Table 1: Elongation and number of emerged lateral shoots per Cabernet franc vine in the fruit zone (fruiting wire to 30 cm above the fruiting wire), middle canopy (30 cm to 60 cm above the fruiting wire), and upper canopy (60 cm to 90 cm from the fruiting wire), subjected to techniques applied early and late in 2017 to 2019 in Lansing, NY. Values are means ± standard errors.

Timing	Technique	Lateral counts per vine Fruit Zone	Lateral counts per vine Middle Canopy	Lateral counts per vine Upper Canopy	Average lateral length per lateral shoot Fruit Zone (cm)	Average lateral length per lateral shoot Middle Canopy (cm)	Average lateral length per lateral shoot Upper Canopy (cm)
			2017				
Early	Control	37 ± 4.5ab	57 ± 7.3b	51 ± 6.0b	10.7 ± 1.7b	27.7 ± 2.6b	66.3 ± 3.2b
	Shoot Tuck	25 ± 4.5a	52 ± 7.3b	43 ± 6.0ab	7.4 ± 1.2ab	21.6 ± 2.7ab	62.7 ± 3.2b
	Shoot Wrap	22 ± 4.5a	28 ± 7.3a	29 ± 6.0a	6.1 ± 1.0a	16.6 ± 2.7a	49.6 ± 3.2a
Late	Control	29 ± 4.5a	54 ± 7.3a	46 ± 6.0 b	10.6 ± 1.7a	25.8 ± 2.7a	62.1 ± 3.2b
	Shoot Tuck	23 ± 4.5a	48 ± 7.3a	55 ± 6.0ab	8.1 ± 1.3a	22.3 ± 2.7a	53.4 ± 3.2b
	Shoot Wrap	15 ± 0.48a	45 ± 7.3a	34 ± 6.0a	6.9 ± 1.1a	21.6 ± 2.7a	40.4 ± 3.3a
	p-value (Technique)[a]	0.0248	0.0277	0.0150	0.0045	0.0093	< 0.0001
	p-value (Timing)	0.1479	0.4929	0.4311	0.5714	0.5264	0.0025
	p-value (Timing: Technique)	0.7639	0.1720	0.3442	0.7870	0.3555	0.6421
			2018				
Early	Control	39 ± 1.5b	-	-	8.2 ± 0.9b	11.6 ± 1.3b	42.0 ± 2.7b
	Shoot Tuck	36 ± 1.4b	-	-	6.3 ± 0.9ab	12.3 ± 1.3b	43.7 ± 2.7b
	Shoot Wrap	30 ± 1.5a	-	-	4.1 ± 0.9a	7.9 ± 1.3a	27.8 ± 2.7a
Late	Control	41 ± 1.6c	-	-	7.3 ± 0.9b	10.0 ± 1.3ab	32.2 ± 2.7b
	Shoot Tuck	35 ± 1.5b	-	-	5.7 ± 0.9ab	11.3 ± 1.3b	27.5 ± 2.7b
	Shoot Wrap	29 ± 1.5a	-	-	4.2 ± 0.9a	7.4 ± 1.3a	15.8 ± 2.8a
	p-value (Technique)	0.0001	-	-	0.0017	< 0.0001	< 0.0001
	p-value (Timing)	0.9903	-	-	0.9293	0.3584	< 0.0001
	p-value (Timing: Technique)	0.4254	-	-	0.9277	0.5720	0.5046
			2019				
Early	Control	45 ± 2.5b	31 ± 2.4	39 ± 2.6	7.5 ± 0.7b	9.2 ± 0.6ab	25.6 ± 2.1b
	Shoot Tuck	30 ± 2.6a	32 ± 2.5	34± 2.6	6.0 ± 0.7b	9.6 ± 0.7b	22.8 ± 2.1b
	Shoot Wrap	20 ± 2.6a	26 ± 2.5	27± 2.6	4.4 ± 0.7a	7.7 ± 0.6a	13.4 ± 2.1a
Late	Control	35 ± 2.6a	29 ± 2.5	36± 2.6	6.6 ± 0.7a	8.8 ± 0.7a	16.3 ± 2.1a
	Shoot Tuck	28 ± 2.6a	29 ± 2.5	37± 2.6	6.4 ± 0.7a	8.5 ± 0.7a	13.0 ± 2.2a
	Shoot Wrap	27 ± 2.6a	26 ± 2.5	37± 2.6	5.8 ± 0.7a	9.5 ± 0.6a	13.7 ± 2.1a
	p-value (Technique)	0.0001	0.0794	0.0989	0.0007	0.6427	0.0094
	p-value (Timing)	0.4074	0.3914	0.1222	0.3178	0.7971	0.0078
		0.0248	0.6935	0.0486	0.0284	0.0053	0.0241

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance
[b]Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.

