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

Zilfina Rubio Ames[1], Mercy Olmstead[1*], Charlie Sims[2], and Rebecca Darnell[1]

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-

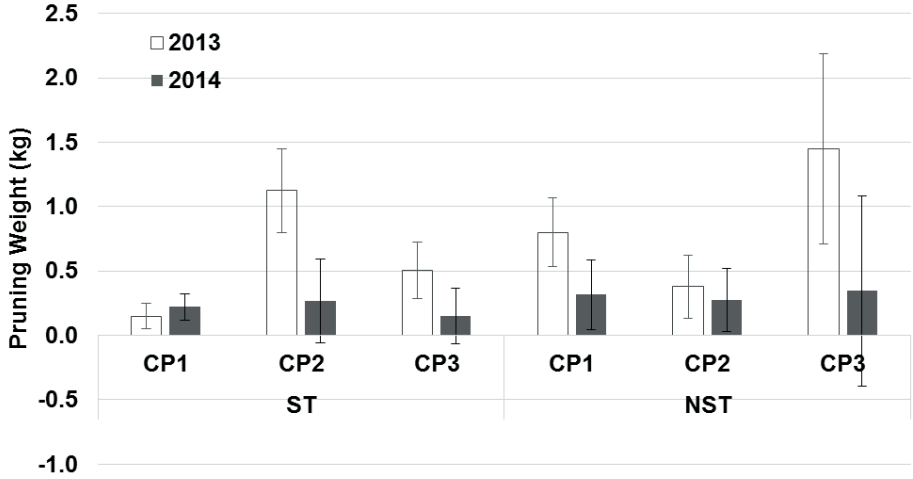

Fig. 1: Pruning weights collected in 2013 and 2014 as affected by shoot and cluster thinning in 'Blanc Du Bois'. NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters per shoot. Error bars denote ±pooled SE of the treatments.

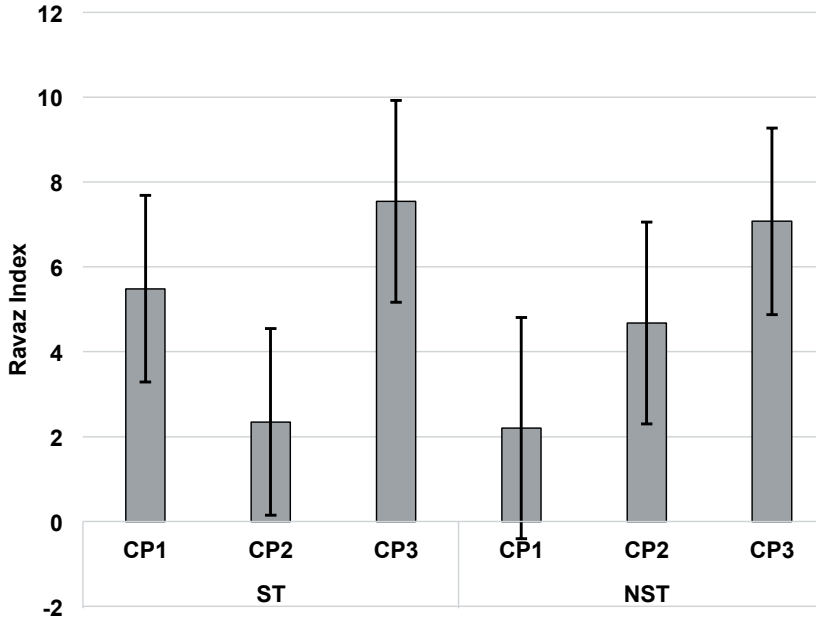

Fig. 2: Ravaz index for 'Blanc Du Bois' grapes as affected by shoot and cluser thinning, 2013 yield/vine divided by 2014 pruning weight/vine. NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters per shoot. Error bars denote ± 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 ($\mu mol \cdot m^{-2}s^{-1}$)	Pn after harvest ($\mu mol \cdot m^{-2}s^{-1}$)	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.

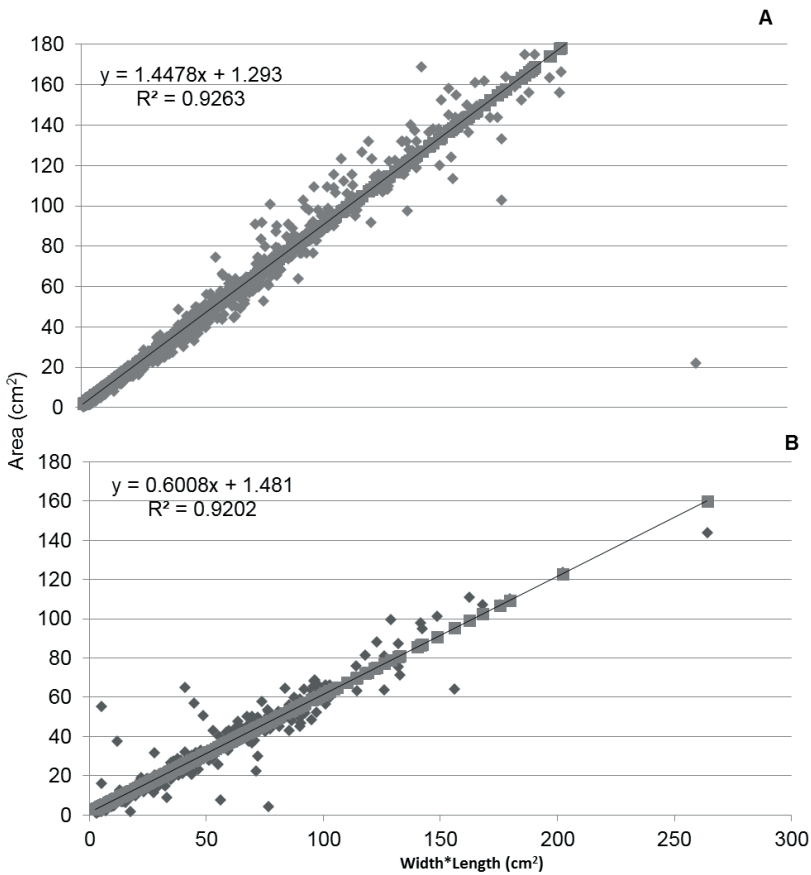

Fig. 3: Regression model used to determine non-destructive leaf area (cm^2) in 'Blanc Du Bois' grapes in 2013 (A) and 2014 (B).

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

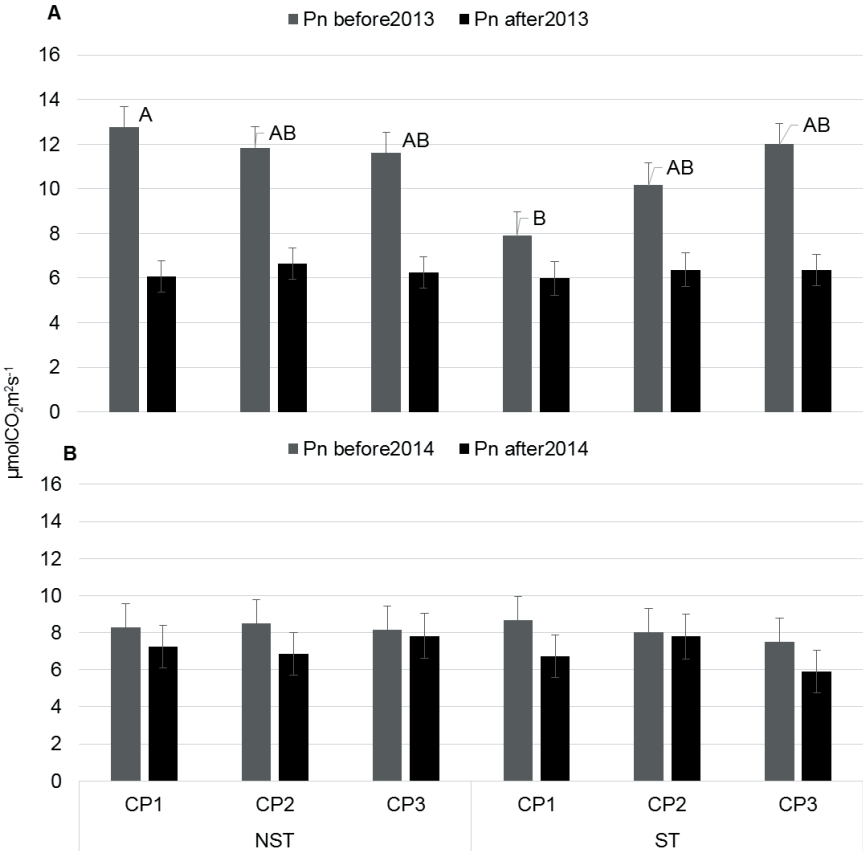

Fig. 4: Photosynthesis rate measurements (µmol CO^2 $m^{-2}s^{-1}$) as affected by the interaction of shoot and cluster thinning before and after harvest in 2013 (A) and 2014 (B). NST: Non-shoot thinned and ST: shoot thinned vines. CP1: one cluster per shoot, CP2: two cluster per shoot, CP3: three clusters 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 ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	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
	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.

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Effect of dehydration during storage on viability of dormant grafted grape

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Additional index words: plant survival, transplant, rootstock

Abstract

This study quantifies the effect of dehydration during storage of bare root grape vines delivered from the nursery and planted in winter. In that period, plants are at risk of dehydration, but it has not been well studied.. One-year-old dormant bench grafts of *Vitis vinifera* cv. 'Redglobe' on Freedom or Harmony rootstocks were exposed to a range of dehydration treatments to observe survival and growth of the vines after planting. Field-finished plants were harvested from nursery soil, and the roots of 25 plants were exposed to air for 0, 4, 8, 22, 32, 70, 96, 128, 192 or 262 h to simulate variable environmental conditions that plants suffer before planting. For each rootstock-time combination, the hydration status was determined gravimetrically on 5 plants and the remaining 20 were individually planted in containers for weekly evaluation of bud break and growth. Plant organs exhibited different dehydration kinetics. Roots and trunk (two-year-old wood) were the most appropriate organs to determine plant hydration status and later planting success, whereas one-year-old wood was highly variable. Hydration status of root and trunk during dormancy were significantly related to growth potential. Dormant plants grafted on Harmony tolerated dehydration better than plants grafted on Freedom.

The plant propagation method choice for different species depends on a series of factors, including feasibility and plant establishment success; the later highly related to dehydration avoidance (Scianna *et al*., 2004). Traditionally, grapevines are propagated by cuttings, which can be rooted in containers or directly in the soil. As grape rootstocks in Chile become more popular, cuttings are normally bench grafted, field-finished (growth in the field for one year before selling) and sold during the following winter. For deciduous plants, the most tolerant stage for transplant and dehydration is dormancy, with some species and cultivar considerations (Murakani *et al.*, 1990; Englert *et al.*, 1993). Harvesting plants at the nursery should be done on cool, cloudy and still days, and with cultural practices that help to avoid dehydration of the roots, maintaining the rootball with its substrate and moisture (Englert *et al.,* 1993; Hartmann *et al.*, 2002). Later, plants are selected based on size and root quality and put in cold storage or are "*heeled-in*" with saw dust, sand or both covering the roots (Hartmann and Kester, 1988; Englert *et al.*, 1993; Hartmann *et al.*, 2002; Schuch *et al.*, 2007). Dehydration during nursery handling of plants has been associated on other species like red oak (*Quercus rubra* L.), Norway maple (*Acer platanoides* L.) and Washington hawthorn (*Crataegus phaenopyrum* Medic.) with poor regrowth and regressive death after transplant (Englert *et al.*, 1993; Murakami *et al.*, 1990). Therefore, a special consideration for nurseries is to avoid dehydration, but no specific information on grapevines has been developed.

Until recently small nurseries produced plants for local growers (McKay, 1996), but nowadays the industry has transitioned to large-scale nurseries distant from the plant-

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ing site, increasing the time and risks associated to plant dehydration. For table grapes in Chile the situation is even worse, since nurseries are located in the central region with relatively mild and humid winters, but vineyards are spread all over and many plants are intended for the north region, more than 800 km away and with a warm and dry climate that increases dehydration potential. Plant shipping is done in truck containers with controlled temperature and humidity and roots maintained in moist sawdust, but often there are problems during or after transport

Grapevines are generally considered tolerant to water stress (Keller, 2010), but there are no specific studies regarding dehydration behavior during harvest, storage, transport or planting of propagating material. New vineyards may develop problems with plant survival associated with dehydration, which is hard to evaluate since grapevines do not have leaves at that time (Chen *et al.,* 1991).

