The Effects of Potting Container Size and Irrigation Frequency on Medium Temperature©

Gabriela Nunez and R. Keith Osborne
Gro-Bark (Ontario), Ltd., 12300 Britannia Road, Milton, Ontario, L9T 7G5, Canada
Email: keith@gro-bark.com

This report focuses on the effects that potting container size and irrigation frequency has on the medium temperature and overall appearance of *Senecio cineraria* (dusty miller). A 7-week trial was conducted in which 20 four replicates of *S. cineraria* were potted into 1-, 2-, and 3-gal containers and evenly divided into two irrigation treatments: as needed (Treatment A), and on a daily basis (Treatment B). Their medium temperatures, as well as ambient and ground temperatures, were recorded throughout the trial.

Quantitative results showed that plants in Treatment A tended to exhibit higher medium temperatures, usually surpassing ambient temperatures. Results also showed that the medium temperatures of plants in 1-gal container were usually the highest ones and tended to fluctuate more than those of plants in 2- and 3-gal containers, and they also tended to exceed ambient temperatures. Finally, difference in temperature between container size was less evident for plants in Treatment B. Qualitative results showed that plants in Treatment B were bigger, more abundant, and had less dry leaves than plants in Treatment A; and that plants in 1 gal containers were the smallest and exhibited more dry leaves.

It was concluded that daily watering of *S. cineraria* helps to maintain their medium temperatures close to their preferred range more effectively, that *S. cineraria* grow faster and healthier when potted into 2-gal and 3-gal containers, and that medium temperature is ultimately dependant upon their surroundings. Recommendations include watering *S. cineraria* every day, potting them into containers bigger than 2 gal, and conducting further research and enhanced trials on this area.

INTRODUCTION

Over the past years, container-grown plants have emerged as the most popular method of growing plants for sale in the horticulture industry (Evans, 2013). With its many benefits, such as better establishment of plants after transplanting, decreased labour, and increased product availability, growers have started to shift from traditional in-ground production to the container one (Mathers et al., 2007). Nevertheless, growing plants in containers alters root growth and function, and it may change root morphology (Mathers et al., 2007). In fact, roots of container-grown plants are especially susceptible to temperature and moisture extremes that are not normally found in field production (Henley et al., 2006). *Senecio cineraria* (Dusty Miller), in particular, prefers a medium temperature of 18 to 23°C (Cornell University, 2006) and is especially water hungry when grown in containers (Wishhart, 2014). Two important factors that affect medium temperature of container-grown plants are the size of the potting container and water regimes. According to Martin and Ingram (1993), different potting container dimensions might either alleviate or intensify optimal rooting medium temperatures, which in turn have an effect on the well-being of the plant. Irrigation water also plays an important role in affecting the medium temperature of plants as it may help disperse heat energy and maintain plant media at an optimal temperature (Martin and Ingram, 1991). Even though it is well known in the horticulture industry that these two factors affect the medium temperature of plants, many growers have issues determining the optimal container size and water regimes for their crops. Therefore, the purpose of this report is to analyze the effect that potting container size and water regimes have on the medium temperature of *S. cineraria*, and to clarify the role of container size and irrigation as a useful management tool for heat dispersal. The report will examine the results of a seven-week temperature trial, reach a conclusion, and propose appropriate recommendations.

CONTAINER-GROWN PLANT PRODUCTION

Container-grown plant production is the practice of growing plants exclusively in containers as opposed to planting them in the ground (Mills, 2012). Due to its flexibility, portability, and compaction, container-grown plant production has become extremely popular nowadays, with more and more growers adapting this method and seeing it as more appropriate (Missouri Botanical Garden, 2014). Some benefits of container-grown plant production include control of growing conditions, such as soil, water, sunlight, and nutrients; low requirements of money, human capital, and tools; maximization of growing space; and many more (Mills, 2012).The growth of plants will ultimately depend on providing the basic needs of each species, an adequate growing medium, sufficient light, proper temperature, and necessary moisture and nutrients (Missouri Botanical Garden, 2014).

Even though container-grown plants are extremely popular, it is important to keep in mind that growing in a closed system unfortunately increases the susceptibility of plants to health issues and causes the root zone to be very fragile (Million et al., 2011). This is because containers are an artificial environment and thus lack the healthy soil ecosystem usually found in raised beds and in-ground gardens (Williams, 2014). Containers also do not retain water for long periods of time and they tend to heat up a lot faster, depending on their size (Martin and Ingram, 1991). These factors ultimately affect the medium temperature of the plant and, in turn, the success of its growth (Martin and Ingram, 1991). Since physical support is the only feature sustained after the initial planting, appropriate container size, and levels of irrigation are essential for the cultivation of premium quality plants (Bailey et al., 2001).

SIGNIFICANCE OF MEDIUM TEMPERATURE IN PLANT HEALTH AND IMPORTANCE OF STUDY

Maintaining an adequate medium temperature is extremely important for the well development of plants (Mathers, 2001). High medium temperatures are a major limiting factor in the distribution, adaptability, and productivity of wild and cultivated plants and may result in inhibition of growth or plant decline (Mathers, 2001). Net photosynthesis, in particular, is one of the most heat-sensitive processes that govern plant growth (Hamerlynck and Knapp, 1995). Heat stress has been shown to be a major limiting factor for plant production and adaptability in containers since the roots of container plants are exposed to more rapid fluctuations and greater extremes in temperatures than plants grown in the ground (Henley et al., 2006). With the increased use of containers as a culturing method, determining the appropriate temperature for the optimal growth of specific species has become of high importance (Bunt, 1988). In fact, growers could encounter a cost of more than $200 per cubic yard of container plants through losses in plants or reduced plant quality due to a poor container medium (Henley et al., 2006). Since the size of the potting container and the watering regimes are important factors that affect medium temperatures, choosing the right container and developing an adequate irrigation regime is an investment that will pay great dividends in terms of plant growth and quality (Martin and Ingram, 1991). In hopes of improving the horticultural industry and the container stock production, Mr. Keith Osborne has proposed to do a study about the effects of potting container size and irrigation on the medium temperature of *S. cineraria.* This study will ultimately help determine the effects container size and irrigation frequency have on medium temperature of plants, as well as provide insight for prospective investigations.

