Floriculture

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The Light Weight Aggregate HydRocks® as a Perlite Substitute

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Index of words: Particle size, floriculture, porosity

Significance to the Industry: Perlite used in greenhouse production is expensive and contains a great deal of dust which is a nuisance and potentially a hazardous concern for workers. Large percentages of dust of fine aggregates in perlite can reduce the porosity expected form coarse particles. The results of this study suggest that HydRocks® lightweight clay aggregate could be used in place of perlite to increase porosity without degradation in peat based mixes. HydRocks® is a local product of the southeast and is available readily throughout the region.

Nature of Work: Lightweight, peat-based mixes are commonly amended with expanded perlite in order to increase porosity. Total porosity influences water retention and aeration, both of which are determined by the particle size distribution and packing density at potting (2). In peat mixes, perlite is known to increase airspace and decrease available water as the fraction of perlite to peat increases (3). erlite's lightweight nature allows it to be available readily in bag or bulk shipments. Perlite, however, is expensive and contains a great deal of dust that is a nuisance to workers and has raised health concerns among growers (personal communication). The effectiveness of perlite's influence on porosity will depend upon the grade or quality of the material used. The increase in dust and small particles can potentially decrease porosity by filling in already available pore space. Dust and fine aggregates have a dual effect on substrates' cost effectiveness and physical effectiveness. Physical effectiveness is reduced, as mentioned, due to the reduced porosity from dust filling in the pore space and reducing the amount of coarse (useful) aggregates on a volumetric basis. The cost effectiveness of the product is also volumetric by replacing coarse aggregates in the bag. Reduced utility and expense contribute to a need for a perlite alternative.

HydRocks® is a light expanded clay aggregate marketed for horticulture applications available from Big River Industries (Alpharetta, GA). HydRocks® is formed by fully calcining clay at temperatures reaching 2000° F in a rotary kiln and is readily available from several quarries in the southeast. HydRocks® is generally inert and pH neutral when compared to most substrate components. HydRocks® has a cation exchange capacity (CEC) of 8 meq/100g. The objective of the following experiments was to evaluate HydRocks® as a perlite substitute in peat based substrates.

Materials and Methods: Six perlite (1 liter) samples were collected and were each sieved for 3 minutes using a Ro-Tap (Ro-Tap RX-29; W.S. Tyler, Mentor, OH) sieve shaker. Percentage of particles retained on screens is reported on Table 1.

Aggregates greater than 2.36 mm (#8 U.S. Standard Sieves) were considered coarse. Aztec™ Red Velvet and New Guinea Celebrette Red (donated by Ball Horticulture, Chicago IL) were used to evaluate HydRocks effectiveness as a perlite substitute in hanging baskets. Three plugs were potted separately into 8" hanging baskets (8.0 ESL HB Dillen, Middlefield, OH) filled with peat moss (Conrad Fafard Inc. Agawam, MA) amended with the following amendment treatments: 15 % perlite, 15% course perlite (≥ 2.36mm) 15 % course HydRocks®, 7% reduced course perlite, and 7% reduced course HydRocks® (reduction based on 45% of perlite samples being ≥ 2.36; reduction equals a 55% reduction in the amended percent (Table 1)). Plants were grown as suggested by Ball Horticulture Culture Sheets (1) for 13 weeks at the Ornamental Horticulture Research Station, Mobile, Alabama in a complete randomized design and hand watered as needed. Physical properties of substrate treatments were analyzed using the NC State Porometers.

Results and Discussion: Perlite sampled contained 55% of what was considered medium and fine aggregates (< 2.36 mm) and 45 % of what was considered coarse aggregates. Hanging baskets were evaluated on marketability, root ball density, and shoot fresh weight 13 weeks after potting. No block effect was detected and data was analyzes as a complete randomized design using Duncan's Multiple Range Test. Marketability was based on a 5 point scale (1=not sellable, 5= high quality). Impatient hanging baskets had no differences across treatment in marketability. Verbena hanging baskets marketability was highly dependent on treatment. Peat amended with 15% HydRocks® had the highest marketability rating (4.6) and was similar to a 7% HydRocks® amendment (4.2). Peat amended with 7% coarse perlite had the lowest salability rating (1.6). Root density was rated on a 5 point scale with 5 having the densest root system and 1 being the least dense. Impatient hanging baskets containing perlite were not different and both treatments containing HydRocks® were not different. HydRocks® treatments were different than perlite treatments. HydRocks® treatments had almost 3 times the density of perlite treatments. Verbena baskets had similar results to the impatient baskets in root density. Verbena baskets containing perlite were not different from each other but were different than verbena grown with HydRocks®. Plants grown in peat amended with 15% HydRocks® had the greatest density of roots across treatments, with as great as three times as many roots as plants as plants in any perlite treatment.

Plants in each HydRocks® treatment outperformed plants grown in perlite treatments for both species with regards to marketability, root density, and shoot weight. Fresh weight was taken for each basket for both species. Impatiens, across treatments, were similar in shoot fresh weight. Verbena hanging baskets containing coarse perlite treatments had the lowest fresh weights for all treatments. Peat amended with 15% perlite (61.5g) and peat amended with 7% HydRocks® (74.6g) were not different in fresh weight. Peat amended with 15% HydRocks® had the highest shoot weight across treatments (101.6 g).

Similar results were found with a preliminary study (data not shown) in which no plant growth differences were seen between perlite and HydRocks®. Shoot dry weights and shoot quality were not different between perlite and HydRocks® but immense differences were observed in root density. HydRocks® treatments outperformed perlite treatments by 3 fold in most situations.

The situation in which these plants were grown would be considered wet by most growers. No differences in marketability were seen when observing inpatients (a wet tolerating plant). However, verbena (moisture sensitive) plants were markedly different in marketability and overall quality. No differences were found in porosity among substrates using the NC State Porometer method (data not shown), but observations of the root systems indicated extreme differences in porosity. Perlite treatments had no roots below 3" of the container surface suggesting that the container stayed to wet for adequate root growth. HydRocks® grown plants had roots throughout the pot and a number at the bottom of the root ball indicating that moisture was more prevalent at the bottom of the container. Overall results across all observations suggest HydRocks® as being a suitable perlite replacement in floriculture substrates. HydRocks® bulk density (0.54 g/cm^3) is considerable higher than that of perlite (0.18 g/cm^3). The weight difference between HydRocks® and perlite is more of a concern in nursery container production when cargo weight load capacity is a plausible issue, however the cargo space required for floriculture crops is greater than nursery crops due to the delicacy of materials. High space requirements of floriculture crops dictate the load instead of weight, therefore an increase in substrate bulk density is not of great concern with regards to shipping. HydRocks® is more uniform in size than perlite and it does not break down over time or during handling. HydRocks® has a relatively low CEC (8 meq/100g) and it is unlikely that results were influenced by CEC, however further testing is warranted. It is currently unknown how HydRocks® aggregates behave in different mechanical mixing equipment and caution should be taken when using HydRocks® in mixers and on conveyer belts.

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Table 1. Analysis of particle size distribution of Perlite

US standard sieve #	Sieve opening (mm)	Perlite	
		Volume[Z]	Weight[Y]
1/2	12.50	0.0	0.0
3/8	9.50	0.0	0.0
1/4	6.30	0.0	0.0
6	3.35	20.6	20.9
8	2.36	33.0	30.3
10	2.00	12.4	10.4
14	1.40	17.2	13.0
18	1.00	8.7	5.9
35	0.50	7.4	5.8
60	0.25	1.8	2.9
140	0.11	0.9	1.7
270	0.05	2.2	2.6
Pan	0.00	6.0	0.8

[Z] Mean percent volume of perlite retained on each screen from 1000 ml sample

[Y] Mean percent weight of material retained on each screen from 100 g sample.

Table 2. Comparison of course HydRocks® to perlite when amended in a peat based substrate.

Species	Treatment	Salability[Z]	Root Density[Y]	Fresh Weight
Impatiens	85:15 (v:v) peat moss:perlite	4.8 A[X]	2.0 B	198.0 A
	85:15 (v:v) peat course:course perlite[V]	4.5 A	1.5 B	175.0 AB
	85:15 (v:v) peat moss:HydRocks®	4.5 A	4.2 A	189.4 AB
	93:7 (v:v) peat moss:course perlite (reduced)[U]	4.5 A	1.5 B	150.2 B
	93:7 (v:v) peat moss:HydRocks® (reduced)	4.8 A	4.2 A	211.2 A
Verbena	85:15 (v:v) peat moss:perlite	3.4 BC	1.0 C	61.5 B
	85:15 (v:v) peat course:course perlite	2.4 CD	1.0 C	36.2 C
	85:15 (v:v) peat moss:HydRocks®	4.6 A	4.2 A	101.6 A
	93:7 (v:v) peat moss:course perlite (reduced)	1.6 D	1.0 C	25.2 C
	93:7 (v:v) peat moss:HydRocks® (reduced)	4.2 AB	2.5 B	74.5 B

[Z] Salbaility was based on a scale on of 1 to 5 (1being not salable; 5 being high quality).

[Y] Root density was based on a 5 point scale (1 being poor with very few roots; 5 being good full coverage).

[X] Means with different letters within columns are significantly different, separated by Duncan's multiple range test (α = 0.05).

[W] Perlite ≥ 2.3 2.36 mm were considered course

[V] Reduced amendments were based on 55% of the perlite sampled being < 2.36 mm; 7% is a 55% reduction in a 15% amendment rate.

