Variation in Plant and Soil Water Relations among Irrigated Blueberry Cultivars Planted at Two Distinct In-Row Spacings

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Abstract

A study was conducted to determine the effect of in-row spacing on plant and soil water relations in 'Duke', 'Bluecrop', and 'Elliott' highbush blueberry (*Vaccinium corymbosum* L.) and to identify possible mechanisms that may enhance the ability of these cultivars to tolerate short-term soil water deficits. Changes in soil water content, stem water potential, and leaf stomatal conductance were measured 4 years after planting on well-irrigated plants of each cultivar spaced 0.5 or 1.2 m within rows on raised beds (~0.3 m high) and 3.0 m between rows. Irrigation (711 mm) was applied equally to all treatments by overhead sprinklers during the dry summer months from mid-May to early-September. Close spacing significantly reduced individual shoot dry weight, but also significantly increased crop light interception and water uptake from 0-0.6 m soil depth compared to plants spaced further apart. Spacing had little effect, however, on plant water relations. Independent of cultivar and spacing, stomatal conductance decreased rapidly as stem water potential approached -0.6 to -0.8 MPa. Among cultivars, 'Bluecrop' had the lowest root mass and root:shoot dry weight ratio at either spacing, while 'Elliott' had the highest. 'Duke', however, produced the deepest root system, extracting a significant amount of water below 0.6 m when plants were closely spaced. 'Duke' also maintained, on average, higher stem water potentials and greater stomatal conductance than the other cultivars as soil water was depleted.

INTRODUCTION

Highbush blueberry is a shallow-rooted crop that is highly sensitive to soil water deficits (Améglio et al., 2000; Perrier et al., 2000). When exposed to even mild episodes of drought, vegetative growth of the plant is rapidly reduced and fruit development is often diminished. However, despite this vulnerability, little is known about the water relations of this crop, particularly with regard to any variation that may occur among cultivars or with cultural practices.

There are 13 cultivars of highbush blueberry commonly grown in the U.S. Pacific Northwest (Yang, 2002). Blueberry cultivars vary in size and shape of the plant canopy and root system, as well as the timing of harvest, which influence biomass production and water requirements of the crop (Monteith and Unsworth, 1990).

Various cultural practices that may also affect crop water use include mulching, type of irrigation system, ground cover, cultivation practices, and planting density (Allen et al., 1998). Most blueberry fields in the Pacific Northwest are mulched with sawdust and irrigated by overhead sprinklers. Grass is often grown as groundcover between rows and cultivation is typically minimal after planting. Traditional planting densities have been 1.2-1.5 m within rows and 3.0 m between rows. With rising production costs, however, many growers are beginning to space plants at higher densities to increase early productivity and improve machine-harvest efficiency (Strik and Buller, 2002).

The objectives of the current study were to determine the effect of traditional and close in-row spacing on plant and soil water relations in common highbush blueberry

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cultivars and to identify possible mechanisms that may enhance the ability of the cultivars to tolerate short-term episodes of soil water deficit. More information on blueberry water relations is needed to help develop better water management practices for the crop.

MATERIALS AND METHODS

The study was conducted on a 0.15-ha field of highbush blueberry established at the North Willamette Research and Extension Center, Aurora, Oregon (45°23′ N 122°75′ W) in October 1999. Three cultivars, 'Duke', 'Bluecrop', and 'Elliott', were planted at the site on Willamette silt loam (fine-silty, mixed, mesic Pachic Ultic Argixerolls) soil fumigated with methyl bromide/chloropicrin. 'Duke' and 'Bluecrop' are the two most popular cultivars grown in the Pacific Northwest and are typically harvested in late-June and early-July, respectively; 'Elliott' is a popular late-season cultivar harvested mid- to late-August. Each cultivar was spaced either 0.5 or 1.2 m apart within rows and 3.0 m apart between rows on raised beds (~0.3-m high and 0.4-m wide) amended with sawdust and ammonium sulfate fertilizer (66 kg N ha^{-1}) incorporated prior to planting. Grass alleyways (~2-m wide) were maintained between bed rows after the blueberries were planted. Each treatment plot consisted of a 6.1 m row of plants and was replicated five times. Treatments were arranged in a randomized complete-block design.

The field was irrigated by overhead impact sprinklers with risers spaced 12.2 x 12.2 m apart. Water applications were applied as needed (between May and September) at a rate of 25-50 mm $week^{-1}$ and monitored periodically with a turbine water meter (model W-120, Invensys Metering Systems, Uniontown, Pa., USA) installed at the inflow of the irrigation system. The total amount of irrigation applied in 2003 was 711 mm. Fertilizer was applied each spring as ammonium sulfate. Weeds, insects, and diseases were controlled with herbicides and pesticides as needed. Fruit were hand-picked following standard commercial practices beginning the third year after planting.