MATERIALS AND METHODS

Methodology

The study began on 17 June 2014, and lasted for 6 weeks until 25 July 2014. The entire trial took place at Gro-Bark's Milton site located on 12300 Britannia Road East, Milton, Ontario, Canada, where 30 replicates of *S. cineraria* in 1-gal, 2-gal, and 3-gal potting containers were placed on the west field next to the front parking lot. The following section explains the materials used, the experimental set-up, the watering regimes, and the data collection for this study.

Materials

- 10 1-gal black potting containers
- 10 2-gal black potting containers
- 10 3-gal black potting containers
- 30 plugs of *S. cineraria*
- 8 HOBO® meter
- Hanna® pH and conductivity metre
- Temperature metre
- 60 gal of bark mix of Sheridan 2014 #3
- Distilled water
- Plant rack and collecting tray
- White oil-based pen
- 40-cm identifying flag
- 50-ml testing cup
- 550-ml measuring cup
- 250-ml graduated cylinder
- Hose
- Data collection sheet

Experimental Set-Up

Set-up for the study began on the first day during the afternoon when ten replicates of *S. cineraria* were potted in a 1-gal, 2-gal, and 3-gal potting containers for a total of 30 replicates. Plants were located on the west field next to the front parking lot and separated into two different sections based on their watering regimes, as shown in Figure 1. Plants in section A were irrigated as needed (Treatment A), and plants in section B were irrigated once a day during the early morning (Treatment B). A buffer zone of approximately 2.65 m was left between the two sections. Within Treatment A and Treatment B, plants were separated into three different subsections depending on their potting container size. For example, plants in Treatment A that were potted into the 1-gal potting containers were in one group called TA-1; those that were potted into the 2-gal potting containers were in another group called TA-2; and those potted into the 3-gal potting containers were in group TA-3. All plants were potted in a soilless mix called Sheridan 2014 #3, which was supplied by Gro-Bark. This mix contains 40% of composted pine bark, 35% of aged bark – Blend A, 15% of compost, 10% of peat moss, and fertilizer Osmocote© 21-4-8 at a rate of 3.18 kg per yard^3.

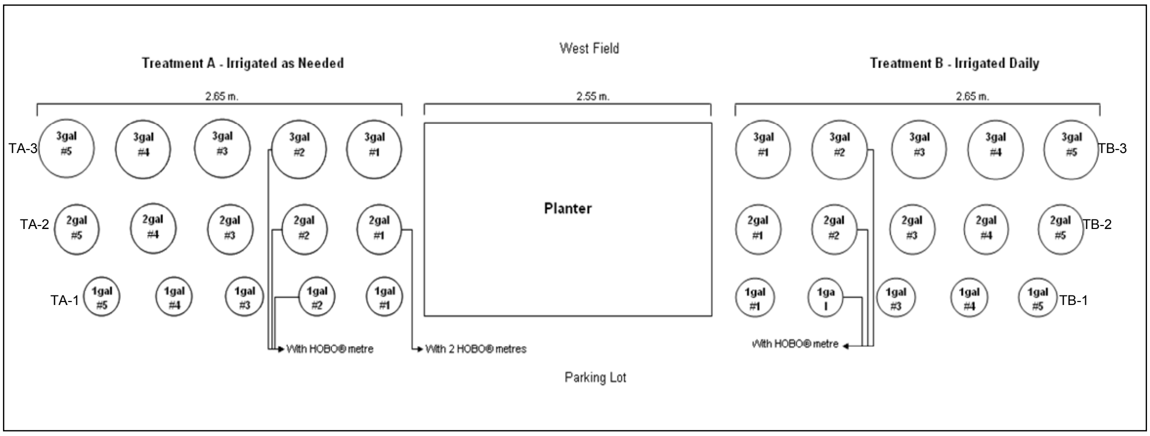

Fig. 1. Experimental set-up for the temperature trial.

Potting

Plugs were obtained from Sheridan Nurseries and were transferred to Gro-Bark Milton's location. Potting began on the first day of the trial on 17 June 2014 and took place at the west field. All plugs were potted by one Gro-Bark employee in order to reduce the variability in potting techniques. The plant species, mix, and fertilizer rate combination were repeated five times per potting container size and per water treatment to decrease variability of experimental results and increase the chance of statistical significance. The potting procedure is explained below.