Salt Tolerance of Ten Bedding Plants

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Index Words: landscape irrigation, salinity tolerance, water reuse

Significance to Industry: Bedding plants are extensively used in landscapes in the United States. As high quality water supply becomes limited in many parts of the world, recycled water is being encouraged to irrigate landscapes. Therefore, information on salt tolerance of bedding plants is of increasing importance. This study quantified the relative salt tolerance of ten bedding plants irrigated with water at various salinity levels. The results indicated that the selected bedding plants may be irrigated with water at moderate salinity level without any visual damage, although growth may be reduced, depending on species.

Nature of Work: Seeds of ten bedding species (Table 1) were sown on 20 March 2008 in 72-cell trays filled with a germination mix (Sunshine Mix No. 5, SunGro Hort., Bellevue, WA). Seedlings were grown in 500-mL pots filled with similar potting mix with more and coarse perlite (Sunshine Mix No. 4, SunGro Hort.) in the greenhouse. On 23 May 2008, seedlings were transplanted to 2.6-L for the three angelonia cultivars, licorice plant, and plumbago or 10-L pots containing Sunshine Mix No. 4 for the other species. Slow released fertilizer 14N–6P–12K (Osmocote 14–14–14, Scotts-Sierra Hort. Products, Marysville, OH) was applied at 5.0 $g \cdot L^{-1}$ and Micromax (Scotts-Sierra Hort. Products) at 0.5 $g \cdot L^{-1}$. On 2 June 2008, all plants were moved to a shade house with shade cloth of 25% light exclusion.

Solutions of five salinity levels were prepared by adding appropriate amounts of sodium chloride (NaCl), magnesium sulfate ($MgSO_4 \cdot 7H_2O$), and calcium chloride ($CaCl_2$) at 87:8:5 (by weight) to tap water, creating electrical conductivity (EC) of 1.5, 2.5, 3.5, 5.0, and 7.0 $dS \cdot m^{-1}$. The major ions in the tap water were Na^+, Ca^{2+}, Mg^{2+}, Cl^-, and $SO_4^{\ 2-}$ at 184, 52.0, 7.5, 223.6, and 105.6 $mg \cdot L^{-1}$, respectively. The composition of the created saline solutions was similar to that of the reclaimed water of local water utilities. A 100-L tank of saline solution was prepared each time with confirmed EC for each treatment. Saline water irrigation was initiated on 5 June and terminated on 5 Sept. 2008. Plants were irrigated with 1 L or 2 L solutions per pot for 2.6 L or 10 L pots. Irrigation intervals were determined according to plant species, treatment and weather conditions.

Plant height and two perpendicular canopy widths were recorded monthly to calculate the growth index: (height + (width 1 + width 2)/2)/2. Upon termination of the experiment, shoot dry weight (DW) was determined after oven-dried at 70 °C to constant weight. Data were analyzed separately by species. The experiment was a split-plot design with irrigation water as the main plot and species as subplots with 6 replications. To determine the threshold of salinity level, Student-Newman-Keuls multiple comparison at *P* = 0.05 were conducted, in addition to regression analysis using SAS software (Version 9.1.3, SAS Institute Inc., Cary, NC).

Results and Discussion: All plants survived, regardless of treatment, except for ornamental pepper 'Purple Flash'. The mortality rate of 'Purple Flash' was 17%, 17%, 33%, 50% and 100%, respectively, when plants were irrigated with solutions of 1.5, 2.5, 3.5, 5.0, and 7.0 dS·m^{-1}. Since mortality occurred at the beginning of the study, elevated salinity may not be the sole cause. Further investigation is needed on why 'Purple Flash' did not survive. No visual foliar damage was observed in any species, regardless of salinity treatment.

Shoot DW of angelonia 'White' and 'Lavender Pink' decreased linearly as the EC of irrigation water increased (Fig. 1). Shoot DW of angelonia 'Purple' decreased as EC increased in a quadratic fashion. Generally, there were no differences in shoot DW of angelonia cultivars at EC of 1.5, 2.5, and 3.5 dS·m^{-1}. The EC of 5.0 and 7.0 dS·m^{-1} decreased shoot DW by 25% to 50% compared to those at EC of 2.5 dS·m^{-1}. Shoot DW of 'Black Pearl' and 'Calico' decreased linearly as EC of irrigation water increased and the magnitude of growth reduction was larger in 'Black Pearl' than in 'Calico'. For example, per unit increase of EC, shoot DW decreased 11.69 g and 6.49 g in 'Black Pearl' and 'Calico', respectively. No differences in shoot DW of 'Purple Flash' were found. Among the three cultivars of ornamental peppers, 'Black Pearl' was the most sensitive to elevated salinity based on its shoot DW reduction at every increased level of EC of irrigation water. For vinca and helenium, shoot DW also decreased linearly as EC of irrigation water increased. The shoot DW of licorice plant at 7.0 dS·m^{-1} was lower than those in other treatments and shoot DW of plumbago at EC of 7.0 dS·m^{-1} was lower than those at EC of 1.5 dS·m^{-1} and 2.5 dS·m^{-1}.

Growth index of angelonia 'White' was not affected by the treatment (Fig. 2). For angelonia 'Purple' and 'Lavender Pink', growth index was generally larger at EC of 2.5 dS·m^{-1} and 3.5 dS·m^{-1} compared to other treatments. In ornamental peppers, growth index of 'Black Pearl' decreased linearly as EC of irrigation water increased, while those of 'Calico' and 'Purple Flash' were not affected. Growth index of helenium and vinca also decreased linearly as EC increased. No differences in growth index of licorice plant and plumbago were found among the treatments.

In summary, the threshold EC for minimizing growth reduction was 3.5 dS·m^{-1} for angelonia and ornamental pepper 'Calico' and between 3.5 to 5.0 dS·m^{-1} for helenium, licorice plant and plumbago. Ornamental pepper 'Black Pearl' and vinca tended to have greater growth reduction as EC of irrigation increased. Although EC of recycled water vary with location and water source, EC of recycled water is generally below 2 dS·m^{-1}. A wide range of salinity tolerance for herbaceous annuals and perennials has been reported, and some of them are sensitive salinity with foliar injury (2, 3, 4). Since no foliar injury was observed on any species, these plants may be considered moderate tolerant to salinity stress. Further confirmation is needed for these bedding plants on their salinity tolerance because the results of study were obtained from a single growing season. Recommended salt tolerance or threshold of salinity for landscape plants should be based primarily on their aesthetical appearance, instead of maximizing growth (1), especially for rapidly growing plant species. For example, although a significant reduction of growth in ornamental peppers 'Black Pearl' and 'Calico' was observed under elevated salinity conditions, their compact appearance may not have a significant effect on their aesthetic value, especially when they are used as annual ornamental plants.

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Table 1. A list of plant species used in the experiment

Botanical name	Common name	Cultivar
Angelonia angustifolia Benth	Angelonia	Lavender Pink
A. angustifolia Benth	Angelonia	Purple
A. angustifolia Benth	Angelonia	White
Capsicum annuum L.	Ornamental pepper	Black Pearl
C. annuum L.	Ornamental pepper	Calico
C. annuum L.	Ornamental pepper	Purple Flash
Catharanthus roseus (L.) G. Don	Vinca	Titan
Helenium amarum (Raf.) H. Rock	Helenium	Dakota Gold
Helichrysum petiolatum (L.) DC.	Licorice Plant	Silver Mist
Plumbago auriculata Lam.	Plumbago	Escapade Blue

Seeds were provided by Ball Horticultural Company (Chicago, IL).