For this research we obtained objective and quantitative data to evaluate vineyard establishment success of one-year-old grafted plants with varying hydration status.

Materials and Methods

The study was conducted between July (winter) and Dec. (end of spring) 2009, in a commercial grapevine nursery located in Malloa, Región del Libertador Bernardo O`Higgins, Chile (34º 24´56´S; 70º 55´27´W)

Previously (winter 2008), a large number (commercial nursery operation) of one-bud 'Redglobe' scions were grafted onto Freedom or Harmony cuttings and rooted in the field for one season. These one-year-old dormant grafts were harvested on July 3rd and graded by trunk diameter, length, and size of root system, choosing the #1 size (1.5 cm diameter, 40 cm trunk length and 40-60 cm root system). After harvest, dormant bench grafts were mounded in 100% sawdust trenches for five days and irrigated daily, a common nursery practice. Plants were rehydrated for 20 h by full immersion in water. Then, plants were put on pallets and dehydrated under uncontrolled conditions, with their roots exposed to air; simulating field conditions at planting. During air exposure time (AET) the average temperature was 7.4 ± 3.9 ºC; with maximum 22.5 ºC and minimum -1.5º C; and average relative humidity was 82 ± 16.7%

The AET was 0, 4, 8, 22, 32, 70, 96, 128, 192 or 262 h. Plants were randomly assigned to each AET/ rootstock combination. Roots, trunk and one-year-old wood of five plants were used to determine water content by the gravimetric method (Eq. 1) using the dry weight.

$$Wc = \frac{Fw - Dw}{Dw} \qquad \text{Eq. 1}$$

Where:
Wc: water content (g)
Dw: Dry weight (g) after 72 h at 62ºC oven
Fw: Fresh weight (g) immediately after AET

Cumulative vapor pressure deficit (VPD) was then calculated using the equation suggested by Murray (1967) and reported as VPD per second for each AET period.

The remaining 20 plants were individually planted in 3 L-polyethylene containers filled with composted pine bark. Roots were lightly pruned to allow proper root distribution in the container and NPK was added according to nursery standards. Containers were irrigated to saturation when control containers had lost 20% of their weight (approximately every 3-4 days) and put in a polyethylene greenhouse for 3 weeks between 12º (night) and 28ºC (day), then moved to a plastic-covered growth area, where containers could be irrigated. One week after bud break the three shoots (corresponding to the three buds left after cutting back the plants) were retained on each plant and new lateral shoots were periodically removed. Every seven days, from Aug. 7 to Nov. 28, bud break (stage 04 of the modified Eichhorn-Lorenz system, Pearce and Coombe, 2004) and length of the longest shoot were recorded.

Bud break value (BbV) and bud break peak period (BbP) were calculated, relating to the

number of days for bud break, by Eq. 2 and 3, modified from the seed germination analysis (Hartmann *et al*., 2002). The mean days for bud break (DBb) were obtained from the sum of the number of plants beginning bud break on each evaluation day by the corresponding number of days (N1 plants x days for bud break 1 + N2 plants x days for bud break 2 +…… Nn plants x days for bud break n).

$$BbV = BbP \times DBb \quad \text{Eq. 2}$$

Where:

BbV: Bud break value
BbP: Bud break peak period
DBb: Mean days for bud break

$$BbV = \frac{MBb/100}{DMBb} \times \frac{FBb/100}{DFBb} \quad \text{Eq. 3}$$

Where:

MBb: Maximum bud break (%) (when bud break rate begins to slow down)
DMBb: Days for maximum bud break (days)
FBb: Final bud break (%)
DFBb: Days for final bud break (days)
Bud break rate was calculated by Eq. 4.

$$BbR = \frac{1}{DBb/(DFBb - DIBb)} \quad \text{Eq. 4}$$

Where:

BbR: Bud break rate
DBb: Mean days for bud break
DFBb: Days for final bud break
DIBb: Days for initial bud break

Statistical Analysis

The experiment was a two x 10 factorial, with 2 rootstocks and 10 levels of AET and there were 25 replicates per treatment combination in a completely randomized design. Data were analyzed graphically according to data position and scattering. The data for plant survival did not fit lineal models; therefore non-lineal regressions were used (*Curve Expert Professional v1.3.0*). Regression models were evaluated with *Infostat* (Di Rienzo *et al*., 2008) and Akaike Information criterion (AIC) and Baysian Information criterion (BIC) were used to select the best model among the set of candidate models to predict plant survival.

The main selection criterion was AIC, choosing models based on maximum likelihood, with the smaller AIC (Balzarini *et al.,* 2008; Gómez *et al.* 2012). To choose a model representing both rootstocks and also plant parts, models for DFBb, BbR, BbV and shoot dry matter and maximum shoot length were ranked according to AIC. Lineal models were adjusted using dummy variables.

Results

In general, based on visual observations in July (winter time) Harmony plants had thicker roots, a lighter root color and 3 to 5 main roots; whereas Freedom plants had fascicular brown-reddish roots and a shorter root system.

Fresh weight of dormant plants declined when exposed to increasing VPD (Fig. 1) and this supports the results of Allen *et al*.(2006). Roots had the highest rate of water loss (Fig. 1D), followed by the whole plant (Fig. 1A). Dehydration kinetics of dormant bench grafts is stronger for the roots and weaker for the one-year-old wood. Standard errors were smallest for whole plants and trunk. Therefore, taking into account the rate of water content change and the standard deviation, the best organs to determine water content loss are trunks and roots.

Plant survival decreased with increasing AET and plants on Harmony tolerated dehydration better than plants on Freedom (Table 1.) Plants grafted onto Freedom had 90% sur-

Table 1. The number of hours of exposure (AET) of bare-root grapevines on two rootstocks required for several plant survival rates.

Survival probability	AET*	
	Freedom	Harmony
%	----- h -----	
95	0.0 – 1.9	0.0 – 31.1
90	9.3 – 11.9	51.8 – 53.1
50	59.2 – 65.0	95.7 – 99.4

*For local ambient conditions of the study

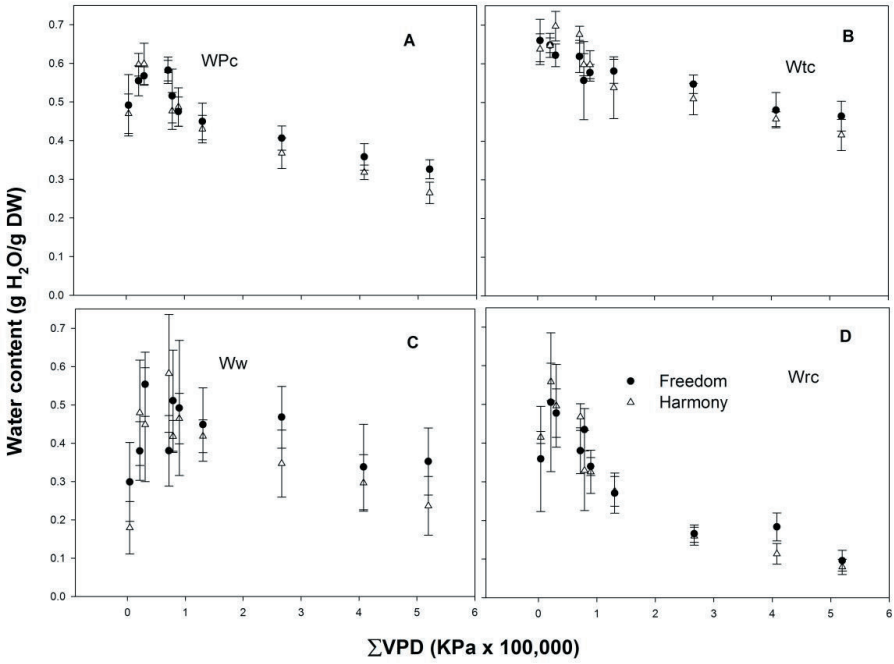

Fig. 1. The relationship between gravimetric water content (Wc) and accumulated VPD during the AET period for one-year-old dormant 'Redglobe' grapevines on two rootstocks: (A) Whole plant, WPc; (B) trunk, Wtc ; (C) one-year-old wood, Wwc; and (D) roots, Wrc. Bars represent standard errors of the means.

vival after only 9-11 h of AET, whereas plants on Harmony had the same survival probability after 51-53 h, corresponding to 20.0 to 23.1 and 102.0 to 106.0 KPa of cumulative VPD respectively (data not shown). Plants exposed to air for 192 or 262 h did no survive.

The relationship between plant survival and water content was evaluated for whole plant, trunk, one-year-old wood and roots, and the best predictive model was obtained when the model contained both trunk and roots (Wc t+r). Plants on Harmony and Freedom with values of Wc t+r from 0.46 to 0.52 g H_2O/g DW, respectively had 95% survival rates (Fig. 2).

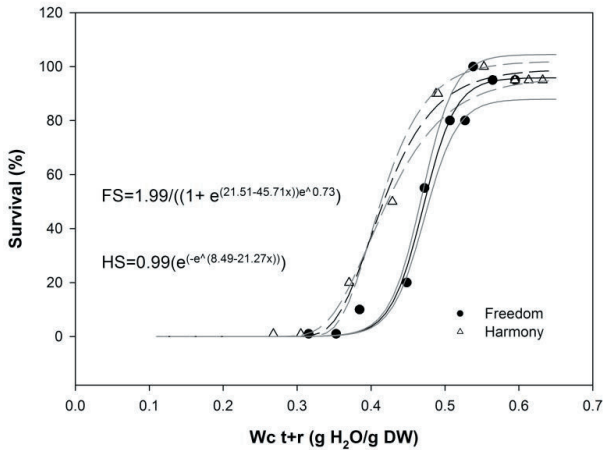

Fig. 2. Survival of one-year-old dormant grape 'Redglobe' plants grafted on two rootstocks as affected by water content of trunk and roots (Wc t+r) on a dry weight base (DW). FS: Freedom survival; HS Harmony survival.

Table 2. Dehyrdation effect on time needed for bud break (DBb) of one-year-old dormant Redglobe grafted grapevines.

Rootstock	Air exposure time (AET) h	Plants n[z]	Days for bud break (DBb) (Number of days)
Harmony	0	20	61.4 A[y]
	4	19	66.1 A B
	8	19	69.6 A B C
	22	19	71.5 A B C D
	32	18	82.7 B C D E
	70	18	82.8 B C D E
	96	10	91.1 E F
	128	4	113.0 G
Freedom	0	20	70.3 A B C
	4	19	75.6 A B C D E
	8	19	84.1 B C D E
	22	16	86.3 C D E
	32	16	89.4 D E F
	70	2	91.5 E F
	96	11	105.3 F G
	128	2	113.0 G

[z] Different n are due to varying plant survival following treatment, with maximum of 20 plants.
[y] Means followed by common letters do not difference, by, Tukey ($p<=0.05$).

Cumulative bud break was negatively related to the duration of AET and plants on Harmony broke bud earlier than on Freedom (Table 2). For control plants 50% bud break occurred at 50 and 65 days after planting when grafted on Harmony and Freedom, respectively. For plants exposed to air for 32 hours, 70 and 85 days were required for 50% budbreak and no plants had 50% bud break when exposed to air for 96 or 128 hours.

Days for bud break were negatively and linearly correlated with Wc t+r (Fig. 4A), and bud break was delayed on plants exposed to dehydration. Bud break rate and bud break value were positively and linearly related to water content (Fig. 4 B& C). Rootstocks did not differ significantly for all three response variables. Shoot dry matter and maximum shoot length increased linearly with increasing water content, but rootstocks were not different (Fig. 5).

Low values for Wc t+r were associated with short shoots with low dry matter in shoots (Fig. 5), with no differences between rootstocks (data not shown).

Discussion

One of the main causes for poor growth sprouting and establishment of bare root deciduous plants is dehydration stress during harvest and postharvest of plants in the nursery, and dehydration can occur at other times before planting (Remmick, 1995; Englert *et al.*, 1993; Guehl *et al*., 1993; Chen *et al.,* 1991).