1) Fill a 1-gal container three quarters of the way with Sheridan 2014 #3 mix.
2) Compact the mix by lifting the pot approximately 3 in. off the floor and then let it fall. Repeat this two more times.
3) Insert the plug into the container.
4) Backfill the container with the mix.
5) Firm mix by repeatedly applying light pressure with your fingertips to top surface of the mix.
6) Add or subtract soil as necessary to ensure there is 1.5 cm between the medium and the pot lip.
7) Label the pot with the correct container size, sample number, and watering treatment name and code.
8) Place the species in its corresponding section as shown in Figure 1 and ensuring equal spacing between each pot.
9) Repeat steps 1-8 nine more times to achieve a total of 10 identical replicates.
10) Repeat steps 1-9 for the 2-gal and 3-gal potting containers.
11) Insert one HOBO meter into the core of Sample #2 of the 1-gal, 2-gal, and 3-gal potting containers for both watering treatments. Position it in the centre of the pot and right below the plant.
12) Place one HOBO meter on top of Sample #1 of the 2-gal container of Treatment A as shown in Figure 2.
13) Tie another HOBO meter to the top of the 40-cm identifying flag and stick the flag onto Sample #1 of the 2-gal container of Treatment A as shown in Figure 2.

Fig. 2. HOBO® metres placed in Sample #1 of the 2-gal container of Treatment A.

Irrigation

Plants were irrigated by placing a hose on top of the soil and watering it until a bed of water of approximately 1 cm was visible. The first irrigation took place right after potting on 17 June 2014 at around 4:30 PM. After that, plants in Treatment A were irrigated once or twice a week, depending on precipitation levels and dryness of the plants. Hot and dry weeks usually resulted in plants being watered twice a week, whereas mild and wet weeks resulted in only one irrigation treatment per week. Plants in Treatment B were irrigated every day during the early morning around 8:30 AM. Due to lack of personnel, plants were not irrigated during the weekends and holidays.

Data Collection

The data that the temperature trial looked at was ambient temperature, soil temperature, precipitation levels, pH, and electrical conductivity (EC), as well as overall appearance of the plants. Ambient temperature was obtained with the two HOBO meters placed in Sample #1 of Treatment A, and soil temperature was obtained with the other six HOBO meters that were inserted into the core of Sample #2 for the 1-gal, 2-gal, and 3-gal potting containers for both watering treatments. All eight probes were programmed to collect data at 15 min intervals from 17 July 2014 at 4:00 PM until 25 July 2014 at 4 PM. Precipitation data was obtained every morning using a standard rain gauge that was placed on top of one the planters by the west field. A week after activating the probes, weekly pour through tests for all Samples #3 were performed every Friday around 8 AM to measure pH and EC levels for the medium. Pour through tests were conducted in accordance with the procedure below.

1) Place Sample #3 of the 1-gal container size of Treatment A upon a rack with collecting tray.
2) Measure 250 ml of distilled water and pour this into the pot. It is important to pour the water in the center of the pot and to pour slowly to avoid water running down the inside wall of the pot without being filtered through the soil.
3) Check to see if the collecting tray contains any leachate. If there is no leachate, slowly continue to pour water onto the soil in 100-ml increments until at least 30 ml of leachate is obtained.
4) Record the amount of water poured into the pot in the data collection sheet.
5) Pour the leachate into a small 50-ml testing cup.
6) Obtain the pH/EC probe and rinse with distilled water.
7) Turn on the probe and set it to the pH function.
8) Insert the probe into the testing cup and wait for the pH to stabilize.
9) Once the pH has stabilized enter the EC mode by pressing the EC button located on the meter, wait for the EC to stabilize and record this number on the data collection sheet.
10) Enter the pH mode once more and record this number on the data collection sheet.
11) Record the amount of leachate by pouring the remaining liquid left in the collecting tray in the 250-ml graduated cylinder and then adding this amount to the 30 ml of leachate that was poured into the testing cup.
12) Rinse all equipment with distilled water.
13) Place plant back into its corresponding section.
14) Repeat steps 1-13 for Sample #3 of the 2-gal and 3-gal potting containers in Treatment A.
15) Repeat steps 1-14 for Treatment B.

RESULTS

Results were divided into quantitative and qualitative ones. A total of 18 graphs were constructed to depict the data obtained for the entire duration of the trial and were divided according to their specific purpose. The week of 8 July to 14 July 2014 shows the typical outcome, with ambient temperatures peaking at noon and declining as the day progresses, and it will be the focus of this section.

Quantitative Results

The data showed that the temperature recorded with the HOBO meter placed on top of the soil and the one placed 1½ m above it was significantly different, with the ground temperature being generally 10°C higher. The maximum ground temperature was 56.6°C and the maximum ambient temperature was 40.2°C. They both occurred on 28 June 2014 at 14:15. Out of all the plants with HOBO meters, the plant in the 1-gal container in Treatment A (irrigated as needed) showed the highest maximum medium temperature of

43.8°C, while the plants in the 3-gal container in Treatment B (irrigated daily) showed the lowest maximum medium temperature of 38.8°C. The plant in the 1-gal container for Treatment A also showed the lowest minimum medium temperature of 9.3°C, while the plant in the 3-gal container for Treatment A showed the highest minimum temperature of 13.1°C. The plant in the 3-gal container for both Treatment A and B showed the highest average medium temperature of 25.2°C for the one in Treatment A, and 24.5°C for the one in Treatment B. Statistics are depicted in Table 1.

Table 1. Maximum, minimum, range, and average ambient and medium temperatures.

	Temperature (°C)							
	Ambient ground	Ambient 1½ m	Treatment A			Treatment B		
			1 gal as needed	2 gal as needed	3 gal as needed	1 gal daily	2 gal daily	3 gal daily
Max	55.6	40.2	43.8	41.9	40.5	41.6	40.3	38.8
Min	6.5	7.5	9.3	11.4	13.1	9.6	10.9	12.1
Range	49.1	32.7	34.6	30.5	27.5	32.0	29.4	26.7
Average	24.6	22.9	24.5	25.1	25.2	23.6	24.3	24.5

During the afternoon, plants in Treatment A tended to exhibit higher medium temperatures, while during the night and early morning plants in both treatments shared similar medium temperatures, as shown in Figures 3, 4, and 5. Medium temperatures of plants in both treatments generally exceeded ambient temperatures, although plants in treatment A had a tendency to do so more often. They only exceeded ground temperatures during the night and early morning. After that, ground temperatures tended to be significantly higher than medium temperatures.

