SPUR AND SHORT CANE PRUNING INFLUENCE BUD VIABILITY, YIELD, AND FRUIT QUALITY

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ABSTRACT

Balanced pruning is used to manage vegetative vigor and fruit load to optimize yield and fruit quality in most of fruit species. The objective of this study was to determine the bud viability, yield, and fruit quality potential of four grapevine cultivars using three pruning strategies. Four cold climate grapevine cultivars--Brianna, Frontenac, La Crescent, and Marquette--were tested with spur (SP), short cane (SC), and spur plus short cane (SPSC) pruning treatments in 2018, 2019, and 2020. The SP treatment was 10 two-bud spurs per vine, SC was five four-bud short canes, and SPSC vines had four SP and three SC. Soluble solids, pH, and total acid were measured for individual bud positions on all spurs, canes or spurs and canes on each treated vine. Yield in all cultivars was lower in 2019 and 2020 due to severe winter cold. The greatest bud viability across the three years in each cultivar was achieved in Frontenac and Marquette with SP, followed by Brianna with SP and SC and La Crescent with SPSC pruning treatments. The highest yield for pruning treatments was Brianna with SC, Frontenac with SPSC, La Crescent with SC and SPSC, and Marquette with SP and SC pruning treatments. Brianna had the greatest fruit soluble solids and pH in SC pruning treatment. In contrast, Frontenac and La Crescent had greatest fruit soluble solids and lowest total acid with SP pruning treatment. Marquette showed similar soluble solids across all pruning treatments; however, pH was greatest in SC and total acid was lower in SP and SC than in SPSC. The pruning strategy impacted bud viability, yield and fruit quality measures most differently in Brianna and La Crescent; however, with these vigorous vines the SC could provide greater yield. In contrast, in Marquette and Frontenac bud viability, yield, and fruit quality were generally favored with SP. Results of this study indicate different pruning techniques, which taken in consideration with winter injury, can be used to optimize each grape cultivar yield and fruit quality.

Keywords

Spur pruning, short cane pruning, bud viability, fruit quality, cold hardy grapevines

INTRODUCTION

Development of complex hybrids with *Vitis riparia* in their pedigree has enabled grape production in regions of the United States with extreme low winter temperatures (Atucha et al. 2018; Rice et al. 2017; Riesterer-Loper et al. 2019). Different pruning strategies in these grape cultivars are used to manage vine vigor, crop load, yield, and fruit quality (Heazlewood et al. 2006, Jones et al. 2018). However, inconsistent yield, low fruit quality, high vegetative vigor and insufficient fruit ripening are issues frequently reported in cold hardy wine grapes grown in the upper Midwest (Atucha et al. 2018; Riesterer-Loper et al. 2019). Spur pruning has been reported to result in balanced vigor, yield, and uniform budbreak in Cabernet Sauvignon (Rosner and Cook 1983). Use of spur (SP) and short cane (SC) pruning are well adapted to mechanization (Poni et al. 2004) and produce a more standardized shoot growth pattern (Bernizzoni et al. 2009).

Balancing vegetative and fruit bearing shoots (balanced pruning) is important as increasing bud number per vine does not always give a linear yield response (Wolpert et al. 1983). It is also important to consider that the vine can compensate for unbalanced pruning or injury by regulating the flower cluster numbers and average cluster weight (Heazlewood et al. 2006). Bud viability varies based on node position in the cane and has a role in yield (May 2004; Kose and Kaya 2017; Buztepe et al. 2017). Spur pruning in contrast to cane pruning showed greater fruit phenolic content quality and starch in overwintering wood in Pinot noir and Chardonnay (Jones et al. 2018). However, there is limited information on the effect of pruning on bud viability and yield on cold hardy grapevine cultivars managed with SP and SC pruning. The main aim in this study was to identify how different pruning methods (spur and cane) affect bud viability, yield, and fruit quality in a high cordon training system. Therefore, the objective of this study was to determine the effect of three different pruning strategies in four cold hardy wine cultivars (*Vitis* hybrid) to provide growers information for vine management with high cordon training.

