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EFFECTS OF SUPRAOPTIMAL ROOT TEMPERATURES ON BANANA, *IXORA, DRACAENA* AND CITRUS

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ABSTRACT

Thermostability of root cell membranes of excised roots of 'Grande Naine' banana, 'Carrizo' citrange, *Ixora coccinea* and *Dracaena marginata* 'Tricolor' were determined utilizing electrolyte leakage techniques. Mathematical models were developed to predict interaction of temperature (25° to 60°C) and exposure time (30 to 300 min.) on root membrance injury. Predicted critical exposure durations at 50°C were 45, 105, 221 and 221 min. for citrus, banana, *ixora* and *dracaena*, respectively. The physiological response to root temperature of 28°, 34° and 40°C for 6 hours daily differed with plant genera, although 34°C appeared to be the optimum or maximum allowable temperature in this study. Shoot to root ratio was highest at the 40°C root temperature for *ixora*, citrus and *dracaena* and was the lowest at 40°C for banana.

RESUMEN

La termostabilidad de membranas de celulas radiculares de raices cortados de banano 'Grande Naine', citrange 'Carrizo', *Ixora coccinea* y *Dracaena marginata* 'Tricolor' fue determinado usando tecinas de goteo electrolítico. Se desarrolló modelos mátematicos para predicar interacción de temperatura (25° a 60°C) y tiempo de exposicion (30 a 300 minutos) sobre daño a la membrana radicular. Duraciones predicados de exposición crítico a 50°C eran 45, 105, 221 y 221 minutos para cítrico, banano, *ixora* y *dracaena*, respectiveamente. La reacción fisiológica con temperaturas radiculares de 28°, 34° y 40°C por 6 horas diario varió entre genero, pero 34°C pareció ser la temperatura óptima o maxima permisible en este estudio. La relación del tallo a raíz era la mas alta con una temperatura radicular de 40°C para *ixora*, citrico y *dracaena* y era la mas baja a 40°C para banano.

Although many tropical plant species are tolerant of high soil temperatures in the field (19), the rapid temperature fluctuations and extremes that occur in container media under subtropical and tropical conditions (5, 9, 23) severely limit the nursery production phase of many fruits and ornamentals.

Higher evapotranspiration in containers as compared to field conditions can also lead to water stress which may be induced by high soil temperatures even under optimum soil moisture conditions (4, 18). Root temperatures have also been shown to influence several growth and physiological processes, including photosynthesis (7, 8), carbohydrate partitioning (1, 3, 6, 22), shoot to root ratios and whole plant weights (2, 3, 16).

Before effective measures can be taken to reduce supraoptimal root temperatures effects, it is important to identify the critical high temperature limits of tropical plant roots and to characterize some of the physiological responses induced by high root temperatures. This paper presents a review of preliminary results of a project on heat stress of plant roots funded by special Grants, USDA, Tropical Agriculture Section. The objective of this project was (a) to identify critical interactions of exposure duration and temperature on thermostability of excised roots of banana, ixora, dracaena, and citrus and (b) to study the influences of varying root temperatures on growth and physiology of container plants of the same species.

Critical exposure durations and temperatures for excised roots

Tissue-cultured plantlets of *Musa* spp. AAA 'Grande Naine', rooted cuttings of *Draceaena marginata* 'Tricolor' and *Ixora coccinea* and seedlings of 'Carrizo' citrange *(Citrus sinensis* x *Poncirus trifoliata)* were grown in 9 liter plastic containers. Osmocote 18–6–12, controlled release fertilizer was applied every 3 months at 24g per container. Plants were grown in 30 percent shade for 4 months before root thermostability determinations in August 1984.

Electrolyte leakage (L_e) procedures (10, 11, 12, 21) were used to measure themostability. Fifty 1g samples of carefully washed excised roots of each test plant were placed in test tubes and inserted into a temperature controlled circulating ethylene glycol bath for each of 12 temperature treatments (25 to 60°C) and 5 tubes were withdrawn at 30 min. intervals for up to 300 min. Twenty-five ml of deionized water were added to each sample tube before an ice bath incubation for 24 hrs. Conductivity of the incubation solution was then determined at room temperature and the samples were killed by autoclaving for 20 min at 120°C. Samples were incubated for another 24 hrs. before final conductivity measurements were taken. L_e of each sample was expressed as the ratio of the incubation solution conductivity before and after autoclaving. A sigmoidal response curve was fitted to L_e data across temperature treatments for each of the 10 exposures using a least-squares approach as described by Ingram (12). Mathematical models to describe temperature and exposure time interactions were derived (13, 14).

