The

Connecticut

Agricultural

Experiment

Station,

New Haven

Bulletin 1025

February 2010

Effects of Fruit Thinning on Yield, Fruit Quality, and Vine Performance of Red Bordeaux Winegrape Cultivars

WILLIAM R. NAIL, Ph.D.
Department of Forestry and Horticulture

Effects of Fruit Thinning on Yield, Fruit Quality, and Vine Performance of Red Bordeaux Winegrape Cultivars

William R. Nail, Ph.D.
Department of Forestry and Horticulture

A common maxim among winegrape growers is that there is an inverse relationship between crop load and resulting wine quality, i.e. fruit from lower yielding vines produce higher quality wines than fruit from higher yielding vines. This concept evolved in the major winegrape growing regions of Europe over centuries. Vineyards in these regions typically receive moderate rainfall during the growing season, and are rarely, if ever, irrigated. There is frequently relatively little leaf area to support a large crop. Crop control in such vineyards has traditionally been done by manipulating bud number during dormant pruning.

Winegrape production has greatly expanded in many other areas of the world during the last century. Most of these regions are also characterized by relatively dry growing seasons. Vine vigor in these relatively new areas, such California and Australia, can be controlled by managed irrigation (Bravdo et al. 1985). Yields tend to be significantly higher than in European vineyards (Kliewer and Dokoozlian 2005). In many cases, lower yields have not necessarily resulted in superior quality fruit (Jackson 2000, Intrieri and Poni 1995). Growers in these regions typically leave greater numbers of buds during dormant pruning than on non-irrigated sites in Europe, resulting in higher yields.

Grapevines growing in the Eastern United States usually receive adequate rainfall during the growing season to maintain vine vigor throughout the growing season. However, rainfall patterns are very variable and unpredictable. Excessive vine vigor is frequently a problem, especially on highly fertile sites (Zoecklein et al. 2008). Manipulating crop via dormant pruning in the region can result in either too large or too small a crop, depending on rainfall and temperature patterns during the growing season.

Fruit thinning is sometimes used to regulate crops in vines with relatively high bud numbers in areas with high, but unpredictable, vigor. By leaving high bud numbers, growers can take advantage of good growing seasons when a large crop can be matured. This can be especially important in Connecticut, where Farm Wineries currently (2009) are legally required to use a minimum of 25% state-grown fruit in their wine production. As a consequence, Connecticut-grown fruit currently commands a higher price than fruit from other states. Crop thinning could be employed when the season is unusually dry or cool, ensuring that the fruit will properly mature. Many growers routinely thin the crop in the belief that the remaining fruit will be of superior quality. However, the maximum yields that can be adequately matured have not been experimentally determined.

Studies were conducted during the 2004 through 2008 growing seasons to examine the effects of fruit thinning on fruit quality and yield in the red Bordeaux cultivars Cabernet Franc, Cabernet Sauvignon, and Merlot at a commercial vineyard.

MATERIALS AND METHODS

The vineyard is located in Shelton, CT. The site consists of Charlton-Chatfield and Woodbridge soils, both well-drained fine sandy loams (Wolf 1981). Rows are oriented in a northwest to southeast direction, on a southwest-facing slope. Vines are spaced six feet apart within the rows, with ten feet between rows. Row middles consist of mowed, mixed sod. Overhead irrigation was available, but was only used once in August, 2005. Vines were spur-pruned each spring to 3-node spurs. Cordons were trained to a ≈30 inch fruiting wire, and shoots were trained through three pairs of catch wires at ≈48, 60, and 72 inches as needed during the growing season. Vines were fertilized lightly with four pounds actual N/acre near bloom each year. Vines were typically hedged three to four times a year by the grower beginning in July. Pest management, fertilization, and harvest date were at the discretion of the grower. Some leaf removal was done in the fruit zone in 2006-2008 to expose fruit to air circulation and sunlight.

