Effects of s-ABA on the Physiology and Marketability of Various Container-Grown Taxa During Short-Term Desiccation[1]

Cary J. Hebert[2], Anthony V. LeBude[3], and Craig Campbell[4]
Department of Horticultural Science, Mountain Horticultural Crops Research and Extension Center
North Carolina State University, 455 Research Drive, Mills River NC 28759

Abstract

Reduced post harvest care of woody plant material in mass retail settings can decrease the number of days plants remain marketable. If plants are sold on consignment for growers, reduced sales can lead to poor profitability. This study investigated the effect of spray applications of s-abscisic acid (s-ABA) (ConTego™ Pro SL, Valent Biosciences Corp.) to increase the number of days of marketability for various woody taxa in a simulated retail setting. In the first stage of the study, various well-watered container-grown taxa were treated with a spray application of either 0, 1000 or 2000 mg·liter^{-1} of s-ABA and water was withheld. Daily, desiccation symptoms were recorded to determine if plants had reached the critical wilting point (CWP) and thus became unmarketable. Marketability was increased approximately 1–7 days for plants treated with 2000 mg·liter^{-1} of s-ABA compared to nontreated plants. In the second stage, marketability and physiology of *Ligustrum japonicum* 'Recurvifolium' (wavy leaf privet) were monitored after plants were treated with spray applications of 0, 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA and water withheld. Stomatal conductance (g_s) declined for all plants depending on the concentration applied. Plants treated with s-ABA had lower g_s rates and remained marketable longer than nontreated plants. All plants fully recovered to pretreatment g_s rates provided they were rewatered immediately upon reaching the CWP. Spray applications of s-ABA can increase shelf life of select woody ornamentals.

Index words: critical wilting point, ConTego™ Pro SL, nursery crops, s-ABA, stomatal conductance, stem water potential.

Significance to the Nursery Industry

s-ABA is a practical, safe, and affordable chemical used to improve the shelf-life of woody plant material marketed in retail settings (1). Spray applications of 1000 to 2000 mg·liter^{-1} of s-ABA increased shelf-life of plant material approximately 1–7 days after water was withheld. Potentially, the compound could be applied to plants at nursery before they are shipped to retail locations to increase the number of marketable days. Alternatively, since s-ABA application allows plants to maintain a higher water status for a longer period of time without injury, plants may be able to be shipped lighter, thus reducing transportation costs. Additionally, the compound has potential to be used for lowering irrigation frequency during a short period of production because plants can withstand short periods of desiccation without injury. This might compromise growth in the short term, but would utilize limited water resources during times of drought and preserve plant material for continued production when water resources return. These possibilities need further testing at nurseries and in retail settings.

Introduction

In recent years there has been an increase in the number of customers purchasing ornamental plants from mass retail outlets compared to independent garden centers (27). It is estimated that over 60% of the gardening public purchases plant material from large retail markets (27). In some mass retail platforms, growers are paid on consignment, thus, reimbursement for shrinkage (e.g., unsold plants lost to poor post delivery care) is not recovered by growers.

Valent Biosciences, Corp. has developed and formulated a plant derived abscisic acid compound (s-ABA) (ConTego™ Pro SL, Valent Biosciences Corp., Libertyville, IL), which has been shown to prolong shelf life in vegetable transplants

[1]Received for publication January 7, 2010; in revised form June 28, 2010. This research was funded in part by the North Carolina Agricultural Research Service (NCARS), Raleigh, NC 27695-7643, and Valent Biosciences Corp., Libertyville, IL. Assistance of Joe Conner is gratefully appreciated. This manuscript is from a thesis submitted by C.J.H. as partial fulfillment of the requirements for the M.S. degree.

[2]Graduate Research Assistant.

[3]Assistant Professor and corresponding author. anthony_lebude@ncsu.edu.

[4]Valent BioSciences Corp., Ocoee, FL 34761.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

including *Capsicum annuum* L. (pepper), *Cynara scolymus* L. (artichoke), and *Lycopersicon esculentum* Mill. [sic] (tomato), as well as annuals such as *Antirrhinum majus* L. (snapdragon), *Impatiens wallerana* Hook. f. 'Blitz Orange' (impatiens), *Petunia ×hybrida* Hort. Vilm-Andr. 'Royal Pearls' (petunia), and *Tropaeolum majus* L. (nasturtium), and woody ornamentals including *Gardenia* 'August Beauty' (gardenia), *Hydrangea* Endless Summer™ (French hydrangea), *Malus sargentii* Rehd. (Sargent's crabapple), *Nandina* 'Gulfstream' (nandina), *Nerium oleander* L. (oleander), *Ulmus parvifolia* Jacq. (lace bark elm), and *Viburnum plicatum* var. *tomentosum* Thunb. (doublefile viburnum) (1, 2, 3, 5, 12, 14, 20). The compound is applied as a spray or drench to plants prior to shipment to retailers to extend shelf life and preserve marketability. Once applied, the compound increases the number of days before desiccation symptoms appear, e.g. wilting, compared to plants that have not received the compound. Thus, plants remain marketable for a longer period of time in retail settings while receiving minimal irrigation.

Initial experiments with s-ABA applied as a drench found that the time to critical wilting point (marketability) was increased for a wide range of container grown woody taxa (3, unpublished data). Despite being effective at lower concentrations, drench applications apply more volume of water per square meter, are difficult to apply or are less efficient than spray applications, and may not integrate as smoothly as spray applications into existing production systems. Stamps and Chandler (21) reported that s-ABA concentration was negatively correlated with both transpiration rate and cumulative water loss when applied as a spray to container-grown cultivars of *Hibiscus rosa-sinensis* L. (hibiscus). Total hours of marketability was increased, but cultivar dependent, which suggests that spray applications of s-ABA are effective in increasing number of days of marketability in container-grown tropical plants during periods of short term desiccation.