A sigmoidal response curve was the appropriate function to describe electrolyte leakage from roots of all test plants as influenced by temperature, T, at each exposure time, E. The temperature corresponding to the midpoint of the 10 sigmoidal curves decreased exponentially as E increased. The general equation describing the interactive effects of temperature and exposure time on root thermostability as measured by L_e was

$$L_e = z + (x-z)/1 + e^{-k(T-c-s(\ln E))}$$

where z was the baseline level of L_e, x was the maximum proportion of L_e, T was the treatment temperature, k was a function of the slope at the inflection point, c was the intercept of the temperature axis in

reference to critical temperatures, s was the slope of the fitted line of T across exposure times and E was the exposure time. The model has been described in detail for banana and dracaena and citrus and ixora. An equation was derived from the model for each test genera to predict cirtical exposure times, E_c, for given temperatures (13, 14).
These were:

Banana $E_c = e^{(62.168 - T)/2.615}$

Draceana $E_c = e^{(62.783 - T)/2.367}$

Citrus $E_c = e^{(65.073 - T)/3.964}$

Ixora $E_c = e^{(65.34 - T)/2.838}$

These equations were used to calculate E_c for selected temperatures presented in Table 1. The predicted E_c at 50 °C for example was twice as long for dracaena and ixora as for banana and 5 times as long for 'Carrizo' citrange. This would indicate a greater tolerance of dracaena and ixora roots to supraoptimal root temperatures as compared to roots of banana and citrus.

Table 1. Predicted critical exposure time for root cell membranes of 'Carrizo' citraize 'Grande Naine' banana *Ixora coccinea* and *Dracaena marginata* 'Tricolor' for selected temperatures.

Temperature (°C)	Predicted[y] critical exposure time, E_c (min)[z]			
	'Carrizo' citrange	*Ixora coccinea*	'Grande Naine' banana	*Dracaena marginata*
45	158 ± 25 [x]	-- -- --[w]	-- -- --	-- --
48	74 ± 23	-- -- --	225 ± 36	-- -- --
50	45 ± 10	221 ± 60	105 ± 14	221 ± 51
52	27 ± 8	110 ± 29	49 ± 6	95 ± 11
55	13 ± 5	38 ± 15	16 ± 5	27 ± 11
57	8 ± 4	19 ± 9	7 ± 4	11 ± 6

[z] Adapted from Ingram and Ramcharan (1986) *Trop. Agric. (Trinidad)* (In press) and Ingram and Ramcharan. (1986) J. Enuriron Hort. (In review)

[y] Calculated values derived from model describing temperature and exposure time interactions on membrane thermostability measured by electrolyte leakage.

[x] Confidence intervals calculated as $E_c + t_{.05}$ var (E_c).

[w] Predicted values were greater than 300 min. therefore, out of the range of the model.

Growth and physiological response to root zone temperatures

Dracaena, ixora, banana and citrus plants as described above were potted in 12 cm x 12.5 cm x 85 cm plastic containers. After 6 weeks, the containers were securely inserted into styrofoam-lined wooden 1m x 1m x 20cm air-bath boxes (15) in which the root systems were exposed to 28 ± 2, 34 ± 2, or 40 ± 2°C for 6 hrs. daily. Each box contained 9 plants. Four 100W aluminum foil-covered incandescent light bulbs provided convective heat, which was distributed by small 10cm x 10cm box fans. The bulbs were thermostatically controlled and temperatures in each box were characterized periodically with an Easterline Angus data logger using copper-constantan thermocouples. The boxes were located in a glasshouse with 800 µmol $m^{-2}s^{-1}$ maximum light intensity.

There were 4 replicate boxes for each treatment temperature and 2 or 3 plants per genera were randomly located in each box. Plants were drip irrigated with 300ml and fertilized weekly with a 20N-10P-17K solution at 150ppm N. The experiment was terminated after 90 days when shoot and root dry weights were determined and root and shoot samples taken for sugar and starch analysis using a previously described method (20).

