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Original article – Thematic Issue

Cane productivity and fruit quality in highbush blueberry are affected by cane diameter and location within the canopy

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Summary

Cane productivity in blueberries can be affected by their diameter, but the effect of cane spatial location (i.e., position within the canopy) on fruit yield and quality is unknown. This study aimed at assessing for two seasons the effect of cane diameter and location on yield and fruit quality of mature highbush blueberries cv. O'Neal and Brigitta (*Vaccinium corymbosum* L.). In a field in Romeral, Chile (34°58'00"S, 71°08'00"W), cane diameter was measured at 10 cm from the cane base. Canes were then grouped into three diameter classes: 0–0.9, 1–1.9 and 2–2.9 cm. In every bush, the spatial location of each cane was defined as external (located within 25 cm from the canopy periphery), or internal (those canes growing in the canopy center). Fruit with >80% blue color were harvested every five to seven days from each cane; fruit number and weight, yield, as well as fruit soluble solids, firmness and diameter were determined. Availability of radiation (% full sun: % FS) was measured for cane location and every 30 cm from top to the base of the canopy. The extension of the productive zone (cm) was established for each cane according to its location and diameter. Fruit firmness, weight loss, dehydration, soft fruit and decay were determined after 40 d storage (0°C and 90% HR). For both years external canes had on average higher yield (67% for 'Brigitta'; 69% for 'O'Neal') and fruit number (54% for 'Brigitta'; 62% for 'O'Neal') than internal canes. Yield increased with greater cane diameter and this was due mainly to larger fruit number per cane. Fruit number and yield per cane were highly correlated for both varieties and seasons ($r^2 \geq 0.86$). In the first season for cv. O'Neal, fruit weight was higher (34%) in 0–0.9 cm canes than in canes >1 cm diameter. In cv. Brigitta, no differences were found for fruit weight. For cv. O'Neal, soluble solids, firmness and fruit diameter were not affected by cane location or diameter. In cv. Brigitta, external canes had fruit with lower soluble solids (13.1 °Brix) than internal ones (14.4 °Brix). Fruit diameter in 'Brigitta' was significantly higher in canes with diameters >1 cm. Cane diameter and location did not affect fruit weight loss after 40 d storage in cv. O'Neal. In cv. Brigitta, fruit weight loss was higher in 0–0.9 cm canes than in 1–1.9 cm canes. The productive zone in external canes as compared to internal canes was 32% higher for cv. O'Neal and 38% for cv. Brigitta. The extent of the productive zone was greater (56–72%) in thicker canes. Availability of radiation was higher for external (42% FS) than internal canes (27% FS). Radiation decreased from the top to the base of the plant (from 51% to 18% FS). As in the canopy center the intensity of radiation was lower, this would have reduced the productive area of those canes, which would have induced lower fruit numbers ending up in decreased yield but with little effect on fruit quality. Orchard practices should aim at increasing light availability in the center of canopies to maintain high flower number and high yields.

Keywords
fruit number, fruit weight, light availability, *Vaccinium corymbosum* L., yield, yield components

Significance of this study

What is already known on this subject?

- It is already known that cane productivity decreases in very old (thick) canes and also that light availability within the plant affects flower induction.

What are the new findings?

- Cane productivity is highest when canes are around five- to eight-year-old (2.5–3.0 cm diameter at their base); besides, we found that canes located in the center of the canopy (internal canes) had lower yield than external ones. Light availability in the center of the canopy (internal canes) was lower, and this reduced flower induction, which minimized fruit number and finally induced lower yield than canes in the periphery (external canes). Fruit quality at harvest and fruit postharvest life were not affected by cane diameter and location.

What is the expected impact on horticulture?

- Our results show that pruning older canes could be postponed, since this would increase yield without affecting fruit quality at harvest and during postharvest. Whole cane removal in the canopy center through basal pruning and canopy opening would allow greater light availability in this area of the canopy and these practices should increase fruit number and yield of internal canes.

Introduction

Blueberry yield depends upon the interaction of different components (canes/plant, fruit number/cane and fruit weight). In highbush blueberries there is compensation between fruit number and fruit weight (Siefker and Hancock, 1986); thus, as fruit number increases, fruit weight decreases. Besides, these authors concluded that the number of

canes per bush and the number of fruit per cane had a greater influence on yield than fruit weight.