METHODS

This study was performed in 2018, 2019, and 2020 with four cold hardy grapevine cultivars (Brianna, Frontenac, La Crescent, and Marquette) (Maul 2014) growing in the Hansen Research Center, Brookings, SD (lat. 44° 18’ 40.8816” N, long. 96° 47’ 54.1896” W) in USDA Plant Hardiness Zone 4b (USDA 2021). The vineyard was planted in a randomized complete block design with six vine replicates in each block. All vines were trained to a high cordon under non-irrigated conditions. The study had three pruning treatments: SP (10 two-bud spurs), SC (five four-bud canes), and SPSC (three four-bud canes + four two-bud spurs) (Figure 1). Thus, each pruning treatment resulted in 20 buds per vine. Three replicates were used for each treatment (vine = experimental unit) with each replicate from a separate block. The position of the buds on spurs (one and two) and canes (one, two, three, and four) were each monitored

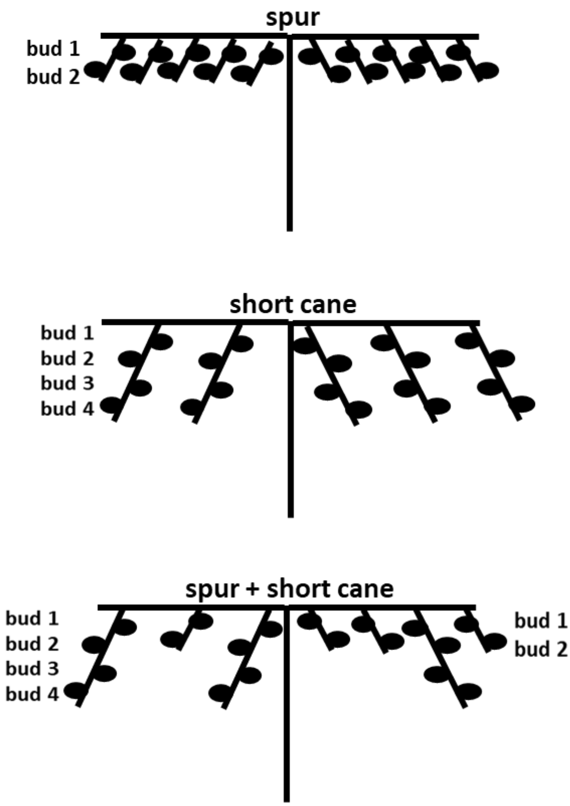

Figure 1. Pruning treatments applied to 3 replicate vines for each treatment, cultivar and year.

separately, with position number one being the basal or closest to cordon and number two through four away from the cordon. Bud viability was determined after bud break by checking for an actively growing shoot (viable) or no bud break (dead) at each bud position. Harvest timing was determined when field measure of soluble solid was estimated at 18% to 20% for Brianna (Okie, 2004) and 22% to 24% for Frontenac, La Crescent, and Marquette (Dharmadhikari 2001; Hemstad 2008; Okie 2002). A cluster for each bud position was collected separately, and then total yield (grams), total cluster number and cluster weight were recorded for each bud position in the spurs or canes for each replicate vine. Clusters were collected for each bud position separately, maintaining vine replicate, and the bud position identity in each spur or cane on the vine replicate. Data for each bud position and spur or cane number on each vine was tracked throughout harvest, extraction, and analysis. Therefore, although one to two cluster(s) were collected from a single shoot arising from one bud resulting in 20 to 40 clusters per vine, all clusters were kept separate by bud position on spur or short cane. After we took cluster weight, twenty-five random berries from all berries from an individual bud/shoot were frozen and maintained at -20 ^{0}C until tested for soluble solids, pH, and total acid. Thawed but cold berry samples were pressed using a Stomacher 400 circulator (Cole-Parmer, Vernon Hills, IL) for five minutes to produce juice. The juice samples were centrifuged in 1.5 ml tubes to remove particles. Finally, soluble solids, pH, and total acid were measured using an OenoFOSS, which uses near infrared and standard curves for each parameter to determine concentrations (FOSS, Hillerød, Denmark).

