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Heat stress of container-grown tropical fruit and ornamental plants

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Effects of 3 plant container types and 3 spacing treatments on plant growth and container temperatures were determined in St. Croix, U.S.V.I. These effects were compared with plant physiological response to supraoptimal root-zone temperatures in controlled environment studies. White rigid plastic plant containers or polyethylene containers placed inside large rigid plastic containers reduced the temperature in containers as compared to single black rigid plastic containers. *Dracaena marginata* 'Tricolor' root and shoot dry weights were greatest in white containers. *Ixora chinensis* 'Maui' height was greatest in white containers but dry weights were not affected by container type. A close pot spacing, also reduced the heat load, but the effect on maximum temperatures was minimal from September to March. Such treatments did not affect 'Carrizo' citrange and 'Barbados Dwarf' papaya growth in containers. 'Grand Naine' banana root weight was significantly greater for plants in close spaced pots, compared to other spacing treatments.

Keywords: Plant containers; Ornamentals; Fruits; Root temperatures

Introduction

Many tropical fruit and ornamental plants destined for landscaping or for planting in the field are started in containers. Although this production method offers many advantages, high growth medium temperatures can reduce plant growth and quality. Temperatures in excess of 50°C have been recorded in growth media in such containers and temperatures about 40°C are commonly maintained for more than 4 hr. daily (Fretz, 1971; Young and Hammet, 1980).

Direct heat injury to plant roots, as described by Levitt (1980), results from a short exposure to an extreme temperature. This lethal temperature for excised roots of various woody and tropical plants exposed for 20 min. ranged from 46.5 $\pm$0.5°C to 53.5 $\pm$0.5°C (Ingram, 1985; Ingram and Buchanan, 1984). Indirect heat injury can result from prolonged exposure to temperatures below those causing direct injury. Some of the postulated mechanisms of indirect injury include plant starvation, biochemical lesions and the accumulation of toxic by-products (Levitt, 1980).

Research has been conducted at the University of the Virgin Islands in Kingshill, St. Croix and the University of Florida, Gainesville, to determine critical supraoptimal root-zone temperatures for selected tropical and subtropical crop plants and to evaluate cultural practices aimed at reducing heat stress to container-grown plants.

This paper reports the results of two experiments conducted in the Virgin Islands and results of experiments conducted in Florida in 1985 and 1986. The objective in the Virgin Islands was to evaluate the effects of container type and container spacing on root-zone temperatures (RZT) and growth of *Dracaena marginata* cv. Tricolor; citrange [*Citrus sinensis* (L.) Osbeck x *Poncirus trifoliata* Raf.] cv. Carrizo; *Ixora chinensis* cv. Maui; banana (*Musa* sp. AAA) cv. Grande Naine and papaya (*Carica papaya* L.) cv. Barbados Dwarf. The objective in the Florida experiments was to determine critical RZTs for the physiological processes and growth in Dracaena, Citrange, Ixora and banana. Results of the studies conducted in Florida have been published previously (Ingram and Ramcharan, 1985; Ingram and Ramcharan, 1986; Ingram, et al., 1986; Ingram, et al., 1987).

Materials and Methods

Container Trials: Uniform rooted cuttings of Ixora and Dracaena and seedlings of Citrange and papaya were transplanted into 3 container types on May 20, 1986. The volume of each container was 7.6 liters. The container types were black rigid plastic containers (C_b) plastic container painted white (C_w) and black polyethylene bags inserted into black rigid plastic containers 7.5 cm greater in diameter than the bags (C_{b+p}). A soilless growth medium (Metro Mix 500, W.R. Grace, Inc., Cambridge, MA., USA) amended with 0.6 kg m^{-3} of Perk (a micronutrient formulation by Estech Inc. Winter Haven, FL, USA) was used in all container types. Plants in containers were placed on a gravel bed in full sun and irrigated daily to container capacity through a low-volume irrigation system. There were six replicates of each species in the 3 container types and species were analyzed as separate experiments.

