Floriculture

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An Evaluation of the Chelating Agent EDDS for Floriculture Crop Production

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Index Words: chelating agents, plant nutrition, bedding plants, EDTA, DTPA, fertilizer

Significance to Industry: Aminopolycarboxylic acid (APCA) ligands (chelating agents) like ethylenediaminetetraacetic acid (EDTA) and diethylenetriaminepentaacetic acid (DTPA) are commonly used in soluble fertilizers to supply copper (Cu), iron (Fe), manganese (Mn), and/or zinc (Zn) to plants. When complexed with Fe, EDTA and DTPA are vulnerable to photodegradation (1), but otherwise, the chemical or biological destruction of these chelating agents once in water or in soils is slow to occur. Ethylenediaminedisuccinic acid (EDDS) is a chelating agent that has been reported to provide the chelating abilities of EDTA, but with the benefit of being biodegradable (2). The use of EDDS in soluble fertilizers for the production of floricultural crops is the subject of investigation reported here.

Nature of Work: Inorganic salts of Cu, Fe, Mn, and Zn are too insoluble at chemically-safe pHs (for both human handling and plant production) for use in fertilizer products that can be maintained as concentrated stock solutions. Fertilizer manufacturers, therefore, use chelating agents like EDTA and DTPA to provide these metals in a soluble form in complete fertilizers. The offsite runoff and contamination of surface waters with these chelating agents is of increasing concern due to their ability to remobilize heavy metals in sediments and their low susceptibility to biodegradation. Therefore, a series of studies were conducted with the objective of evaluating FeEDDS as an Fe source for the production of marigold and to assess the capacity of EDDS to extract metals from a commercial peat-based medium.

Marigold (*Tagetes erecta* L.) 'First Lady' seeds were sown in 806 grow packs in peat-based media and grown in a greenhouse in Fort Pierce, FL. Treatments were initiated with the emergence of the 1st true-leaf pair at 12 days after sowing (DAS) and plants were harvested 35 DAS. Treatments consisted of a complete [200 $mg \cdot L^{-1}$ (ppm) N] nutrient solution containing 1 $mg \cdot L^{-1}$ Fe from FeEDDS, FeEDTA, or FeDTPA (Fe-source treatments). In all Fe-source treatments, Cu (0.02 $mg \cdot L^{-1}$), Mn (0.5 $mg \cdot L^{-1}$), and Zn (0.05 $mg \cdot L^{-1}$) were supplied as EDTA chelates. Treatments [300 ml (10.1 oz)] were applied on 12, 19, 24, 26, 28, 30, 32, and 34 DAS. Leaf tissue at harvest was washed, dried, dry weight recorded, and then processed via microwave-assisted acid digestion. The study used a completely randomized statistical design with 4 replications per treatment.

To determine the ability of EDDS to extract metals (Cu, Fe, Mn, and Zn) from a commercial peat-based medium (Fafard 4P, Conrad Fafard, Anderson, SC), 1:2 media extractions [50 cm^3 (cc) substrate and 100 ml (3.4 oz) distilled-deionized water] were performed using unbuffered solutions of EDDS or DTPA at 2, 4, or 6 mM EDDS or DTPA as the extractant with substrate-extractant mixtures incubated for 15, 30, 45, or 60 min at 23 °C (73.4 ˚F). Three replications per chelate concentration and incubation time were made, and extract solutions were gravity filtered prior to analysis. An ICP was used to measure Cu, Fe, Mn, and Zn in solutions. Data were analyzed by ANOVA and means separated by LSD.

Results and Discussion: There was no significant difference in foliar Fe or Mn between Fe-chelate treatments, averaging 140 $\mu g \cdot g^{-1}$ (ppm) and 88 $\mu g \cdot g^{-1}$, respectively, as a mean of all Fe sources. Foliar Cu and Zn, however, were significantly higher by 23% in the FeEDTA treatment than in either FeEDDS or FeDTPA treatments, which were not significantly different in foliar levels of these metals (Table 1). The higher levels of foliar Cu and Zn in FeEDTA treatments may be the result of the compounding effects of multiple EDTA sources in that treatment as Cu, Mn, and Zn in all Fe-source treatments was supplied as EDTA-chelates. Regardless, the foliar Fe level in all Fe source treatments was sufficient; i.e. at a level to promote normal plant growth. Iron-source had no affect on plant height, number of true-leaf pairs (data not presented), or leaf biomass (Table 1).

Chelating agents, especially DTPA, are used to estimate extractable metals from peats and mineral soils (3), and the repeated application of fertilizer solutions that contain chelates can result in excessive levels of soluble Fe in the root zone (4). Therefore, the capacity of EDDS to extract metals from peat-based media was assessed. As a mean of all chelate concentrations and incubation times, EDDS extracted significantly less Cu, Fe, Mn, and Zn than DTPA from media (Table 2).

In summary, these preliminary results indicate that FeEDDS is a suitable Fe source for the formulation of soluble fertilizers for the production of floricultural crops. Furthermore, the lower capacity of the EDDS chelate to extract metals from peat-based media under the conditions studied here, suggests that EDDS may be a “safer” chelate for the production of the marigold and geranium group of bedding plants that are prone to develop nutrient disorders related to toxic levels of Fe or Mn (5, 6). In the FeEDDS form, however, EDDS is vulnerable to phtotodegradation, so fertilizer stock solutions formulated with EDDS would need to be protected from exposure to light (7).

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Table 1. Foliar metal concentration and dry wt (DW) for marigold treated with 1 mg·L^{-1} Fe (Fe-Source) at harvest, 35 days after sowing.

	Leaf Tissue Metal Concentration (µg·g^{-1})				
Fe Source	Cu	Fe	Mn	Zn	Leaf Tissue DW (g) per grow pack
FeEDDS	17.19 b[z]	133.13	85.21	103.14 b	2.27
FeEDTA	21.75 a	150.35	95.50	122.58 a	2.42
FeDTPA	17.36 b	137.68	82.95	88.33 b	2.22

[z]Means within columns followed by different letters indicates significant difference at *P* <0.05, LSD. Where no letters appear in a column, means were not significantly different.

Table 2. Metals extracted from a peat-based media by EDDS or DTPA using a 1:2 (substrate:water) method. Values are means of all chelate concentration and incubation times.

	Extract Concentration (mg·L^{-1})			
	Cu	Fe	Mn	Zn
EDDS	0.062	1.903	2.223	0.106
DTPA	0.108	8.390	4.751	0.170
		Statistics		
P > *F*	0.001	0.001	0.001	0.001

Fafard Research Leader Program: An Industry Model for Horticultural Research

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Index Words: soilless media, internship, data collection, product trials, research and development

Significance to Industry: Conrad Fafard, Inc. is a leading supplier of professional mixes, retail mixes and Canadian sphagnum peat moss with corporate headquarters in Agawam, Mass. and production facilities in Anderson, S.C., Apopka, Fla., and Marshall, Texas. Conrad Fafard, Inc. is a Syngenta Group Company. The Fafard Research Leader Program was initiated by Syngenta in 2007 to trial advanced potting media formulations at commercial greenhouses to help growers achieve healthy plants and profitable crops. Other goals of the trials were to generate awareness in the horticultural industry of Conrad Fafard's research and development capabilities and enhance the skill set and professionalism of horticultural interns seeking positions in the industry or pursuing advanced degrees. From its launch in January of 2008 to 30 July over 300 individual experiments, evaluating 37 genera at 27 trial sites have been conducted across the United States.

Nature of Work: Before 2008 funds had not been budgeted for R&D activities within Conrad Fafard, Inc. (CFI). All science-related projects were combined with Quality Assurance and Technical Services, with emphasis on comparing competitor mixes with CFI mixes, as well as evaluating customer requests. Scope of science-related activities was limited by 3 staff members (1 Ph.D. and 2 QA Managers), relatively small greenhouse facilities, and trials were evaluations or comparisons rather than statistically measurable studies. To gather sound data, Syngenta approved the approach of a nationwide research program by placing interns (Fafard Research Leaders) in large scale greenhouse operations to conduct academic-style studies. Fafard Research Leader (FRL) candidates represented varying degrees of horticultural experience and education and were selected based on previous research experience and/or knowledge of greenhouse management principles. After FRL candidates were hired they underwent a rigorous training program involving customer relations, experimental design, and data management technology. FRLs then visited their assigned grower operations with their regional Fafard sales representative and conducted interviews to become acquainted with the business. Projects were split into three phases of floriculture production: 1) propagation, 2) production, and 3) container gardens (retail/postharvest/landscape).

The FRL had the largest responsibility for Program success. At the beginning of the Program they conducted a greenhouse audit of the operation by collecting media and irrigation water samples. They established and conducted the experiments, and upon completion reported research findings (photos, research journals, data) to CFI

Management by use of an electronic file transfer system. FRLs presented weekly findings to the grower as well as pest/disease problems or abiotic issues that impacted research crops, and introduced data collection tools such as electronic microscopes, pH/EC meters, infrared thermometers, and portable weather stations. For each phase, CFI provided the media formulations and coordinated shipments of Syngenta genetics (cuttings and seeds) to the operation.

Over the past six months, research activity has taken place in Alabama, California, Florida, Maryland, Massachusetts, New Hampshire, New Jersey, North Carolina, South Carolina, Texas, and Wisconsin. During Phase 1 FRLs evaluated several rates of a controlled release fertilizer (CRF), various beneficial microbes, and different percentages of calcined clays on propagation performance of unrooted cuttings and seedlings. Phase 2 examined several CRFs, biological amendments, rice hull blends, and chipped pine:peat substrates on finished crops. Phase 3 measured plant response to various organic and synthetic polymers, biologicals, or CRFs blended into garden soil or in container garden media. Data collected in all three phases included photographs of treatment comparisons, visual quality, root quality, plant height, diameter, and media pH and EC. FRLs were also required to create weekly reports which outlined each research week's events as well as a journal that listed any observations made during each phase.

It is the aim of the FRL Program to improve traditional grower trials that have in the past focused on observational data with the operation's employees or sales representatives managing the research. Oftentimes data are not collected on a routine basis, therefore the offering of well qualified research associates to manage trials for both qualitative and quantitative data was implemented. Initial trials were designed to determine the barriers of doing practical research in a wide variety of commercial greenhouse facilities. This approach required executing similar experiments in these facilities to determine media/environmental variations across the country.

Results and Discussion: The first six months has presented an enormous data set. During this short period of time, we were able to conduct and complete 311 different experiments that evaluated 37 genera (Table 1) at 27 different locations. These trials involved 20 different commercial growers, 5 Fafard/Syngenta facilities, and 2 non-commercial facilities. All of this was accomplished with only 14 researchers during the busy spring growing season.

It was important to gain grower acceptance and to be as non-obtrusive as possible, therefore it was stressed that a minimal amount of space (less than 100 square feet) was required that demanded limited cultural attention (watering, fertilization and pest management) by the growers. Continued grower participation in all three phases was a sign of both acceptance and a desire to continue the FRL Program. Despite the successes, there were multiple hindrances and obstacles presented on a routine basis. A major challenge was the research tools and data collection systems, proven effective in academic settings, needed to be evaluated under field conditions. FRLs learned how to use these tools and systems by reviewing standardized protocols and tutorials via email. Adopting this field training approach ensured that data was being taken correctly and in the same way across the U.S. These standardized

protocols have also been made available to growers and sales representatives as educational tools for conducting research trials properly and effectively.

A file transfer web site was put into service with corresponding folders for each researcher, site and experiment to streamline data collection and facilitate the upload of large data files. Standardized weekly progress reports were developed for observations, work hours and expenses. The file transfer site is also available to Syngenta research personnel to review raw data and research reports.

In summary the Research Program has shown the industry that on-site grower trials can be studied and measured effectively. Syngenta Global Research is complimentary of the Program and research agenda and future activity will continue in fall 2008 and 2009.

Table 1. List of genera utilized in the first three phases of the Fafard Research Leader Program.

*Angelonia**	*Gerbera*	*Petunia**
*Argyranthemum**	*Impatiens**	*Philodendron*
Begonia	*Ipomoea*	*Plectranthus*
Brassica	*Kalanchoe*	*Polypodium*
*Calibrachoa**	*Lamium*	*Rosmarinus*
*Catharanthus**	*Lantana**	*Salvia**
Chrysanthemum	*Lycopersicon*	*Scaevola**
*Coleus**	*Maranta*	*Spathiphyllum*
Crossandra	*Mentha*	*Tagetes**
Dieffenbachia	*Osteospermum**	*Thymus*
Epipremnum	*Pachystachys*	*Verbena**
Euphorbia	*Pelargonium**	
Ficus	*Pentas*	*Syngenta Genetics

ABA Drenches Induce Stomatal Closure and Prolong Shelf Life of *Salvia splendens*

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Index Words: retail, postproduction, drought, bedding plant, stomatal conductance, transpiration

Significance to Industry: Providing adequate water to bedding plants during retail is often problematic, and drought stress can shorten their shelf life. To help plants conserve water and reduce water needs, stomatal closure can be induced by applying abscisic acid (ABA). ABA drenches caused stomatal closure in salvia (*Salvia splendens* Sellow ex Schult.) 'Bonfire' within three hours of application. ABA-induced stomatal closure and reduced transpiration caused a much slower decrease in the water content of the substrate (θ). This water conservation delayed wilting by two (250 - 500 ppm) to three days (1000 - 2000 ppm). A negative side effect of ABA was a rate-dependent leaf abscission. ABA applications can be used to extend the shelf life of salvia, but the lowest possible dose should be used to minimize leaf abscission.

