with 8, 20, and 5 cultivars in the 7, 8, and 9 week flowering groups, respectively. As in 1985, cultivars were generally marketable 3-5 days after inital flowering. An exception was 'Baby Tears' (white button) which had erratic flowering. Often by the time 1/3 of the flowers had opened, the first flowers had discolored which detracted from the overall quality of the plant. A similar cultivar ('Pearls') not only flowered a week earlier (54.7 vs. 63.6 days) but had more uniform flowering with less pinking of the petals.

Plant height ranged from 5.7 to 11.2 inches, represented by 'Goldmine' and 'Bingo,' respectively. Height of most of the cultivars in 1986 was within one-half inch of their height in 1985, which indicated their consistency in this production system. Of the 33 cultivars evaluated, 22 (67%) were in the 7- to 9-inch height range and would require no growth retardant. The button types ('Bandit,' 'Pearls,' and 'Sunbeam') were all about 6.7 inches tall but their spreading growth habit made them highly acceptable as a small potted plant.

Range of flower potential among the cultivars was not as great in 1986 since the most sparse flowering cultivars from 1985 were not included in 1986. Flower potential ranged from 32.0 ('Adorn') to 87.3 ('Goldmine'), with the button type cultivars which had a spreading growth habit exhibiting the greatest number of flowers. Number of flowers on all cultivars evaluated would be acceptable. Pot value changed little from 1985 to 1986, with 26 of the cultivars above 4.0. Several of the cultivars, such as 'Flare' and 'Panther,' scored lower in 1986 due to late and uneven flowering.

Data from 1985 to 1986 indicate that many garden chrysanthemum cultivars are adapted to a mass market unit of one pinched plant per 4-inch pot without use of a growth retardant or supplemental lighting. Cultivars which performed well in these studies are listed in Table 3.

Table 3. Garden chrysanthemum cultivars suitable for culture in small containers.

White	Yellow
Ballerina (Quill)	Allure (Daisy)
Lobo (Pompon)	Compatriot (Pompon)
Pearls (Button)	Fortune (Decorative)
Spartan (Decorative)	Freedom (Pompon)
Starfire (Decorative)	Sunbeam (Button)
	West Point (Button)
Orange	**Lavender/Pink/Red**
Bandit (Button)	Adorn (Daisy)
Goldmine (Decorative)	Buckeye (Daisy)
Grenadine (Pompon)	Camelot (Decorative)
Triumph (Pompon)	Debonair (Decorative)
Viking (Decorative)	Fireside Cushion (Daisy)
Zest (Pompon)	Stargazer (Daisy)

Literature Cited

1. Ball, V. 1977. 4-inch-bedding plant of the future? Grower Talks 41(7):1-13.
2. Harbaugh, B. K. and W. E. Waters. 1979. Evaluation of flowering plants under simulated home conditions. HortScience 14:437. (Abstr.)
3. Howe, T. K. and W. E. Waters. 1984. Evaluation of impatiens: Spring and Fall 1983. Proc. Fla. State Hort. Soc. 97:235-239.
4. Howe, T. K. and W. E. Waters. 1985. Evaluation of petunia: Spring and Fall 1984. Proc. Fla. State Hort. Soc. 98:335-341.
5. Otte, J. A., B. K. Harbaugh, and G. J. Wilfret. 1979. Production costs for 10 and 15 cm potted chrysanthemum. HortScience 14:500-502.
6. U. S. Dept. Agr. 1985. Floriculture crops. 1984 summary and intentions for 1985. U.S. Dept. Agr. Stat. Reporting Serv. SpCr 6-1 (85).
7. Wilfret, G. J., F. J. Marousky, and J. C. Raulston. 1973. Evaluation of chrysanthemum cultivars as single-plant pots for mass market sales. Proc. Fla. State Hort. Soc. 86:391-395.
8. Wilfret, G. J. 1974. Effect of B-Nine and A-Rest on height of garden chrysanthemums grown as single-plant pots. Proc. Fla. State Hort. Soc. 87:483-488.
9. Wilfret, G. J. and B. K. Harbaugh. 1979. Mini-pot garden chrysanthemums: cultivar characteristics and consumer preferences. Proc. Fla. State Hort. Soc. 92:317-319.
10. Wilfret, G. J. 1985. Mini-pot garden chrysanthemums: cultivar characteristics Fla. Orn. Growers Newsletter 8(1):1, 4.

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HEAT TOLERANCE OF *IXORA COCCINEA* EXCISED ROOTS

DEWAYNE L. INGRAM AND CHRISTOPHER RAMCHARAN[1]
Ornamental Horticulture Department, IFAS,
University of Florida
Gainesville, FL 32611 (USA)

Index words. heat stress, electrolyte leakage, modeling.

