape Foundation
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Objectives

- 1) Compare the yield, quality, sustainability, and economics of three mechanized production systems with traditional hand production of Concord grapevines.
- 2) Evaluate the method of estimating crop level and mechanical crop adjustment one month after bloom.

Comparison of mechanized pruning systems (Betts Vineyard)

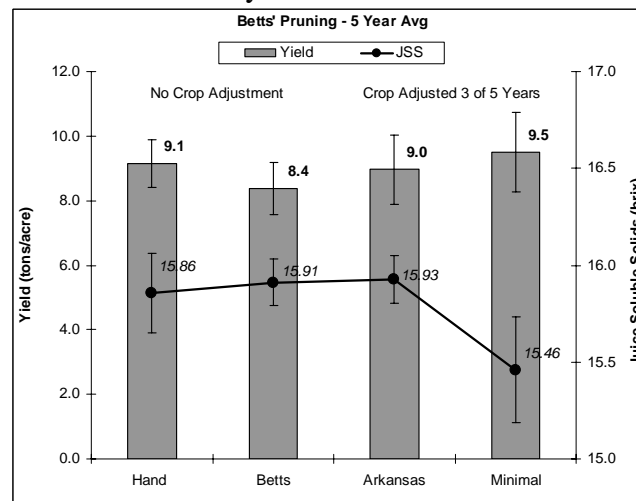
An experiment was initiated in 1999 to compare mechanical production systems on single-wire cordon trained vines.

Treatments:

- 1) Hand prune to the best 100 nodes
- 2) Betts' system (Morris-Oldridge machine pruning with hand pruning follow-up)
- 3) Arkansas system (Morris-Oldridge system for pruning, shoot positioning, and thinning)
- 4) Minimal prune (undercut only)

Results:

The following figure shows the five year yield and juice soluble solids averages from the mechanical pruning trial at the Betts' vineyard.



Although there were year to year differences between the pruning treatments (table 1), there were no statistical yield differences between any of the pruning treatments over the five year period. However, one of the goals of the experiment was to maintain similar yields between the treatments. The Hand and Betts treatments controlled crop through pruning alone while the Arkansas and Minimal treatments required mechanical thinning at 30 days after bloom 3 out of 5

years to control crop. Juice soluble solids were similar for the Hand, Betts, and Arkansas treatments while minimal pruning gave significantly lower juice soluble solids, on average.

Table 1: Viticulture results of 1999-2003 Betts' mechanical pruning trial. Yield and juice soluble solids data are from 45 vine bin samples. All other data were collected from sample count vines within the treatment rows. Means with different letters (within a given year) are separated by Duncan's multiple range test at the 0.05% level.

