The Effect of Canopy Management on Yield and Fruit Composition of Noiret Wine Grape (*Vitis* sp.)

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Abstract

Noiret is a complex interspecific hybrid red wine grape (*Vitis* sp.) released by Cornell University in 2006 for cold-climate growers. Shoot thinning (ST), before capfall, to 15 shoots per meter and basal leaf removal (BLR) to 75% visual exposure of pea-sized berries were performed separately and in combination (ST/BLR) and tested versus control vines of field-grown vertically shoot positioned Noiret grapevines. Vine size was excessive in this experiment and crop load ratios (yield/pruning weights) ranged from 1.9 to 2.2. Using point quadrat analysis, it was determined that BLR and ST/BLR improved cluster exposure versus ST, but there were no differences from the control. Fruit from all treatments was similar in soluble solids, titratable acidity, and pH except shoot thinning which lowered the pH to 3.76 versus 3.84 in the control. Canopy management treatments did not affect total phenolics, flavonols, tartaric esters, anthocyanins, color density, or hue. This work shows that the canopy management tools used were minimal in their effects, likely due to the excessive vigor of the vines.

Introduction:

Hybrid grapes are a permanent and indispensable component of modern viticulture. Grape breeding is an active area of research with prolific programs like those at the University of Minnesota and the New York State Agricultural Experiment Station, Cornell University.

In 2006 Cornell released three new cultivars, including a red variety, Noiret (*Vitis* sp.). Noiret is a complex interspecific hybrid red wine grape from the cross of Steuben X NY65.0467.08 (Chancellor X NY33277) and has a diverse background of *V. vinifera*, *V. labrusca*, and *V. rupestris* (Reisch et al 2006). Noiret represents the next generation of interspecific hybrids because it displays *vinifera* like tannins with fine peppery and berry aromas without the 'foxy' hybrid aroma. Additionally, Noiret retains many of the disease resistances and the cold hardiness that are sought after in hybrids (Reisch et al 2006).

Since Noiret is promising both viticulturally as a cold hardy, disease resistant grape, and enologically as a *vinifera*- like wine, it has captured the interest of many growers in the northeast. However, there has been little research to provide guidance about the appropriate viticultural practices for this new cultivar. Being noted for strong vigor and large leaves (Reisch et al 2006), it is essential that research based recommendations for optimizing vine productivity, fruit composition, and winter hardiness be made. Thorough knowledge of the effects of canopy management on fruit composition of Noiret will enable growers to produce consistently high quality grapes, leading to improved wine quality.

The impacts of canopy management on cluster microclimate (and hence fruit quality) are often quantified using Point Quadrat Analysis (PQA) (Smart and Robinson 1991). PQA expresses the vigor of a vine through the fruiting zone, where increased leaf layer numbers (LLN) correlate inversely with light penetration to the fruit (Vanden Heuvel et al 2004; Dokoozlian and Kliewar 1995).

Reduced LLN in a vine may have many beneficial impacts. The photosynthetic efficiency of the canopy may improve, as shaded leaves have been shown to act as net carbohydrate sinks (Vanden Heuvel et al 2002). Removal of these sinks may allow more carbon to be shunted towards production of flavor and aroma compounds. In addition, having leaves in a higher light environment leads to synthesis of UV-C defenses (Bonomelli et al 2004), and that may explain a variety of results noted in the literature: greater anthocyanins and phenolics in Sangiovese harvested after leaf removal (Poni et al 2006), more red pigment in Cynthiana after leaf removal (Main and Morris 2004), and additional phenols and anthocyanins in Cabernet Franc after shoot thinning (Reynolds 2005). Additionally, the increased light interception (and hence increased temperature) of the berry can lead to enhanced biochemical processes such as malic acid metabolism (Lakso and Kliewar 1978); a worthy explanation for the decreased titratable acidity and increased pH in unshaded Cabernet Sauvignon (Bergqvist et al 2001; Morrison and Noble 1990). Reduced drying time in more open canopies can result in inhibition of diseases like *Botrytis cinerea* Pers. on numerous varieties from Riesling (Zoecklein et al 1992) to Seyval Blanc and Vignoles (English et al 1993).

