Journal of the American Pomological Society 70(1): 2-15 2016

Effect of Shoot and Cluster Thinning on Vine Performance, Fruit and Wine Quality of 'Blanc Du Bois'

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Additional index words: cropload adjustment, freeze damage, consumer sensory panel, *Vitis* spp.

Abstract

'Blanc Du Bois' exhibits resistance to Pierce's Disease (*Xylella fastidiosa*) (Wells et al. 1987) and is cultivated in the southeastern United States for wine production. Yet, little research has been conducted on horticultural practices to optimize yield and wine grape fruit quality in a subtropical climate. Shoot thinning (ST) and cluster thinning (CP) were used to optimize vine balance in five-year old 'Blanc Du Bois' vines. Shoot thinning (ST) or no shoot thinning (NST) in addition to cluster thinning (one cluster [CP1], two clusters [CP2] or three clusters [CP3] per shoot) were applied, with NST + CP3 serving as a grower control and industry standard. Vegetative measurements and fruit quality were measured in both years. In 2013 alone, vines with NST + CP1 showed higher photosynthetic rates compared to other treatments. In the other parameters measured no significant interaction was observed between shoot thinning and cluster thinning. Therefore significance was only observed when ST and CP were analyzed as main effects. Yield per vine increased in NST vine while shoot thinning significantly lowered juice pH. Cluster thinning increased soluble solids in CP1, but at the cost of total yield/vine, reducing overall yield. Neither shoot nor cluster thinning affected any vegetative measurements. Freeze damage in 2013 caused shoot damage and reduced fruit yield and quality, making treatment effects difficult to separate from vine damage. Thus, additional research needs to be conducted to understand the impact of these cultural practices on vine growth and fruit quality in 'Blanc Du Bois'.

'Blanc Du Bois', a Florida hybrid (*Vitis* spp.), has gained popularity throughout the southeastern United States for its good grape and wine quality (Halbrooks, 1986; Westover, 2012). 'Blanc Du Bois' is a moderately vigorous grapevine, with excellent resistance to Pierce's Disease, caused by *Xylella fastidiosa,* and produces white bunch grapes (Mortensen, 1987). Previous research of wine sensory components indicated that Florida 'Blanc Du Bois' wines had lower volatile amounts and exhibited phenolic/rubber and greenwood/stemmy flavors when compared to wines produced in similar climates such as Louisiana and Texas (Dreyer, et al., 2013). In Florida, the major challenges for optimizing vine and berry growth are high daytime temperatures that promote excessive vigor and disease, and high nighttime temperatures that limit sugar accumulation in the berries.

Optimizing vine balance between vigorous vegetative growth and high yields is essential to produce high quality wine in Florida. Cultural practices, such as shoot thinning, can be used to improve the balance between shoot growth and crop load to enhance fruit quality. Dense foliage alters the canopy microclimate, and can result in increased temperature and humidity due to a reduction in air movement. These conditions promote fungal diseases and have negative effects on fruit quality, reducing sugars and yield in the current and following year (Smart and

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Sinclair, 1976; Smart, 1980). Ideal canopy temperatures should be in the range of 20°C to 30°C to optimize photosynthesis, water transport and fruit ripening (Buttrose, 1970; Chaves, 1981). Grapes from warmer climates tend to produce wines with less aroma and green-fruity flavor contrary to cooler areas (Coombe, 1987; Reynolds et al., 1994). In addition temperatures higher than 30°C causes a decline in soluble solids therefore fruit quality decreases (Buttrose et al., 1971). In Florida, high nighttime temperatures (>20°C) and high humidity often occur due to the subtropical climate. As a result, berries have lower soluble solids since accumulated sugars are used in respiration (Kliewer and Lider,1968).

Shoot thinning improves the canopy light environment, which is a key requirement in flower bud formation, fruit color, phenolic development, and sugar accumulation (Buttrose,1969; May et al.,1976; Shaulis,1980; Sommer et al., 2000). Vines with excess shading and low light levels produce fruit with low soluble solids and pH (Kliewer and Lider, 1970; Spayd et al., 2002). However, shoot thinning of 'Marechal Foch', 'Barbera' and 'Norton', reduced yield and cluster number, although berry weight increased (Bernizzoni et al., 2011, Jogaiah et al., 2013; Sun et al., 2011).

Cluster thinning can improve carbohydrate distribution in grapevines by reducing the crop load and the sink demand (Naor et al., 2002; Vasconcelos and Castagnoli, 2000). Combined with shoot thinning, cluster thinning can improve reproductive/vegetative balance in grapevines. In 'Riesling', higher shoot density and higher crop load increased yield, clusters per vine and pH; whereas cluster weight, berries per cluster, berry weight, and soluble solids all decreased (Reynolds et al., 1994). 'De Chaunac' and 'Corot Noir' responded similarly (Fisher et al., 1997; Sun et al., 2012). Conversely, fruit quality was not consistently affected when cluster thinning were applied to 'Seyval Blanc' (Kaps and Cahoon, 1989). In a subtropical climate, shoot trimming and cluster thinning of 'Merlot' and 'Cabernet Sauvignon' decreased yield but did not affect fruit soluble solids (Mota et al., 2010).

There is little information on the use of shoot and cluster thinning to optimize fruit and wine quality of 'Blanc du Bois' in a subtropical climate. The hypothesis is that these canopy management techniques will reduce vine vigor and optimize vine balance leading to an ideal crop load for subtropical climates. Therefore the objectives were to investigate the impact of shoot thinning and varying levels of cluster thinning, individually and in combination on vine performance and fruit quality of 'Blanc Du Bois' in Florida.