Abstract. **Relative heat tolerance of excised roots from *Ixora coccinea* L. was determined using electrolyte leakage procedures. Mathematical models were developed to describe effects of treatment temperature (25 to 60°C) and exposure time (30 to 300 min) interactions on membrane thermostability. Three dimensional plots of the fitted mathematical functions are presented. Predicted critical exposure times at 45 and 50°C were 45 and 221 min, respectively.**

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[1]Associate Professor and graduate student, respectively.

The majority of woody landscape plants produced in the United States are container-grown. Speed of production, ease of shipping and marketing, extension of seasonal sales and efficient land-use are among the advantages of container production over field production. Among the limiting factors to container production is increased environmental stress due primarily to the large exposed container surface area relative to the volume.

Heat stress effects on container-grown plants may not be obvious to the grower, because the first symptom of moderate heat stress is simply a decrease in growth rate (11). It is difficult to detect this symptom unless plants growing at near optimum rates are available for comparison. Other symptoms of such heat injury may include water stress effects, nutritional disorders and abnormal growth. These symptoms may be due to direct injury to a portion of the root system (7, 8) or prolonged exposures to sublethal yet supraoptimal temperatures (11).

Daily maximum temperatures approaching 50°C are common in the southern and southwestern regions of container media (2, 5, 14) and the critical temperature and exposure time differs among plant species. Exposure to 48°C for 156 and 181 min has been shown to be critical for *Pittosporum tobira* Thunb. and *Ilex vomitoria* Ait. 'Schellings', respectively, while only an 80 min exposure to 48°C caused direct root cell damage to *Ilex crenata* Thunb. 'Helleri' (6, 9). Such a difference in critical temperature and exposure duration between plants, even plants of closely related species, indicates the importance of knowing the relative heat tolerance of crop species before cultural practices aimed at reducing heat stress can be properly evaluated.

Electrolyte leakage, L_e, has proven to be an effective means of measuring the thermostabililty of plant cell membranes in fruit (3), leaf (12, 13) and root tissue (6, 7, 8, 9). This technique has been substantiated for use in determining critical temperatures causing direct heat injury as described by Levitt (12) revealed through membrane damage and cell death (7). A mathematical model describing the interactive effects of temperature and exposure time on the thermotolerance of *Pittosporum tobira* excised roots revealed a sigmoidal response of electrolyte leakage to high temperatures for a given exposure time and critical temperatures decreased linearly as exposure time increased exponentially (6).

The purpose of this research was to determine critical high temperatures and exposure durations for direct injury to roots of ixora for comparison to other plants. Electrolyte leakage was measured as an indicator of cell membrane damage and a mathematical model was derived to describe treatment temperature and exposure time interactions.

Materials and Methods

Ixora coccinea were grown in 9-liter containers with a medium of 3 pine bark : 2 Canadian peat : 1 builders' sand (by volume) amended with 3.0, 1.8, 1.2 and 6.0 kg/m^3 of dolomitic limestone, superphosphate, Perk (micronutrient manufactured by Estech, Inc., Winter Haven, FL) and Osmocote 18-6-12 (18N-3P-10K, manufactured by Sierra Chemical Co., Milpitas, CA), respectively. Osmocote 18-6-12 was also surface applied every 120 days at 24 g per container. Plants were grown in a glass house with 30 percent light exclusion in Gainesville, FL (USA) for 5 months before determination of root cell thermotolerance in August, 1984.

L_e procedures as described by Sullivan (13) and modified by Ingram and Buchanan (7, 8) were employed to measure the thermotolerance of ixora root cell membranes. Fifty test tubes for each test plant containing 1 g samples of excised roots were placed in a temperature controlled circulating water bath for each of 12 temperature treatments (25° to 60°C) and 5 tubes were taken from the bath every 30 min for 300 min. Deionized water (25 ml) was added to each sample before a 24 hour ice bath incubation and a measurement of electrical conductivity. Samples were then autoclaved at 120°C for 20 min and incubated in an icebath for another 24 hours before the second conductivity measurement. L_e of each sample was expressed as the ratio of conductivity after treatment to the conductivity after autoclaving.

A sigmoidal response curve was fitted to L_e data across temperature treatments for each of the 10 exposure times using a least-squares procedure as previously described (8). A mathematical model to describe temperature and exposure time interactions was derived by mathematically characterizing changes in each variable of the fitted sigmoidal equation in relation to exposure time and substituting these in the original equation (6).

