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Growth and leaf physiology of sun- and shade-grown Sargent viburnum (*Viburnum sargentii* K.) "Onondaga" potted plants

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Abstract

In order to verify the effects of reduced light intensity on plant growth and on selected morphological and physiological characteristics of the leaves, 50 uniform two-year-old, asexually propagated plants of *Viburnum sargentii* K. 'Onondaga' were subjected to two shading levels (52 and 14% of the full solar radiation) for the entire growing season. A third group of 25 plants was grown in full sun and used as control. No differences were found in terms of leaf gas exchange, while leaf chlorophyll content was lower in the full sun-grown plants. A significantly higher a/b ratio was also found in this plants. Leaves were smaller in the heavy-shaded plants, which also showed a lower weight and specific leaf weight (leaf weight/area ratio). These plants also showed a reduced growth for all the parameters considered, while no differences were found between the full sun-grown plants and the mid-shaded ones. Based on our results, *Viburnum sargentii*, though classified as a facultative shade species, can also be used in full sun spots when a sufficient amount of water is provided.

Key words: Photosynthesis, chlorophyll, shading, container, biomass, *Viburnum sargentii* K.

Introduction

The genus *Viburnum* is comprised of about 150 species of evergreen and deciduous shrubs and small trees, widely distributed mainly in the Northern Hemisphere. Sargent viburnum (*Viburnum sargentii* Koebe) is one of the more popular species among gardeners and landscape architects as a shrub border, screen, large areas and massing for its appealing leaf shape and colour, often bronze-purple in spring, assuming yellowish to reddish tones in fall. Flowers are pink-budded, white-maturing, born in flat-topped 7-10 cm in diameter corymbs, which bloom in May; sterile outer flowers are greater in diameters. The fruits are scarlet, berry-like drupe, effective August through late fall (Dirr, 1991; Hillier, 1991).

This species is considered best suited to colder climates and partially shaded spots but some cultivars have been reported to have some sun and heat tolerance (Meakin Poor and Peterson Brewster, 1996). For increasing of sargent viburnum cultivation in different habitat other than the original one, deeper knowledge about some biological aspects of this species in relation to light intensity is required. Nurserymen often need information concerning the shade requirement or tolerance of nursery stock.

As shown in previous research projects conducted on woody ornamentals, sun- and shade-acclimation responses can vary according to the species (Fails *et al.*, 1982a; 1982b; Andersen *et al.*, 1991a; 1991b; Norcini *et al.*, 1991) but we are not aware of any published data that have determined the adaptation of *V. sargentii* to different light levels. Information regarding sun/shade tolerance of *V. sargentii* may prove beneficial for nursery and landscape industries. To gain information on this aspect, a study was undertaken to ascertain and quantify the effects caused by two different levels of solar radiation on plant growth and on selected morpho-physiological characteristics of the leaves.

Materials and methods

In March, 75 uniform, 2-year-old, *V. sargentii* K. 'Onondaga' plants through propagated cutting were planted in 5 litre (20 cm in diameter) black plastic containers using a peatmoss-pumice medium (3/2 by volume) supplemented with a 3 g l^{-1} of a slow-release fertilizer, N P K 15-10-2 + 2 Mg + microelements (commercial product Osmocote Plus 5-6Scotts Co., Marysville, OH). At transplant, root and canopy fresh and dry weight were determined on a 6-plants sample following the procedure described later. All the plants were sheared to uniform size after planting.

Plants were placed outdoors in three distinct plots (25 plant per treatment, 5 replicates of 5 plants each, spaced 0.15 m within and 0.6 m between replicates) and subjected to two shading levels for the entire vegetative cycle. Two open-sided structures were constructed with the longitudinal axis oriented North-South direction, and light intensity was reduced by using commercially available shade material consisting of black woven polypropylene fabric that acted as a neutral filter (Yates, 1986). Previous measurements carried out with a spectroradiometer did not show any significant difference in the spectrum between full light exposure and reduced light inside the different fabrics both in the direct and diffused light and reduced to 48 and 86% of the photosynthetically active radiation. The two levels of shading correspond to medium (48%) and heavy light reduction (86%), and are among the more widely used in the local nursery industry for shade-preferring and shade-obligate plants. 25 additional plants were grown in full sun and used as control. In early July, plants were topdressed with N P K 15-9-12 (commercial product Nitrophoska Gold, Basf). Weeds were controlled by hand weeding.