Plant heights and widths were recorded initially and monthly thereafter. Shoot and root dry weights were determined when the experiment was terminated on November 20, 1986. Diurnal temperature and solar radiation intensity were recorded on 2 representative 24 hr. periods each month using a microdatalogger (Model 21X, Campbell Scientific Inc., Logan, Utah, USA). Welded copper-constantan thermocouples were positioned in the growth medium equidistant from the top and bottom and 1 cm from the container sidewall on the north, east, south, and west coordinates and in the center of the container medium. Temperatures at each location were sensed every 5 min. and 15 min. averages were recorded from before sunrise to sunset.

Spacing Trials: Rooted cuttings of Ixora and Dracaena, Citrange seedlings and established *in vitro* cultured plantlets of 'Grande Naine' banana were transplanted into 7.6 liter, rigid plastic containers in 1986. Three spacing treatments comprised: a) container centers spaced at 46 cm (S1); b) containers touching each other for the entire period (S2) and; c) as (b) until adjacent plants began to touch and then at 46 cm. (S3). A border row was maintained at the same spacing for each group. Plant heights and widths were recorded initially and monthly thereafter. Shoot and root dry weights were determined at termination of the experiment on February 12, 1987. Diurnal temperature and solar radiation intensity were recorded as described above.

Critical temperatures for physiological processes: Plants were transplanted into 7.5 cm dia. x 23 cm tall polyethylene bags that were inserted into electronically controlled heating tubes in a walk-in growth room at Gainesville, Florida. Growth room ambient day/night temperatures were maintained at $28^{o}C/25^{o}C$. A 14 hr. photoperiod with an irradiance of approximately 1100 umol m^{-2} s^{-1} at canopy height, 65 to 70% relative humidity and a CO_2 concentration of 300 to 400 $mg.L^{-1}$ were maintained during lighted hours. RZT treatments of 28°, 34°, 40° and 45°C for 6 hr. daily were provided within ±0.3°C of the desired temperatures. Temperature treatments were replicated 6 times in a randomized complete block design.

Midday photosynthesis, leaf conductance and transpiration were determined after 11 weeks using a portable gas analyser (LICOR 6000) and shoot and root dry weights were determined after 12 weeks and root and leaf samples were taken for analysis of soluble and structural carbohydrates. Data from this study were published previously (Ingram, et al., 1987).

Results and discussion

Container types: Dracaena height, root and shoot dry weights were significantly greater ($P = 0.05$) in plants grown in white containers compared to black containers (Table 1). Treatment C_{b+p} resulted in intermediate height and root dry weight. Citrange and Papaya were not significantly influenced by container type. Ixora final height was less in treatment C_b than C_{b+p} but the shoot and root dry weights were lowest in the white containers.

The mean maximum temperature recorded in black containers on May 23, 1986 was 45.5°C and temperatures above 40°C were maintained for 4 hours (Table 2.). The maximum temperature was recorded on the western side of the container and temperatures in this treatment were generally 5 to 10°C higher than in the other treatments. Temperatures recorded in container media in the Virgin Islands were generally lower than temperatures recorded in Gainesville, Florida, during the same season (Ingram, 1981).

Container spacing: Banana height was greatest at the S3 spacing, while treatment S2 produced greater plant height than the S1 spacing (Table 3.). Shoot dry weights did not reflect these differences in plant height, but root dry weight was greatest for the S2 spacing. A similar trend was noted in Papaya with the tallest plants produced at the S2 spacing, but dry weights were not affected by treatments. Dracaena shoot dry weight, width and height were not influenced by spacing treatment, but plants grown with S1 spacing had slightly greater root dry weight than plants grown at the S3 spacing. Citrange was not affected by spacing treatments. Ixora height was reduced in the S1 spacing but other parameters were not influenced by spacing treatments.