Nature of Work: The shelf life of ornamental plants in retail stores depends on their aesthetic condition and how quickly it deteriorates. Inadequate watering is a common cause of decreases in aesthetic quality, and can lead to severe drought stress, wilting, and plant death. The plant hormone ABA induces stomatal closure and has been shown to reduce water loss from bedding plants for 2 days after application, while synthetic ABA analogs have a longer-lasting effect (3). ABA has potential to improve the shelf life of greenhouse crops (1); shelf life of a variety of bedding plants was increased by 1 to 6 days after drenches with 125 or 250 ppm ABA (2). Our objective was to quantify how ABA affects water uptake from the substrate, as well as the physiology and quality of the plants. We used salvia as a model crop because it is very drought-sensitive.

Salvia 'Bonfire' seeds were sown in 72-cell plug trays and transplanted into 4" square plastic pots with soilless medium (60% peat – 40% perlite, Fafard 2P, Conrad Fafard, MA) after one month. Plants were grown in a glass-covered greenhouse and when they became marketable, plants were drenched with 50 mL of 0, 250, 500, 1000, or 2000 ppm ABA. All ABA solutions were prepared by diluting a 10% (w/v) stock solution (VBC-30074, Valent BioSciences Co., Libertyville, IL) with deionized water. Plants were no longer watered after the ABA application.

During the following 10 days, volumetric substrate moisture content (θ) was measured every 10 minutes with soil moisture sensors (EC-5, Decagon Devices, Pullman, WA). Stomatal conductance (g_s) was measured four times a day during the first three days after the ABA applications, and once a day thereafter (LI-1600, LI-COR, Lincoln, NE). Wilting and the number of abscised leaves from each plant were monitored throughout the experiment.

The experimental design was a randomized complete block design with 5 blocks per treatment. Data were analyzed using linear and quadratic regression analysis (proc GLM, SAS v. 8.1, SAS Institute, Cary, NC). Because hormonal effects are commonly not directly proportional to the applied dose, ABA concentrations ([ABA]) were transformed using log([ABA] + 50) for the analyses of g_s and θ data.

Results and Discussion: ABA applications reduced g_s within 3 hours. Control plants maintained a high g_s (Fig. 1) and transpiration rate (results not shown) throughout the first day, and had a higher g_s than ABA treated plants on the morning of the second day as well (Fig. 1). However, from 30 to 48 hours after treatment, g_s in the control treatment was lower than that in any of the ABA treatments, and g_s was highest with 250 ppm ABA. By this time, the substrate in the control treatment had dried out ($\theta < 0.20$ $m^3 \cdot m^{-3}$) causing drought stress and the initiation of wilting, explaining the low g_s. There were no treatment effects on g_s from 51 to 96 hours after treatment. During the latter part of the experiment (147 to 195 hours after treatment), g_s increased with increasing [ABA], because there was more water left in the substrates drenched with high [ABA], allowing those plants to continue to transpire. At the end of the experiment (219 hours after treatment), all plants were completely wilted and g_s was low and similar in all treatments.

The ABA effects on g_s and transpiration had a direct effect on θ. Higher [ABA] resulted in higher θ from 6 hours after treatment until the end of the experiment. During the first day after the ABA application, θ in the control treatment decreased by 0.48 $m^3 \cdot m^{-3}$, from 0.73 to 0.25 $m^3 \cdot m^{-3}$. In treatments that received ABA, this decrease in θ ranged from 0.27 to 0.13 $m^3 \cdot m^{-3}$, with smaller changes at higher [ABA]. On day 3, θ in the control treatment was less than 0.10 $m^3 \cdot m^{-3}$, whereas the 250, 500, 1000, and 2000 ppm ABA treatments still had θ of 0.24, 0.31, 0.44, and 0.47 $m^3 \cdot m^{-3}$, respectively. The θ in the 2000 ppm treatment did not drop below 0.10 $m^3 \cdot m^{-3}$ until day 9.

Leaf abscission was a negative side effect of the ABA treatments, with a strong correlation between the number of abscised leaves and [ABA], starting on day 2 ($P <$ 0.0001, Fig. 3). The number of abscised leaves increased until day 5 with little leaf abscission thereafter. Control plants started wilting on day 2, 250 and 500 ppm ABA resulted in wilting on day 4, while 1000 and 2000 ppm ABA delayed wilting until day 5. Therefore, all [ABA] extended the shelf life of salvia, but with the negative side effect of leaf abscission. ABA applications also have been shown to postpone wilting and improve the shelf life of many other bedding plant species (1, 2, 3). Further study is needed to find out the most effective concentration to increase the shelf life of bedding plants in retail settings with minimal side effects.

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Figure 1. Stomatal conductance of *Salvia splendens* during a 10-day period, as affected by drenches with different concentrations of ABA. 'L' and 'Q' indicate significant linear or quadratic effects of (log([ABA] + 50) on stomatal conductance at P = 0.05 (*), 0.01 (**), and 0.001 (***) and NS = non-significant. Data points represent the mean ± standard error.

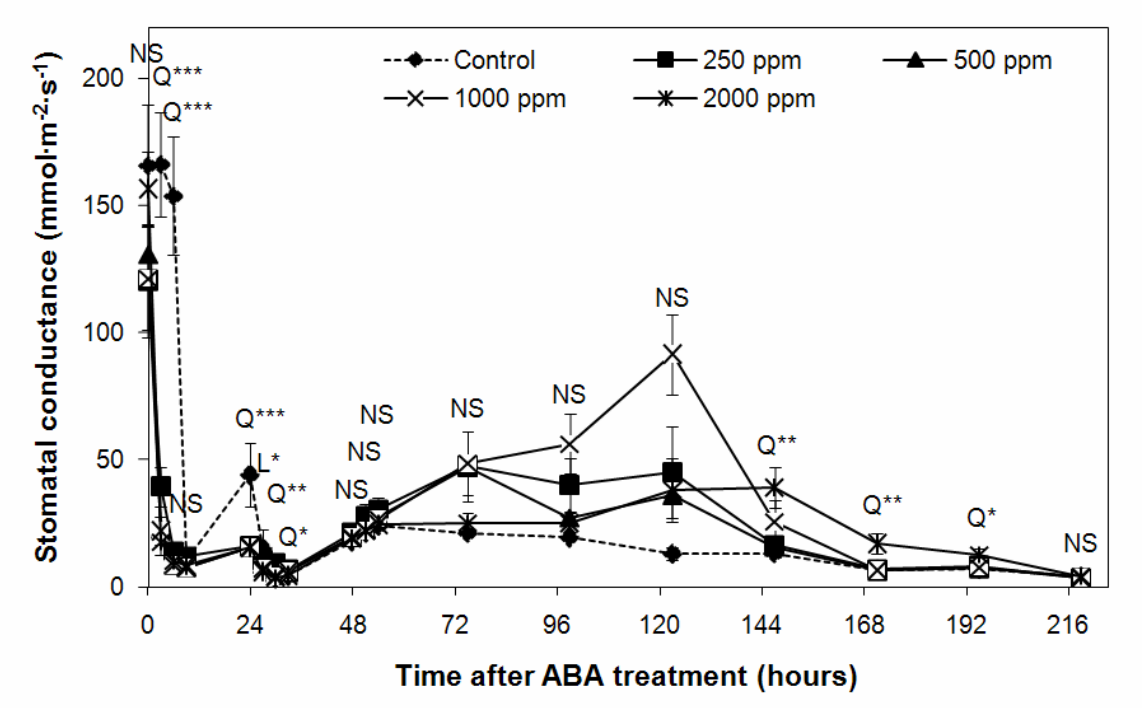


Figure 2. The substrate water content after drenches with different concentrations of ABA. 'L' and 'Q' indicate significant linear or quadratic effects of (log([ABA] + 50) at *P* = 0.05 (*), 0.01 (**), and 0.001 (***) and NS = non-significant. Data points represent the mean ± standard error.

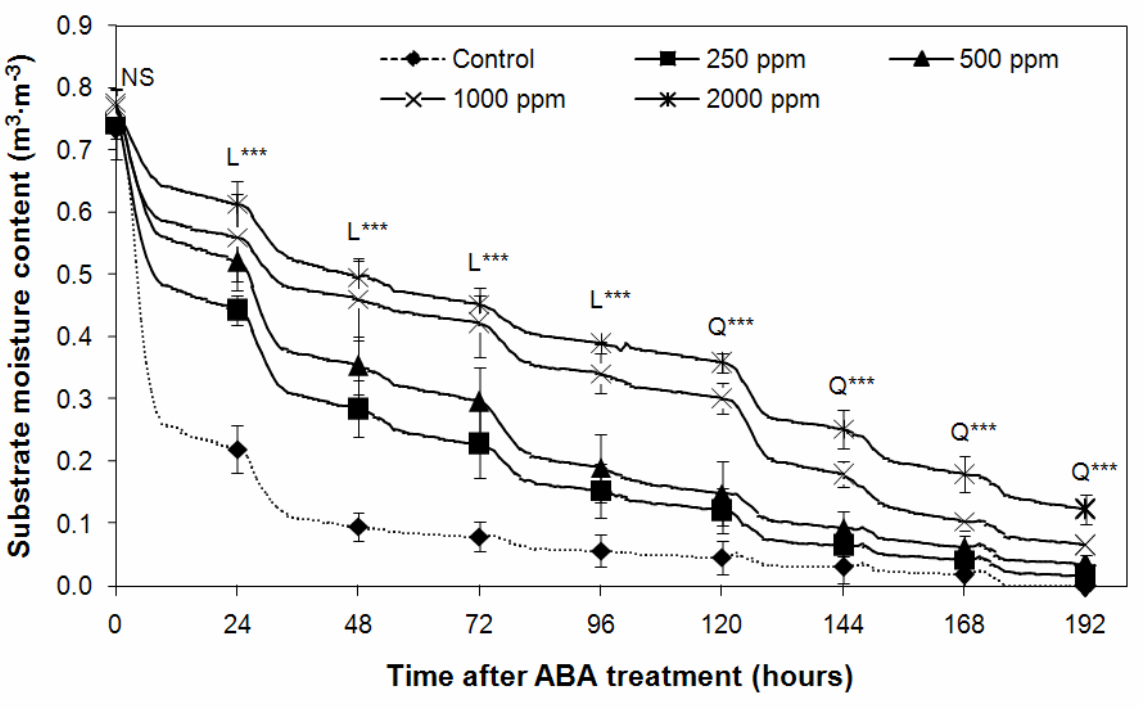
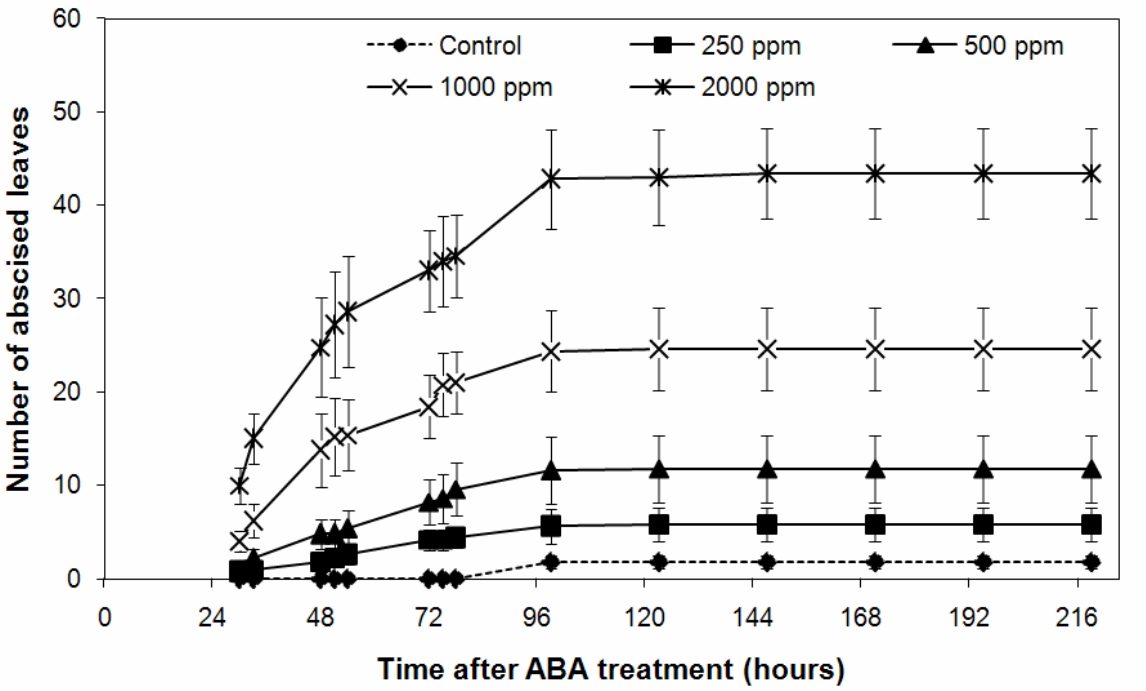


Figure 3. The effect of drenches with different concentrations of ABA on the number of abscised leaves of *Salvia splendens* 'Bonfire'. Data points represent the mean ± standard error. There was a highly significant correlation between the ABA concentration and the number of abscised leaves throughout the study ($P < 0.001$).



