Scientia Horticulturae 241 (2018) 51–56

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effect of source/sink ratio on leaf and fruit traits of blueberry fruiting canes in the field

E. Jorquera-Fontena[a,*], C. Pastenes[b], C. Meriño-Gergichevich[c,d], N. Franck[b,e]

[a] Departamento de Ciencias Agropecuarias y Acuícolas, Universidad Católica de Temuco, Chile
[b] Departamento de Producción Agrícola, Universidad de Chile, Santiago, Chile
[c] Scientific and Technological Bioresource Nucleus (BIOREN), Universidad de La Frontera, Temuco, Chile
[d] Facultad de Ciencias Agropecuarias y Forestales, Universidad de La Frontera, Temuco, Chile
[e] Centro de Estudios en Zonas Áridas (CEZA), Universidad de Chile, Santiago, Chile

ARTICLE INFO

Keywords:
Leaf area-to-fruit number ratio
Regression
Leaf mass area
Leaf nitrogen
Stomatal conductance
Fruit weight
Soluble sugars

ABSTRACT

The source/sink relationship affects plant production and fruit quality in the field. This study aims to evaluate leaf and fruit traits of two field-grown blueberry cultivars as affected by variability of source/sink ratio (expressed as cm^2 leaf area-to-fruit number ratio) at fruiting cane level. We found that range of source/sink ratio was larger in cv. 'Legacy' than cv. 'Bluegold' with no effect of season on this variable. There was a curvilinear increase of leaf dry mass-to-leaf area ratio (LMA) with source/sink ratio, which suggests that leaves acted as alternative carbon sinks to fruits. The relation between theses variable was no affected by cultivar. Mass-based nitrogen linearly decreased with source/sink ratio, while area-based nitrogen increased in curvilinear form by the effect of LMA. For leaf nitrogen values, a notable difference between cultivars was observed. Stomatal conductance (g_s) dropped with increasing source/sink ratios with 'Bluegold' achieving higher g_s than 'Legacy' for any given source/sink ratio. Dry (DW_f) and fresh mass, diameter and total soluble solids (SS) of the fruit were related to source/sink ratio through curvilinear fit in both cultivars. The observed relations were similar between cultivars for DW_f and SS, which suggest that the rate of the response of fruit carbon gain to changing source/sink ratios was conservative between the studied cultivars. Our results showed that fruit-bearing blueberry canes are semiautonomous regulating their resource allocation as function of source/sink ratio.

1. Introduction

The source/sink relationship is a crucial factor affecting plant production and fruit quality. In the field, the source/sink relationship results from the balance between fruit number and leaf area and can be manipulated by means of agronomical practices such as manual or chemical fruit thinning or nitrogen supply, irrigation or pruning. Besides, fruiting branches or shoots differing in vigour, length and age, are normally observed in fruit species, which can result in a large distribution of fruit size. Also, in extreme situations, the occurrence of biennial production patterns might occur, as described in *Coffea arabica* L. (Bote and Vos, 2016) and *Olea europea* L. (Dag et al., 2010).

In commercial blueberry (*Vaccinium corymbosum* L.) production systems, plants are annually pruned, ensuring a sustainable balance between fruit yield and size. However, growers seeking high yield per surface area tend to apply rather slight pruning, increasing both, the number of canes and number of reproductive buds, reducing the total leaf area of the bush. As a consequence, fruit size and sweetness, two of the most important components of blueberry fruit quality (Mennella et al., 2017), are negatively affected (Jorquera-Fontena et al., 2014). In this line, Maust et al. (1999), who adjusted different fruit bud densities (number of fruit buds per cm cane length) in southern blueberry cultivars, found that lower berry weight and soluble solids resulted from higher fruit densities, suggesting that source (carbohydrates) supply did not reach the fruit sink demand. On the other hand, Jorquera-Fontena et al. (2016) recently reported that the light-saturated photosynthesis rate of leaves is reduced in girdled blueberry branches with a low fruit sink demand, with photosynthesis correlating negatively to leaf soluble sugar content and positively to nitrogen and chlorophyll concentration in leaves. These results are in line with other fruit crops subjected to higher source/sink ratios such as mango (Léchaudel et al., 2005), apple (Wünsche et al., 2005) and coffee (Franck et al., 2006).

Based on the hypothesis that blueberry plants grow as a collection of semiautonomous, interacting organs that compete for resources (White, 1979; Sprugel et al., 1991), this study aimed to evaluate leaf and fruit traits of two field-grown blueberry cultivars as affected by variability of

* Corresponding author.
E-mail address: ejorquera@uct.cl (E. Jorquera-Fontena).

https://doi.org/10.1016/j.scienta.2018.06.041
Received 3 April 2018; Received in revised form 5 June 2018; Accepted 13 June 2018

source/sink ratio at fruiting cane level.

2. Material and methods

2.1. Plant material

In 2015–2016 and 2016–2017 seasons, eight representative plants from 'Bluegold' and 'Legacy' blueberry cultivars were selected from a 0.8 ha surface planted in 2008 at the Agricultural Experimental Station of the University of La Frontera, Temuco, Chile (38°84′S 72°69′W). The orchard was established at a spacing of 3 × 0.7 m, in east–west oriented rows on an Andisol soil. The annual fertilization was 45 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} applied along the season, according to soil analysis. Irrigation was applied following the soil water balance approach (based on FAO-56) and pests and diseases were controlled according to the locally recommended practices. Winter pruning was annually performed in orchard, removing old wood, damaged canes, unproductive branches, and short shoots that develop from the base of the plant. About 50% of the reproductive buds formed during the previous season were removed when plants were pruned.