Bud viability, yield, cluster number and fruit quality parameters were analyzed using the statistical package in R (R, 2013). The effect of pruning treatment (n = three), cultivar (n = four), year (n = three), bud position (four), and factor interactions on viability, yield, cluster number, cluster weight and fruit quality (soluble solids, pH, and total acid) were assessed by ANOVA. Mean separations were performed using Tukey's HSD ($P < 0.05$) for treatment, cultivar, and bud position.

RESULTS

Bud viability varied by cultivar and pruning treatment. Frontenac had the greatest bud viability across treatments, followed by Marquette, Brianna, and La Crescent, respectively. Brianna with SP and SC had more viable buds than SPSC.

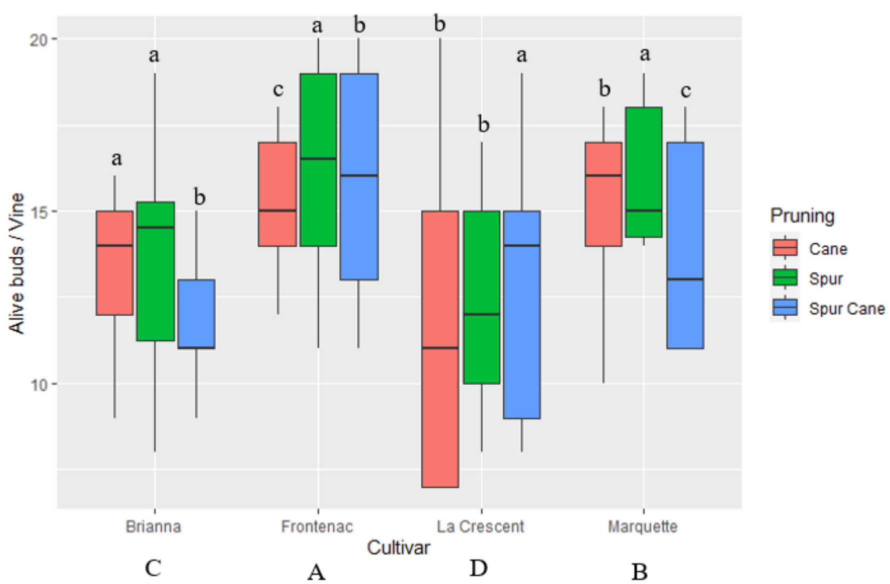

Figure 2. Bud viability in each cultivar under different pruning strategies. Distribution and mean of live buds are shown for each pruning treatment across three years in Brianna, Frontenac, La Crescent, and Marquette. Lower case letters represent significant difference between pruning treatment within a cultivar. Upper case letters show significant differences in bud viability among cultivars across all treatments. Significance determined by Tukey's HSD with a P < 0.05 n = 3.

Frontenac and Marquette had the greatest bud viability with the SP treatment and La Crescent with the SPSC pruning treatment (Figure 2).

Yield was affected by treatment, cultivar, years, positions, and interactions between treatment by cultivar, treatment by year, and cultivar by year (Table 1). All cultivars had highest yield in 2018 and lowest in 2020. Brianna had similar yield in 2018 and 2019. Winter injury in dormant seasons prior to the 2019 growing seasons impacted the yield for the other three cultivars. Brianna had the greatest yield across all years followed by Frontenac, Marquette, and La Crescent, respectively (Table 2, Figure 3). The greatest vine yield occurred with SC in Brianna, SPSC in Frontenac, SC in La Crescent, and SP and SC in Marquette. Total cluster number and cluster weight results corresponded with the yield results (Table 2).