Materials and Methods

Shoot and cluster thinning treatments were applied to vines located in Clermont, FL (28.5° lat., 81.7° long.) during the 2013 and 2014 growing seasons. The soil is classified as a Candler fine sand (Hyperthermic, uncoated Lamellic Quartzipsamments), with excellent drainage. Five-year-old 'Blanc Du Bois' vines were planted in rows oriented north-south with 7 m between rows and 2 m between vines. Vines were trained to a bilateral cordon with two catch wires to direct shoot growth upward. All vines were drip-irrigated, spur pruned to 80 buds per vine, and fertilized using standard practices (Andersen et al., 2001) by vineyard staff. The experiment was a randomized complete block with 8 replicate and each replicate was composed of 6 treatments. Each treatment was applied to a panel of 3 vines and data were collected from the middle vine in each treatment when possible. Three levels of cluster thinning, one cluster (CP1), two clusters (CP2) or three clusters (CP3) per shoot, were combined with shoot thinning (ST) or vines with no shoot thinning (NST). The combination of shoot thinning (ST) and cluster thinning was arranged as 2 x 3 factorial, giving a total of six treatment combinations.

Shoot thinning treatments were applied when shoots reached stage 12-15 (~10 cm long) according to the modified Eichorn-Lorenz (E-L) scale (Coombe, 1995). Only non-count shoots were removed. In 2013, shoot thinning was applied on 29 Mar. and 9 Apr. due to a delay in shoot phenology from a freeze event on 4 Mar. 2013. In 2014, vines were shoot thinned on 26 Mar. 2014. Cluster thinning was applied when clusters were at stage 31 (pea-sized stage; approx. 7 mm in diameter) on the modified E-L scale. Distal clusters were removed. Cluster thinning was applied on 3 May, 7 May, and 15 May 2013 due to delays in berry phenology as a result of the freeze event on 4 March 2013, and on 6 May 2014.

Vegetative measurements

Beginning the last week of March in both years, shoot length was quantified by tagging a randomly selected shoot per vine, and measured monthly. A measuring tape (1.5 m, Singer Sewing Company, LaVergne, TN) was used to measure each shoot from the base of the shoot to the apical meristem. When a shoot was broken or damaged, another shoot with similar vigor was tagged and measured for the remainder of the season.

Leaf area was estimate from non-destructive leaf length and width measurements. Briefly, 18 shoots were collected from vines adjacent to experimental vines on 5 May 2013 and 21 May 2014. Collected shoots were transported in a cooler to the laboratory for leaf area measurements. For each individual shoot, total length (cm) was measured. Beginning at the apical portion of the shoot, the width and the length of each leaf was measured and recorded. Subsequently, each leaf was scanned using a leaf area meter (LI- 3100C, LI-COR, Lincoln, NE) and the leaf area recorded. These data were then used to fit a regression model to estimate leaf area via non- destructive measurements of leaf width or length on experimental vines. Leaf area measurements were recorded on 16 Jun. 2013 and 20 Jun. 2014.

A ceptometer (Decagon Devices, Pullman, WA) was used to calculate leaf area index (LAI). Measurements were recorded by taking a reading above and below the canopy in the fruit zone, parallel to the cordon to obtain the LAI. One vine per treatment was measured in each treatment on 15 May 2013 and 20 May 2014.

Single-leaf photosynthesis (Pn) was measured before (31 May 2013, 27 May to 11 Jun. 2014) and after harvest (9 Aug. 2013 and 9 Jul to 25 Jul. 2014). A portable gas exchange system (Licor 6400XT; LI-COR Inc., Lincoln, NE) was used to measure net photosynthesis (Pn). A most recently, fully expanded leaf, located in the middle of the shoot was used to measure Pn. Instrumental settings were as follows: CO_2 level was 400 µmol CO_2 m^{-2} s^{-1}, flow rate was 500 µmol m^{-2} s^{-1} and light was 1000 µmol photons m^{-2} s^{-1} photosynthetically active radiation (PAR).

Fruit measurements

Data vines were harvested on 24 Jun. 2013 and 23 Jun. 2014 and total yield (kg) recorded for each data vine. Three random clusters per vine were transported in a cooler with ice to the laboratory for analysis of cluster and berry weight, and berry number per cluster. A 100-berry subsample was weighed on a laboratory scale (PL3001 S, Mettler Toledo LLC, Columbus, OH) and mean berry weight was calculated. In both years, samples were kept at 2°C and analyzed within 48 h after harvest.

Berries were blended for 5 min in a Kitchen Aid 2-Speed Immersion Blender (St. Joseph, MI) to extract juice for soluble solids, pH, and titratable acidity (TA) analysis. The mixture was transferred to a 30 mL centrifuge tube (Nalgene™, Thermo Scientific, Inc., Waltham, MA) and centrifuged for 20 min at 10,000 rpm (Sorvall Legend XTR, Thermo Scientific, Inc., Waltham, MA) to separate solids from the juice. The juice was transferred to a 15 mL tubes and stored in a freezer (-20°C) until the day of analysis. Samples were thawed at room temperature and analyzed for juice soluble solids, TA and pH.

Soluble solids were measured using a hand held digital pocket refractometer (PAL-1, ATAGO, Bellevue, WA) with automatic temperature compensation. Titratable acidity was measured using an autotitrator and calibrated before use (DL15 Autotitrator, Mettler Toledo, Columbus, OH). Juice samples (6 ml) were added to 50 mL of DI water in a 100 mL beaker to measure pH with a pH probe after vortexing to ensure sample was homogeneous (DL15, Mettler Toledo, Columbus, OH). Titratable acidity was determined using 0.1 N NaOH to an end point of pH 8.2. Titratable acidity is expressed as a percent tartaric acid.

Wine and sensory evaluation

In 2014 only, wine evaluations were conducted. Grapes were harvested on 24 June 2014 and placed in cold storage (2°C) overnight. Grapes were de-stemmed and crushed using a manual crusher and 50 ppm potassium metabisulfite was added. Grapes were pressed in a bladder press and juice was collected in a 15 L bucket. The juice was allowed to settle overnight at 2°C. The clarified juice was adjusted to 20% soluble sugars using sucrose and inoculated with wine yeast (Red Star Cuvee) at 0.25g/L. The juice was allowed to ferment to dryness in glass containers at 13°C. The wines were then racked twice and cold stabilized at 2°C for 3 weeks. After cold stabilization, the wines were treated with 25 ppm potassium metabisulfite and stored at 13°C for about 3 months. Wines were then bottled in 375 mL wine bottles with screw on closures and stored at 13°C until evaluation.

