

lands. Therefore this species was generally considered resistant until 1978 when 2 cultivars, 'Petite Yellow' and 'Petite Orange', were reported to be severely infected in Australia (4); in our study, however, 'Petite Yellow' exhibited mild symptoms.

Results of the greenhouse tests were similar to those from the field trial.

Host Age. Seeds of 'Moonshot' and 'Orange Jubilee' marigold were sown at 2-week intervals in a 27°C greenhouse and were

simultaneously inoculated when the plants were 3-, 5-, 7-, 9- and 11-weeks-old. They were observed for 3 weeks for symptom development.

The 3- and 5-week-old plants of both cultivars developed leaf spots and apical chlorosis within 7 days after inoculation. However, the chlorotic tissue of the 5-week-old 'Orange Jubilee' plants subsequently became green during later flower development. The 7-, 9- and 11-week-old 'Orange Jubilee' plants, which were all in full flower at the time of inoculation, did not develop any symptoms. Among the 7-week-old 'Moonshot' plants dramatic differences in symptom expression existed. Plants which had not formed flower buds at the time of inoculation developed apical chlorosis and leaf spots; the remainder, which had just formed buds, exhibited only a few leaf spots on the youngest leaves and only slight chlorosis on one or 2 small shoots. The 9- and 11-week-old 'Moonshot' plants were in full flower when inoculated and did not develop any symptoms.

Symptom development in marigold in response to *P. syringae* pv. *tagetis* is dependent on the maturity of the host tissue. Reactions develop only on immature tissue; thus, for most cultivars the time period over which symptoms can develop and the extent of symptom development will parallel the duration of vegetative growth. However, the period of vegetative growth is not the only factor determining susceptibility for, although most dwarf marigolds had only mild symptoms, our observations and the description of severe symptoms on dwarf cultivars in Australia (5) indicate that some cultivars of this type are quite susceptible.

Once a shoot flowers it will not develop any new symptoms. Flowering, however, does not produce a systemic effect because vegetative shoots will develop symptoms on plants already having flowering shoots. Additionally, when inoculated but symptomless, flowering dwarf cultivars 'Harmony Boy', 'Gypsy Sunshine' and 'Queen Sophia' were transplanted from the greenhouse outside, the newly-induced growth developed symptoms. This may explain the occurrence of apical chlorosis of mature marigolds in Australia (4), since these plants were in parks where transplants are commonly used.

This pattern of symptom development provides a new perspective from which to examine the previous literature. The irregular appearance of apical chlorosis observed by both Hellmers (2) and Bakker (1) may reflect differences in host age rather than differences in the pathogen.

We believe these findings are important for the proper timing of inoculations and disease ratings, and should greatly facilitate the selection of resistant marigolds.

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Table 1. Symptoms exhibited by different marigold cultivars in response to *Pseudomonas syringae* pv. *tagetis*.

| Type | Reaction class ² |
|-------------------------------------|-----------------------------|
| <i>Tagetes erecta</i> | |
| Dwarf | |
| Aztec series | |
| Aztec Gold | I |
| Aztec Yellow | M |
| Chrysanthemum-flowered | |
| Cupid Yellow | M |
| Crush series | |
| Dolly | M ³ |
| Pineapple Crush | M ³ |
| Pumpkin Crush | M ³ |
| Semidwarf | |
| Galore series | |
| Gold Galore | I |
| Yellow Galore | I |
| Jubilee series | |
| Diamond Jubilee | S |
| Happy Face | S |
| Orange Jubilee | I |
| Lady series | |
| First Lady | M |
| Orange Lady | I |
| Space Age series | |
| Apollo | I |
| Moonshot | S |
| Viking | M |
| Tall | |
| Crackerjack | S |
| Chrysanthemum-flowered | |
| Fantastic Orange | M |
| Mellow Yellow | S |
| Climax series | |
| Golden Climax | I |
| Yellow Climax | S |
| Gold Coin series | |
| Doubleloon | S |
| Sovereign | S |
| <i>T. patula</i> | |
| Dwarf Crested | |
| Gypsy Sunshine | M |
| Dwarf Double | |
| Honeycomb | M |
| Panther | M |
| Queen Sophia | I |
| Spanish Brocade | M |
| Sparky | M |
| Dwarf Single | |
| Burgundy Ripple | M |
| Dainty Marietta | M |
| Extra Dwarf Crested | |
| Lemon Drop | M |
| Extra Dwarf Double | |
| Brownie Scout | I ⁴ |
| Harmony Boy | M |
| Petite Harmony | M |
| Petite Yellow | M |
| <i>T. erecta</i> x <i>T. patula</i> | |
| Gingersnap | S |
| Triple Yellow (Honeybee) | M |
| <i>T. tenuifolia</i> | |
| Golden Gem | M |