Lateral emergence and elongation: Lateral emergence did not differ in 2016 for the whole vine; fewer laterals per vine were observed possibly due to the Class III drought. SW technique reduced lateral emergence by nine to twenty-five lateral shoots per vine, compared to C in the fruit zone for 2017 to 2019, and when applied early in 2019 (Table 1). A similar trend was observed in the middle and upper canopy zones except in 2019. Lateral shoots that emerged were significantly shorter in vines subjected to the SW technique by 3.1 to 4.6 cm per lateral shoot in the fruit zone for 2017 to 2019. In 2017, lateral elongation per lateral shoot was shorter by 11.1 cm in the middle canopy in SW vines, which also had shorter lateral shoots by 25.9 cm when applied late in the upper canopy. ST vines had the longest average lateral shoot in the middle (0.7 cm longer than C) and upper canopy (1.7 cm longer than C) in 2018 and in the middle canopy in 2019 when applied early (Table 1). Lateral elongation was reduced in the upper canopy in both SWE and SWL. In 2019, SWE vines had the shortest lateral shoots in both the middle and upper canopy, 1.5 cm and 12.2 cm shorter than CE vines, respectively.

Timing of technique application reduced lateral elongation in the upper canopy, with techniques applied late having shorter laterals than techniques applied early, by 12.6 to 27.9 cm in all years. This was not observed in the middle canopy in most years. In 2019, depending on technique, timing impacted lateral shoot elongation in all zones with longer lateral shoots observed in the palissage techniques and shorter lateral shoots observed in the Control technique applied late.

Enhanced Point Quadrant: Canopy density differed among techniques applied at different timings (Table 2). Leaf layer numbers were 0.1 to 0.3 layers higher in 2019 for E techniques, meaning denser canopies. There were no significant impacts of techniques applied early or late on leaf or occlusion layer numbers otherwise for all observed years. SW vines had a lower percent of interior leaves than C vines in 2018. In 2017, STE vines had the most cluster exposure layers while in 2018, SW vines showed the lowest leaf exposure layers. Cluster exposure flux availability was the highest in SWE vines in 2017 and in SW vines regardless of timing in 2018.

Table 2: Enhanced point quadrant metrics in Cabernet franc vines subjected to techniques applied early and late from 2017 to 2019, collected at 50% veraison in Lansing NY. Values are means ± standard errors.

Timing	Technique[a]	LLN[c]	OLN	PIL	PIC	CEL	LEL	CEFA	LEFA
2017									
Early	Control	3.3 ± 0.2	4.7± 0.3	48.9 ± 1.8	78.7 ± 3.3	1.3 ± 0.06ab	0.7 ± 0.05	0.11± 0.01a	0.26 ± 0.01a
	Shoot Tuck	3.4 ± 0.2	4.8 ± 0.3	48.4 ± 1.8	85.2 ± 3.3	1.4 ± 0.06b	0.6 ± 0.05	0.12 ± 0.01a	0.30± 0.01ab
	Shoot Wrap	2.8 ± 0.2	4.0 ± 0.3	42.6 ± 1.8	75.0 ± 3.3	1.1 ± 0.06a	0.5 ± 0.05	0.19 ± 0.01b	0.34 ± 0.01b
Late	Control	2.9 ± 0.2	4.3 ± 0.3	45.1 ± 1.8	75.7 ± 3.3	1.1 ± 0.06a	0.6 ± 0.05	0.18 ± 0.01a	0.32 ± 0.01a
	Shoot Tuck	2.9 ± 0.2	4.0 ± 0.3	44.1 ± 1.8	76.6 ± 3.3	1.1 ± 0.06a	0.6 ± 0.05	0.16 ± 0.01a	0.32 ± 0.01a
	Shoot Wrap	3.0 ± 0.2	4.4 ± 0.3	43.0 ± 1.8	82.2 ± 3.3	1.2 ± 0.06a	0.5 ± 0.05	0.16 ± 0.01a	0.33 ± 0.01a
	p-value (Technique)	0.3413	0.7037	0.1415	0.5146	0.1078	0.2387	0.0097	0.0059
	p-value (Timing)	0.2097	0.3428	0.1771	05816	0.0645	0.4909	0.0262	0.0192
	p-value (Timing: Technique)	0.1670	0.2046	0.4890	0.0795	0.0159	0.5238	0.0008	0.0679
2018									
Early	Control	3.2 ± 0.2	4.2 ± 0.2	46.8 ± 1.6a	76.8 ± 4.4	1.1 ± 0.08	0.6 ± 0.03ab	0.13 ± 0.02a	0.27 ± 0.01a
	Shoot Tuck	3.3 ± 0.2	4.2 ± 0.2	46.7 ± 1.7a	76.7 ± 4.0	1.1 ± 0.07	0.6 ± 0.03b	0.19 ± 0.02ab	0.32 ± 0.01b
	Shoot Wrap	3.0 ± 0.2	3.9 ± 0.2	42.5 ± 1.7a	71.1 ± 4.0	0.9 ± 0.07	0.5 ± 0.03a	0.22 ± 0.02b	0.34 ± 0.01b
Late	Control	3.4 ± 0.2	4.4 ± 0.2	51.0 ± 1.6b	75.0 ± 4.0	1.1 ± 0.07	0.7 ± 0.03b	0.19 ± 0.02a	0.29 ± 0.01a
	Shoot Tuck	3.1 ± 0.2	3.9 ± 0.2	49.0 ± 1.7ab	66.2 ± 4.4	1.0 ± 0.08	0.6 ± 0.03ab	0.22 ± 0.02a	0.30 ± 0.01a
	Shoot Wrap	2.9 ± 0.2	4.0 ± 0.2	44.3 ± 1.6a	70.6 ± 4.0	0.9 ± 0.07	0.5 ± 0.03a	0.23 ± 0.02a	0.34 ± 0.01b
	p-value (Technique)	0.1622	0.1034	0.0151	0.4459	0.0618	0.0008	0.0389	0.0006
	p-value (Timing)	0.8909	0.9269	0.0688	0.2377	0.6226	0.1423	0.1083	0.9072
	p-value (Timing: Technique)	0.4414	0.3773	0.7434	0.4475	0.7273	0.2529	0.5465	0.3292
2019									
Early	Control	2.9 ± 0.13b	3.9 ± 0.14	43.8 ± 2.11	68.0 ± 6.2	0.9 ± 0.1	0.5 ± 0.03	0.19 ± 0.03	0.30 ± 0.01a
	Shoot Tuck	2.8 ± 0.13b	3.6 ± 0.14	41.6 ± 2.11	67.7 ± 6.2	0.9 ± 0.1	0.5 ± 0.03	0.24 ± 0.03	0.36 ± 0.01b
	Shoot Wrap	2.5 ± 0.13b	3.4 ± 0.14	36.8 ± 2.11	63.7 ± 6.2	0.8 ± 0.1	0.4 ± 0.03	0.30 ± 0.03	0.39 ± 0.01b
Late	Control	2.6 ± 0.13a	3.6 ± 0.14	39.2 ± 2.04	66.2 ± 6.2	0.8 ± 0.1	0.5 ± 0.03	0.26 ± 0.03	0.37 ± 0.01a
	Shoot Tuck	2.4 ± 0.13a	3.2 ± 0.14	38.0 ± 2.11	62.4 ± 6.2	0.7 ± 0.1	0.4 ± 0.03	0.29 ± 0.03	0.38 ± 0.01a
	Shoot Wrap	2.6 ± 0.13a	3.6 ± 0.14	39.4 ± 2.04	60.2 ± 6.2	0.7 ± 0.1	0.4 ± 0.03	0.29 ± 0.03	0.37 ± 0.01a
	p-value (Technique)	0.1283	0.0928	0.2150	0.6069	0.4972	0.1374	0.0827	0.0020
	p-value (Timing)	0.0324	0.1068	0.2348	0.4127	0.2353	0.1051	0.1683	0.0427
	p-value (Timing: Technique)	0.1004	0.1891	0.1379	0.9429	0.7497	0.3511	0.3391	0.0020