Berry size is very important for consumers. Larger fruit are cheaper to harvest (Strik et al., 2003) and would behave differentially in storage. Thus, inducing high yields of large fruit would increase profitability in blueberries. When fruit size is affected, other quality characteristics should also be altered, such as: soluble solids, acidity, firmness, etc. (Retamales and Hancock, 2012).

Productivity in blueberries would increase up to when canes are five-year-old, then it would stabilize for a couple years and finally it would be reduced in older canes; however, these authors did not present supporting data on this issue (Shutak and Marucci, 1966).

In deciduous fruit crops it has been reported that at least 30% FS is needed for flower bud induction (Rom, 1991). In rabbiteye blueberries a minimum of 25% FS is needed for flower induction (Yáñez et al., 2009). In highbush blueberries, light availability affects among other variables: flower induction, berry size, fruit colour, soluble solids and postharvest behavior (Lobos et al., 2013).

Cane productivity should vary with cane age and spatial location. These issues influence the decision of which canes should be removed when pruning. In this trial, we evaluated the effect of cane diameter and location on yield and fruit quality in highbush blueberry plants. In this context, the hypothesis of this study was that in adult highbush blueberry plants cv. O'Neal and Brigitta, intermediate diameter canes (1.5–2.5 cm) growing in external locations of the canopy, had higher yields and fruit quality.

Materials and methods

General

The trial was conducted in a commercial blueberry field located in Romeral, Chile (34°58'00"S, 71°08'00"W) over two growing seasons. Fifteen plants were selected in both cv. O'Neal (twelve-year-old plants) and cv. Brigitta (six-year-old plants). Plants with similar number of canes were selected (average 25 canes per plant). For both varieties, plants were established at 3 × 1.2 m in rows oriented southwest-northeast. They were drip-irrigated (4 L h^{-1}) with one line per row. The soil in the field has a silty loamy texture at 0 to 40 cm, and clay loam texture at 40 to 55 cm (CIREN, 1997). The maximum average temperatures of January and July (hottest and coldest months) are 28.2°C and 2.7°C, respectively (CIREN, 1990). Plants were not pruned during the trial. Plants initiate growth in August, bloom occurs in September; depending on cultivar, harvest is done between November and February; finally, leaves drop in March–April (Bañados, 2007).

Measurements

The diameter of each cane was measured at ten cm from the base (Siefker and Hancock, 1986). Canes were then grouped into three diameter classes: 0–0.9, 1–1.9, and 2–2.9 cm. In every bush, the spatial location of each cane was defined as either external (E), located within 25 cm from the canopy periphery, or internal (I) those growing in the canopy center. Fruit with at least 80% of blue coverage were hand-harvested every five to seven days from each individual cane; fruit weight, number and yield per cane were determined for each cane and picking. Soluble solids were measured (20 fruits per replication) with a hand-held refractometer (ATAGO, Master-α, Japan), fruit firmness and diameter were measured in 25 fruits for each combination of cane diameter and location with a FirmTech II firmness tester (Bioworks, Inc., Wamego, USA). Photosynthetically active radiation (PAR) was measured on clear days with a ceptometer (SunScan SS1, Delta-T Devices Ltd., Cambridge, England) for each cane location (internal-external) and every 30 cm from the top to the base of the plant once a month between December and February for every season and variety. Data were expressed as percent of full sun (% FS) with respect of total PAR radiation measured five cm above the plant apex (full sunlight). We defined productive zone (cm) of each cane, as the length of the cane that produced fruit; this was determined for every cane location and diameter. A total of 100 fruits per cane location and diameter were picked and stored (0°C and 90% HR) within five to seven hours after harvest for 40 d. After storage, weight loss and the proportion of decay, soft and dehydrated fruit were determined.

Statistics

The experimental design was a factorial with a completely randomized arrangement. The factors were three classes of cane diameters and two cane locations (internal and external). Data were submitted to analysis of variance using the Statgraphics Centurion XVI software. Significant variables were submitted to multiple comparison of means (Tukey's test), with a confidence level of 95%. In both varieties, the correlations between cane diameter and yield, as well as fruit number and yield per cane were established.