The mechanism of improved short-term desiccation tolerance is thought to be closure of stomata by the application of s-ABA. Although not exogenously applied, ABA concentration in the xylem sap of field-grown corn was found to be correlated with stomatal conductance (23). Typically synthesized in the root system and transported to the stomata, ABA plays an important role in the communication of drought stress signals from the roots in drying soil through the xylem (4, 8, 6, 7, 18). Abscisic acid also plays other roles in various short-term plant responses, such as fruit and leaf abscission. It also induces long-term responses such as reduced mean stomatal conductance and stomatal dimensions, as well as increasing the density of stomata and mean water use efficiency (4, 10, 15, 16). In a study comparing the physiological effects of ABA analogs to ABA, Flores and Körfling (9) found similar decreases in stomatal pore width and transpiration rate in both the ABA analog and ABA treated plants as compared to the controls. Sharma et al. (19) found tissue concentrations of the ABA analog 8' acetylene ABA methyl ester in tomato seedlings were significantly higher in root-dip applications as compared to foliar applications, however, both application methods resulted in decreases in cumulative water use. Trejo et al. (24) also found that stomatal closure was highly sensitive to method of ABA application with both the cuticle and mesophyll cells posing as significant barriers either by forming an obstruction to osmotic diffusion (cuticle) or through metabolism into inactive forms (mesophyll). For spray applications, presumably, the plant absorbs s-ABA through the stomata, which affects similar physiological changes as when the chemical is transported from the roots.

In this study we hypothesize that the concentration of s-ABA negatively impacts transpiration. Higher concentrations decrease transpiration more substantially than lower concentrations, thus lengthening the time it takes to reach the critical wilting point (CWP). Lower concentrations of s-ABA reduce transpiration slightly, therefore, water is still lost, but at a faster rate than if higher concentrations of s-ABA were applied. Nevertheless, the degree to which stomatal conductance recovers to pre-drought, pre-treatment conditions is unknown. Therefore, the main objectives of the present study were to evaluate the effect of spray applications of s-ABA on the number of days to CWP for select woody ornamental taxa, and the effect of s-ABA on gas exchange and recovery of gas exchange parameters to pre-desiccation rates for *Ligustrum japonicum* 'Recurvifolium.'

Materials and Methods

Determining days to critical wilting point of various container grown woody taxa. Thirty plants of five taxa were separated into two runs of two or three taxa each. Taxa were tested separately by a randomized complete block design. Each test contained 10 blocks with a single plant for each treatment in each block (10 blocks × 3 treatments = 30 plants per taxa). Plants in both runs were watered to container capacity before being treated with s-ABA under a clear polyethylene covered structure at McCorkle's Nursery in Dearing, GA. The first run, conducted on May 19, 2009, included *Hydrangea macrophylla* 'Bailmer' Endless Summer® Blushing Bride™ (12 liters) (3.2 gal) and *Rhododendron* 'Roblel' PP#16278 Autumn Debutante™ (26.5 liters) (7 gal). The second run, conducted on June 8, 2009, included *Loropetalum chinense* var. rubrum 'Sizzling Pink' (12 liters) (3.2 gal), *Trachelospermum jasminoides* var. *pubescens* 'Madison' (19 liters) (5 gal) and *Lagerstroemia* 'GAMAD I' PP#16917 Cherry Dazzle™ (26.5 liters) (7 gal). Container plants were treated with spray applications of either 0 [water control + Capsil® (surfactant) (Aquatrols Corporation of America, Inc., Cherry Hill, NJ)], 1000, or 2000 $mg \cdot liter^{-1}$ of s-ABA (Contego®, Valent BioSciences Corp., Libertyville, IL) supplemented with the addition of 0.47 $mL \cdot liter^{-1}$ (0.05%) of CapSil® and applied until runoff using a diaphragm pump backpack sprayer (model 473-D, Solo Inc., Newport News, VA) through a wide-angle, single fan-spray nozzle at a pressure of 14 psi. After treatment application, water was withheld for the remainder of each experiment. Within 24–48 h after treatment, plants were delivered via covered tractor trailer to the Mountain Horticultural Crops Research Station (MHCRS, Mills River, NC). Plants were scored daily for marketability between 0900 and 1100 HR by determining if they had reached the critical wilting point (CWP). Critical wilting point was inferred from plants being unable to recover turgidity unless rewatered. Plants were designated as unmarketable upon reaching CWP or if discoloration (yellow foliage) was present on over 25% of the plant. All plants of a particular species were rewatered when all plants of that species had reached CWP and marketability was recorded again the following day to denote recovery.