For wine evaluation, pH and TA were determined as for juice and color was measured by determining absorbance at 420nm using a spectrophotometer. For sensory evaluation, wines were subjected to a difference from control test (29 Apr. 2015) (Lawless and Heymann, 2010). Panelists (n=54) tasted each of the wines and compared to a sample of the control (Treatment 6: NST/CP3). Each panelists tasted six wine samples (all six treatments with the control labeled as a sample) and compared each to the identified control wine. Samples were presented to panelists in 4 oz. plastic cups labeled with 3 digit random numbers, and the order of presentation of the 6 treatments was randomized. Panelist rated each wine in individual booths using a scale from 0 = ‘not different at all’ to 10 = ‘very different’ from the control’.

Statistical Analysis

Statistical analysis was completed using FIT MODEL (JMP Pro, v 10, SAS Institute, Inc., Cary, NC). Data were transformed when necessary using LOG or SQRT functions. Data from 2013 and 2014 were analyzed separately. Shoot thinning and cluster thinning were tested for interaction and as main effects. A two-way ANOVA was performed, and mean separation was conducted using Tukey’s HSD or Fisher’s Protected LSD (p<0.05). Sensory evaluation data were analyzed using SAS (Compusense, Ontario, Canada). The sensory panel data were treated as a complete block design. Each panelist was consider a block. Data was analyzed with a two-way ANOVA.

Results and Discussion

Vegetative responses

The freeze event on 4 Mar. 2013 affected some of the vegetative measurements such as pruning weights and Ravaz index (RI; 2013 yield/vine divided by 2014 pruning weight/vine). In 2013 pruning weights were collected as a baseline to determine the effect of shoot and cluster thinning. In 2014 pruning weights were reduced due to the freeze damage which affected 2013 vegetative growth (Figure 1). Thus, the RI was only obtained in 2014 (Figure 2), using fruit yield per vine from 2013 and pruning weights from 2014. Ravaz index values from 5 to 10 indicate balanced vines, while values greater than 10 indicate over cropping. The RI values indicate that none of the treatments led to over cropped vines; since all of the vines had val-

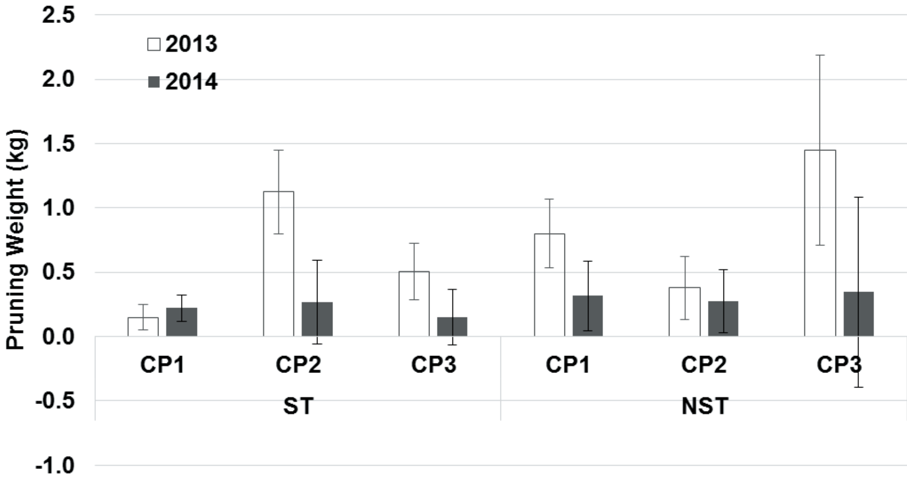

Fig. 1: Pruning weights collected in 2013 and 2014 as affected by shoot and cluster thinning in 'Blanc Du Bois'. NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters per shoot. Error bars denote ±pooled SE of the treatments.

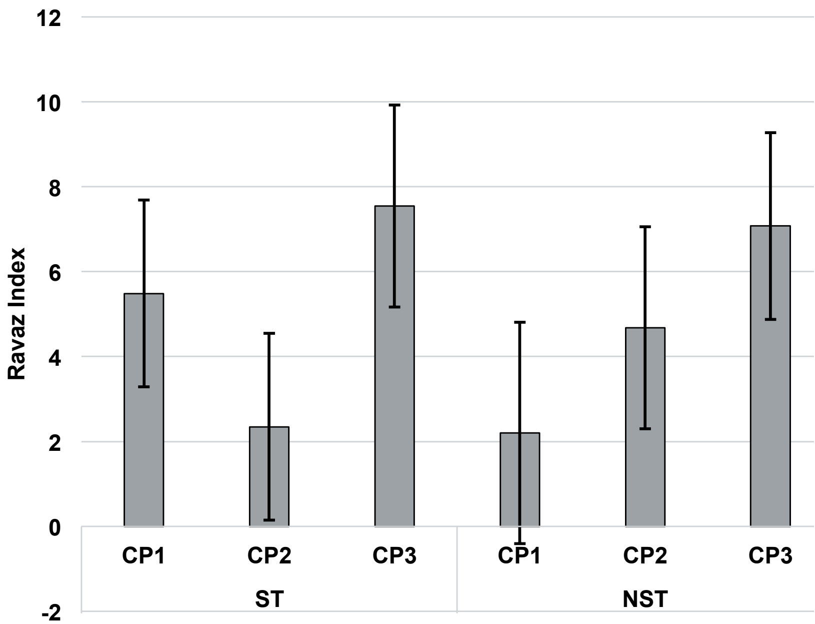

Fig. 2: Ravaz index for 'Blanc Du Bois' grapes as affected by shoot and cluser thinning, 2013 yield/vine divided by 2014 pruning weight/vine. NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters per shoot. Error bars denote ± SE of the mean.

Table 1: *P*-values from analysis of variance for shoot thinning (ST) and cluster thinning (CT) effects on vegetative growth, yield parameters and fruit quality of 'Blanc Du Bois' vines in 2013 and 2014. ST treatments included shoot thinning vs. no shoot thinning, and CT treatments included 1, 2, or 3 clusters per shoot.