Year	Treatment	pruning weight	retained nodes	Yield (tons/acre)		°brix	grown periderm	clusters/vine	clusters/node	cluster weight (g)	berries/cluster	berry weight (g)								
1999	Hand	2.2	100	d	11.9	ab	15.8	ab	364.3	a	205.5	c	2.1	a	88.4	a	33.8	a	2.6	a
	Betts		122	c	11.3	b	16.2	a	338.9	a	191.6	c	1.6	b	82.0	a	31.7	a	2.6	a
	Arkansas		166	b	11.9	ab*	15.5	b	245.9	b	255.7	b	1.6	b	59.8	b	24.0	b	2.5	a
	Minimal		270	a	12.3	a*	14.6	c	235.1	b	373.1	a	1.4	b	50.0	c	22.4	b	2.2	b
2000	Hand	1.9	100	b	9.2	a	16.1	a	493.6	a	153.1	b	1.5	a	80.6	a	21.9	a	3.7	a
	Betts		111	b	8.5	a	16.1	a	487.8	a	155.5	b	1.4	ab	74.9	a	20.0	b	3.8	a
	Arkansas		143	a	9.8	a	16.0	a	433.6	a	191.1	a	1.3	b	64.0	b	18.2	b	3.5	b
	Minimal		157	a	8.6	a	16.4	a	445.1	a	201.8	a	1.3	b	54.0	c	16.1	c	3.4	c
2001	Hand	1.9	100	c	8.0	bc	16.1	a	455.0	a	153.7	b	1.5	a	63.5	a	17.8	a	3.6	a
	Betts		98	c	7.4	c	16.0	a	434.5	a	140.6	b	1.4	a	61.5	a	17.3	ab	3.6	a
	Arkansas		138	b	8.5	b	16.2	a	408.1	a	192.2	b	1.5	a	53.5	b	15.6	bc	3.4	a
	Minimal		234	a	11.5	a	15.4	b	413.0	a	316.4	a	1.4	a	45.8	c	14.6	c	3.2	b
2002	Hand	2.3	100	c	8.4	ab	16.3	a	357.5	ab	190.1	c	1.9	a	56.4	a	17.1	a	3.3	a
	Betts		117	c	7.9	b	15.8	ab	372.2	a	186.8	c	1.5	b	52.8	a	16.8	a	3.1	b
	Arkansas		198	b	9.2	ab*	15.8	ab	281.9	b	269.0	b	1.4	bc	42.6	b	14.5	a	3.0	c
	Minimal		296	a	9.7	a*	15.4	b	293.3	ab	337.7	a	1.1	c	39.8	b	14.5	a	2.8	d
2003	Hand	2.1	100	c	8.1	a	15.1	c	242.4	a	137.3	c	1.4	a	78.4	a	29.5	a	2.7	ab
	Betts		108	c	6.7	ab	15.5	ab	281.4	a	136.2	c	1.3	a	62.1	b	22.1	b	2.8	a
	Arkansas		155	b	5.3	c*	16.2	a	278.5	a	144.1	b	1.0	b	46.7	c	17.5	c	2.7	ab
	Minimal		262	a	5.4	c*	15.5	bc	276.0	a	198.6	a	0.8	b	39.4	c	15.6	c	2.5	b
99-03	Hand		100	c	9.1	ab	15.9	a	382.5	a	167.9	c	1.7	a	73.5	a	24.0	a	3.2	a
	Betts		111	c	8.4	b	15.9	a	382.9	a	162.1	c	1.5	b	66.6	b	21.6	b	3.2	a
	Arkansas		160	b	9.0	b	15.9	a	329.6	a	209.9	b	1.3	bc	53.2	c	18.0	c	3.0	b
	Minimal		244	a	9.5	a	15.4	b	332.5	a	285.5	a	1.2	c	45.8	d	16.6	c	2.8	c

General conclusions are. . .

1. Bud selection with a machine was inferior to hand pruning, which led to less fruitful buds (clusters/node). Therefore, 10-20% more buds per vine were needed in the Betts treatment to achieve the same yield as the Hand treatment.
2. Betts' pruning (machine pruning with hand follow) was nearly identical to hand pruning in canopy structure, yield, and °brix. On average, the Betts' treatment retained 112 nodes per vine and the target should probably be closer to 120-130 nodes per vine to compensate for lower fruitfulness.
3. Machine pruning alone (Arkansas, without hand follow-up) retained more buds than Hand or Betts, which led to a higher crop that needed to be adjusted by crop thinning 30 days after bloom. The Arkansas treatment was thinned three of the five years of the experiment.
4. Minimal pruning retained even more buds than the other treatments, which led to high yield, low brix, low periderm, and low fruitfulness. It is important to note that Minimal pruned vines did not make minimum brix in 1999 even with thinning.

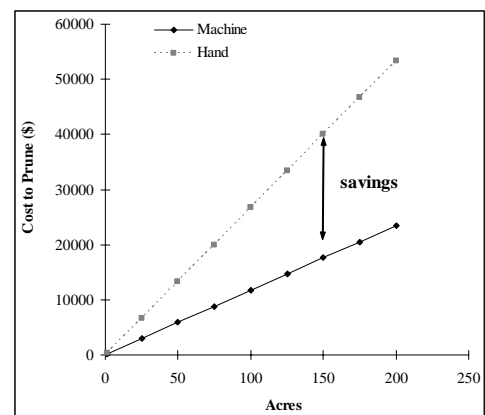
Economics of the Hand pruning vs. Modified Machine Pruning

Since the Betts' and Hand treatments are identical in yield and juice quality, a 'pruning calculator' was created to compare the costs of the two pruning systems. The calculator includes mechanical pruner operation and maintenance as well as hand follow-up costs. The Betts' system is compared to hand pruning at 30 cents per vine with additional costs for tying and suckering.