The plot was established as a cultivar and clone trial. It is a randomized complete block design consisting of four blocks; there are four to five vines in each block. There are multiple clones of Cabernet Franc (clones 1, 214, 332, and 623). Within each block, two crop levels were employed: thinned vines, where clusters were removed to reach an estimated target of three tons per acre, and non-thinned vines, where no fruit was removed. Thinned and non-thinned treatments were applied randomly within each block. Crop was estimated in mid-July of each year by counting clusters on vines to be thinned and multiplying the number of clusters by the average cluster weighs for each cultivar as determined by Zabadal (undated). Fruit thinning was completed by late July in each year. The date of harvest was determined by the grower in each year. There was a single harvest for all cultivars and clones each season.

Yield, number of clusters, dormant cane pruning weights, and the number of retained nodes after pruning were collected on a vine-by-vine basis each year. Pruning weights were not collected in 2004 and, due to labor constraints, only obtained on approximately half of the vines in each subsequent year. On the day prior to harvest, random berry samples of a minimum of 50 berries were collected from each block by cultivar, weighed, and frozen for later fruit quality analysis. Yield in estimated tons per acre, average cluster weight, average berry weight, and berries per cluster were calculated from the measured values. The Ravaz Index, an indicator of vine balance, was calculated on a vine-by-vine basis by dividing the yield in pounds per vine by the pounds of cane prunings from the following spring's pruning weights (Ravaz 1911). Because of significant vine mortality on Cabernet Sauvignon vines, there was inadequate replication to compare pruning weights or the Ravaz Index for that cultivar.

The previously frozen berry samples were thawed to room temperature, crushed by hand, and filtered through cheesecloth and filter paper. Each berry sample was measured individually for °Brix, *p*h, and titratable acidity (TA, expressed as tartaric acid equivalents) according the methods of Iland et al. (2002). Due to predation, mostly from raccoons, there were not enough berries per replicate to perform TA analyses on all cultivars and *p*h on Merlot in 2004.

Data were analyzed using Statistica software (version 8.0; StatSoft, Tulsa, OK) by the general linear model and F-test. There were usually significant cultivar x year interactions, so both individual and combined cultivars were also analyzed by t-test for each season.

RESULTS

Thinning significantly reduced yields in all years except 2004. This was largely due to the reduced number of clusters (Figure 1), although unthinned vines had significantly higher cluster weights in 2007. Year-to-year variations for all measured and calculated parameters were almost always greater than differences between treatments within a given year (Table 1, Appendix Tables 1 and 2). Cluster weights, berry weights, and berries per cluster varied among years between thinned and unthinned vines, and had no significant effect on yield in any year (data not shown). Cane pruning weights varied among years. They were only significantly different in 2007, when thinned vines had higher pruning weights. There were no significant differences in the Ravaz Index between treatments in any year.

Thinning had a negligible effect on fruit quality. Over all years, thinning had no significant effect on °Brix or TA, and slightly decreased pH. While thinned vines had higher °Brix in all years, the differences were only significant in 2005 and 2006. Except for slightly higher *p*h in 2007, there were no significant differences in *p*h or TA between treatments.

DISCUSSION

Cluster thinning had very little effect on vine performance and fruit quality in this experiment. The slight increase in °Brix resulting from thinning is unlikely to affect wine quality, as the only aspect of flavor that sugar lends to the final product of a red wine fermented to completion is the alcohol level. This can easily be manipulated in the winery, if necessary, by the addition of sugar to the must prior to fermentation (chaptalization). Therefore, based on the parameters measured in this experiment, thinning had no beneficial impact on production.

The reduction in yield in all years except for 2004 would have significant economic impact to the grower. The five-year average decrease in yield resulting from cluster thinning was 1.8 tons per acre, or 67% of the yield of unthinned vines. While prices for grapes vary widely, this would have significant economic consequences for the grower. Using a fairly conservative estimate of $1,400 per ton, thinning would result in a loss of income of $2,520 per acre per year for the grower due to reduced production. There are also significant additional labor costs involved in fruit thinning. Vine-by-vine crop estimation, as done in this experiment, is unrealistic for a commercial grower. However, all reasonably accurate methods of crop estimation still command a significant amount of time (Pool and Bates, personal communication). Hand thinning requires substantially more labor than crop estimation, which would contribute even more to the grower's costs.