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance
[b]Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.
[c]LLN = leaf layer numbers, OLN = occlusion layer numbers, PIL = percent interior leaves, PIC = percent interior clusters, CEL = cluster exposure layer, LEL = leaf exposure layer, CEFA = cluster exposure flux availability, LEFA = leaf exposure flux availability

Downy mildew metrics and spray card penetration: Spray penetration to clusters of Cabernet franc vines as shown by the spray cards' turning blue increased by 32% in the SW technique compared to the C technique in 2018 (Figure 5). In 2017 and 2019, no significant difference was observed for all techniques applied early and late. But there may be an anecdotal 15% increase in spray penetration in SWE, compared to C in 2019.

Downy mildew, a foliar disease common to winegrowing regions with high rainfall and humidity including the Finger Lakes, was evaluated for severity and incidence in response to concerns by local grape growers (Wolf 2008). In 2018, while vines from both the ST and SW techniques significantly showed 13% more severity than C, ST vines also had 9% more incidence than C vines (Table 3). In both 2017 and 2019, all techniques had bad downy mildew incidence which may have been a result of high precipitation early in the growing season before bloom (Wolf 2008).

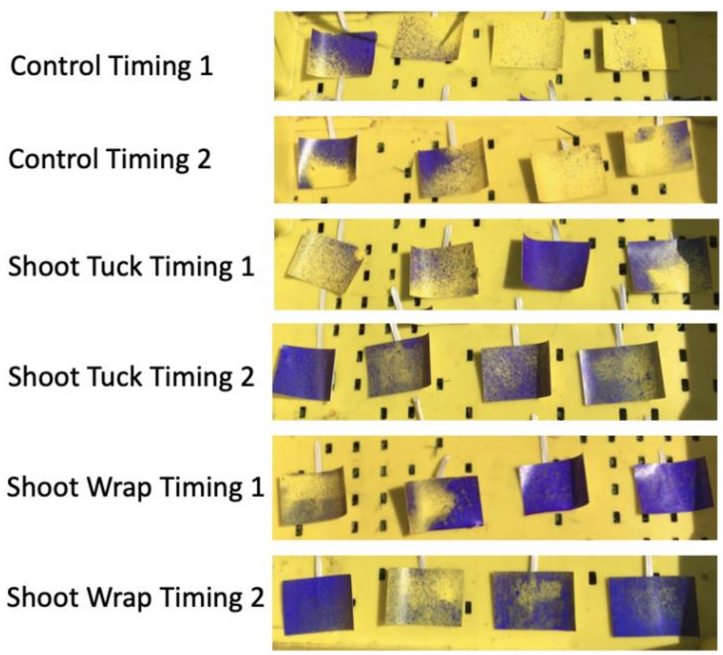

Figure 5: spray penetration to the clusters, measured by counting 1-cm grids that turned more than 50% blue in 2018.