Standard commercial nursery production for irrigation and pest control were followed. Water requirement was provided by sprinkle irrigation (30 minutes delivering 7 mm of water applied twice a day from 900-1000 hours and from 1700-1800).

Net photosynthesis (A), transpiration rate (E) were measured 90 and 150 days after bud break (DAB) with a Model LCA-2 portable infrared gas analyzer (Analytical Development Corp., Hoddesdon, Herts, England), an air supply unit (flow rate maintained at 400 $cm^3 min^{-1}$) and a Parkinson leaf chamber (aperture = 6.25 cm^2). Leaf gas exchange was measured on five fully expanded leaves on one plant per replicate per treatment between 0900 and 1800 hours under conditions of light saturation (PAR > 1000 µmol $m^{-2}s^{-1}$) with the exception of the date of the last measurement of the day (Fig. 1A).

Chlorophyll content was also determined 150 DAB. Ten 0.8 cm leaf disks were obtained from five plants per block per treatment, then immersed in *N,N* dimethylformamide (DMF) for 48 h in the dark at 4°C. Total chlorophyll, chlorophyll a and chlorophyll b, were quantified by measuring the absorbance at 664, 647 and 625 nm, with an Hitachi U-2000 spectrophotometer (Moran, 1982). Chlorophyll a/b ratio was also calculated.

At the end of the growing season (mid October) tops of 10 plants per treatment were removed and biomass production was determined. Roots were washed free from the media. Roots and shoot were excised to determine root and shoot growth, leaf area, fresh and dry weight. For the dry weight, the vegetative material was oven-dried at 80°C until constant weight was achieved. Leaf area was calculated by measuring the area of all the leaves per plant with a leaf area meter (CID CI-203, CID Inc., Vancouver, WA, USA). Specific leaf weight (SLW g cm^{-2}) was also calculated on this sample.

Relative growth rate (RGR) calculated as $(\ln W_2 - \ln W_1)*(t_2 - t_1)^{-1}$ (W_1 and W_2 are respectively the dry matter at the beginning and at the end of the observations, t_2 and t_1 are the number of days between the two sampling dates) and shoot/root ratio were also determined in both dates.

All the data were subjected to one-way analysis of variance (SPSS Statistical Package, Release 11.5 for Windows). Treatment means were separated using the LSD test at *P*=0.05.

Results and discussion

Gas exchange: No differences were found for net photosynthesis (A), transpiration (E) and water use efficiency (WUE) among the different treatments on both sampling dates (Table 1). Some differences were found considering the different sampling hour (Fig. 1A, 1B, 1C, 1D). Net photosynthesis was in fact higher in the less shaded plants and in the control plants during morning while the later exhibited higher Pn in most of the shaded leaves, clearly showing an adaptation to low light intensity, that, according to other authors can include a different leaf orientation (Bjorkman, 1981; Nilsen and Orcutt, 1996) and maximized photon absorption (Nilsen and Orcutt, 1996).