Growers have two widely accepted practices for reducing LLN during the growing season: shoot thinning (Reynolds et al. 2005) and basal leaf removal (Reynolds et al 1996). Though both can serve as valuable tools to reduce LLN and improve fruit composition, hybrids in New York tend to be grown with a minimalist approach for canopy management, and growers have to date failed to widely implement either practice (J. Vanden Heuvel, personal communication).

The goal of shoot thinning is to reduce canopy density, although the ideal shoot number per meter of row is dependent on cultivar and site (Reynolds et al 2005). Shoot thinning helps to establish balance after the grower has safely diagnosed the variability that comes with late frosts, blind nodes, and prolific non-count buds (Morris et al 2004). When shoot spacing is optimized, the vine is more efficient at radiation interception (Smart 1988). Appropriate shoot spacing can improve fruit composition in vinifera (Reynolds et al 1994; Smart 1988; Reynolds et al 2005). For interspecific hybrids, shoot thinning improved soluble solids in Chancellor by 5% over a 3-year average (Morris et al 2004). The impact of shoot thinning on fruit composition of Noiret is unknown.

Basal leaf removal is a tool used by some grape growers to reduce shading in the fruiting zone of the vine, particularly on vertically shoot positioned (VSP) trained vines. In practice, anywhere from 50-100% of leaves on the lowest five nodes of the vine are removed to improve cluster light interception. Basal leaf removal has enhanced fruit composition with vertically shoot positioned *vinifera* (Reynolds et al 1996; Zoecklein et al 1992; Poni et al 2006) and with downward trained Cynthiana, an interspecific hybrid, where soluble solids, pH, and TA were improved by 4, 3, and 8%, respectively (Main and Morris 2004). The effect of basal leaf removal has not been studied on interspecific hybrids in NY.

In summary, canopy management practices, such as leaf removal and shoot thinning, are proven tools to improve fruit composition, particularly in vigorous cultivars. When growers can control LLN, they enhance the microclimate for the cluster to improve fruit composition and avoid disease. The objective of this research is to determine the impact of shoot thinning and/or basal leaf removal on canopy microclimate and fruit composition of VSP-trained Noiret.

Materials and Methods:

Vines and Vineyard:

Five-year-old own-rooted Noiret vines (*Vitis* sp.) were located at a private vineyard on the west side of New York's Keuka Lake (42°35'N, 77°09'W). Rows ran north/south on an east facing slope of Chenango gravelly loam (National Cooperative Soil Survey 2004) with drainage tile running east/west. Vines averaged about 0.9kg of prunings per vine in spring 2007 according to the vineyard manager and had been pruned to establish cordons. Vines were a mixture of cordon and cane-pruned vertically shoot positioned (VSP)-trained vines in 1.83m x 2.74m spacing, with four vines per panel. All vines, including the controls, were maintained to the industry standard for hybrids in regards to desuckering, top-hedging, and pest control. Shoot positioning was performed by vineyard staff. Resident vegetation, which was a mix of grasses and weed species, grew in row middles, then straw mulch was applied in every other row by the grower. An herbicide strips were maintained underneath the vines.

Four canopy management practices were compared in this study: shoot thinning to 15 shoots per meter, leaf removal through the fruiting zone pre-veraison, a combination of shoot thinning and leaf removal, and a control. Treatments were implemented in a RCBD with four replications across six rows of own-rooted Noiret. Each treatment replicate consisted of ten panels, two of which were randomly selected per replicate as data collection panels.

Shoot thinning

Shoot thinning (ST) was applied 31 May, 2007 before the inflorescences underwent capfall. All secondary and tertiary shoots were hand removed and remaining shoots were thinned evenly, as necessary, to 15 shoots/m. Additionally, all vines were desuckered to 1 or 2 suckers for potential trunk renewals.