Shoot to root ratio (S:R) was the major morphological feature affected by high root zone temperatures (Table 2). In the woody species ixora and citrus, S:R was increased by the 40°C treatment, as has been recorded for other woody plants (16). Increased lateral shoot growth and fewer flowers were evident also on ixora plants exposed to the higher temperatures. Increased S:R in dracaena was a consequence of reduced root growth. The 40 °C treatment also caused chlorosis and leaf drop with a consequent reduced quality of dracaena.

As has been reported for other herbaceous monocots (17, 3), morphological responses to high temperatures in banana were somewhat different. Shoot dry weight (leaf & pseudostem) increased linearly with increasing root temperatures. Since neither plant height nor leaf production were affected (data not shown) it may be deduced that the 40 °C treatment affected shoot size in banana mainly through its effect on reduced corm size.

Alterations in translocation and partitioning patterns of carbohydrates were apparently the major physiological effects of supraoptimal temperatures recorded in this experiment. Although absolute concentrations of sugar and starch did not differ with root temperature, partitioning or ratio between them differed (Table 2). Increased sugar: starch ratio (SU:ST) was found in the roots and decreased SU:ST in the shoots of ixora grown at 40 °C. This indicated increased translocation but not at the expense of shoot or root growth. In banana there was a decreased SU:ST in the roots and this appeared to be at the expense of shoot growth, particularly the corm. In dracaena, 40 °C caused considerable root growth reduction, and this was reflected in increased S:R ratio. This indicated increased translocation of photosynthates to the roots and probably high root respiration at the expense of root growth.

Table 2. Response of 'Grande Naine" banana, *Ixora coccinea, Dracaena marginata*, 'Tricolor' and 'Carrizo' citrange to three root zone temperatures. All data presented are means based on dry weight (g). (Adapted from Ingram *et al.* (1986). *HortScience*; In press)

Treatment Temperature (°C)	Shoot wt. (g)	Root wt. (g)	Shoot / root	Shoot sugar content (mg/g)	Shoot starch content (mg/g)	Shoot sugar/ starch	Root starch content (mg/g)	Root sugar content (mg/g)	Root sugar/ starch
				Ixora coccinea					
28	12.7	4.5	2.7	31.4	8.2	4.0	14.8	13.8	1.1
34	11.2	4.3	2.8	35.5	7.2	4.9	15.8	10.6	1.5
40	14.3	4.5	3.9	27.0	9.4	2.9	20.4	9.9	2.1
Linear[z]	NS	NS	NS	NS	NS	NS	NS	NS	0.05
Quadratic	NS	NS	0.06	NS	NS	0.05	NS	NS	NS
				'Grande Naine' Banana					
28	23.3	23.4	1.0	20.7	10.3	3.0	16.4	11.2	1.5
34	21.9	32.6	0.7	21.0	12.4	1.7	19.6	11.8	1.7
40	18.4	37.4	0.5	22.1	10.8	2.0	11.0	11.8	0.9
Linear	0.02	NS	0.02	NS	NS	NS	NS	NS	0.05
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	0.03
				'Carrizo citrange'					
28	2.4	2.6	1.0	19.0	26.4	0.7	16.0	20.4	0.8
34	3.0	3.3	0.9	21.3	24.2	0.9	11.1	19.2	0.6
40	3.2	2.6	1.3	31.9	25.4	1.3	11.0	21.9	0.5
Linear	NS	NS	0.05	NS	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS
				Dracaena marginata 'Tricolor'					
28	31.8	23.8	1.3						
34	29.2	25.7	1.1						
40	26.8	13.6	2.0						
Linear	NS	0.05	NS						
Quadratic	NS	0.005	0.06						

[z] Regression analyses were used to test for significant linear and quadratic responses.

Summary

Plant roots in containers may be exposed briefly to temperatures approaching 50 °C several times per week during the summer months (11). Injury sustained in such a short period is called direct injury. Temperatures above 45 °C may be maintained for 3 to 6 hours daily and can result in indirect injury to plant roots (16). The temperatures causing direct injury of excised banana, citrus, dracaena and ixora roots were determined using electrolyte leakage procedures. Growth and physiological responses of the same species in containers exposed to 28, 34 or 40 °C for 6 hr daily were measured.