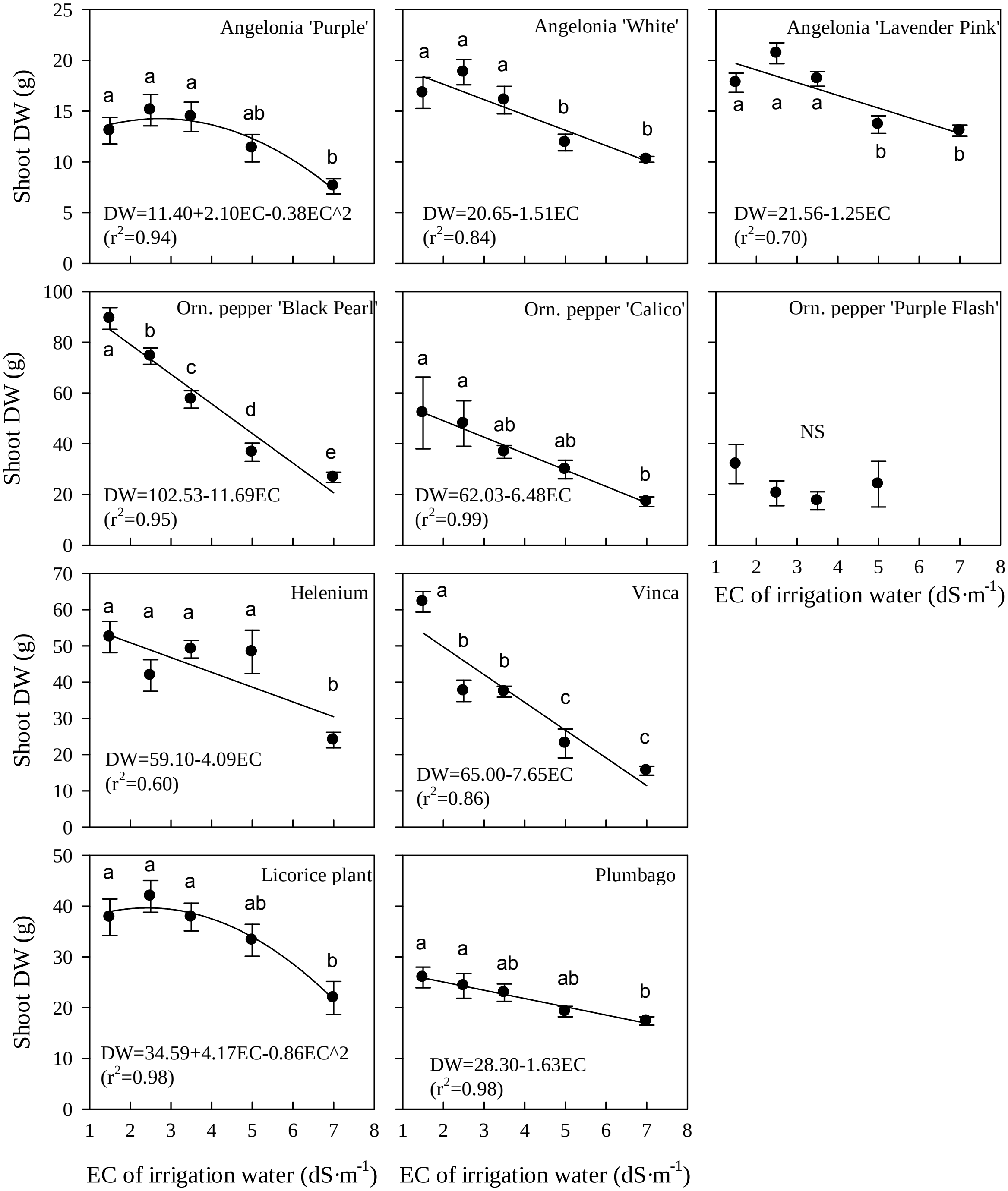

Fig. 1. Shoot dry weight (DW) of angelonia (*Angelonia angustifolia*) 'Purple', 'White', and 'Lavender Pink', ornamental pepper (*Capsicum annuum*) 'Black Pearl', 'Calico', and 'Purple Flash', helenium (*Helenium amarum*), vinca (*Catharanthus roseus*), licorice plant (*Helichrysum petiolatum*), and plumbago (*Plumbago auriculata*) irrigated with water at EC of 1.5, 2.5, 3.5, 5.0, or 7.0 dS·m^{-1}. Vertical bars represent standard errors. NS indicates nonsignificance.

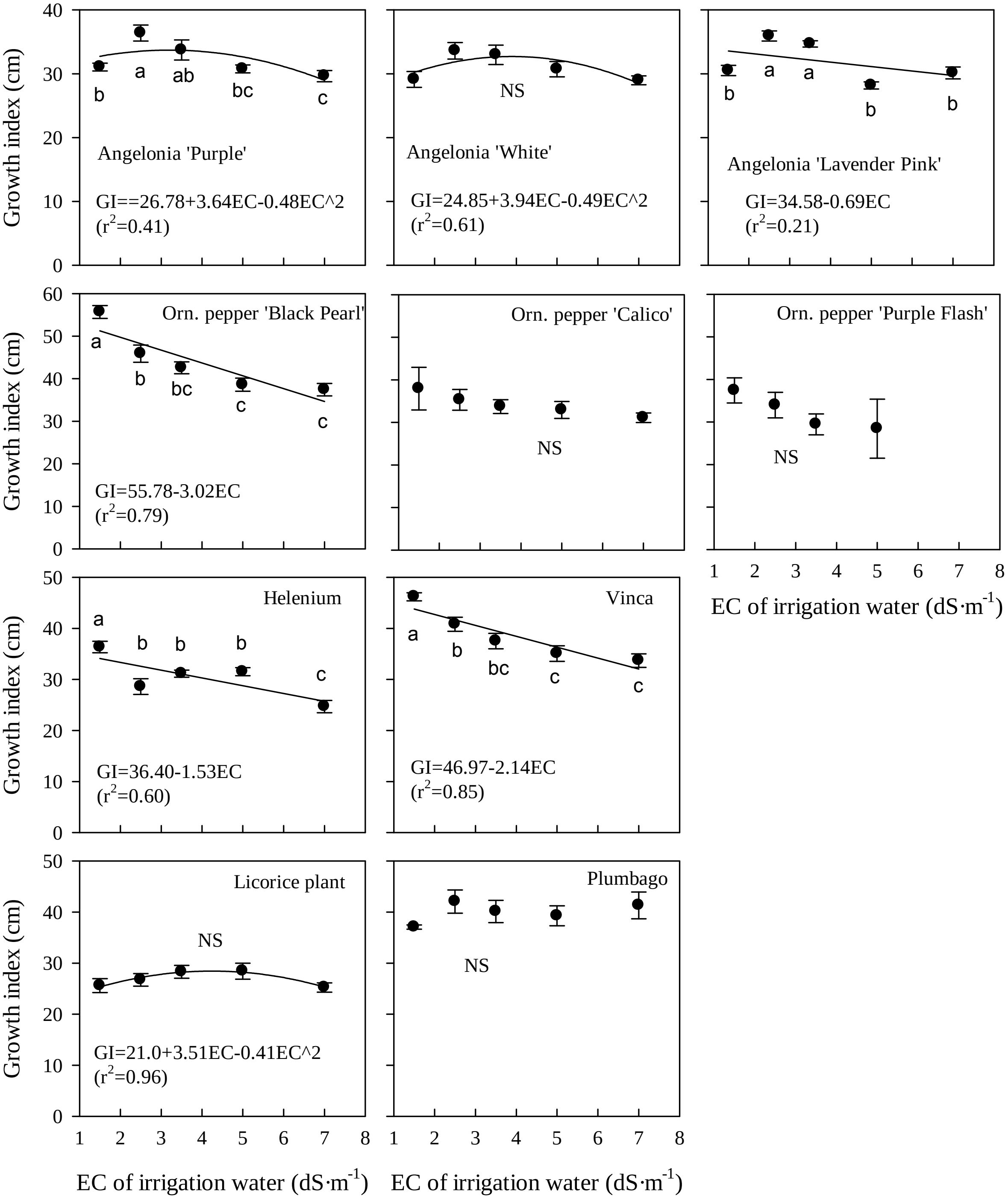

Fig. 2. Growth index (GI) of angelonia (*Angelonia angustifolia*) ‘Purple’, ‘White’, and ‘Lavender Pink’, ornamental pepper (*Capsicum annuum*) ‘Black Pearl’, ‘Calico’, and ‘Purple Flash’, helenium (*Helenium amarum*), vinca (*Catharanthus roseus*), licorice plant (*Helichrysum petiolatum*), and plumbago (*Plumbago auriculata*) irrigated with water at EC of 1.5, 2.5, 3.5, 5.0, or 7.0 dS·m^{-1}. Vertical bars represent standard errors. NS indicates nonsignificance.

The Effect of Rootstocks on the Salinity Tolerance of Greenhouse Roses

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Index Words: salinity, irrigation, water quality, dry weights, cut flower production

Significance to Industry: The production of greenhouse (cut flower) and garden (landscape) roses is largely based on cultivars budded/grafted on rootstocks. Most rootstocks have been historically selected to deal with soil-borne diseases and challenging soil textures/structures, and have in general enhanced the growth and flowering performance of the rose varieties grafted on them. This study evaluated the salinity tolerance of two widely used greenhouse rose rootstocks, ‘Manetti’ and ‘Natal Briar’. The results indicate that ‘Manetti’, used extensively in the US for over eight decades, was more tolerant to moderate NaCl-$CaCl_2$ salinities (0 - 24 m*M* range) than the recently and widely adopted ‘Natal Briar’ rootstock. As growers face water quality-related issues like use of naturally saline irrigation waters and the need to recycle salty and chemically-challenging drainage effluents, the use of salt-tolerant rootstocks like ‘Manetti’ will become an important tool in the irrigation-nutrition management of their rose crops.

Nature of Work: The production of rose for both cut flowers (greenhouse) and gardens/landscapes is largely based on cultivars budded/grafted on clonally propagated rootstocks (8). The literature indicates that rose growth and flowering performance is higher in grafted plants than in plants growing on their own roots (5). Also, roses have historically been reported to be sensitive to salinity, with significant yield losses when the electrical conductivity (EC) in saturated soil/media paste extracts exceeds 3 dS/m and/or sodium (Na^+) and chloride (Cl^-) concentrations exceed 2-4 m*M* (1, 2, 6). Such EC levels are easily reached because rose crops are typically irrigated with nutrient solutions (fertigation) that commonly range between 1.5 and 2 dS/m (2, 8). In recent years, reduced availability of good quality irrigation water and environmental pressures are forcing growers to use poor quality waters and recycle/reuse leached and run-off solutions, all of which contribute to higher salt stress levels.

Recent studies suggest that greenhouse roses could tolerate increasing NaCl-based salinity levels (up to 30 m*M*), and contend that rootstock selection was a key factor involved in this salt tolerance (3). Most salinity studies are based on NaCl, whereas the ion composition in irrigation waters is often dominated along with- or by other ions like Ca^{2+}, Mg^{2+}, SO_4^{-2} and HCO_3- (4). The use of NaCl as the main or only salinizing salt thus seriously limits the extent to which the results can be interpreted and extrapolated for practical application (4). The main objectives of this study were to evaluate the interactive effects of salinity (mixed NaCl-$CaCl_2$) and rootstock selection in greenhouse rose yield, quality and ion uptake responses.