² S = Severe chlorosis and many leaf spots; I = Intermediate chlorosis and leaf spots; M = Mild chlorosis and few leaf spots

³No apical chlorosis

⁴Intermediate chlorosis only

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Measurement of Direct Heat Injury of Roots of Three Woody Plants¹

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Additional index words. electrolyte leakage, *Ilex*, *Illicium*, *Juniperus*

Abstract. Electrolyte leakage was used to measure direct heat injury to roots of *Illicium anisatum* L., *Ilex cornuta* L. cv. *Burfordii* and *Juniperus chinensis* L. cv. *Parsonii*. A sigmoidal relationship was found between percent electrolyte leakage and temperature treatment. About 50% electrolyte leakage was realized from a 20 minute exposure of roots to 50.5 ± 0.5°, 48.5 ± 0.5° and 46.5 ± 0.5°C for *I. anisatum*, *J. chinensis*, and *I. cornuta*, respectively.

Container media temperatures higher than air temperatures are due primarily to direct or reflected solar radiation on container

sidewalls with container design (7) and color (2) affecting temperature extremes. Media temperatures in excess of 50°C have been reported (2) and maximum daily temperatures normally occur for less than 1 hr (11). Root death caused by short exposures to these extremes may be due to direct injury revealed through loss of membrane integrity (3).

Wong et al. (8) using visual observations, concluded that root tips of several woody plants were killed by 4 hr exposure to 45°C. A

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Table 1. Effects of post treatment root segment length and incubation temperature on mean percent electrolyte leakage and corresponding variances from 41 and 57°C treatments of *Illicium anisatum*.

| Treatment | 41°C | | 57°C | |
|-------------------------------|---------------------|---------------------|--------|----------|
| | Mean ^a | Variance | Mean | Variance |
| <i>Post treatment</i> | | | | |
| <i>root segment length</i> | | | | |
| No Cut | 8.3 a ^b | 19.3 a ^b | 83.2 a | 20.9 a |
| 20 mm | 10.6 b | 12.4 a | 85.2 a | 5.7 ab |
| 10 mm | 11.6 b | 9.5 a | 86.6 a | 2.8 b |
| <i>Incubation temperature</i> | | | | |
| Ice bath | 10.0 a ^b | 3.3 a ^b | 83.4 a | 3.1 a |
| 25°C | 16.0 b | 24.2 b | 86.9 b | 16.5 b |

^aMeans of electrolyte leakage after temperature treatment expressed as a percentage of electrolyte leakage of tissue after killed.

^bMean separation within columns by Duncan's multiple range test, 5% level.

^cVariance separation by Hartley's maximum F ratio, 5% level.

4 day exposure to 43° resulted in pecan root death (9). Root injury at these temperatures and exposure times probably resulted from indirect injury and not direct injury (3). Levitt (3) indicated exposure time was less critical at temperatures that induced direct heat injury. Sullivan et al. (6) reported differences in heat tolerance of grain sorghum leaves among species and genotypes within species; therefore, differences in heat tolerance among woody plants are likely.

Electrolyte leakage from leaf and fruit tissue exposed to various injurious conditions has been used to measure degree of cellular damage (1, 5, 6, 10). The technique is a measurement of change in membrane permeability caused by membrane damage. Martineau et al. (4) employed this technique to determine heat injury to soybean leaves was a sigmoidal function of temperature.