Results

Yield, fruit number and fruit weight

In both varieties, the interaction between cane diameter and location was not significant for yield, fruit number or fruit weight.

1. Effect of cane location on yield, fruit number and fruit weight. For cv. O'Neal, yield per cane in both seasons was significantly higher in external canes than in internal ones (Table 1). The yield for external canes was 82% and 56% higher than that of internal canes, for the first and second season respectively. In 'Brigitta' the tendency was similar, as yield was 64% and 70% higher in external than in internal canes, for the first and second season, respectively (Table 2). A similar trend was registered for fruit number. In average, external canes of 'O'Neal' had 62% higher fruit number than internal canes. External canes of 'Brigitta' had 54% higher fruit number than the internal ones. Yield was positively correlated with fruit number in both varieties and in both seasons (r^2 = 0.86–0.99; $P < 0.05$). Thus, yield would be mainly explained by the higher fruit number rather than greater fruit weight. Fruit weight was equivalent for external and internal canes. Average fruit weight was 1.19 g, for 'O'Neal' and 'Brigitta' (Tables 1 and 2).

2. Effect of cane diameter on yield, fruit number and fruit weight. In both seasons, yield in cv. O'Neal increased with greater cane diameter (Figure 1a). The relationship between cane diameter and yield for this variety was positive in the first season, with r^2 = 0.71 and r^2 = 0.78 for internal and external canes, respectively. In 'O'Neal', cane yield in the first season was four times higher in canes of 1.0–1.9 cm of diameter than in canes of 0–0.9 cm diameter; besides, yield in canes of 2.0–2.9 cm diameter doubled the yield of canes with 1.0–1.9 cm diameter. The same trend was registered in the second season. In both seasons, fruit number increased when cane diameter increased. In the first season, fruit weight was significantly higher in thinner canes (0–0.9 cm

Table 1. Effect of cane location (Internal = I; External = E) and diameter (cm) on yield (g cane^{-1}), number of fruits per cane and fruit weight (g) for cv. O'Neal in two seasons (year 1 and 2).

Factor		Yield[1] (g cane^{-1})		No. fruits cane^{-1}		Fruit weight (g)	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Location (L)	I	205 b	203 b	206 b	154 b	1.00	1.32
	E	374 a	317 a	340 a	242 a	1.10	1.31
Significance[2]		***	**	***	**	n.s.	n.s.
Diameter (D)	0 – 0.9	60 c	78 c	45 c	62 c	1.33 a	1.26
	1 – 1.9	263 b	272 b	254 b	207 b	1.04 b	1.31
	2 – 2.9	546 a	430 a	520 a	326 a	1.05 b	1.32
Significance		***	***	***	***	***	n.s.
L*D		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: *** = $p < 0.001$; ** = $p < 0.01$; n.s. = not significant at $p < 0.05$.

Table 2. Effect of cane location (Internal = I; External = E) and diameter (cm) on yield (g cane^{-1}), number of fruits per cane and fruit weight (g) for cv. Brigitta in two seasons (year 1 and 2).

Factor		Yield[1] (g cane^{-1})		No. fruits cane^{-1}		Fruit weight (g)	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Location (L)	I	210 b	250 b	154 b	266 b	1.36	0.94
	E	344 a	425 a	246 a	402 a	1.40	1.06
Significance[2]		**	**	**	**	n.s.	n.s.
Diameter (D)	0 – 0.9	63 c	77 c	48 c	83 c	1.31	0.93
	1 – 1.9	287 b	270 b	215 b	305 b	1.33	0.89
	2 – 2.9	479 a	665 a	337 a	614 a	1.42	1.08
Significance		***	***	***	***	n.s.	n.s.
L*D		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: *** = $p < 0.001$; ** = $p < 0.01$; n.s. = not significant at $p < 0.05$.

Table 3. Availability of radiation (%FS) for different cane locations (Internal = I; External = E) and for three different distances from the top to the base of the plant, in adult highbush blueberries of cv. O'Neal and Brigitta in two seasons (year 1 and 2).

