Automated Measurement of Container Temperature and Moisture for Improvement of Irrigation Scheduling in Nurseries

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Introduction

The availability of water for agriculture has become an important issue, especially due to the continuing droughts that Georgia has experienced during the last four years. Although rainfall was above normal in 2003, it is expected that water availability for agriculture will be reduced in the near future. Without water, agriculture and especially the green industry can not survive, as water is one of the most critical inputs for nursery plants. Some type of improvement in monitoring of water use by nursery crops is needed. The goal of this project was to develop automated procedures that can determine changes in container temperature and moisture. This information can then be used for the development of improved irrigation scheduling systems to reduce the total amount of water required for irrigation of nursery crops.

Materials and Methods

The experiment was conducted at the Center for Applied Nursery Research (CANR), located in Dearing, Mc Duffie County, Georgia. Fifteen soil temperature probes and fifteen soil moisture probes were installed in three different container sizes, including 3, 5 and 7-gallon pots for the first three experiments and 5, 7, and 15-gallons pots for the fourth experiment that was started on October 15, 2003. The soil temperature and soil moisture probes are connected to an automated data logger and monitored continuously. The conditions of each container are recorded every 15 minutes. At midnight daily averages for all parameters are calculated. This information is retrieved hourly by a computer located at the College of Agricultural and Environmental Science-Griffin Campus via a dedicated telephone line and modem.

The first experiment was started in May, 2002 and completed on November 18, 2002. The 3-gallon containers were planted with *Euonymous* "Blondie", the 5-gallon containers were planted with *Buddleia* Seedling #7 and the 7-gallon containers were planted with *Philadelphus* x *lemoinei* (Figure 1). The second experiment was conducted during the fall and winter seasons of 2002/2003, from November 19, 2002 to May 20, 2003. The 3-gallon containers were planted with *Ilex chinensis* "Bufordi", Dwarf Burford, the 5-gallon containers were planted with *Cuppressocyparis* "Leylandi" and the 7-gallon containers were planted with *Ilex* x "Ruby Sceptor" (Figure 2). The third experiment season was installed during the 2003 spring and summer seasons, starting on May 21, 2003 and completed on October 14, 2003. The 3-gallon containers were planted with *Euonymus japonicus* 'Aureo-Marginata' (Golden Euonymus) # 1, the 5-gallon containers were planted with *Buddleia davidii* 'Attraction ' (Attraction Butterfly Bush) # 1, and the 7-gallon containers were planted with *Viburnum nudum* 'Winterthur' #5 (Figure 3). The fourth experiment season was installed in October 15, 2003 and we expect to end this experiment on March 20, 2004. With this experiment we initiated a new experimental design, using larger containers and larger plants. Thus, 5, 7, and 15-gallon container are being used. The 5-gallon containers were planted with *Ilex* x "Oak Leaf" (Oak Leaf Holly), the 7-

gallon containers were planted with *Illicium parviflorum* (Japanese Anise), and the 15-gallon containers were planted with *Magnolia grandiflora* "Bracken's Brown Beauty" (Figure 4).

(a) **(b)** **(c)**

Figure 1 – First Experiment: (a) 3-gallon containers planted with *Euonymous* "Blondie", (b) 5-gallon containers planted with *Buddleia* Seedling #7, and (c) 7-gallon containers planted with *Philadelphus* x *lemoinei*.

(a) **(b)** **(c)**

Figure 2 – Second Experiment: (a) 3-gallon containers planted with *Ilex chinensis* "Bufordi", Dwarf Burford, (b) 5-gallon containers planted with *Cuppressocyparis* "Leylandi", and (c) 7-gallon containers planted with *Ilex* x "Ruby Sceptor".

(a) **(b)** **(c)**

Figure 3 – Third Experiment: (a) 3-gallon containers planted with *Euonymus japonicus* 'Aureo-Marginata' (Golden Euonymus) # 1, (b) 5-gallon containers planted with *Buddleia davidii* 'Attraction ' (Attraction Butterfly Bush) # 1, and (c) 7-gallon containers planted with *Viburnum nudum* 'Winterthur' #5.

(a) **(b)** **(c)**

Figure 4 – Fourth Experiment: (a) 5-gallon containers planted with *Ilex* x "Oak Leaf" (Oak Leaf Holly), (b) 7-gallon containers planted with *Illicium parviflorum* (Japanese Anise or Small), and (c) and 15-gallon containers planted with *Magnolia grandiflora* "Bracken's Brown Beauty".