Year	Treatments and Interactions	Leaf area	Shoot length (cm^2)	LAI[z]	Pn[y] before harvest (µmol·m^{-2}s^{-1})	Pn after harvest (µmol·m^{-2}s^{-1})	Clusters/ vine	Yield (Kg)/ vine	Cluster weight (g)	Berries/ cluster	Berry weight (g)	Soluble Solids (Brix °)	TA[x] (%)	pH
2013	ST	0.47	0.08	0.99	0.02*[w]	0.89	0.01**	0.04*	0.19	0.29	0.07	0.4	0.13	0.001***
	CT	0.55	0.83	0.37	0.34	0.73	0.02*	0.03**	0.54	0.1	0.79	0.02**	0.23	0.25
	ST*CT	0.53	0.92	0.58	0.04*	0.95	0.84	0.99	0.65	0.71	0.34	0.96	0.14	0.86
2014	ST	0.22	0.05	0.14	0.80	0.39	0.96	0.85	0.64	0.58	0.64	0.39	0.28	0.99
	CT	0.21	0.14	0.72	0.85	0.80	0.26	0.19	0.54	0.52	0.44	0.36	0.59	0.15
	ST*CT	0.47	0.05	0.16	0.89	0.35	0.37	0.88	0.27	0.21	0.44	0.17	0.44	0.66

[z] LAI: Leaf area index
[y] Pn: Photosynthesis rate
[x] TA: Titratable acidity
[w] Significant statistical differences are indicated by asterisks: *$p<0.05$, $p<0.01$ and $p<0.001$.

ues lower than 10, and ideal ranges of vine balance were achieved with the highest crop load treatment (CP3).

In both years, leaf width multiplied by leaf length (width*length) was the best predictor of leaf area as determined by regression analysis (R^2=0.90, R^2=0.93; Figure 3). Therefore, width*length was used as a non-destructive measurement to predict leaf area. In both years, neither shoot nor cluster thinning had an effect on leaf area (Table 1). However, there was a trend in both years for increased leaf area and decreased LAI when vines were shoot thinned compared to non-shoot thinned vines (Table 3). Shoot thinning decreased LAI 20% (2013) and 22% (2014) compared to non-shoot thinned vines. A lower LAI means fewer leaves within the canopy and increased light penetration. In addition, the freeze event on 4 March 2013 significantly damaged exposed leaf tissue, resulting in reduced leaf area compared to 2014 for both treatments (NST and ST).

Contrary to what has been previously reported in other hybrid grape varieties. The improved light conditions of shoot thinned vines did not increase bud fruitfulness in 'Blanc Du Bois'. An increase in yield was observed in NST vines with denser canopies. It is probable that the non-count shoots in the NST treatments had flower buds that accounted for increased yield; or perhaps 'Blanc Du Bois' may not require high light intensity for bunch primordia differentiation (Buttrose, 1970). This could be due to inherited climatic adaptation (Tarara et al., 1990), and may explain why no significant differences were found for leaf area and LAI.

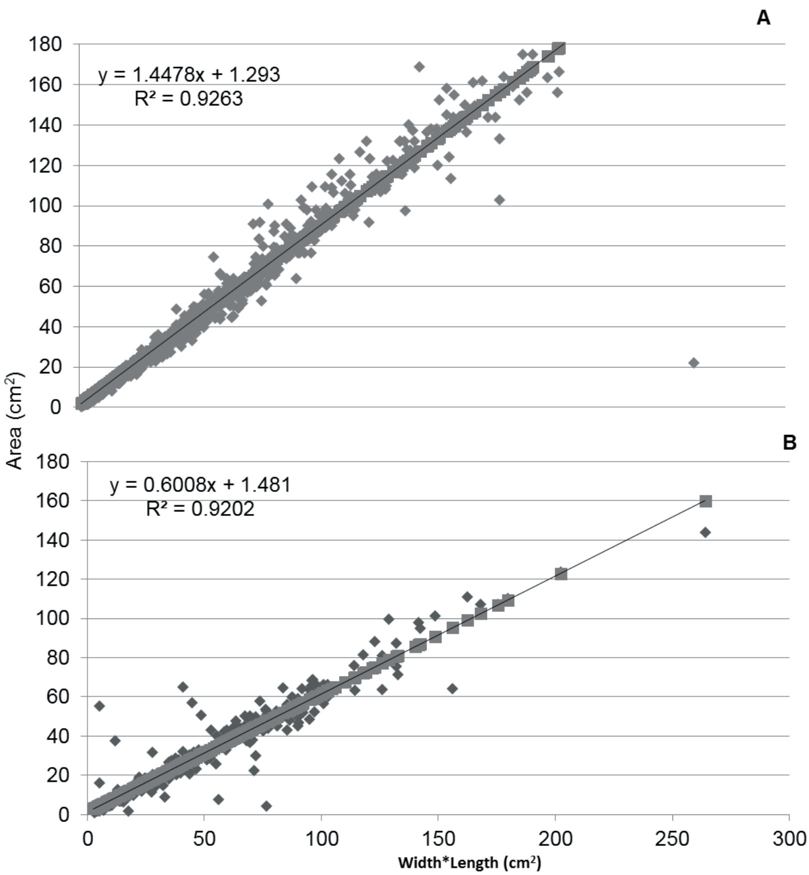

Fig. 3: Regression model used to determine non-destructive leaf area (cm^2) in 'Blanc Du Bois' grapes in 2013 (A) and 2014 (B).

Vegetative measurements collected during the growing season were not statistically significant for any of the parameters measured (i.e., shoot length, leaf area, or LAI; Tables 2 and 3). Conversely, Pn rate significantly differed before harvest in 2013, with vines in the NST + CP1 treatment exhibiting higher Pn rate compared to those vines in the ST + CP1 treatment. This significant interaction observed in photosynthesis in the first year could be due to an increase in lateral shoots (Edson et al., 1993). In 2013, the Pn rate was reduced approximately 50% in each treatment after harvest (Figure 4). Similar findings were observed on 'Seyval', 'Pusa Seedless' and 'Tas' grapes near or after harvest (Edson et al., 1995; Pandey and Farmahan, 1977). This is likely due to the reduced sink demand after harvest (Chaves 1981; Edson et al., 1995).