Machine Pruning with Hand Follow-up vs. Hand Pruning

	User Entered	Calculated
Machine Pruning with Hand Follow-Up		
Price of Pruner		25,000.00
Pruner Operation		
Total vineyard acres?	50	50
Row and Vine spacing?	vine sp. 8 row sp. 9	
Vines per acre.		605
Acres covered by machine pruner in one hour?	1	
Hours per day the pruner is operated?	8	
Acres covered in one day.		8.0
Cost of fuel (per gallon)?	1	
Gallons used per hour?	1	
Daily Fuel Cost		8.00
Hourly pay rate of machine pruner operator?	12	
Labor cost of machine pruning per day.		96.00
Benefit Rate (SS, WC, Health, Ret.)%	40	
Paid benefits of machine pruning per day.		38.40
Total Machine Pruning Labor per Day		134.40
Pruner Maintenance		
Maintenance hours per day?	1	
Hourly pay rate for machine maintenance?	12	
Labor cost for maintenance per day		12.00
Benefit Rate (SS, WC, Health, Ret.)%	40	
Paid benefits of maintenance per day.		4.80
Total Maintenance Labor per Day		16.80
Fuel, Pruning, Maintenance cost per day		159.20
Daily cost per acre		19.90
Estimated days to prune total acres		6.3
Estimated cost to prune total acres		995.00
Hand Follow-up (large pruning cuts, tying, suckering)		
Vines covered in one hour?	100	
Hours to cover one acre.	6.05	
Hourly pay rate for hand follow-up?	12	
Labor cost per acre.		72.60
Benefit Rate (SS, WC, Health, Ret.)%	40	
Paid benefits per acre.		29.04
Total labor cost per acre.		101.64
Estimated cost to follow-up total acres.		5,082.00
Pruning with Hand Follow-Up		
Total pruning with hand follow-up cost per acre.		121.54
Total pruning with hand follow-up cost for total acres.		6,077.00
Hand Pruning		
Dollar rate per vine? (30 cents = 0.30 dollars)	0.3	
Labor cost per acre.		181.50
Benefit Rate (SS, WC, Health, Ret.)%	40	
Paid benefits per acre.		72.60
Pruning labor cost per acre.		254.10
Follow-up (tying and suckering)		
Vines covered in one hour?	300	
Hours to cover one acre.	2.02	
Hourly follow-up rate.	8	
Labor cost per acre.		16.13
Benefit Rate (SS, WC, Health, Ret.)%	40	
Paid benefits per acre.		6.45
Follow-up labor cost per acre.		22.59
Total Cost per Acre		276.69
Total Cost to Hand Prune Vineyard		13,834.33
Savings per Year		
Savings per Year		7,757.33
Years to pay for pruner		3.22

The pruning calculator in this example compares the cost of hand pruning with mechanical pruning and hand follow-up of 50 acres of Concord grapes. This example assumes the mechanical pruner costs \$25,000 and the operator is paid \$12/hour with a 40% benefit rate. For hand pruning, the piece rate is \$0.30/vine with the same 40% benefit rate. In this comparison, mechanical pruning with hand follow up saves \$7,757.33/year. This savings would pay for the pruning machine in 3.22 years.



This figure again compares hand vs machine pruning from the calculator with only changing the number of vineyard acres in the calculation. The difference between the two lines represents the savings with machine pruning. A 100 acre vineyard would save enough in pruning costs to pay for the machine in two years.

Machine pruning and shoot positioning of Geneva Double Curtain vines (Vercant Vineyard)

An experiment was initiated in a commercial GDC vineyard in 1998 which compared two mechanized systems with hand pruning. Data collection was similar to the other mechanized pruning activity.