Two healthy fruiting canes of average vigor and length but differing in number of fruits were selected from each selected plant. In the 2015–2016 season, the number of fruits per cane averaged 47.92 (range from 23 to 123) and 31.8 (range from 5 to61) for 'Bluegold' and 'Legacy', respectively, whereas in 2016–2017 averaged 32.6 (range from 16 to 52) and 36.8 (range from 7 to 100) for 'Bluegold' and 'Legacy', respectively.

2.2. Leaf measurements

When more than 85% of the fruits reached color for harvest, each cane was completely defoliated in order to estimate total leaf dry weight (g) by drying at 65 °C to constant weight. Prior to drying leaves, a leaf subsample (5 g fresh leaves) was obtained from each cane to calculate leaf dry mass-to-leaf area ratio (g m^{-2}). Leaf area of the subsamples was determined by scanning leaves and the subsequent use of an image analysis program developed in our laboratory and validated following the recommendations of O'Neal et al. (2002). Subsequently, total leaf area (LA, m^2) was estimated as indicated by Eq. (1):

$$\mathrm{LA} = \frac{LDW_{\mathrm{cane}}}{\mathrm{LMA}} \quad (1)$$

Where LDW_{cane} is the total cane leaf dry weight (g) and LMA is the leaf dry mass-to-leaf area ratio (g m^{-2}).

Total nitrogen (N) and carbon (C) concentration of each sample was measured on 1 mg of powdered dry leaves with an elemental analyser (EuroEA 3000, EuroVector, Italy), designed for CHNS analysis of organic compounds. From data, C/N ratio was calculated. The N was expressed both in mass-based (N_{m}, mg g^{-1} DW) and area-based (N_{a}, g m^{-2}) units. The N_{a} was calculated as (Eq. (2)):

$$N_a = N_{\mathrm{m}} \times \mathrm{LMA} \quad (2)$$

Stomatal conductance to water vapour (g_s, mmol m^{-2} s^{-1}) was measured by using a Leaf Porometer SC-1 (Decagon, WA, USA) two times before cutting the canes in the 2016–2017 season. Two expanded sun exposed leaves per cane were measured between 11:30 to 13:30 (solar time) on cloudless days during the green to pink fruit phenological stage (final stage of rapid fruit growth) in order to ensure a high carbon demand by fruits.

2.3. Fruit measurements

Yield and berry number of each cane were recorded and then, the mean berry weight (FW_f) was estimated as the ratio of both variables. From calculated FW_f, berry dry weight (DW_f) and diameter (Di_f) were estimated through allometric model approach (Jorquera-Fontena et al., 2017) as indicated in Table 1:

Table 1
Allometric relationships used for estimating berry dry weight and equatorial diameter in two blueberry cultivars from berry fresh weight measurements.

Cultivar	Variable	Allometric relationship*
Bluegold	Dry weight (g $berry^{-1}$)	$y = 0.168x^{0.971}$; $n = 105$
	Equatorial diameter (mm)	$y = 12.84x^{0.356}$; $n = 110$
Legacy	Dry weight (g $berry^{-1}$)	$y = 0.192x^{0.938}$; $n = 128$
	Equatorial diameter (mm)	$y = 12.87x^{0.359}$; $n = 128$

* P-value of each one coefficients was lower than 0.001.

A 10 g fruit subsample was taken from each selected cane to measure total soluble solids by means of a manual, temperature-compensated refractometer (ATAGO, Japan).

2.4. Data analysis

In order to give account for the effect of cultivar and season on source/sink ratio expressed as cane cm^2 leaf area-to-fruit number ratio, an Analysis of Variance (ANOVA) followed by Multiple Comparison of Means (Tukey's test at $P < 0.05$) was used. Studied variables were plotted against source/sink ratio and then, the best fit was explored, following linear and power models. To evaluate differences between slopes and intercepts for cultivars an analysis of covariance (ANCOVA) was performed. When variables followed a power fit, $\log_e$-transformation was previously applied. Thus, if slopes and intercepts were significantly similar between cultivars, a common model was fitted. Data from both seasons were grouped for each cultivar to encompass a high dispersion. ANOVA and Tukey's test was performed through R Commander (Rcmdr version 1.8-3 in R version 2.14.2). For fitting models, R software (R version 2.15.0), through lm' and 'nls' functions, was employed. Analysis of slopes and intercepts were carried out by using of Statgraphics XVII software.

3. Results

3.1. Source/sink ratio

The mean source/sink ratio was significantly different between cultivars, with cv. 'Legacy' having values almost four times higher than cv. 'Bluegold' (Table 2). The growth seasons did not induce significant changes in source/sink ratio within-cultivar, although slightly lower values were observed in the 2016–2017 season (Table 2). As noted in table, the magnitude of the variation in the source/sink ratio range was largely different between cultivars, reaching 83.17 points for cv. 'Legacy' in 18.74 points for cv. 'Bluegold'.

3.2. Leaf traits as function of source/sink ratio

A curvilinear trend was observed for LMA against source/sink ratio

Table 2
Calculated source/sink ratio for fruiting canes of two field-grown blueberry cultivars in two growth season.

Cultivar	Season	Source/sink ratio (cm^{-2} leaf area/ Nro. Fruit)
Bluegold	2015–2016	8.16 (± 5.42) b
	2016–2017	5.19 (± 4.46) b
	Mean	**6.67 (± 5.15; 0.68–19.42) B**
Legacy	2015–2016	25.27 (± 26.24) a
	2016–2017	23.88 (± 23.97) a
	Mean	**24.57 (± 24.73; 1.37–84.54) A**

Standard deviation (± S.D) is shown in parenthesis; for means, the range of data is also included in parenthesis. Letters indicating statistic differences for seasons (lowercase) and cultivars (uppercase) are shown.