Rose plants of the cv. ‘Red France’ grafted on the rootstocks *R*. ‘Manetti’ and *R*. ‘Natal Briar’, were transplanted into 20-L containers with a peat: pine bark: sand substrate (3:1:1 v/v) amended with 5 and 1.3 lb/yd^3 of dolomitic limestone and Micromax® micronutrient fertilizer, respectively. The pots were placed on gravel-lined beds within a climate-controlled greenhouse (85°F day/ 65°F night). A modified 0.5X Hoagland No. 1 formulation (Hoagland and Arnon, 1950) was used as the base (control) nutrient solution, which was salinized with six NaCl-$CaCl_2$ (2:1 molar ratio) salt mixture concentrations: 0, 1.5, 3, 6, 12 and 24 m*M*. The plants were irrigated based on gravimetrically-based evapotranspiration measurements and enough solution was applied at each irrigation event to produce an average leaching fraction of 25%. Crop management, flower harvesting and tissue sample collection over the 38-week experimental period (there were six flushes of growth and flowering) were done according to Langhans (7). Dried and ground leaf tissue samples from flower shoots were analyzed for essential nutrient concentrations, including Na and Cl. The experimental design was a RCBD with a factorial (2×6) arrangement of rootstock (RS) by salt mixture concentrations (SC), for a total of 12 treatments with 7 replications (one plant/container as single replication). Data were analyzed using SAS for Windows ® 9.1.

Results and Discussion: Leaching fractions were similar between rootstock selections and among salinity levels averaging 25.1 ± 2.6%. There were no differences between rootstocks for leachate EC and Cl concentration [Cl], and these two variables were highly correlated (r=0.96, $P<0.0001$) and positively affected by increasing salt levels. The EC and [Cl] throughout the experiment exceeded significantly the maximum thresholds recommended for roses (1, 2, 3, 6, 8), averaging 3.0, 3.6, 6.4 and 7.2 dS/m and 177, 463, 1,473 and 1,960 mg/L for the 0, 3, 12 and 24 m*M* salt levels, respectively.

Yield and flower quality: Total average flowering stem length, total cumulative dry weight and total cumulative number of flowering shoots harvested per plant (sum of all harvests) were affected by the rootstock, with ‘Manetti’ plants having larger values for all variables (Table 1). Leaf chlorophyll index (SPAD) was the same for both rootstocks (Table 1). Increasing concentrations of the salt mixture in the nutrient solution had a detrimental effect on total cumulative dry weight, number of flowering shoots harvested per plant, total average flower stem length, and leaf chlorophyll index (Table 1; Fig. 1).

Salt burn in foliage. Since these ratings were based on a categorical scale, they were analyzed by a Chi-square test. The extent of salt injury on the lower foliage of the plants after removing flowering shoots (older leaves) was different between rootstock selections across salt concentration levels ($X^2=35.2$; $P<0.0001$). Foliage of ‘Manetti’ plants was less affected by salinity since approximately 83.3% of the plants presented salt damage on only 0-20% of the foliage, 14.2% had salt damage on 21-60%, and only 2.5% of the plants had salt damage on 61-100% of the foliage (Fig. 2). On the other hand, in ‘Natal Briar’ 19% of the plants had damage on 1-20% of the foliage, 33.3%

between 21-40%, and 47.7% had salt burn damage on 41-100% of the foliage. Salt injury (as bronzing and scorching of leaf edges) on the lower leaves of flowering shoots of both rootstocks started to appear by the harvest event IV (144 DAT), in 'Manetti' plants only for the highest SC (24 m*M*) while in 'Natal Briar' plants salt damage was present on plants exposed to the 3 to 24 m*M* SC (data not shown).

Tissue chloride concentration: There were interactions between rootstocks (RS) and DAT (P<0.0001), salt concentration levels (SC) and DAT (P<0.0001), and between RS and SC (P=0.0368). Leaf [Cl] was positively affected by the salinity level (P<0.0001) similarly for both rootstock selections (Fig. 3). Leaf [Cl] increased from one harvest to the next in both RS and in all SC (data not shown), although their rate of change was not the same. Plants on 'Manetti' had higher leaf [Cl] increase rates over time for all SC, except for the 24 m*M*. Across salt treatments leaf [Cl] in 'Manetti' plants averaged 2.32, 4.28, 7.42, 7.62 and 8.82 g/kg, at 31, 67, 144, 192 and 265 DAT, respectively, with an average increase of ~ 280% over the experimental period. For 'Natal Briar' leaf [Cl] values were 8.02, 9.25, 9.96, 11.67 and 12.27 g/kg at 31, 67, 144, 192 and 265 DAT, respectively, with an increase of ~53% over the experimental period. Nevertheless, across SC and harvest events, flower shoots of plants grafted on 'Natal Briar' had on average 73% higher leaf [Cl] than those on 'Manetti' (overall averages of 5.9 vs. 10.2 g/kg, respectively). In both rootstocks leaf [Cl] had negative correlations with dry weight and # of flower shoots harvested per plant (P<0.0001 for both RS and variables; r=-0.65 and -0.55 in 'Manetti', respectively; and, r=-0.36, and -0.36 in 'Natal Briar, respectively).

Tissue sodium concentration**:** For leaf [Na] there was an interaction among RS, SC and harvest events (P=0.0103). Leaf [Na] In 'Manetti' plants were similar between harvest events and among SC, averaging 43.4 mg/kg. In 'Natal Briar', on the other hand, DAT and SC had interactive effects (P=0.0148), with average leaf [Na] of 41 mg/kg for all SC in harvest II (67 DAT) increasing significantly all the way up to 70 mg/kg in the 24 m*M* SC level by harvest V (192 DAT; data not shown). No correlations between leaf [Na] and productivity and quality variables were found in 'Manetti' plants. The leaf [Na] in 'Natal Briar' plants showed negative correlations with dry weights and number and length of flower stems, and leaf SPAD (P=0.0004, 0.0013, 0.0649, and <0.0001; and, r=-0.49, -0.45, -0.27,-0.54, respectively).

Tissue calcium concentration**:** For leaf [Ca] RS and DAT had interactive effects (P=0.0010). In 'Manetti' plants leaf [Ca] was similar between harvests (avg. 17.2 g/kg), while in 'Natal Briar' they decreased by 17% from harvest II to harvest V (19.9 and 16.6 g/kg). Salt stress had a linear positive effect on leaf [Ca] (Fig. 3). In 'Natal Briar' plants leaf [Ca] was correlated with stem length (P=0.0323; r=0.31) and leaf chlorophyll index (P=0.0277; r=-0.32), whereas no associations were found between Ca and productivity/quality variables in 'Manetti' plants.

Conclusions: Across all salinity treatments the rose plants grafted on 'Manetti' were more vigorous, produced more and longer flowering shoots per plant, and their foliar salt burn injury was considerably less compared plants grafted on the 'Natal Briar' rootstock. These results confirm previous observations of 'Manetti' being a rootstock that is relatively more tolerant to abiotic stresses like waterlogging, salinity and soil compaction (2, 3, 5, 6, 8). These findings are significant to the greenhouse rose industry, which has widely adopted 'Natal Briar' as the primary rootstock due to its ease of propagation grafting and vigor under non-stressful greenhouse environments. As growers face water quality-related issues like use of naturally saline irrigation waters and the need to recycle salty and chemically-challenging drainage effluents, the use of salt-tolerant rootstocks like 'Manetti' will become an important tool in the irrigation-nutrition management of their rose crops.

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Table 1. Total cumulative dry weight, number of flowering shoots harvested per plant, average stem length and leaf chlorophyll index in 'Red France' roses grafted on 'Manetti' and 'Natal Briar' rootstocks, and subjected to increasing NaCl-$CaCl_2$ salinity. The means values per rootstock selection and salt concentration level are averages of 42 and 14 plants, respectively.

Main Effect		**Dry weight (g/plant)**	**Number of Flowers**	**Avg. Stem Length (cm)**	**Chlorophyll Index (SPAD)**
Rootstock					
'Manetti'		141	39	38	51
'Natal Briar'		119	35	37	51
Difference *Significance*[z]		*22* **	*4* *	*1.0* **	*0.0* *ns*
NaCl-$CaCl_2$					
(mM)	**EC (dS/m)**[z]				
0.0	1.65	156	44	38	52
1.5	1.85	141	39	38	51
3.0	2.05	139	39	37	51
6.0	2.45	145	40	38	52
12.0	3.25	117	34	36	51
24.0	4.85	82	25	37	49
Significance[x]		L***	L***	L**	Q*

[z] Significance according to GLM: *ns*, *, **, *** non significant, and significant at P ≤ 0.05, P ≤ 0.01, P ≤ 0.001, respectively.

[y] EC= estimated EC of applied solutions (nutrient solution plus NaCl-$CaCl_2$ salts).

[x] Regression: L=linear, Q=quadratic.