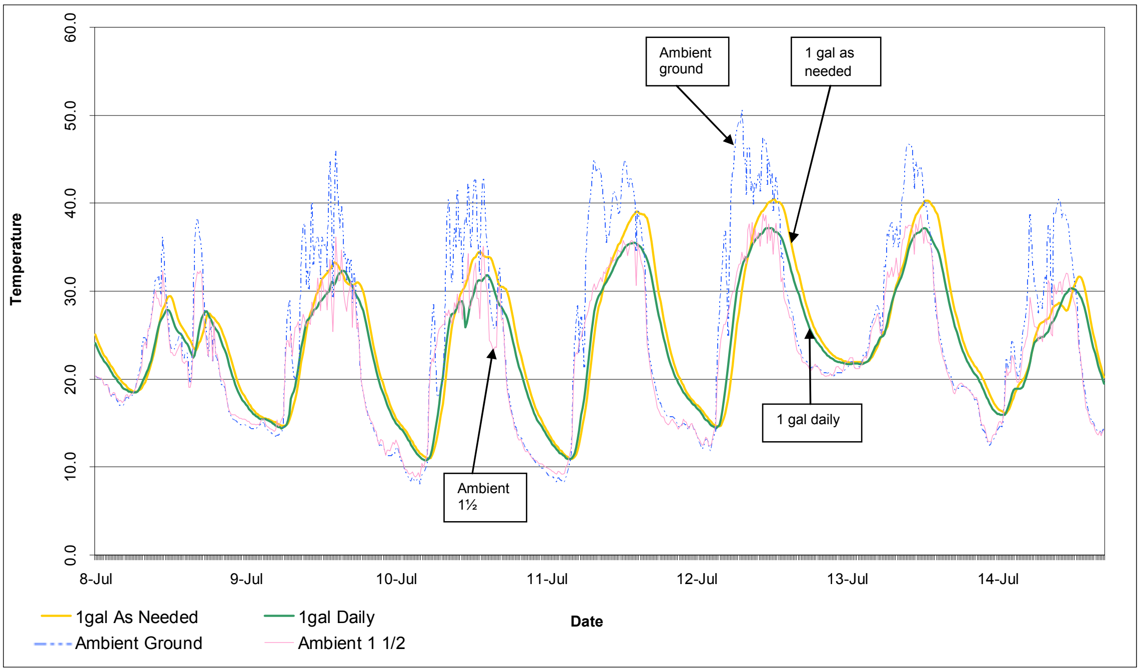

Fig. 3. Comparison of the medium temperature between Treatment A and B for 1-gal containers (8-14 July 2014).

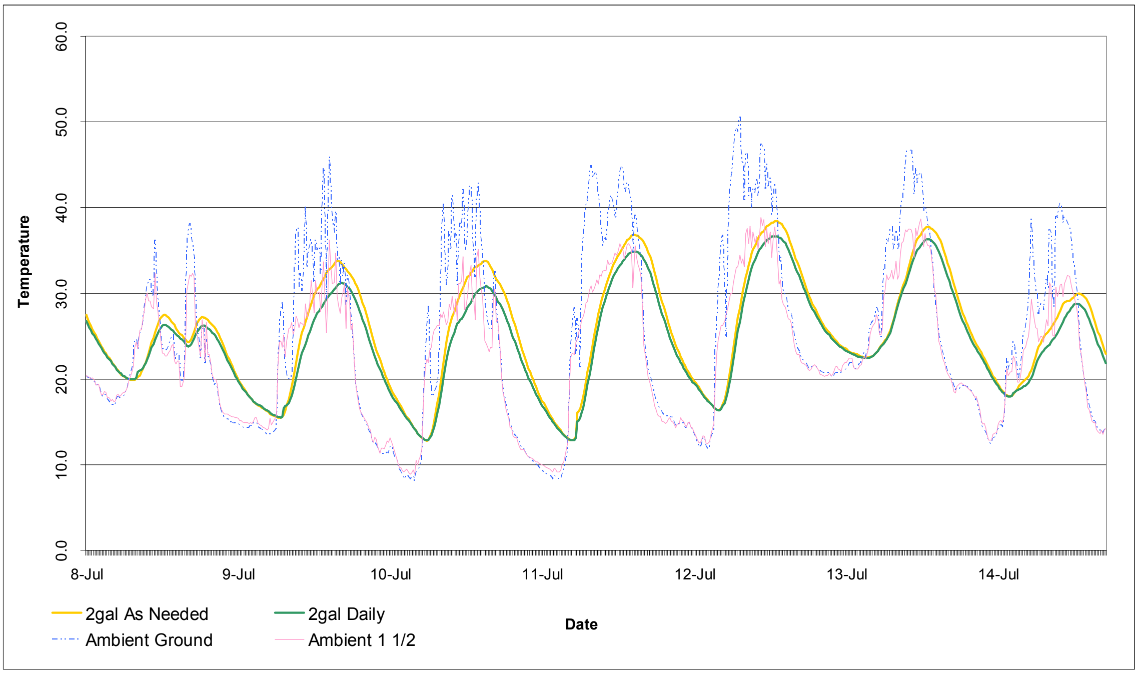

Fig. 4. Comparison of the medium temperature between Treatment A and B for 2-gal containers (8-14 July 2014).