Results and Discussion

L_e from excised ixora roots, as a function of temperature, T, at each exposure time, E, was appropriately described by a sigmoidal equation. The general equation was $L_e = z + [(x-y)/1 + e^{-k(T-T_m)}]$, where z was the baseline level of L_e, x was the maximum proportion of L_e, T_m was the temperature corresponding to the midpoint (inflection point) of the response curve, k was a function of the slope at the inflection point and T was the treatment temperature. The T_m of the 10 sigmoidal curves decreased exponentially as E increased, as was reported for *Pittosporum tobira* (6), *Ilex crenata* 'Helleri' and *Ilex vomitoria* 'Schellings' (9). Regression of T_m on ln E is presented in Fig. 1. Other variables in the sigmoidal equation did not differ with E. Therefore, the exponential relationship of $T_m = c + d$ (ln E) was substituted in the original sigmoidal equation and a least-squares fit of the substituted equation to the L_e data was performed for each plant as previously reported (6). Interactions of T and E are defined by the following mathematical expressions, and these fitted response surfaces are presented graphically in Fig. 2.

$$L_e = .2549 + \frac{0.4291}{+\ e^{-0.4284\,(T - 65.34 + 2.838 * \ln E)}}$$

Percent variability explained by the model (PVEM), as described by Ingram, et al. (1981), was used to indicate the fit of this response surface to the data for the test plant. The PVEM was 88.9 for ixora.

By solving for E in the expression $T_m = c + d(\ln E)$, $E = e^{(c - T)/d}$ was derived and thus can be used to calculate critical exposure times, E_c, for temperatures between 25° and 60°C. The predictive equations for ixora is as follows:

$$E_c = e^{(65.34 - T)/2.8378}$$

These equations were used to calculate the E_c for selected temperatures presented in Table 1. Confidence limits were calculated from $E_c = \pm\ t_{.05} \sqrt{\text{variance } (E_c)}$, where t was Student's t at the 0.5 level. The predicted E_c for a 55°C exposure was 38 min. The predicted E_c for a 48°C treatment of ixora roots was greater than 300 min, therefore, unpredictable with the derived model. This tolerance level appears to be higher than for *Pittosporum tobira* (6), *Ilex vomitoria* and *Ilex crenata* (9).

Critical temperatures and exposure times must be known for crop plants before cultural practice modifications to reduce temperatures can be meaningfully evaluated. If daily maximum root zone temperatures can be reduced to 48°C for less than 5 hrs daily, roots of *Ixora coccinea* may not sustain direct membrane injury. The im-

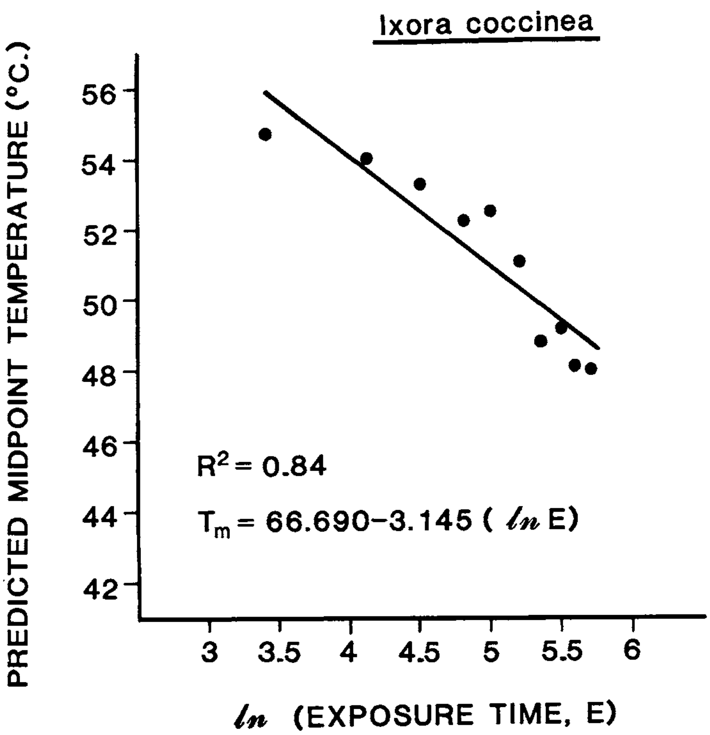

Fig. 1. Regression of predicted midpoint temperatures (T_m) on the ln of exposure time (E) for *Ixora coccinea.*