Determine the effect of s-ABA applications on gas exchange of container grown Ligustrum japonicum *'Recurvifolium'*

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

during short term desiccation. Two trials, approximately 6 weeks apart, were conducted. For each trial, plants in 12 liter (3 gal) containers were watered to container capacity 1 hr before treatment with s-ABA. In the first trial, beginning on May 19, 2009, plants were treated under a clear polyethylene covered structure at McCorkle's Nursery in Dearing, GA, prior to shipment to MHCRS. Plants were treated with spray applications of either 0 (water control), 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA at a rate of 3 qt per 100 ft^2 (0.306 liters·m^{-2}) supplemented with the addition of 0.47 mL·liter^{-1} (0.05%) CapSil using the same equipment described above. After treatment, water was withheld for the remainder of the experiment. Upon arrival at MHCRS, plants were moved to a clear polyethylene covered structure equipped with fans and a cooling system set to 22–26C (72–78F) day and 20–22C (68–72F) night temperatures. Daily, between 0900 and 1100 HR, plants were assessed for their marketability by determining whether or not they had reached CWP. After all plants in each block reached CWP, that block was rewatered and marketability was recorded the following day.

In Trial 2, beginning on June 20, 2009, plants were shipped to the MHCRS prior to treatment. All treatments and applications were the same as described for Trial 1. Plants were treated and then moved into a clear polyethylene covered structure with cooling fans, but no cooling pads. Environmental settings were similar. The vapor pressure deficit for each trial is shown in Fig. 1. Marketability was recorded daily between 0900 and 1100 HR as described previously. Each individual plant was rewatered after reaching CWP, regardless if the other plants in the same block had reached CWP.

Initial gravimetric weight was measured using an electronic balance (model FV-30K, A&D Engineering Inc., San Jose, CA) for plants at container capacity, and then daily for each plot between 0900 and 1100 HR until the end of each trial. Stomatal conductance (g_s) and net photosynthesis at ambient conditions (A_{net}) was measured on all plants in either four (Trial 1) or five (Trial 2) randomly chosen blocks between 0900 and 1100 HR daily for 1 to 5, 7, 9, and 11 days after treatment (DAT) in Trial 1 or all DAT in Trial 2. Ambient light readings were recorded prior to each trial to provide a basis for leaf cuvette conditions. Stomatal conductance (g_s) was measured on the most recently expanded leaves using a Ciras-1 portable photosynthesis system (PP Systems, Inc., Amesbury, MA) with cuvette conditions set to 25C (77F), PAR 500 µmol·m^{-2}·s^{-1}, 350 ppm CO_2, 0.63 kPa VPD. Stem water potential was recorded daily between 0900 and 1100 using a pressure chamber (3005-Series model, SoilMoisture Equipment Corp., Santa Barbara, CA) for plants in Trial 2 only. Data for gas exchange were used to determine any initial effects of s-ABA application and to determine the extent s-ABA effected plant gas exchange prior to reaching CWP. Gravimetric data were used to monitor cumulative water loss (CWL) from the container and plant system over time.

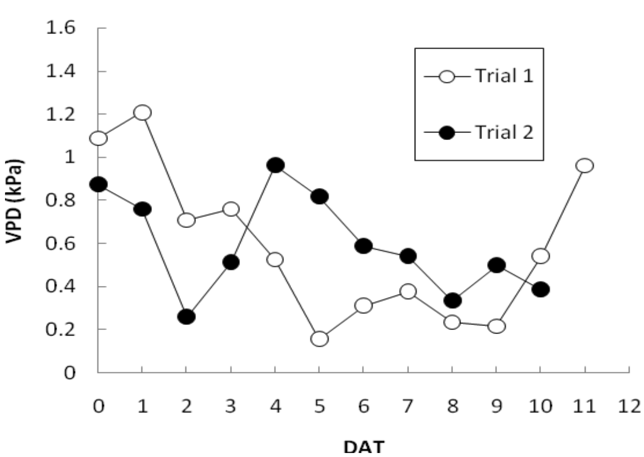

Fig. 1. Mean vapor pressure deficit (VPD) between 0800 and 1900 HR for each day after treatment (DAT) for two trials of *Ligustrum japonicum* 'Recurvifolium.'

Determine the length of time necessary for recovery to pre-treatment stomatal conductance levels for Ligustrum japonicum *'Recurvifolium'.* This objective utilized the plant material from Trial 2 only in the second objective. When all plants in a block in Trial 1 reached CWP they were rewatered. In Trial 2, plants were rewatered immediately upon reaching CWP regardless of the status of other plants within the block. After rewatering in both trials, measurements of marketability and gas exchange were recorded on 1, 3 and 5 DAT for Trial 1 and daily for 7 DAT in Trial 2. Unfortunately, the two different methods of rewatering plants in Trials 1 and 2 confounded the ability to determine, and thus compare the recovery responses between the two trials. Therefore, only data from Trial 2 will be presented.

The experimental design for both trials in objective 2 and the recovery portion in objective 3 was a split-plot with DAT on the main plot and treatment on the subplot. Treatments were arranged randomly within each block in each trial. Trial 1 contained 10 blocks, while trial 2 contained 5 blocks. Each block contained five plants, one plant corresponding to each treatment.

Data analysis. All taxa were treated as separate experiments and data were analyzed separately. Days to CWP (marketability) for all taxa were subjected to analysis of variance (ANOVA) using the general linear models procedure. When the treatment main effect was significant (probability of a greater F-value ≤ 0.10), means were separated using Tukey's HSD. Means separation was used for the three rates of s-ABA tested for species in Table 1 because so few degrees of freedom would be available to determine conclusively if trends were either linear or quadratic. When treatment main effects were significant for *Ligustrum* only, data for days to CWP, gas exchange, Ψ_s, or CWL were regressed on either s-ABA concentration, DAT, or both to determine if the relationship between those variables was significant (17). Data for recovery after rewatering were treated similarly, but separately from data recorded during the dry-down experiments.