Preliminary Results

First Experiment

Four of the five plants in the 3-gallon pots did not survive the experiment. The plants in the 5-gallon containers showed adequate growth and development and the plants in the 7-gallon containers showed slow development. Extreme soil temperatures as high as 50^{o}C were observed in the three gallon containers, whereas the 5 and 7-gallon containers showed maximum temperatures that were at least 5 degrees less for the same day. The temporal variation of the daily average temperature for the 3, 5 and 7-gallon containers was very similar and showed the same trend. The highest average temperatures were found in the 3-gallon containers and the lowest average temperatures were found in the 5-gallon containers (Figure 5).

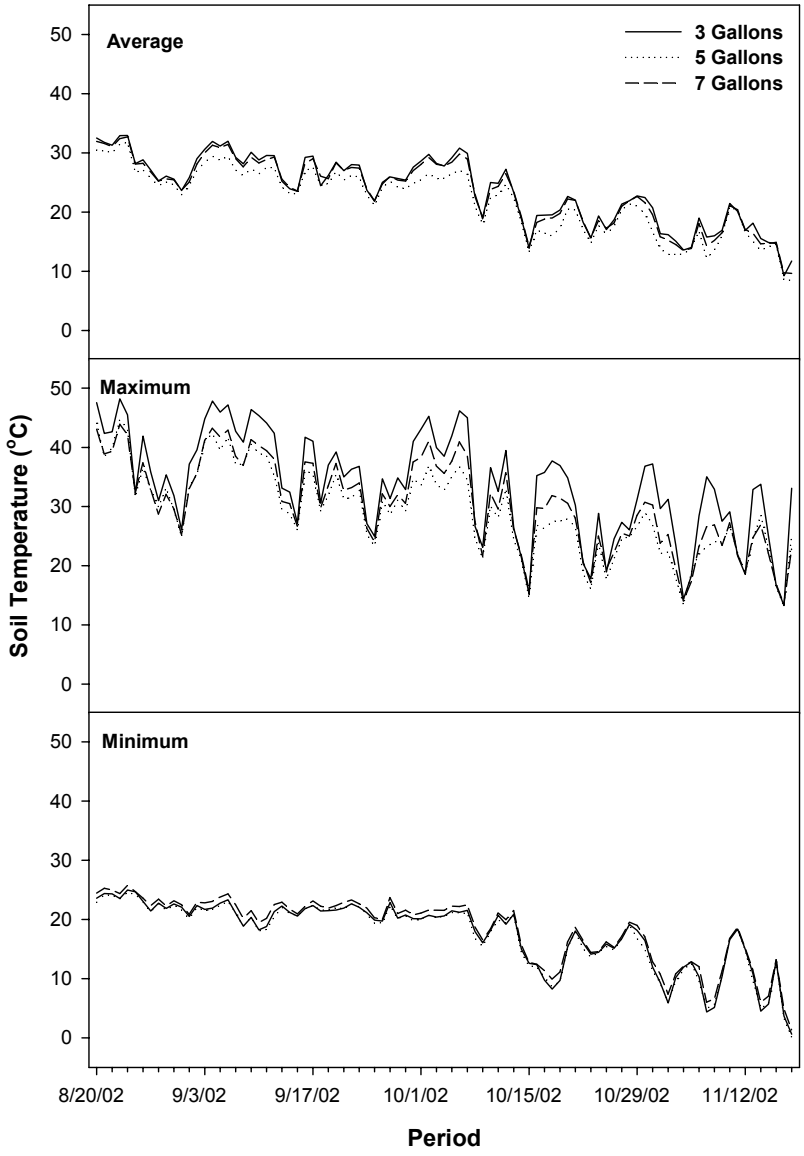

Figure 5 – Temporal Variation of Containers Soil Temperature During the First Experiment.

The volumetric soil moisture in the 3 and 7-gallon containers varied between 22 [Relative Soil Moisture (RSM) = 0.43] and 44% (RSM = 0.90), while the volumetric soil water content was extremely low in the 5-gallon containers, reaching values as low as 5% (RSM = 0.14) and as high as 36% (RSM = 0.92). The largest plants were found in the 5-gallon containers. Consequently those plants had higher water uptake rates, which was the cause for the differences in water content between the three container sizes. The trend for changes in volumetric soil water content was very similar for the 3 and 7-gallon containers, but different for the 5-gallon containers. While in the 3 and 7-gallon containers the average daily soil moisture content increased over time, it decreased in the 5-gallon containers (Figure 6).