Leaf Removal

Basal leaf removal (BLR) was applied on 13 July, 2007 while berries were pea sized (6 to 8mm). In simulating grower applied hand leaf removal, leaves and laterals in about the first 5 nodes were hand removed from both sides of the trellis for approximately 75% visual cluster exposure.

Point Quadrat Analysis

Point quadrat analysis (PQA) was performed with a 1 meter, sharp, thin metal rod inserted horizontally into the middle of the fruiting zone via the procedure outlined by Smart and Robinson (1991). PQA was performed 3 times during the 2007 season, on 20 July before the clusters closed, 16 August at about 30% veraison, and again on 21 August, after the vines were top-hedged a second time.

Yield Components

All vines were hand harvested on 2 October, 2007 one day prior to commercial harvest of the site. Yield/vine was measured with an ElectroSamson digital hanging scale (Salter Brecknell, Fairmount, MN) and the number of clusters/vine was recorded. Cluster weight was determined by dividing vine yield by cluster number. A randomly selected 15-cluster sample was removed from each data panel. The samples were stored in plastic bags at 3^{o}C for three days, then transferred to a -40^{o}C freezer. From each sampling of 15 clusters, a subsample of 50 berries was selected randomly and weighed shortly after removal from the -40^{o}C freezer, while berries remained frozen. Pruning weights were measured in the field during Spring 2008.

Berry Composition

Frozen clusters were hand destemmed (8 October 2007) allowing for homogenization of berries prior to analysis. Subsamples of 100 berries were warmed for 1 hour in an 80^{o}C water bath, then left at room temperature to cool for 2 hours. Berries were juiced by hand and tested for soluble solids, pH, and titratable acidity. Soluble solids, reported as degree Brix, were found using a Reichert r2 hand-held refractometer (Reichert Analytical Instruments, Depew NY). The pH and the titratable acidity, as g tartaric/L, were determined using an Metrohm 809 Titrando autotitrator (Brinkman Instruments, Inc, Westbury, NY) according to the standard methods of Amerine and Ough (1980). The titratable acidity was quantified by titrating to pH 8.2 with 0.1N NaOH.

Concentration of total phenolics, flavonols, anthocyanins, and tartaric esters were quantified using a spectrophotometric method modified from Girard et al (2002). Subsamples were transferred from -40^{o}C to 3^{o}C to thaw overnight. Skins were removed from a 50g sample of berries, blotted dry and transferred to an Erlenmeyer flask. Ten mL of a 50 methanol: 1.5 formic acid: 48.5 distilled water mix was added to the skins and they were stirred overnight while covered by foil. A five mL portion of the extract was decanted off and mixed with 15mL of 10% ethanol. Two hundred fifty µL of the resulting mix was added to a test tube and diluted with 250µL of 0.1% HCL in 95% ethanol and 4.55mL of 2% HCl. The solution was mixed and allowed to sit for 15 minutes before reading the absorbances at 280nm (for total phenolics), 320nm (for tartaric esters), 360nm (for flavonols), and 520nm (for anthocyanins) using a Thermo Scientific Genesys 10uv spectrophotometer (Thermo Fisher Scientific, Inc. Waltham, MA). The standards used were gallic acid in 10% ethanol for total phenolics, caffeic acid in 10% ethanol for tartaric esters, quercetin-3-glucoside in 95% ethanol for flavonols, and malvidin chloride in 18 parts 2%HCL, 1 part 0.1HCl in 95% ethanol and 1 part 10% ethanol for anthocyanins.