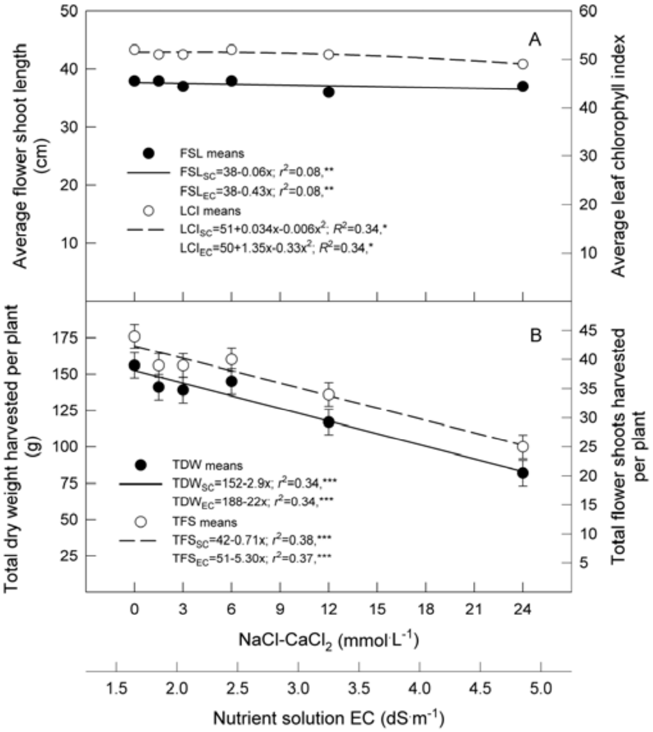

Figure 1. Total average flowering stem length (FSL) and average leaf greenness (LCI), total cumulative dry weight (TDW) and number of flower shoots harvested (TFS) in 'Red France' roses subjected to incrementing NaCl-$CaCl_2$ salinity. Symbols represent the mean ± s.e. of 14 plants. Significance according to GLM: ns, *,**,*** non significant, and significant at P≤0.05, P≤0.01, and P≤0.001, respectively. SC= salt concentration; EC= electrical conductivity.

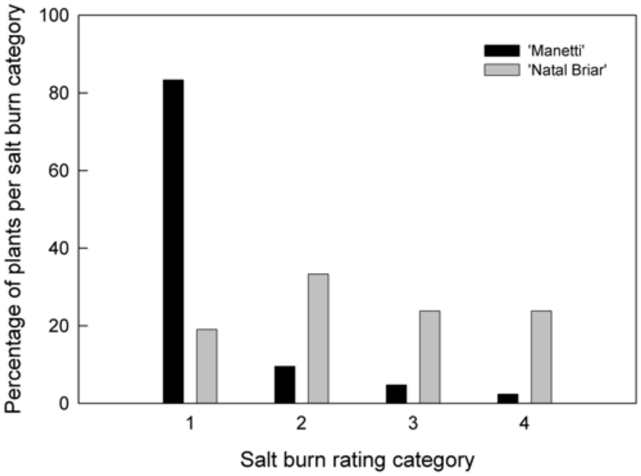

Figure 2. Salt damage ratings in foliage of 'Red France' roses grafted on 'Manetti' and 'Natal Briar' rootstocks subjected to increasing NaCl-$CaCl_2$ salinity (n=42).

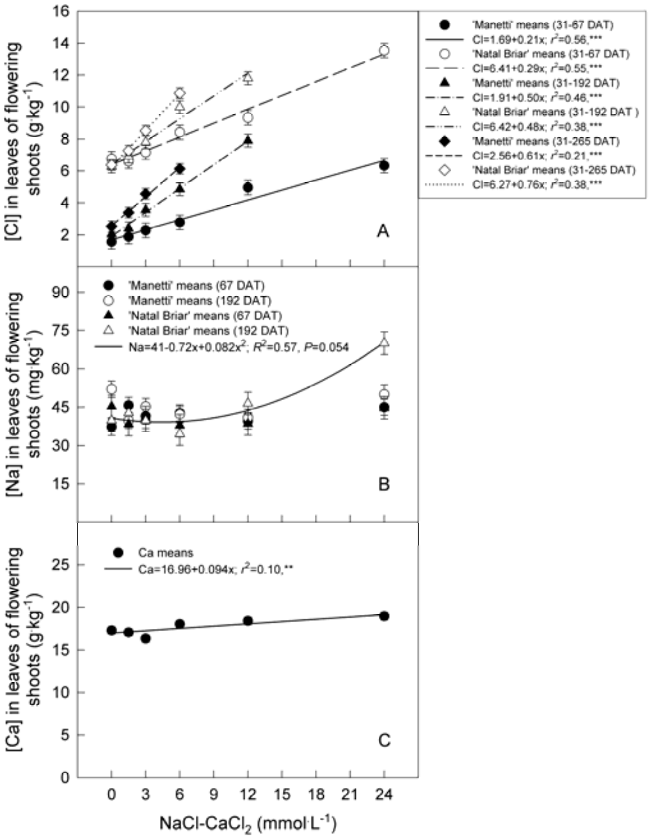

Figure 3. Leaf chloride (A), sodium (B) sodium and calcium (C) concentrations in flower shoots of 'Red France' roses grafted on 'Manetti' and 'Natal Briar' rootstocks and subjected to increasing NaCl-$CaCl_2$ salt stress. Symbols represent the mean ± s.e. of 7, 4 and 8 plants for plots A, B and C, respectively. Symbols obscure the error bars that are not apparent. Significance according to GLM: ns, *,**,*** non significant, and significant at $P≤0.05$, $P≤0.01$, and $P≤0.001$, respectively.

Horticulture as Therapy

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Index Words: Horticulture, therapy, mental health

Significance to Industry: In a time when marketing is so important to the green industry, it is imperative that the many benefits of horticulture be recognized. Horticulture therapy is one avenue in which the industry touches people's lives in a qualitative manner. It is well documented that green spaces, plants, and floral arrangements boost mood. Horticulture therapy takes that notion a step farther by providing opportunity for people-plant interaction.

Nature of Work: Horticulture has traditionally been defined as the production of specific, high-value plants for the commercial market and the subsequent services related to the installation and maintenance of landscape plants (2). The process of combining plants and people is at the core of horticulture therapy. As a treatment used in psychiatric settings horticulture therapy programs strive to create environments that promote and allow for growth (3). A therapeutic garden or nature-based setting provides stress-reducing, mood-enhancing qualities setting the stage for soothing therapeutic interaction, while group or individual work in the setting can foster behavioral and social learning to help reduce maladaptive behavior (1)

The Mental Health Association of Mississippi was established in 1963 as a grassroots organization to serve the mental health needs of the citizens of Harrison County, MS. As an advocacy agency giving voice to the mental health needs of the community, the Association now serves clientele in 3 coastal counties. One of the Association's services is the Opal Smith Day Support Center which provides recreational, social, and work skills training opportunities for persons with a mental illness or experiencing homelessness.

Discussion: What began as a one-time invitation to help the Center's clientele plant flowers in containers has grown to become a quarterly programming opportunity. Programs now include container gardening, vegetable identification, preparation, and nutrition, as well as food hygiene. With this increased participation comes several opportunities for outreach and study. The goal of this work is not only to educate those citizens with mental health concerns, but also to promote cognitive, physical, psychological, and social functioning through the use of horticulture.

Feedback from participants has been overwhelmingly positive. In some instances, the clients have never even planted a seed before. The experience of nurturing a living thing throughout the season instills a sense of wonder and pride in the patients. Throughout the exercises, clients are encouraged to ask questions and participate in discussion. Often questions arise about the particulars of the plants and the handling of the material. On many occasions, clients simply share their own gardening experiences with the group.

While the sessions are optional for the clients, most present participate. Several people choose to observe without actually taking part in the activity. Those clients usually contribute to the discussion or choose to participate in the next session.

While the field of horticulture therapy is rapidly growing, there is still a great need for applied research. Such research will ensure that horticulture therapy becomes a universally and unequivocally recognized therapy option for the mentally ill (4). The field of horticulture therapy is also one more identifiable component of the benefits that the green industry provides the public.

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Effects of Water Stress and Plant Growth Regulators on Flowering and Growth of *Bougainvillea* 'Raspberry Ice'

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Index words: Chlormequat chloride, daminozide, ethephone

Significance to Industry: Bougainvillea is a very popular tropical and subtropical evergreen landscape plant with showy, vibrantly colorful petaloid bracts. However, the vigorous grow habit makes bougainvillea a labor intensive plant as a container plant. It is necessary to do regular pruning because the shoots often grow too vigorously. The objective of this study was to investigate the feasibility of plant growth regulators (PGR) and water stress as alternatives to prune bougainvillea as potted plants.

Nature of Work: Experiment was conducted in Mississippi State University greenhouse. One rooted cutting of 'Raspberry Ice' bougainvillea was transplanted in 6" pot with Sunshine Mix #1 (SunGro Hort., Bellevue, WA) on 16 Jan. 2008. Plants were fertilized with 200 ppm 20N−4P −16K (Peters 20−10−20, Scotts Professional, Allentown, PA). All plants were pruned to approximately 6" on 9 May.

This experiment was started on 13 May and finished on 8 Aug. 2008. Plants treated with chlormequat chloride (Cycocel®, OHP, Inc., Mainland, PA) and ethephone (Florel®, Southern Agricultural Insecticides, Inc., Boone, NC) were foliar sprayed with 0.43 ounces PGR solution with surfactant (Spreader sticker, Voluntary Purchasing Group, Inc., Bonham, TX) with a trigger sprayer. Plants treated with daminozide (Dazide™, Fine Americas Inc., Walnut Creek, CA) and treatments with daminozide were drenched by applying 3.4 ounce PGR solution per pot. Substrates in pot were kept relative dry before drenching to minimize leaching from the pot. PGRs treatments were conducted on 13 May and 26 May. Water stress was withholding water from 13 May to 24 May until mild wilt occurred. Supplementary watering started on 24 May by giving 50ml fertilizer solution per pot every other day for 3 weeks. Daminozide and chlormequat chloride were tank mixed and were applied by drench to the media, and the applications were conducted on 6 June and 20 June.