Optimal Leaf Tissue Nutrient Ranges for Pot Gerbera

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Index Words: Calcium, Magnesium, Nitrogen, Phosphorus, Potassium, Sulfur

Significance to Industry: Gerberas for pot plant production are considered moderate feeders. This moderate level of fertility produces a plant with a proportional leaf area to flower ratio. Sub-optimal fertility leads to lower leaf yellowing due to nitrogen (N) deficiency. Excessive fertility can lead to lush growth and delayed flowering. Balancing the plants needs and periodic monitoring will help assure the nutritional requirements are being met. When growers face nutritional problems and symptoms are visible on plants, accurate diagnosis can be done by plant tissue analysis. Therefore, the standard of leaf tissue concentration ranges is highly significant to determine nutritional status of plants. In this study, the optimal macro nutrient concentrations observed were narrower than previously published concentrations for gerberas for pot plant production. In addition, this study accounted for differences in concentrations over the entire crop cycle and reflected modern fertilization practices. At 2 weeks, N ranged from 2.94-3.2%, and increased to 3.33-4.16% at 8 weeks. The range of potassium (K) concentrations was 2.73-3.28% at 2 weeks, and increased to 3.22-4.55% at 8 weeks. At 2 weeks, optimal concentration of phosphorous (P), calcium (Ca), magnesium (Mg), and sulfur (S) were 0.24-0.33%, 1.31-1.33%, 0.74-0.75%, and 0.26-0.31%, respectively, and the ranges decreased at 8 weeks.

Nature of Work: The recommended fertilization concentration for gerbera production is 300 $mg \cdot L^{-1}$ (ppm) N and K supplied using a constant liquid fertilizer (1, 2). This recommendation was geared towards cut gerbera production and growing large sized potted plants. As a result, the recommended leaf tissue concentration ranges (1, 4) may reflect luxury uptake by the plant in excess of what is required for optimal plant growth. Although leaf tissue concentration is changed by plant growth stage, the tissue nutrient standards did not account for plant age. Therefore, the available tissue standards are broad for gerbera pot plants. This research was undertaken to determine optimal tissue levels for pot gerbera over cropping time.

Gerbera liners (2.3 x 2.3 x 3.7 cm cell size) of 'Festival Yellow with Light Eye' were transplanted one plant per 5-inch pot on Feb. 28, 2007. Plants were grown in the greenhouse at 68°F (20°C) day and 65°F (18°C) night temperatures. Plants were fertilized with one of six constant liquid fertilizer levels (50, 75, 100, 200, 300, or 400 $mg \cdot L^{-1}$ N) using 1:1 N ratio of Excel® 13-2-13 and Champion WSF 20-2-20 (The Scotts Co., Marysville, Ohio), which contained 13N-0.86P-10.8K and 20N-0.86P-16.6K, respectively. Plants were irrigated as needed using a drip system.

Plants were harvested at three-week intervals for a total of three samples. At each harvest date, plant height (measured from the pot rim to the uppermost part of the plant), plant diameter (measured at the widest dimension, turned 90°, and averaged), and shoot dry weight were recorded. The experiment was a complete randomized block design with five single-plant replications and three sample times for the six levels of fertilization.

The youngest fully expanded leaves were sampled; the harvested tissue was washed in a solution of 0.5 N HCl for 1 min, and rinsed with deionized water before drying at 158°F (70°C) for tissue analysis. Dried tissue was ground in a Foss Tecator Cyclotec ™ 1093 sample mill (Analytical Instruments, LLC, Golden Valley, MN) to pass a $\leq$ 0.5 mm sieve. Tissue was then analyzed for macronutrient concentrations. Tissue analysis for N was performed with a C-H-N analyzer (Model 2400 series II, Perkin-Elmer, Norwalk, CT) by weighing 3.5mg of dried tissue into tin cups and placed into the analyzer. Other nutrient concentrations were determined with inductively coupled plasma optical emission spectroscopy (ICP-OES; Model IRIS Intrepid II, Thermo Corp., Waltham, Mass.).

Data were tested by analysis of variance (ANOVA) using general linear model (SAS Institute, Cary, NC) and means were separated by least significant differences (LSD) at $P \leq 0.05$. Tissue concentrations of each fertilizer rate were regressed using the PROC REG to determine the best-fit, linear or quadratic model. Terms of the model were evaluated for significance based on a comparison of F values at $\alpha = 0.05$.

Upper and lower optimal nutritional limits were established for each element by analyzing the growth of 'Festival Yellow with Light Eye' plants over time using plant height, diameter, dry weight, and growth index (GI) (Equation 1). Plants fertilized with 50 and 75 $mg \cdot L^{-1}$ N had a significantly smaller plant height, diameter, dry weight, and growth index. Therefore, the values from the next highest fertilizer rate (100 $mg \cdot L^{-1}$ N) were established as the lower range limit.

The GI was statistically similar for the 100 to 200 $mg \cdot L^{-1}$ N fertilizer concentrations, which established the upper sufficiency range. The GI was less for plants fertilized with 300 and 400 $mg \cdot L^{-1}$ N. In addition, drawing from experience concerning cost of fertilizer, common grower practices, and environmental impacts, it was concluded that with greater than 300 $mg \cdot L^{-1}$ N the plants would be entering a situation of luxury nutrient consumption and the additional fertilizer was not beneficial to quality.

Equation 1. Growth Index (GI) where height (ht) was measured from the pot rim to the uppermost part of the plant and diameter (dia_1) was measured from the widest dimension turned 90º to take second diameter (dia_2).

$$GI = \frac{ht + \frac{dia_1 + dia_2}{2}}{2}$$

Results and Discussion:

Nitrogen. Published recommended tissue ranges for nitrogen are between 2.52-4.90% for pot gerberas (Table 1). Based on the research with 'Festival Light Eye Yellow', the target ranges for plants grown with 100 to 200 mg·L^{-1} N increased over time from two weeks after transplanting until bloom – with the range being wider at bloom than just after transplanting (Fig. 1, Table 2). Nitrogen tissue levels were within a narrower band than the recommended published ranges (two weeks after transplanting with 2.94-3.20 and at bloom 3.30-4.16%).

Phosphorus. The recommended range for phosphorus is between 0.25-0.7% for pot gerberas (Table 1). Based on the research with 'Festival Light Eye Yellow', the lower optimal range was 0.24% at 2 weeks after transplant to 0.19% at bloom (Fig. 1, Table 2). This was slightly less than the lower published limit of 0.25%. For plants grown with 200 mg·L^{-1} N, the P levels increased from 0.33-0.44% by 5 weeks after transplanting, and then decreased to 0.31% at bloom. Phosphorus tissue levels were lower and within a narrower band than the recommended published ranges. Luxury uptake of phosphorus by the plant may account for the high upper recommended limit of 0.7%, because 5 weeks after transplant 'Festival Light Eye Yellow' plants fertilized with 400 mg·L^{-1} N contained 0.73% P.

Potassium. The recommended range for potassium is between 3.1-5.0% for pot gerberas (Table 1). Based on the research with 'Festival Light Eye Yellow', the lower optimal range was 2.73% at 2 weeks after transplant, increasing to 3.93% five weeks after transplant, to 3.22% at bloom (Fig. 1, Table 2). The initial value two weeks after transplant was slightly less than the lower published limit of 3.1%. For plants grown with 200 mg·L^{-1} N, the K levels increased from 3.28%-4.87% by 5 weeks after transplanting, and then back down to 4.55% at bloom. Potassium tissue levels were within a narrower band than the recommended published ranges.

Calcium. Published recommended tissue ranges for calcium are between 0.4-4.2% for pot gerberas (Table 1). Based on the research with 'Festival Light Eye Yellow', the optimal ranges for plants grown with 100 to 200 mg·L^{-1} N decreased over time from two weeks after transplanting until bloom – with the range being wider at bloom than just after transplanting (Fig. 1, Table 2). Calcium tissue levels were within a much narrower band than the recommended published ranges (two weeks after transplanting with 1.31-1.33 and at bloom 0.90-1.02%). The irrigation water used in the experiment did not contain Ca, therefore the only sources of Ca were from the initial lime charge provided in the substrate and the continual amount supplied from the fertilizer mixture containing 6% Ca.

Magnesium. The recommended range for magnesium is between 0.24-2.8% for pot gerberas (Table 1). Based on the research with 'Festival Light Eye Yellow', the optimal ranges for plants grown with 100 to 200 mg·L^{-1} N decreased over time from two weeks after transplanting until bloom – with the range being wider at bloom than just after transplanting (Fig. 1, Table 2). Tissue levels were higher in plants grown with 100 mg·L^{-1} N than 200 mg·L^{-1} N and may reflect the antagonistic competition of the corresponding

increase in potassium being supplied in the fertilizer solution. Magnesium tissue levels were within a much narrower band than the recommended published ranges (two weeks after transplanting with 0.74-0.75 and at bloom 0.36-0.43%). The irrigation water used in the experiment did not contain Mg, therefore the only sources of Mg were from the initial lime charge provided in the substrate and the continual amount supplied from the fertilizer mixture containing 4.1% Mg.

Sulfur. There are limited recommendations for optimal sulfur levels. The only recommend range is for cut gerbera grown in tropical conditions of South America and is between 0.25-0.5% (Table 1). Based on the research with 'Festival Light Eye Yellow', the optimal ranges for plants grown with 100 to 200 $mg \cdot L^{-1}$ N increased slightly from two to five weeks after transplant and then declined until bloom (Fig. 1, Table 2). Sulfur tissue levels were within a narrower band than the recommended published ranges (two weeks after transplanting with 0.26-0.31 and at bloom 0.24-0.26%). Sulfur deficiency is uncommon in greenhouse production.

This study updates the optimal tissue concentrations for pot gerbera production with lower fertility levels than 300 $mg \cdot L^{-1}$ N. The macro nutrient concentrations of plants fertilized with 100 and 200 $mg \cdot L^{-1}$ N resulting in the maximum GI. Optimal concentration ranges for the most nutrients were within a narrower band than the recommended ranges. Results will be suitable for interpreting values for other light leafed colored gerbera varieties.

Acknowledgements: We gratefully acknowledge the funding support provided by Sakata America.

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Table 1. Recommended leaf tissue concentrations for pot and cut gerberas.

Nutrient	Pot Gerbera		Cut Gerbera			
	Dole and Wilkins	Mills and Jones	Klossowski and Strojny	Valenzuela de Ocampo[1]		
				Deficient	Low to Medium	Excessive
Nitrogen (% N)	2.7-4.1	2.52-4.90	2.70-3.10	1.20	1.5-3.5	6.0
Phosphorus (% P)	0.3-0.7	0.25-0.62	0.19-0.35	0.15	0.2-0.5	0.6
Potassium (% K)	3.1-3.9	3.91-5.00	3.06-3.64	2.00	2.5-4.5	6.0
Calcium (% Ca)	0.4-4.2	1.00-2.40	1.66-2.18	0.70	1.0-3.5	5.0
Magnesium(% Mg)	0.3-2.8	0.24-0.63	0.30-0.48	0.15	0.2-0.7	1.2
Sulfur (% S)	-	-	-	0.16	0.25-0.5	0.7

[1] The target leaf tissue concentration for cut gerberas grown under tropical and subtropical conditions would be within the Low to Medium range, while nutrient deficiencies could be expected under Deficient levels, and toxicities under Excessive levels.

Table 2. Optimal leaf tissue concentrations for 'Festival Light Eye Yellow' pot gerberas grown with 100 to 200 $mg \cdot L^{-1}$ N.

Nutrient	Weeks After Transplanting		
	2 Weeks	5 Weeks	8 Weeks (bloom)
Nitrogen (% N)	2.94-3.2	3.36-3.94	3.33-4.16
Phosphorus (% P)	0.24-0.33	0.23-0.44	0.19-0.31
Potassium (% K)	2.73-3.28	3.93-4.87	3.22-4.55
Calcium (% Ca)	1.31-1.33	1.21-1.23	0.90-1.02
Magnesium (% Mg)	0.74-0.75	0.46-0.50	0.36-0.43
Sulfur (% S)	0.26-0.31	0.27-0.31	0.24-0.26

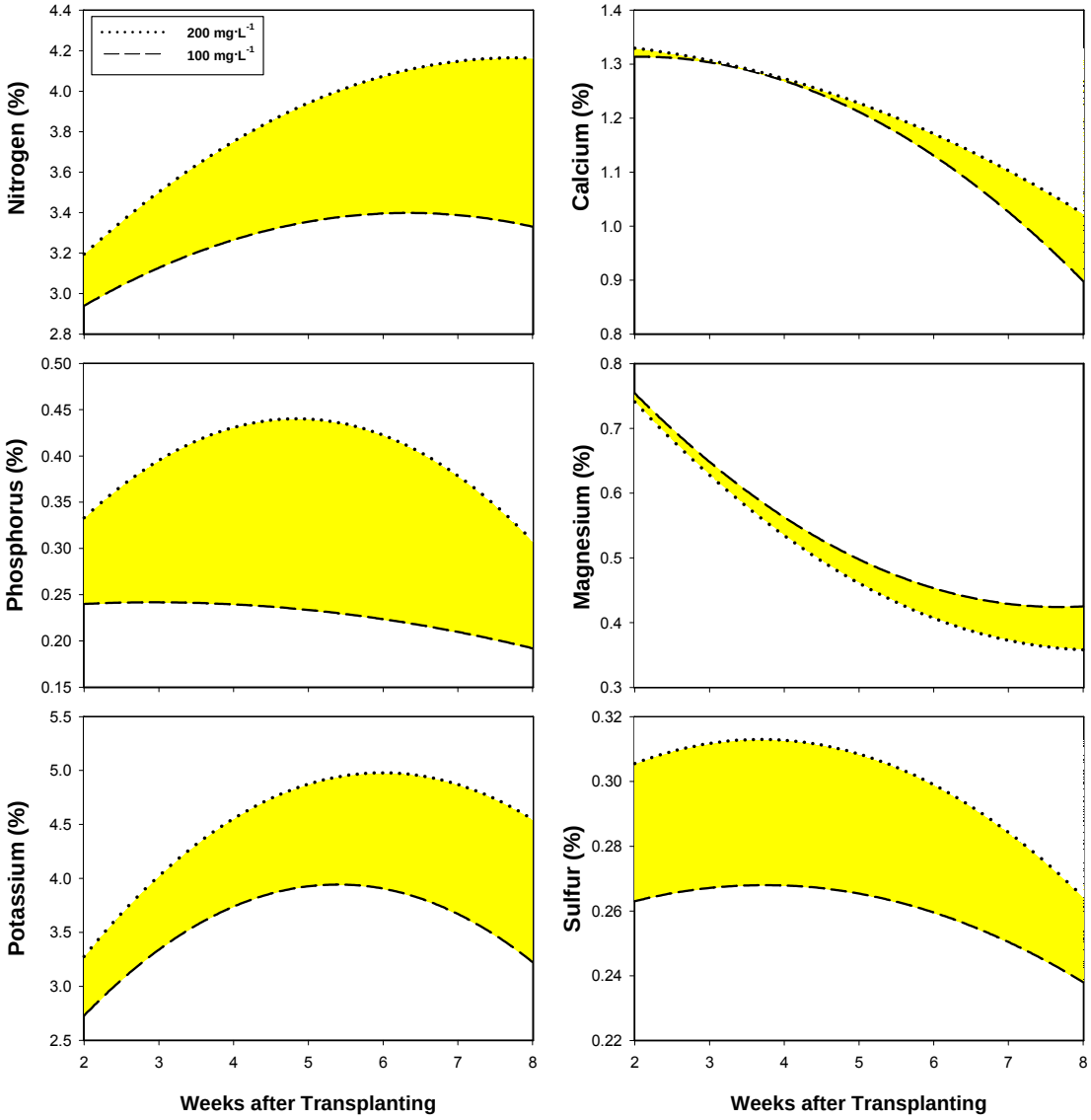

Figure 1. Macro nutrients tissue concentration over time of 'Festival Light Eye Yellow' gerberas grown with 100 and 200 mg·L^{-1} N. Tissue samples were collected and analyzed at weeks 2, 5, and 8 after transplant.

