EFFECT OF HEAT STRESS ON CONTAINER-GROWN PLANTS

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Reduced growth rate, leaf chlorosis and wilting, abnormal branching habit, root death or injury, and reduced flower number and quality in container-grown plants are symptoms of heat stress on roots. These symptoms occur even when fertilization, irrigation, and other production inputs are maintained at near optimum levels. Root injury or death decreases water and nutrient uptake, disrupts hormone synthesis and translocation patterns, and alters biochemical reactions. Physiological and biochemical processes such as photosynthesis, respiration, flower initiation and development, apical dominance, and shoot extension are influenced by high root-zone temperatures. Economic ramifications of heat stress to roots of nursery crops include increased production time, reduced plant quality, and ultimately, increased production costs.

Container medium temperatures substantially above air temperature are possible due to direct solar radiation on container walls. Container medium temperatures in excess of 130 °F (54 °C) are common in the southern regions of the United States, and temperatures above 110 °F (43 °C) may be maintained for more than 5 hours daily (2, 3, 7). Cultural practices aimed at reducing the incidence and/or absorption of direct solar radiation on container walls warrant consideration. Such practices include altering spacing schedules, container color, radiation shields for containers, and overhead shading.

Not only is it important to evaluate techniques for reducing temperatures in container media but also it is imperative to determine critical temperatures for essential plant processes such as photosynthesis, respiration, and nutrient and water uptake. Knowledge of critical temperatures provides a ''yard stick'' with which to measure the potential benefits of modifying cultural practices. Such knowledge may also lead to identification of critical reactions in physiological processes and possible techniques for altering these processes to increase plant heat tolerance. Upon examination of the problem, one can readily see the need for both basic and applied research.

TEMPERATURE FLUCTUATIONS IN CONTAINER MEDIA

Temperature fluctuation patterns in container media differ with time of year and latitude. A southern exposure receives more direct solar radiation in late fall and winter months than during June and July and, therefore, roots on the south side experience higher temperatures during the fall and winter. Eastern and western exposures receive more direct solar radiation during the summer months and temperatures above 125 °F (52 °C) are common (9). In fact, temperatures above 100 °F (38 °C) are often routinely maintained for six hours per day in the majority of container media in full sun during summer months.

Temperature in a given zone of a sun-exposed container can remain below critical levels during one season but may elevate above these critical temperatures for other times of the year. Roots actively growing in favorable conditions during one period may die later in the year due to higher temperatures.

We are currently using mathematical modeling with computers to characterize temperature fluctuations in container media. Whereas earlier research was limited to recording temperatures at 5 to 7 points in the container profile, computer modeling now enables the researcher to predict the thermal behavior at 1164 positions in a container medium under any environmental condition. This expanding knowledge could lead to pracitcal and economically feasible strategies for reducing container medium temperatures.

CRITICAL ROOT-ZONE TEMPERATURES

The absolute temperature causing disruption of root cell membranes varies with exposure duration (4). Such disruption of cell membranes is a direct, irreversible injury that results in death of the cell, much the same result as steaming vegetables. The lethal temperature for a 30-min. exposure of *Pittosporum tobira* roots was predicted to be 126 °F (52 °C), while the lethal temperature for a 3-hr. exposure was only 118 °F (48 °C) (4). The lethal temperature for all plants studied to date decreases linearly as exposure duration increases exponentially.

Lethal temperature regimes also differ among plant genera and species. Predicted lethal temperatures for a 30-min. exposure for several ornamental plants are presented in Table 1. One can determine the relative thermal tolerance of root membranes by comparing these predicted lethal temperatures. *Ilex vomitoria* 'Schellings' tolerated a higher temperature for a 30-min. exposure than *Ilex crenata* 'Helleri', and exposure duration was more critical for the 'Helleri' holly. It would appear that roots of citrus rootstocks, *Dracaena marginata*, and *Ixora coccinea* remain viable at higher temperatures than roots of the *Ilex* spp. or the *Juniperus* spp. tested. However, the relative tolerance of root membranes to high temperatures is not necessarily an indication of the ability of a plant to withstand long-term exposure to supraoptimal temperatures below those causing direct injury.