Color density and hue/tint were estimated spectrophotometrically using the method described by Girard et al (2002). Berries were pressed by hand and 3mL of juice was centrifuged at 4^{o}C for 10 minutes at 10,000g. The supernatant and 3.5mL of distilled water was filtered through a 0.45 µm Acrodisc LC PVDF syringe filter. The sample absorbances were read at 420, 520, and 700nm. Color density and hue/tint were calculated as:

$$\text{Color density} = (A_{520}\text{-}A_{700}) + (A_{420}\text{-}A_{700})$$

and

$$\text{hue/tint} = (A_{420}\text{-}A_{700})/(A_{520}\text{-}A_{700})$$

Statistical Analysis

Analysis of variance was performed for each response variable using the SAS statistical package v.8 (SAS Institute, Cary, NC). Least significant differences among treatments were calculated. The Type I error rate was set at 0.05 for all statistical tests.

Results

Yield Components. Yield and yield components did not significantly differ among treatments (Table 1). Yields per vine were not different among treatments (Table 1). Clusters per vine ranged from 22.2 to 25.8 but was not significantly affected by treatment, while cluster weight was approximately 0.17 kg, and berry mass ranged from 1.7-1.8 g (Table 1). Pruning weights were similar similar among treatments, averaging approximately 1.9 kg per vine (Table 1). There was a narrow range of crop loads (kg fruit/ kg prunings) across treatments, 1.9 to 2.1 with no statistical significance in the differences (Table 1).

Berry Composition. Generally all treatments failed to affect berry composition (Table 2). Brix ranged from 17.4 to 18.4 but differences were not significant among treatments (Table 2). Shoot thinning lowered berry pH by 2% compared with the control, while other treatments did not differ significantly (Table 2). Titratable acidity differences were not significant (Table 2).

Differences in phenolic composition of the berries were not significant among treatments (Table 3). Total phenolics were not significantly different among treatments (Table 3). Tartaric esters ranged from 48.0 to 55.8 mg caffeic acid/g skin, but differences were not significant (Table 3). All treatments averaged total flavonols around 0.8mg quercetin/g skin (Table 3). Anthocyanins ranged from 6.5 to 8.1 mg malvidin/g skin and color density ranged from 8.4 to 10.3 but neither range was significant (Table 3). Hue was 0.6 in all treatments (Table 3).

Canopy Characteristics

Results of canopy characterization of vines in the treatments are shown in Tables 4 and 5. Data for point quadrat analysis performed on 20 July have been omitted. The data panels tested on that date were not representative of the replicate panels used for harvest, as replicate panels were moved after shoot positioning failed in many panels due to the procumbent growth habit of Noiret. Catch wires were moved too high based on current shoot length causing many shoots to grow under and downwards, cancelling the treatments. Prior to the second hedging event, PQA on 16 August revealed an insignificant range of LLN between treatments that spanned from 3.3 to 3.8 (Table 4).

Leaf and cluster exposure differences were not significant among treatments until after hedging (Table 4). The BLR and ST/BLR treatments both showed a 334 and 296% increase, respectively, in cluster exposure compared to the ST treatment, but neither was different from the control (Table 5). The cluster exposure increase was probably due to the lowered LLN in the BLR treatment, although the ST/BLR did not have a significantly lower LLN (Table 5). Treatments did not improve leaf microclimate (Tables 4 and 5).

Discussion

Clearly excessive vigor was an issue in this vineyard. Although top-hedging was performed twice during the season, the shade of canopy overgrowth interfered with treatments. Based on the work of Reynolds and Wardle (1989), top-hedging was done during lag phase (pea-sized berries) to reduce vigor and maintain the treatments, but growth continued forcing a second application of light hedging during mid-veraison, where more severe hedging has been shown to adversely affect overwintering (Reynolds and Wardle 1989). Hedging of such vigorous vines may have exacerbated shading in the fruiting zone due to subsequent emergence of laterals (Reynolds and Wardle 1989).