Table 3: Downy mildew severity and incidence quantified at veraison in Cabernet franc vines subjected to shoot tip modification techniques applied early and late in Lansing, NY. Values are means ± standard errors.

Timing	**Technique**	**Downy Mildew Severity (1 = least, 5 = most)**	**Downy Mildew Incidence (%)**
		2017	
Early	Control	1.6 ± 0.1	88 ± 2.3
	Shoot Tuck	1.5 ± 0.1	89 ± 2.6
	Shoot Wrap	1.6 ± 0.1	92 ± 2.3
Late	Control	1.3 ± 0.1	88 ± 2.3
	Shoot Tuck	1.4 ± 0.1	86 ± 2.3
	Shoot Wrap	1.6 ± 0.1	90 ± 2.3
	p-value (Technique)[a]	0.1239	0.2462
	p-value (Timing)	0.3056	0.4979
	p-value (Timing: Technique)	0.1511	0.8538
		2018	
Early	Control	1.3 ± 0.1ab[b]	60 ± 10.1a
	Shoot Tuck	1.5 ± 0.1ab	69 ± 10.1a
	Shoot Wrap	1.5 ± 0.1b	57 ± 9.9a
Late	Control	1.2 ± 0.1a	41 ± 9.9a
	Shoot Tuck	1.4 ± 0.1a	62 ± 9.9a
	Shoot Wrap	1.4 ± 0.1a	56 ± 9.9a
	p-value (Technique)	0.0054	0.0454
	p-value (Timing)	0.0865	0.0990
	p-value (Timing: Technique)	0.7110	0.5401
		2019	
Early	Control	1.6 ± 0.1	96 ± 1.0
	Shoot Tuck	1.8 ± 0.1	95 ± 1.0
	Shoot Wrap	1.8 ± 0.1	97 ± 1.0
Late	Control	1.7 ± 0.1	95 ± 1.0
	Shoot Tuck	1.8 ± 0.1	97 ± 1.0
	Shoot Wrap	1.8 ± 0.1	96 ± 1.0
	p-value (Technique)	0.4254	0.6250
	p-value (Timing)	0.5366	0.9038
	p-value (Timing: Technique)	0.8733	0.2042

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance
[b] Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.

Vines subjected to SW technique applications showed the longest rachis in 2016, at 2.6 cm longer than the C, and 1.9 cm longer than the ST (Table 4). While there was no statistical significance for rachis length in 2017 to 2019, vines in the SW technique seemed to have longer rachises up to 1.1 cm longer than the C vines. Vines in the ST technique also seemed to have modest increases in rachis length in 2017 to 2019. In 2016 and 2017, clusters from SW vines had 25 fewer berries per cluster than clusters from C vines. ST vines also had fewer berries per clusters in 2016 and 2017 but more than vines from the SW technique. 2017 was a very heavy crop year and many clusters were especially large and had more berries than in the other years. This may be due to a warm, dry spring in 2016, when flowers for 2017 were being formed for 2016 (Wolf 2008). In 2018 and 2019, there was no statistical significance difference between techniques or timings. Cluster compactness, or the number of berries per centimeter of rachis length, was reduced by 1.5 to 2.4 berries per cm of rachis in both the ST and SW technique in 2016 to 2018, and by 2.4 berries per cm of rachis in SWE in 2016.

Table 4: Rachis length, number of berries per cluster, and cluster compactness in Cabernet franc vines subject to techniques applied early or late, collected at veraison in Lansing, NY. Values are means ± standard errors.