Grape soluble solids were affected by treatment, cultivar, year, and their interactions (Table 1). Soluble solids were greater for Brianna in SC compared to the other pruning methods. Frontenac soluble solids were greatest in SP and lowest in SC pruning treatment. La Crescent had the greatest soluble solids with SP and did not differ between SC and SPSC. Marquette had similar soluble solids across all pruning methods (Table 3). Grapevine pH was affected by treatment, cultivar, year, bud position, and their interactions (Table 1). The pH was highest in SC in Brianna, Frontenac, and Marquette and was not significantly different between SC and SPSC for Brianna and Frontenac. In contrast, the pH was highest with SPSC in La Crescent (Table 3). Grapevine total acid was also affected by treatment, cultivar, year, bud position, and their interactions (Table 1). Total acid was

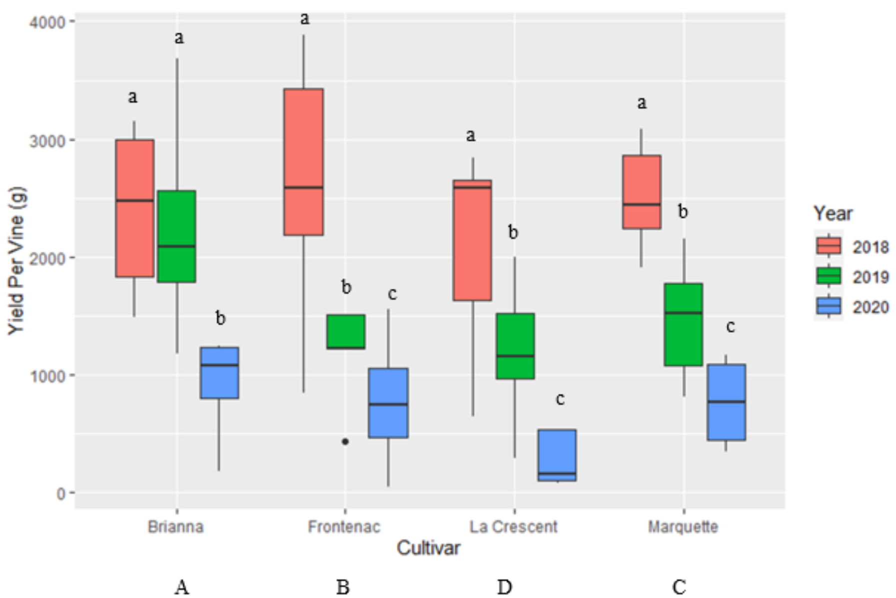

Figure 3. Yield for Brianna, Frontenac, La Crescent, and Marquette across three years. Lower case letters represent significant difference in yield among years within a cultivar. Upper case letters show significant differences in yield between cultivars across all years. Significance determined by Tukey's HSD with a P < 0.05.

greatest with SPSC in Brianna and Marquette, and SC and SPSC in Frontenac and SC in La Crescent (Table 3).

DISCUSSION

In Iowa, Marquette was the top performing cold hardy cultivar when yield, total number clusters, and fruit quality were considered (Schrader et al. 2020). Frontenac was also one of the highest yielding red cultivars in Iowa (Schrader et al. 2020), and Frontenac and Marquette were the highest yielding red wine cultivars in this study. In our findings, all cultivars had similar yield across all treatments in 2018, but winter injury in 2019 and 2020 reduced yield in all cultivars. Early low temperatures in November 2019 damaged primary buds. The sequential winter damage of 2019 and 2020 (Yilmaz et al. 2021) resulted in greater yield reduction in the 2020 growing season as all cultivars had less yield resulting from secondary buds after winter damage, which typically have lower yield compared with primary buds (Fennell 2004; Keller 2020). Spur pruning in a high cordon training system provides good light exposure to the developing buds, and in this study, the spur pruning treatment resulted in greater bud viability across all cultivars except for La Crescent. Other training systems, such as low cordon training (Scott Henry, Vertical shoot positioning) or high cordon double curtain (Geneva double curtain), have been shown to increase yield in comparison to the single high cordon; however, further comparisons would need to be made under critical winter temperatures (Bavougian et al. 2013; Luby 2012; Wimmer et al. 2018).