Pruning weights were excessive, sometimes over 4kg/vine (data not shown). Previous work with Noiret had pruning weights only as high as 1.5kg/vine, while vines produced 5.6kg of fruit, a crop load balance of 3,7 (Reisch et al 2006). The high pruning weights left the vines with especially low crop load ratios, all below 3. Bravdo and colleagues (1984, 1985) suggest that crop loads should range from 3 to 10 for optimal quality, while Smart and Robinson (1991) suggest a narrower range of 5 to 10 , although these values were suggested for vinifera vines; crop loads for hybrids should likely be higher (Reynolds and Wardle 1994). The low crop load ratios in this experiment would have induced a vegetative growth cycle, where shoots were stimulated by the under cropping to undergo excessive growth (Smart and Robinson 1991). The high LLNs of all the treatments are consistent with this observation. Ideal LLNs are described as 1-1.5, while the lowest LLN seen in this study was 2.6 and most LLNs were over 3 (Smart and Robinson 1991). By the end of the season, shoots in all treatments were observed to be growing over the top catchwire and drooping down to add to the LLN in the fruiting zone.

The high LLN has serious implications for next season as they indicate poor shoot light microclimate, which has been documented as a cause for low bud fruitfulness (Sanchez and Dokoozlian 2005). Poor cropping next season will further decrease the crop load ratios and induce a greater vegetative response.

Yield was not affected by any of the canopy management treatments, although previous work has often equated shoot thinning to reduced yields through reduced cluster numbers (Reynolds et al 1994; Naor et al 2002; Morris et al 2004). Yet, some work thinning Pinot Noir and Cabernet Franc at similar phenology also reported no effect on yield (Reynolds et al 2005). In that study, yields were maintained via compensation as increased cluster weights. In previous experiments, BLR has not affected yield in *vinifera* (Reynolds et al 1996; Zoecklein et al 1992) or in hybrids (Main and Morris 2004).

No treatment created an ideal LLN situation or appropriate crop load ratio, and the subsequent shading created an erratic effect on composition. This trend was reflected in the phenolic composition, where even a 30% increase of total phenolics in the ST/BLR treatment was not significant. Increasing phenolics is important for wine color stability (Robinson et al 1966), and plays a role in sensations like roughness and puckering that contribute to overall mouthfeel (Cliff et al 2007). There are also implications that adding to total phenolic content will increase the health benefits of finished wine (Ho et al 1992).

The only compositional change was lowered pH in the ST treatment, although titratable acidities were low as compared to previously reported values for Noiret (Reisch et al 2006). Lowered shoot densities have been equated to increased pH (Reynolds et al 2005). However, it has also been noted on Pinot Noir and Cabernet Franc that shoot thinning before bloom can induce greater lateral development, expressed as increased leaf area per shoot (Reynolds et al 2005). The increased LLN of the ST treatment compared with the control suggests that such lateral development took place through the fruiting zone of the Noiret. The subsequent shading left berries 14% more shaded than the control by 20 August. With increased shading, berries should remain cooler, leading to lower pH (Bergqvist 2001) due to decreased malic acid metabolism (Lakso 1978).

Disease pressure was especially low in the 2007 growing season, due to higher than normal growing degree days and lower than normal levels of rainfall. At harvest, no significant signs of disease were noted on the clusters. As a result, disease incidence differences were not measured between treatments and the general inference was that Noiret's genetic resistances in combination with the favorable growing conditions and the commercial spray regiment prevented disease across all treatments.

Conclusion

This study draws attention to the necessity of vine balance. Although previous experimentation has shown benefits after the application of shoot thinning or basal leaf removal, neither treatment nor the combination of the two was able to accomplish significant differences from the control. In fact, shoot thinning decreased berry quality by decreasing the pH. A second, balanced vineyard site may have shown more promise for the treatments with VSP Noiret. Under the current conditions, it is worthwhile to consider wider vine spacing or a split canopy system, like Scott Henry or Geneva Double Curtain trellising, which has proven successful in increasing canopy length per vine and controlling vine vigor in the hybrid Chancellor (*Vitis* sp.) (Reynolds 1995). Growers may also avoid applying mulch, thus maintaining the devigorating competition inherent of alley ground covers in grape (Celette et al 2005). For future plantings of Noiret, a devigorating rootstock like Riparia Gloire should be considered (Vanden Heuvel 2004).