Impact of Various PGRs on Shelf Life of Geraniums Grown in Pots

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Index Words: Plant growth regulator, postharvest quality, gibberellic acid, 6-benzyladenine, 1-MCP, *Pelargonium* x *hortorum*, *Pelargonium* x *peltatum L.*

Significance to Industry: Geraniums in pots and hanging baskets, including ivy (IG, *Pelargonium* x *peltatum* L.) and zonal geraniums (ZG, *Pelargonium* x *hortorum*), are popular flowering plants for holiday and spring markets. Postharvest quality of geraniums in pots can be adversely affected by conditions during shipping such as extended darkness and exposure to ethylene. Treatments with plant growth regulators prior to shipping may improve plant quality after shipping and extend the shelf life of geranium plants.

Nature of Work: Most geranium cultivars are sensitive to ethylene (1). Plants exhibit senescence signs when exposed to ethylene gas, such as abscission of flower petals and yellow leaves (2). Although 1-methylcyclopropene (1-MCP) treatment can reduce petal shattering (3), effects may vary (4) or are transient in some varieties (5). Gibberellic acid (GA) and 6- benzyladenine (BA) were reported to increase vast life of carnation cut flowers at a low rate from 1 to 10 ppm (6, 7) and the action of BA was initiated in the leaves (6). The objective of this study was to determine effects of GA_{4+7}, BA, GA_{4+7}+BA, or 1-MCP on the shelf life of geraniums.

Rooted cuttings of IG 'Tutti Fruitti' and ZG 'Tango' were received and potted into 6-inch azalea pots on February 1, 2007. Controlled release fertilizer Osmocote 14-14-14 was added into potting media (MetroMix 380) at a rate of 0.5 lb N per cubic yard medium. Plants were maintained in greenhouse with day/night temperature set at 85/75 ºF. ZG received a soft pinch on February 22, and IG received soft pinches on February 22 and March 7. PGR treatments were applied when plants had 2 to 3 open florets. ZG and IG plants were treated on April 17 and April 26, respectively. Fascination (GA_{4+7} + BA, Valent Inc.), NovaGib (GA_{4+7}, Fine Americas), ExilisPlus (BA, Fine Americas) and MaxCel (BA, Valent Inc.) were applied as foliar spray at 50 and 100 ppm. Distilled water was applied as control. Each treatment had 10 replications (pots) arranged in a completely randomized design. Another group of 10 pots were treated with 1-MCP (EthylBloc, Floralife). Plants were placed in a plastic container (42"x24"x26") and EthylBloc powder was placed in a weighing boat in the center of the container. The container was sealed after the buffer solution was added to release 1 ppm 1-MCP and kept under lab condition with temperature set at 72 ºF. After 12 hours, plants were placed back to greenhouse benches. After treatment, IG and ZG followed the same time sequence with simulated shipping and post shipping quality evaluation. All plants were left on benches during 1 and 2 days after treatment (DAT) to simulate a waiting period before shipping. On 3 DAT, all plants were placed in cardboard boxes (30"x 24"x 20")

and moved to a walk-in cooler with temperature set at 46 °F for a period of 48 hours in dark to simulate shipping. On 5 DAT, all plants were placed back onto greenhouse benches for postproduction evaluation. Plants were watered as needed during the four weeks of evaluation. Temperature and relative humidity (RH) in the greenhouse were monitored by HOBO sensors. Temperature ranged from 68 to 92 °F with a daily average temperature at 83 °F. Relative humidity ranged from 42% to 95% with a daily average RH of 59%.

Plant height and diameter was measured before and after simulated shipping. Plant growth index was calculated as height + (diameter 1 + diameter 2)/2. The number of open florets was counted on 5, 14, 22, and 28 DAT. Phytotoxicity was rated on a scale from 0 to 10 (where 0 being no injury, 1 to 2 represent minor or transient injuries, 3 to 5 represent moderate injuries, 6 to 9 represent severe injuries, and 10 being total plant death) on 3 DAT. Overall plant quality was rated on a scale of 1 to 10 (where 1 represents plant death, 1 to 5 represent plants to be discarded, 6 to 8 represent sale at a discounted price, and 9 and 10 being premium quality) on 3 DAT. The shelf life was counted as number of days after treatment until no flower remained on the plant. Length of the flower stem was measured from the rim of pot to the tallest point of all the inflorescences of a plant with open florets. Data were analyzed with analysis of variance (ANOVA) by using SAS General Linear Models. Differences between treatment means were compared by Fisher's LSD.

Results: On 3 DAT, IG 'Tutti Fruitti' plants treated with Fascination (GA+BA) received low overall quality rating due to the moderate to severe injuries caused by 50 and 100 ppm treatments (Table 1). Injuries included necrosis on young leaves and drop of flower buds. These plants had fewer numbers of open flowers by 14 DAT and no flowers by 22 DAT. Plants treated with ExilisPlus and MaxCel at 100 ppm had minor injuries noticeable to a potential customer. Plants treated with NovaGib (GA) at both rates, and ExilisPlus and MaxCel at 50 ppm had no or minor injuries and received overall quality ratings similar to control and the current standard 1-MCP (table 1). Plants treated with ExilisPlus and MaxCel at 50 ppm had more open flowers than standard 1-MCP and control by 28 DAT (table 2). ZG 'Tango' treated with 100 ppm Fascination, ExilisPlus, or MaxCel had lower overall plant quality due to phytotoxicity (table 1). Minor injuries were found with NovaGib treatments and MaxCel and ExilisPlus at 50 ppm on 3 DAT (Table 1). By 22 DAT these treatments resulted in fewer numbers of open flowers than 1-MPC and control treatments (Table 2). By 28 DAT, all PGR treated plants had fewer flowers than control treatment (Table 2). In summary, none of the PGRs tested extended shelf life of ZG 'Tango'. BA products at 50 ppm showed some effects on IG 'Tutti Fruitti' and are relatively safe for use on this crop.

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Table 1. Phytotoxicity and overall plant quality rating of Ivy Geranium (IG) 'Tutti Fruitti' and Zonal Geranium (ZG) 'Tango' at 3 days after treatment.

	Phytotoxicity Rating (0-10)[z]		Overall Plant Quality(1-10)[y]	
Treatment	IG	ZG	IG	ZG
NovaGib (GA_{4+7})				
50 ppm	0.11 ef[x]	0.78 bc	8.33 ab	9.11 abc
100 ppm	0.44 def	0.33 c	8.22 ab	9.78 a
ExilisPlus (BA)				
50 ppm	0.89 cd	0.22 c	8.44 a	9.56 a
100 ppm	1.33 c	1.17 abc	7.56 cd	8.56 bc
MaxCel (BA)				
50 ppm	0.11 ef	0.56 c	8.33 ab	9.33 ab
100 ppm	0.56 de	0.67 bc	7.78 bcd	9.11 abc
Fascination (GA_{4+7}+BA)				
50 ppm	2.67 b	1.00 abc	7.22 d	9.44 a
100 ppm	3.56 a	1.78 a	5.11 e	8.33 c
Standard (1-MCP 1ppm)	0.33 ef	0.39 c	8.11 abc	9.22 ab
Untreated Control	0.00 f	0.28 c	8.11 abc	9.44 a
$LSD_{0.05}$	0.48	1.08	0.61	0.82

[z]Phytotoxicity rating where 0 represents no plant injury, 1 to 2 represent minor or transient injuries, 3 to 5 represent moderate injuries, 6 to 9 represent severe injuries and 10 total plant death)

[y]Overall plant quality rating where1 represents plant death, 1 to 5 represent plants to be discarded, 6 to 8 represent sale at a discounted price, and 9 and 10 being premium quality.

[x]Means followed by different letters within columns are significantly different at $P = 0.05$ according to Fisher's LSD.

Table 2. Number of open flowers of Ivy Geranium (IG) 'Tutti Fruitti' and Zonal Geranium (ZG) 'Tango' at 5, 14, 22, and 28 days after treatment (DAT).

	IG Evaluation (DAT)				ZG Evaluation (DAT)			
Treatment	5	14	22	28	5	14	22	28
NovaGib (GA_{4+7})								
50 ppm	1.1	1.00 cde[z]	0.00 d	0.00 d	1.44	6.44 bc	3.11 cd	2.00 cde
100 ppm	2.9	0.11 e	0.00 d	0.00 d	1.78	8.22 ab	0.67 d	0.33 e
ExilisPlus (BA)								
50 ppm	1.0	2.89 ab	5.00 ab	3.33 ab	2.78	8.44 ab	4.89 c	2.11 bcde
100 ppm	3.7	1.56 cd	3.33 b	4.67 a	2.22	5.11 bc	5.78 c	4.11 bcd
MaxCel								
50 ppm	2.4	3.22 a	5.89 a	4.56 a	3.33	10.44 a	6.56 bc	3.11 bcde
100 ppm	1.7	0.33 de	1.33 cd	1.11 cd	0.67	3.44 c	5.56 c	4.67 bc
Fascination (GA_{4+7}+BA)								
50 ppm	3.0	1.44 cd	0.00 d	0.11 d	0.44	3.44 c	0.56 d	0.67 de
100 ppm	2.6	0.11 e	0.00 d	0.00 d	1.22	3.22 c	1.0 d	0.22 e
Standard (1-MCP 1ppm)	4.1	3.67 a	3.11 bc	2.33 bc	4.33	8.33 ab	11.22 a	5.56 b
Untreated Control	2.8	1.67 bc	0.89 d	0.89 cd	2.00	5.56 bc	10.11 ab	10.33 a
$LSD_{0.05}$	3.37	1.25	1.89	1.63	3.22	3.99	3.57	3.55

[z]Means followed by different letters within columns are significantly different at $P = 0.05$ according to Fisher's LSD.

Sodium Chloride Effects on Growth and Physiology of Chrysanthemum

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Index Words: salinity, NaCl, stomatal conductance, *Chrysanthemum* × *morifolium*, growth retardant

Significance to Industry: Salinity tolerance of greenhouse crops is of increasing importance due to the decreasing availability of high-quality irrigation water. We determined how NaCl in the irrigation water affects the growth and physiology of chrysanthemums (*Chrysanthemum* × *morifolium* Ramat.). NaCl concentrations of 3 g/L or higher, greatly stunted growth and resulted in unmarketable plants. A NaCl concentration of 1 g/L reduced plant height by 4 cm, increased the water use efficiency, and had little or no impact on shoot dry weight or time to flowering. Slightly saline water could be used for chrysanthemums without negative side effects, while potentially reducing the need for growth retardants.

Nature of Work: Salinity tolerance of greenhouse crops is of increasing importance due to the decreasing availability of high-quality irrigation water. In coastal areas, ground water is affected by saltwater intrusion. Saline water has many negative effects on greenhouse crops. Excessive concentrations of NaCl can inhibit water uptake, causing a physiological drought stress. NaCl also may decrease photosynthesis, transpiration, stomatal conductance, chlorophyll, and plant growth (1, 2, 4). On the other hand, NaCl-induced reductions in plant height (2) may improve the quality of floricultural crops. The objective was to determine the effect of saline water on the growth, morphology, and physiology of chrysanthemums. A better understanding of such effects can help to improve cultivation with saline water and perhaps lead to the use of saline water as a growth regulator.

Forty rooted chrysanthemum ‘Yellow blush’ cuttings were planted in 6” pots filled with a peat-perlite substrate (Fafard-2P, Fafard, Agawam, MA) and placed in a greenhouse. After the initial watering with tap water, plants were watered with 250 mL of solutions with 0, 1, 3, 6, or 9 g/L NaCl as needed. Stomatal conductance and transpiration were measured during week 7 (LI-1600, Li-Cor Inc., Lincoln, NE). Substrate electrical conductivity (EC) (FieldScout EC probe, Spectrum, Plainfield, IL), chlorophyll content (SPAD-502, Minolta, Tokyo), plant height, shoot dry weight, and the area of the uppermost fully-expanded leaf (LI-3100, Li-Cor Inc.) were measured at harvest (week 8). Water use efficiency (WUE) was calculated as shoot dry weight divided by the total irrigation volume. Tissue samples were analyzed for nutrients by the USDA-ARS application technology research unit in Toledo (OH). The plants were arranged in a randomized complete block with five NaCl treatments in eight blocks. Data were analyzed using linear and non-linear regression with the NaCl concentration of the water as the independent variable.