Results and Discussion

An application of s-ABA significantly increased days to critical wilting point (CWP) for all species except *Hydrangea* Blushing Bride™ (ANOVA not presented). *Loropetalum* and *Rhododendron* had an average increase of 1 or 3 days, respectively, over the control (Table 1). *Trachelospermum* was generally slow to reach CWP as the nontreated controls remained marketable for 12 days; however, an application of either 1000 or 2000 mg·liter^{-1} of s-ABA increased marketability another 4 or 7 days, respectively. For *Lagerstroemia*, days to CWP was extended 3 days regardless of concentration of s-ABA applied. Although marketability of *Hydrangea* Blushing Bride™ was not affected by spray applications of s-

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

Table 1. Effect of exogenous s-ABA application on the mean days to critical wilting point (CWP) of selected container-grown woody ornamentals. Numbers within columns separated by different letters are significantly different ($P < 0.10$). Data points are the mean of 10 blocks.

	Days to critical wilting point				
s-ABA concn. (mg·liter^{-1})	*Loropetalum chinense* 'Sizzling Pink'	*Lagerstroemia* 'GAMAD I' Cherry Dazzle™	*Hydrangea macrophylla* Endless Summer® Blushing Bride™	*Rhododendron* Autumn Debutante™	*Trachelospermum jasminoides* var. *pubescens* 'Madison'
0	5.8c	5.3b	8.4a	7.0c	12.1c
1000	6.5b	8.0a	8.8a	9.3b	16.6b
2000	7.0a	8.6a	9.5a	9.9a	18.6a

ABA, previous experiments have shown drench applications to be effective in increasing days to CWP for *Hydrangea* Endless Summer® (3) and *Hydrangea macrophylla* 'Dooley' (unpublished data). Generally, hydrangeas transpire heavily and wilt frequently, so either the concentration may need to be increased if spray applications are to be effective or the drench application method may be used preferentially for this species. For all species, s-ABA treated plants recovered full turgidity after rewatering to container capacity and were considered marketable. Nontreated controls remained unmarketable after rewatering.

Treatment with s-ABA also affected days to CWP for *Ligustrum japonicum* 'Recurvifolium'. Overall marketability between the two trials of *Ligustrum* differed by approximately 1.5 days for each treatment (ANOVA not presented). Because there was not a trial by treatment interaction, data were averaged over both trials to show the positive linear relationship between days of marketability and s-ABA concentration (Fig. 2). Approximately 10 days of marketability occurred for plants treated with 2000 mg·liter^{-1} of s-ABA. This was more than 2 days of additional marketability over the nontreated control and suggests that spray applications of s-ABA can increase shelf life of select container grown woody ornamentals.

Stomatal conductance (g_s) of *Ligustrum* was affected by trial, treatment, DAT, and all interactions between those variables (ANOVA not presented). After treatments were applied

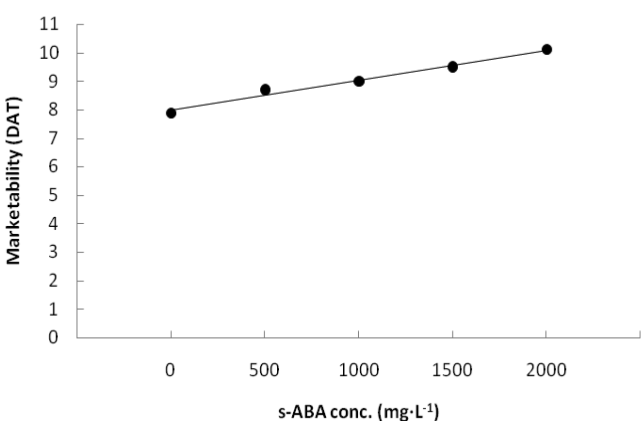

Fig. 2. Days after treatment (DAT) with a spray application of 0, 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA to plants of *Ligustrum japonicum* 'Recurvifolium' and water withheld before reaching the critical wilting point and becoming unmarketable. Data points are the mean of two trials and 10 (Trial 1) or 5 (Trial 2) replications. Marketability (DAT) = 8.0 + 0.001 (s-ABA); $P < 0.01$, $r^2 = 0.98$.

and water withheld in each trial, g_s generally declined until rewatering for both treated plants and non treated controls (Figs. 3 and 4). From the beginning of Trial 1 to 1 DAT, g_s decreased from an average of 172 mmol·m^{-2}·s^{-1} for all treatments to approximately 50 mmol·m^{-2}·s^{-1} for the nontreated controls and 15 mmol·m^{-2}·s^{-1} for all other treatments (Fig. 3). Stomatal conductance in *Populus cathayana* Rheder and *Populus kangdingensis* Z.Wang and S.L. Tung was also reduced with the application of exogenous ABA under both nonstressed and drought stressed conditions (26). In the present study, from 1 DAT until the nontreated controls reached CWP at 7 DAT, g_s declined linearly and at a greater rate than treated plants as represented by the steeper slope of the regression line. With the exception of the 1000 mg·liter^{-1} of s-ABA treatment (relationship was not significant) the relationship between g_s and DAT was quadratic for treated plants until 9 DAT when all plants reached CWP. The greater rate of water loss for controls resulted in fewer days to CWP (7 days) compared to all other treated plants (9 days).