This research was established to determine critical temperatures at which direct heat injury to roots occurred for *Ilex cornuta* cv. Burfordii, *Illicium anisatum* and *Juniperus chinensis* cv. Parsonii. Plants were grown in 20 liter containers in a medium of 2 pine bark:1 peat:1 sand (v/v/v). Plants were grown in Gainesville, Florida under 47% light exclusion during the summer of 1980, then moved into a greenhouse (12°C minimum, 32°C maximum) for winter months.

Membrane thermostability was measured in March and April, 1981, using electrolyte leakage procedures described by Sullivan (6) with modifications. One gram samples were taken from 15 to 20 cm of actively growing roots, rinsed in deionized water, cut into 5 cm segments and placed in stoppered test tubes with 2 drops of deionized water. Six test tubes were placed in a thermostatically regulated water bath at each treatment temperature for 20 min and 6 controls were maintained at 24°C. Tissue temperatures were monitored by an Esterline-Angus PD2064 temperature recorder with welded copper-constantan thermocouples. Root tissue temperatures reached equilibrium within 2 min.

These procedures were performed 4 times at 5 to 7 tissue temperatures (38° to 60°C) per replicate to obtain multiple points on a response curve. Temperature bath and monitoring equipment could yield a variability up to $\pm 0.5^\circ$.

A preliminary experiment was conducted with *I. anisatum* to evaluate effects of incuba-

tion temperature (ice bath and 25°C) and cutting root segments into 10 or 20 mm sections following heat treatment on electrolyte leakage. Five samples per treatment exposed to 41°C and 57° were replicated 3 times. Ice bath incubation and 10 mm root sections were used in subsequent experiments.

Samples were incubated after heat treatment in 25 ml deionized water for 24 hr and electrical conductivity of each solution was measured. Root tissue was then quick killed by dipping test tubes in liquid nitrogen. After another 24 hr ice bath incubation the conductivity of the solutions was determined again. Heat injury was expressed as percentage of solution conductivity after heat treatment compared to conductivity after immersion in liquid nitrogen.

Cutting *I. anisatum* roots into 10 and 20 mm sections slightly elevated percent electrolyte leakage compared to the no cut treatment, but the variance was reduced by the 10 mm cut at 57°C temperatures (Table 1). Heat treatments could have suberized root epidermal layers enough to inhibit free flow of electrolytes from intercellular spaces into the solution. Cutting treated roots into 10 mm sec-

tions provided a shorter route for electrolyte diffusion. Ice bath compared to 25° incubation reduced the variance of percent electrolyte leakage after exposure to 41° and 57° (Table 1) Ice bath incubation probably reduced or eliminated injurious products of anaerobic respiration and bacteria growth that could be prevalent during incubation at higher temperatures.

A sigmoidal relationship was evident between treatment temperatures (20 min exposures) and percent heat electrolyte leakage for roots of all 3 species (Fig. 1). The shapes of these response curves were similar to that for soybean leaves (4) and most other taxa investigated. The most sensitive region on the curve for measuring heat injury was at temperatures resulting in about 50% electrolyte leakage. Therefore, this point would be best for comparing species or treatments. Little injury of *I. anisatum* roots occurred at temperature treatments below 47°C, but above 50° the percent root injury increased rapidly as temperature increased. Electrolyte leakage increased from 20% at 46°C to 80% at 55°. Direct extrapolation on the response curve drawn through the array of points showed a 20 min exposure to $50.5^\circ \pm 0.5^\circ$ resulted in about 50% electrolyte leakage of *I. anisatum* roots. Temperature treatments of $48.5^\circ \pm 0.5^\circ$ resulted in about 50% electrolyte leakage of *J. chinensis* cv. Parsonii roots and 50% electrolyte leakage of *I. cornuta* cv. Burfordii roots corresponded to a 20 min exposure to $46.5 \pm 0.5^\circ$. These data indicate that *I. anisatum* roots are less sensitive to short exposure of high temperatures than *J. chinensis* cv. Parsonii roots which are less sensitive than *I. cornuta* cv. Burfordii roots.