Timing	Technique	Rachis length (cm)	Berry number/cluster	Cluster compactness (no. berries/ cm rachis length)
		2016		
Early	Control	13.4 ± 0.9ab	88 ± 6.0b	6.5 ± 0.6b
	Shoot Tuck	14.1 ± 0.9ab	76 ± 5.9ab	5.5 ± 0.6b
	Shoot Wrap	16.0 ± 0.9b	67 ± 5.8a	4.1 ± 0.6a
Late	Control	13.9 ± 0.9a	74 ± 5.8b	5.1 ± 0.6a
	Shoot Tuck	14.5 ± 0.9ab	68 ± 5.8ab	4.7 ± 0.6a
	Shoot Wrap	14.8 ± 0.9b	63 ± 5.8a	4.7 ± 0.6a
	p-value (Technique)	0.0337	0.0306	0.0008
	p-value (Timing)	0.8741	0.0818	0.0705
	p-value (Timing: Technique)	0.2963	0.6272	0.0131
		2017		
Early	Control	12.8 ± 0.4	144 ± 5.0a	11.4 ± 0.5a
	Shoot Tuck	13.2 ± 0.4	130 ± 5.0ab	10.1 ± 0.5ab
	Shoot Wrap	13.7 ± 0.4	123 ± 5.0b	9.0 ± 0.5b
Late	Control	12.9 ± 0.4	130 ± 5.0a	10.2 ± 0.5a
	Shoot Tuck	13.3 ± 0.4	125 ± 5.0a	9.6 ± 0.5ab
	Shoot Wrap	13.2 ± 0.4	122 ± 5.0a	9.3 ± 0.5b
	p-value (Technique)a	0.3138	0.0100	0.0184
	p-value (Timing)	0.8127	0.0931	0.2409
	p-value (Timing: Technique)	0.6964	0.4203	0.3141
		2018		
Early	Control	10.1 ± 0.3	75 ± 4.0	7.5 ± 0.4a
	Shoot Tuck	10.8 ± 0.3	71 ± 4.0	6.7 ± 0.4a
	Shoot Wrap	11.2 ± 0.3	73 ± 4.0	6.6 ± 0.4a
Late	Control	10.6 ± 0.3	77 ± 4.0	7.5 ± 0.4b
	Shoot Tuck	10.5 ± 0.3	69 ± 4.0	6.8 ± 0.4ab
	Shoot Wrap	10.5 ± 0.3	65 ± 4.0	6.3 ± 0.4a
	p-value (Technique)	0.2382	0.1481	0.0357
	p-value (Timing)	0.3708	0.4392	0.8861

	p-value (Timing: Technique)	0.0702	0.3907	0.8957
		2019		
Early	Control	12.7 ± 0.7	90 ± 5.6	7.1 ± 0.4
	Shoot Tuck	12.6 ± 0.7	80 ± 5.5	6.4 ± 0.4
	Shoot Wrap	12.8 ± 0.7	70 ± 5.5	5.7 ± 0.4
Late	Control	12.5 ± 0.7	75 ± 5.5	6.0 ± 0.4
	Shoot Tuck	13.0 ± 0.7	71 ± 5.6	5.7 ± 0.4
	Shoot Wrap	13.4 ± 0.7	82 ± 5.6	6.2 ± 0.4
	p-value (Technique)	0.7732	0.4261	0.3377
	p-value (Timing)	0.6535	0.4385	0.2028
	p-value (Timing: Technique)	0.8174	0.0836	0.1973

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance
[b]Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.

Yield Components: Yields per vine did not differ in 2016 or 2019 between technique and timing while in 2017, CE and STE had the highest yields per vine. In 2018, CL and STL had higher yields than CE and STE and SW. In 2019, yields were insignificant and low due to due to insufficient leaf area possibly because of bad downy mildew incidence and feeding damage. Number of clusters did not differ among techniques or timings except in 2018 when vines from techniques applied early had fewer clusters per vine than late especially STE. In 2019, SW applied early had the fewest clusters per vine. Cluster weight on the other hand was significantly heaviest in the C technique and lightest in SW in 2017 and did not differ in the other years among techniques or timings. In 2019, SWE seemed to have the smallest cluster weight but did not statistically differ from the other techniques or timings. Berry weight did not significantly differ among techniques or timings in all years except 2019. In 2019, reduced berry weight per berry was observed in techniques applied early. Pruning weights did not differ among technique or timing of application for all years. Ravaz Index (ratio of crop load per vine to pruning weight per vine) is higher for techniques applied in 2017 only.

Fruit Composition: Veraison rating, or the scoring of how far along veraison clusters are at, was significantly impacted by technique only in two years but not by timing. In 2016, vines from both ST and SW techniques had higher veraison progression than vines in C technique by up to 0.5 (Table 6). A similar trend was observed for 2018 with higher veraison progression by up to 0.8. Soluble solids did not significantly differ between techniques or timings. In 2018, vines from both CL and SWE applications had higher titratable acidity, while in 2019, both STE and SWE biologically had higher titratable acidity; there was no statistical significance. The pH was 0.24 units lower for STE vines than either C or SW vines in 2016 only. In the other years, the pH did not differ between technique or timing. There was no significant difference in anthocyanins in 2018 or 2019. Yeast assimilable nitrogen was higher for SW vines by 25 mg/L than ST vines and by 19 mg/L than C vines in 2018. No difference was observed for 2019.