Table 1. *Predicted lethal temperatures for roots of selected ornamental plants for a 30-minute exposure*

Plant	Predicted lethal temperature (°F)
Ixora coccinea	> 132
Dracaena marginata 'Tricolor'	131
Musa sp 'Grande Naine'	127
Citrus rootstocks 'Swingle'	129
sour orange	126
carrizo	126
Magnolia grandiflora 'Glen St Mary'	126
Ilex vomitoria 'Schellings'	127
Ilex crenata 'Helleri'	124
Ilex crenata 'Rotundifolia'	118
Ilex cornuta 'Dwarf Burfordii'	115
Illicium parviflorum	124
Juniperus chinensis 'Parsonii'	118

High root-zone temperatures can reduce photosynthesis, even though air temperatues are near optimum. This reduction can be caused indirectly by heat-induced water stress, even though adequate water is present in the container medium. Such reductions have been found in banana (*Musa* spp.), *Dracaena marginata*, and *Ixora coccinea*. As a result of water stress, stomata usually close to reduce water loss through transpiration. This closure inhibits exchange of gases necessary for photosynthesis. However, not all reductions in photosynthesis by high root-zone temperatures are caused by water stress. *Ilex crenata* 'Rotundifolia' photosynthesis was reduced by 32% by a 6-hour daily root-zone temperature of 92 °F (33 °C) compared to 82 °F (28 °C) treatment, and stomata remained open (1). Therefore, physiological and/or biochemical factors other than stomatal closure must be involved in such cases. Subsequent research has revealed no evidence of stomatal inhibition as root-zone temperature increased in 'Rotundifolia' holly up to 108 °F (42 °C). However, decreased chlorophyll levels and differences in photosynthetic enzyme activity indicated that 'Rotundifolia' holly was able to alter metabolism at higher root-zone temperatures to maintain photosynthetic rates (10).

Root respiration generally increases with increasing root-zone temperatures, up to a temperature causing direct root injury.

Respiration involves release of energy stored in carbohydrates and fats that is necessary to maintain cell integrity and support growth. As root-zone temperature increases, the percent of available energy necessary for maintaining existing tissues increases. This means that less energy is available for growth. Root respiration in 'Rotundifolia' holly increased 80% during a one week period as the root-zone temperature was increased from 82 °F (28 °C) to 104 °F (40 °C) (1). However, a three-week exposure to temperatures up to 108 °F (42 °C) did not affect respiration rate. Root-zone temperatures have been shown to influence where photosynthates were transported and utilized (10).

Synthesis of plant hormones, such as cytokinins, usually occurs in the roots with translocation to other parts of the plant. In many physiological process, the ratio of hormones is as important as the absolute concentration of each. Therefore, altering the synthesis, compartmentalization, degradation, or translocation of hormones can affect the hormonal balance in the plant. Such imbalances can delay flower initiation and development, disfigure flowers, and alter branching habits. Flower number and size of *Magnolia grandiflora* 'Glen St. Mary' were reduced by root-zone temperatures of 100 °F (38 °C) and 108 °F (42 °C) maintained for 6 hours daily (unpublished data). The critical root-zone temperatures for hormone synthesis and translocation are currently unknown for woody plants.