Results and Discussion: Substrate EC increased from 0.17 mS/cm without NaCl to 15.2 mS/cm with 9 g/L NaCl (Fig. 1), indicating salt build-up in the substrate. Stomatal conductance decreased with increasing NaCl concentrations, from 174 $mmol \cdot m^{-2} \cdot s^{-1}$ for control plants to 10 $mmol \cdot m^{-2} \cdot s^{-1}$ in the 3 to 9 g/L NaCl treatments. Transpiration was affected similarly (Fig. 2). Transpiration of tomato (*Solanum lycopersicum* L.) (4) also was reduced with increasing salinity. Chlorophyll content was decreased to 29 SPAD units in the 9 g/L NaCl treatment, as compared to 42 SPAD units in the other treatments (data not shown). Leaf chlorophyll of tomato (2), *Chrysanthemum indicum* 'Nanjing' and *C. chanetii* (1) also were reduced by high NaCl concentrations.

Plant height ranged from 31.9 cm in the control to 14.2 cm with 9 g/L NaCl, while the area of the uppermost leaf decreased from 25.4 cm^2 in the control to 15.4 cm^2 with 9 g/L NaCl (Fig. 3). Tomato height and leaf elongation also decrease with increasing NaCl in the nutrient solution (2). The NaCl-induced reduction in height suggests that moderately saline water could be used as a growth retardant. Shoot dry weight decreased with increasing NaCl (weight = 8.19 – 0.69 × [NaCl], r^2 =0.95, $P < 0.0001$), while WUE was 1.5 g/L in the control, 1.7 g/L with 1 and 3 g/L NaCl, and decreased to 0.8 g/L with 9 g/L NaCl (WUE = 1.57 + 0.0932 × [NaCl] – 0.0204 × $[NaCl]^2$, $r^2 = 0.83$, $P < 0.0001$). The increase in WUE with 1 and 3 g/L NaCl is consistent with the large reduction in transpiration at these concentrations (Fig. 2), while dry weight was reduced much less.

Shoot tissue in the 9 g/L NaCl treatment contained almost 100 mg/g Na^+, while control plants contained only 1 mg/g (Table 1). Increased Na^+ uptake may interfere with uptake of K^+ (2). However, we found the lowest K^+ concentrations in the control treatment, and the highest K^+ concentrations with 6 g/L NaCl (Table 1). Tissue N concentrations were lowest with 9 g/L NaCl, which is consistent with NaCl-induced senescence of the leaves (3) and the low chlorophyll concentrations in this treatment.

Application of 1 g/L NaCl resulted in a small reduction in dry weight, while reducing height by 4 cm and increasing WUE. This reduction in height may reduce the need for plant growth regulators, while the increase in WUE could save water. NaCl concentrations higher than 1 g/L stunted growth severely and decreased marketability. Thus, chrysanthemums may be grown with slightly saline water (up to 1 g/L NaCl) without harmful effects on plant growth or quality.

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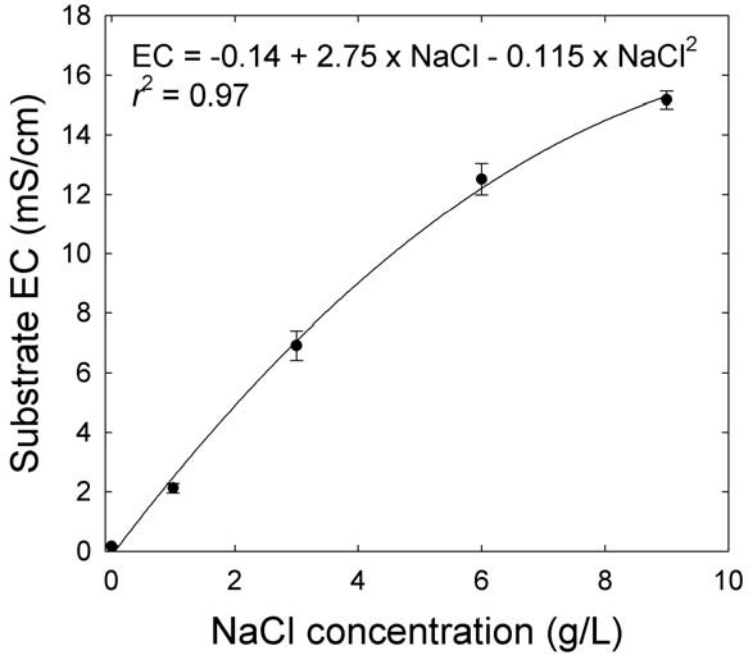

Fig. 1. The substrate electrical conductivity (EC) as affected by the NaCl concentration of the irrigation water. Data points are the mean ± standard error (n = 8). The curve represents a significant quadratic effect ($P < 0.0001$).

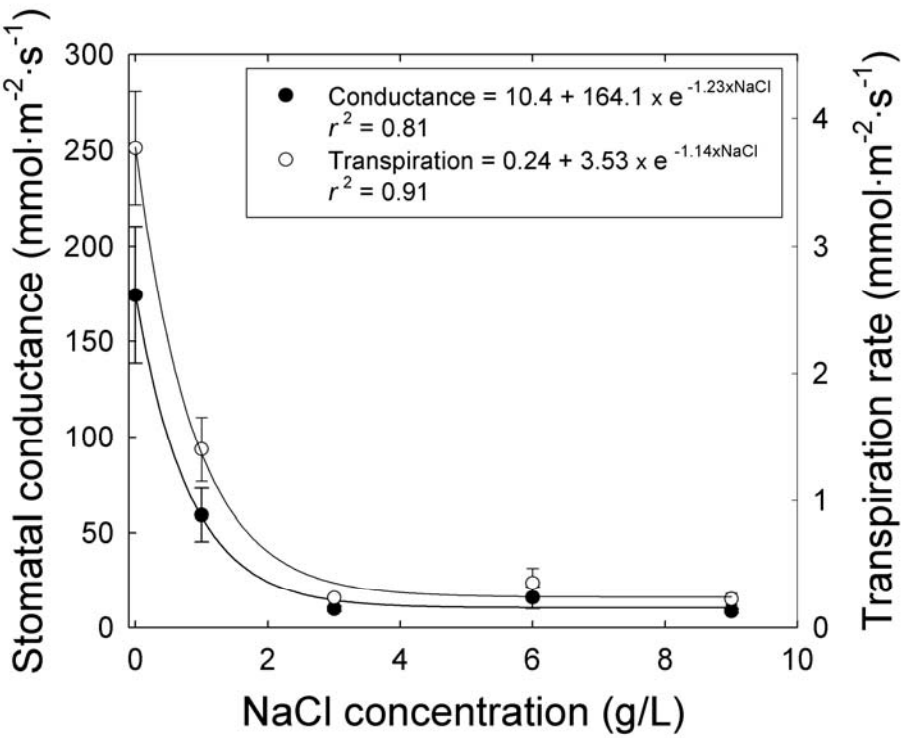

Fig. 2. Stomatal conductance and transpiration of chrysanthemum leaves as affected by the NaCl concentrations of the irrigation water. Data points are the mean ± standard error (n = 8). Curves show significant effects ($P < 0.0001$).

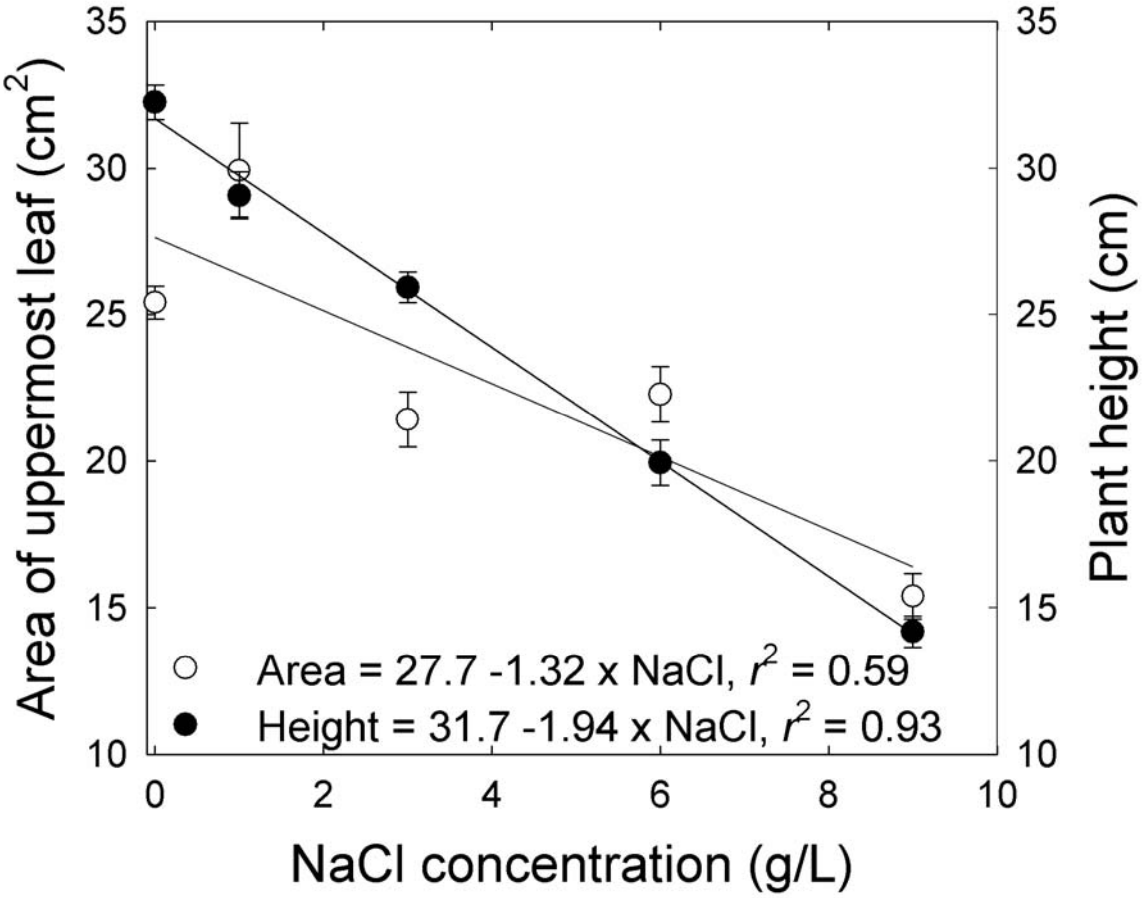

Fig. 3. The effect of the NaCl concentration of the irrigation water on the final plant height and area of the uppermost fully-expanded leaf of chrysanthemums. Data points are the mean ± standard error (n = 8). There are significant correlations between the NaCl concentration and both plant height and leaf area (P < 0.0001).Table 1: The effect of NaCl concentrations in the irrigation water on the mineral composition of chrysanthemum.

Table 1: The effect of NaCl concentrations in the irrigation water on the mineral composition of chrysanthemum.

NaCl concentration	N	P	K	Ca	Mg	S	Na	B	Cu	Fe	Mn	Mo	Si	Zn
g/L	---------- mg/g ----------							---------- ppm ----------						
0	27.9	7.19	37.1	8.6	4.28	2.35	1.0	15.3	6.77	60	131	1.10	220	27.8
1	28.3	5.95	37.6	9.7	5.23	2.51	13.8	13.5	6.42	68	157	1.22	230	32.0
3	30.1	6.11	44.7	9.9	4.34	2.38	18.7	15.4	6.83	75	191	1.50	225	35.9
6	31.9	5.96	49.2	10.5	4.63	2.82	42.6	16.4	6.98	98	194	1.62	224	41.3
9	25.9	4.93	44.6	11.2	5.81	2.75	98.0	15.3	5.95	73	140	1.06	207	34.8
Significance [z]	Q***	L***	Q***	L***	Q*	L***	Q***	ns	Q**	ns	Q***	Q*	ns	Q***
R^2	0.51	0.53	0.62	0.48	0.45	0.50	0.90	-	0.51	-	0.64	0.24	-	0.74

[z] ns, *, **, and *** indicate non-significant, or significant linear (L) or quadratic (Q) effects at $P > 0.05$, $P > 0.01$, and $P > 0.001$, respectively.

Processed Whole Pine Trees as a Substrate for Boston Fern Production

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Index Words: peat moss, whole tree, media, Boston fern

Significance to the Industry: This experiment demonstrated whole pine tree (WPT) substrates could be substituted for peat-lite (PL) substrates in commercial Boston fern production. Benefits include maintaining plant quality, little to no increase in water use and possible savings in substrate costs.

Nature of the Work: The wholesale value of the floriculture industry has remained stable since 2004, following a period of rapid growth from 1997 to 2002 (4). In order to stay profitable, producers are constantly seeking ways to save money. The cost of container substrates containing peat moss and pine bark has steadily increased, due to rising fuel prices and added demand for pine bark as a fuel (3). The utilization of alternative substrate components has been a successful practice for producers near such materials, although few operations benefit. Pine trees would provide uniform, comparably priced (possibly less expensive) substrates from a sustainable, regionally available source. Substrates can be processed from whole pine trees (WPT), whole debarked pine logs (DPL) or harvested pine tree residuals (PTR).

Several research projects have shown floriculture crops can be produced in alternative pine tree substrates. Wright and Latimer (5) produced comparable poinsettias in a DPL substrate compared to a PL substrate. A study by Boyer et al. (1) found that annuals grown in PTR substrates had comparable growth to plants grown in pine bark. With the addition of an adequate nutrient starter charge, quality marigold and petunia plants were produced in a 100% WPT substrate when compared to a PL substrate (2).