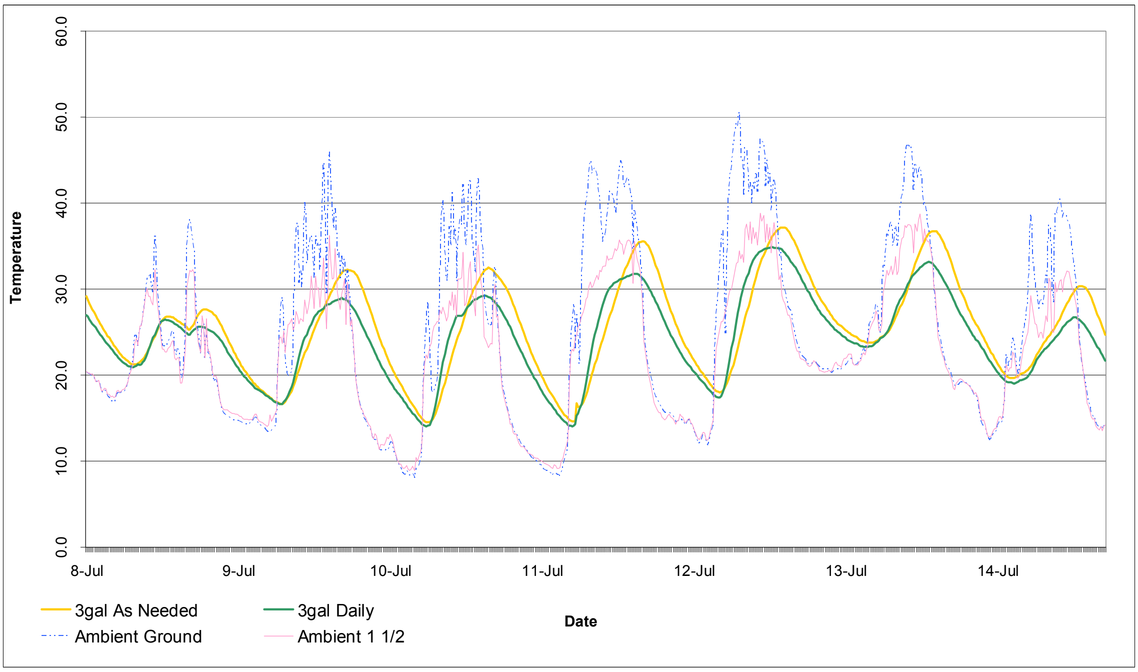

Fig. 5. Comparison of the medium temperature between Treatment A and B for 3-gal containers (8-14 July 2014).

Results also showed that the medium temperature of plants in 1-gal containers of both treatments fluctuated more than medium temperatures of plants in 2-gal and 3-gal containers, exhibiting the highest range of all containers of 34.6°C for Treatment A and 32.0°C for Treatment B. Medium temperatures of plants in 1-gal containers were usually the highest ones, especially during the late morning and afternoon, and they tended to exceed the ambient temperature with more frequency. All plants exceeded the ambient and ground temperature during the night and early morning, where plants in 3-gal containers had the highest medium temperature. Finally, differences in temperature between containers size was less evident for plants in Treatment B.

As for pH and EC results, plants in both treatments shared the same average pH of 6.7 and very similar average EC results of 1.62 mS·cm^{-1} for Treatment A and 1.58 mS·cm^{-1} for Treatment B. Plants in Treatment A yielded a lower leachate percentage of 31.09% as compared to plants in Treatment B with a leachate percentage of 33.89%, as shown in Table 2. Both pH and EC tended to increase as container size increases, although this is more evident with pH.

Table 2. Field test result averages for Treatment A and B.

Treatment	Pot size (gal)	H_2O added (ml)	Leachate (ml)	Leachate (%)	pH	EC (mS·cm^{-1})
A: As needed	1	208.33	79.83	38.32	6.5	1.24
	2	333.33	119.17	35.75	6.7	1.84
	3	533.33	102.33	19.19	6.8	1.78
	Average	358.33	100.44	31.09	6.7	1.62
B: Daily	1	225.00	97.50	43.33	6.5	1.45
	2	333.33	86.67	26.00	6.8	1.65
	3	533.33	172.50	32.34	6.8	1.65
	Average	363.9	118.9	33.89	6.7	1.58

Qualitative Results

At the end of the trial, plants in Treatment A exhibited more dry leaves and looked less abundant than plants in Treatment B, as shown in Figure 6. Plant size and abundance increased as potting container size increased, making the plants in 1-gal containers the smallest for both treatments, also shown in Figure 6. The biggest plants were found in the 3-gal containers. Plants in 1-gal containers in both Treatments also tended to exhibit some dry and yellow leaves at the bottom, as shown in Figure 7. When it comes to plants in 2-gal and 3-gal pots, plants in Treatment B did not exhibit any dry leaves but those in Treatment A seemed to have a few dry leaves at the bottom.