It should be emphasized that this experiment was conducted in a vineyard with very high vigor, so these conclusions may not be applicable to all vineyard situations. Average pruning weights of approximately two and a half to three pounds per vine are generally considered to be optimal for most high quality vinifera winegrapes in cool-climate areas such as Connecticut. The optimal range for the Ravaz Index varies among authors, but is generally accepted to be between five and twelve for high-quality vinifera grapevines. Unthinned vines were at the low end of the Index, and the thinned vines were frequently below optimum levels. This is in spite of the repeated hedging of the vines during the growing season, which reduces dormant pruning weights.

This vineyard had significantly lower Ravaz Index ratings relative to other experimental vineyards in cultivar trials in Connecticut (Nail 2008). It is quite possible that fruit thinning in vineyards with lower vigor, which are quite common in Connecticut, might benefit from some cluster thinning to improve fruit quality. However, unpublished studies from Michigan suggest that Cabernet Franc vines with similar vigor to those in this study could consistently produce yields of five to six tons per acre with no reduction in fruit quality (Treloar and Howell, personal communication).

Excess vigor can also result in increased shading of fruit. This is detrimental to optimal fruit development, especially for red winegrapes. The importance of exposing both leaves and fruit to sunlight, regardless of vine vigor, was established by Shaulis et al. (1966). This concept was further refined and popularized by Smart and Robinson (1991). No more than one and a half leaf layers in the canopy is desired. Greater leaf densities result in decreased photosynthetic efficiency of the grapevine. Highly shaded leaves can actually result in a net carbon loss, as the rate of respiration can be greater than the carbon fixed through photosynthesis (Jackson 2000). Shading of fruit reduces anthocyanin concentration in grapes, especially in red cultivars (Spayd et al. 2002). Shading has also been shown to increase the concentration of methoxypyrazines, which lend a "green bell pepper" component to the fruit that is usually considered undesirable (Ryona et al. 2008). Point quadrant analysis of leaf layer density was not measured in this experiment, but was visually estimated to be approximately 2.5-3.0 layers. This estimation, combined with the need to hedge the vines multiple times during the growing season to prevent additional shading, confirm the vigorousness of the grapevines.

High leaf density can also lead to increased disease problems, as air circulation is inhibited and spray penetration can be impaired. This is especially important in the fruit zone. The grower was very conscientious regarding pest management and no major insect or disease problems were encountered during the study. However, growers with less aggressive pest management practices could be expected to encounter greater disease pressure with vines of similar vigor.

Although there were no measured benefits to fruit thinning in this trial, it may be a beneficial practice in some vineyards. Many vineyards in Connecticut have relatively low vigor. This can be due to a variety of factors. Poor soil drainage is a common problem, and vines grown in such soils are not capable of as high a production as those grown on well drained soils. Weed control during the first two years of vineyard establishment is critical. Vines which have to compete with weeds during this period almost always have reduced vigor, as measured by pruning weights, than similar vines grown where weeds were controlled. This is usually a permanent condition that cannot be overcome by extra care after the vines are established. Vines grown in areas that have cooler growing seasons, common in the northern corners of the state, also have reduced vigor compared to those grown in warm areas such as the Shelton site.

LITERATURE CITED

Bravdo, B., Y.. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1985. Effect of Irrigation and Crop Level on Growth, Yield and Wine Quality of Cabernet Sauvignon Am. J. Enol. Vitic. 36:132-139.

Intrieri, C. and S. Poni. 1995. Integrated evolution of trellis training systems and machines to improve grape quality and vintage quality of mechanized Italian vineyards. Am. J. Enol. Vitic. 46:116-127.

Jackson, R.S. 2000. Wine Science: Principles, practice, perception, 2nd ed.. Academic Press, San Diego, CA.

Kliewer, W.M. and N.K. Dokoozlian. 2005. Leaf area/ crop weight ratios of grapevines: Influence on fruit composition and wine quality. Am. J. Enol. Vitic. 56:170-181.