Plants on Harmony tolerated dehydration stress better than plants on Freedom, with higher survival at similar Wc t+r or at similar AET and environmental conditions. Our data support reports for other species such as maple (*Acer platanoides* L.), and hawthorn (*Crataegus phaenopyrum* Med.), where roots dehydrated faster than one-year-old wood (Murakami *et al.*, 1990), possibly due

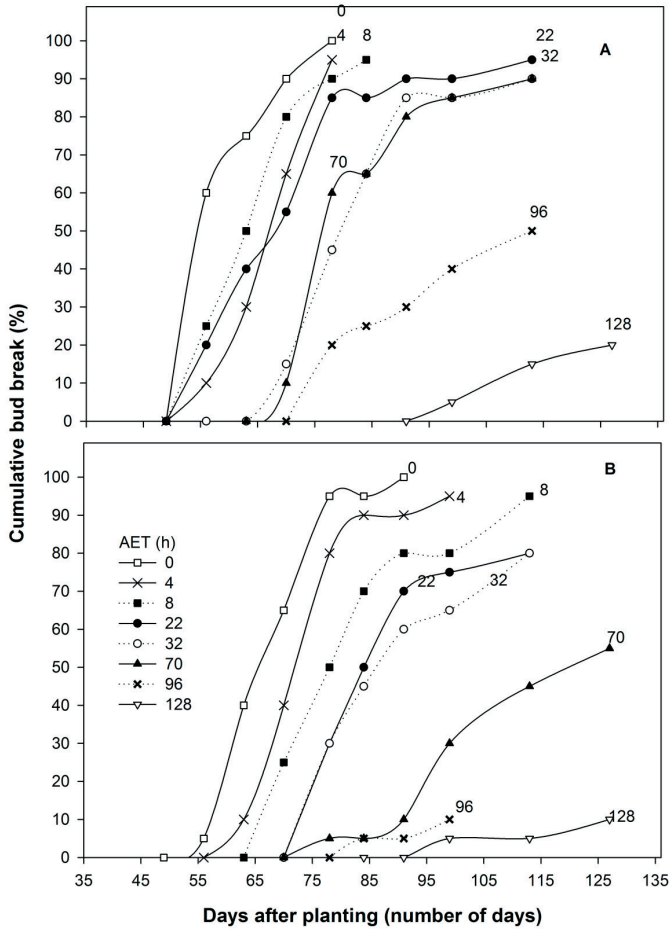

Fig. 3. Cumulative bud break after planting for one-year-old dormant 'Redglobe' grapevines grafted on (A) Harmony and (B) Freedom rootstocks for different AET.

to greater exposed surface area and thinner cuticles for roots (Schuch *et al.*, 2007). Similarly, Chen *et al.* (1991) found differences in dehydration tolerance between apple rootstocks, with MM.111 being more tolerant than MM.106 or M.7. Differences among rootstocks could be in part explained by root morphology. Dehydration tolerance is related to root size, for example the exposed area; species with smaller area/volume (thicker roots) were more resistant to dehydration (Englert *et al.*, 1993). Harmony and Freedom are rootstocks with similar parentage (1613 (*V. solonis* x Othello (*V. vinifera x (V. labrusca x V. riparia)*)) x Dogridge (*V. champinii*)) and are very similar. However, plants grafted onto Freedom are often more vigorous than plants grafted on Harmony (UC-ANR, 2003), a characteristic that could be related to differences in root systems. We found that Harmony root systems had 3 or 4 thick main roots and few thinner roots, whereas Freedom plants had many main roots and more thin roots, and these differences could explain the better dehydration tolerance of Harmony (Fig. 6).

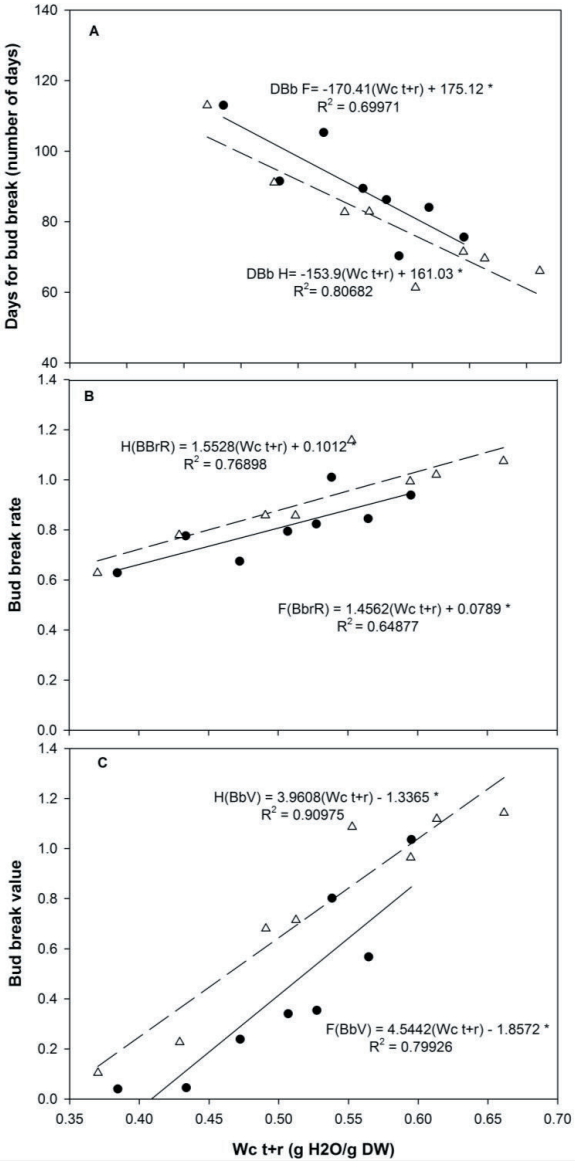

Fig. 4. The relationship between water content of trunk and roots (Wc t+r) and (A) Days for budbreak, DBb; (B) bud break rate, BbR and (C) bud break value, BbV for one-year-old dormant 'Redglobe' grapevines grafted on two rootstocks.

Slopes are significantly different from zero, but slopes were not affected by rootstock..

Bates and Niemiera (1994) used root water content as a plant water status indicator during transplant of bare-root trees and confirmed its usefulness to predict establishment success. Dehydration stress or the lower water content of different tissues increased DBb and reduced BbR and BbV, and maximum shoot growth and dry matter accumulation, similar to the results reported by McKay (1996) and Shuch *et al*. (2007) on trees and roses showing delayed sprouting and reduced shoot growth.

The results of this study point out the need for quality evaluation of dormant plants including plant water content, to determine the establishment success of new vineyards. Results from this research are restricted to our conditions and the two rootstocks chosen, but they represent a first phase for future work toward developing guidelines for proper handling of dormant plants.

The Wc t+r expressed as g H_2O/g dry weight represents an objective quantitative tool to estimate survival of 'Redglobe' grapevines grafted on Freedom or Harmony. The Wc t+r threshold for 95% survival for both Harmony and Freedom plants was 0.52 g H_2O/g dry weight, though Harmony had higher survival. Low water content prolonged dormancy, increased dormancy level, delayed bud break, and reduced uniformity of plant growth in the field.

Threshold values for other rootstocks should be determined, and should include quick and objective measurements of hydration status, like root xylem water potential that according to other authors would relate to survival and

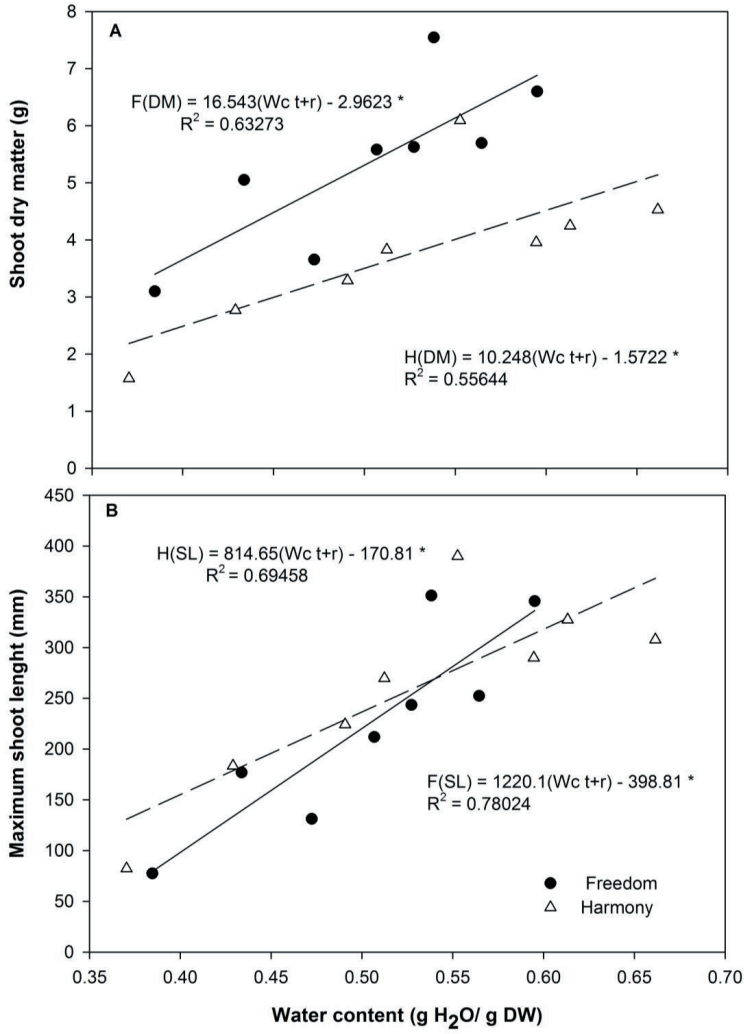

Fig. 5. Effect of trunk and root water content on (A) shoot dry matter; and (B) maximum shoot length for one-year-old dormant 'Redglobe' grapevines grafted on two rootstocks. All slopes were significantly different than zero ($P = 0.05$), but slopes were not affected by rootstock.

dormancy stage (Bates and Niemiera 1994; Chen *et al*., 1991; McKay, 1996). Likewise, practices to rehydrate plant material should also be evaluated.

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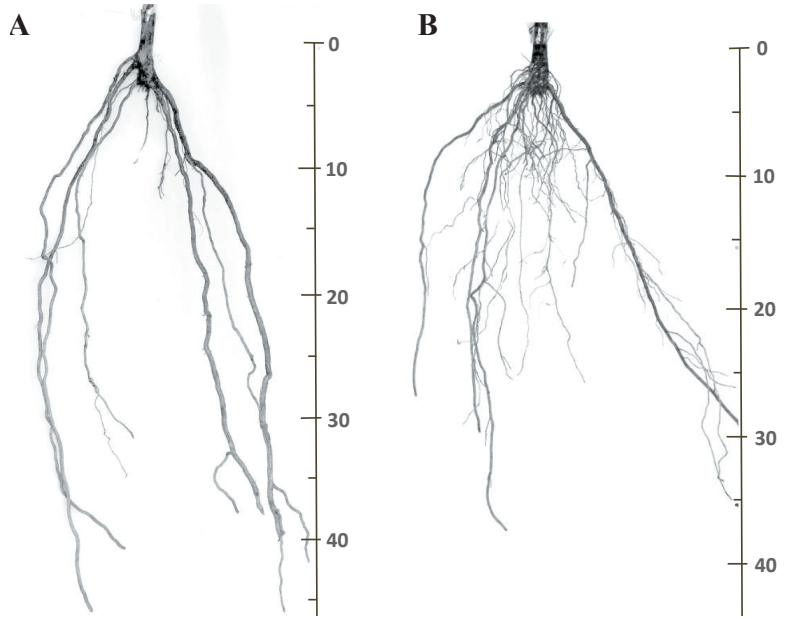

Fig. 6. Typical root systems for (A) Harmony and (B) Freedom (b) grape rootstocks. Image taken July 15th (winter time).

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Characterizing the effect of harvest maturity on ripening capacity, postharvest fruit quality, and storage life of 'Gem' pear

Todd Einhorn[1], and Yan Wang

Additional index words: *Pyrus communis*, postharvest physiology, European pear, ethylene production, fruit respiration, ripening capacity

Abstract

'Gem' is a recently-released, unique European pear cultivar that possesses crisp, juicy texture and exceptional eating quality at harvest, but can also ripen to a soft, buttery texture; however, relatively little is known about the optimal harvest maturity (HM) and storage behavior of the fruit. We, therefore, evaluated the effect of HM on postharvest fruit quality attributes of 'Gem' pears [fruit size, flesh pressure (FF), soluble solids concentration (SSC), titratable acidity (TA), and extractable juice (EJ)] in two different seasons. Four and two harvests were performed one week apart in 2011 and 2012, respectively. Fruit were stored in regular air (RA) for 7 months and evaluated monthly, either directly from cold storage (un-ripened), or after provision of a 7 day ripening regime (ripened). Throughout the 7 month storage period, un-ripened pears behaved fairly similarly despite a wide range in HM (i.e., FF between 54.3 to 42.7N). In general, FF decreased 0.5 to 0.75 N per month; TA declined by ~40%; and, EJ and SSC remained relatively stable. Fruit size, however, significantly increased with each delayed harvest date. Fruit required a minimum of 30 days cold storage to attain ripening capacity (i.e., to soften to ≤17.8 N and develop a buttery, juicy texture), though results differed depending on year and HM. Ripened fruit had significantly lower EJ than non-ripened fruit. After 5 months in RA storage, EJ and FF of ripened fruit increased in both years indicating the loss of ripening capacity. Internal browning was not observed until 6 or 7 months, depending on HM. Respiration and ethylene production rate (EPR) of 'Gem' pears, measured daily for 15 days (at 20°C), progressively increased between 1 and 5 months of RA storage. At 6 months, a change in the pattern of EPR signified the end of the eating-quality, storage life. For both ripened and un-ripened 'Gem' pears, optimal fruit quality was achieved at a HM between 44 and 42N. At a harvest pressure of 44 N, fruit showed no increase in scuffing incidence after processing over a commercial packing line. The maximum RA storage life of 'Gem' pears was 5 months.