Previous comparison of fruit quality in Chile with vines pruned with spurs or long canes (eight buds) has shown no differences in yield or fruit soluble solids and pH (Peppi and Kania 2013). However, three node spurs had higher soluble solids and vine vigor compared with short cane (six-node) even though there was no differences on pH and yield (Morris and Main 2010). In contrast, Chardonnay vines had higher soluble solids and pH in one year comparison of spur pruned than long cane pruned vines (Jones et al. 2018). Although fruit quality (chemically) of cold hardy grapevine cultivars is still under research (Riesterer-Loper et al. 2019), the quality of harvested berries, 21% to 22% soluble solids, 3.2 to 3.4 pH for white cultivars and 22 % to 24% soluble solids, 3.3 to 3.5 pH for red cultivars are standard target values for wine grapes (Dharmadhikari 2001). In the white cultivars, La Crescent met the standards on soluble solids with SP and SPSC pruning. Brianna is typically collected at lower soluble solids as pH begins increasing at lower soluble solids than the other cultivars. Brianna and La Crescent reached the recommended pH level under all pruning strategies. In our trial, Marquette fruit reached recommended soluble solids and pH target values under all pruning methods; however, Frontenac's soluble solids and pH were lower for all pruning methods. The Marquette and La Crescent soluble solids values were lower than shown in Iowa and western Vermont studies (Schrader et al. 2020; Luby 2012), however they were similar to the fruit quality results in Wisconsin studies (Wimmer et al. 2018). The current study indicates that pruning method does impact soluble solids, pH, and total acid differently in the cultivars tested and should be considered when choosing a pruning strategy. It should be noted that training systems other than the high cordon were not tested in this study, and bud number was maintained at 20 buds per vine in coordination with pruning weight. Studies in other states have shown increased yield with different training systems (Aipperspach et al. 2020; Bavougian et al. 2013; Wimmer et al. 2018); however, all training decisions will need to consider local winter injury and vine vigor to determine optimal training and pruning strategies.

CONCLUSIONS

The bud viability, yield, and fruit quality results indicated SC is a good pruning strategy for Brianna with a high cordon training system. In Frontenac, SP provided the greatest viability; however, good yield and fruit quality can be achieved with either SP or SPSC. SPSC resulted in the greatest bud viability in La Crescent, but SP provided the best fruit quality. For Marquette SP pruning resulted in greater bud viability, yield, and fruit quality. Therefore, growers can adapt a pruning strategy to vigor and bud viability if winter injury is a common problem, whereas SP pruning can be utilized in most cultivars to optimize fruit quality.

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Table 1. ANOVA results of pruning treatment, cultivar, year, bud position, and their interactions on yield, total cluster number, cluster weight and fruit quality (soluble solids, pH, and total acid) in 2018, 2019, and 2020 growing seasons. ANOVA based on three replicate vines for each cultivar in each treatment and year.

	Yield(g)/ Vine (P^z-value)	Total cluster number/vine (P-value)	Cluster Weight (P-value)	soluble solids(%) (P-value)	pH (P-value)	Total acid (P-value)
Treatment (T)	0.000	0.000	0.000	0.000	0.000	0.000
Cultivar (C)	0.000	0.000	0.000	0.000	0.000	0.000
Y (Year)	0.000	0.000	0.000	0.000	0.000	0.000
P (Position)	0.027	0.016	0.000	ns	0.000	0.007
T x C	0.000	0.000	0.000	0.000	0.000	0.000
T x Y	0.000	0.000	0.075	0.000	0.000	0.000
C x Y	0.000	0.000	0.000	0.000	0.000	0.000
T x P	ns	ns	0.001	ns	0.000	ns
C x P	ns	0.000	0.000	0.004	0.002	0.000
Y x P	ns	ns	0.000	ns	0.001	0.022
T x C x Y	0.000	0.000	0.000	0.000	0.000	0.000
T x C x P	ns	0.037	0.002	0.000	0.008	0.000
T x Y x P	ns	ns	0.002	0.000	0.000	0.003
C x Y x P	ns	ns	0.000	ns	0.000	0.000
T x C x Y x P	ns	ns	0.001	0.000	0.000	0.000

[z]Statistical analysis was made by ANOVA with main effect of treatments throughout 3-year evaluation. If important main effects were detected among treatments, mean values were separated by Tukey's HSD with $P < 0.05$. ns = not significant.