Nail, W.R. 2008. Winegrape cultivar trials in Connecticut 2004-2006. CT. Agr. Exp. Sta. Bull. 1015.

Ryona, I., B.S. Pan, D.S. Intrigliolo, A.N. Lakso, and G.L. Sacks. 2008. Effects of cluster light exposure on 3-Isobutyl-2-methoxypyrazine accumulation and degradation patterns in red wine grapes (*Vitis vinifera* L. Cv. Cabernet Franc). J. Agric. Food Chem. 56:10838–10846

Shaulis, N. J., H. Amberg, and D. Crowe. 1966. Response of Concord grapes to light, exposure, and Geneva Double Curtain training. Proc. Am. Soc. Hortic. Sci. 89:268-280.

Smart, R. and M. Robinson. 1991. Sunlight into wine: A handbook for wine grape canopy arrangement. Winetitles Pty. Ltd., SA, Australia.

Spayd, S.E., J.M. Tarara, D.L. Mee, and J. C. Ferguson. 2002. Separation of sunlight and temperature effects on the composition of *Vitis vinifera* cv. Merlot berries. Am. J. Enol, Vitic. 53:171-182.

Wolf, B.L. 1981. Soil Survey of Fairfield County, Connecticut. United States Department of Agriculture, Soil Conservation Service. 127 pp.

Zabadal, T. Undated. Crop estimation in wine grapes. SWMREC Special Report #24, Michigan State University Cooperative Extension.

Zoecklein, B.W., T.K. Wolf, L. Pélanne, M.K. Miller, and S.S. Birkenmaier. 2008. Effect of vertical shoot-positioned, Smart-Dyson, and Geneva double-curtain training systems on Viognier grape and wine composition. Am. J. Enol. Vitic. 59:11-21.

Table 1. Effects of cluster thinning on vegetative, reproductive, and fruit quality parameters on red Bordeaux winegrape cultivars in Shelton, CT 2004-2008.

	Yield per vine (lbs)							Yield per Acre (tons)						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value [b]	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned	10.22	12.13	8.08	11.91	7.88	<.001	10.04	3.71	4.40	2.93	4.32	2.86	<.001	3.65
unthinned	12.33	20.18	12.21	15.98	13.67	<.001	14.87	4.48	7.33	4.43	5.80	4.96	<.001	5.40
p -value [a]	0.550	0.002	<.001	0.012	<.001		0.001	0.550	0.002	<.001	0.012	<.001		0.001

	Number of Clusters							Cluster Weight (g)						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned	38.4	43.0	39.7	39.7	43.1	<.001	40.8	123.5	129.7	93.6	143.9	86.0	<.001	115.3
unthinned	48.7	68.2	61.6	49.6	63.8	<.001	58.4	117.0	137.4	92.7	151.3	93.5	<.001	118.4
p -value	0.397	0.002	<.001	0.036	0.010		0.010	0.419	0.901	0.230	0.048	0.330		0.329

	Average Berry Weight (g)							Berries per Cluster						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned	1.76	1.47	1.30	1.54	1.43	<.001	1.50	71	89	72	95	60	<.001	77
unthinned	1.79	1.00	1.33	1.55	1.40	<.001	1.41	66	95	72	100	67	<.001	80
p -value	0.010	0.610	0.164	0.081	0.791		0.791	0.027	0.790	0.017	0.011	0.103		0.103