Factor		%FS			
		'O'Neal'[1]		'Brigitta'	
		Year 1	Year 2	Year 1	Year 2
Location	I	30 b	28 b	21 b	29 b
	E	38 a	45 a	30 a	55 a
Significance[2]		***	*	***	***
Distance (cm)	30	40 a	49 a	38 a	63 a
	60	27 b	21 b	24 b	33 b
	90	22 b	13 c	22 b	20 c
Significance		***	***	***	***

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: *** = $p < 0.001$; * = $p < 0.05$; n.s. = not significant at $p < 0.05$.

diameter) than in the other cane diameter classes, but in the second season there were no significant differences in fruit weight among these cane diameter classes (Table 1).

The same trend reported previously in cv. O'Neal was also observed in 'Brigitta' (Figure 1b). Thus, in the first season, when cane diameter increased there was a concurrent increase in yield ($r^2 = 0.65$ for internal canes; $r^2 = 0.72$ for external canes). Yield was higher in thicker canes (2–2.9 cm diameter) than in medium size canes (1–1.9 cm diameter), and in turn these canes had higher yields than thinner ones (0–0.9 cm diameter). Fruit number followed the same trend; thus, with greater cane diameter fruit number increased. For 'Brigitta' no significant differences were found in fruit weight for different cane locations or diameters for any of the two seasons (Table 2).

Effect of cane location on radiation availability and productive zone

For both varieties and in the two seasons, the availability of radiation (% FS) was significantly higher in external canes than in internal ones (Table 3). Our results show that radiation intensity decreased from the apex to the base of the plant (Table 3). In the first season of cv. O'Neal, we measured 27% FS at 60 cm from the apex of the plant. The intensity of radiation was gradually lower towards the base of the bush. In the second season and for the same zones inside the bush, lower radiation intensities were registered (<21% FS). For cv. Brigitta, at 30 cm from the top of the plant, we registered an average of 38% FS in the first season. For the second season, in this cultivar there were significant differences for % FS between the three distances from the top of the canopy, with only 20% FS being registered at 90 cm from the top of the plant.

The productive zone was significantly higher in external canes than in internal ones. Our data show that the productive zone was 32% higher in external canes of cv. O'Neal and 38% in those of cv. Brigitta (Table 4). Furthermore, the extent of the productive zone was greater in canes of larger diameter (2–2.9 cm) than in thinner ones (0–0.9 cm). No significant effects in the productive zone were detected for the interaction between location and cane diameter.

Effect of cane diameter and location on fruit quality

Fruit quality, as determined by soluble solids, firmness and fruit diameter, was not affected by cane location or its diameter in cv. O'Neal (data not reported). In cv. Brigitta, significant differences were found only for soluble solids due to cane location (Table 5); thus, external canes had lower soluble solids concentration (13.1 °Brix) than internal canes (14.4 °Brix). Regarding cane diameter, canes of 'Brigitta' in the 0–0.9 cm class had a significant lower fruit diameter than thicker canes.

Effect of cane diameter and location on fruit postharvest

Fruit postharvest quality after 40 d of cold storage was not affected by cane location and diameter in cv. O'Neal (Table 6). In cv. Brigitta, fruit weight loss was higher in thinner cane diameters (0–0.9 cm) than in canes of intermediate