Experiment was in completely randomized experimental design with eight replications per treatment. During the experiment, natural daylength became longer from 13 May at 13.8 h to 22 June at 14.3 h, and then declined to 13.5 h on 8 Aug. 2008. The temperature in the greenhouse was set up as 35°C/25°C (day/night).

The number of structural branches (branch>1 inch long) per plant were counted before and 4 weeks after the experiment started. The number of inflorescences (bracteole >0.8

inch) for each plant was counted every week. Plant height was recorded every other week.

Results and Discussion: Of all treatments applied in the experiment (Table 1), 1,000 ppm and 1,500 ppm ethephone and the combination of water stress and 1,000 ppm ethephone had significant lower increase in height compared to control. Although not statistically significant, seven other treatments that induced 40% less increase in height than control included 1,800 ppm chlormequat chloride, water stress + 600 ppm chlormequat chloride, water stress + 1,250 ppm daminozide, water stress + 800 ppm daminozide + 1,000 ppm chlormequat chloride, 500 ppm ethephone, water stress + 500 ppm ethephone, and water stress + 1,500 ppm ethephone. Water stress, 600 ppm chlormequat chloride, water stress + 2,500 ppm daminozide + 2,500 ppm chlormequat chloride significantly induced more inflorescences than control. Although not statistically significant, six other treatments that induced approximately 3 inflorescences more than control included water stress + 600 ppm chlormequat chloride, water stress + 1,200 ppm chlormequat chloride, water stress + 1,800 ppm chlormequat chloride, water stress + 2,500 ppm daminozide, water stress + 800 ppm daminozide + 1,000 ppm chlormequat chloride, and water stress + 1,250 ppm daminozide + 1,250 ppm chlormequat chloride.

Treatments including 1,000 ppm and 1,500 ppm ethephone produced significantly less branches compared to control. Although not significantly, all the other treatments except 1,250 ppm daminozide produced less branches than control 4 weeks after experiment started.

Although ethephone was very effective in controlling growth in height in bougainvillea at two high concentrations applied in the experiment, significant defoliation was observed with application of ethephone (Figure 1). There was a linear relationship between ethephone concentration and percentage of defoliation with two high concentrations of ethephone induced close to 100% or 100% defoliation in bougainvillea. When being used for controlling growth in bougainvillea, ethephone should not be applied at high concentration (>1,000ppm) due to possibility of reduced aesthetic value from defoliation.

Previous researches indicated that dikegulac (Atrimmec®, Gordon's, Kansas City, MI) did reduce the height of 'Raspberry Ice' and 'San Diego Red' bougainvillea under short days without enhancing flowering (Dierking and Sanderson, 1985). While 1600 mg dikegulac/liter was reported stimulated profuse flowering on 'Barbara Karst' and 'Rainbow Gold' bougainvillea during midspring to early summer (Norcini et al., 1993). 1 ounce/gallon of dikegulac was recommended to induce branching. Besides, benzyladenine at 50-100 ppm was reported to induce lateral branching as well as retard growth. chlormequat chloride, ancymidol (A-Rest™, SePRO, Carmel, IN), and paclobutrazol (Bonzi®, Syngenta Crop Protection, Inc., Greensboro, NC) were reported effective to retard bougainvillea growth (Kobayashi et al., 2007; Shao et al., 2006; Tang et al., 2006).

Based on the results in this experiment, three-week water stress and water stress + 2,500 ppm daminozide + 2,500 ppm chlormequat chloride can be conducted to promote flowering and may have slight effect on producing compact plants. Chlormequat chloride at low concentration could promote flowering in bougainvillea while higher concentrations produced more compact bougainvillea plants in the experiment. Daminozide alone did not show significant effect on bougainvillea flowering or controlling growth in this experiment. Ethephone alone or combined with water stress could control height in bougainvillea, however defoliation induced at high concentration might not be appealing to growers due to reduced aesthetic value of plants.

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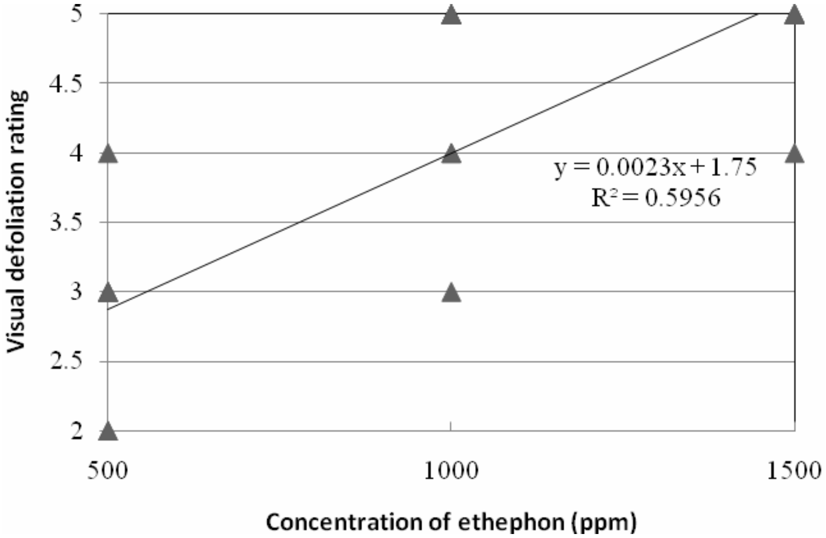
Table 1. Effects of water stress and plant growth regulators applied on growth and flowering of 'Raspberry Ice' bougainvillea transplanted on 16 Jan. 2008.

Treatment (ppm)	**Increase in height[z](cm)**	**No. of inflorescences/ plant[y]**	**Increase No. of branches [x] /plant**
Control	5.8ab[w]	0.4d	3.6a
Three-week water stress	3.6abcde	5.6a	2.1abc
CCC[v] (600)	6.5a	4.9abc	2.5abc
CCC (1,200)	4.6abc	1.1cd	3.3ab
CCC (1,800)	2.6bcde	1.8bcd	1.9abc
Water stress + CCC (600)	2.9bcde	4.1abcd	2.0abc
Water stress + CCC (1,200)	4.9abc	3.0abcd	2.4abc
Water stress + CCC (1,800)	3.6abcde	3.4abcd	2.5abc
Dazide[u] (1,250)	5.0abc	0.1d	3.4a
Dazide (2,500)	4.9abc	2.0bcd	3.0ab
Dazide (3,750)	3.6abcde	0.7cd	3.0ab
Water stress + Dazide (1,250)	3.4abcde	1.8bcd	2.9ab
Water stress + Dazide (2,500)	5.6ab	3.5abcd	2.4abc
Water stress +Dazide (3,750)	4.8abc	0.5cd	2.9ab
Water stress +Dazide (800) + CCC (1,000)	3.5abcde	3.3abcd	1.1bcd
Water stress +Dazide(1,250) + CCC (1,250)	4.8abc	3.5abcd	1.1bcd
Water stress +Dazide(2,500) + CCC (2,500)	4.0abcd	5.6ab	1.8abc
Ethephone (500)	3.4abcde	0.0d	2.1abc
Ethephone (1,000)	0.8de	0.0d	1.9abc
Ethephone (1,500)	0.4e	1.0cd	0.7cd
Water stress + Ethephone (500)	2.9bcde	0.9cd	2.3abc
Water stress + Ethephone (1,000)	1.6cde	0.0d	0.0d
Water stress + Ethephone (1,500)	2.8bcde	0.0d	0.0d

[z] Increase in height was recorded on 8 Aug. 2008.
[y] Number of inflorescences (bracteole>0.8 inch) was recorded on 17 July 2008.
[x] Increase number of branches data were only recorded on branch>1 inch on 11 June2008.
[w] Means followed by same letters are not significantly different by LSD multiple comparison (*P*=0.05).
[v] Chlormequat chloride
[u] Daminozide

Figure 1. The correlation between foliar spray concentration of ethephone and visual rating of defoliation for ‘Raspberry Ice’ bougainvillea on 18 May 2008



Effects of Plastic Mulch Color on Cut Flower Size in Snapdragons Grown in a High Tunnel

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Index words: *Antirrhinum majus*, cut flowers, high tunnels, colored plastic mulch

Nature of work: High tunnels are simplified growing systems that enhance crop growth, yield, and quality (Wells, 1998). They are nonpermanent, infield structures, lacking electrical service, automated ventilation, and permanent heating systems, though temporary heaters may be used during frosts, that resemble traditional polyethylene covered greenhouses, but are a completely different technology (White et al., 2003; Wells, 1998). High tunnels are used for growing season extension in the spring and fall. They produce excellent flower quality and make it possible to harvest cut flowers earlier in the spring and later in the fall than in an open air, field environment. High tunnels benefit cut flower production by offering many production options ranging from herbaceous perennials, being over-wintered for spring cut flower production, to summer annuals, and natural fall season mums (Lamont et al., 2003). Most cut flowers sold in the U.S. are imported from Columbia and the Netherlands (USDA APHIS, 1996). Despite the high volume of cut flower imports, the U.S. market has demand for domestically grown cut flowers. Locally grown cut flowers can be delivered fresh to the florist eliminating problems associated with shipping and the extra cost. Snapdragons (*Antirrhinum majus*) must be stored and shipped upright because the stems bend upwards if they are not (Armitage and Laushman, 2003). This and their need to be refrigerated can cause problems with importation into the U.S. The warm temperatures that snapdragons can be exposed to at airport loading docks can greatly decrease their usable floral life.