Table 5: Yield components of Cabernet franc vines subjected to early and late applications of different canopy management techniques from 2016 to 2019 at harvest in Lansing, NY. Values are means ± standard errors

Timing	Technique	Yield (kg/vine)	Number of clusters/vine	Cluster weight	Berry weight	Pruning weight (kg/vine)	Ravaz Index

				(g/cluster)	(g/berry)		
2016							
Early	Control	5.7± 0.9	68 ± 6.8	140.6 ± 13.7	1.39± 0.08	0.72 ± 0.07	7.1 ± 0.97
	Shoot Tuck	5.4 ± 0.9	58 ± 6.9	127.6 ± 12.8	1.51± 0.08	0.92 ± 0.08	6.4 ± 1.00
	Shoot Wrap	4.6 ± 0.9	62 ± 6.8	116.7 ± 12.6	1.51± 0.08	0.68 ± 0.07	8.0 ± 0.97
Late	Control	6.5 ± 0.9	69 ± 6.9	128.0 ± 12.6	1.53± 0.08	0.75 ± 0.08	9.2 ± 0.98
	Shoot Tuck	5.3 ± 0.9	64 ± 6.9	120.4 ± 12.6	1.53± 0.08	0.80 ± 0.08	7.2 ± 1.03
	Shoot Wrap	4.9 ± 0.9	56 ± 6.8	114.8 ± 12.6	1.57± 0.08	0.75 ± 0.07	8.0 ± 1.03
	p-value (Technique)[a]	0.2979	0.2831	0.3641	0.4444	0.1094	0.1884
	p-value (Timing)	0.6353	0.9548	0.5262	0.1880	0.9188	0.6160
	p-value (Timing: Technique)	0.8717	0.6365	0.8436	0.6866	0.3324	0.7672
2017							
Early	Control	11.9±0.4b	63 ± 2.5	166.2 ± 6.6b	1.12± 0.07	0.81 ± 0.07	16.2 ± 1.1b
	Shoot Tuck	11.7±0.4ab	65 ± 2.5	145.3 ± 6.6ab	1.14± 0.07	0.91 ± 0.07	14.8 ± 1.1b
	Shoot Wrap	10.3±0.4a	64 ± 2.5	134.7 ± 6.6a	1.18± 0.07	0.72 ± 0.07	15.9 ± 1.1b
Late	Control	9.9±0.4a	69 ± 2.5	152.0 ± 6.5a	1.10± 0.07	0.89 ± 0.07	12.0 ± 1.1a
	Shoot Tuck	10.4±0.4a	67 ± 2.6	152.1 ± 6.5a	1.11± 0.07	1.00 ± 0.07	12.0 ± 1.1a
	Shoot Wrap	11.0±0.4a	68 ± 2.6	140.5 ± 6.5a	1.16± 0.07	0.93 ± 0.07	12.3 ± 1.1a
	p-value (Technique)	0.0668	0.9998	0.0020	0.7771	0.2083	0.7391
	p-value (Timing)	0.0136	0.0676	0.9146	0.7890	0.0507	0.0001
	p-value (Timing: Technique)	0.0389	0.7157	0.1484	0.8259	0.6021	0.8425
2018[c]							
Early	Control	5.0± 0.3a	59 ± 2.0a	-	1.40 ± 0.03	0.43 ±0.04	12.7 ± 1.2
	Shoot Tuck	5.3 ± 0.4a	54 ± 2.0a	-	1.47 ± 0.03	0.50±0.04	12.5 ± 1.2
	Shoot Wrap	4.8 ± 0.4a	55 ± 2.0a	-	1.44 ± 0.03	0.52 ±0.04	10.6 ± 1.2
Late	Control	5.8 ± 0.4ab	63 ± 2.0b	-	1.46 ± 0.03	0.50 ±0.04	12.1 ± 1.2
	Shoot Tuck	6.1 ± 0.4b	64 ± 2.1b	-	1.46 ± 0.03	0.60 ±0.04	11.0 ± 1.2
	Shoot Wrap	4.8 ± 0.4a	56 ± 2.0a	-	1.45 ± 0.03	0.53 ±0.04	9.8 ± 1.2
	p-value (Technique)	0.0030	0.0254	-	0.5501	0.1614	0.1795
	p-value (Timing)	0.0083	0.0030	-	0.4089	0.1173	0.3008
	p-value (Timing: Technique)	0.2264	0.0906	-	0.6151	0.6091	0.9135

2019[d]							
Early	Control	4.1 ± 0.3b	53 ± 2.8b	114.0 ± 9.7	1.24 ± 0.05a	1.08 ± 0.17	4.3 ± 0.6
	Shoot Tuck	3.4 ± 0.3ab	47 ± 2.8ab	104.1 ± 9.7	1.27 ± 0.05	1.28 ± 0.17	4.9 ± 0.6
	Shoot Wrap	2.9 ± 0.3a	39 ± 2.8a	84.2 ± 9.7	1.14± 0.05a	1.17 ± 0.17	4.4 ± 0.6
Late	Control	3.3 ± 0.3a	50 ± 2.8a	104.9 ± 9.6	1.31± 0.05b	1.17 ± 0.17	4.5 ± 0.6
	Shoot Tuck	2.9 ± 0.3a	47 ± 2.8a	98.5 ± 9.7	1.30± 0.05b	1.26 ± 0.17	4.5 ± 0.6
	Shoot Wrap	3.4 ± 0.3a	51 ± 2.8a	114.8 ± 9.7	1.30± 0.05b	1.29 ± 0.17	5.0 ± 0.6
	p-value (Technique)	0.1360	0.0694	0.5615	0.4137	0.4444	0.7570
	p-value (Timing)	0.2925	0.1960	0.5182	0.0319	0.5409	0.7644
	p-value (Timing: Technique)	0.0713	0.0346	0.1156	0.4063	0.8095	0.6086

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance
[b]Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.
[c]Cluster weights for 2018 were not obtained.
[d]Yields in 2019 were calculated on a per panel basis of four vines. Yields were low due to animal feeding, lost leaf from downy mildew damage.

