'Grande Naine' banana and *Dracaena marginata* 'Tricolor' root cell membrane heat tolerance.

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'GRANDE NAINE' BANANA AND *DRACAENA MARGINATA* 'TRICOLOR' ROOT CELL MEMBRANE HEAT TOLERANCE.

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ABSTRACT - Excised roots of 'Grande Naine' banana grown from tissue culture propagation and *Dracaena marginata* 'Tricolor' were subjected to temperatures of 30° to 60°C for 30 to 300 min. Mathematical models were derived to describe the interactions of treatment temperature and exposure time (E) on the thermostability of root cell membranes as measured by electrolyte leakage (L_e). Critical temperature for each plant decreased exponentially as E increased. Predicted critical exposure times at 48° and 52°C were greater than 300 and 221±51 min, respectively, for dracaena and 225±36 and 105±14 min for banana, respectively.

RESISTANCE A LA CHALEUR DE LA MEMBRANE CELLULAIRE DE LA RACINE DE BANANIER 'GRANDE NAINE' ET DE *DRACAENA MARGINATA* 'TRICOLOR'.

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RESUME - Des racines de bananier 'Grande Naine' excisées d'une culture de tissus ainsi que des racines de *Dracaena marginata* 'Tricolor' ont été soumises à des températures de 30 à 60°C durant des périodes de 30 à 300 minutes. On a établi des modèles mathématiques pour décrire les interactions température et durée d'exposition (E) sur la thermostabilité des membranes de cellules racinaires mesurée par la fuite d'électrolyte (L_e).
Pour chacun des plants la température critique décroît d'une façon exponentielle lorsque E augmente. Les durées d'exposition critique calculées à 48 et à 52°C ont été plus élevées, respectivement, pour le *Dracaena* de 300 et 221 ± 51 min. et pour le bananier de 225 ± 36 et 105 ± 14 min.

High root temperatures can be an undetected but significant constraint to plant growth in general (11) especially container-grown nursery crops (6). High temperatures in container media are possible due to direct solar radiation on container sidewalls and the large surface area to volume ratio of production containers. Year-round high ambient temperatures and intense solar radiation in the tropics could cause severe heat loads on container growth medium temperatures. Although many tropical species tolerate relatively high soil temperatures in the field (12), rapid temperature fluctuations and temperature extremes characteristic of container production could cause direct and/ or indirect injury (3, 6, 15).

With the advent of tissue culture for mass propagation of several horticultural crops including 'Grande Naine' banana (2), a new container phase has been added to the overall production scheme. Tissue-cultured plants are then prone to be stressed by supraoptimal temperatures in this containerized phase of production and the effects of such stress could increase required production time and result in less vigorous plants, limiting future growth potential. This certainly could be true in banana production, but could also limit production of economically important tropical ornamental plants such as *Dracaena marginata* grown for local use and export (13).

Critical limits of tropical plant roots must be determined before cultural practices to reduce heat stress to plant roots can be effectively evaluated. Heat tolerance differs with species, genotype within species and cultivar (5). A first step in determining sensitivity of plant roots to high temperatures is to identify those temperatures and exposure times that cause direct injury to roots. After these lethal conditions have been defined, characteristics of indirect heat injury can be defined.

Electrolyte leakage (L_e) has proven to be an effective means of measuring the thermostability of plant cell membranes in fruit (4), leaf (14) and root tissue (7, 8, 9). This technique has been substantiated for use in determining critical temperatures causing direct heat injury to plant roots, as described by Levitt (11), revealed through membrane damage and cell death (7).

The purpose of this study was to identify the critical interactions of exposure duration and temperature on the thermostability of 'Grande Naine' banana and *Dracaena marginata* root cells. L_e was measured as an indicator of direct cell membrane damage to excised roots.

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MATERIALS AND METHODS

Stage IV tissue-cultured 'Grande Naine' Banana and rooted tip cuttings of *Dracaena marginata* 'Tricolor' were grown in 9 L 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 formulation by Estech, Inc., Winter Haven, FL) and Osmocote 18-6-12 (18N-3P-10K; slow-release fertilizer 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 for 4 months before determination of root cell membrane thermostability in August, 1984.