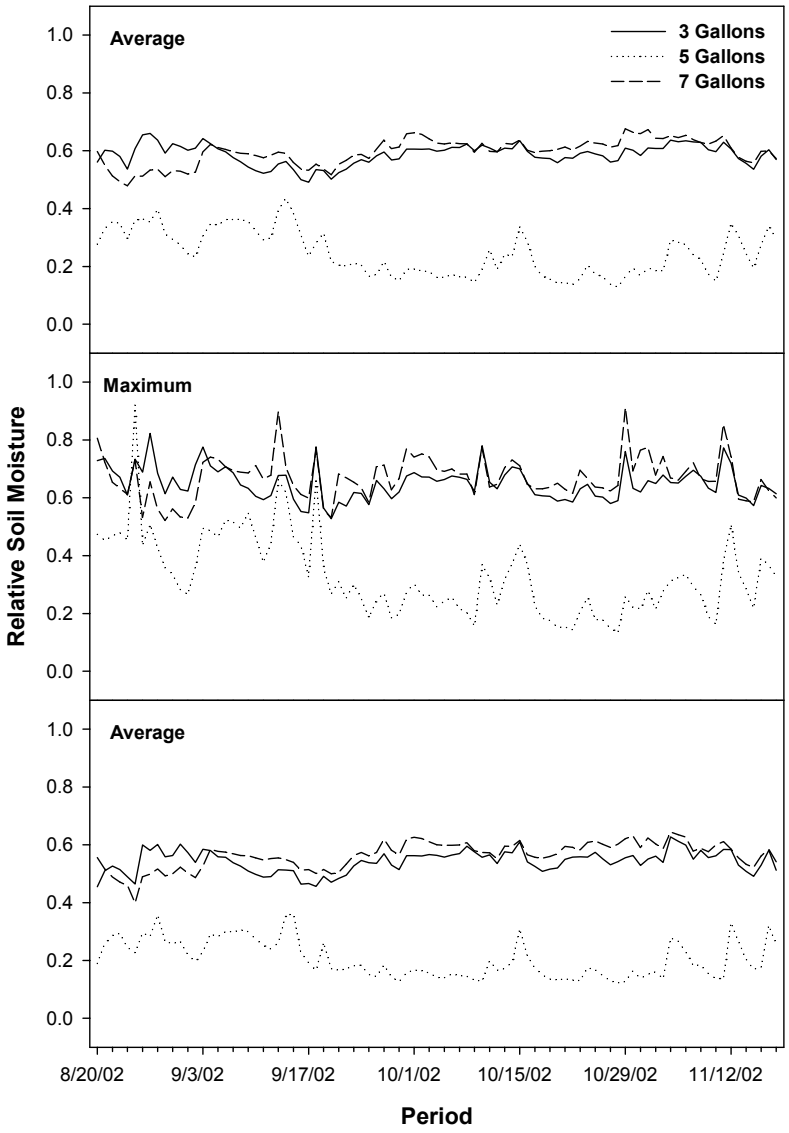

Figure 6 – Temporal Variation of Containers Soil Moisture During the First Experiment.

For this experiment the relationship between moisture and temperature in each container was unclear. However, a functional relationship was found when both variables were analyzed for a specific daily period (Figure 7). The average conditions from midnight to 08:00 AM appeared to be better for the 3 and 7-gallon containers, while no good correlation was found between soil moisture and soil temperature for the 5-gallon containers.