'Gem' is a new, fire-blight resistant European pear with several distinguishing extrinsic attributes including a smooth, russet-free fruit finish and red blush (Bell et al., 2014). Productive and precocious fruiting habits, however, predispose 'Gem' to small fruit size and require crop load adjustment (Castagnoli et al., 2011). At harvest, 'Gem' pears are characterized by a crisp, juicy texture – a trait not typically associated with European pears. Crispness, defined as an acoustical sensation during the fracturing of crisp foods when first bitten with the front teeth, differs from firmness, which is described as, the force required to bite completely through a sample placed between the molars (Chauvin et al., 2010; Harker et al., 2002). Firmness, is associated with unripe pears and is preferred less than soft, juicy texture when compared side-by-side (Bruhn et al., 1991; Gallardo et al., 2011; Steyn et al., 2011), though firmness preferences of 'Forelle' pears varied between consumers in the UK and Germany (Crouch et al., 2012). Crispness, on the other hand, was proposed as a trait worthy of future pear breeding attention (Deckers and Schoofs, 2011) and is preferred by a significant

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segment of pear consumers (Jaeger et al., 2003). A preliminary sensory evaluation of 'fresh', un-ripened 'Gem' pears corroborates these findings (Einhorn, unpublished). Selection pressure for crisp, juicy texture has not been widely targeted in the European pear germplasm but has recently been introduced through interspecific hybridization among diverse *Pyrus spp*. (Brewer et al., 2008; Brewer and Palmer, 2011).

Consistent with other European pear cultivars, 'Gem' can also ripen to a soft, buttery and juicy texture when subjected to room temperature for 5 to 7 d. To attain ripening capacity, however, European pears require pre-exposure to low temperatures (i.e., conditioning; Villalobos et al., 2008). This process depends on the generation and perception of ethylene within the fruit. The duration of low temperature conditioning to induce ripening varies according to genotype (Agar et al., 2000; Chen et al., 1982; Sugar and Basile, 2009) and can be affected by harvest maturity (HM) (Chen and Mellenthin, 1981; Elgar et al., 1997; Ma et al., 2000; Sugar and Basile, 2009; Sugar and Einhorn, 2011), storage temperature (Porritt, 1964; Sfakiotakis and Dilley, 1974; Sugar and Basile, 2013; 2014; Sugar and Einhorn, 2011) and ethylene conditioning (Blankenship and Richardson, 1985; Chen et al., 1996; Sugar and Basile, 2013; 2014; Villalobos et al., 2008). Pears that have not received sufficient low temperature conditioning for their maturity level do not soften and ripen properly. Further, ripening capacity can be lost by prolonged storage (Murayama et al., 2002; Xie et al., 2014) resulting in fruit that fail to develop a buttery, juicy texture after exposure to warm temperatures. Inconsistent fruit quality is the principal reason for reduced repeat purchases of pears (Bruhn et al., 1991), placing European pears at a considerable disadvantage in the marketplace relative to other fresh fruits. Hence, developing information characterizing the storage life and ripening behavior of new cultivars is critical to optimizing fruit quality and, subsequently, consumption.

While the dichotomy in texture may increase the marketing versatility of 'Gem', little is known about the postharvest storage life and fruit quality of 'Gem' pears in either the fresh, crisp state or ripened, softened condition. Given the dependence of postharvest fruit quality on physiological maturity, the objectives of the present study were to determine the storage life and describe the postharvest quality and ripening behavior of 'Gem' pears harvested at different maturities.

Materials and Methods

A single row (N:S orientation) of 22 contiguous 7-year-old 'Gem' trees on Old Home × Farmingdale 97 (OH × F 87) rootstock was planted 3.05 × 4.88 m (in row × between row spacing; 672 trees per ha) and trained to a free-standing, central leader architecture at Oregon State University's Mid-Columbia Agricultural Research and Extension Center (MCAREC) in Hood River, Oregon (45.7°N, 121.5°W, elevation 150 m). All trees were lightly thinned at 35 d after full bloom by reducing spur crop load to one to two fruits depending on the fruit density of individual limbs. A randomized complete block design with four replicates was applied to 20 contiguous trees (excluding the end trees of the row) resulting in four blocks of five trees each. In 2011, a roughly equivalent sample of fruit was harvested from each of the five trees comprising a replicate (divided evenly between east and west sides of the row) each week for four weeks (i.e., H1-H4). The first harvest date (H1) coincided with a fruit firmness (FF) value of ~ 54 N; a preliminary indication that fruit was entering the maturity range (Bell et al., 2014). Initial maturity was determined from a 10-fruit sample (per replicate) by measuring FF on opposite sides of each fruit, after removing a ~2.5 cm disc of peel, using a Fruit Texture Analyzer (Güss Manufacturing, Strand, South Africa) fitted with an 8 mm diameter probe. For each harvest, fruit were selected

Table 1. Harvest date, fruit firmness, fruit weight, and fruit size of 'Gem' pears harvested at weekly intervals during 2011 and 2012.

Harvest Maturity	Date	Firmness (N)	Avg. fruit wt. (g)	Avg. fruit size (no. per 20 kg. box)
		2011		
H1	13-Sep	54.7 a[z]	205.1 d	100
H2	19-Sep	49.4 b	215.9 c	90
H3	27-Sep	47.6 b	230.9 b	90
H4	4-Oct	44.1 c	253.3 a	80
Pr>F		*<0.0001*	*<0.0001*	
		2012		
H1	4-Sep	47.3 a	210.6 b	100
H2	13-Sep	42.8 b	222.8 a	90
Pr>F		*0.0002*	*0.0003*	

[z] Data within columns and year with different letters are significantly different by Fisher's Protected LSD test at P=0.05

to represent the 'average' condition of fruit in the orchard. Based on 2011 results and previous, preliminary data indicating optimum post-harvest fruit quality between 48 to 41 N (Einhorn, unpublished), two harvests were performed in 2012, each one week apart (i.e., H1 and H2). Identical trees were utilized in 2012 as in 2011 and fruit were thinned at 38 d after full bloom to achieve similar crop loads as in 2011. The maturity index (FF) and fruit size for all harvest dates and years are provided in Table 1.

Each week, 150 fruit were harvested from each of four replicate groups of trees. Ten fruit per replicate were used to determine fruit quality attributes at harvest. The remaining 140 fruit per replicate were placed in poly-lined, wooden lugs in a regular air (RA) cold storage room maintained at -1 °C and ~95% RH. Each year, RA temperature was monitored twice daily throughout the entire storage period. Thirty days after each harvest date, a 20-fruit sample per replicate was removed from RA. Ten fruit per replicate were evaluated for FF, extractable juice (EJ), soluble solids concentration (SSC), and titratable acidity (TA) after 4 hr at room temperature. After determining FF (described above), two slices per fruit (from opposite sides) of 10 fruit were peeled and juiced (Juice Extractor 6001C, Waring Products, New Harford, Conn.). Using a pipette, 500 µL of juice was pipetted onto a digital refractometer (Palette series, PR-101α, Atago USA, Inc., Kirkland, WA) to determine SSC. TA, as malic acid equivalents, was determined using 10 mL of juice + 10 mL of de-ionized water and titrated with 0.1 N sodium hydroxide to an endpoint pH of 8.1 using a titrator fitted with an automated sampler (DL15 and Rondolino, Mettler-Toledo Inc., Zurich, Switzerland). A separate juice sample was collected over 30 s from 100 g (± 0.25 g) of fresh fruit (~ 10 g slice taken from each of 10 fruits) and transferred to a graduated cylinder for determining EJ. EJ is an objective measure that correlated well with texture of European pears (Chen and Borgic, 1985; Xie et al., 2014). All fruit were individually weighed and averaged across all sampling dates to estimate average fruit weight for each harvest date. Insignificant moisture loss from fruit in poly-lined wooden lugs was assumed to occur throughout the 7 month storage period based on previous experiments under identical RA conditions (Wang and Sugar, 2013); thus, fruit weight represented mass at harvest. The remaining 10 fruit per replicate were placed in 20 °C (± 1 °C) for 7 d. On the seventh

day, FF, EJ, SSC and TA were measured as described above to evaluate ripeness . A FF value of 17.8 N was used to indicate ripeness to the onset of a buttery, juicy texture (Sugar and Einhorn, 2011). This sampling regime was repeated monthly until fruit quality was compromised by the presence of storage disorders (i.e., 7 and 6 consecutive months in 2011 and 2012, respectively). An identical protocol was followed in 2012, with the exception that fruit of both harvest dates were ripened immediately after harvest.

In 2012, ethylene production rate (EPR) and respiration rate (Rs) of fruit were determined daily over a 15 d period each month for the entire 6-month postharvest period. Briefly, five fruit per replicate were placed in a 3.8-L airtight jar immediately after removal from RA and maintained at 20 °C. Gas samples were withdrawn through a septum using a 1-mL gas-tight syringe after 1 hr. Jars were then opened for a 24-hr period (air temperature was maintained at 20 °C). Fruit were gently removed from jars and the jars were flushed with air to ensure that no residual CO_2 or ethylene existed prior to replacing the fruit and resealing the jars for the subsequent 1 hr incubation period. This procedure was repeated daily over a 15 d period. The headspace gas was injected into a GC (GC-8A; Shimadzu, Kyoto, Japan) to quantify ethylene. Nitrogen was used as the carrier gas at a flow rate of 50 mL/min. The injector and detector port temperatures were 90 and 140 °C, respectively. An external standard of ethylene (1.0 $\mu L \cdot L^{-1}$) was used for calibration and EPR was expressed as $\mu L \cdot kg^{-1} \cdot hr^{-1}$. Headspace CO_2 concentration was measured using a CO_2 analyzer (Model 900161; Bridge Analyzers Inc., Alameda, CA). Fruit Rs was expressed as mL of $CO_2 \cdot kg^{-1} \cdot hr^{-1}$.

In 2013, ~ 45 kg of fruit was harvested from each 5-tree replicate when FF reached ~44 N, which was between the HM of H4 fruit of 2011 and H2 fruit of 2012. Fruit were delivered immediately to a commercial packing house (Duckwall Fruit, Hood River, OR) and processed over a 'Comice' packing line (i.e., belts were employed to cover brushes given the higher sensitivity of 'Comice' pears to surface injury compared to other cultivars) and commercially packed into 20-kg boxes. Two, 20-kg boxes per replicate were transported to MCAREC and placed in RA storage (-1 °C, ~95% RH). Boxes were removed from RA storage after 4 months. Half of the fruit in each box was evaluated 4 hr upon removal from RA for fruit quality attributes (FF, SSC and TA) and surface blemishes. An objective scale was developed to assess surface blemishes that comprised five discrete classes: Clear, [no visible surface blemishes]; Very Slight, [0.5 cm^2 or less fruit surface area blemished]; Slight, [0.6-1.0 cm^2]; Moderate, [1.1-3 cm^2]; and, Severe, [> 3 cm^2]. A weighted value between 1 and 5 was assigned to each class (i.e., Clear=1, Severe=5). The number of fruit in each class were multiplied by their respective severity scores, summed and divided by the number of fruit evaluated. A scuffing incidence was calculated as the sum of fruit in Slight, Moderate and Severe classes divided by the sum of fruit evaluated. The scuffing incidence is based on thresholds for surface blemishes for packing grades and was developed in collaboration with commercial packing house representatives. The remaining ~ 10 kg of fruit per box was ripened and evaluated as outlined above after 7 d at 20 °C.

Statistical analyses were performed using the SAS system software (SAS 9.3, SAS Institute, Cary, N.C.). Treatment means were compared using analysis of variance (ANOVA) with PROC GLM and significance was tested at $P \leq 0.05$. Mean separation was determined by Fisher's protected least significant difference test (LSD). Data shown in Figs. 1 and 2 are means of 4 replicates ± se.