Fruit Responses

'Blanc Du Bois' vines responded differently to shoot thinning and cluster thinning compared to other hybrid varieties in previous studies in which the grapevines compensated for yield reduction by increasing cluster weight or berry weight (Morris et al., 2004; Naor et al., 2002; Reynolds et al., 2005; Sun et al., 2012). Neither shoot thinning nor cluster thinning increased cluster or berry weight in 'Blanc Du Bois' (Table 3). In 2013, when shoot thinning was analyzed as a main effect, clusters/vine and yield/vine were higher in NST vines compared to ST vines (Table 3), indicating that NST vines produced flowers on non-count shoots. Significant differences were only found in 2013 for clusters/vine and yield/vine for shoot thinning and cluster thinning treatments overall (Table 1), perhaps due to freeze damage to the primary bud, resulting in fruit arising from secondary buds.

Grapevine buds contain primary, secondary, and tertiary buds, each with a certain potential for fruit production. Clusters arising from secondary shoots (secondary buds) are smaller, whereas the majority of tertiary shoots (buds) have been reported to not produce any clusters (field observation; Dry, 2000). In contrast, shoots coming from the cordon of cold-injured Merlot vines were fruitful (Keller and Mills, 2007). Thus, freeze damage in combination with shoot thinning most likely resulted in fewer clusters with fewer berries and lower berry weight in the ST treatment (Table 3). In addition, juice from shoot thinned vines possessed significantly

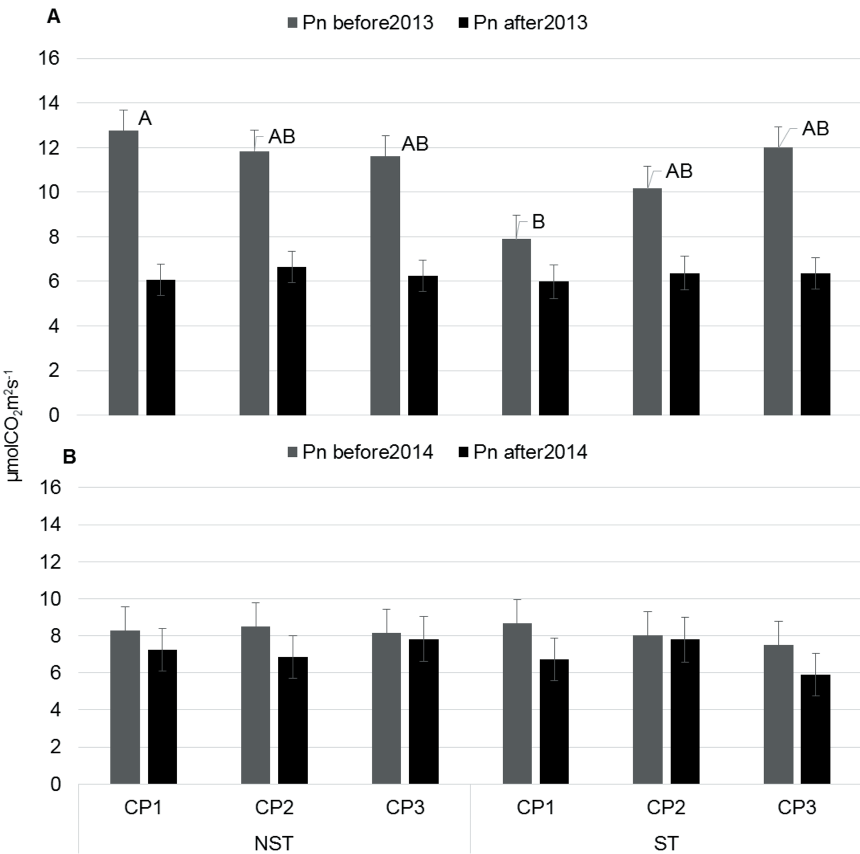

Fig. 4: Photosynthesis rate measurements (µmol CO^2 $m^{-2} \cdot s^{-1}$) as affected by the interaction of shoot and cluster thinning before and after harvest in 2013 (A) and 2014 (B). NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters per shoot. Error bars denote ± SE of the mean. Letters indicate mean separation as determined by Tukey's HSD ($p < 0.05$).

Table 2: Effects of shoot thinning (ST) and no shoot thinning (NST) and cluster thinning with one (CP1), two (CP2) or three (CP3) clusters per shoot on vegetative growth, yield parameters and fruit quality of 'Blanc Du Bois' vines in 2013 and 2014.

Year	Treatments		Leaf area (cm^2)	Shoot length (cm)	LAI[z]	Pn[y] before harvest ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Pn after harvest ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Clusters /vine	Yield (Kg)/ vine	Cluster weight (g)	Berries/ cluster	Berry weight (g)	Soluble Solids (°Brix)	TA[x] (%)	pH
2013	NST	CP1	27.00	35.28	3.58	12.75 a[w]	6.06	10.14	0.48	50.66	25.97	1.82	14.18	0.69	3.71
		CP2	24.21	32.80	3.36	11.84 ab	6.64	13.53	0.89	53.41	35.44	1.61	13.18	0.69	3.57
		CP3	30.53	38.04	3.55	11.60 ab	6.25	23.95	1.22	51.01	30.86	1.68	12.57	0.75	3.59
	ST	CP1	27.40	34.69	2.75	7.89 b	5.99	6.74	0.30	36.33	24.62	1.50	14.73	0.71	3.47
		CP2	30.00	31.21	3.19	10.18 ab	6.38	11.52	0.65	47.13	29.45	1.62	13.44	0.88	3.40
		CP3	29.79	40.50	2.42	12.00 ab	6.37	11.77	0.87	48.54	29.45	1.47	12.93	0.74	3.40
2014	NST	CP1	67.90	45.00	3.44	8.27	7.27	16.16	0.95	72.62	43.25	1.83	13.83	0.69	3.32
		CP2	75.51	45.23	3.92	8.51	6.87	27.10	1.73	69.88	39.67	1.86	13.68	0.69	3.23
		CP3	76.76	57.52	2.23	8.17	7.82	14.46	1.00	79.20	48.11	1.83	14.19	0.68	3.24
	ST	CP1	72.99	50.17	2.48	8.69	6.12	15.54	1.15	97.81	55.49	2.18	14.60	0.69	3.35
		CP2	98.46	43.09	2.48	8.04	7.80	20.74	1.39	85.89	46.30	1.91	13.49	0.70	3.27
		CP3	76.67	30.49	2.44	7.50	5.90	18.96	1.28	59.25	37.97	1.68	11.85	0.79	3.18