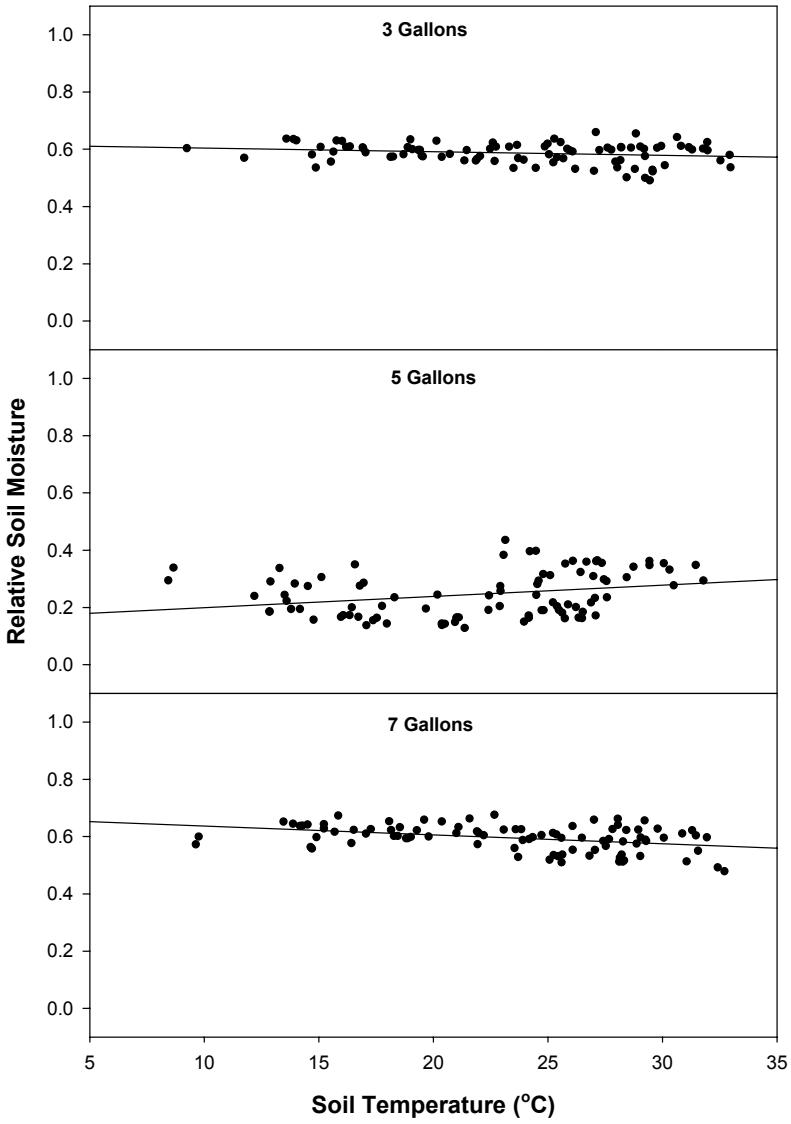

Figure 7 – Relationship between Containers Soil Temperature and Soil Moisture During the First Experiment.

Second Experiment

All plants were in good condition and showed excellent growth and development during the experimental season; no biotic or abiotic stress was observed. Also, both the soil moisture and soil temperature probes responded well to the temporal and seasonal variation of soil water and temperature, as well as water applications.

Extreme temperatures as low as -1.3°C and as high as 35°C were observed in the 3-gallon containers, whereas temperatures between -0.5°C and 35°C were observed in the 5-gallon containers and between -0.6°C and 32°C in the 7-gallon containers. The temporal variation of the daily minimum and average temperature for the 3, 5, and 7-gallon containers were similar during the experimental season, while slight differences were observed in the temporal variation of the maximum temperature. As expected, a slight increase in container temperatures was observed during the spring (Figure 8).

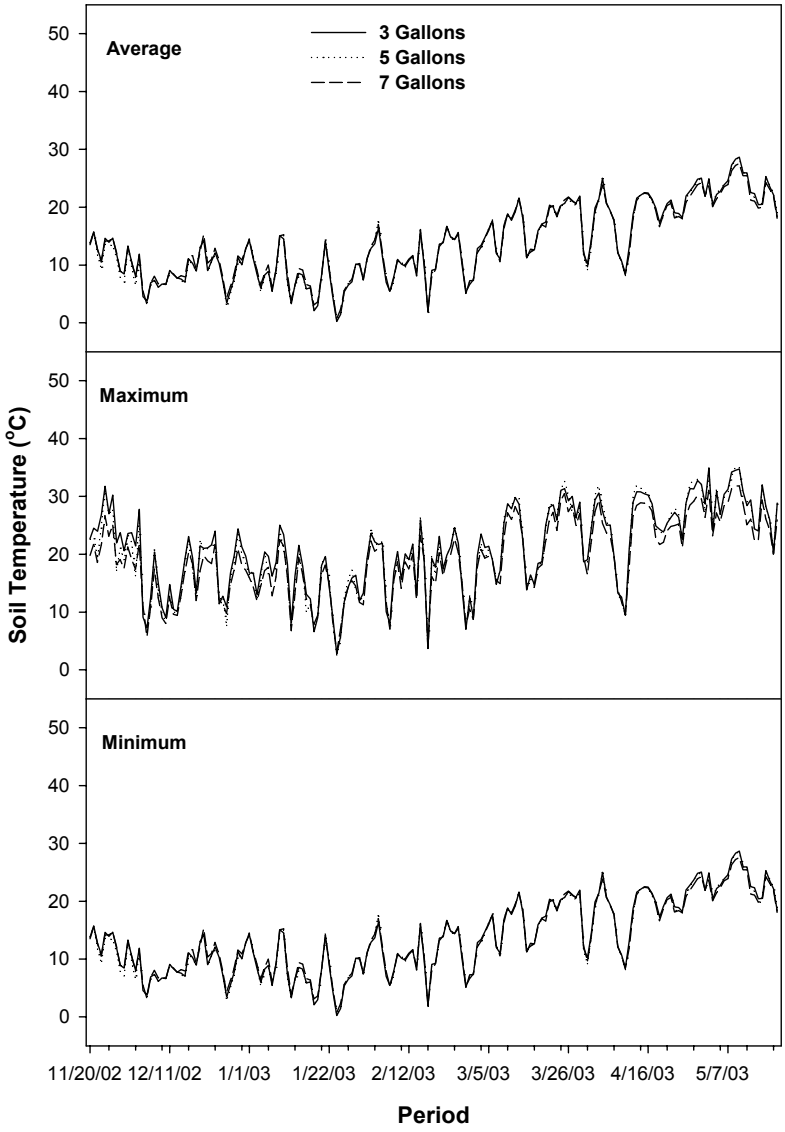

Figure 8 – Temporal Variation of Containers Soil Temperature During the Second Experiment.