L_e procedures as described by Sullivan (14) and modified by Ingram and Buchanan (9, 10, 11) were employed to measure the thermostability of root cell membranes. Fifty test tubes for each genera containing 1 g samples of excised roots were placed in a temperature-controlled circulating polyethylene glycol bath (Forma Scientific Model 2425) for each of 12 temperature treatments (25° to 60°C) and 5 tubes were taken from the bath every 30 min for 300 min. Twenty-five ml of deionized water were added to each sample before an ice bath incubation for 24 hrs. Conductivity of the incubation solution was then determined and the samples were killed by submersion by autoclaving at 120°C for 20 min. Samples were then incubated for another 24 hrs before the final conductivity measurement was taken. L_e of each sample after treatment was expressed as the ratio of the incubation solution conductivity after treatment to the conductivity after autoclaving.

A least-squares approach as previously described (9) was used to fit a sigmoidal response curve to L_e data across temperature treatments for each of the 10 exposure times. Mathematical expressions characterizing each variable with respect to exposure time was substituted in the equation of the sigmoidal curve to describe temperature and exposure time interactions (7).

RESULTS AND DISCUSSION

A sigmoidal response curve was the appropriate function to characterize L_e from 'Grande Naine' banana and *Dracaena marginata* 'Tricolor' root tissue across treatment temperature (T) at each exposure time (E). The general equation describing this response was

$$L_e = z + \frac{x - z}{1 + e^{-k(T - T_m)}}$$

where z was the baseline level electrolyte leakage, x was the maximum proportion of electrolyte leakage, T_m was the temperature corresponding to the midpoint (i.e inflection point) of the response curve, k was a function of the slope at the inflection point, and T was the treatment temperature. The temperature corresponding to the midpoint, T_m, of the 10 sigmoidal curves decreased exponentially as E increased. Similar response was found with *Pittosporum tobira* Thunb. (7). The equation describing the relationship between predicted T_m and E can be written as $T_m = c + d$ (l_n E), where c is the intercept and d is the slope of the fitted line. Regressions of T_m on ln E for both plants are presented in Fig. 1. Comparison of the slope of the regression lines and the corresponding temperatures indicates that *Dracaena* roots could tolerate higher supraoptimal temperatures but were more sensitive to exposure time than banana.

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 for each genera resulted in the following mathematical expressions of T and E interactions. These fitted response surfaces are presented graphically in Fig. 2.

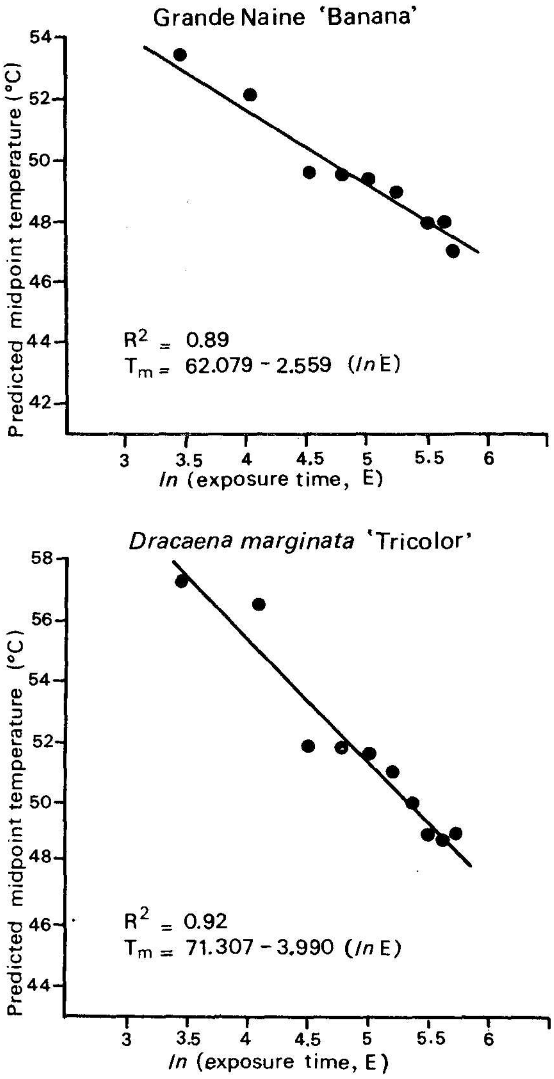

Figure 1 - Regression of predicted midpoint temperatures (T_m) of the ln of exposure time (E) for 'Grande Naine' Banana and *Dracaena marginata* 'Tricolor'.