Results and Discussion

In 2011, the first harvest commenced when fruit softened to <55 N. At this firmness, 'Gem' pears ripened to acceptable

fruit quality following several months of cold storage (Bell et al., 2014). Subsequent harvests occurred at ~1 week intervals until FF softened to levels perceived to represent the end of the acceptable maturity range (44 N). Over this 21 d harvest period, a 22% increase in fruit wt. (Table 1) was well-described by a linear function (fruit wt. = 2.2547d + 203.18, $R^2 = 0.9804$). Delayed harvesting, therefore, is a plausible strategy to increase fruit size of small-fruited European pear genotypes such as 'Gem' (Bell et al., 2014), so long as the effects on postharvest fruit quality and storage life are determined. Although fruit of a given FF were smaller in 2012 compared to 2011, a roughly equivalent increase in the rate of weight gain between harvest dates was observed both years (Table 1). The absolute difference in fruit size between years was attributed to vastly different environmental conditions, since crop load was similar in 2011 compared to 2012.

In both years, the presence of storage disorders [primarily internal browning (IB)] limited the maximum storage life of 'Gem' to 6 months, notwithstanding H1 fruit of 2011 (i.e., harvest FF > 50 N), which remained free of IB through 7 months. Over the entire storage period FF of fruit evaluated within 4 hr of removal from RA declined linearly ~ 0.75 N per month irrespective of HM or year (Fig. 1A and B). A monthly, informal sensory evaluation of 'Gem' pears after removal from RA, but before ripening, indicated that fruit maintained both firm and crisp properties throughout the entire postharvest period, including the final, 6-month analysis of H4 fruit (i.e., 40.2 N). Although the Güss penetrometer is primarily used to quantify FF, it also produced relatively high correlation coefficients for crispness when compared to alternative instruments to assess textural properties of apples and pears (Chauvin et al., 2010). Since crispness is the principle attribute distinguishing 'Gem' pear from most un-ripened European pear cultivars, and based on the similar postharvest performance of 2011 H2, H3 and H4 fruit (Fig. 1), a narrower and more advanced range of maturity was targeted for 2012 harvests (47.1 to 42.7 N). These FF levels are considerably lower than those associated with the harvest of all other major European pear cultivars produced in the US, potentially predisposing 'Gem' to higher levels of damage during commercial postharvest procedures. 'D'Anjou' pears showed minimal blemishes following commercial packing operations when FF values exceeded 35.3 N (Mellenthin and Chen, 1981); however, the threshold FF for injury would be expected to differ based on biochemical, anatomical and physiological features of the epidermal and cortex tissues of different genotypes. 'Gem' pears harvested at ~44 N and immediately processed over a commercial packing line, including packaging into 20-kg boxes, showed a slight, significant increase in surface blemishes (i.e., scuffing severity) but remained at relatively low levels that did not translate to a higher incidence in scuffing compared to control fruit (Table 2). Importantly, scuffing incidence did not increase after fruit were ripened to FF of < 15 N (Table 2); however, we emphasize that 'Gem' pears were not exposed to brushes during travel through the packing line, a practice commonly utilized for 'Comice' pears, based on a presumption that their smooth finish would predispose them to greater injury.

Ripening capacity of H2, H3 and H4 pears in 2011 and H2 pears in 2012 was achieved by 30 d RA storage after provision of a 7 d ripening period (Fig. 1A and B). In 2011, the more mature fruit of H1 required between 30 and 60 d to soften below 17.8 N. It is unclear why H1 fruit in 2012 did not attain ripening capacity after 1 month of RA (Fig. 1B) despite having an equivalent harvest FF as H3 fruit of 2011, which softened to 6.2 N after 30 d. The duration of chill required to attain ripening capacity at a given HM was similar over multiple years for 'd'Anjou' (Sugar and Einhorn, 2011), 'Comice' and 'Bosc' (Sugar and Basile, 2009), and 'Packham's

Table 2. The effect of commercial packing operations on scuffing severity and incidence of un-ripe and ripened 'Gem' pears harvested at FF of ~44 N and immediately processed over a commercial packing line and packaged into 20-kg boxes. Fruit were stored in regular air cold storage (-1 °C, >95% RH) for 4 months prior to evaluation. Unripe pears were evaluated within 4 hr of removal from cold storage. Ripened pears were exposed to 20 °C for 7 consecutive days prior to evaluation. Fruit quality attributes at each evaluation are provided: FF, fruit firmness; SSC, soluble solids concentration; and, TA, titratable acidity.

	Scuffing severity[z] (1 to 5 scale)		Suffing incidence[y] (%)		FF (N)		SSC (%)		TA (%)	
Treatment	Unripened	Ripened	Unripened	Ripened	Unripened	Ripened	Unripened	Ripened	Unripened	Ripened
Control Packing	1.04	1.09	0	0	41.8	14.7	14.2	14.5	0.36	0.25
line	1.08	1.15	0	1	43.0	14.2	14.3	14.6	0.28	0.26
Pr>F	0.3665	0.0098	- - -	0.3739	0.4435	0.4981	0.7951	0.3739	0.192	0.606

[z] Fruit were classified into 5 classes: Clear, no visible surface blemishes; Very Slight, 0.5 cm^2 or less fruit surface area blemished; Slight, 0.6-1.0 cm^2; Moderate, 1.1-3 cm^2; and, Severe, > 3cm^2. A weighted value between 1 and 5 was assigned to each class (i.e., Clear=1, Severe=5). The sum of the number of fruit in each class multiplied by their respective severity scores was divided by the number of fruit evaluated.

[y] Scuffing incidence was calculated as the sum of fruit in Slight, Moderate and Severe classes divided by the sum of fruit evaluated.

Triumph' and 'Gebhard Red d'Anjou' (Sugar and Basile, 2014). Interestingly, the well-established 60-d chill requirement to induce ripening of 'd'Anjou' pears entering maturity (i.e., ~65 N) in Hood River, OR (Chen and Mellenthin, 1981; Sugar and Einhorn, 2011) was extended to 75 d in 2012 (Wang, unpublished). Varied chill requirements for inducing ripening were also reported for 'd'Anjou' pears in Medford, OR for different production years (Sugar and Basile, 2013). The reasons for this disparity are unclear. To elucidate whether 'Gem' pears could ripen in the absence of low temperature conditioning, we subjected pears to 7 d of 20 °C immediately after each of the two 2012 harvest dates; results confirmed that 'Gem' does indeed require low temperature conditioning to soften and attain a buttery, juicy texture (Fig. 1B).

After 5 months of RA storage, 'Gem' pears began to lose their capacity to ripen as indicated by increasingly higher FF of ripened fruit (i.e., FF ≥18 N at 6 months; Fig. 1A and B). Importantly, this phenomenon was consistent between years and was not affected by HM. Concomitantly, EJ increased with cumulative storage duration for ripened fruit after 4 to 5 months, albeit non-significantly (Fig. 1C and D). Biochemical changes in cell wall polysaccharides were associated with higher FF (Chen et al., 1983; Murayama et al., 2002) and EJ (Chen et al., 1983) following ripening of pears subjected to prolonged storage periods (Chen and Borgic, 1985; Murayama et al., 2002; Wang et al., 1985); thus, we propose that the optimal RA storage life of 'Gem' is 5 months.

Throughout the duration of RA storage, there was no detectable change in fruit SSC, irrespective of HM or ripening treatment (Fig. 1E and F). A postharvest increase in SSC, as a function of starch hydrolysis, is rarely observed in European pears given the negligible starch content of cortex tissue at harvest. This, in combination with respiratory preference for organic acids, results in stable SSC throughout the postharvest life of European pears. Titratable acidity, on the other hand, declined by ~ 40% over the 6 month storage period, irrespective of HM or year (Fig. 1G and H). Interestingly, the pattern of TA loss differed between years. Reasons for this are unclear since equivalent storage temperatures (monitored daily) were maintained between years, but one possibility is that fruit of the same HM were physiologically more advanced in 2011 than

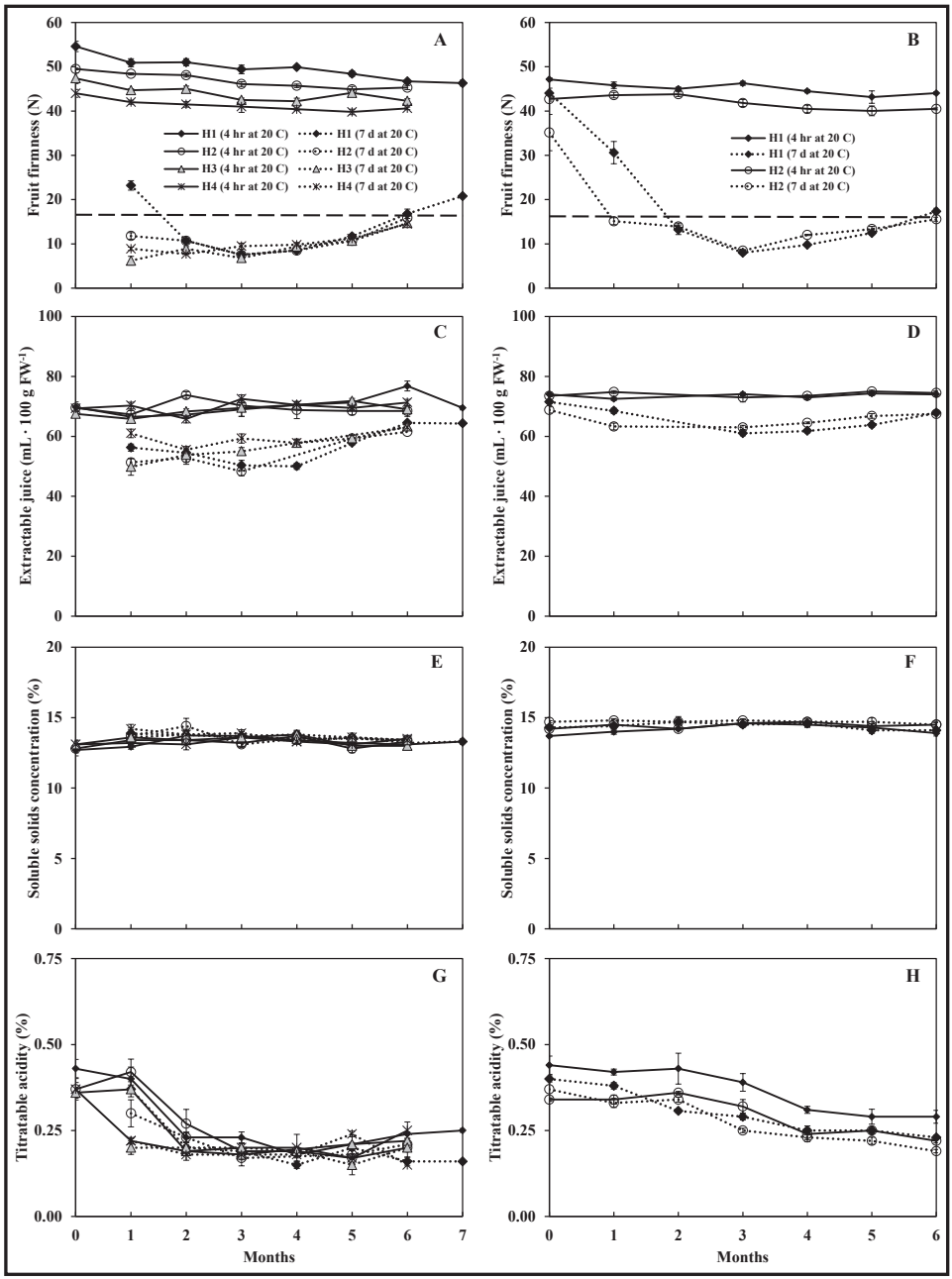

Figure 1. The effect of harvest maturity in 2011(H1-H4) and 2012 (H1-H2) on fruit firmness (FF) (A, B), extractable juice (EJ) (C, D), soluble solids concentration (SSC) (E, F), and titratable acidity (TA) (G, H) each month at 4 hr from removal from regular air cold storage (-1°C) (solid lines) and after ripening for 7 days at 20°C (dotted lines). The hashed line in panels A and B signifies the maximum FF required for fruit to attain ripening capacity (i.e., 17.8 N). Data are means of 4 replicates ±se.

2012. The developmental period between full bloom and harvest for fruit harvested at ~ 47 N was 148 and 134 d for H3 and H1 fruit of 2011 and 2012, respectively. This 14 d developmental difference may also help to explain the disparate ripening behavior between these treatments after 30 d of RA storage.