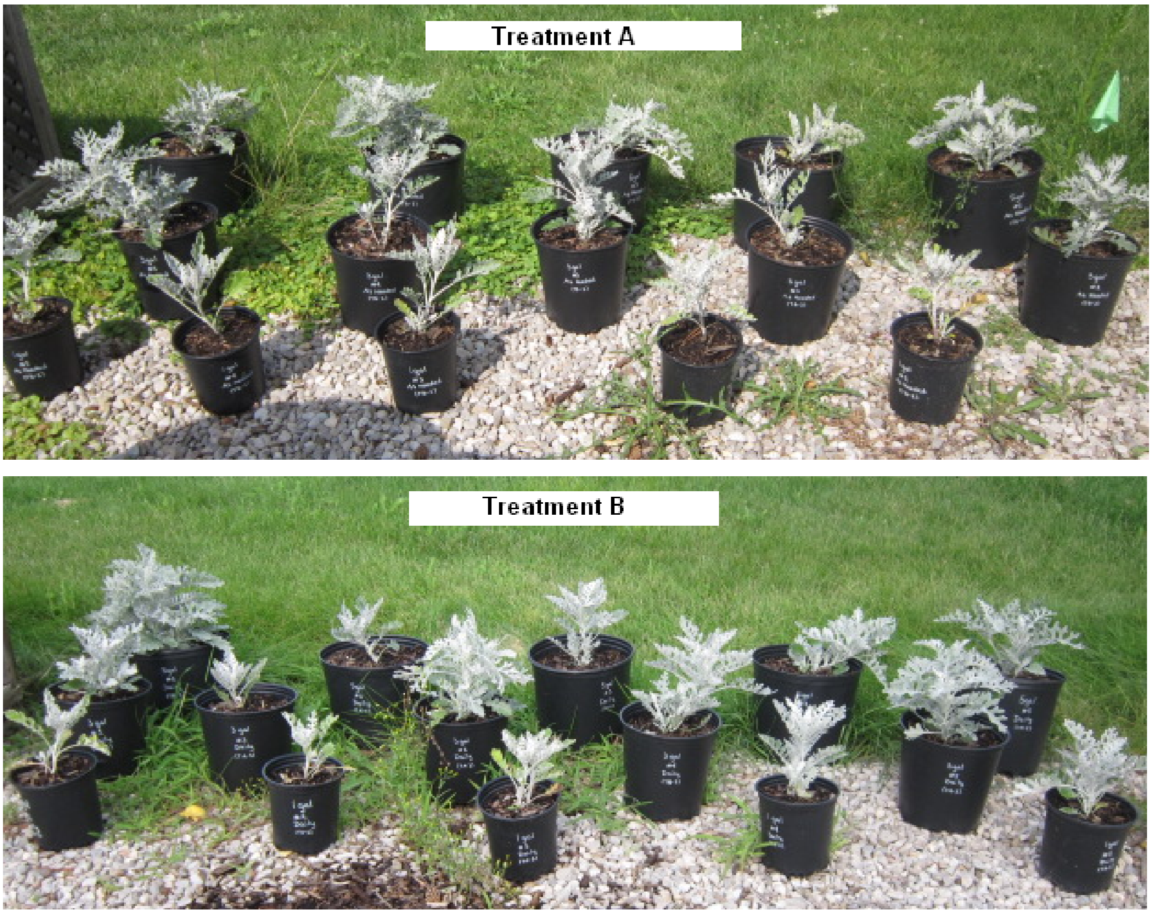

Fig. 6. Comparison of size and abundance of plants in Treatment A and B.

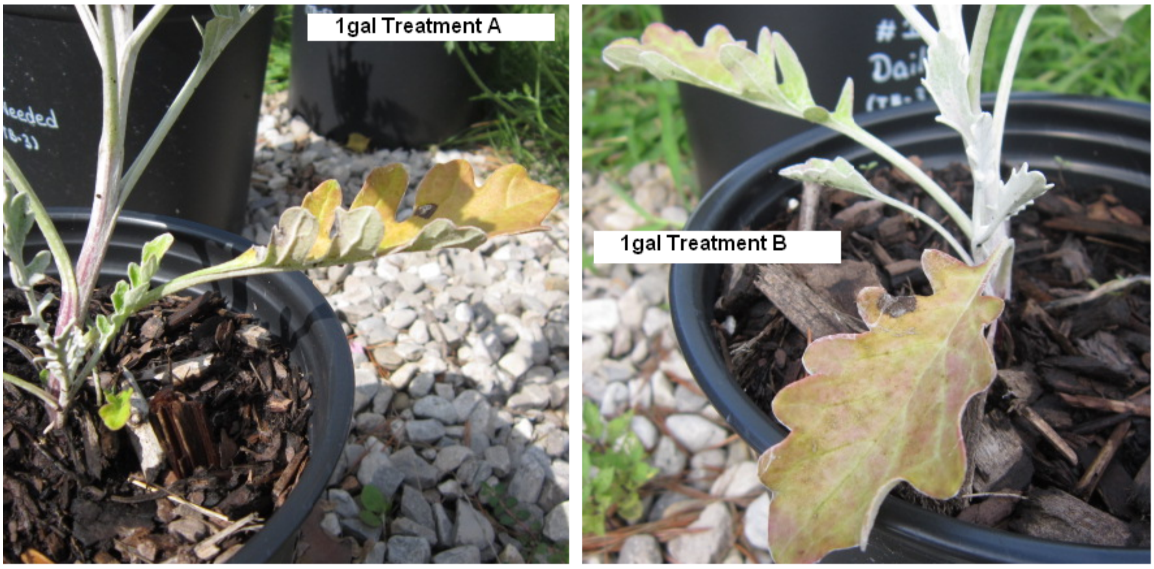

Fig. 7. Plants in 1-gal pots exhibiting yellow leaves in Treatments A and B.