'Grande Naine' Banana

$$L_e = 0.2818 + \frac{0.4630}{1 + e^{-0.9182\,[T - 62.1678 + 2.6151\,(\ln E)]}}$$

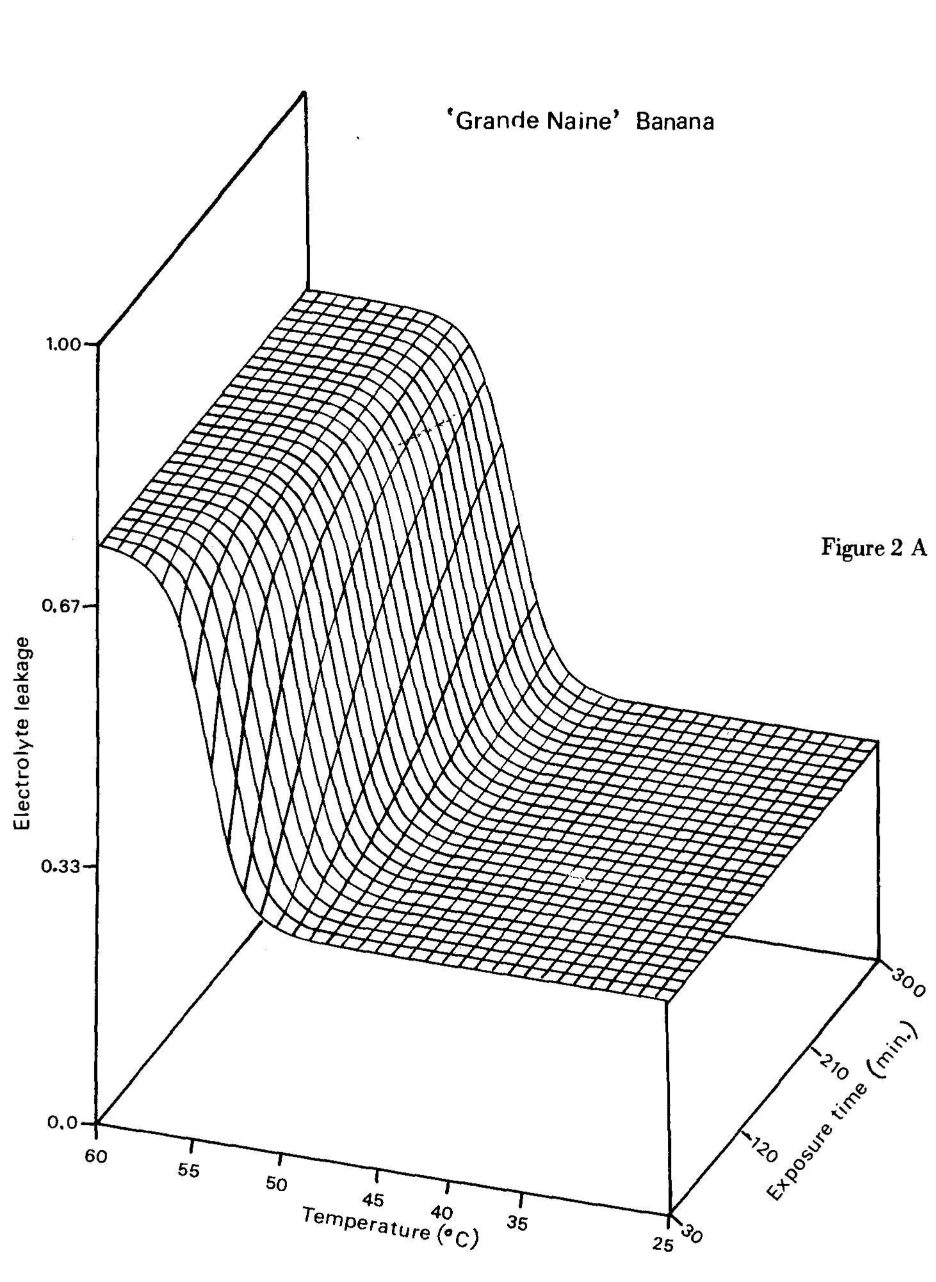

Figure 2 - Response of 'Grande Naine' Banana and *Dracaena marginata* 'Tricolor' excised roots to temperature and exposure time.