Fruit respiration followed a climacteric pattern between 2 and 6 months of storage, typically peaking on day 3 to 4, irrespective of HM (Fig. 2B and D). A slightly higher, basal level of Rs was detected for the more mature H2 fruit after 1 month RA storage (i.e., between days 3 and 13). EPR was also slightly, albeit significantly, higher for H2 fruit compared to H1 fruit after 1 month RA storage (Fig. 2A and C). Higher EPR and Rs likely explain the differences in the ripening behavior of H1 and H2 fruit after 30 d of storage (Fig. 1A and B). Between 2 and 4 months, the levels and patterns of Rs and EPR were similar for H1 and H2 fruit. The EPR peak occurred earlier (i.e., from 12 to 5 d) as time in storage increased, until 6 months when a rapid and steady decline was observed after day 1. Such a pattern indicates the loss of ripening capacity (Ma and Chen, 2003; Wang and Sugar, 2013) and corroborates the increasing FF and EJ observed for fruit stored for 6 months (Fig. 1B). Internal ethylene production of fruit stimulates synthesis of flavor compounds and accelerates pear ripening (Villalobos et al., 2008). In fact, 'd'Anjou' pears treated with exogenous ethylene ripened to a higher eating quality than fruit not conditioned with ethylene (Chen et al., 1996; Sugar

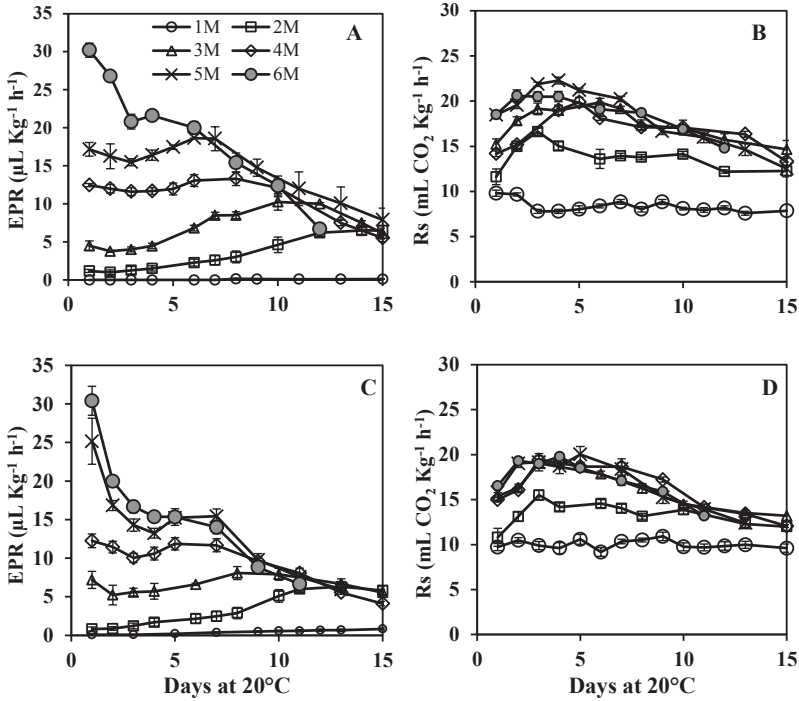

Figure 2. The effect of 2012 harvest maturity on daily ethylene production rate (EPR; A,C) and respiration rate (Rs; B, D) of 'Gem' pears each month (M) after removal from regular air cold storage (-1°C). Fruit were harvested 10 days apart based on fruit firmness (FF): Harvest 1 (H1) FF was 47.1 N (A,B); and, Harvest 2 (H2) FF was 42.7 N (C, D). Data are means of 4 replicates ±se.

and Einhorn, 2012). Within 4 hr from RA storage, un-ripened 'Gem' pears developed exceptional flavor when provided ≥3 months of cold storage, compared to fruit stored for 0, 1, or 2 months (Einhorn, unpublished). The fact that pears stored for 3 to 4 months RA had an EPR roughly 5 to 10-fold greater than pears stored <2 months supports this observation (Fig. 2A and B). Enhancing the flavor profile of 'Gem', while maintaining the cultivar's distinguishing, crisp attributes, warrants future research attention.

In conclusion, when harvested between 42 and 44 N, 'Gem' pears required 30 d of RA storage to attain ripening capacity. At these harvest pressures, fruit withstood commercial packing operations without an increase in the incidence of scuffing. Fruit quality between 1 and 5 months of RA storage was not greatly impacted by HM between 54.7 to 42.7N; however, fruit size was markedly improved with delayed harvests. A loss of ripening capacity with prolonged RA storage limited the postharvest storage life of 'Gem' pears to 5 months.

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Pruning style and long term irrigation regime effects on 'Sunpreme' raisin quality and fruitfulness

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Additional index words: *Vitis vinifera*, soluble solids

Abstract

Crop harvest suitability and raisin quality were examined for the new natural dry-on-the-vine raisin cultivar 'Sunpreme' as influenced by irrigation and pruning style. Cane- and spur-pruned vines were evaluated under three irrigation regimes: full evapotranspiration (ET), 50% ET and a further reduced "Shock" treatment. Irrigation regimes were established on the vines in 2007, six years prior to the onset of the test in 2013. Vine fruitfulness and dormant pruning mass were compared during each of the study years, as were product moisture content and raisin quality. Vines irrigated at Full ET, both cane- and spur-pruned, were consistently lower in juice total soluble solids as compared with other irrigation treatment x pruning style combinations during 2014. Full ET treated vines had significantly higher product moisture content at harvest as compared with Shock-treated vines in both years of the study. 'Sunpreme' raisin quality was very high (> 93% B or Better) across irrigation plots during 2013 when crop load was adjusted to 62% of available clusters. A higher percentage of crop load (81%) was allowed in 2014, and B & better percentage was 91% for Full ET treated vines, but was considerably lower in other irrigation plots. B & better percentages did not differ significantly across pruning styles in either study year, but the percentage of substandard raisins was lowest for Full ET in 2014 when there was a higher crop load.

Raisin production in California has developed over the last 100 years into an 80,000+ ha industry currently producing approximately 3.94 T/ha (California Department of Food and Agriculture, 2014). An important export commodity, California raisins are shipped throughout the world with active marketing campaigns now in 18 countries to promote sales (California Raisin Marketing Board, 2014). The industry was initially based on *Vitis vinifera* L. cv Thompson Seedless grape, with mature fruit clusters being hand cut and laid on paper trays for drying between rows of vines. A variety of other harvest procedures have since been developed to improve raisin production efficiency and improve growers' profit margins. While the climate of California's central San Joaquin Valley is very suitable for the culture and drying of raisin grapes, early winter rains can sometimes occur with the raisins still on the ground, causing problems during harvest and field pickup.

Irrigation quantity and timing has significant effects on berry maturity, canopy density and general fruit quality. Deficit irrigation during the early season, prior to flowering, reduced vegetative growth as well and had an irreversible negative effect on berry size (Matthews et al., 1987; Ojeda et al., 2001), whereas reduced irrigation after verasion could help management of vegetative vigor in shifting photosynthate to reproductive sinks and away from cane/leaf development (Chaves et al., 2007). Yield efficiency and average berry weight of 'Thompson Seedless' was maximized between 0.6 – 0.8 of vineyard

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evapotranspiration (Williams et al., 2010). Drying down the soil profile in raisin vineyards after verasion is a logical step in hastening the ripening process, as well as a necessary step in preparing vineyard rows as a drying bed for the paper trays of harvested grapes.

To combat problems of early winter rains, raisin grape breeders developed new cultivars with earlier maturity dates. 'Fiesta' was introduced in 1973 by the Agricultural Research Service (ARS), providing growers with a raisin grape harvestable 12-14 days prior to 'Thompson Seedless' (Weinberger, 1973). Other ARS raisin cultivar releases followed, including 'DOVine' (Ramming, 1995) and 'Selma Pete' (Ramming, 2001), with each release having successively earlier fruit maturity dates.

Mechanized raisin production practices begun in the early 1950s first focused on harvest techniques. Mechanical cutting and shaking devices were devised to remove grape clusters cleanly from vines to save labor hours (Winkler and Lamouria, 1956, Winkler, et al., 1957). While cane or cluster cutting technology efficiency improved each year, it became apparent that the maturity window of 'Thompson Seedless' in the raisin grape region of the central San Joaquin Valley was simply too late to effectively and consistently dry down the fruit after cane cutting (Studer and Olmo, 1973). However, newer earlier-maturing raisin grape cultivars changed mechanized raisin production in California. Fruit maturity of 'DOVine' and 'Selma Pete' raisin cultivars are sufficiently early for drying fully on the vine with severed canes (Fidelibus et al., 2008).

Further raisin breeding efforts at ARS led to the development of 'Sunpreme' (B82-43), a raisin grape capable of drying naturally on the vine in the central San Joaquin Valley without severance of canes (Ramming, 2015). 'Sunpreme' fruit ripen early, with berry wilting and raisining being a natural progression after verasion. Actual harvest suitability of 'Sunpreme' is both crop load and accumulated degree day dependent, but the new cultivar has typically been harvested with adequately dried raisins prior to September's end during the last 10 harvests.

The release of 'Sunpreme' for propagation and culture further facilitates mechanized raisin production by eliminating the cane severing operation. Cane severance and removal after harvest has been estimated at $326/ha, or 36% of total harvest/postharvest costs for San Joaquin Valley raisin vineyards (Vasquez et al., 2003). Vines of the new cultivar have been grown under several irrigation regimes since 2007 to examine long-term effects on crop productivity and vine health/vigor. Our current objective was to examine raisin quality and harvest suitability of cane- and spur-pruned vines grown in different irrigation plots.

Materials and Methods

*Plant Materials.*Vines used for the study were own-rooted clones of *Vitis vinifera* L. cv Sunpreme raisin grape, planted in 2005 at the research vineyard of the San Joaquin Valley Agricultural Sciences Center in Parlier, CA. 'Sunpreme' is a newly-released natural dry-on-vine raisin grape bred by the Agricultural Research Service (Ramming, 2015). Vines to be maintained as spur-pruned were trained to quadrilateral cordons with seven two-bud spur positions per cordon. Cane-pruned vines were trained with six canes to split heads centered between the staked trunk and each lateral wire. Vines were cultured on a single cross arm (91 cm) T trellis positioned approximately 142 cm above the soil surface. Vine spacing was 2.44 m between vines and 3.66 m between rows (1122 vines/Ha).

Irrigation treatments. Three irrigation treatments were imposed on 'Sunpreme' vines: 100% evapotranspiration (ET), 50% ET and a further reduced "Shock" treatment. Irrigation treatments were imposed on vines starting in the third leaf (2007), the first year production was allowed on the vines. As such, vines were accustomed to these irrigation volumes and timings, with six

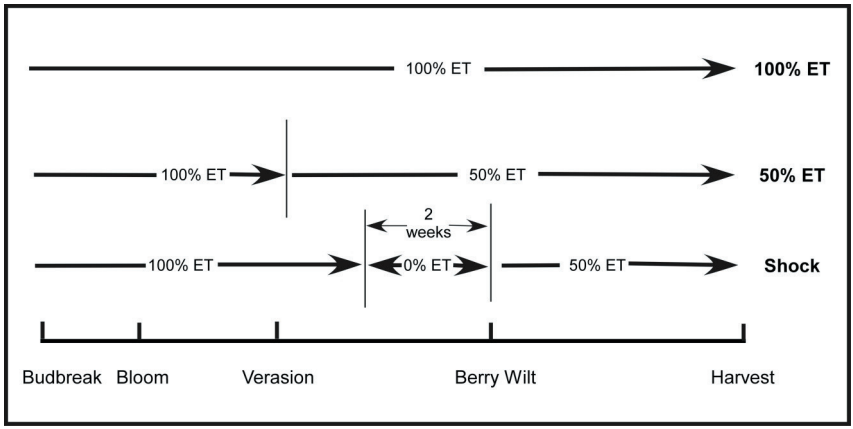

Fig. 1: Representation of three imposed irrigation treatments on 'Sunpreme' raisin, expressed as a percentage of evapotranspiration (ET), relative to phenological stages of grape berry development.

years of applied treatments prior to the onset of this study. Volumes of water applied to the various treatments were based on the San Joaquin Valley Drip Irrigation Scheduler (Peacock and Christensen, 2006). Input values used for running the scheduler during the 2013 and 2014 harvest years included an estimated 55% mid-July vineyard canopy coverage, 90% irrigation system efficiency and a vine density of 1,122 vines/ha. Application time was then calculated for each treatment and adjusted weekly through the growing season. After harvest, all vines were irrigated heavily to re-fill the soil profile. Specifics of the irrigation treatments relative to phenological stages in raisins are presented in Fig. 1.