DISCUSSION AND INTERPRETATION

Once all the data was organized, theories could then be revised. Throughout the trial, ambient and ground temperatures showed extremes changes unlike the medium of all plants which generally followed the same curvy pattern. However, medium temperatures of all plants usually tended to correlate with the ambient and ground temperatures. As seen in Figure 4, the peak medium and ground temperature occurred around noon when there is more direct sunlight. After that, temperatures decreased as the sun started to set. Medium temperatures revealed a similar tendency, with temperatures increasing and decreasing around the same time as ambient and ground temperatures do so and strongly suggesting that the warmth of the medium of all plants is dependent upon its surroundings. It is interesting to note that medium temperatures of all plants generally tended to exceed ambient temperatures, suggesting that the medium was usually warmer than its exterior. In comparison to temperature data obtained by previous Gro-Bark trials, medium temperatures for this study were significantly higher. In fact, medium temperatures in previous studies were well below the ambient temperature. This raises the question of why medium temperature for this trial was significantly higher and provides opportunities for future research. Possible reasons could include the proximity of the plants, the level of shade received, the colour of the pots, and the solar radiation. Another interesting observation is that ground temperatures were generally higher than ambient temperature. This could be because the HOBO meter recording ground temperature was placed directly on top of the soil, and thus it was receiving some of the heat that the soil itself was releasing and it was barely receiving any currents of air.

There were also many interesting findings when comparing medium temperatures and the appearance of plants between both irrigation treatments. In general, plants in Treatment A had higher medium temperatures and tended to exceed ambient temperatures more often than plants in Treatment B. Additionally, plants in Treatment A exhibited more dry leaves and were less abundant than plants in Treatment B. These findings are consistent with the theory that irrigation usually lowers the medium temperature of container-grown plants and, in turn, allows for a healthier plant growth. In fact, a study performed by Keever and Cobb (1985) showed that overhead irrigations reduced container medium temperatures and increased the root growth of *Rhododendron* 'Hershey's Red' compared to irrigations applied as needed. This is because the temperature differential between the irrigation water and container medium "creates a gradient for the flow of heat energy by the thermal processes of conduction and convection until temperature equilibrium is established" (Martin and Ingram, 1991). However, Keever and Cob (1985) discuss that this is only true if the temperature of the irrigation water is lower than the medium temperature and a sufficient volume of water is applied to physically disperse the thermal energy, which was indeed the case for this trial. Furthermore, the results showed that the difference in medium temperature between container sizes is less evident for plants in Treatment B. This could be because water mitigates temperature fluctuations by allowing plants to release more energy, making in this way medium temperatures less variable in Treatment B. Temperature results and overall appearance of plants in Treatment A when compared to those in Treatment B strongly suggest that irrigation water, when cold and applied in sufficient volumes, may be a successful method for lowering container medium temperatures, dispersing heat energy, and optimizing root development and the well-being of plants.

The trial also provided interesting findings when comparing medium temperatures and the appearance of plants between different container sizes. In general, medium temperatures of plants in 1-gal containers were usually higher. This is also consistent with previous studies and theories that discuss that smaller containers tend to heat up faster as heat has a more limited space to disperse and thus it is concentrated more intensely (Martin and Ingram, 1993). Plants in smaller containers also do not retain water as well as those in bigger containers, and thus the medium temperature is usually higher (Martin and Ingram, 1993). High medium temperatures could be the cause of why plants in 1-gal containers showed browner leaves than those in 2 and 3-gal containers, especially at the bottom. However, another cause could also be that when the plants in the 1-gal containers were irrigated the water coming out of the hose usually made contact with the leaves at the bottom due to limited space, and this ultimately might have caused some ornamental damage (Wishhart, 2014). Further research is necessary to determine the main cause of this. Plants in 1-gal containers also showed a more variable medium temperature than that of plants in 2 and 3-gal containers. Reasons for this include the fact that the HOBO meter inserted into the 1-gal containers had less insulation, less soil volume, and less water present, and thus ambient temperature had a bigger impact in the temperature readings. Another reason could be that the plants in the 1-gal containers were smaller, and thus the soil was not receiving as much shade. The results also showed that plant size and abundance increased as potting container size increased. This could be due to the fact that 1-gal containers had a more limited space for roots to growth. In fact, a similar study performed by Navindra and others (2011) showed that plants in 3-gal pots produced the highest number of leaves and roots per seedling, and greater stem height and diameter than the ones in 1-gal pots. Bar-Tal and others (1995) affirmed that plant height, number of leaves as well as shoot and root dry weight increases with increasing container size, and Keever and others (1985) reported that root confinement within a limited volume results in reduced root growth. These theories correspond to the findings in this study with regard to the increase of container size and plant size and abundance, whereby plants in 1-gal containers in both treatments were the smallest.

It is important to note that all of these findings should be taken in the strictest manner. As the experiment was conducted on *S. cineraria* using a custom soil substrate supplied by Gro-Bark, the estimate is only valid under the same conditions. The trial also had some limitations and sources of error. For example, plants were not always watered at the same time or in the exact same manner since they were irrigated by hand. This might have caused some deviation in the data, although exact effects are unknown. Additionally, the medium temperature of only one plant per container size was recorded and this prevents the results to be generalized to a larger scale. Finally, numerous factors that could have affected the results were not measured, such as the amount of solar radiation, exact levels of precipitation, proximity of the plants, amount of shade received, currents of winds, etc.

CONCLUSIONS

After an analysis and interpretation of both quantitative and qualitative result, it is concluded that a water regime that consists of daily irrigation helps to maintain the medium temperature of *S. cineraria* close to its preferred range more effectively than irrigating the plant on a once or twice a week basis. This will ultimately help the plant to achieve a more rapid growth and greater leave abundance, as well as to prevent the generation of dry and yellow leaves.