Table 2. Main effects of pruning treatments for each cultivar on yield, total cluster number and cluster weight evaluated in Brookings in 2018, 2019, and 2020 growing seasons. Values for treatments for each cultivar are means across years and positions of three replicate vines for each treatment in each year.

	Yield(g)/Vine (mean ± SE)	Total cluster number/Vine (mean ± SE)	Cluster Weight (mean ± SE)
Brianna			
SP[z]	1715 ± 59.7 b	16.5 ± 0.5 a	113 ± 4.8 ab
SC	2007 ± 33.8 a	17.3 ± 0.3 a	116 ± 2.7 a
SPSC	1411 ± 46.7 c	13.1 ± 0.4 b	104 ± 3.7 b
Frontenac			
SP	1513 ± 49.0 b	15.6 ± 0.2 b	101.4 ± 3.4 a
SC	1099 ± 48.0 c	11.8 ± 0.2 c	89.1 ± 3.4 b
SPSC	1915 ± 43.0 a	18.0 ± 0.2 a	98.5 ± 3.0 a
La Crescent			
SP	1049 ± 70.3 b	14.1 ± 0.6[ns]	56.5 ± 4.1 b
SC	1323 ± 55.3 a	13.0 ± 0.5	81.9 ± 3.2 a
SPSC	1199 ± 43.1 ab	13.9 ± 0.3	77.0 ± 2.5 a
Marquette			
SP	1613 ± 23.2 a	23.6 ± 0.2 a	76.2 ± 2.3 a
SC	1651 ± 26.4 a	23.8 ± 0.3 a	67.2 ± 2.6 b
SPSC	1419 ± 21.7 b	17.6 ± 0.2 b	75.4 ± 2.2 a

[z]Statistical analysis was made by ANOVA with main effect of treatments throughout 3-year evaluation. If important main effects were detected among treatments, mean values were separated by Tukey's HSD with $P < 0.05$. ns = not significant.

Table 3. Main effects of spur (SP), short cane (SC), and spur plus short cane (SPSC) pruning treatments for each cultivar on soluble solids, pH, and total acid evaluated in Brookings in 2018, 2019, and 2020 growing seasons. Values for three treatments for each cultivar are means across years and bud position.

	soluble solids (%) (mean ± SE)	pH (mean ± SE)	Total acid (mean ± SE)
Brianna			
SP[z]	14.8 ± 0.1 b	3.19 ± 0.0 b	11.3 ± 0.1 b
SC	15.8 ± 0.1 a	3.26 ± 0.0 a	11.5 ± 0.0 b
SPSC	14.7 ± 0.1 b	3.28 ± 0.0 a	12.0 ± 0.1 a
Frontenac			
SP	22.1 ± 0.1 a	3.08 ± 0.0 ab	11.4 ± 0.7 b
SC	20.7 ± 0.1 c	3.10 ± 0.0 a	11.8 ± 0.8 a
SPSC	21.6 ± 0.1 b	3.06 ± 0.0 b	11.9 ± 0.8 a
La Crescent			
SP	21.9 ± 0.1 a	3.16 ± 0.0 ab	11.4 ± 0.1 a
SC	20.7 ± 0.1 b	3.11 ± 0.0 b	12.8 ± 0.1 a
SPSC	21.0 ± 0.1 b	3.22 ± 0.0 a	11.4 ± 0.0 b
Marquette			
SP	22.4 ± 0.1[ns]	3.35 ± 0.0 b	9.43 ± 0.0 b
SC	22.7 ± 0.1	3.41 ± 0.0 a	9.19 ± 0.1 b
SPSC	22.5 ± 0.1	3.31 ± 0.0 c	10.13 ± 0.0 a

[z]Statistical analysis was made by ANOVA with main effect of treatments throughout the 3-year evaluation. If important main effects were detected among treatments, mean values were separated by Tukey's HSD test. Different letters demonstrate significant differences at $P < 0.05$, n = 3. ns = not significant.