Treatments:

- 1) Hand pruned to 100 buds with manual curtain separation
- 2) Arkansas system (Mechanical pruning, curtain separation, and shoot positioning)
- 3) Vercant system (Mechanical pruning and curtain separation - No shoot positioning)

Year	treatment	pruning weight (lbs)	retained nodes	yield (tons/acre)	°brix	yield missed (tons/acre)	ripe periderm	clusters/vine	clusters/node	cluster weight (g)	berries/cluster	berry weight (g)										
1998	Hand	0.9	100	b	7.6	b	17.3	a	0.1	b	518	a	154	b	1.6	a	71	a	23	a	3.0	a
1998	Arkansas		185	a	10.2	a	16.8	a	1.0	a	457	a	274	a	1.5	a	59	b	21	b	2.8	b
1998	Vercant		166	a	9.7	a	17.2	a	0.7	a	490	a	242	a	1.5	a	58	b	21	b	2.8	b
1999	Hand	2.0	100	b	11.3	b	16.3	a	0.3	b	368	a	250	b	2.5	a	78	a	28	a	2.8	a
1999	Arkansas		273	a	11.8	b	15.1	b	0.5	ab	240	b	530	a	2.0	b	41	b	16	b	2.5	b
1999	Vercant		293	a	12.9	a	14.9	b	1.0	a	299	b	573	a	2.0	b	42	b	17	b	2.5	b
2000	Hand	2.3	100	b	9.4	b	16.7	a	0.4	a	459	a	178	b	1.8	a	90	a	25	a	3.5	a
2000	Arkansas		174	a	10.4	a	16.1	b	1.1	a	376	c	305	a	1.8	a	61	b	18	b	3.3	b
2000	Vercant		180	a	10.7	a	16.1	b	1.0	a	413	b	307	a	1.7	a	61	b	19	b	3.3	b
2001	Hand	2.8	100	b	6.1	b	16.2	a			470		171	b	1.7	a	63	a	17	a	3.7	a
2001	Arkansas		237	a	8.4	a	15.8	a					354	a	1.5	a	48	b	15	ab	3.3	a
2001	Vercant		244	a	8.2	a	15.8	a					343	a	1.5	a	49	b	14	b	3.5	a
2002	Hand	3.0	100	b	4.6	c	15.8	a	0.2	a	341	a	133	c	1.3	a	55	a	16	b	3.5	a
2002	Arkansas		179	a	7.7	a	15.7	a	0.5	a	227	b	237	b	1.3	a	57	a	18	a	3.1	b
2002	Vercant		178	a	7.4	b	15.9	a	0.4	a	277	ab	276	a	1.5	a	52	a	16	b	3.3	c
98-02	Hand	2.2	100	b	7.8	b	16.4	a	0.2	b	431	a	177	b	1.8	a	71	a	22	a	3.3	a
98-02	Arkansas		209	a	9.7	a	15.9	b	0.6	a	325	c	340	a	1.6	b	53	b	18	b	3.0	b
98-02	Vercant		212	a	9.8	a	16.0	ab	0.6	a	370	b	348	a	1.6	b	52	b	17	b	3.1	b

1. Machine pruning, either Arkansas or Vercant, retained 100% more nodes and gave 100 % more clusters/vine but yielded only 25% more crop than hand pruned vines.
2. Yield compensation in mechanical treatments resulted in 6%-9% lower berry weight, 18%-23% fewer berries per cluster, and 25%-27% lower cluster weight than in hand pruned vines.
3. In large crop years (1999, 2000), the higher yield in the machine pruned treatments was accompanied by a significant decrease in juice soluble solids. In moderate crop years (2001, 2002), machine pruned vines still yielded significantly more crop but achieved the same concentration of juice soluble solids. In heavy years, the mechanically pruned vines are on the shoulder or downward slope of the crop load – brix relationship. In light years, all treatments are on the plateau of the curve.
4. At harvest, the mechanical grape harvester missed between 0.5 and 1.0 tons/acre of fruit in the machine pruned treatments.
5. On average, machine pruning ripened 20%-25% fewer nodes than hand pruning and this effect was more apparent on dry years (1999, 2002).
6. There was no effect of shoot positioning between the two machine pruned treatments except that shoot positioning further decreased the amount of ripe periderm (probably by depressing shoot growth). However, shoot positioning did not lead to higher bud fruitfulness or higher °brix at a given yield.