Fruit and raisin evaluation. To evaluate berry maturity progression, total soluble solids (TSS) was determined weekly from vines in each irrigation plot using 50 berry samples. Berries were collected randomly from cluster mid-regions throughout each quadrant of sampled vines. Sampled berries were macerated before determining TSS with a hand-held refractometer. Samples were collected from the onset of verasion until the first sign of berry wilting (raisining).

For raisin quality evaluations, a composite 1.0 kg sample was collected using random dried clusters from each quadrant of the vine (20 Sept 2013, 10 Sept 2014). Date of harvest was determined subjectively, based on product appearance and feel. Samples were shipped to the USDA/Agricultural Marketing Service Fruit and Vegetable Program, Specialty Crops Inspection Division laboratory in Fresno, CA where raisin quality evaluations were performed. Moisture content was determined with a standard electrical conductivity test on raisin paste and air stream sorters were used for determinations of B & better and substandard percentages present in each sample (Kagawa, 2000).

Vine fruitfulness was evaluated through cluster counts after initial shoot extensions, during mid-April, when clusters were beginning to elongate. After cluster numbers were determined, studied vines were thinned to equal crops levels (77 clusters/vine in 2013; 169 clusters/vine in 2014) for valid comparisons of harvest suitability and product quality.

Experimental design and statistical analyses. When established in 2005, 27 'Sunpreme' vines available for study were divided equally into three plots representing the irrigation treatments (100% ET, 50% ET, Shock). Each irrigation plot was divided

further into three spur-pruned and three cane-pruned vines, with unused cane-pruned guard vines separating each pruning treatment. Irrigation treatments have been imposed on these vines since 2007, six years prior to the onset of this study.

This experiment does not have true replication because the three-vine plot was the experimental unit. Although the experiment had a factorial arrangement of treatments, interaction cannot be tested with analysis of variance (ANOVA) because the model would be saturated. When there is no interaction, the main effects can be analyzed with ANOVA. The presence of interaction was evaluated with graphical techniques and with a heuristic test (Milliken and Rasmuson, 1977). Since the interaction of pruning method and irrigation method was not significant, an ANOVA was performed, where the model contained only the main effects of pruning method and irrigation method using SAS's Proc GLM. When appropriate, means were compared with Tukey's Test. To evaluate the influence of the treatment combinations on the relationship between soluble solids concentration and harvest date, analysis of covariance was performed with SAS's Proc GLM, where pruning and irrigation methods were included in the model as indicator variables and Julian data was included as the regressor.

Results

At the onset of the experiment in 2013, study vines averaged 121.5 clusters/vine across irrigation plots, ranging from 134.7 (Full ET) to 103.2 (50% ET). By comparison, vine fruitfulness was higher in 2014 (207.6 clusters /vine) with cluster counts ranging from 213.3 (Full ET) to 198.3 (Shock). Cluster counts were unaffected by both irrigation method and pruning style in both study years.

Visual differences in canopy size and density were apparent in both study years across the irrigation plots, both during the growing season and in dormancy. Pruning weights were always higher for Full ET-treated vines, ranging from 8.7 kg (2013) to 3.9 kg (2014), but were not significantly different from the other irrigation treatments. Spur-pruned vines consistently had more dormant prunings than cane-pruned vines (6.0 kg vs. 5.0 kg in 2013, 2.7 kg vs. 2.3 kg in 2014, 4.3 kg vs. 2.9 kg in 2015), although these differences were not significant.

Across irrigation plots and pruning styles, juice TSS at verasion was similar in 2013 (10.1%) and 2014 (10.7%). Final juice samples taken prior to berry wilt were also comparable (22.2% in 2013 vs 23.2% in 2014), although the 2014 sampling period lasted a full two weeks longer than in 2013. Multiple regressions were used to examine juice TSS accumulation throughout berry development (verasion through berry wilting) as a function of irrigation method and pruning style. The interaction of irrigation method, pruning style and harvest date was significant in both study years, with the greatest effect on juice TSS accumulation in the 2014 season (Fig. 2). During 2013 when crop load was relatively low (77 clusters per vine), there were only small differences in juice TSS concentration among treated vines at any of the six sampling dates. Variation in juice TSS across sampling dates averaged only 0.58 % TSS among treated vines during the 2013 season. Cane-pruned vines in the Full ET and 50 % ET plots had the lowest juice TSS accumulation throughout berry development (Fig. 2a). With a higher crop load in 2014 (169 clusters per vine) there were larger differences in juice TSS accumulation compared with the previous season. Juice TSS differences averaged 2.9 % during 2014 across the treatment combinations. Full ET-treated vines, both cane- and spur-pruned, were consistently lower in juice TSS as compared with other irrigation treatment x pruning style combinations during 2014 with the larger crop load (Fig. 2b).

With a low crop loads, raisining of the 2013 crop proceeded rapidly and uniformly. By 20 September, mean moisture content of raisins

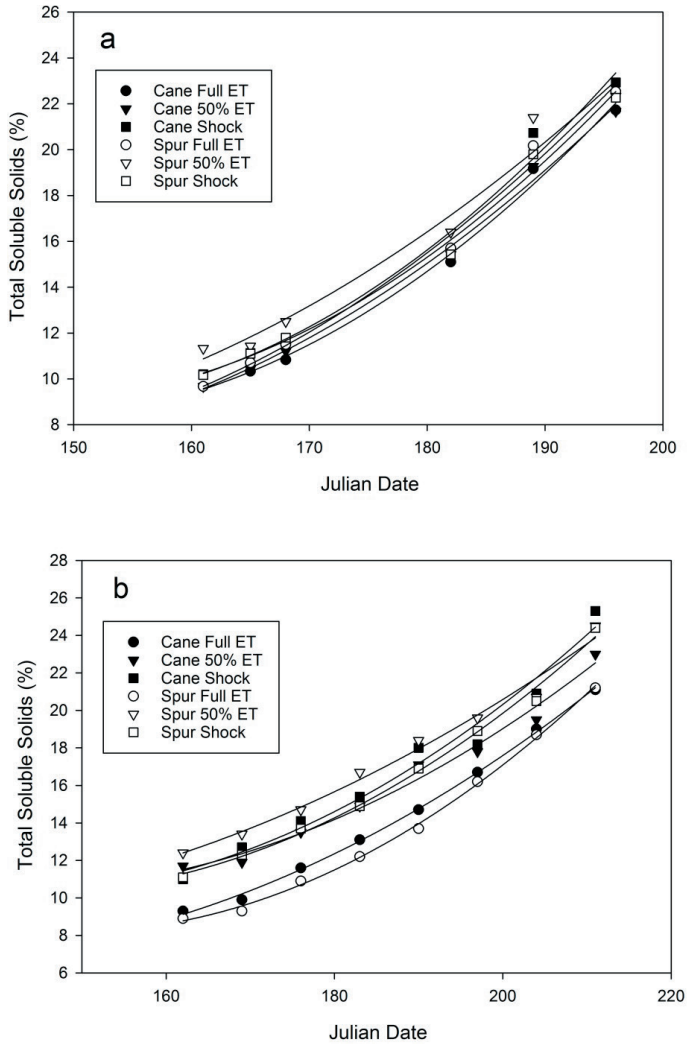

Fig. 2: Juice total soluble solids concentration of 'Sunpreme' grape during 2013 (a) harvested on six dates, and during 2014 (b) harvested on eight dates. Interaction of irrigation method, pruning style and harvest date was significant in 2013 ($P = 0.0308$) and in 2014 ($P < 0.0001$).

sampled across all study vines was 11.6%. Irrigation, but not pruning styles, influenced product moisture content (Table 1). Product from Shock-treated vines averaged 11.0 % moisture, significantly less than product from Full ET-treated vines (12.1 %). Product from 50 % ET-treated vines did not differ significantly in moisture content from the other two irrigation treatments (Table 1). B & better percentage was exceptionally high in 2013, but was not influenced by irrigation treatments or pruning styles. Among irrigation treatments, B & better raisin percentage ranged from 99.8 % (full ET) to 93.9 % (Shock). Similarly small differences existed between cane-pruned (98.1 %) and

Table 1. The influence of main effects of irrigation treatment and pruning style on product moisture, percentages of B & better and Substandard raisins produced during 2013 in Parlier, CA.

		Raisin Quality Analysis		
Treatment	Level	Moisture (%)	B & better (%)	Substandards (%)
Irrigation				
	Full ET	12.1 a	99.8	0.6
	50 % ET	11.6 ab	97.4	1.3
	Shock	11.0 b	93.9	1.0
Pruning				
	Cane	11.7	98.2	1.5
	Spur	11.5	95.9	0.4
ANOVA *P*-value				
	Irrigation	0.029	0.511	0.490
	Pruning	0.306	0.578	0.123

spur-pruned (95.9 %) vines. Across all study vines, substandard percentage averaged 0.96 %, ranging from 1.3 % (50 % ET) to 0.6 % (Full ET) among the irrigation plots and 1.5 % (cane-pruned) to 0.4 % (spur-pruned) for pruning styles (Table 1). Irrigation and pruning treatments did not significantly affect raisin substandard percentage.

Final sample moisture content was similar for the 2014 crop, averaging 11.4 % moisture across all treated vines on 10 September. Irrigation treatment again had a significant effect on product moisture with Shock-treated vines (10.6 %) having significantly lower moisture content than vines receiving Full ET (12.8 %). Pruning style did not influence product moisture (Table 2). Despite similar product moisture in the two study years, raisin quality differed considerably, with 77.6 % overall B & better percentage across study vines during 2014 vs. 97% in 2013. Neither irrigation treatment nor pruning style influenced the B & better percentages in the 2014 crop. The percentage of substandard raisins was influenced by irrigation treatment, with 50 % ET-treated vines (4.4 %) having significantly more substandards than Full ET-treated vines

Table 2. The influence of main effects of irrigation treatment and pruning style on product moisture, percentages of B & better and Substandard raisins produced during 2014 in Parlier, CA.

		Raisin Quality Analysis		
Treatment	Level	Moisture (%)	B & better (%)	Substandards (%)
Irrigation				
	Full ET	12.8 a	91.0	1.6 b
	50 % ET	10.8 ab	67.2	4.4 a
	Shock	10.6 b	74.5	2.9 ab
Pruning				
	Cane	11.5	79.2	2.6
	Spur	11.4	75.9	3.4
ANOVA *P*-value				
	Irrigation	0.041	0.088	0.048
	Pruning	0.891	0.535	0.158

(1.6 %). Pruning style did not significantly affect levels of substandard raisins.

Discussion

This study was conducted to examine the cumulative effects of long-term irrigation differences on crop maturity progression and raisin quality of the new natural dry-on-vine raisin cultivar 'Sunpreme.' Existing vines used in the study, receiving the same irrigation treatments for six years before the onset of the study, were evaluated for fruitfulness at the start of each growing season. Based on current season cluster counts, crop loads on all vines were adjusted to similar levels before bloom each season. Crop maturity progression was evaluated by measuring juice TSS periodically between verasion and berry wilting. Raisin quality was based on product moisture content at harvest, and sample evaluations with air stream sorters. Crop load levels differed greatly in the two years of the study (77 vs. 169 clusters/vine), leading to seasonal differences in the studied variables.

Although it was possible to analyze data collected from this study with ANOVA and regression, a lack of replication may have influenced the results. The 27-vine plot established for evaluating 'Sunpreme' under different irrigation regimes and pruning styles represents a significant investment in field space and annual maintenance costs, given the perennial nature of the crop. However, the linear arrangement of experimental units, while necessary for efficiency in maintaining plots, can introduce bias through non-randomized experimental units being associated with specific sections of row. It is possible that results may have been influenced by something other than treatment that was unique to a particular row section. Examination of the soil survey for Fresno County, California shows Fresno sandy loam being the dominant soil type in and around Parlier, without variation in the specific location where the 'Sunpreme' plot was established (Strahorn et al., 1914). While there is confidence that the soil type doesn't vary amongst experimental units in this study, other unknown factors associated with the site could have influenced treatment responses measured during this study.