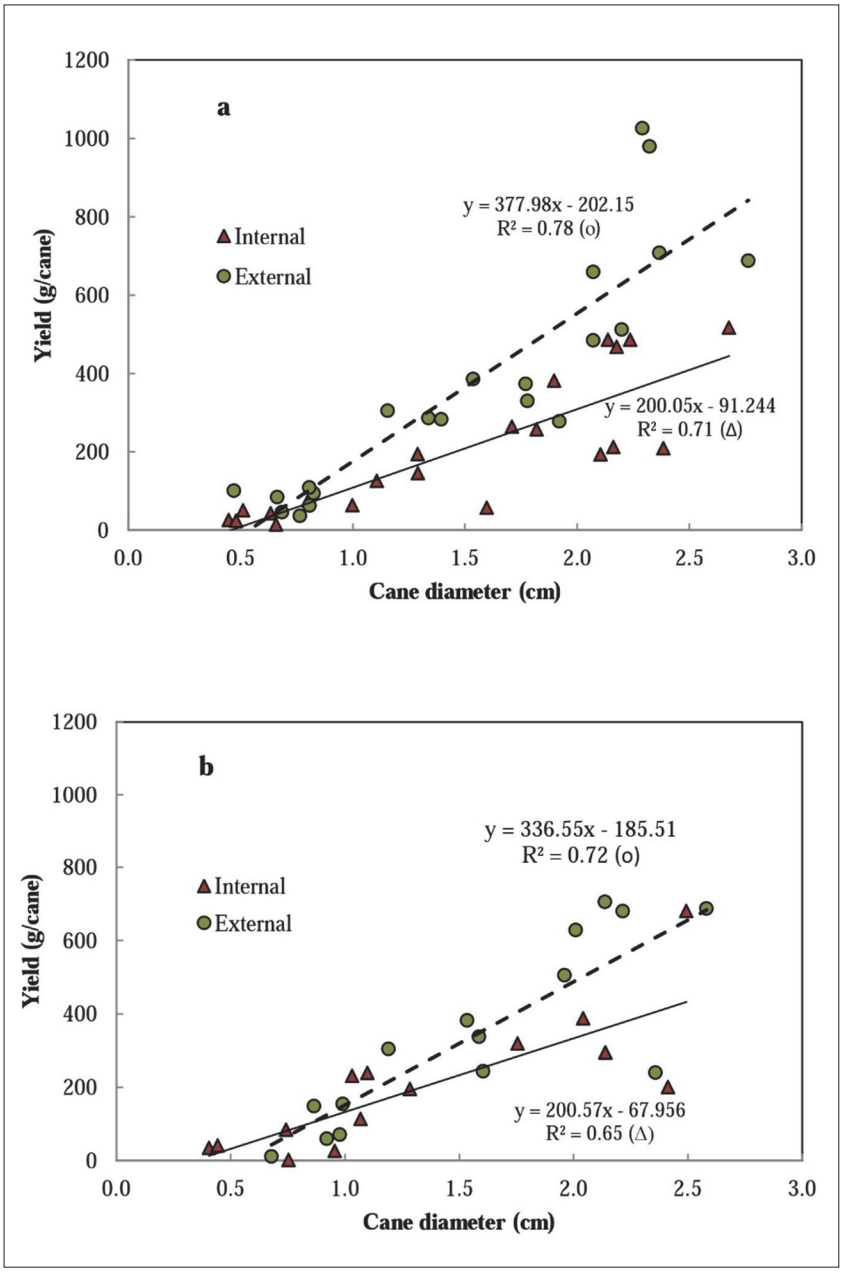


Figure 1. Relationship between cane diameter (cm) and yield (g cane^{-1}) for external (o; dashed line) and internal canes (Δ; solid line) in (a) cv. O'Neal and (b) cv. Brigitta for season 1. Romeral, Chile (34°58'00"S, 71°08'00"W).

diameters (2–2.9 cm). The proportions of undamaged, soft and dehydrated fruits did not show significant differences for cane location and diameter in both cultivars (Table 6). The proportion of decay fruits was not shown because it was close to zero for both cultivars.

Discussion

The hypothesis of this study was that in adult highbush blueberry plants cv. O'Neal and Brigitta, intermediate diameter canes (1.5–2.5 cm) growing in external locations of the canopy, had higher yields and fruit quality. This hypothesis is not entirely confirmed by our results, since we obtained higher yields in thicker canes (2.0–2.9 cm) which were located in the periphery of the bush, but these thicker canes did not induce significant differences in fruit quality at harvest or in postharvest. In both varieties and in both seasons, yield was affected by both cane diameter and location but not by their interaction. Thus, thicker canes produced higher yields. This effect would be mainly due to the higher number of fruits per cane, as fruit weight was in general not significantly affected by cane diameter.

Table 4. Productive zone (cm) in cv. O'Neal and Brigitta for different locations (Internal = I; External = E) and cane diameters (cm) in the second season.

Factor		Productive zone (cm)	
		'O'Neal'[1]	'Brigitta'
Location (L)	I	34 b	42 b
	E	45 a	58 a
Significance[2]		*	*
Diameter (D)	0 – 0.9	29 b	32 b
	1 – 1.9	40 ab	50 ab
	2 – 2.9	50 a	68 a
Significance		**	***
L*D		n.s.	n.s

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: *** =$p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$; n.s. = not significant at $p < 0.05$.