Another conclusion is that potting *S. cineraria* in 2-gal and 3-gal containers also helps the plant to maintain a medium temperature that is close to its preferred temperature range, more stable throughout the day, and more resistant to extreme weather conditions than when they are potted in 1-gal containers. *Senecio cineraria* also tend to achieve a bigger size, greater abundance, and an overall healthier appearance when they are potted in 2- or 3-gal containers since roots have more space to spread out.

One final conclusion is that, even though the medium temperature of *S. cineraria* may be controlled by their container size and watering regime, medium temperatures are ultimately dependant upon their surroundings, and thus choosing an optimal container size and irrigation regime are not enough to ensure that the medium temperature of *S. cineraria* is within the plant's preferred range. Other factors such as the proximity of the plant, the colour of the pot, the amount of solar radiation, and the overall weather conditions could also play a big role and more research on this area is necessary.

RECOMMENDATIONS

Based on the analysis and previous conclusions, it is recommended that *S. cineraria* are thoroughly watered everyday in order to maintain optimum medium temperatures, achieve a faster growth rate, and improve the general appearance of the plants. Irrigation should occur in the morning, either by hand or with sprinkles, and growers should make sure that the roots of the plants are indeed receiving enough water, especially during the early stages of growth.

It is also recommended that *S. cineraria* are potted in medium to big containers of at least 2 gal. This will help maintain the medium temperature of plants close to its preferred range and increase the size and plant abundance of plants. If space is an issue, *S. cineraria* could be potted into 1-gal containers during their early stages of growth, but it is recommended to increase the frequency of water and decrease the amount of solar radiation received. It is also recommended to re-pot them into bigger containers later on if greater plant abundance is desired.

Finally, it is strongly suggested to conduct further research on this area and perform more trials in which a greater number of variables are measured, such as solar radiation, proximity of the plants, amount of shade received, precipitation levels, and wind currents. The use of more HOBO meters in future trials is also recommended to decrease variability of experimental results and increase the chance of statistical significance. For example, every plant should have a HOBO meter, instead of just one per container size.

Literature Cited

Bailey, D., Cavins, T. and Dole, J. July, 2001. Plant Root Zone Management. Raleigh, North Carolina: North Carolina Commercial Flower Growers' Association.

Bart-Tal, A., Feigin, S., Sheinfield, R., Rosenberg, B., Rylsk, T. and Pressman, T. 1995. Root restriction and $N\text{-}NO_3$ solution concentration effects on tomato plant growth and fruit yield. Acta Hort. 58(1):91-103.

Bunt, A.C. 1988. Media and Mixes for Container-Grown Plants: a Manual on the Preparation and Use of Growing Media for Pot Plants (2^{nd} ed.). Unwin Hyman Ltd., London, UK.

Cornell University. 2006. Growing guide—dusty miller. Retrieved from <http://www.gardening.cornell.edu/homegardening/scene58a1.html>.

Evans, E. 2013. Planting container-grown plants. Retrieved from <http://www.ces.ncsu.edu/depts/hort/consumer/quickref/shrubs/planting_containergrown.html>.

Hamerlynck, E. and Knapp, A. 1995. Photosynthetic and stomatal responses to high temperatures and light in two oaks at the western limit of their range. Tree Physiol., 16(1):557-565.

Henley, R., Ingram, D. and Yeager, T. 2006. Growth Media for Container Grown Ornamental Plants. Gainesville, Florida: University of Florida Institute of Food and Agricultural Sciences.

Keever, G. and Cobb, G. 1985. Irrigation scheduling effects on container media and canopy temperatures and growth of 'Hershey's Red' azalea. HortSci. 20(1):921-923.

Martin, C. and Ingram, D. 1991. Evaluation of thermal properties and effect of irrigation on temperature dynamics in container media. HortSci. 9(1):24-28.

Martin, C. and Ingram, D. 1993. Container dimension affects rooting medium temperature patterns. HortSci. 28(1):18-19.

Mathers, H., Lowe, S., Scagel, C., Struve, D. and Case, L. 2007. Abiotic factors influencing root growth of woody nursery plants in containers. Hort. Tech. 17(2):151-162.

Mathers, H. 2001. Tackling heat stress in container stock. Columbus, Ohio: The Ohio State University.

Million, J., Ritchie, J., Yeager, T., Larsen, C., Warner, C. and Albano, J. 2011. CCROP – simulation model for container-grown nursery plant production. Sci. Hortic. 130(4):874-886.

Mills, L. January 29, 2012. Reap benefits of container gardening. Las Vegas Review Journal. Retrieved from <http://www.reviewjournal.com/gardening-linn-mills/reap-benefits-container-gardening>.

Missouri Botanical Garden. 2014. Containers for growing plants. Retrieved from <https://www.missouribotanicalgarden.org/Portals/0/Gardening/Gardening%20Help/Factsheets/Containers13.pdf>.

Navindra, B., Gianjeet, D. and Joyce, G. 2011. Influence of soilless growing media, pot size and sieved media on the production of *Hibiscus sabdariffa* L. seedlings. Aust. J. Agr. Eng. 2(5):147-154.

Reed, D. 1996. Water, Media, and Nutrition for Greenhouse Crops. Batavia, New York: Ball Publishing.

Williams, A. January 27, 2014. The pros and cons of containers, raised beds, and in ground gardens. Sprout School. Retrieved from <http://school.hellosprout.com/ the-pros-and-cons-of-containers-raised-beds-and-in-ground-gardens/>.

Wishhart, M. 2014. Cineraria plant care. Demand media. Retrieved from <http://homeguides.sfgate.com/cineraria-plant-care-38984.html>.