The objective of our research was to evaluate processed whole pine trees as an alternative container substrate for Boston fern production. The experiments were performed at the Southern Horticultural Laboratory in Poplarville, MS. WPT chips (consisting of needles, limbs, bark, wood and cones) were obtained from a commercial whole tree chipping operation in western Georgia. WPT chips were further processed with a swinging hammer mill (C.S. Bell No. 30) to pass a ¼ in screen. The experiments contained four substrates (Table 1), each amended per yd^3 with 1 lb micromax, 4 lbs Harrell's 16-6-12 Plus (4-5 month formulation) and 8 lbs Harrell's 18-6-12 (9-10 month formulation). The pH of each substrate was modified with the addition of dolomitic lime (100% WPT = 1lb / yd^3, 3:1 WPT:Peat = 2 lbs / yd^3, 1:1 WPT:Peat = 3 lbs / yd^3 and Peat-lite = 4 lbs / yd^3), each ranging from 4.5-5.0 pH at the beginning of the experiment.

On September 21, 2007, liners (4 in) of true Boston fern (*Nephrolepis exaltata* 'Massii') and dwarf Boston fern (*Nephrolepis exaltata* 'Bostoniensis Compacta') were planted in hanging baskets (10 in) filled with substrate. Containers were placed on the ground in a shaded greenhouse and irrigated twice daily with a low or high irrigation volume (1x or 2x), utilizing an automated drip irrigation system with hanging basket assemblies (Netafim). Irrigation volume fluctuated throughout the experiment and was adjusted as needed based on personal observations of plant appearance and substrate water holding capacity. Plants were arranged by cultivar in a randomized complete block design with six single plant replications. Pour-through extractions were performed at 0, 32, 87, 175 (massii) and 186 (compacta) days after planting (DAP) to analyze substrate pH and electrical conductivity (EC). Plant growth indices (PGI) were recorded at 73, 167 (massii) and 179 (compacta) DAP. Leaf chlorophyll content was quantified using a SPAD-502 Chlorophyll Meter (Minolta, Inc.) at 167 DAP (massii). Shoot dry weight was recorded at 168 (massii) and 182 (compacta) DAP.

Results and Discussion: A significantly lower pH occurred in 100% WPT substrates (at 32 DAP and project termination in both cultivars) compared to the PL substrate, regardless of irrigation volume (Table 1). At 32 DAP substrate pH remained in an acceptable range for Boston fern production (4.77 – 5.97 pH). At project termination, pH ranged from 3.17 in 100% WPT to 5.13 in the PL substrate. Although such a low pH may be unsuitable for many crops, no adverse affects were visible in either fern cultivar. No obvious trends were noticed for differences in substrate EC between substrates, although EC was significantly lower under high irrigation (compared to low irrigation) in the PL substrate at project termination for each cultivar.

The plants under high irrigation had consistently greater PGI in both cultivars, regardless of substrate (Table 2). At project termination, high irrigation treatments (both cultivars) in the 1:1 WPT:peat substrate had significantly greater PGI compared to the low irrigation treatments. Within each irrigation treatment (low or high), no significant differences in PGI occurred between substrates. Shoot dry weight was consistently greater for plants (both cultivars) subjected to the high irrigation treatments, regardless of substrate. Significantly greater shoot dry weights occurred between irrigation treatments of the PL and 1:1 WPT:peat substrates in both cultivars, in addition to the 3:1 WPT:peat substrate for the massii fern. Within each irrigation treatment (low or high), no significant differences in shoot dry weight occurred between substrates.

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Table 1. Effects of substrate and irrigation volume on substrate pH and electrical conductivity from two Boston fern cultivars (*Nephrolepis exaltata* 'Massii' and *Nephrolepis exaltata* 'Bostoniensis Compacta')

		Substrate pH				Substrate EC (mS/cm)			
		Massii	Compacta	Massii	Compacta	Massii	Compacta	Massii	Compacta
Substrate[z]	Irrigation[y]	32 DAP[x]	32 DAP	175 DAP	186 DAP	32 DAP	32 DAP	175 DAP	186 DAP
Peat-lite	low	5.77[w] ab	5.58 a	4.68 ab	4.32 ab	1.17 a	0.71 b	0.93 a	1.48 a
Peat-lite	high	5.97 a	5.71a	5.13 a	4.59 a	0.56 a	0.69 b	0.19 b	0.59 b
1:1 WPT:Peat	low	5.38 bc	5.45 a	4.21 bc	4.12 ab	1.55 a	1.03 ab	0.45 ab	0.83 ab
1:1 WPT:Peat	high	5.53 ab	5.26 ab	4.49 ab	4.08 bc	1.53 a	1.44 ab	0.32 b	0.47 b
3:1 WPT:Peat	low	5.03 cd	5.23 ab	4.01 bcd	3.59 cde	1.93 a	1.49 ab	0.67 ab	0.89 ab
3:1 WPT:Peat	high	5.05 cd	5.32ab	4.26 b	3.83 bcd	1.73 a	0.82 b	0.36 b	0.51 b
100% WPT	low	4.79 d	4.83 b	3.36 d	3.37 de	1.57 a	2.15 a	0.68 ab	0.81 ab
100% WPT	high	4.92 d	4.77 b	3.52 cd	3.17 e	1.03 a	1.12 ab	0.56 ab	0.75 ab

[z] Substrate treatments were: Peat-lite = 8:1:1 peat moss:perlite:vermiculite, WPT = ¼" whole pine tree, and Peat = sphagnum peat moss.

[y] Irrigation volume treatments: low=x and high=2x

[x] DAP = days after planting

[w] Values within column followed by a different letter are significant using Tukey's Studentized Range Test (*P*=0.05)

Table 2. Effects of substrate and irrigation volume on growth of two Boston fern cultivars (*Nephrolepis exaltata* 'Massii' and *Nephrolepis exaltata* 'Bostoniensis Compacta')

		Plant Growth Index[v]				Shoot Dry Weight (g)		SPAD[u]
		Massii	Compacta	Massii	Compacta	Massii	Compacta	Massii
Substrate[z]	Irrigation[y]	73 DAP[x]	73 DAP	167 DAP	179 DAP	168 DAP	182 DAP	167 DAP
Peat Lite	low	49.5[w] bc	38.2 bc	81.4 bc	65.4 bc	101.5 bc	103.2 bc	37.3 a
Peat Lite	high	56.2 a	42.0 abc	87.9 ab	74.4 ab	144.7 a	171.7 a	34.5 a
1:1 WPT:Peat	low	48.3 bc	35.4 c	79.0 c	61.2 c	101.1 bc	91.1 c	35.0 a
1:1 WPT:Peat	high	53.4 ab	44.6 ab	88.1 ab	73.7 ab	145.3 a	160.0 a	33.3 a
3:1 WPT:Peat	low	47.7 c	40.8 abc	77.7 c	67.1 abc	93.7 c	106.9 bc	33.7 a
3:1 WPT:Peat	high	53.6 ab	46.4 a	89.2 a	78.1 a	132.4 a	148.3 ab	32.2 a
100% WPT	low	46.2 c	40.6 abc	78.7 c	66.1 abc	101.4 bc	105.3 bc	32.4 a
100% WPT	high	51.2 abc	42.6 abc	84.4 abc	67.8 abc	126.0 ab	129.5 abc	32.2 a

[z] Substrate treatments were: Peat-lite = 8:1:1 peat moss:perlite:vermiculite, WPT = ¼" whole pine tree, and Peat = sphagnum peat moss.
[y] Irrigation volume treatments: low=x and high=2x
[x] DAP = days after planting
[w] Values within column followed by a different letter are significant using Tukey's Studentized Range Test (*P*=0.05)
[v] Plant Growth Index = (height + width 1 + width 2)/3
[u] SPAD = Leaf chlorophyll content determined using a SPAD-502 chlorophyll meter (average of 4 leaves per plant).

Fertility Effects on Acclimation of *Philodendron scandens* to Low Light Levels

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Index Words: fertilization, chlorophyll, fluorescence

Significance to Industry: Plants placed in interiorscapes need to acclimate to low light. Lack of acclimation can result in leaf senescence, abscission, and plant death. Our objective was to determine how fertilizer levels (Osmocote 14-14-14 at 0, 3, 6, or 12 g per 6" pot) during the production period affect the acclimation of *Philodendron scandens spp*. o*xycardium* to low light. We studied changes in leaf chlorophyll content and some of the physiological processes involved in converting light into chemical energy inside chloroplasts [dark-adapted quantum yield (Fv/Fm) and maximum electron transport rates (ETR_{max})]. Although plants grown with higher fertilizer levels had more chlorophyll and higher ETR_{max}, we found no evidence that fertilizer levels affected the ability of plants to acclimate to low light levels. Thus, growers can fertilize to achieve optimal growth without negative effects on the ability of the plants to acclimate.

Nature of Work: Interiorscape plants normally are produced under much higher light levels than those they subsequently encounter in interiorscapes. Therefore, these plants need to acclimate to the low post-production light levels. A lack of acclimation may result in leaf abscission and eventually plant death. Chlorophyll and the associated photosystems in the chloroplasts are responsible for the absorption of light and the subsequent conversion of the absorbed light into chemical energy, which can then be used for growth processes. Thus, changes in chlorophyll and photosystems, and particularly photosystem II (PSII), which is considered to be rate limiting, may play an important role in acclimation of plants to low light.

Chlorophyll content depends on both light intensity and fertilizer levels, especially nitrogen. Since nutrients can affect leaf chlorophyll content, fertilizer rates may affect the ability of plants to acclimate to low light. Thus, our objective was to quantify the effects of fertilizer rates on chlorophyll content and PSII activity during the acclimation of philodendron to low light levels.

Rooted philodendron cuttings were transplanted into 6" pots on Dec.15, 2006. The pots were filled with a peat-based growing medium (Fafard 2P, Fafard, Anderson, SC). A controlled release fertilizer (Osmocote 14-14-14, Scotts, Marysville, OH) was incorporated into the bottom third of the substrate at rates of 0, 3, 6, or 12 g/pot (0, 0.5, 1, and 2x the recommended rate). Plants were subirrigated with tap water twice daily. After plants had been in the greenhouse for 97 days, they were transferred to growth chambers, which were kept at 77 °F with a 12 h photoperiod, and a photosynthetic photon flux of 29 $\mu mol \cdot m^{-2} \cdot s^{-1}$, provided by incandescent bulbs. This simulated interiorscape conditions.

Leaf chlorophyll content and chlorophyll fluorescence were determined using a SPAD-502 chlorophyll meter (Minolta, Japan) and mini-PAM fluorometer (Walz, Germany) after 0, 3, 5, 7, 14, 21, 28, and 38 days in the growth chambers. A fully expanded leaf was marked on each plant before plants were moved into the growth chambers, and the same leaves were measured throughout the study. On each measurement day, chlorophyll fluorescence of dark-adapted plants (Fv/Fm) was measured after plants had been in the dark for at least 4 hours. Immediately after measuring Fv/Fm, eight more fluorescence measurements were taken while increasing the light from 6 to 700 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Fv/Fm is an indicator of damage to PS II, which can be caused by environmental stress, such as excess light. The electron transport rate was calculated from the fluorescence measurements, assuming that 84% of the incident light was absorbed by the leaf and an equal distribution of light between PSI and PSII. From each light response curve, the maximum value of the electron transport rate (ETR_{max}) was determined, and used as an indicator of the capacity of photosystem II for electron transport (a measure of the capacity of the light reactions of photosynthesis).
The experimental design was a randomized complete block with eight replications and repeated measures. Results were analyzed with regression.

Results and Discussion: Leaf chlorophyll content increased with increasing fertilizer concentrations, especially as fertilizer rates increased from 0 to 6 g/pot. Chlorophyll levels in the 6 and 12 g/pot treatments were similar throughout the study. In addition, the chlorophyll content of the leaves increased throughout the experiment, irrespective of the fertilizer treatment (Fig. 1). An increase in chlorophyll in response to low light levels is a normal acclimation response (Nemali and van Iersel, 2004). However, our data suggest that chlorophyll content is not a good indicator of the rate of acclimation, since it kept increasing throughout the study.
Fv/Fm was lowest (0.723) immediately after the plants were transferred to the growth chamber, indicating that the relatively high light level in the greenhouse caused damage to PSII. The increase in Fv/Fm from day 0 to day 3 indicates that the plants were able to repair this damage within a few days. From day 3 through the end of the experiment, Fv/Fm averaged 0.763, and it was not affected by the fertilizer treatment.
Increasing fertilizer concentrations increased the ETR_{max} on day 0, indicating that the photosynthetic capacity of PSII increased with increasing fertilizer rates. Differences in ETR_{max} among fertilizer treatments had disappeared after three days in the growth chamber, and ETR_{max} in all treatments decreased during the first seven days in the growth chamber. This decrease was most dramatic in the plants fertilized with 12 g/pot, where ETR_{max} decreased from 17 to 8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (53%). The ETR_{max} of unfertilized plants decreased from 12 to 8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (33%).
Some physiological changes occurred quickly while others took weeks after the plants were transferred to low light levels: damage to PSII was repaired within a few days, while the ETR_{max} decreased for approximately one week. Leaf chlorophyll kept increasing during the entire 38-day period of this study. The observed changes were not surprising; increasing chlorophyll content at low light levels is a common acclimation mechanism and allows plants to absorb a larger fraction of the available light. A decrease in ETR_{max} under low light occurs, because light is the driving force for electron

transport. Therefore, when light levels are low, there is no benefit to the plant to have a high capacity for electron transport.