Table 6: Veraison rating of berry progression at 50% veraison and fruit composition metrics in clusters at harvest of Cabernet franc subjected to techniques applied early or late, at Lansing, NY. Values are means ± standard errors.

Timing	Technique	Veraison Rating	Soluble Solids (Brix)	Titratable acidity (g/L)	pH	Total anthocyanins (mg/L)[c]	YAN (mg/L)
2016							
Early	Control	3.3 ± 0.18a	17.7 ± 0.5	8.2 ± 1.6	3.47 ± 0.08ab	-	-
	Shoot Tuck	3.6 ± 0.18a	17.5 ± 0.5	11.2 ± 1.9	3.23 ± 0.08a	-	-
	Shoot Wrap	3.5 ± 0.18a	17.9 ± 0.5	7.4 ± 1.6	3.43 ± 0.08b	-	-
Late	Control	3.3 ± 0.18a	17.3 ± 0.5	7.0 ± 1.6	3.44 ± 0.08ab	-	-
	Shoot Tuck	3.7 ± 0.18b	18.2 ± 0.5	7.9 ± 1.6	3.42 ± 0.08a	-	-
	Shoot Wrap	3.8 ± 0.18b	18.4 ± 0.5	6.7 ± 1.6	3.59 ± 0.08b	-	-
	p-value (Technique)[a]	0.0058	0.2468	0.2125	0.0483	-	-
	p-value (Timing)	0.2809	0.3855	0.1452	0.0639	-	-
	p-value (Timing: Technique)	0.2541	0.3275	0.5947	0.2332	-	-
2017							
Early	Control	2.3 ± 0.12	-	-	-	-	-
	Shoot Tuck	2.0± 0.12	-	-	-	-	-
	Shoot Wrap	1.9 ± 0.12	-	-	-	-	-
Late	Control	2.1 ± 0.12	-	-	-	-	-
	Shoot Tuck	2.2 ± 0.12	-	-	-	-	-
	Shoot Wrap	2.0 ± 0.12	-	-	-	-	-
	p-value (Technique)	0.1855	-	-	-	-	-

	p-value (Timing)	0.7689	-	-	-	-	-
	p-value (Timing: Technique)	0.2310	-	-	-	-	-
			2018				
Early	Control	2.3 ± 0.20a	20.1 ± 0.3	5.0 ± 0.2a	3.55 ± 0.04	28.3 ± 4.0	79 ± 7.9ab[b]
	Shoot Tuck	2.7 ± 0.20a	20.1 ± 0.3	5.4 ± 0.2ab	3.49 ± 0.04	32.0 ± 4.0	70 ± 7.9a
	Shoot Wrap	2.6 ± 0.20a	20.0 ± 0.3	5.9 ± 0.2b	3.46 ± 0.04	27.9 ± 4.0	95 ± 7.9b
Late	Control	2.2 ± 0.20a	19.6 ± 0.3	5.7 ± 0.2a	3.41 ± 0.04	18.4 ± 4.0	76 ± 7.9ab
	Shoot Tuck	2.9 ± 0.20b	20.2 ± 0.3	4.9 ± 0.2a	3.46 ± 0.04	25.9 ± 4.0	69 ± 7.9a
	Shoot Wrap	3.1 ± 0.20b	19.6 ± 0.3	5.6 ± 0.2a	3.54 ± 0.04	24.0 ± 4.0	90 ± 7.9b
	p-value (Technique)	0.0121	0.1434	0.0572	0.8151	0.4099	0.0362
	p-value (Timing)	0.1753	0.4647	0.7243	0.3347	0.0676	0.6447
	p-value (Timing: Technique)	0.3017	0.3716	0.0464	0.0621	0.7623	0.9650
			2019				
Early	Control	2.4 ± 0.23	-[e]	8.6 ± 0.5	3.08 ± 0.02	19.8 ± 2.9	44 ± 3.6
	Shoot Tuck	1.9 ± 0.23	-	9.9 ± 0.5	3.04 ± 0.02	11.9 ± 2.9	43 ± 3.6
	Shoot Wrap	1.7 ± 0.23	-	9.2 ± 0.5	3.07 ± 0.02	18.7 ± 2.9	41 ± 3.4
Late	Control	2.0 ± 0.23	-	8.7 ± 0.5	3.09 ± 0.02	20.2 ± 2.9	43 ± 3.4
	Shoot Tuck	2.0 ± 0.23	-	8.8 ± 0.5	3.10 ± 0.02	16.5 ± 2.9	43± 3.4
	Shoot Wrap	1.6 ± 0.23	-	8.9 ± 0.5	3.06 ± 0.02	11.4 ± 2.9	42 ± 3.8
	p-value (Technique)	0.0628	-	0.1316	0.2893	0.1428	0.7655
	p-value (Timing)	0.5372	-	0.1206	0.1530	0.7452	0.5048
	p-value (Timing: Technique)	0.4223	-	0.2121	0.1098	0.1644	0.9755

[a] *p*-value for the fixed variables technique and timing in a mixed model analysis of variance.
[b]Lowercase letters indicate a separation of treatments by Tukey's honest significant difference test at a 5% significance level.
[c]Anthocyanin and YAN data were not obtained from the 2016 samples.
[d]Samples were misplaced so no data were available in 2017.