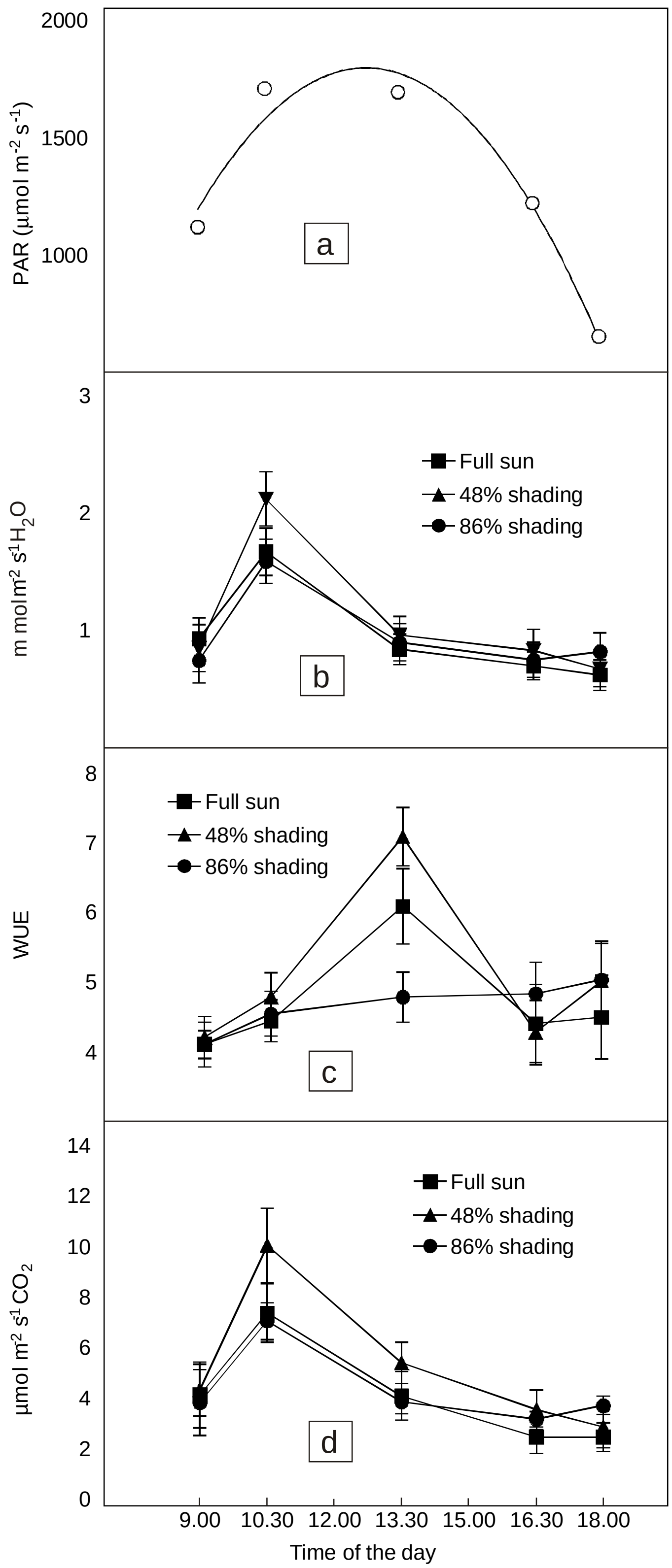

Fig. 1. Daily course of PAR (µmol$_*$m^2$_*$s^{-1}) (a), Evaporation rate (mmol$_*$m^2$_*$s^{-1} H_2O) (b), Water use efficiency (c) (Pn/Evaporation rate) and Net photosynthesis (µmol$_*$m^2$_*$s^{-1} CO_2) (d) in full-sun (0%) and shade (48-86%) leaves in *Viburnum sargentii* K. potted plants on July the 7th. Bars represent ±SE of the mean.

Chlorophyll content: Total chlorophyll content was higher in the shaded leaves compared to the leaves grown in full sun (Table 2) and this is consistent with research conducted in other species (Kappel and Flore, 1983, Israeli *et al.*, 1995). Leaves grown at low

Table 1. Effect of different shading levels on net photosynthesis (A), evaporation rate (E) and water use efficiency (WUE) of *Viburnum sargentii* potted plants (Pn - µmol $m^{-2} s^{-1}$ of CO_2; Evaporation rate – mmol $m^{-2} s^{-1}$ of H_2O; WUE – Pn/Evaporation rate)

Treatment	10 July			23 September		
	E(mmol $m^{-2} s^{-1}$)	A(µmol $m^{-2} s^{-1}$)	WUE(µmol $mmol^{-1}$)	E(mmol $m^{-2} s^{-1}$)	A(µmol $m^{-2} s^{-1}$)	WUE(µmol $mmol^{-1}$)
Full sun	1.11NS	4.7NS	4.46NS	0.93NS	4.54NS	5.82NS
48 % shading	1.31	6.03	4.91	1.06	5.86	5.84
86 % shading	1.16	5.17	4.81	0.94	4.4	5.03

Means with different letters are significantly different at $P \leq 0.05$

Table 2. Leaf morphological (area, dry weight, SLW) and biochemical (chlorophyll) parameters in *Viburnum sargentii* K. potted plants grown under different light conditions