Table 5. Soluble solids, firmness and fruit diameter as affected by cane location (External = E; Internal = I) and cane diameter (cm) for cv. Brigitta in the second season.

Factor		Soluble solids (°Brix)[1]	Firmness (mm g^{-1})	Fruit diameter (mm)
Location (L)	I	14.4	170.3	11.4
	E	13.1	175.1	11.7
Significance[2]		**	n.s.	n.s.
Diameter (D)	0 – 0.9	13.6	173.1	11.0 b
	1 – 1.9	13.7	170.9	12.0 a
	2 – 2.9	14.0	174.1	11.8 a
Significance		n.s.	n.s.	**
L*D		n.s.	n.s.	n.s.

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: ** = $p < 0.01$; n.s. = not significant at $p < 0.05$.

Table 6. Fruit weight loss after 40 d of storage (0°C and 95% relative humidity) and proportions of undamaged, soft and dehydrated fruit for cv. O'Neal and Brigitta in the second season.

Factor		Weight loss (%)		Type of damage (% of fruit)					
				Undamaged		Soft		Dehydrated	
		'O'Neal'[1]	'Brigitta'	'O'Neal'	'Brigitta'	'O'Neal'	'Brigitta'	'O'Neal'	'Brigitta'
Location (L)	I	13.0	8.5	54	65	34	19	11	16
	E	12.3	8.0	50	69	31	13	18	19
Significance[2]		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Diameter (D)	0 – 0.9	13.6	9.0 a	45	70	39	13	17	17
	1 – 1.9	12.3	7.7 b	55	63	31	17	14	21
	2 – 2.9	11.2	8.0 ab	59	69	28	18	13	14
Significance		n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
L*D		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[1] Means within a column followed by the same letter do not differ statistically by Tukey's test, $p \leq 0.05$.
[2] Significance: * = $p < 0.05$; n.s. = not significant at $p < 0.05$.

As reported by Shutak and Marucci (1966), yield in a given cane would increase up to when canes are around five-year-old, then it would remain stable up to when canes reach seven years, but beyond this age their yield would decrease. Consequently, it has been proposed that in pruning, canes older than five- and six-year-old should be removed from the plant, because every year these canes would decrease in vigor, yield and fruit size (Shutak and Marucci, 1966; Bañados, 2007; Hanson et al., 2000; Strik et al., 2003). According to our data, canes of medium thickness (2–2.9 cm in diameter), which would correspond to five- and up to eight-year-old canes, were the most productive ones and then it would not be convenient to remove them from the bush during pruning. In our study, the number of thicker canes (>3 cm diameter) was low (around 1% of the total number of canes), and since they were not statistically representative, it was not possible to include them in the evaluation.

Yáñez et al. (2009) reported that 25% FS is the minimum requirement for floral induction in rabbiteye blueberries. They also showed that the number of flower buds within the canopy were directly related to the amount of available radiation (% FS). They determined that 63.7% of the flower buds were in the top 60 cm of the canopy, where higher radiation intensities were recorded (>25% FS). This lower flower induction would reduce fruit number and finally decrease cane productivity (Lobos et al., 2013). It has been reported that canes in the center of the bush (internal canes) had lower light availability and reduced floral induction (Lobos et al., 2013). Research in *Corylus avellana* (Hampson et al., 1996), *Prunus persica* L. Batsch (Lewallen and Marini, 2003) and *Gossipium hirsutum* L. (Reta-Sánchez and Fowler, 2002), found that the radiation decreased from the apex to the base of the plant, a condition which affected both vegetative and reproductive characteristics of those species. Furthermore, it has been shown that the availability of radiation inside blueberry canopies also influences fruit set, size and color development (Lobos et al., 2009; Kim et al., 2011).