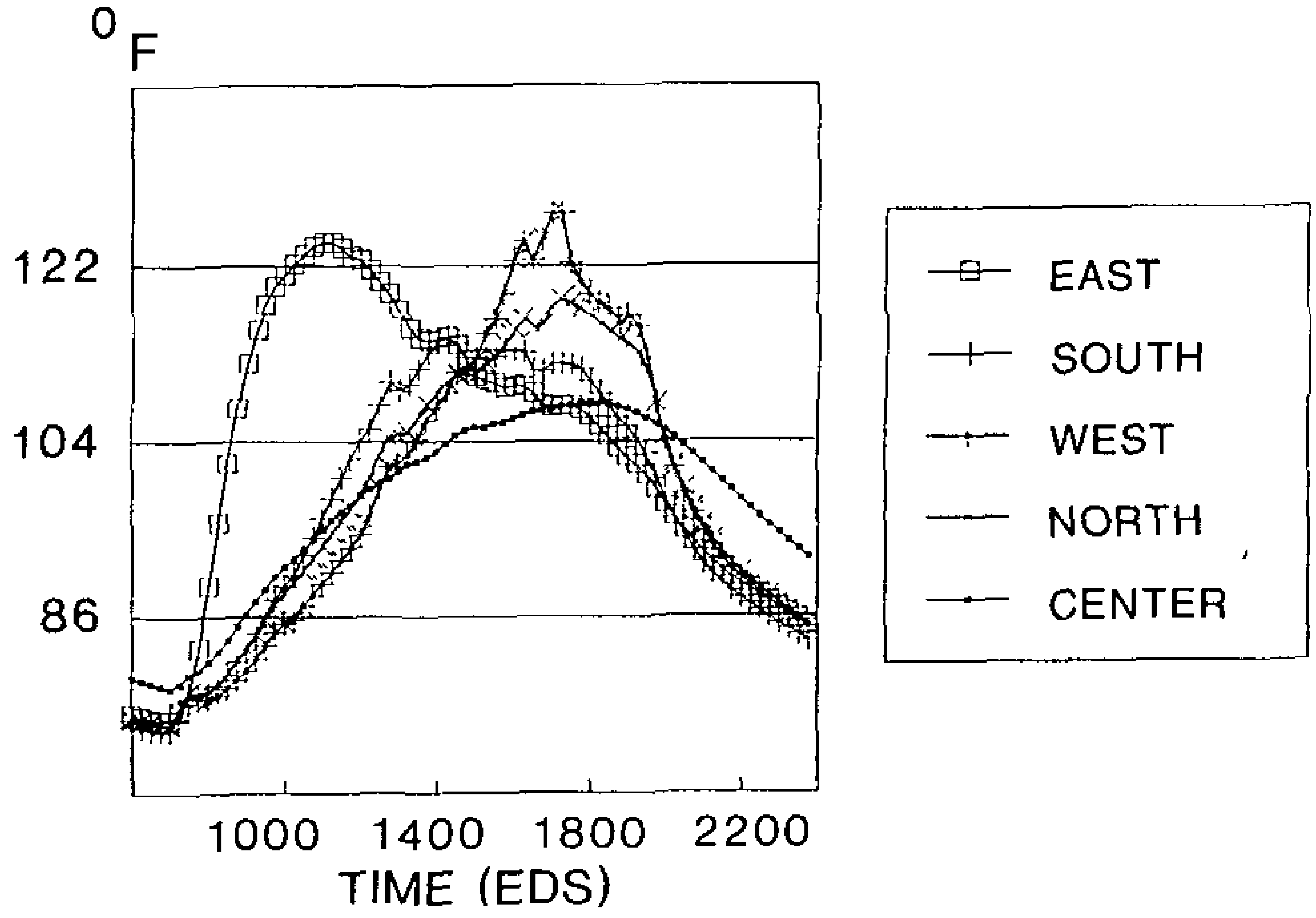

Figure 1. Temperature fluctuations in growth medium of a 3-gallon container 0 4 in. (1 cm) from the wall on the east, south, west, north and center coordinates Data were recorded on July 7, 1989 in Gainesville, Florida.

CULTURAL PRACTICE MODIFICATIONS

Reports of research results over the last few years have increased the awareness of nursery operators to the causes and effects of heat stress in container-grown plants. Although there is much room for refinement of cultural practices, many innovative nursery operators and researchers have developed unique ways to reduce heat load to containers.

Generally, cultural practices that reduce the incidence of direct solar radiation on the side of containers warrant consideration. These practices include spacing containers together and separating them as canopies of adjacent plants touch (5, 6, 8, 9). Plant canopies not only provide shading for containers in which they are being grown but also provide shading of walls of adjacent containers. If containers are initially spaced can-tight until canopies touch and are then spread to a ''final'' wide spacing, root-zone temperatures can be high enough to kill roots near the exposed container wall. Therefore, sequential spacing of containers as canopies grow is advisable.

Placing a container in another container to create a shield from solar radiation has also been effective in reducing plant heat stress (5). Although the practicality of this procedure may be questionable, the principle may be applied in other innovative ways. Placing discarded containers or some type of insulated barrier on the periphery of container beds will reduce heat stress to containers on the outside rows. Container orientation has been studied (6), but optimum orientation for one container to shade another differs with time of year due to the changing angle of the sun.

Ground cover color also affects the temperature regime in container media. A white ground cover reflects more light energy up into the plant canopy and onto the side of containers, thus increasing the heat load (7). A black ground cover absorbs more incoming radiation and re-radiates it as long wave radiation over several hours. Therefore, a black ground cover contributes less to the heat load on containers.

Preliminary experimentation suggests that a midday irrigation is more effective in reducing temperature extremes than early morning watering. Usefulness of applied irrigation in removing sensible heat appears to correlate with the temperature of irrigation water, volume of water added, and growth medium pore space and thermal properties. Enough water should be added to at least replace the current water in the medium. Syringing container-grown plants in the afternoon may not appreciably affect container medium temperature. Irrigation scheduling should be considered as a tool in managing container medium temperatures.

In summary, heat that injures roots of container-grown plants results from direct solar radiation on container walls and can result in several different types of symptoms. Reduced plant growth and plant quality increase production costs and ultimately alter profitability and competitiveness of Florida's nursery industry. Some cultural modifications will reduce the heat load and thus maximum temperatures in container media.

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CHARLES PARKERSON: How do you determine the extent of root damage in the plants?

DEWAYNE INGRAM: We test the electrolyte leakage from root tissue, which changes when the plant's root is damaged.