[z] LAI: Leaf area index
[y] Pn: Photosynthesis rate
[x] TA: Titratable acidity
[w] Means followed by different letters within a column indicate significant differences as determined by Tukey's HSD at =0.05.

lower juice pH, which can improve the resistance to oxidation in white wines (Conde et al., 2007; Recamales et al., 2006). Browning and oxidation are often challenges for 'Blanc du Bois' wine, and thus reducing the pH may lead to higher wine quality (Jackson, 1986; Morrison and Noble, 1990, Mpelasoka et al., 2003). Nonetheless, sensory evaluation differences between the control and other treatments were not easy to differentiate by the panelists.

As with shoot thinning, cluster thinning influenced certain fruit parameters in 2013, but not in 2014. These included number of clusters/vine, yield/vine, and soluble solids (Table 1-4). As expected, there were more clusters/vine in CP3 than in CP1 which translated to higher yield/vine (Table 4). There were no differences in cluster or berry weight, or the number of berries/ cluster indicating that the increase in yield was due to the increased number of clusters/vine. Cluster thinning, which reduces the crop load, typically decreases yield, unless the vines compensate for this loss by increasing berry and cluster weight. This decrease in overall yield can lead to an increase in fruit quality in terms of higher soluble solids (Kliewer and Smart,1989), while vines with high crop loads can delay ripening resulting in lower soluble solids at harvest (Winkler, 1954). In very productive cultivars reducing the cluster number did not affect yield but improved fruit quality (Almanza-Merchan et al.,2011; Bravdo et al.,1984; Reynolds,1989) since carbohydrates were allocated to the remaining clusters, thus increasing soluble solids. In 'Blanc Du Bois' under the reported climactic conditions, decreasing the yield by thinning to one and to two clusters per shoot improved soluble solids. However, there was no difference in soluble solids between vines that had either two or

Table 3: Effects of shoot thinning (ST) and no shoot thinning (NST) on vegetative growth, yield parameters and fruit quality of 'Blanc Du Bois' vines in 2013 and 2014.

Year	Treatments	Leaf area (cm^2)	LAI[z]	Shoot length (cm)	Pn[y] before harvest ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Pn after harvest ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Clusters /vine	Yield (kg)/ vine	Cluster weight (g)	Berries/ cluster	Berry weight (g)	Soluble Solids (°Brix)	TA[x] (%)	pH
2013	NST[z]	27.12	3.50	35.31	12.06 a[w]	6.32	16.80 a	0.86 a	51.68	30.76	1.70	13.31	0.71	3.62 a
	ST	29.04	2.79	35.26	10.02 b	6.25	9.71 b	0.60 b	43.64	27.84	1.53	13.70	0.78	3.42 b
2014	NST	73.28	3.20	48.92	8.32	7.32	18.50	1.23	73.80	43.68	1.84	13.90	0.69	3.26
	ST	81.98	2.47	40.40	8.08	6.61	18.28	1.27	79.25	46.59	1.91	13.31	0.73	3.26

[z] LAI: Leaf area index
[y] Pn: Photosynthesis rate
[x] TA: Titratable acidity
[w] Means followed by different letters within a column indicate significant differences as determined by Tukey's HSD at =0.05.

Table 4: Effects of cluster thinning with one (CP1), two (CP2) or three (CP3) clusters per shoot on vegetative growth, yield parameters and fruit quality of 'Blanc Du Bois' vines in 2013 and 2014.

Year	Treatments	Leaf area (cm^2)	LAI[z]	Shoot length (cm)	Pn[y] before harvest (µmol•m^{-2}•s^{-1})	Pn after harvest (µmol•m^{-2}•s^{-1})	Clusters /vine	Yield (Kg)/ vine	Cluster weight (g)	Berries/ cluster	Berry weight (g)	Soluble Solids (°Brix)	TA[x] (%)	pH
	CP1[z]	27.20	3.17	34.99	10.32	6.02	8.27 b[w]	0.39 b	42.9	25.30	1.65	14.57 a	0.70	3.59
2013	CP2	26.95	3.28	31.99	11.01	6.51	15.00 ab	0.77 ab	50.17	32.44	1.62	13.31 ab	0.79	3.48
	CP3	30.16	2.99	39.25	11.80	6.31	16.79 b	1.04 a	49.76	30.15	1.58	12.75 b	0.75	3.49
	CP1	70.40	2.96	47.52	8.48	6.70	15.85	1.05	84.28	49.37	2.00	14.22	0.07	3.33
2014	CP2	86.23	3.20	44.15	8.28	7.33	23.71	1.56	77.47	42.99	1.88	13.58	0.70	3.25
	CP3	76.71	2.34	41.88	7.84	6.86	16.56	1.14	68.50	43.04	1.75	13.02	0.73	3.21

[z] LAI: Leaf area index
[y] Pn: Photosynthesis rate
[x] TA: Titratable acidity
[w] Means followed by different letters within a column indicate significant differences as determined by Tukey's HSD at =0.05.

Table 5: Main effects of shoot thinning (ST) or no shoot thinning (NST) and cluster thinning on 2014 'Blanc Du Bois' wine quality.

Treatments		Abs @ 420 nm	pH	TA[z] (% tartaric)	Difference from Control Results[y]
NST	CP1	0.072 c[x]	3.32 a	0.77 c	3.03 ab
	CP2	0.068 cd	3.15 c	0.93 a	4.14 a
	CP3	0.052 e	3.13 c	0.87 b	2.80 b
ST	CP1	0.101 a	3.26 b	0.86 b	3.65 ab
	CP2	0.066 d	3.14 c	0.95 a	3.39 ab
	CP3	0.083 b	3.14 c	0.94 a	3.29 ab
P-value		*<0.05*	*<0.05*	*<0.05*	*0.047*

[z] TA: Titratable acidity
[y] Rated on a 0-10 scale with 0=not different and 10=very different. NST-CP3 treatment was considered the control.
[x] Means followed by different letters within a column indicate significant differences as determined by Tukey's HSD at =0.05.

three clusters/shoot (Table 4), indicating that growers willing to have slightly lower soluble solids can maintain a larger crop load and yield.