Of the parameters measured in this study, ETR_{max} appears to be the best indicator for acclimation to low light, with a decrease indicating acclimation. ETR_{max} decreased gradually over the course of a week and then remained low and stable during the rest of the experiment. Leaf chlorophyll content increased throughout the entire 38-day period, and even then showed no signs of leveling off. Although this may indicate ongoing acclimation, the persistent changes in chlorophyll content make it difficult to use this parameter to quantify the level of acclimation. Finally, Fv/Fm changed quickly, within three days, but this may be more of an indication of the ability of plants to repair damage to PSII than actual acclimation.

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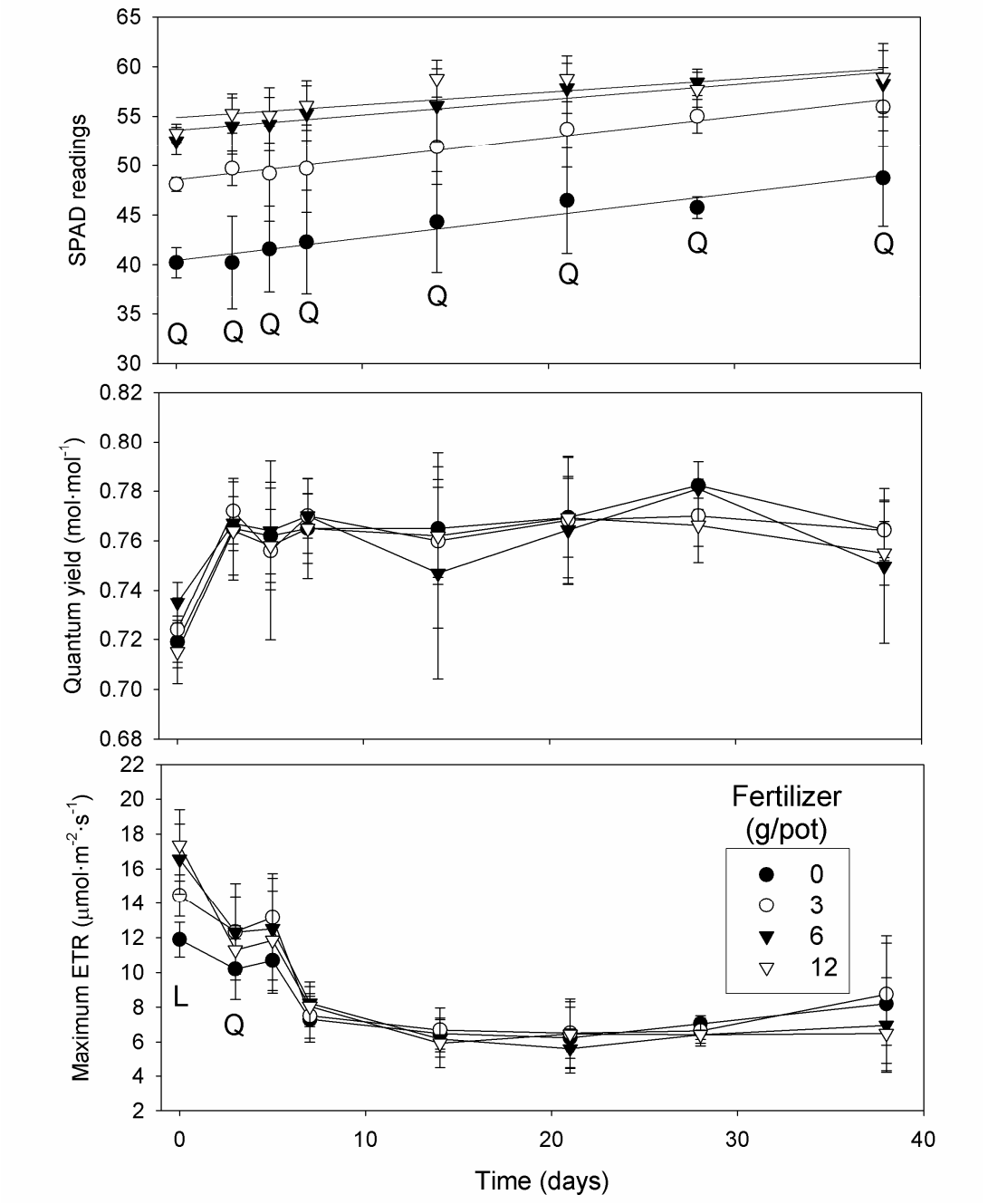

Fig. 1. Leaf chlorophyll content (SPAD reading, top), dark-adapted quantum yield (middle), and maximum electron transport rate of photosystem II (bottom) of philodendron from 0 to 38 days after transferring the plants to a simulated interiorscape. Plants were fertilized with 0, 3, 6, or 12 g/pot of a 14-14-14 controlled release fertilizer at the start of greenhouse production. Data show the mean ± standard error. L and Q indicate linear or quadratic effects on a particular measurement day ($P < 0.05$).

Monaco Snapdragon Production for Fresh Cut Flowers

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Index Words: *Antirrhinum majus*, field production

Significance to Industry: Snapdragon, *Antirrhinum majus*, is a cut flower crop that has potential for field production of a spring crop in the Gulf South (2, 3). A survey of Mississippi consumers reported that they would pay a premium to purchase fresh, cut flowers that were grown in Mississippi (1). The production and market potential of snapdragon as a cut flower crop could have an immediate impact in the local and regional markets.

Nature of Work: The objective of this study was to plant six Monaco cultivars (Group 3, 3) on three spring planting dates to evaluate the potential for a continuous supply of cut flowers. Days to first harvest, stem length, stem diameter, and number of stems per plant were measured. The snapdragons were seeded in a greenhouse and then transplanted to the field beds in an unheated cold frame at the North Mississippi Research & Extension Center in Verona, MS. on 16 Jan., 20 Feb., and 20 March 2007. Data collected during the trial were analyzed by SAS PROC MIXED (SAS Institute Inc, Cary, NC). Mean separation was conducted with Fisher's protected least significant difference (LSD) at the 0.05 significance level.

Results and Discussion: Plants from the January planting date took longer to produce the first harvested blooms compared to the February and March planting dates (Figure 1). The effect of planting date on first harvest varied among cultivars for the February and March dates. The stem diameter for 4 of 6 cultivars was greater in the February planting date compared to January and March (Figure 2). Stem length was shorter for 5 of 6 cultivars planted in January compared to February and for 4 of 6 compared to March (Figure 3). More stems per plant were produced from snapdragons planted in March (Table 4). There were no differences in the number of stems produced per plant due to planting date in January and February. The Monaco series of snapdragons are Group 2, 3. For optimum field production under a cold frame in the Gulf South, Monaco snapdragons should be transplanted to cold frame beds in February - March. Twelve Potomac series cultivars (Group 3, 4) planted in this trial produced more and larger stems when planted in March (data not shown).

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Figure 1. The effect of three planting dates, Jan., Feb., and March 2007, on the number of days required to first harvest of Monaco snapdragon cultivars grown in field beds was observed at the North Mississippi Research & Extension Center, Verona, MS. There was a cultivar x planting date interaction ($P < .0001$). The LSD to compare planting dates for a cultivar was 3.2 while the LSD to compare cultivars for a planting date was 4.7.

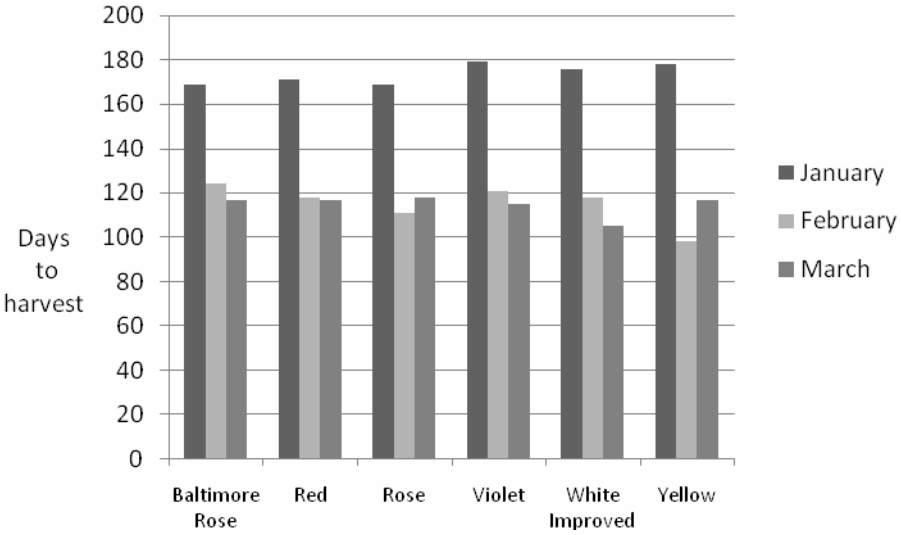


Figure 2. The effect of three planting dates, Jan., Feb., and March 2007, on the stem diameter of Monaco snapdragon cultivars grown in field beds was observed at the North Mississippi Research & Extension Center, Verona, MS. There was a cultivar x planting date interaction (*P* = .0261). The LSD to compare planting dates for a cultivar was 0.03 while the LSD to compare cultivars for a planting date was 0.02.

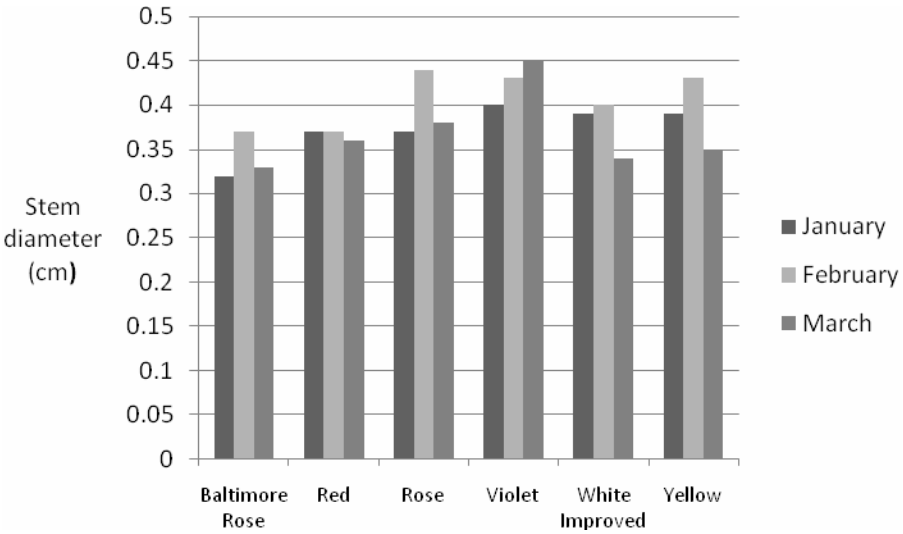


Figure 3. The effect of three planting dates, Jan., Feb., and March 2007, on stem length of Monaco snapdragon cultivars grown in field beds was observed at the North Mississippi Research & Extension Center, Verona, MS. There was a cultivar x planting date interaction (*P* = .0002). The LSD to compare planting dates for a cultivar was 1.6 while the LSD to compare cultivars for a planting date was 2.4.

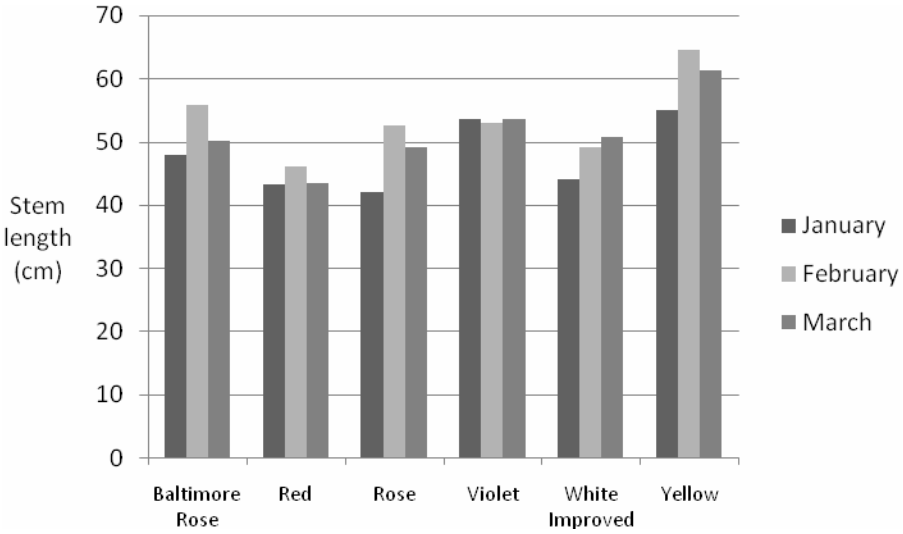
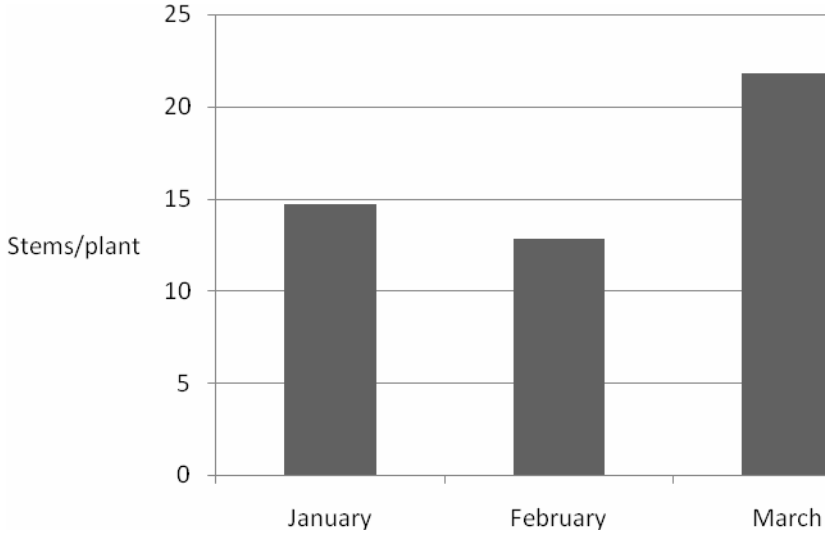


Figure 4. The effect of three planting dates, Jan., Feb., March 2007, on the number of stems per plant of Monaco snapdragon cultivars grown in field beds was observed at the North Mississippi Research & Extension Center, Verona, MS. The LSD to compare planting dates was 5.4.