The low fruit weight values that were obtained in our trials could be due to the fact that all fruits in each cane were harvested, independent of the criterion for fresh fruit exports (fruit diameter >10 mm) (Chilean Blueberry Committee, 2013). This similarity in weight of fruit from various canopy locations and cane diameters, does not coincide with results reported by Lobos et al. (2013) for cv. Elliott, in which treatments with greater shading (75% shade) had greater fruit weight (1.68 g) and lower fruit number than fruit from plants with less shading (25% shade; 1.48 g). Retamales et al. (2008), studied the effect of net color (red, black, white and grey) and degree of shading (50 or 35% shade) in highbush blueberry cv. Berkeley and they did not find differences on fruit weight due to the color of the net or the level of shading; although some treatments increased yield (white 50%, grey 50% and red 50%), they attributed this effect to the impact of shading on fruit set. The lower fruit weight in the second season was probably due to the higher number of fruit collected in that period (Siefker and Hancock, 1986).

The productive zone was higher in external than in internal canes, and this would be associated with higher intensities of radiation available in the outside portion of the canopy. Light availability inside the canopy is not homogeneous. Some sections in the center of the plant may suddenly receive high radiation intensity due to sunspots, wind, or changes in solar position during the day (Rom, 1991). Tiyayon and Strik (2004) studied the effect of overhead shading on yield, fruit quality, and subsequent flowering of kiwifruit. Individual vines were shaded with shade cloth (45% FS). Their results show that vines shaded for two months before harvest had 48% fewer flowers per vine than unshaded vines (control). Furthermore, in the following season shaded vines had fewer fruit (30%) and lower yield (50%) than unshaded plants. These findings agree with our results, since radiation intensities are lower inside the canopy, which in blueberries would reduce floral induction (Yáñez et al., 2009); as a result fruit number would be reduced and the extent of the productive zone would be decreased.

Fruit quality in cv. O'Neal was not significantly affected by location or cane diameter. In cv. Brigitta, soluble solids was higher for internal than external canes. Thinner 'Brigitta' canes (0–0.9 cm diameter) had a significantly lower fruit diameter than thicker canes. Lobos et al. (2013) working on highbush blueberry cv. Elliott, reported that as intensity of PAR radiation decreased, there was a linear decrease in the concentration of soluble solids ($r^2 = 0.86$; $P < 0.0001$) from 12.9% (control, full sun) down to 9.3% (75% shade with black net). These results differ from those published by Retamales et al. (2008), in which the concentration of soluble solids in highbush blueberry cv. Berkeley was not affected by shading treatments (black, gray, red and white nets; 35 and 50% shading) in comparison to control treatments (full sun). Total sugar concentration in blueberry fruits usually represents more than 10% of fresh fruit weight (Retamales and Hancock, 2012; Bremer et al., 2008). Shaded leaves in close proximity to the fruit induce lower fruit soluble solids concentration, but this can be compensated by assimilates translocated from more exposed zones of the canopy (Marini et al., 1991). No significant differences were found in apple fruit firmness in response to different radiation intensities (Campbell and Marini, 1992; Dussi et al., 2005; He et al., 2008). These results in other fruit crops differ from those obtained by Lobos et al. (2013) in highbush blueberry in which firmness in fruits under 75% shade was higher than in plants under 25% shade. It has been reported that lower radiation intensities in plants under shade affect fruit cell wall formation and increase fruit water content which influences fruit firmness (Dussi et al., 2005; Lobos et al., 2013).

During postharvest, weight loss was higher in thinner canes (0–0.9 cm) than in canes of intermediate diameters (1–1.9 cm); this would be explained by fruit size, where smaller fruits had more surface exposure per unit weight. During postharvest, commercially acceptable blueberries should have fruit weight losses lower than 8% (Sanford et al., 1991; Paniagua et al., 2013). Fruit weight losses in our trials surpassed the above-mentioned limit (Table 6), and this may be due to the rather long waiting period between harvest and storage. Weight losses vary in different cultivars according to fruit handling, temperature settings and storage conditions (Paniagua, 2012).

Growers want to increase blueberry yields without reducing fruit quality. Therefore, pruning strategies and canopy management in highbush blueberries should aim at increasing the availability of light in the center of canopies in order to consistently maintain high flower numbers and high yields. For these varieties and cane diameters, growers could postpone pruning canes of larger diameters, since this would generate higher yields without affecting the quality and postharvest life of the fruit.

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