Wine Quality and Sensory Evaluation

Wine analysis showed that NST treatments with CP1 had darker color and higher pH (Table 5). Fruit from ST and NST treatments with one cluster per shoot had higher pH at harvest (Table 2) but no significant differences were found. Darker color (higher absorbance) could indicate slight oxidation in the wine under high pH conditions. Similar results were found when color of 'Blanc Du Bois' was measured after one year of storage (Sims and Mortensen, 1989).

Sensory evaluation showed that panelists only perceived significant differences between NST/CP2 and NST/CP3 (p=0.047; Table 5). The lack of a strong significance led to the conclusion that shoot thinning treatment did not affect wine quality as much as cluster thinning. In previous studies, more open canopies resulted in wines with fruitier flavors (Reynolds et al., 1994; Smart, 1980; Sun et al, 2011); however, 'Blanc Du Bois' wines did not exhibit a significant change in wine quality.

Improving fruit quality and vine balance is limited by the cost of labor and the low price per ton received by Florida growers for their fruit (Stonebridge Research Report, 2010). In the Florida grape industry, growers will find it difficult to incorporate a cultural practice that diminishes yield as part of their canopy management techniques, even though increased sugars can be achieved in the fruit. The market dynamics in Florida do not allow for increased bottle prices to compensate for additional labor costs, and thus growers do not want to add additional vineyard management costs unless there are clear economic benefits. Shoot thinning could be feasible for the industry to incorporate as part of their cultural practices without an additional increase in labor costs and increase fruit quality, particularly by lowering juice pH. There is still a need for further research to verify the response of 'Blanc Du Bois' to shoot and cluster thinning since 2013 freeze damage severely impacted vines in this experiment.

Literature Cited

Almanza-Merchán, P.J., G. Fischer, P.A. Serrano-Cely, H.E. Balaguera-López, and J.A. Galvis. 2011. Effects of leaf removal and cluster thinning on yield and quality of grapes (*Vitis vinifera* L., Riesling × Silvaner) in Corrales, Boyaca (Colombia). Agron. Colombiana. 29:35-42.

Andersen, P., T.E. Crocker, and J.A. Mortensen. 2001. The Bunch Grape. University of Florida/IFAS Extension Electronic Document Information Service HS17A. Accessed: 16 Sept. 2015. < http://edis.ifas.ufl.edu/mg105>.

Bernizzoni, F., M. Civardi, M. Van Zeller, M. Gatti, and S. Poni, 2001. Shoot thinning effects on seasonal whole-canopy photosynthesis and vine performance in *Vitis vinifera* L. cv. 'Barbera'. Austral. J. Grape and Wine Res. 17:351-357.

Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1984. Effect of crop level on growth, yield and wine quality of a high yielding carignane vineyard. Amer. J. Enol. Vitic. 35:247-252.

Buttrose, M.S. 1970. Fruitfulness in grapevines: the response of different cultivars to light, temperature and day length. Vitis 9:121-125.

Buttrose, M.S., C.R. Hale, and W.M. Kliewer. 1971. Effect of temperature on the composition of 'Cabernet Sauvignon' berries. Amer. J. Enol. Viticult. 22:71-75.

Buttrose, M.S. 1969. Fruitfulness in grapevines: effects of daylength. Vitis 8:188-190.

Chaves, M.M. 1981. Photosynthetic characteristics and environmental control in some grapevine cultivars, p. 105-113. In: N. S. Margaris and H. A. Mooney (eds.). Components of Productivity of Mediterranean-Climate Regions Basic and Applied Aspects. Springer, Netherlands.

Conde, C., P. Silva, N. Fontes, A.C. Pires Dias, R.M. Tavares, M.J. Sousa, A. Agasse, S. Delrot, and H. Gerós. 2007. Biochemical changes throughout grape berry development and fruit and wine quality. Food 1:1-22

Coombe, B.G. 1987. Distribution of solutes within the developing grape berry in relation to its morphology. Amer. J. Enol. Viticult. 38:120-127.

Coombe, B.G. 1995. Adoption of a system for identifying grapevine growth stages. Austral. J. Grape. Wine. Res. 1:100-110.

Dry, P.R. 2000. Canopy management for fruitfulness. Austral. J. Grape. Wine. Res. 6:109-115.

Dreyer, E., C. Sims, R. Rouseff, D. Gray, and M. Sipowicz. 2013. Sensory and compositional characteristics of Blanc Du Bois wine. Amer. J. Enol. Viticult. 64:118-125.

Edson, C.E., G.S. Howell, and J.A. Flore.1993 Influence of crop load on photosynthesis and dry matter partitioning of 'Seyval' grapevines I. Single leaf and whole vine response pre- and post-harvest. Amer. J. Enol. Vitic. 44:139-147.

Edson, C.E., G.S. Howell, and J.A. Flore. 1995. Influence of crop load on photosynthesis and dry matter partitioning of 'Seyval' grapevines. III. Seasonal changes in dry matter partitioning, vine morphology, yield, and fruit composition. Amer. J. Enol. Vitic. 46:478-485

Fisher, K.H., O.A. Bradt, J. Wiebe, V.A.,Dirks. 1997. Cluster thinning 'De Chaunac' French hybrid grapes improves vine vigor and fruit quality in Ontario. J. Amer. Soc. Hort. Sci. 102:162-165.

Halbrooks, M.C. 1986. Viticulture in Florida:The next five years. Proc. Fla. State Hort. Soc. Florida. 99:186-192.

Jackson, D.I. 1986. Factors affecting soluble solids, acid, pH, and color in grapes. Amer. J. Enol. Vitic. 37:179-183.

Jogaiah, S., K.R. Striegler, E. Bergmeier, J. Harris. 2013. Influence of canopy management practices on canopy characteristics, yield, and fruit composition of 'Norton' grapes (*Vitis aestivalis* Michx). Intl. J. Fruit Sci. 13:441-458.