Plant and soil measurements were made in 2003 during the fourth growing season after planting. Crop light interception was measured periodically in each plot using a line quantum sensor (model LI-191SA, Li-Cor Inc., Lincoln, Neb., USA); measurements were made on clear days in light conditions ranging from 1465-1710 μmol m^{-2} s^{-1} PPFD. The sensor was positioned beneath the plant canopy, at ground level and perpendicular to the row, between 1200-1300 hours PST. The readings were taken on both sides of the row in 75-mm increments from the base of one randomly-selected plant to half the distance of an adjacent plant, and then averaged and divided by above-canopy readings to estimate the percent light intercepted by the canopy. Changes in soil water content were measured using a calibrated neutron probe (503-DR Hydroprobe, CPN International Inc., Martinez, Calif., USA) and galvanized-steel access tubes installed 1.5-m deep. One tube was located in the center of each plot at 0.2 m from the base of a plant and neutron counts (15-s intervals) were made (1 d before irrigation) at each 0.3-m depth increment between 0.15-1.05 m from the soil surface. Stomatal conductance and stem water potential were used as indicators of crop water status and were measured bi-weekly in each treatment using a steady-state porometer (model LI-1600, Li-Cor Inc., Lincoln, Neb., USA) and a pressure chamber (model 600, PMS Instrument Co., Corvallis, Ore., USA), respectively, following the recommendations of Hsiao (1990). Both measurements were made at midday between 1330-1530 hours PST. Stomatal conductance was measured on a single leaf exposed to full sun (1270-1960 μmol m^{-2} s^{-1} PAR at the leaf surface) from each plot. Stem water potentials were estimated by measuring the water potential of a branch tip with three fully-expanded leaves that had been enclosed for at least 1 h in foil-laminated plastic bags. Preliminary measurements indicated that daily changes in stem water potential were less variable than changes in leaf water potential and are therefore probably more sensitive indicators of plant water stress.

All data were subjected to two-way analysis of variance (ANOVA) using Proc-GLM (SAS Institute, Cary, N.C.) and means were separated at the 0.05 level using least square means.

RESULTS AND DISCUSSION

Close in-row spacing of blueberry cultivars either had no effect or significantly reduced individual shoot (crown and all canes) dry weight compared to plants spaced further apart (Fig. 1a), but significantly increased the total amount of light intercepted by the crop canopy ($P \leq 0.01$; Fig. 2). Close spacing also significantly increased water uptake from 0-0.6 m soil depth than further spacing (Figs. 3a and b), demonstrating that close spacing increased the overall water requirements of the crop. Crop water used was previously shown to be correlated with canopy light interception in 'Bluecrop' blueberries grown in New Jersey (Storlie and Eck, 1996).

Plant spacing had little effect on plant water relations of the cultivars. Regardless of cultivar or in-row spacing, stomatal conductance decreased rapidly as stem water potential approached -0.6 to -0.8 MPa (Fig. 4). Rapid stomatal closure may reduce the susceptibility of blueberry to xylem cavitation during drought (Améglio et al., 2000). We found, however, that 'Duke' maintained, on average, significantly higher stem water potentials and greater stomatal conductance than the other cultivars as soil water was depleted (Table 1), which may indicate that this cultivar has the highest tolerance to short-term soil water deficits. 'Bluecrop', on the other hand, had the lowest stem water potentials and stomatal conductance, and thus may be more sensitive to water deficits. 'Bluecrop' also had the lowest root mass (Fig. 1b) and root:shoot dry weight ratio (Fig. 1c) at either spacing, while 'Elliott' had the highest. 'Duke', in comparison, produced the deepest root system and extracted more water below 0.6 m when plants were closely spaced (Fig. 3c), and may therefore require less frequent irrigation than other cultivars for optimum growth and production.

The results of this study indicate that there is considerable variation in the morphological and physiological adaptations of the cultivars to tolerate short-term episodes of water deficits, such as deeper root systems or the ability to maintain higher plant water status, which may influence their irrigation water requirements throughout the growing season. The results also indicate that significantly more water is required when plants are spaced close together than when they are spaced further apart, although the difference in the amount of water required was not determined. Irrigation requirements of each cultivar and plant spacing will be determined as the study continues in 2004.

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Tables

Table 1. Mean stomatal conductance and stem water potential of highbush blueberry cultivars (‘Duke’, ‘Bluecrop’, and ‘Elliott’) spaced 0.5 or 1.2 m apart within rows. Values are the seasonal average of seven sets of measurements made May-Sept 2003.

Cultivar	In-row spacing (m)	Stomatal conductance (mmol m^{-2} s^{-1})	Stem water potential (MPa)
Duke	0.5	129 a[1]	-0.55 b
Bluecrop	0.5	83 cd	-0.72 c
Elliott	0.5	98 bcd	-0.62 b
Duke	1.2	115 ab	-0.46 a
Bluecrop	1.2	78 d	-0.72 c
Elliott	1.2	109 abc	-0.58 b
Analysis of variance			
Cultivar		<0.001	<0.001
Spacing		ns	<0.05
Cultivar*spacing		ns	ns

[1] Within columns, means followed by the same letter are not significantly different at $P \leq 0.05$ using least square means.