Dracaena marginata 'Tricolor'

$$L_e = 0.2579 + \frac{0.5679}{1 + e^{-0.5535\,[T - 62.783 + 2.3673\,(\ln E)]}}$$

Percent variability explained by the model (PVEM) as described by Ingram, *et al.* (12) was used to indicate the fit of this response surfaces to the data for each test plant. The PVEM was 89.2 for the *Dracaena* and 90.5 for the banana.

An equation can be derived from each of the models above to predict critical exposure times for given temperatures. This predictive equations for the two test plants are as follows.

'Grande Naine' Banana	*Dracaena marginata* 'Tricolor'
$E_c = e^{(62.1678-T)/2.6151}$	$E_c = e^{(62.783-T)/2.3673}$

These equations were used to calculate the critical exposure times for selected temperatures presented in Table 1. Confidence limits were calculated from $E_c \pm t_{.05}\sqrt{\mathrm{var}\,(T_c)}$, where var ($T_c$) is the variance of E_c and t is Student's t at the .05 level of significance. Greater variability in the *Dracaena* resulted in wider confidence intervals about the predicted E_c for *Dracaena* than for banana. Lack of variability in banana could have been due to the uniformity of tissue culture propagated plants.

The predicted E_c at 50°C was twice as long for *Dra-*

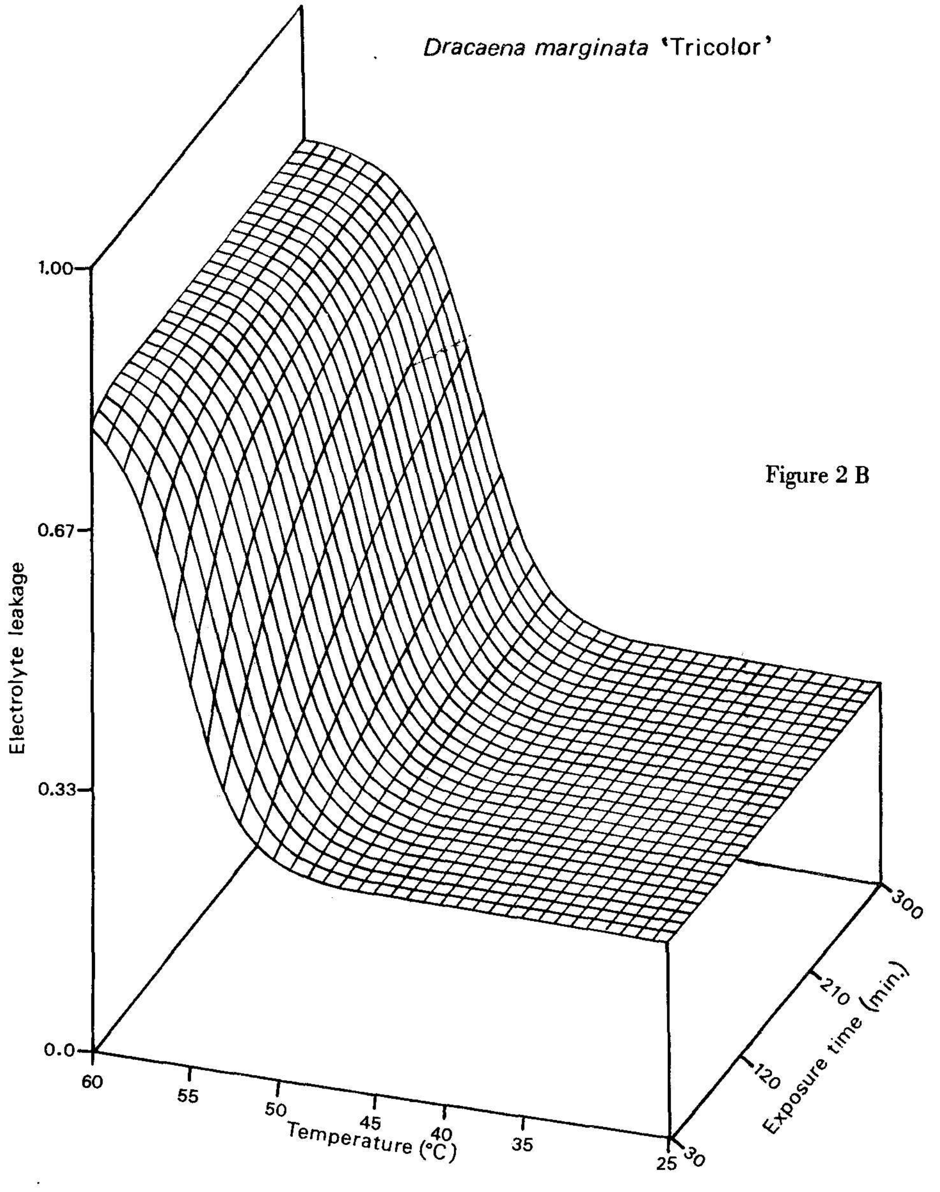

Figure 2 B

TABLE 1 - Predicted critical exposure time for root cell membranes of for 'Grande Naine' banana and *Dracaena marginata* 'Tricolor' for selected temperatures.

Temperature (°C)	Predicted critical exposure time, E_c (min) *	
	banana	*Dracaena*
48	225 ± 36 **	---------------***
50	105 ± 14	221 ± 51
52	49 ± 6	95 ± 22
55	16 ± 5	27 ± 11
57	7 ± 4	11 ± 6

* - calculated values derived from model describing temperature and exposure time interactions on membrane thermostability measured by electrolyte leakage.
** - confidence intervals calculated as $E_c \pm t_{.05}\sqrt{\text{var}\ (T_c)}$
*** - calculated value was greater than 300 min, therefore out of the range of the predictive model.