The temporal variation in soil moisture was similar between treatments and showed a strong variation starting at the beginning of the spring season. Soil moisture in the 3 and 7-gallon containers was very similar and higher than in the 5-gallon containers. Extreme soil moisture

contents varied from 17% (RSM=0.49) to 33% (RSM=0.94) in the 3-gallon containers, from 8% (RSM=0.31) to 23% (0.96) in the 5-gallon containers, and from the 14% (RSM=0.36) to 40% (RSM=1.00) in the 7-gallon containers (Figure 9).

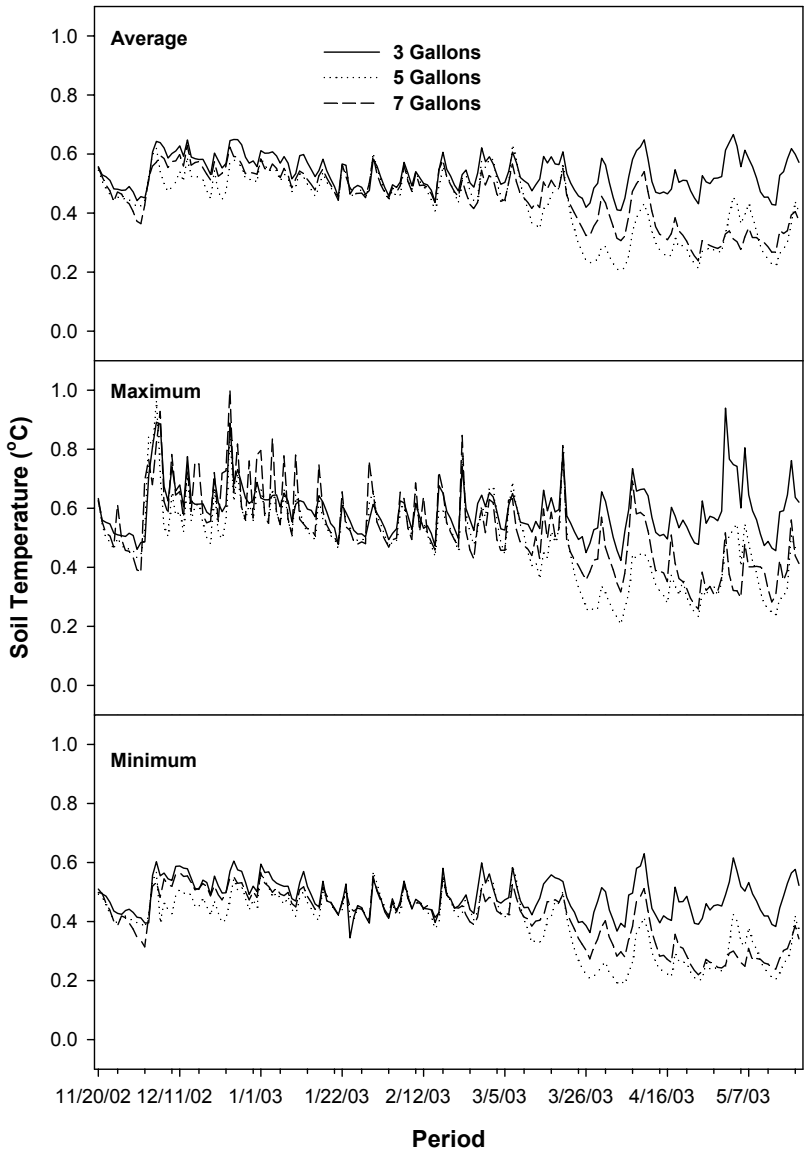

Figure 9 – Temporal Variation of Containers Soil Moisture During the Second Experiment.

A better relationship between the container temperature and moisture was found in this experiment compared to the first experiment.