For Trial 2, the relationship between g_s and DAT differed depending on the concentration of ABA applied. The relationship was similar for the control and the 500 mg·liter^{-1} of s-ABA treatment, as g_s declined with similar, negative linear coefficients (–19 and –23 linear coefficients for 0 and 500 mg·liter^{-1} of s-ABA, respectively) and similar quadratic coefficients (–1.0 and 0.01 quadratic coefficients for 0 and 500 mg·liter^{-1} of s-ABA, respectively) (Fig. 4). Although not a parallel decline for the nontreated control and 500 mg·liter^{-1} of s-ABA treatment, g_s differed by approximately 25 and 20 mmol·m^{-2}·s^{-1} at days 1 and 5, respectively, between the two treatments. Plants in both treatments reached CWP 8 DAT. In contrast, 1 DAT, g_s of plants treated with 2000 mg·liter^{-1} of s-ABA was approximately 75 mmol·m^{-2}·s^{-1} less than plants treated with 1500 mg·liter^{-1} of s-ABA. By 5 DAT, however, there was no difference between those treatments. Plants in the 1500 mg·liter^{-1} treatment reached CWP by 9 DAT, whereas those in the 2000 mg·liter^{-1} of s-ABA treatment reached CWP 10 DAT. The g_s rate of plants treated with 1000 mg·liter^{-1} of s-ABA had a relationship that appeared intermediate between that of the nontreated controls and 500 mg·liter^{-1} of s-ABA treatment, and that of plants treated with 1500 and 2000 mg·liter^{-1} of s-ABA. The g_s rates 1 DAT for the 1000 mg·liter^{-1} of s-ABA treatment were similar to the nontreated control and 500 mg·liter^{-1} of s-ABA, but as DAT progressed, rates were more similar to the 1500 and 2000 mg·liter^{-1} of s-ABA treatments. Nevertheless, plants treated with 1000 mg·liter^{-1} of s-ABA reached CWP 8 DAT, which was similar to both the control and 500 mg·liter^{-1} of s-ABA treated plants. The relationships between g_s and DAT for each concentration of s-ABA in Trial 2 indicate that s-ABA

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

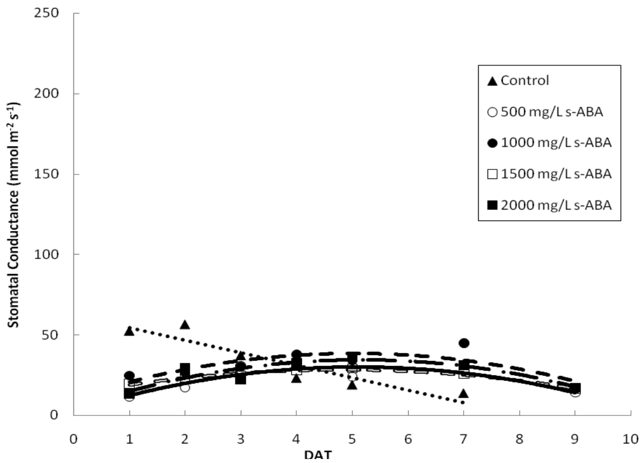

Fig. 3. Mean stomatal conductance (g_s) (mmol·m^{-2}·s^{-1}) for each day after treatment (DAT) with a spray application of 0, 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA to plants of *Ligustrum japonicum* 'Recurvifolium' and water withheld before reaching the critical wilting point in Trial 1. Data points are means of 10 replications. Trendline designations and regression equations are:

········ g_s (control) = 62 – 7.7 (DAT); $P < 0.05$, $r^2 = 0.86$;
——— g_s (500 mg·liter^{-1} of s-ABA) = 2.5 + 10.9 (DAT) – 1.1 (DAT^2); $P < 0.05$, $r^2 = 0.79$;
– – – g_s (1000 mg·liter^{-1} of s-ABA) = 10.6 + 11.2 (DAT) – 1.1 (DAT^2); $P = 0.13$, $r^2 = 0.64$;
▭ ▭ ▭ g_s (1500 mg·liter^{-1} of s-ABA) = 13.2 + 6.3 (DAT) – 0.66 (DAT^2); $P < 0.01$, $r^2 = 0.97$;
·—·— g_s (2000 mg·liter^{-1} of s-ABA) = 4.4 + 11.6 (DAT) – 1.1 (DAT^2); $P < 0.04$, $r^2 = 0.79$.

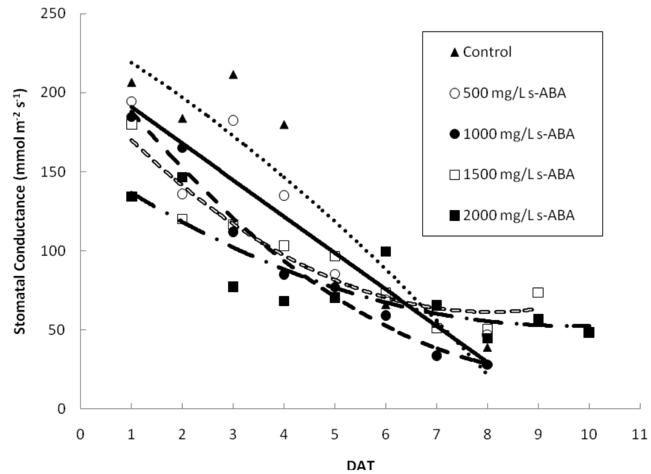

Fig. 4. Mean stomatal conductance (g_s) (mmol·m^{-2}·s^{-1}) for each day after treatment (DAT) with a spray application of 0, 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA to plants of *Ligustrum japonicum* 'Recurvifolium' and water withheld before reaching the critical wilting point in Trial 2. Data points are means of 5 replications. Trendline designations and regression equations are:

········ g_s (control) = 239.0 – 19.0 (DAT) – 1.0 (DAT^2); $P < 0.01$, $r^2 = 0.86$;
——— g_s (500 mg·liter^{-1} of s-ABA) = 214.4 – 23.2 (DAT) + 0.01 (DAT^2); $P < 0.01$, $r^2 = 0.86$;
– – – g_s (1000 mg·liter^{-1} of s-ABA) = 228.7 – 42.5 (DAT) + 2.2 (DAT^2); $P < 0.01$, $r^2 = 0.98$;
▭ ▭ ▭ g_s (1500 mg·liter^{-1} of s-ABA) = 202.7 – 35.1 (DAT) + 2.2 (DAT^2); $P < 0.01$, $r^2 = 0.91$;
·—·— g_s (2000 mg·liter^{-1} of s-ABA) = 157.8 – 21.9 (DAT) + 1.1 (DAT^2); $P < 0.01$, $r^2 = 0.71$.

had an effect on g_s with as little as 500 mg·liter^{-1} of s-ABA application, but prolonged desiccation tolerance was not imparted to these plants until concentrations were above 1000 mg·liter^{-1} of s-ABA.

Initial g_s rates 1 DAT for Trial 2 were over 7 times higher than those in Trial 1. This could be due to where s-ABA was applied. In Trial 1, plants were shipped via tractor-trailer (temperature not recorded) after treatment, and placed within a greenhouse provided with cooling pads and fans at the MHCRS, whereas, in Trial 2, plants were treated at MHCRS after shipping. High temperatures, low humidity and the absence of light experienced during handling and transit (22) could have had a significant effect on g_s values. Stomatal conductance declined in seedlings of *Cucumis sativus* L. (cucumber) and tomato, depending on the concentration of exogenous s-ABA applied and the temperature at which seedlings were stored (25). At a storage temperature of 20C (68F) and in total darkness, all seedlings had the same transpiration rate regardless of the s-ABA concentration sprayed (25). Large reductions in g_s have been achieved previously by applications of exogenous ABA. In Goreta et al. (11), an application of exogenous ABA to pepper seedlings produced a sharp decline in g_s rates from 864 mmol·m^{-2}·s^{-1} to 390 mmol·m^{-2}·s^{-1} (55% reduction in g_s rate) within 24 hr after treatment. In the present study, a third trial using the same methods as in Trial 2 was also conducted and the g_s responses were intermediate between Trials 1 and 2; however, most of the data were not publishable due to instrument malfunctions over the course of the entire study.

Due to the large disparity in g_s responses between the two trials in the present study, it is difficult to determine which model (Trial 1 or Trial 2) best describes the general response of g_s in plants after treatment with s-ABA. In Trial 1, g_s was reduced to a similar rate for all treated plants and remained so until the end of the experiment. In contrast, g_s in Trial 2 was reduced depending on the s-ABA concentration and remained distinct until plants reached CWP. These findings support the original hypothesis that s-ABA negatively impacts g_s, and higher concentrations impact g_s more negatively. Yet, it is quite possible that the environmental conditions within which the plants are treated, shipped and ultimately marketed affect the physiological parameters controlling transpiration. Nevertheless, in both trials, s-ABA applications reduced gs and plants receiving higher concentrations of s-ABA tended to have lower g_s and remained marketable longer.

Cumulative water loss (CWL) was affected by s-ABA treatment, DAT, and the interactions of trial by treatment and trial by DAT (ANOVA not presented). The interactions indicated that initial water loss rates (1–5 DAT) were higher in Trial 2 than Trial 1, yet overall CWL became similar at 9–10 DAT for both trials (data not presented). In Trial 1, CWL decreased with increasing concentrations of s-ABA, whereas in Trial 2 there was no relationship. This is consistent with the results reported by Sharma et al. (19) indicating applications of an ABA analog to tomato seedlings resulted in significantly lower cumulative moisture use (CMU) compared to the controls, with CMU decreasing with increasing ABA concentration. Similarly, Kim and van Iersel (13) found

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

that applications of s-ABA to *Salvia splendens* Sellow ex Schult. (salvia) delayed water loss through stomatal closure and lower cumulative water loss rates, increasing marketability by two (250–500 mg·liter^{-1} of s-ABA) to three days (1000–2000 mg·liter^{-1} of s-ABA). A subset of data containing just the last day of CWL, before plants in both trials reached CWP, was analyzed separately (ANOVA not presented). There was no effect of trial or treatment, indicating that all plants, regardless of treatment, ultimately accumulated the same amount of water lost (3212 g) (113.3 oz) before reaching CWP. Davenport et al. (5) reported that applications of a film-forming antitranspirant to *Nerium oleander* resulted in approximately 2 days of additional marketability even though both treated and nontreated plants transpired approximately equal amounts of water over a ten day period. The current study also found concentrations of s-ABA delayed days to CWP by further delaying water lost through stomates compared to nontreated controls under desiccated conditions.

Net photosynthesis at ambient conditions (A_{net}) was affected by trial, s-ABA treatment, DAT, and all interactions except trial by treatment by DAT (ANOVA not presented). The relationship of A_{net} to treatment and DAT for each trial was very similar to the relationships between g_s with those variables (data not shown). The natural log g_s was highly correlated with A_{net} ($P < 0.01$; $R^2 = 0.92$; data not shown), indicating that the effect of ABA on photosynthesis was largely due to its effect on g_s.