caena than banana. Direct injury to root cell membranes of banana would probably be avoided if growth medium temperatures approaching 50°C were maintained for less than 1.5 hrs daily. *Dracaena marginata* 'Tricolor' root cell membranes would not be disrupted even with a 3 hr exposure to 50°C. Daily temperatures as high as 50°C have been reported to be maintained only for 1 hr or less in container media in Florida (6) and Australia (15), therefore, temperature regimes causing direct injury to roots of container-grown *Dracaena* are unlikely. This does not address indirect injury that may occur due to prolonged and/or repeated exposure to supraoptimal yet sublethal temperatures.

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WÄRMEFESTIGKEIT DER ZELLMEMBRAN DES WURZELWERKS DER 'RIESENZWERG'-BANANENPFLANZE UND VON *DRACAENA MARGINATA* 'TRICOLOR'.

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KURZFASSUNG - Die einer Gewebekultur entnommenen Wurzeln einer Riesenzwerg-Bananenpflanze und Wurzeln von *Dracaena marginata* 'Tricolor' wurden über Zeitspannen von 30 bis 300 Minuten einem Temperaturbereich von 30 bis 60°C ausgesetzt. Anschliessend wurden mathematische Modelle erarbeitet zur Schilderung der Folgewirkungen von Temperatur und Einwirkungsdauer (E) auf die Thermostabilität der Wurzelzellenmembranen, welche anhand des Elektrolytverlustes (Le) gemessen worden ist.
Bei jeder Pflanze sinkt die kritische Temperatur mit steigendem E-Wert gemäss einer Exponentialkurve. Die für 48 und 52°C berechneten, kritischen Zeiten der Wärmeeinwirkung lagen bei *Dracaena* um 300 bzw: 221 ± 51 Min. höher und bei der Bananenpflanze um 225 ± 36 bzw. 105 ± 14 Min. höher.

RESISTENCIA AL CALOR DE LA MEMBRANA CÉLULAR DE LA RAÍZ DE BANANO 'GRANDE NAINE' Y DE *DRACAENA MARGINATA* «TRICOLOR».

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RESUMEN - Raíces de banano 'Grande Naine' cortadas de un cultivo de tejidos así como raíces de *Dracaena marginata* «Tricolor» se han sometido a temperaturas de 30 a 60°C durante períodos de 30 a 300 minutos. Se han establecido modelos matemáticos para describir las interacciones temperatura y duración de exposición (E) sobre la termostabilidad de las membranas de células de raíces medida por la fuga de electrolito (Le). Para cada una de las plantas la temperatura crítica decrece de manera exponencial cuando E aumenta. Las duraciones de exposición crítica calculadas a 48 y a 52°C han sido más elevadas, respectivamente, para el *Dracaena* de 300 y 221 ± 51 min. y para el banano de 225 ± 36 y 105 ± 14 min.