A cost analysis was developed to assess potential costs of palissaging compared to different viticultural practices, using assumptions of labor and equipment costs for the Finger Lakes region (Table 7). If palissage applications were applied to each vine in 30 or 45 seconds, it would be more expensive than mechanical hedging twice. However, if it would take 45 seconds or more to palissage each vine, palissage applications may be cheaper to implement than a program of hedging twice and either mechanical or hand leaf removal (Table 8). It may be also be cheaper to implement palissage if it is applied once than to hedge more than two times.

Table 7: Economic analysis: assumed costs of labor and equipment for different viticultural practices and predicted costs of time spent palissaging.

Viticultural Practice	Cost	Assumption	Source
Hedging 2x	$110/acre	$23/hour skilled	Davis et al 2020
Hedging 2x + Leaf Removal	$226/ acre	$23/hour skilled, $17.50/hour unskilled	Davis et al 2020
Hand Leaf Removal	$270/acre	$17.50/hour unskilled	Julian et al 2008

Hedging 2x + Hand Leaf Removal	$496/acre	$23/hour skilled, $17.50/hour unskilled	Davis et al 2020, Julian et al 2008
Time spent palissaging per vine	**Cost**	**Assumption**	**Source**
30 seconds	$117.78/ acre	$17.50/hour unskilled	Davis et al 2020
45 seconds	$176.50/acre	$17.50/hour unskilled	Davis et al 2020
60 seconds	$235.38/acre	$17.50/hour unskilled	Davis et al 2020
90 seconds	$353.06/acre	$17.50/hour unskilled	Davis et al 2020
120 seconds	$470.75/acre	$17.50/hour unskilled	Davis et al 2020

Table 8: Comparison of cost of time spent palissaging to cost of common viticultural practices

Time spent palissaging per vine	Viticultural Practice
30 seconds (117.78/acre)	Hedge 2x ($110/acre)
45 seconds (176.50/acre)	Hedging 2x + Leaf Removal ($226/acre)
60 seconds ($235.38/acre)	Hedging 2x + Leaf Removal ($226/acre)
120 seconds ($470.75/acre)	Hedging 2x + Hand Leaf Removal ($496/acre)

Cluster compactness, or number of berries per cm of rachis was reduced by both SW and ST techniques. Number of lateral shoots that emerged per vine in the fruit zone was also reduced by at least fourteen shoots to twenty-five shoots by SW technique. Lateral length was reduced by SW in the fruit zone and by both ST and SW techniques in the upper canopy. These reductions may potentially improve cluster microclimate and reduce cluster rot disease incidence and severity. ST had modest reductions in lateral emergence and cluster compactness metrics, making it a promising tool for growers who are concerned about maintaining yields. The findings presented above also suggested that delaying shoot tip modifications might also be instrumental in slowing down lateral growth, potentially improving light penetration, without negatively impacting yields in C and ST. Downy mildew incidence only slightly differed between techniques, although ST vines showed the highest incidence in 2018. Severity did not differ among techniques or timings, which showed that palissage may be used in a humid region to regulate vegetative growth without greatly exacerbating Downy mildew severity. Yeast assimilable nitrogen (YAN), which is important for yeast fermentation in winemaking, was higher in the SW technique in 2018, which may make SW a good canopy management tool to improve YAN levels.

References:

Davis, T.J., M.I. Gómez., R. Moss., H. Walter-Peterson. 2020. Cost of Establishment and Production of V. vinifera Grapes in the Finger Lakes Region of New York – 2019. Charles H. Dyson School of Applied Economics and Management College of Agriculture and Life Sciences. Cornell University, Ithaca, New York 14853-7801

France, J., M.Y. Chou., J.E. Vanden Heuvel. 2018. Palissage Reduces Cluster Zone Lateral Shoots Compared to Hedging. Catalyst: Discovery into Practice November 2018 2: 50-58

Reynolds, A.G., and D.A. Wardle. 1989. Effects of Timing and Severity of Summer Hedging on Growth, Yield, Fruit Composition, and Canopy Characteristics of de Chaunac. I. Canopy Characteristics and Growth Parameters. Am J Enol Vitic. 40(2): 109–120.

Vasconcelos, M.C., and S. Castagnoli. 2000. Leaf Canopy Structure and Vine Performance. Am. J. Enol. Vitic. 51(4): 390.

Wolf, T.K. 2008. Wine Grape Production Guide for Eastern North America. Natural Resource, Agriculture, and Engineering Service, Ithaca, New York.