Stem water potential (Ψ_s) in Trial 2 (Ψ_s was not measured in Trial 1) was affected by DAT and treatment but not their interaction (ANOVA not presented). As expected, Ψ_s decreased for all plants after water was withheld and continued to decrease with a quadratic response until plants reached CWP (Fig. 5). The nontreated control and plants treated with 1000 mg·liter^{-1} of s-ABA had the lowest Ψ_s over all DAT, whereas plants treated with 2000 mg·liter^{-1} of s-ABA had the highest Ψ_s. Despite decreasing the rate of Ψ_s over DAT, s-ABA applications did not change the Ψ_s values measured at CWP for each treatment. At 8 DAT, when plants in the nontreated control reached CWP, Ψ_s was –2.1 MPa, while plants treated with 2000 mg·liter^{-1} of s-ABA had Ψ_s of –1.2 MPa. When plants in the 2000 mg·liter^{-1} of s-ABA treatment reached CWP 10 DAT, Ψ_s was –2.1 MPa. All treatments, including the nontreated control, reached a mean of –2.4 MPa at CWP.

All plants in Trial 2 recovered 90% of g_s to pretreatment rates (% g_s) and had similar Ψ_s (–0.6 Mpa) seven days after rewatering In Trial 2, individual plants were rewatered the day CWP was reached, which appears to have allowed plants to recover from desiccation. Based on these findings, applications of s-ABA to *Ligustrum* reduced g_s rates while water was withheld, but s-ABA did not impair recovery of g_s provided plants were rewatered immediately after reaching CWP.

In conclusion, results of the study herein suggest that applications of s-ABA to plants can delay desiccation symptoms when water is withheld. With the exception of *H. macrophylla* Blushing Bride™, exogenous ABA applications of 2000 mg·liter^{-1} increased days of marketability by approximately 1 to 7 days depending on species. Initially, reduction in stomatal conductance depended on the concentration of s-ABA applied. During the time water was withheld, decreased conductance rates allowed plants to maintain both turgidity and a high Ψs, therefore the days to CWP were increased. An application of 500 mg·liter^{-1} of s-ABA affected g_s but

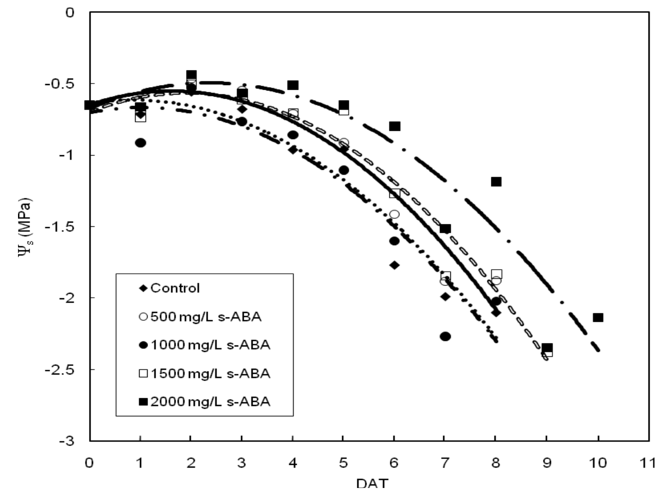

Fig. 5. Mean stem water potential (Ψ_s) for each day after treatment (DAT) with a spray application of 0, 500, 1000, 1500 or 2000 mg·liter^{-1} of s-ABA to plants of *Ligustrum japonicum* 'Recurvifolium' and water withheld before reaching the critical wilting point in Trial 2. Trendline designations and regression equations are:

Ψ_s (Control) = 0.65 – 0.07 (DAT) + 0.04 (DAT^2); $P < 0.01$, $r^2 = 0.62$;
Ψ_s (500 mg·liter^{-1} of s-ABA) = 0.69 – 0.15 (DAT) + 0.04 (DAT^2); $P < 0.01$, $r^2 = 0.71$;
Ψ_s (1000 mg·liter^{-1} of s-ABA) = 0.83 – 0.14 (DAT) + 0.04 (DAT^2); $P < 0.01$, $r^2 = 0.69$;
Ψ_s (1500 mg·liter^{-1} of s-ABA) = 0.73 – 0.14 (DAT) + 0.04 (DAT^2); $P < 0.01$, $r^2 = 0.82$;
Ψ_s (2000 mg·liter^{-1} of s-ABA) = 0.72 – 0.17 (DAT) + 0.03 (DAT^2); $P < 0.01$, $r^2 = 0.72$.

appeared to have a shortened period of efficacy because plants reached CWP the same day as nontreated controls. An increase in days to CWP was not imparted to plants until s-ABA concentrations were above 1000 mg·liter^{-1} of s-ABA. While all *Ligustrum* in Trial 1 treated with s-ABA had similar market life (9 days), in Trial 2, the controls, 500 and 1000 mg·liter^{-1} of s-ABA treatments remained marketable for 8 days, plants treated with 1500 mg·liter^{-1} of s-ABA lasted 9 days, and plants in the 2000 mg·liter^{-1} of s-ABA treatment remained marketable for 10 days; thus indicating that exogenously applied s-ABA is efficacious in reducing water loss and increasing marketability. The 2000 mg·liter^{-1} of s-ABA treatment had lower rates of g_s in both trials, accumulated less water loss and had the highest Ψ_s per day over the experiment As a result, those plants remained marketable for longer periods than plants treated with lower concentrations.