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Table 1 Effect of Basal Leaf Removal (BLR) and Shoot Thinning (ST) on yield of Noiret

Treatment	Clusters/ Vine	Weight/ Cluster (kg)	Yield/ Vine(kg)	Berry Mass (g)	Pruning Weight (kg)	Cropload Index[b]
Control	25.8A[a]	0.17A	4.0A	1.8A	1.9A	2.2A
ST	25.8A	0.16A	4.1A	1.7A	2.0A	2.1A
BLR	23A	0.17A	3.7A	1.8A	1.9A	2.0A
ST/BLR	22.2A	0.17A	3.6A	1.7A	1.9A	1.9A

[a] Means followed by different letters are significantly different, $p \leq 0.05$
[b]Yield per vine/ pruning weight

Table 2 Effect of Basal Leaf Removal (BLR) and Shoot Thinning (ST) on berry composition of Noiret

Treatment	Brix	pH	Titratable Acidity (g/L tartaric acid)
Control	17.4A[a]	3.8A	8.5A
ST	18.4A	3.8B	8.7A
BLR	17.7A	3.9A	8.9A
ST/BLR	18.3A	3.8AB	8.0A

[a] Means followed by different letters are significantly different, $p \leq 0.05$

Table 3 Effects of
Basal Leaf Removal (BLR) and Shoot Thinning (ST) on the Phenolic Composition and Color Parameters of Noiret berries

Treatment	Total Phenolics (mg gallic acid/g skin, 280nm)	Tartaric Esters (mg caffeic acid/g skin, 320nm)	Flavonols (mg quercetin/g skin, 360nm)	Anthocyanins (mg malvidin/g skin, 520nm)	Color Density	Hue
Control	128.3 A[a]	48.0A	0.7A	6.5A	8.8A	0.6A
ST	153.8A	51.9A	0.8A	7.3A	9.0A	0.6A
BLR	154.5A	51.4A	0.8A	7.1A	8.4A	0.6A
ST/BLR	167.4A	55.8A	0.9A	8.1A	10.3A	0.6A

[a] Means followed by different letters are significantly different, $p \leq 0.05$

Table 4 Effects of Basal Leaf Removal (BLR) and Shoot Thinning (ST) on Canopy Characteristics of Noiret vines as assessed by point quadrat analysis on August 16, 2007 (before hedging)

		Leaves		Clusters	
Treatment	Leaf layer number	Sun exposed (%)	Shaded (%)	Sun exposed (%)	Shaded (%)
Control	3.8 A[a]	53.0A	47.0A	12.5A	87.5A
ST	3.8A	52.4A	47.6A	7.1A	92.9A
BLR	3.3A	58.5A	41.5A	16.5A	83.5A
ST/BLR	3.4A	58.1A	41.9A	13.4A	86.6A

[a] Means followed by different letters are significantly different, $p \leq 0.05$

Table 5 Effects of Basal Leaf Removal (BLR) and Shoot Thinning (ST) on Canopy Characteristics of Noiret vines as assessed by point quadrat analysis on August 21, 2007 (post hedging)

		Leaves		Clusters	
Treatment	Leaf Layer Number	Sun exposed (%)	Shaded (%)	Sun exposed (%)	Shaded (%)
Control	3.0 AB[a]	63.7A	36.3A	18.7AB	81.3AB
ST	3.4A	58.2A	41.8A	7.3B	92.7A
BLR	2.6B	68.9A	31.1A	31.8A	68.2B
ST/BLR	3.1AB	60.6A	39.5A	28.9A	71.1B

[a] Means followed by different letters are significantly different, $p \leq 0.05$