Kaps, M.L. and G.A. Cahoon. 1989. Berry thinning and cluster thinning influence vegetative growth, yield, fruit composition, and net photosynthesis of 'Seyval Blanc' grapes. J. Amer. Soc. Hort. Sci. 114:20-24.

Keller, M. and L.J. Mills. 2007. Effect of pruning on recovery and productivity of cold-injured Merlot grapevines. Amer. J. Enol. Vitic.58:351-357.

Kliewer, W.M. and L.A. Lider. 1968. Influence of cluster exposure to the sun on the composition of Thompson seedless fruit. Amer. J. Enol. Vitic. 19:175-184.

Kliewer, W.M. and L.A. Lider. 1970. Effects of day temperature and light intensity on growth and composition of *Vitis vinifera* L. fruits. J. Amer. Soc. Hort. Sci. 95:766-769.

Kliewer, W.M. and R.E. Smart. 1989. Canopy manipulation for optimizing vine microclimate, crop yield and composition of grapes, p. 275-291. In: C.J. Wright (eds.). Manipulation of Fruiting. Butterworth, London.

Lawless, H.T and Heymann. H. 2010. Sensory evaluation of food: principles and practices. 2nd ed Springer. New York

May, P., P.R. Clingeleffer, and C.J. Brien. 1976. Sultana (*Vitis vinifera* L.) canes and their exposure to light. Vitis 14: 273-238.

Morris, J.R., G.L. Main, and O.L. Oswald. 2004. Flower cluster and shoot thinning for crop control in French-American hybrid grapes. Amer. J. Enol. Vitic. 55:423-426.

Morrison, J.C., and Noble, A.C. 1990. The effects of leaf and cluster shading on the composition of Cabernet Sauvignon grapes and on fruit and wine sensory properties. Amer. J. Enol. Vitic. 41: 193-200.

Mortensen, J.A. 1987. 'Blanc Du Bois': A Florida bunch grape for white wine. Circ. S-FL Agri. Expt. Sta., Inst. Food and Agric. Sci., Univ. of FL., Gainesville, FL

Mpelasoka, B.S., Schachtman, D.P., Treeby, M.T., and Thomas, M.R. 2003. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Austral. J. Grape Wine Res. 9:154-168.

Mota, R.V., C.R. De Souza, C.P.C. Silvia, G. de F. Freitas, T.M., Shiga, E.Purgatto.,F.M. Lajolo., M. de A. Regina. 2010. Biochemical and agronomical responses of grapevine to alteration of source sink ratio by cluster thinning and shoot trimming. Bragantia 69:17-25.

Naor, A., Y. Gal, and B. Bravdo. 2002. Shoot and cluster thinning influence vegetative growth, fruit yield, and wine quality of 'Sauvignon Blanc' grapevines. J. Amer. Soc. Hort. Sci. 127:628-634.

Pandey, R.M., Farmahan, H.L. 1977. Changes in rate of photosynthesis and respiration in leaves and berries of Vitis vinefera grapevines at various stages of berry development.16:106-111.

Recamales, Á.F., Sayago, A., González-Miret, M.L., and D. Hernanz. 2006. The effect of time and storage conditions on the phenolic composition and colour of white wine. Food Res. Intl. 39:220-229.

Reynolds, A.G. 1989. Impact of pruning strategy, cluster thinning, and shoot removal on growth, yield, and fruit composition of low-vigor 'De Chaunac' vines. Can. J. Plant Sci. 69:269-275.

Reynolds, A.G., S.F. Price, D.A. Wardle, B.T. Watson. 1994. Fruit enviroment and crop level effects on 'Pinor noir'. I. Vine performance and fruit composition in British Columbia. Amer. J. Enol. Vitic. 45:452-459.

Reynolds, A.G.,T. Molek , and C. De Savigny. 2005. Timing of shoot thinning in *Vitis vinifera:* Impacts on yield and fruit composition variables. Amer. J. Enol.Vitic. 56:343-356.

Shaulis, N.J. 1980. Responses of grapevines and grapes to spacing of and within canopies. Proc. Univ. California-Davis Grape Wine Symp. p. 353-361., Davis, CA.

Sims, C.A. and J. Mortensen. 1989. Evaluation of wine potential from breeding lines and cultivars in Florida. Amer. J. Agr. Econ. 69:151-157.

Smart, R.E. 1980. Vine manipulation to improve wine grape quality. Proc. Symp. Grape and Wine Cent. 362-75.

Smart, R.E. and T.R. Sinclair. 1976. Solar heating of grape berries and other spherical fruits. Agric. Meteorol. 17: 241-259.

Sommer, K.J., M.T. Islam, and P.R. Clingeleffer. 2000. Light and temperature effects on shoot fruitfulness in *Vitis vinifera* L. Cv. 'Sultana': Influence of trellis type and grafting. Austral. J. Grape Wine Res. 6:99-108.

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. Amer. J. Enol. Vitic. 53:171-182.

Stonebridge Research. 2010. The wine and grape industries in Florida. Stonebrigde Res. Group., St. Helena, CA.

Sun, Q., G.L. Sacks, S.D. Lerch, and J.E. Vanden Heuvel. 2011. Impact of shoot thinning and harvest date on yield components, fruit composition, and wine quality of 'Marechal Foch'. Amer. J. Enol. Vitic. 62:32-41.

Sun, Q., G.L. Sacks, S.D. Lerch, and J.E. Vanden Heuvel. 2012. Impact of shoot and cluster thinning on yield, fruit composition, and wine quality of 'Corot Noir'. Amer. J. Enol. Vitic. 63:49-56.

Tarara, J.M., E.W. Hellman, and T.V. Munson. 1990. The Munson grapes - a rich germplasm legacy. Fruit Var. J. 44:127-130.

Vasconcelos, M.C. and S. Castagnoli. 2000. Leaf canopy structure and vine performance. Amer. J. Enol. Vitic. 51:390-396.

Westover, F. 2012. 'Blanc Du Bois' takes root. Wines and vines. 15 February 2015. <www.winesandvines.com>.

Winkler, A.J. 1954. Effects of overcropping. Amer. J. Enol. Vitic. 5:4-12.