Temperatures during September through February were generally lower than those recorded in May through August. Maximum temperatures were generally found on the southern exposure, and on October 30, 1987 did not exceed 40°C (Table 4.) Maximum temperatures were generally 5 to 8°C higher in containers at the S1 spacing compared to S2 treatments. The same trends in temperatures were noted in data collected during other months (data not shown). Growth medium temperatures were below those causing growth reduction or alterations in measured physiological processes for plants tested (Ingram and Ramcharan, 1985 & 1986; Ingram, et al., 1986 & 1987. Plant response to treatments might have been different if the experiment had been conducted during the summer months because growth medium temperatures recorded in October were generally 8 to 10°C lower than those in the summer.

Table 1 Effects of container type on growth of Ixora, Dracaena, citrus and papaya plants produced in St. Croix, U.S. Virgin Islands.

Container Treatment[1)]	Final Height (cm)	Final Width (cm)	Shoot Dry weight (g)	Root Dry weight (g)
Dracaena marginata 'Tricolor'				
C_b	66.5b[2)]	61.5a	25.7c	10.2b
C_w	74.5a	55.2a	37.1a	15.2a
C_{b+p}	70.2ab	65.2a	31.1b	12.6a
Ixora chinensis 'Maui'				
C_b	46.3b	49.3a	40.2a	11.2a
C_w	53.2ab	43.0a	26.6b	8.6b
C_{b+p}	59.4a	52.0a	42.7a	12.6a
Citrange cv.'carrizo'				
C_b	130.7a	85.7a	60.8a	54.5a
C_w	131.3a	65.0a	55.2a	36.8a
C_{b+p}	122.0a	74.7a	60.8a	39.9a
Papaya, cv. 'Barbados Dwarf'				
C_b	25.0a	31.0a	31.8a	26.1a
C_w	26.6a	30.3a	36.4a	32.2a
C_{b+p}	27.9a	32.8a	43.8a	32.5a

1) Treatments: Cb = Black plastic containers, Cw = White painted plastic containers, Cb+p = black polyethylene bags inside black plastic containers
2) Means within columns for each species with the same letter are not statistically different at the 5% level

Table 2 Mean temperatures (^oC) at one centimetre from the sidewall in four regions of container media on May 2, 1986 in St. Croix, U.S. Virgin Islands, as influenced by container type.

		Container type[1)]											
		C_b				C_w				C_{b+p}			
Time (h:m)	Solar Intensity (kWm^{-2})	North	East	West	South	North	East	West	South	North	East	West	South
7:15	0.37	23.5	24.5	24.3	24.9	23.7	24.6	23.3	23.6	24.5	24.0	23.5	24.3
8:15	0.58	25.3	26.8	26.3	27.8	25.6	27.4	24.8	25.7	25.6	25.0	24.2	26.1
9:15	0.60	27.3	29.3	28.2	29.2	27.0	28.2	26.1	27.0	26.8	26.3	25.4	27.2
10:15	0.59	29.2	31.4	30.2	31.6	28.1	29.6	26.9	28.3	27.8	27.2	26.4	28.4
11:15	1.77	31.1	33.2	32.6	34.5	29.3	31.6	27.8	29.8	29.0	28.4	27.3	30.2
12:15	1.73	34.0	35.5	36.1	36.9	32.0	33.1	30.1	31.5	31.4	30.5	30.0	32.8
13:15	1.45	36.6	37.3	39.3	38.7	33.9	34.3	32.4	33.5	33.6	32.6	32.7	35.0
14:15	1.21	38.5	38.2	42.7	39.2	35.0	34.5	34.6	33.4	35.1	34.1	34.9	36.0
15:15	1.22	39.9	38.6	44.9	39.3	35.3	34.5	35.8	34.5	35.7	34.9	35.7	36.2
16:15	0.75	40.1	38.4	45.2	39.6	35.1	33.9	35.8	34.2	35.7	35.0	35.3	35.8
17:15	0.30	40.2	37.8	45.6	37.6	34.5	33.1	35.5	33.6	35.4	34.9	35.5	35.1

1) Container treatments as Table 1

Table 3 Effect of spacing treatments on growth of container-grown plants in St. Croix, U.S. Virgin Islands.