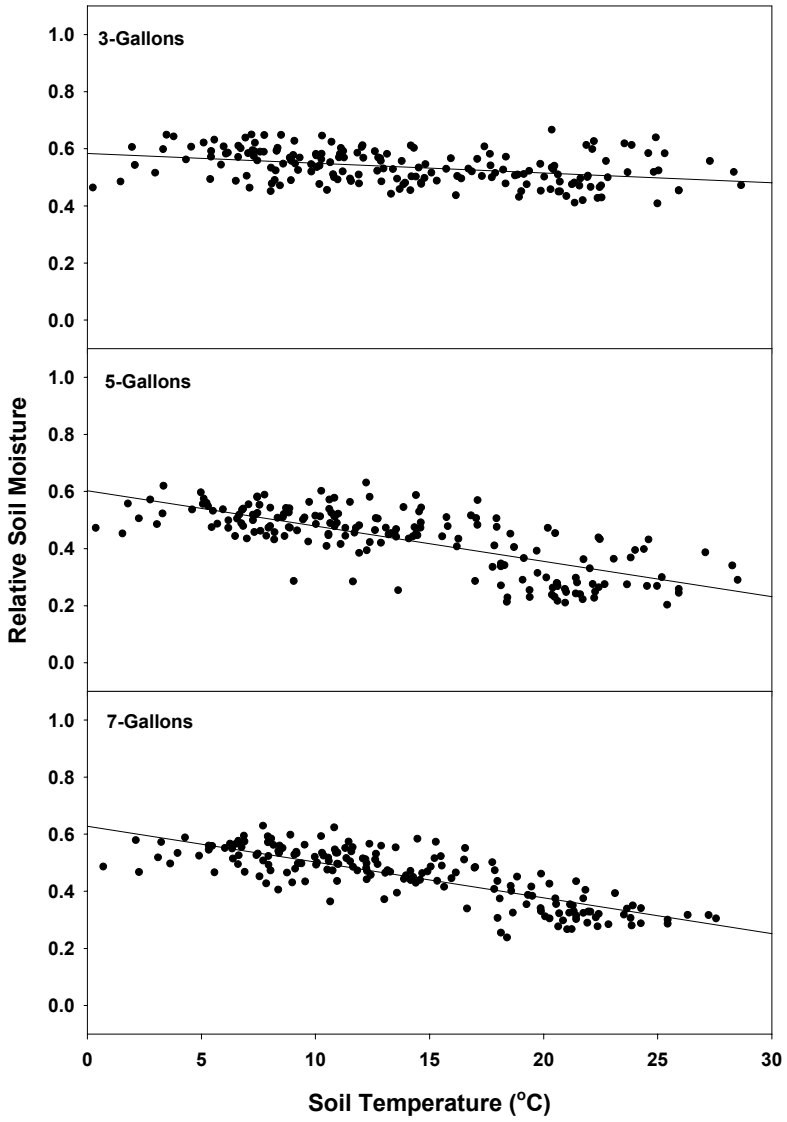

Figure 10 – Relationship between Containers Soil Temperature and Soil Moisture During the Second Experiment.

Third Experiment

All plants showed good growth and development during this experiment, except for some defoliation of the plants in the 7-gallon containers during the final week of the experiment. Also, both soil moisture and soil temperature probes responded well to temporal and seasonal variation as well as irrigation applications for each container.

Extreme temperatures as low as 10°C and as high as 39°C were observed in the 3 and 5-gallon containers, while the extreme temperatures in the 7-gallon containers ranged from 11°C to 34°C. The temporal variation of the daily average and minimum temperature for the 3, 5, and 7-gallon containers were similar, while significant differences in the temporal variation of the maximum temperature were observed (Figure 11).