Literature Cited

1. Barrett, J. and C. Campbell. 2006. s-ABA: Developing a new tool for the big grower. Big Grower 1:26–29.

2. Blanchard, M.G., L.A. Newton, E.S. Runkle, D. Woolard, and C.A. Campbell. 2007. Exogenous applications of abscisic acid improved the postharvest drought tolerance of several annual bedding plant species. Acta Hort. 755:127–132.

3. Campbell, C.A., J. Conner, and A. LeBude. 2008. Short-term drought tolerance of container-grown ornamental plants in response to abscisic acid (ABA). HortScience 43:1104. (Abstr.)

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

4. Cornish, K. and J.A.D. Zeevaart. 1985. Abscisic acid accumulation by roots of *Xanthium strumarium* L. and *Lycopersicon esculentum* Mill. in relation to water stress. Plant Physiol. 79:653–658.

5. Davenport, D.C., P.E. Martin, and R.M. Hagan. 1973. Effects of an antitranspirant on water use by highway oleander (*Nerium oleander* L.) plantings. J. Amer. Soc. Hort. Sci. 98:421–425.

6. Davies, W.J. and J. Zhang. 1991. Root signals and the regulation of growth and development of plants in drying soil. Annu. Rev. Plant Physiol. Plant Mol. Biol. 42:55–76.

7. Davies, W.J., F. Tardieu, and C. Trejo. 1994. Update on long-distance signaling: How do chemical signals work in plants that grow in drying soil? Plant Physiol. 104:309–314.

8. Davies, W.J., G. Kudoyarova, and W. Hartung. 2005. Relation to other signaling pathways in the detection of soil drying and the mediation of the plant's response to drought. J. Plant Growth Regul. 24:285–295.

9. Flores, A. and K. Dörffling. 1990. A comparative study of the effects of abscisic acid and new terpenoid abscisic acid analogs on plant physiological processes. J. Plant Growth Regul. 9:133–139.

10. Franks, P.J. and G.D. Farquhar. 2001. The effect of exogenous abscisic acid on stomatal development, stomatal mechanics, and leaf gas exchange in *Tradescantia virginiana*. Plant Physiol. 125:935–942.

11. Goreta, S., D.I. Leskovar, and J.L. Jifon. 2007. Gas exchange, water status, and growth of pepper seedlings exposed to transient water deficit stress are differentially altered by antitranspirants. J. Amer. Soc. Hort. Sci. 132:603–610.

12. Hummel, R.L. 1990. Water relations of container-grown woody and herbaceous plants following antitranspirant sprays. HortSicence 25:772–775.

13. Kim, J. and M.W. van Iersel. 2008. ABA drenches induce stomatal closure and prolong shelf life of *Salvia splendens.* Proc. South. Nurs. Assoc. Res. Conf. 53:107–111.

14. Leskovar, D.I. and D.J. Cantliffe. 1992. Pepper seedling growth response to drought stress and exogenous abscisic acid. J. Amer. Soc. Hort. Sci. 117:389–393.

15. Morgan, J.M. 1984. Osmoregulation and water stress in higher plants. Ann. Rev. Plant Physiol. 39:299–319.

16. Okhuma, K., L.J. Lyon, F.T. Addicott, and O.E. Smith. 1963. Abscisin II, an abscission accelerating substance from young cotton fruit. Science 142:1592–1593.

17. SAS Institute, Inc. 2001. SAS/STAT User's Guide; Release 9.1.3 Edition, SAS Inst., Cary, NC.

18. Sauter, A., W.J. Davies, and W. Hartung. 2001. The long distance abscisic acid signal in the droughted plant: The fate of the hormone on its way from the root to the shoot. J. Exp. Bot. 52:1–7.

19. Sharma, N., S.R. Abrams, and D.R. Waterer. 2005. Uptake, movement, activity, and persistence of an abscisic acid analog (8' acetylene ABA methyl ester) in marigold and tomato. J. Plant Growth Regul. 24:28–35.

20. Sharma, N., S.R. Abrams, and D.R. Waterer. 2006. Evaluation of abscisic acid analogs as holding agents for bedding plant seedlings. HortTechnology 16:71–77.

21. Stamps, R.H. and A.L. Chandler. 2005. Effects of s-ABA on water loss and desiccation of containerized *Hibiscus rosa-sinensis*. HortScience 40:1115–1116. (Abstr.)

22. Starman, T.W., S.E. Beach, and K.L. Eixmann. 2007. Postharvest decline symptoms after simulated shipping and during shelf life of 21 cultivars of vegetative annuals. HortTechnology 17:544–551.

23. Tardieu, F., N. Katerji, O. Bethenod, J. Zhang, and W.J. Davies. 1991. Maize stomatal conductance in the field: Its relationship with soil and plant water potentials, mechanical constraints and ABA concentration in the xylem sap. Plant Cell Environ. 14:121–126.

24. Trejo, C.L., W.J. Davies, and P.R. Lucero del Mar. 1993. Sensitivity of stomata to abscisic acid: An effect of the mesophyll. Plant Physiol. 102:497–502.

25. Yamazaki, H., T. Nishijima, and M. Koshioka. 1995. Effects of (+)–s-abscisic acid on the quality of stored cucumber and tomato seedlings. HortScience 30:80–82.

26. Yin, C., B. Duan, X. Wang, and C. Li. 2004. Morphological and physiological responses of two contrasting poplar species to drought stress and exogenous abscisic acid application. Plant Science 167:1091–1097.

27. Yue, C. and B.K. Behe. 2009. Factors affecting U.S. consumer patronage of garden centers and mass-merchandisers. Acta Hort. 831:301–308.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access