Treatment	Area(mm^2)	Weight(g)	SLW(g mm^{-2})	Chl. Tot (mg ml^{-1})	Chl. a(mg ml^{-1})	Chl. b(mg ml^{-1})	Chl. a/b
Full sun	46.6 ab	0.5 a	10.0 a	38.8 b	27.3 b	11.5 b	2.4 a
48 % shading	53.0 a	0.4 a	8.3 b	49.3 a	31.9 a	17.4 a	1.9 b
86 % shading	43.7 b	0.2 b	5.8 c	47.3 a	30.4	16.9 a	1.8 b

Means with different letters are significantly different at $P \leq 0.05$

Table 3. Effect of full sun (0%) and different shade levels (48-86%) on biomass (g) produced, shoot/root and on Relative Growth Rate of *Viburnum sargentii* K. potted plants

Treatment	Leaf	Stem	Root	Total	Shoot (stem + leaves)	Shoot/root	RGR
Full sun	10.7NS	25.2NS	36.6 a	72.5 a	35.9 ab	0.98NS	8.4NS
48 % shading	10.9	26.9	39.4 a	77.2 a	37.8 a	0.96	8.9
86% shading	6.6	18.7	21.7 b	46.9 b	25.2 b	1.16	5.7

Chl. Tot.= Total chlorophyll, Chl. a= Chlorophyll a, Chl. b= Chlorophyll b; Means with different letters are significantly different at $P < 0.05$

light intensity often have more chlorophyll per unit weight because of the high density of the grana; however since shade grown leaves are usually thinner than sun-grown ones, the amount of chlorophyll per leaf area is often less than in sun-grown plants (Knox and Hamilton, 1983). Significant differences were also observed in chlorophyll a and, above all, chlorophyll b content was much higher in the shaded leaves. Consequently, leaves exposed to full sun showed a significantly higher a/b ratio. The relative increase in chlorophyll b may enhance the ability of shaded leaves to capture and utilize the light transmitted by exposed leaves, containing wavelengths enriched in the far-red region of the spectrum as stated by other researchers (Bjorkman and Holmgren, 1963; Gross, 1991; Chartzoulakis *et al.*, 1993; Biricolti *et al.*, 1993).

Plant growth: Stem growth was similar for the three light levels, though a slight increase in the shaded plants could be noted. Total, canopy and root dry weight were lower in the plants grown in heavy shade (Table 3). This is consistent to what found by Robinson and Hamilton (1983) on *Viburnum opulus* which showed a significant decrease in plant growth when plants were grown in heavy shade. The shoot/root ratio was not significantly affected. Low-light availability increases shoot/root ratio of plants and therefore reduces nutrient accumulation capacity (Collard *et al.*, 1977; Norcini *et al.*, 1991; Nilsen and Orcutt, 1996). In addition, low light intensities reduces the flow of carbohydrates from leaves to roots; thus there is a limitation to the amount of energy available for nutrient accumulation.

RGR, which is one of the most common index of growth to compare different stages of a plant life cycle regardless of the changing size of the plant, was higher in the sun-grown and in the light shaded plants and lower in the most shaded plants (Table 3).

Leaf parameters: Dry weight and fresh/dry weight ratio were lower in the shaded leaves (Table 3). Leaf area was higher in 48% shade compared to 86% shade. Besides, there was a progressive decrease in specific leaf weight as shading level increased. Higher SLW has been reported for a number of plants grown in full sun compared to the shaded ones and according to other researchers (Doud and Ferree, 1980; Kappel and Flore, 1983; Syversten and Smith, 1984; Marini and Sowers, 1991; Klein *et al.*, 1991; Chartzoulakis *et al.*, 1993; Israeli *et al.*, 1995), it could be hypothesized that SLW might be a useful index of previous light exposure.

In conclusion, the results of the research indicate that the level of light reduction exerts very pronounced effect on growth and on some morpho-physiological characteristics of sargent viburnum. It is quite clear from plant growth that plants in 48% shade perform better compared with plants in full sun and those grown in heavy shade. However, as found in other studies, shade adaptation (*i.e.* net photosynthesis was similar among the different shading levels) did not sufficiently compensate for other factors that may have limited heavy shaded plants performance.

Based on our results, *Viburnum sargentii*, though can be classified as a facultative shade plants can also be used in full sun spots when a sufficient amount of water can be provided.

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