Profitable raisin production in the California environment requires adequate tonnage of a high quality product being removed from the field prior to the onset of winter rains. 'Sunpreme' yield has been previously quantified and reported annually from vines used in this study (California Raisin Marketing Board, 2015). Yields have ranged from 12.2 T/ha (cane-pruned, 2011) to 8.16 T/Ha (cane-pruned, 2009), and reportedly averaged 10.8 T/ha from mature vines trained to quadralateral cordons (Ramming, 2015). 'Sunpreme' has dried on the vine consistently and adequately at this location prior to the onset of winter rains except during the 2010 and 2011 harvests. During these years, degree day accumulation was approximately 8% (2010) and 5% (2011) less than the eight year average (2007 – 2014) at the Parlier, CA location. Degree day accumulations for crop years 2013 and 2014 at the study site were 2863 and 2957, respectively, slightly above the eight year average (2776) as calculated from 15 April through 15 September with 7°C/45°C thresholds and using the single sine / horizontal upper cutoff calculation method. More accumulated heat during the 2014 growing season was undoubtedly a factor in bringing the heavier crop load to maturity at a similar date compared with the lighter crop in 2013.

There were large and obvious differences between the irrigation plots, and thus the volumes of water applied to the 'Sunpreme' vines used in this study. Phenological stages were used as keys for making changes in the imposed irrigation regimes. The Full ET treatment could be easily determined and adjusted weekly by the San Joaquin Valley Drip Irrigation Scheduler (Peacock and Christensen, 2006). Berry verasion was used as a point of change from Full ET to 50% ET for the 50% ET irrigation treatment. The

imposed Shock treatment required a two-week period where no irrigation was applied prior to berry wilt. From experience gained in this study, imposition of the two-week period should coincide generally with TSS levels of approximately 20% in 'Sunpreme.'

Maintenance of proper vine vigor and prevention of over cropping is necessary for 'Sunpreme' to dry on the vine naturally prior to winter rains (Ramming, 2015). Vines treated with Full ET were visually evident, both cane- and spur-pruned, due to their larger or more dense canopies as compared with vine canopies from the other irrigation plots. Since differences in dormant prunings weights were not significant across irrigation plots, and similarly, irrigation method did not influence significantly vine fruitfulness during the course of this study, little appears to be gained through the use of a Full ET irrigation regime throughout the growing season. Furthermore, drying down the soil profile after verasion through deficit irrigation is a logical step to advance the berry ripening process. Given the current drought situation throughout California, raisin growers would be motivated to save any volume of water when it is not actively contributing to their profit margin.

The use of Full ET throughout the growing season also led to significantly higher sample moisture content as compared with Shock-treated vines, regardless of the pruning style used. This was evident in both study years (Tables 1 and 2), and yet another reason to avoid Full ET irrigation regimes. However, all product samples collected during both study years, regardless of irrigation method or pruning style, were well below the required 16% moisture content for 'natural seedless' raisins (Butler, 1978). In years where degree day accumulation is below average, use of Full ET on 'Sunpreme' will further exasperate the raisining process and may delay harvest further.

Raisin quality was extremely high in 2013, with the reduced crop load (62 % available clusters), from all irrigation plots, being more than 90% B & better overall. However, B & better percentage has averaged 89% from 'Sunpreme' vines during seven consecutive harvest years without any crop reduction (Ramming, 2015). Raisin quality was lower in 2014 with the heavier crop load (81 % available clusters), but only in 50% ET and Shock-treated plots (Table 2). Full ET-treated vines still produced better than 90% B & better raisins with the heavier crop load in 2014.

Throughout this study, pruning style had little effect on any of the variables measured. Hence, the new raisin cultivar can be spur-pruned without loss of potential crop as compared with cane-pruned vines. Presently, no other grape cultivar used for raisin production in California is capable of producing a commercial crop when spur-pruned. Given the proven spur-pruned fertility of 'Sunpreme,' raisin growers will probably mechanically pre-prune vineyards to reduce labor inputs further in vine preparation, making raisin production more efficient and automated. With reduced water availability for agricultural purposes being expected for California producers in the future, studies will continue to examine the balance between applied water, raisin quality and the need to bring the crop off the vine before the onset of winter rains.

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About The Cover:
illustration from The Book of Pears

The Journal of the American Pomolgical Society invites book reviews. The first is the review, provided by Dr. Kate Evans, is a review of "The Book of Pears: The Definitive History and Guide to Over 500 Varieties", by Joan Morgan with paintings by Elisabeth Dowle. The illustration on the cover is one of 40 that accompany the text. The illustration of 'Seckle' pear was selected because it is probably the oldest American pear cultivar that is still widely grown. In Pears of New York, U.P. Hedrick described 'Seckle' as "standing almost alone in vigor of tree, productiveness, and immunity to blight, and is equaled by no other variety in high quality of fruit. If the fruits were larger, Seckle would challenge the world as a pear for the markets as it now does as a pear for the home orchard." Seckel was a favorite of Thomas Jefferson. The original tree was found near Philadelphia in the late 1700s and at the first meeting of the American Pomological Society, held in 1949, Seckel was recommended for general cultivation and the variety has ever held its place among the pears recommended by the Society.

Journal of the American Pomological Society 70(1): 46-47 2016

Book Review:
The Book of Pears: The Definitive History and Guide to Over 500 Varieties

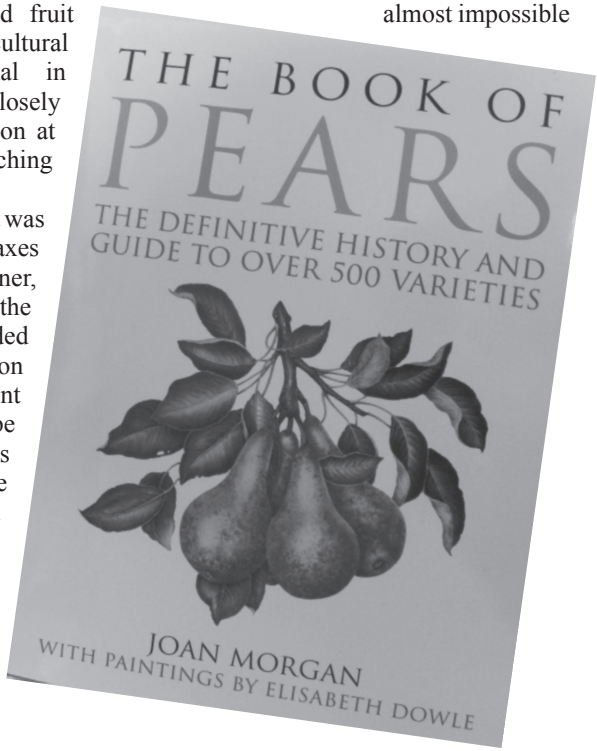
Joan Morgan with paintings by Elisabeth Dowle. 2015. Chelsea Green Publishing. 85 North Main St., Suite 120, White River Junction, VT 05001. Hardcover. ISBN 978-1-60358-666-5. Hardcover $65.000.

'The Book of Pears' takes the reader on a wonderfully rich history of the fruit, providing often surprising details of the importance of pear in ancient and more recent civilizations. Dr. Joan Morgan traces the origins of the cultivated pear back to accounts of massed plantings in ancient Persia around 500BC then skillfully guides us through the spread of pear around the world, interspersing the text with fascinating historic images that support the story.

Dr. Morgan is a pomologist and fruit historian, awarded the Royal Horticultural Society's Veitch Memorial Medal in recognition of her work. She works closely with the UK National Fruit Collection at Brogdale in Kent and has been researching this book for many years.

It is difficult to believe the value that was placed on pears through the ages; taxes from the tenant farmers to the landowner, to prized specimens nurtured by the gardeners of large estates for the landed gentry. Careful collection and selection of varieties resulted in the development of fine quality pears that could be eaten fresh rather than cooked and as such became a standard feature on the dining tables of the rich and powerful. The number of varieties was greatly increased as fruit breeders, especially in Northern Europe, started to focus on pear; new improved varieties were quick to spread throughout the pear-growing regions of the world.

The second part of the book, the directory of pears, provides a comprehensive description of over 500 pear varieties, primarily those from the UK National Fruit Collection but also including others of interest (dessert, culinary, Asian, Asian/Western hybrids and perry pears). Each entry is categorized into season (early, medium or late), use (desert or culinary) and tree vigor with the addition of habit and disease resistance and susceptibility information as available. Triploids, confirmed through cytogenetics, are noted and each description usefully includes synonyms as well as a brief history with parentage if known. Dr. Morgan managed what many would consider almost impossible



by ripening these varieties and fully describing their sensory properties, both appearance and eating quality.

The accompanying website www.thebookofpears.fruitforum.net/ provides a gallery of photographs that attempt to capture the external key features that define each variety and is a wonderful addition to the text.

The 40 plates, accurately painted by artist Elisabeth Dowle, depict fruit, both ripened and on the tree, blossom and leaves. They add a delightfully detailed color splash throughout the chapters, causing the reader to pause in admiration and provide an additional point of reference when attempting to identify a variety. Ms Dowle is an internationally respected artist and has been awarded seven Royal Horticultural Society Gold Medals, one of which was given for some of the paintings in this book.

Dr. Morgan adds an excellent pear identification key based on season and shape, a section on growing pears for the amateur and even a small collection of recipes. Readers are left with a further information section listing pear collections around the world, both public and private, and a comprehensive reference section for those wanting more.

Once again Dr. Morgan has excelled herself with 'The Book of Pears'; it forms a perfect companion to 'The Book of Apples' and I strongly recommend it to all with an interest at every level in pome fruit.

Dr. Kate Evans
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Index for Volume 69

Instructions to Authors

Journal of the American Pomological Society

The prime purpose of the Journal of the American Pomological Society is to provide a repository for information on all aspects of fruit and nut crops. The long-term emphasis of the journal on cultivars and rootstocks continues, but manuscripts reporting original research on a wide range of fruit and nut crops are welcomed. Acceptable areas of research including pruning, nutrition, growth regulators, cultural practices, economics, and pest control. Studies involving the interaction of one or more of these aspects with either cultivars and/or rootstocks are particularly appropriate. If in doubt about the suitability of a particular manuscript, please contact the Editor.

Reports on field studies are expected to contain data from multiple years. Reports are to be the result of adequately replicated trials and the data should be subjected to appropriate statistical analysis. Manuscripts submitted for publication in the Journal must not have been previously published, and submission implies no concurrent submission elsewhere.

Scientific names and authorities for plants, disease organisms, and insects should be include parenthetically when the organism is first mentioned. American spelling conventions and SI units should be used. The number system is used for literature citations. Manuscripts should be double spaced throughout. Typical organization is as follows: Title, Authors, Abstract, Introduction, Materials and Methods,Results, Discussion, Literature Cited,Tables, Figures. The Results and Discussion sections are often combined. Author addresses and acknowledgements are in footnotes on the first page. More detailed instructions for manuscript preparation can be found at: http://www.americanpomological.org/journal/journal.instructions.html

Prior to submission, manuscripts should be reviewed by at least two colleagues and revised accordingly. **At the time of submission, the corresponding author must attest in the covering letter to the Editor that all co-authors on the paper have had the opportunity to review it prior to submission, that it has not been published previously, and that it is not presently under consideration for publication elsewhere. In addition, the names and full contact information (mailing address, e-mail and telephone numbers) for three potential reviewers should be provided.** Submit three copies of the manuscript to the Editor: Dr. Richard Marini, 203 Tyson Building, Department of Plant Science, University Park, PA 16802-4200 USA; E-mail: richmarini1@gmail.com. Electronic submission is encouraged. Acceptable formats are MSWord or WordPerfect.

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Call for Wilder Silver Medal Nominations

The Wilder Committee of the American Pomological Society (APS) invites nominations for the 2016 Wilder Silver Medal Award. All active members of APS are eligible to submit nominations. The award was established in 1873 in honor of Marshall P. Wilder, the founder and first president of APS. The award consists of a beautifully engraved medal which is presented to the recipient at the annual meeting of APS, held during the ASHS Annual Meeting.

The Wilder medal is presented to individuals or organizations that have rendered outstanding service to horticulture in the area of pomology. Special consideration is given to work relating to the origination and introduction of meritorious fruit cultivars. Individuals associated with either commercial concerns or professional organizations will be considered if their introductions are truly superior and have been widely planted. Significant contributions to the science and practice of pomology other than through fruit breeding will also be considered. Such contributions may relate to any important area of fruit production such as rootstock development and evaluation, anatomical and morphological studies, or noteworthy publications in any of the above subjects. Information about the award, past recipients, etc. can be found on the APS website at:
http://americanpomological.org/wilder1.html

To obtain nomination guidelines, please contact committee chairperson,

Dr. John R. Clark
Dept. of Horticulture, University of Arkansas
phone: 479-575-2810
fax 479-575-8619
e-mail: jrclark@uark.edu

Nominations must be submitted by 1 May 2016.

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