Spacing Treatment [1]	Height (cm)	Width (cm)	Shoot dry weight (g)	Root dry weight (g)
Banana cv. 'Grand Naine'				
S1	65.2c	76.2b	20.4a	22.2b
S3	85.9a	85.6a	28.1a	16.5a
S2	76.2b	84.9a	31.2a	30.8a
Papaya cv. 'Barbados Dwarf'				
S1	55.0b	74.2	27.8	9.0a
S3	85.5a	82.5a	31.5a	7.8a
S2	62.5b	78.0a	32.2a	11.6a
Ixora chinensis cv. 'Maui'				
S1	53.5b	56.5a	48.0a	34.6a
S3	65.0a	56.6a	47.9a	25.4a
S2	68.1a	61.9a	50.5a	32.0a
Dracaena marginata cv. 'Tricolor'				
S1	64.0a	62.4a	35.0a	22.8a
S3	60.6a	57.9a	32.0a	13.8b
S2	65.1	58.9a	33.8a	18.5ab
Citrange cv. 'Carrizo'				
S1	57.5a	20.0a	11,6a	9.2a
S3	60.6a	18.8a	10.9a	7.5a
S2	61.8a	16.9a	12.1a	8.1a

1) Spacing Treatments: S1 = 46cm, centre-centre; S2 = containers touching; S3 = S2 until plants touched, then as S1
2) Means within columns for each plant with the same letter are not statistically different (P = 0.05)

Table 4 Mean temperatures one centimetre from the sidewall in four regions of container media on May 23, 1986 in St. Croix, as influenced by container spacing (spacing treatments as in Table 3)

		Spacing Treatment											
		S1				S3				S2			
Time (h:m)	Solar Intensity (kWm^{-2})	North	East	West	South	North	East	West	South	North	East	West	South
8:00	0.33	25.4	27.5	24.9	25.2	24.6	26.8	24.9	27.2	24.7	25.0	24.8	24.7
9:00	0.79	26.2	32.0	27.0	29.6	25.7	31.0	26.4	29.0	26.3	26.3	25.6	25.6
10:00	1.20	28.6	34.2	29.6	34.5	27.4	34.0	28.7	30.7	29.1	26.3	25.6	25.6
11:00	1.41	30.9	36.1	31.8	37.5	29.4	34.7	31.2	31.9	31.1	30.2	29.6	29.6
12:00	1.62	32.7	36.7	33.6	38.8	31.1	34.7	33.1	33.1	32.1	31.2	30.3	30.4
13:00	1.62	34.9	36.3	35.2	38.9	32.4	32.5	34.6	33.8	32.5	31.8	32.0	31.4
14:00	1.23	34.5	35.6	34.9	36.8	33.0	33.9	35.8	33.7	32.8	31.9	32.7	32.1
15:00	0.66	33.2	33.2	34.5	31.8	33.0	32.2	34.2	31.8	32.9	32.0	31.6	30.9
16:00	0.86	32.2	31.4	32.1	31.6	31.8	31.4	32.1	21.8	31.1	30.8	31.3	31.4
17:00	0.17	31.4	30.1	32.0	30.3	31.1	30.4	31.2	31.9	30.5	30.0	30.6	31.0

Results from the spacing and container treatments are consistent with growth room and laboratory research on the response of these plants to elevated RZT. Recorded temperatures in all treatments were below those found to cause direct membrane injury to test plants (Ingram, et al., 1986; Ingram, et al., 1987). Dracaena shoot and root dry weights, midday leaf photosynthesis, stomatal conductance and transpiration decreased linearly with increasing RZT from 28^{o} to 45^{o}C but shoot dry weight was not affected (Ingram, et al., 1986; Ingram, et al., 1987).

Container types that decreased absorption of solar radiation reduced the maximum temperature in the growth medium. Dracaena growth was enhanced by such treatments during summer months but citrus, ixora and papaya were not influenced by these treatments. Spacing treatments in September through February altered RZTs, but less than container treatments during summer months. Variability in plant response reflects this fact. Alternative cultural practices such as close initial spacings, which are increased as plants grow and imported plant containers with reflective colors and/or textures should be considered.

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