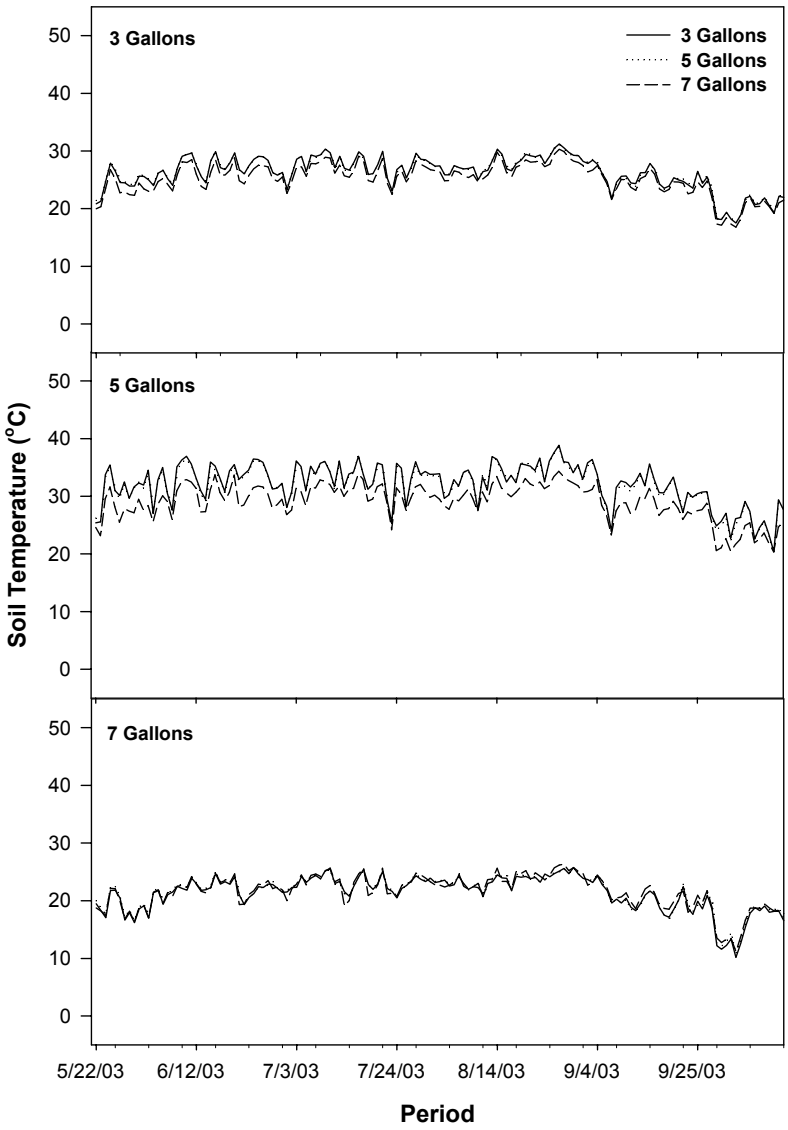

Figure 11 – Temporal Variation of Containers Soil Temperature During the Third Experiment.

The temporal variation in soil moisture was similar between the treatments, especially during the summer season. Average soil moisture in the 3 and 7-gallon containers was slightly different but always higher than the soil moisture of the 5-gallon containers. The extreme values for volumetric soil moisture content varied from 12% (RSM = 0.26) to 42% (RSM = 0.88) in the 3-gallon containers, from 9% (RSM = 0.25) to 36% (RSM = 1.00) in the 5-gallon containers, and from 17% (0RSM = 0.36) to 46% (RSM = 0.99) in the 7-gallon containers (Figure 12).

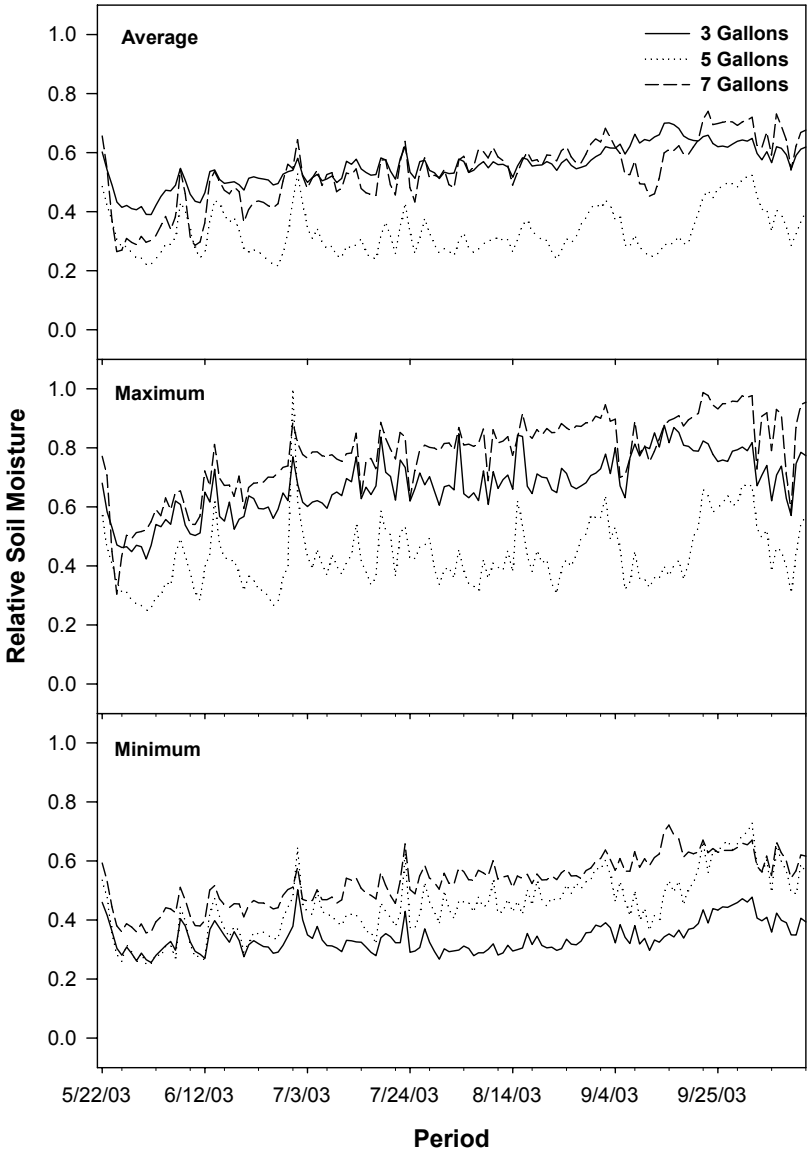

Figure 12 – Temporal Variation of Containers Soil Moisture During the Third Experiment.