Excised dracaena and ixora roots withstood 50°C for up to 3 hr and were more thermotolerant than citrus and banana roots. However, data indicate that dracaena and ixora were less tolerant of prolonged daily exposures to supraoptimal yet sublethal temperatures. Dracaena root dry weight was reduced and leaf chlorosis and leaf drop increased by the 40 °C treatment. Ixora had more axillary growth, less flowering and reduced root sugar/starch ratio at 40 °C, implying a possible hormonal effect and alteration of translocation and/or root respiration.

Additional research has been initiated to more precisely determine the response of these plants to supraoptimal temperatures. Temperatures in container media in the tropics are also being characterized and methods of modifying these temperatures are being evaluated.

References

1. Barlow, F.W.R., L. Boersma, and J. L. Young. 1976. Root temperature and soil water potential effects on growth and soluble carbohydrate concentration of corn seedlings. Crop Sci. 16:59–62.

2. Barta, A.L. 1978. Effect of root temperature on dry matter distribution, carbohydrate accumulation, and acetylene reduction activity in alfalfa and birdsfoot trefoil. Crop Sci. 18:640–647.

3. Brown, R.H. and R.E. Blaser. 1970. Soil moisture and temperature effects on growth and soluble carbohydrates of orchard grass *(Dactylis glomerata)*. Crop Sci. 10:213–216.

4. Chen, H.-H., Z.-Y. Shen, and P.H. Li. 1982. Adaptability of crop plants to high temperature stress. Crop Sci. 22:719–725.

5. Fretz, T.A. 1971. Influence of physical conditions on summer temperatures in nursery containers. HortScience 6:400–401.

6. Guinn, G. and R.F. Hunter. 1968. Root temperature and carbohydrate status of young cotton plants. Crop Sci. 8:67–70.

7. Gur, A., B. Bravdo and Y. Mizirahi. 1972. Physiological response of apple trees to supraoptimal root temperatures. Physiol. Plant 27:130–138.

8. 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 temeperature. J. Hort. Sci. 51:195–202.

9. Ingram, D.L. 1981. Characterization of temperature fluctuations and woody plant growth in white poly bags and conventional black containers. HortScience 16:762–763.

10. 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.

11. 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.

12. Ingram, D.L. and D.W. Buchanan. 1984. Lethal high temperatures for root of three citrus rootstocks. J. Amer. Soc. Hort. Sci. 109:189–192.

13. Ingram, D.L. and C. Ramcharan. 1985. Heat tolerance of 'Carrizo' citrange and *Ixora coccinea* root cell membranes. (In review).

14. Ingram, D.L. and C. Ramcharan. 1985. 'Grande Naine' banana and *Dracaena marginata* 'Tricolor' root cell membrane heat tolerance. Trop. Ag. (In press).

15. Ingram, D.L., C. Ramcharan and T.A. Nell. 1986. Responses of banana, ixora, citrus and dracaena to elevate root temperatures. HortScience 21: (In press).

16. Johnson, C.R. and D.L. Ingram. 1984. *Pittosporum tobira* response to container medium temperature. HortScience 19:524–525.

17. Ketellapper, H.J. 1960. The effect of soil temperature on the growth of *Phalxis tuberosa* L. Physiol. Plant. 13:641–649.

18. Levitt, J. 1980. Response of plants to environmental stresses. Vol. I. Chilling, freezing and high temperature stresses. Academic Press, New York.

19. Medcalf, J.C., 1985. Preliminary studies on mulching young coffee in Brazil. IBEC Res. Inst. Bull. No. 12.

20. Stamps, R.H. 1984. Production temperature effects on anatomy, morphology, physiology and postharvest longevity of leatherleaf fern (*Rumorhra adiantiforms* Forst. Ching). Dissertation Univ. of Florida. Gainesville, FL.

21. 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 (eds.) Sorghum in the seventies. Oxford & I.B.H. Publishing Co. New Delhi. India.

22. Turner, D.W. and E. Lahav. 1983. The growth of banana plants in relation of temperature. Aust. J. Plant Physiol. 19:43–53.

23. Young. K. and D.R.Q. Hammet. 1980. Temperature patterns in exposed black polyethylene plant containers. Agr. Meterol. 21:165 – 172.