Figures

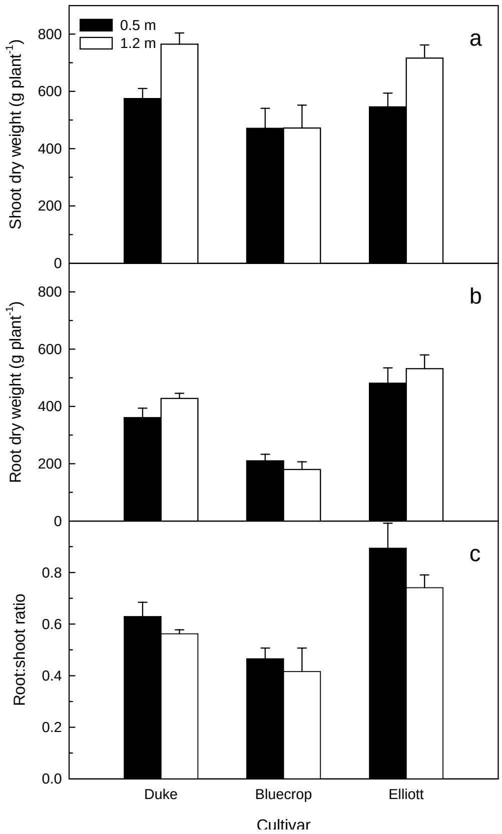

Fig. 1. Shoot (a) and root (b) dry weight and root:shoot dry weight ratio (c) of highbush blueberry cultivars ('Duke', 'Bluecrop', and 'Elliott') spaced 0.5 or 1.2 m apart within rows. Measurements were made in February 2003. Each bar represents the mean of five measurements and error bars represent ±1 standard error of the mean. Adapted from Strik and Buller (Acta Hort., same volume).

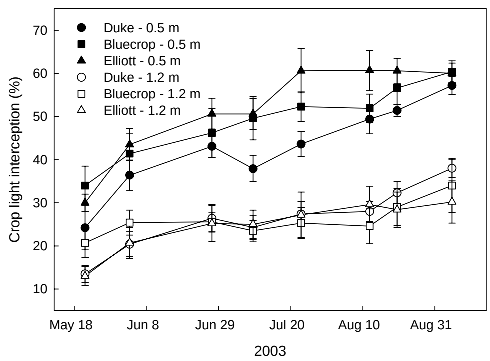

Fig. 2. Crop light interception of highbush blueberry cultivars ('Duke', 'Bluecrop', and 'Elliott') spaced 0.5 or 1.2 m apart within rows. Light interception was measured at ground level on each side of the row at 0-1 m from the row center. Each symbol represents the mean of five measurements and error bars represent ±1 standard error of the mean.

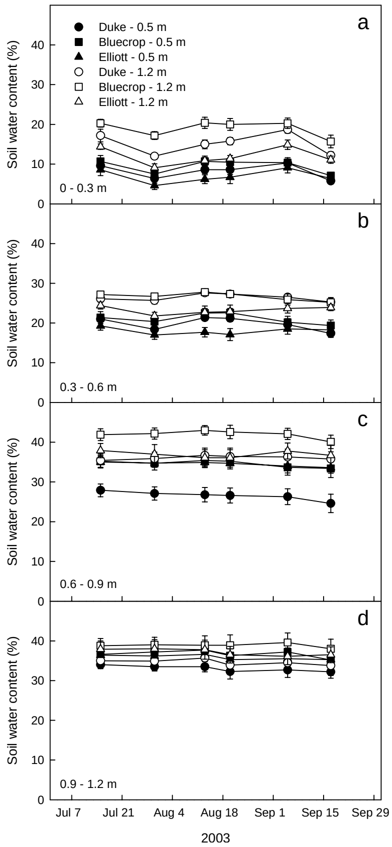

Fig. 3. Soil water content at 0-0.3 (a), 0.3-0.6 (b), 0.6-0.9 (c), and 0.9-1.2 (d) m depth increments for highbush blueberry cultivars (‘Duke’, ‘Bluecrop’, and ‘Elliott’) spaced 0.5 or 1.2 m apart within rows. Each symbol represents the mean of five measurements and error bars represent ±1 standard error of the mean.

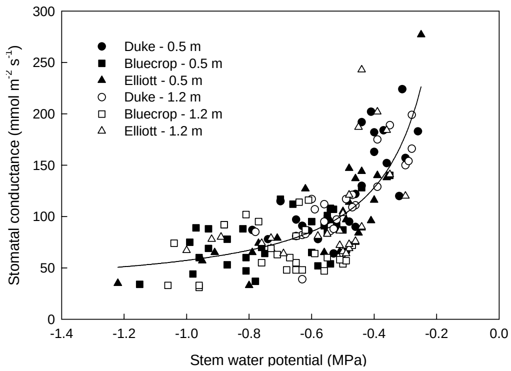

Fig. 4. Leaf stomatal conductance as a function of stem water potential for highbush blueberry cultivars (‘Duke’, ‘Bluecrop’, and ‘Elliott’) spaced 0.5 or 1.2 m apart within rows. Each symbol represents one measurement. The relationship was fitted with an inverse second order polynomial ($y = 6.10/x^2 - 25.82/x + 25.38$ with $r^2 = 0.57$ and $P \leq 0.001$).