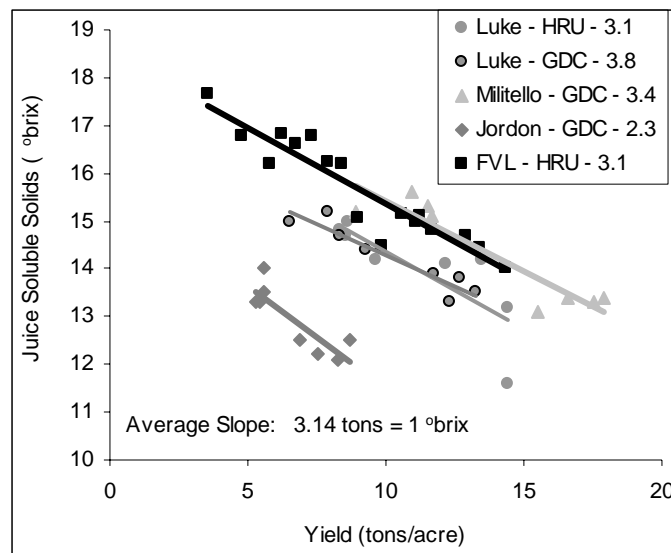
Crop Estimation and Machine Thinning Concord 30 Days-After-Bloom

A full article on crop estimation and mechanical crop adjustment can be found at: http://lenewa.netsync.net/public/bates/Crop_Adjustment.pdf. This article, Concord Crop Adjustment: Theory, Research, and Practice, includes information from the mechanical thinning trials conducted as part of this research effort. The following grower trials in 2003 were not included the larger crop adjustment article.

Four off-station mechanical thinning plots were established in 2003 and compared to manual thinning at the Fredonia Vineyard Lab. The plots were as follows. . .

Grower	Location	Training	Machine
Vineyard Lab	Fredonia, NY	HRU	Manual
Militello	Forestville, NY	GDC	Korvan
Luke	North East, PA	HRU	Chisholm-Ryder
Luke	North East, PA	GDC	Pic-Ryte
Jordon	Portland, NY	GDC	Gregoire

All of the off-station plots were machine thinned by the grower cooperators using their own machine set-up and all of the thinning took place 30-40 days after bloom. The following figure shows the yield and juice soluble solids of both thinned and unthinned vines at each of the plots. Data from the Vineyard Lab is from individual vine measurements. Data from the off-station field plots are bin weights and bin probes from whole treatment rows. There were four thinned and four unthinned treatment rows at each location.



Crop Estimation:

At each plot, potential crop was estimated at 30 days after bloom by weighing the fruit removed from a set of sample vines and predicting final crop weight from % of final berry weight. At the Fredonia Lab and at both plots at the Luke vineyard in PA where the unthinned crop was about 11-12 tons/acre, the crop predictions were accurate. At the Militello GDC plot,

the harvested crop (17 tons/acre) was lower than what was predicted at 30 days after bloom (22+ tons/acre). It is unclear why the crop prediction was inaccurate. It has been our experience that when the crop prediction is in excess of 15 tons/acre that the yield potential does not materialize at harvest. Possible causes may be the spontaneous shelling of fruit when the vine is in severe overcrop or the inaccurate estimation of final berry weight on an excessively large crop. At the Jordon GDC plot, the unthinned harvest at 8 tons/acre was well off from the predicted yield of 15 tons/acre. Excessive fruit shelling and premature canopy discoloration in this plot led to inaccuracy in the crop prediction. However, the canopy and shelling disorder affected both thinned and unthinned rows alike.

The Thinning Response:

Each plot was harvested at a different time during the harvest season based on the individual grower's schedule and fruit maturity in the plot. Therefore, we would expect differences in the yield-brix regression lines from each of the plots. Each of the five thinning plots responded positively to the thinning process and the slope of each regression line indicates how well the vines in each plot responded. Interestingly, all of the lines are close to being parallel with each other indicating that the thinning response was similar among all the plots. The average slope from each of the five plots indicates that for every 3.14 equivalent tons/acre removed with thinning, the fruit increased one degree brix in 2003.