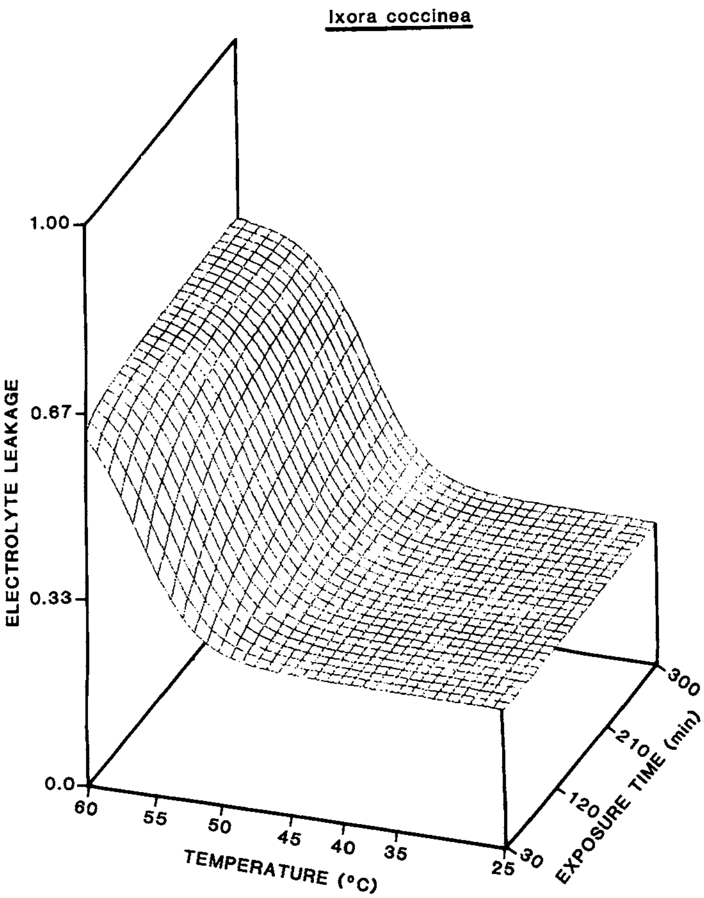

Fig. 2. Electrolyte leakage from *Ixora coccinea* excised roots in response to temperature and exposure time.

Table 1. Predicted critical exposure times for root injury of *Ixora coccinea* for selected supraoptimal temperatures.

Treatment (°C)	Predicted critical exposure time, E_c, (min)[z]
45	—[y]
48	—
50	221 ± 60[x]
52	110 ± 29
55	38 ± 15

[z]Calculated values derived from model describing temperature and exposure time interactions on membrane thermostability measured by electrolyte leakage.
[y]Predicted values were greater than 300 min, therefore, out of the range of the model.
[x]Confidence intervals calculated as $E_c \pm t_{.05} \sqrt{\text{variance }(E_c)}$.

portance of knowing the critical temperatures for selected plants becomes obvious. These findings do not address indirect heat injury caused by prolonged exposure to sublethal yet supraoptimal temperatures. Research has been initiated to determine growth and physiological responses to such sublethal root temperature regimes.

Literature Cited

1. Chen, H.-H., Z.-Y. Shen, and P. H. Li. 1982. Adaptability of crop plants to high temperature stress. Crop Sci. 22:719-725.
2. Fretz, T. A. 1971. Influence of physical conditions on summer temperatures in nursery containers. HortScience 6:400-401.
3. Furmanski, R. J. and R. W. Buesher. 1979. Influence of chilling on electrolyte leakage and internal conductivity of peach fruits. HortScience 14:167-168.
4. Gur. A., Y. Mizirahi, and R. M. Samish. 1976. The influence of root temperature on apple trees. II. Clonal differences in susceptibility to damage caused by supraoptimal root temperature. J. Hort. Sci. 51:195-202.
5. Ingram, D. L. 1981. Characterization of temperature fluctuations and woody plant growth in white poly bags and conventional black containers. HortScience 16:762-763.
6. Ingram, D. L. 1985. Modeling high temperature and exposure time interactions on *Pittosporum tobira* Thunb. root cell membrane thermostability. J. Amer. Soc. Hort. Sci. 110:470-473.
7. Ingram, D. L. and D. Buchanan. 1981. Measurement of direct heat injury of roots of three woody plants. HortScience 16:769-771.
8. Ingram, D. L. and D. W. Buchanan. 1984. Lethal high temperatures for roots of three citrus rootstocks. J. Amer. Soc. Hort. Sci. 109:189-193.
9. Ingram, D. L. 1986. Root cell membrane heat tolerance of two dwarf hollies. J. Amer. Soc. Hort. Sci. 111:270-272.
10. Ingram, K. T., D. C. Herzog, K. J. Boote, J. W. Jones, and C. S. Barfield. 1981. Effects of defoliating pests on soybean canopy CO_2 exchange and reproductive growth. Crop Sci. 21:961-968.
11. Johnson, C. R. and D. L. Ingram. 1984. Pittosporum tobira response to container medium temperature. HortScience 19:524-525.
12. Levitt, J. 1980. Response of plants to environmental stresses. Vol. 1. Chilling, freezing and high temperature stresses. Academic Press, New York.
13. Sullivan, C. Y. 1972. Mechanisms of heat and drought resistance in grain sorghum and methods of measurement. p. 247-264. In: N.G.P. Rao and L. R. House (editors.) Sorghum in the seventies. Oxford & I.B.H. Publishing Co. New Delhi, India.
14. Young, K. and D. R. Q. Hammet. 1980. Temperature patterns in exposed black polyethylene plant containers. Agr. Meterol. 21:165-172.