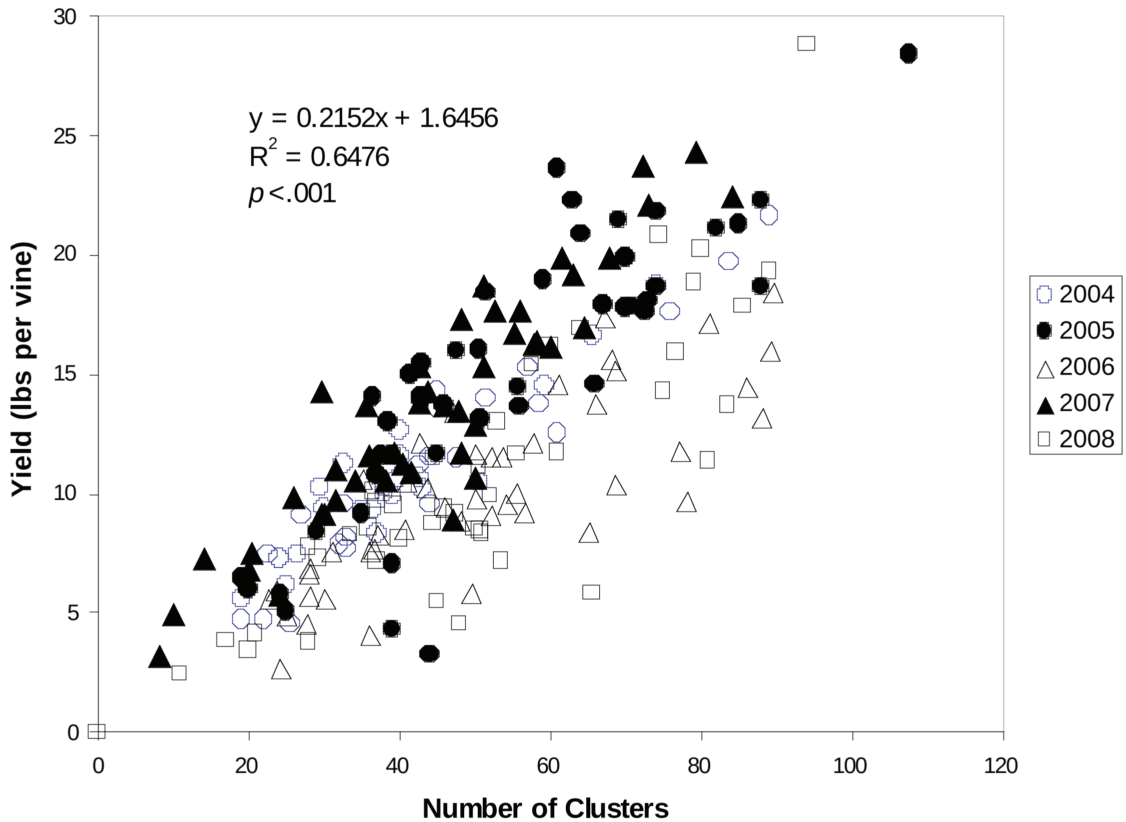
	Retained Node Number							Pruning Weight (lbs)						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned		41	35	48	53	<.001	44		3.6	3.36	5.11	3.73	<.001	3.95
unthinned		40	34	47	54	<.001	44		3.6	3.59	3.61	3.24	<.001	3.51
p -value		0.531	0.434	0.452	0.973		0.598		0.918	0.351	0.031	0.822		0.821

	Ravaz							°Brix						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned	3.68	4.87	2.3	4.07	4.38	<.001	3.86	19.0	20.9	21.0	21.2	20.7	<.001	20.6
unthinned	4.17	7.02	3.08	9.45	5.02	<.001	5.748	18.7	19.2	19.1	20.6	19.9	<.001	19.5
p -value	0.698	0.363	0.085	0.514	0.694		0.362	0.206	<.001	0.005	0.207	0.289		0.289

	p H							Titratable Acidity (g/L)						
Thinning treatment	2004	2005	2006	2007	2008	*p* - value	Mean	2004	2005	2006	2007	2008	*p* - value	Mean
thinned	3.66	3.90	3.57	3.83	3.75	<.001	3.74	6.41	4.88	8.10	5.55	6.69	<.001	6.33
unthinned	3.36	3.84	3.54	3.84	3.69	<.001	3.65	6.49	5.00	8.48	5.48	6.66	<.001	6.42
p -value	0.447	0.112	0.046	0.155	0.100		0.010	0.604	0.051	0.707	0.929	0.185		0.185

[a]Effect of thinning.
[b]Effect of season (within thinning treatments).

Figure 1. Correlation between yield and cluster number for red Bordeaux winegrape cultivars in Shelton, CT 2004-2008.