Seedlings from plug flats of ‘Potomac Apple Blossom, Yellow, Orange, and Pink’ and ‘Supreme Gold Yellow’ snapdragons (*Antirrhinum majus)* were planted 18 seedlings per plot, 3 plants across a row with the rows spaced 6 inches (15.24cm) apart and 6 per row with 4 inches (10.16cm) between seedlings in the row on July 30th, 2007 in 2.5 foot (0.762m) wide raised beds covered with red, white, or blue plastic mulch in a high tunnel (21ft (6.4m) wide x 48ft (14.63m) long x 10.5ft (3.2m) high) at E.V. Smith Research Center in Shorter, AL. They were irrigated with T-Tape® (0.45 gpm/100ft) (T-Systems International, San Diego, CA) and fertigated using a Dosatron® (Dosatron, Clearwater, FL) injector at 150ppm N using Jack’s Professional Water-Soluble Fertilizer (J.R. Peters, Inc., Allentown, PA) every watering. Once the snapdragons were tall enough to need support, 4ft (1.22m) Fi-Shock (Woodstream Corporation, Lititz, PA) Step-In Fence Posts set on either side of the bed to hold 2 ft (0.61m) wide MaxiGrid Warning Barrier Fencing (Easy Gardener Products, Inc., Waco, TX) over the beds and parallel to the ground to support the snapdragons. The support was moved up as the snapdragons grew taller. The snapdragons were harvested whenever 75% of a plot had open flowers. Harvests occurred on September 24th and 29th and October 2nd and 8th, 2007. Inflorescence length, stem length, and stem diameter 12in from the base were measured for each plant. The data were analyzed using a completely randomized split plot design with mulch color as the main plot, cultivar as the sub-plot, and three replications of each mulch treatment.

Results and Discussion: Blue mulch produced the longest stems and red mulch produced the shortest stems for all snapdragon cultivars except 'Supreme Gold Yellow'. Of the cultivars that responded, stem length of plants on blue mulch were 3.5% to 10.6% longer than on red mulch. 'Supreme Gold Yellow' and 'Potomac Orange' produced the longest stems of the cultivars in all of the mulch treatments. White and blue mulch produced the largest stem diameters of the mulch treatments. 'Potomac Yellow' had the largest and 'Potomac Apple Blossom' and 'Supreme Gold Yellow' had the smallest diameters of the cultivars. The white and blue mulch produced the longest inflorescences of the mulch treatments and the red mulch produced the shortest inflorescences, but red was not different from blue mulch. As with stem length, 'Supreme Gold Yellow' and 'Potomac Orange' inflorescence lengths were longer than other cultivars. Based on the results of this study, blue mulch is the best choice for summer-fall production of snapdragons in a high tunnel because it yielded the longest stem lengths, which is an important criterion for cut flower quality. In many cases, white mulch performed as well as blue mulch, but red mulch performed poorly.

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Table 1. Effects of plastic mulch color on cut flowers size in snapdragon cultivars in 2007.

Mulch color	Blue	White	Red
Cultivar		Stem length (cm)[z]	
Potomac Apple Blossom	86.3bA[y]	81.1cB	78.0bB
Potomac Orange	96.8aA	96.3aA	88.7aB
Potomac Pink	87.0bA	86.7bcB	79.3bC
Potomac Yellow	83.6bA	80.7cB	80.8bB
Supreme Gold Yellow	94.2aA	89.2bA	92.6aA
Cultivar	Stem diameter (mm)[x]	Mulch color	Stem diameter (mm)
Potomac Apple Blossom	4.0c[w]	Blue	5.2a
Potomac Orange	5.3b	White	5.3a
Potomac Pink	5.4b	Red	4.8b
Potomac Yellow	5.7a		
Supreme Gold Yellow	5.1c		
Cultivar	Inflorescence length (cm)[x]	Mulch color	Inflorescence length (cm)
Potomac Apple Blossom	14.3b[w]	Blue	15.9ab
Potomac Orange	16.6a	White	16.5a
Potomac Pink	14.5b	Red	14.5b
Potomac Yellow	15.2ab		
Supreme Gold Yellow	17.5a		

[z] The cultivar × mulch color was significant, α = 0.05.
[y] Least squares means. Mean separation within columns (lower case) and rows (upper case) using Bonferroni's test, α = 0.05.
[x] Only the main effects were significant, α = 0.05.
[w] Mean separation within columns using Bonferroni's test, α = 0.05, ns = not significant.

The Effect of Nitrogen Form on pH and Petunia Growth in a *WholeTree* Substrate

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Significance to the Industry: Wood-based products, including *WholeTree* (WT), have been identified as possible replacements for peat-moss in container substrates. The supplemental fertilizer required by WT substrates may affect pH and nutrient availability. This experiment demonstrated nitrogen form and proportion altered the pH of WT and peat-lite (PL) substrates. The wider range of pH in the WT substrate indicated a lower buffering capacity compared with the PL substrate. The WT substrate produced less shoot biomass compared with the PL substrate, consistent with previous studies utilizing identical fertilizer rates. However, an undesirable substrate pH may limit nutrient availability and negatively affect plant growth. Future research will focus on enhancing the buffering capacity of WT substrates to reduce fluctuations in pH.

Nature of the Work: The wholesale value of the floriculture industry increased 35 percent from 1998 to 2004, yet has since remained stable (7). Increased input costs have greenhouse producers seeking less expensive alternative materials, including container substrates. Although a variety of organic materials have been evaluated in container substrates, few offer the benefits of peat-moss. Widespread utilization of such substrates is also hindered by noncompetitive costs, limited availability or inconsistent quality. Research with wood-based material as replacements for peat-moss has demonstrated successful production of numerous crops types (4, 5, 8). Compared with peat-moss, wood-based substrates would be less expensive, sustainable and regionally available products.

One disadvantage to wood-based substrates is the additional fertilizer required to achieve plant growth comparable to peat-moss substrates. Contributing factors may include increased leaching and nitrogen immobilization due to microbial activity (4, 6). Although increased fertilizer rates may improve plant growth, substrate pH and subsequent nutrient availability may also be affected. Substrate pH is affected by the nitrogen form contained in a commercial fertilizer (1), and wood-based substrates may be affected differently than peat-moss substrates.

The objective of our research was to investigate the effect of nitrogen form and proportion on PL and WT substrate pH and petunia growth. The experiment was performed at the Southern Horticultural Laboratory in Poplarville, MS. Chipped whole pine trees (consisting of needles, limbs, bark, wood and cones) were obtained from a commercial fuel wood chipping operation in western Georgia. The WT chips were further processed with a swinging hammer mill (C.S. Bell No. 30, Tiffin, OH) to pass a 3/16-in screen. The WT substrate was compared to a PL substrate (8:1:1 peat moss:perlite:vermiculite). Each substrate was amended (per cubic yard) with 5 lbs dolomitic limestone, 1 lbs gypsum, and 1.5 lbs Micromax.

On October 11, 2007, 5.5-in containers were filled with substrate and each planted with two petunia (*Petunia* × *hybrida* 'Celebrity Rose') plugs (from 288-cell flats). Containers were placed on elevated benches inside a polycarbonate covered greenhouse. Plants were hand irrigated as needed with a nutrient solution. Nutrient solutions contained nitrogen (N), phosphorus (P) and potassium (K) at 300, 150 and 300 ppm, respectively. Five N treatments were supplied as different proportions of ammonium (NH_4^+N) and nitrate (NO_3^-N). The N treatments were 100% NH_4^+N ($100NH_4$), 75% NH_4^+N:25% NO_3^-N ($75NH_4$:$25NO_3$), 50% NH_4^+N:50% NO_3^-N ($50NH_4$:$50NO_3$), 25% NH_4^+N:75% NO_3^-N ($25NH_4$:$75NO_3$) and 100% NO_3^-N ($100NO_3$). Five stock solutions were prepared, diluted at a 1:50 ratio and applied to individual containers in volumes of 100 (1 – 27 DAP) or 130 mL (28 – 35 DAP). As necessary, container substrates were irrigated with clear water two hours before nutrient solution applications.

Containers were arranged in a randomized complete block design, with four replications containing three subsamples per treatment. Pour-through extractions were performed at 8, 15, 22, 29 and 36 days after planting (DAP) to analyze substrate pH. At 39 DAP, plant shoots were harvested, oven dried and weighed. Fixed effect terms for linear models, modeling pH and shoot dry weight in response to the experimental factors, were selected using stepwise, forward, and backward selection procedures with the REG procedure of SAS (SAS Version 9.1.3; SAS Institute, Inc., Cary, NC). Final data analysis was conducted using linear mixed models with the MIXED procedure of SAS; the results are shown in Table 1.

Results and Discussion: Substrate pH at 0 DAP was 6.3 and 5.1 for WT and PL, respectively. At 36 DAP, $100NO_3$ treatments had the highest pH , while $100NH_4$ treatments had the lowest pH, regardless of substrate (Fig. 1A). A trend present in both substrates revealed a correlation between N form proportion and pH (Fig. 1B). Substrate pH decreased as NH_4^+N proportion increased, while an increasing NO_3^-N proportion resulted in a rise in substrate pH. The change in pH due to N form was consistent with previously published reports (2, 3). Although pH was altered by N form in both substrates, the degree of change was clearly different. The PL substrate pH was moderately affected by N form, ranging from 5.0 to 5.9. The WT substrate pH was considerably affected by N form, ranging from 5.2 to 7.7. The wide range of WT substrate pH at 36 DAP, in comparison with the PL substrate, is most likely due to a lower buffering capacity.