The relationship between temperature and soil moisture in each container was less enhanced than in the previous experiment, and showed a better relationship in the 5-gallon than in the 3 and 7-gallon containers (Figure 13).

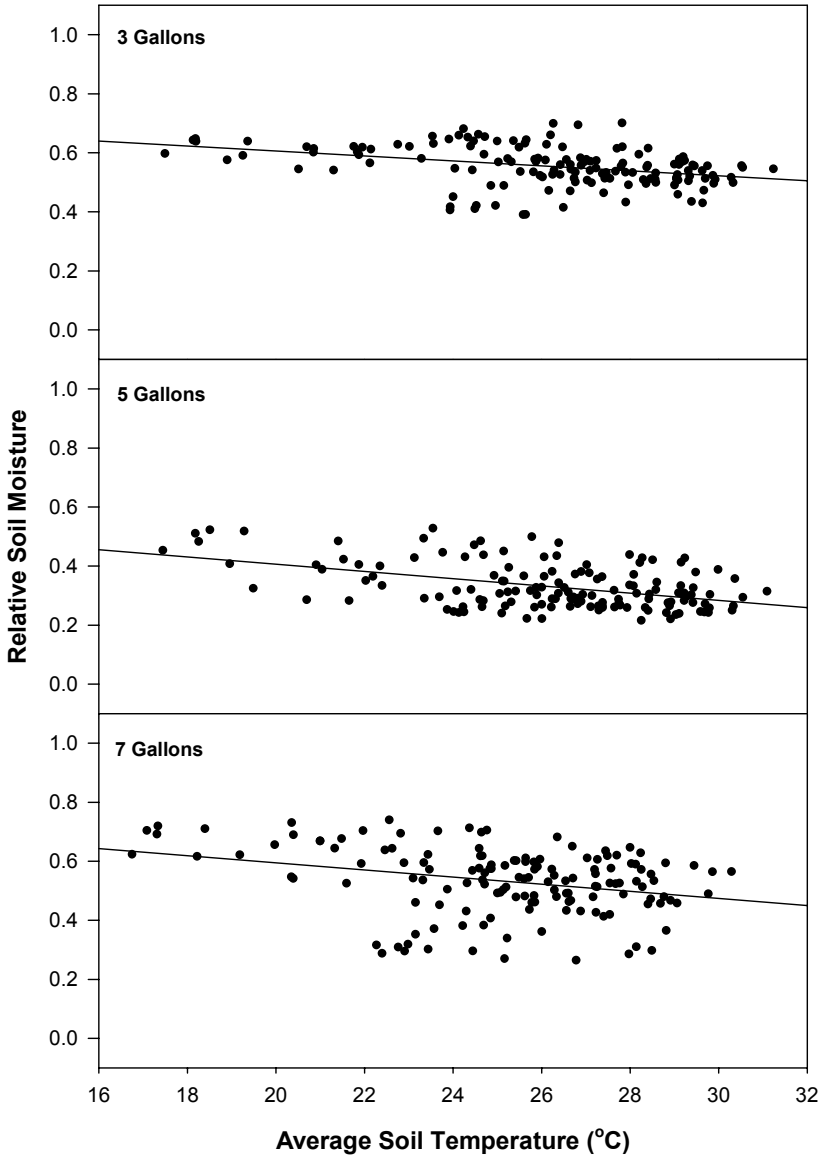

Figure 13 – Relationship between Containers Soil Temperature and Soil Moisture During the Third Experiment.

Fourth Experiment

This experiment was started on October 15th 2003. Initial results showed a very close relationship between average and minimum daily temperature in each container. Average daily maximum temperature was slightly higher in the 15-gallon containers, probably due to a more exposed area to solar radiation, while the average daily maximum temperatures in the 5 and 7-gallon containers were very similar. The temporal variation in soil moisture was similar in all three containers sizes, but slightly lower in the 7-gallon containers. This trend was also observed in the previous experiments.

Experimental Monitoring and Dissemination of Results

For monitoring and evaluation of the experimental conditions, six visits were made to CANR in Dearing, starting on January 15 and ending on December 20, 2003. In addition, we participated in the Open House of the Center for Applied Nursery Research, held on October 23, 2003 in Dearing. One article was published in the February issue of the journal of the Georgia Green Industry Association, issue 41, pages 52-53.