APPENDIX

Appendix Table 1. Effects of cluster thinning on yield and components of yield for red Bordeaux winegrape cultivars in Shelton, CT 2004-2008.

		Yield per vine (lbs)							Yield per Acre (tons)						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value[b]**	**Mean**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned	10.50	12.63	8.45	12.32	8.81	0.007	10.54	3.81	4.58	3.07	4.47	3.20		3.83
	unthinned	12.89	20.21	12.76	14.52	15.91	0.156	15.26	4.68	7.34	4.63	5.27	5.78		5.54
	p-value[a]		0.007	0.004	0.489	0.010		0.280		0.018	0.004	0.489	0.010		0.280
Cabernet Sauvignon	thinned	9.89	7.33	8.07	8.34	7.18	0.065	8.16	3.59	2.66	2.93	3.03	2.61		2.96
	unthinned	9.97	10.08	7.42	14.40	10.44	0.843	10.46	3.62	3.66	2.69	5.23	3.79		3.80
	p-value		0.624	0.693	0.259	0.358		0.253		0.372	0.693	0.259	0.358		0.253
Merlot	thinned	9.57	13.71	6.54	11.92	6.59	<0.001	9.67	3.47	4.98	2.37	4.33	2.39		3.51
	unthinned	12.17	21.06	12.92	18.75	9.89	0.005	14.96	4.42	7.64	4.69	6.81	3.59		5.43
	p-value	0.185	0.293	0.066	0.036	0.407		<0.001		0.293	0.066	0.036	0.407		<0.001

		Number of Clusters							Cluster Weight (g)						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned	40.7	48.9	43.7	42.8	43.0	0.621	43.8	119.6	118.5	90.1	136.3	94.3	<0.001	111.8
	unthinned	51.3	73.7	68.9	47.5	68.0	0.086	61.9	115.8	131.9	85.4	142.6	102.5	<0.001	115.6
	p-value		0.004	0.008	0.644	0.015		0.059		0.738	6.700	0.655	0.430		0.073
Cabernet Sauvignon	thinned	36.2	22.7	38.3	32.3	35.5	0.391	33.0	125.2	149.1	95.8	127.0	90.7	0.493	117.6
	unthinned	32.0	40.2	41.4	44.2	54.2	0.578	42.4	140.7	112.1	81.0	145.8	74.1	0.382	110.7
	p-value		0.521	0.897	0.529	0.102		0.122		0.050	2.520	0.083	0.493		0.709
Merlot	thinned	35.4	42.2	32.9	35.3	46.5	0.717	38.5	124.5	143.8	90.4	152.9	69.7	<0.001	116.3
	unthinned	48.1	63.5	60.8	54.9	57.7	0.281	57.0	116.0	152.6	102.4	158.3	80.6	<0.001	122.0
	p-value	0.258	0.289	0.031	0.025	0.636		<0.001	0.580	0.784	2.580	0.002	0.219		0.023

		Average Berry Weight (g)							Berries per Cluster						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned	1.69	1.45	1.37	1.55	1.42	0.002	1.50	71	80	67	89	67	0.010	75
	unthinned	1.72	1.43	1.29	1.54	1.40	<0.001	1.48	68	92	67	94	73	<0.001	79
	p-value		0.107	0.557	0.509	0.622		0.257		0.278	0.583	0.482	0.176		0.268
Cabernet Sauvignon	thinned	1.63	1.40	1.20	1.43	1.39	0.250	1.41	76	107	82	89	64	0.705	84
	unthinned	1.67	1.32	1.20	1.50	1.46	0.135	1.43	88	76	68	97	53	0.465	76
	p-value		0.426	0.619	0.775	0.702		0.222		0.134	0.046	0.300	0.161		0.596
Merlot	thinned	1.85	1.52	1.33	1.59	1.48	<0.001	1.55	68	95	69	97	47	<0.001	75
	unthinned	1.88	1.49	1.36	1.59	1.40	<0.001	1.54	63	102	76	100	58		80
	p-value	0.004	0.913	0.027	0.114	0.970		0.187	0.041	0.612	0.058	0.014	0.091		0.003

[a] Effect of thinning.
[b] Effect of season (within thinning treatments).