Optimum plant growth occurred in the mixed N-form treatments for each substrate. The lowest shoot dry weight (SDW) occurred with $100NO_3$ in WT substrate and with $100NH_4$

in PL substrate (Fig. 2A). Within N-form treatments, WT substrates produced lower SDW than PL substrates. Lower SDW was expected in the WT substrate, due to higher fertilizer rates required to produce comparable plants (4). However, poor plant growth in WT substrates with 100NO_3 may also be attributable to the high substrate pH and a possible nutrient deficiency.

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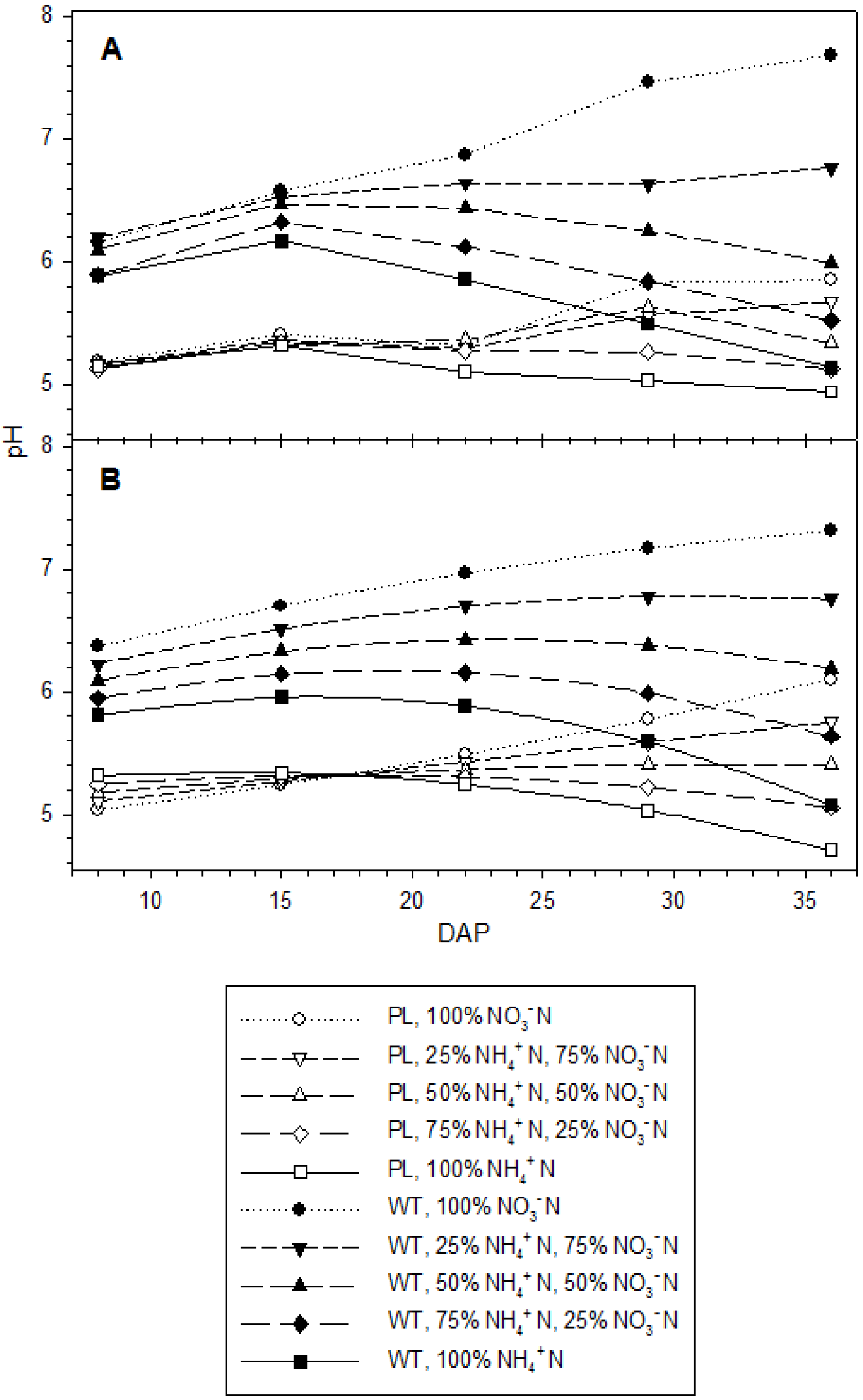

Figure 1. Observed (A) and predicted (B) means for pH as affected by nitrogen form and proportion in peat-lite (PL) and *WholeTree* (WT) substrates. R^2 = 0.937 for the prediction model.

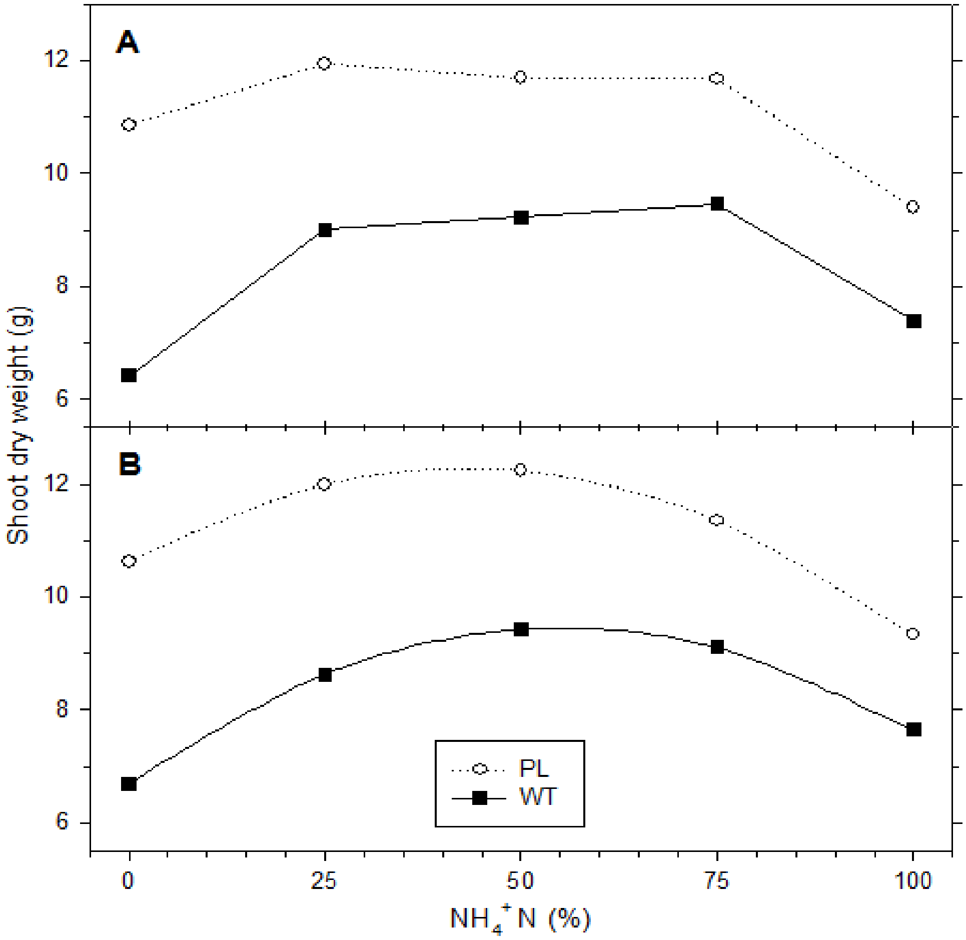

Figure 2. Observed (A) and predicted (B) means for petunia shoot dry weight as affected by nitrogen form and proportion in peat-lite (PL) and *WholeTree* (WT) substrates. R^2 = 0.865 for the projection model.

Table 1. Fixed effects, estimates of coefficients, and p-values for coefficients for linear models modeling the response of substrate pH (obtained using the pour-through method) and shoot dry weight for *Petunia* × *hybrida* 'Celebrity Rose' grown in a greenhouse for 39 days[z] in 5.5-in containers using *WholeTree* (WT) or peat-lite (PL) substrate with increasing percentages of NH_4^+N[y].

Response variable	Effect	Estimate	Significance[x]
pH	Intercept	4.85580	<.0001
	Substrate-WT	1.06090	<.0001
	Substrate-PL	0	
	NH_4^+N	0.00291	0.1082
	DAP[w]	0.01956	0.1309
	$(DAP)^2$	0.00042	0.1493
	Substrate × NH_4^+N	-0.00837	<.0001
	Substrate × DAP	0.04198	0.0013
	Substrate × $(DAP)^2$	-0.00105	0.0003
	DAP × NH_4^+N	0.00011	0.5430
	$(DAP)^2 \times NH_4^+N$	-0.00002	0.0001
Shoot dry weight (g)	Intercept	10.62510	<.0001
	Substrate-WT	-3.93100	<.0001
	Substrate-PL	0	
	NH_4^+N	0.07760	<.0001
	$(NH_4^+N)^2$	-0.00091	<.0001
	Substrate × NH_4^+N	0.02249	<.0001

[z] pH was modeled over the growing period based on weekly data (n =4). Shoot dry weight was modeled based on data collected at harvest (n = 8).

[y] 0% to 100% N supplied by NH_4^+ N. The balance of N was supplied by NO_3^- N.)

[x] *P*-values from *t* tests examining the probability that the value of the estimated coefficient equals zero.

[w] DAP = days after planting.