Do supplemental calcium applications improve salt-tolerance in greenhouse roses?

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Index Words: ameliorative effects, salinity, irrigation, water quality, amendments

Significance to Industry: Results from this experiment are not supported by previous reports stating that amending of saline solutions with supplemental calcium (Ca) ameliorates the adverse effects of salinity on plant growth. The extent of the ameliorative properties of Ca could be influenced by the type of plant, salinity level and/or the counter-ion used. Exploring wider ranges in salt levels and using different Ca salts might help elucidate how influential these factors are in the ameliorative properties of Ca on the tolerance of roses to saline stress.

Natrue of Work: There are three major constraints for plant growth on saline substrates: water deficit due to low water potential of the rooting medium; ion toxicity associated with excessive uptake mainly of Cl and Na; and the nutrient imbalance by depression in uptake and/or shoot transport and impaired internal distribution of mineral nutrients, and calcium in particular (4). Often it is not possible to assess the relative contribution of these three major constraints to growth inhibition at high substrate salinity, as many factors are involved (4). The particular role of calcium in increasing salt tolerance of plants is well documented as is the induction of calcium deficiency in plants grown in saline substrates (4). Amendment of the saline solution with calcium, to increase the Ca/(Na + Mg) ratio, ameliorated the adverse effects of salinity on wheat and barley (2), strawberry (3), and in navel orange it mitigated defoliation and salt injury as well (1). In *Crataegus opaca* 25 m*M* NaCl caused marginal and apical leaf necrosis, and growth, water use and ion uptake selectivity were more negatively affected when supplemental Ca was not included (5). This ameliorative effect of Ca is in accordance with its functions in membrane integrity and control of selectivity in ion uptake and transport (4). Based on these and other results we decided to conduct a study to determine if Ca ameliorates the adverse effects caused by moderately high salinity stress on greenhouse rose plants.

Bare-rooted rose plants (*Rosa spp.* 'Happy Hour') budded on two rootstocks, *R. manetti* and *R.* x 'Natal Briar', were grown in a greenhouse in 12-L (#5) containers filled with a peat moss: pine bark: sand substrate (3:1:1 v/v) amended with dolomitic limestone, Micromax and Aqua-Grow G2000 surfactant (5.0, 1.0 and 1.0 lbs/yd^3, respectively). A modified ½ strength Hoagland solution salinized with 12 m*M* (700 ppm) NaCl and supplemented with 0, 2.5, 5.0, 7.5, and 10.0 m*M* (0, 100, 200, 300 and 400 ppm) Ca (supplied as $CaSO_4$) was used to irrigate the plants. A control treatment (no salinity or supplemental Ca) was included as well. The experimental design was a Randomized Complete Block Design with a factorial arrangement of treatments. Rootstock (RS) and level of supplemental Ca were the factors yielding a total of 10

combinations (treatments) for the supplemental Ca series, plus the control treatments, with six replications per treatment. Solutions were pumped from 150-L containers with submersible pumps and delivered to each plant with calibrated Spot Spitter® spray–stakes connected via spaghetti tubing. Representative plants from each treatment were routinely weighed to gravimetrically determine evapotranspiration (ET). Applied irrigation volumes consisted of ET plus an additional volume to produce a target leaching fraction of 25%. Electrical conductivity, pH, and Cl concentrations in leachates were monitored throughout the experimental period. Dry mass and flower yield and quality were monitored over five flushes of growth and flowering, and leaf tissue was analyzed for chlorophyll (SPAD), Cl (all five harvests), Na (harvests III and IV) and Ca (harvests II and IV) concentration. At the end of the experiment, whole plants from each treatment were destructively harvested and analyzed for biomass partitioning and total nutrient content. Data were analyzed using SAS ® 9.1.

Results and Discussion:

Yield and flower quality: From the variables evaluated during regular flower harvests, only dry weight (DW) was significantly affected by rootstock selection (RS), with *R. manetti* plants showing higher DW than those on *R. x* 'Natal Briar' (132 and 120 g, respectively). There were not effects of supplemental Ca on any of the variables evaluated during regular flower harvests (Fig. 1 A-D). Control plants (non-salinized) had higher DW and harvested flowers than salt stressed plants receiving supplemental Ca (Fig. 1 A-B), while SPAD readings and flower shoot lengths were statistically the same (Fig. 1 C-D). For variables evaluated during the destructive harvest of whole plants at the end of the experiment, there were no differences between RS or effects due to addition of Ca to the saline solutions (data not shown); there were also no differences when comparing the Ca series treatments against the non-salinized controls.

Tissue chloride concentration: There were no effects due to RS or supplemental Ca on tissue Cl concentration in both leaves of harvested flower shoots and in the various plant organs from the destructive harvest (data not shown). As it was expected, the salinized plants (receiving 12 m*M* NaCl) had higher leaf Cl (avg. of 7,155 mg/Kg) compared to the non-salinized controls (avg. of 1,683 mg/Kg). Leaf Cl accumulation in flower shoots increased from one flower harvest to the next over the whole experiment and was similar for all supplemental Ca treatments (averaging 2,852, 4,175, 8,549, 10,238 and 10,699 mg/Kg for harvest I, II, III, IV and V, respectively).

Tissue sodium concentration: There were no effects due to RS or supplemental Ca on leaf Na concentration in flower shoots and there were not differences either when compared to the control plants. Similar to Cl, leaf Na concentrations for all treatments increased from harvest III to harvest IV (281 and 386 mg/Kg, respectively). For the final whole-plant destructive harvests both RS had the same Na concentration for all evaluated organs, except for roots, where *R. manetti* plants had slightly higher Na than in *R.* x 'Natal Briar'. Tissue Na concentrations in all organs, except the leaves, of the non-salinized control plants were lower than in the salinized treatments (results not shown).

Tissue calcium concentration: There were no effects due to RS or supplemental Ca on leaf Ca concentration, and also no differences were detected between the control (non-salinized) treatment and the supplemental Ca treatments. Leaf Ca in harvested flower shoots was higher in harvest II than in harvest II (16.8 vs. 13.6 g/Kg).

Leachate pH, electrical conductivity and Cl concentrations: There was no effect due to RS on leachate pH. However, there were effects due to supplemental Ca, as pH decreased as the levels of Ca in the saline solution increased for both RS (Fig. 2A). Leachate pH values in the Control treatment were higher than those in the salinized treatments for both RS (Fig. 2A). Electrical conductivity (EC) increased as Ca levels increased for *R. manetti* but remained similar among the Ca series treatments in *R.* x 'Natal Briar' (Fig. 2B; data not shown). Leachate Cl concentrations in *R. manetti* plants were similar across all salinized treatments, but in *R.* x 'Natal Briar' they tended to decrease as supplemental Ca concentrations were increased (Fig. 2C). As expected, average EC and Cl concentrations in the salinized treatments were higher than in the control treatment (Fig. 2 B-C).

Salt burn in foliage. In general, salt burn damage was more severe in leaves of *R. manetti* plants than those of *R.* x 'Natal Briar' (Fig. 3 A-B). Average salt burn ratings increased as the level of Ca increased, this being more noticeable in *R.* x 'Natal Briar' plants.

From these results we conclude that supplemental Ca did not ameliorate the effects of moderately high salinity stress on yield and flower quality responses of *Rosa spp*. 'Happy Hour'. On the contrary, it worsened leaf marginal and apical salt burn, especially in plants budded on *R.* x 'Natal Briar'. Supplemental Ca did not affect (neither positively nor negatively) leaf ion content. Leaching fractions from plants budded on *R. manetti* were lower than those from *R.* x 'Natal Briar', particularly in the highest three levels of supplemental Ca, which could explain the increase in leachate EC.

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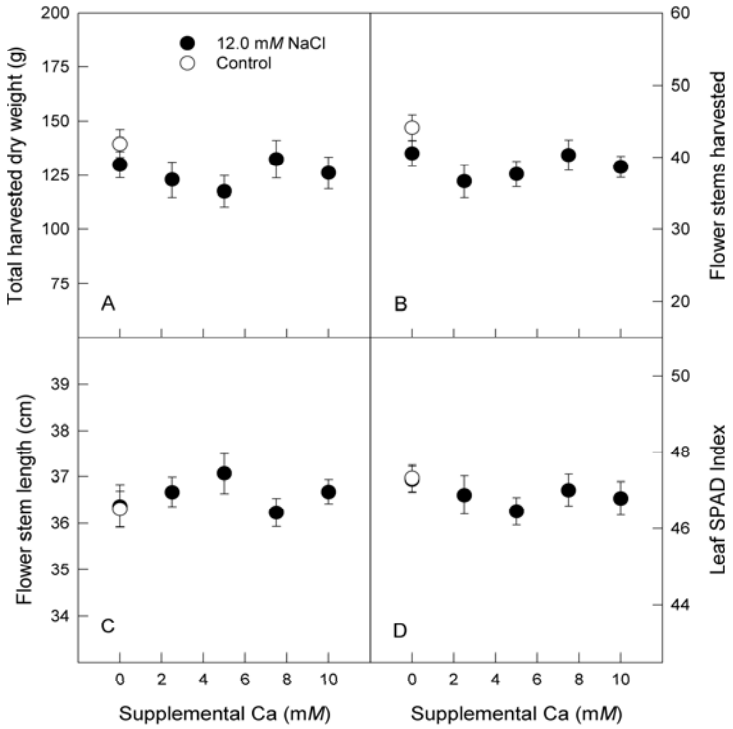

Fig. 1. Effects of supplemental Ca on cumulative harvested dry weight (A), flower shoots (B), flower stem lengths (C) and leaf SPAD index (D) of 'Happy Hour' rose plants subjected to 12 m*M* NaCl. The controls were not exposed to NaCl or additional Ca.

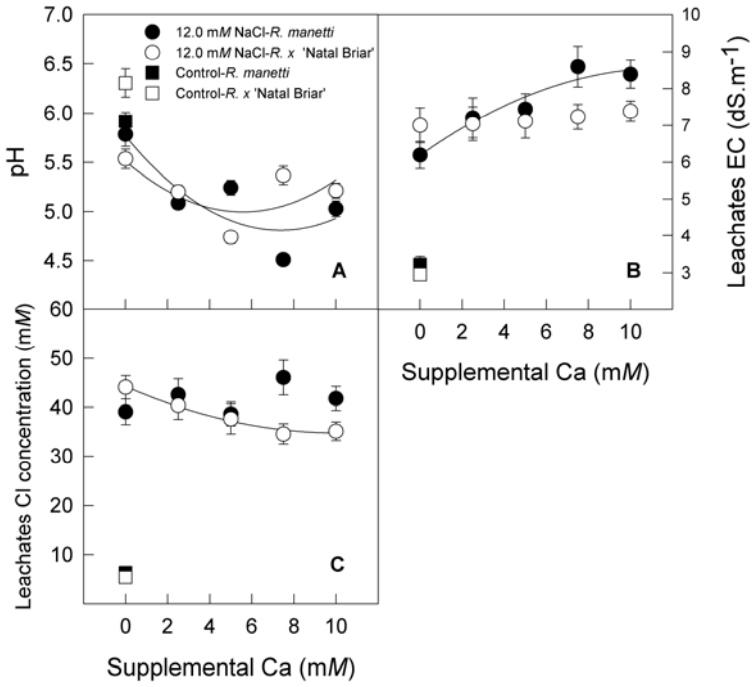

Figure 2. Leachate pH (A), electrical conductivity (B) and Cl concentration (C) in 'Happy Hour' rose plants subjected to 12 m*M* NaCl. The controls were not exposed to NaCl or additional Ca.

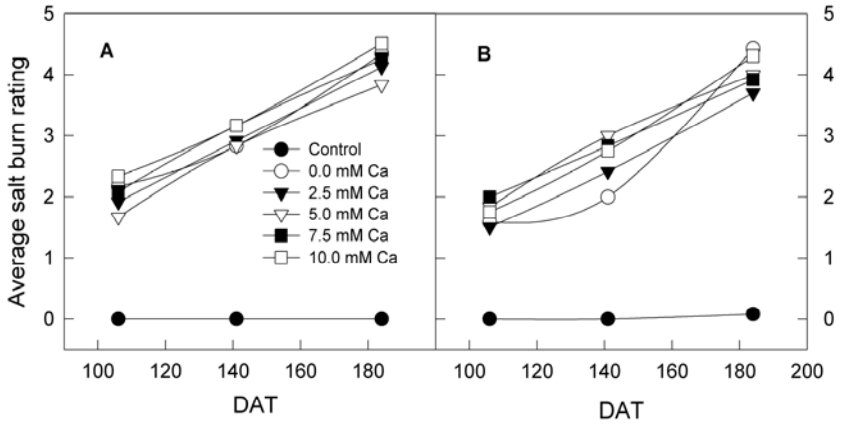

Figure 3. Average salt burn ratings (0= No damage; 5= Worst damage) in foliage of 'Happy Hour' rose plants budded on *R. manetti* (A) and *R.* x 'Natal Briar' (B), salinized with 12 m*M* NaCl and supplemented with additional Ca. Controls were not exposed to NaCl or additional Ca.