Appendix Table 2. Effects of cluster thinning on pruning weights, Ravaz Index, retained node number, and fruit quality parameters for red Bordeaux winegrape cultivars in Shelton, CT 2004-2008.

		Pruning Weight (lbs)							Ravaz						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value[b]**	**Mean**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned		3.51	4.17	5.87	4.51		4.52	3.15	3.38	1.99	3.38			2.98
	unthinned		4.35	3.79	4.23	3.90		4.07	3.44	6.20	3.21	6.19			4.76
	p-value[a]		0.232	0.514	0.018	0.753		0.169	0.724	0.056	0.081	0.056			0.622
Cabernet Sauvignon	thinned														
	unthinned														
	p-value														
Merlot	thinned		2.86	2.27	3.89	2.70		2.93	5.36	6.37	2.70	5.29			4.93
	unthinned		2.46	3.07	2.30	2.34		2.54	6.03	8.01	3.12	10.41			6.89
	p-value		0.600	0.343	0.212	0.941		0.338	0.234	0.847	0.821	0.294			0.158

		Retained Node Number						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned		44	35	50	55	<0.001	46
	unthinned		42	35	47	53	<0.001	44
	p-value		0.429	0.886	0.363	0.491		0.840
Cabernet Sauvignon	thinned		41	33	52	51	0.160	44
	unthinned		32	32	46	52	0.005	41
	p-value		0.085	0.896	0.793	0.268		0.259
Merlot	thinned		38	34	43	51	<0.001	42
	unthinned		39	34	46	51	<0.001	43
	p-value		0.671	0.028	0.626	0.641		0.516

		°Brix							*p*H						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned	18.8	21.2	19.9	21.4	20.7	<0.001	20.4	3.64	3.89	3.53	3.76	3.71	<0.001	3.71
	unthinned	19.2	19.1	19.0	20.9	20.0	0.014	19.6	3.60	3.83	3.51	3.83	3.68	<0.001	3.69
	p-value		<.001	0.033	0.750	0.718		0.284		0.648	0.081	0.054	0.615		0.308
Cabernet Sauvignon	thinned	19.2	21.0	19.5	20.5	20.1	0.004	20.1	3.70		3.59	3.85	3.77	0.002	3.73
	unthinned	18.9	18.7	18.7	19.7	20.2	0.319	19.2	3.64		3.55	3.69	3.73	0.292	3.65
	p-value		0.104	0.268	0.435	0.910		0.052			0.002	0.545	0.544		0.041
Merlot	thinned	18.6	20.4	20.6	21.0	20.8	<0.001	20.3		3.88	3.62	3.88	3.81	<0.001	3.80
	unthinned	18.6	19.3	19.4	21.1	19.5	0.017	19.6		3.84	3.57	3.82	3.71	<0.001	3.74
	p-value	0.687	0.396	0.032	0.192	0.026		<.001		0.678	3.800	0.002	0.305		0.106

		Titratable Acidity (g/L)						
Cultivar	**Thinning treatment**	**2004**	**2005**	**2006**	**2007**	**2008**	***p*-value**	**Mean**
Cabernet Franc	thinned		4.98	8.66	5.94	7.15	<0.001	6.68
	unthinned		5.07	8.96	5.63	6.96	<0.001	6.66
	p-value		0.292	0.082	0.802	0.174		0.523
Cabernet Sauvignon	thinned			8.07	5.90	7.21	0.032	7.06
	unthinned			8.71	5.63	6.24	0.316	6.86
	p-value		0.351	0.589	0.098	0.333		0.834
Merlot	thinned		4.64	6.86	4.71	5.68	<0.001	5.47
	unthinned		4.89	7.19	5.11	6.15	<0.001	5.84
	p-value		0.392	0.750	0.244	0.669		0.579

[a]Effect of thinning.
[b]Effect of season (within thinning treatments).

NOTES