Electrolyte leakage appeared to be a reliable method of measuring heat injury of *I. anisatum*, *I. cornuta* cv. Burfordii and *J. chinensis* cv. Parsonii roots. Removal of container media from root samples leaches some

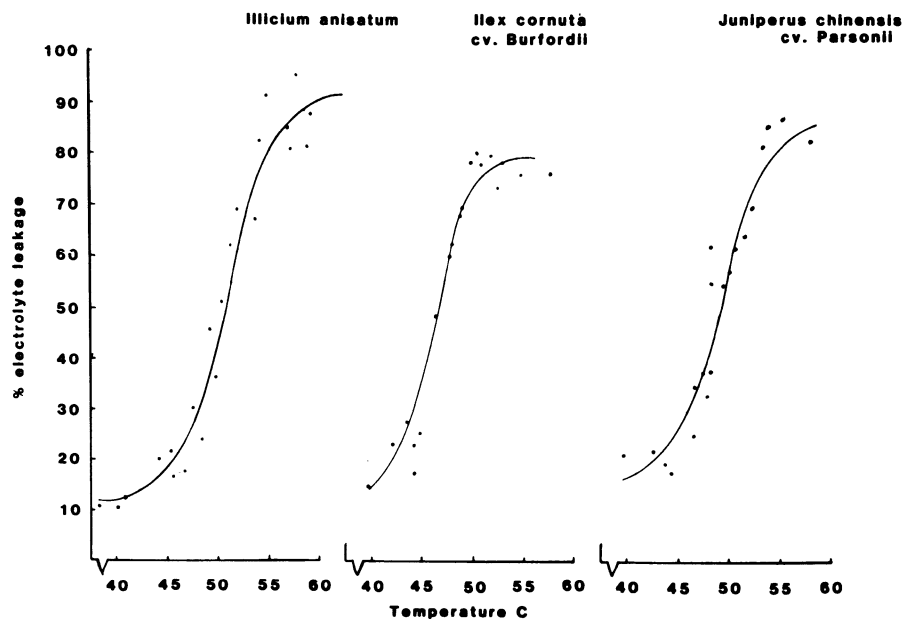


Fig. 1. Relationship of percent electrolyte leakage of roots from 3 woody plants to 20 min exposure to treatment temperature (curves drawn free-hand through array of points).

electrolytes from root free space and causes a degree of physical injury, but media not removed would affect electrolyte leakage measurements.

When container media temperatures exceed 50°C for 20 min, substantial direct heat injury to roots of plants studied can be expected. Heat injury of roots from all 3 plants was minimal below 44 to 45° for 20 min. If maximum temperatures and corresponding exposure times can be maintained below these critical points, direct heat injury can be minimized or avoided. Long exposures to temperatures slightly less than the critical range may result in indirect heat injury (3, 8, 9). Responses of these plants to media temperatures below those inducing direct injury have not yet been characterized.

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Influence of N-P-K Factorial Fertilization on Growth Characteristics and Foliar Content of 4 Foliage Plants¹

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Additional index words. *Dieffenbachia*, *Dracaena*, *Maranta*, *Peperomia*, nitrogen, phosphorus, potassium

Abstract. Data indicated the N-P₂O₅-K₂O ratio of 1-1-1 is unnecessarily high in P₂O₅ and K₂O for *Dieffenbachia maculata* (Lodd.) G. Don 'Exotica', *Dracaena sanderana* Hort. Sander ex M. T. Mast, *Maranta leuconeura* var. *kerchoviana* E. Morr., and *Peperomia obtusifolia* (L.) A. Dietr. Plant growth and tissue nutrient levels were more sensitive to changes in N fertilization level than P and K. Tissue N was a more sensitive indicator of optimum growth and fertility practices than P or K.

Most foliage plants grow well with a 1-1-1 N-P₂O₅-K₂O ratio, such as an 8-8-8 or 20-20-20 fertilizer analysis, but they also grow satisfactorily with a 3-1-2 ratio, such as a 9-3-6 or 18-6-12 analysis (1).

Research on the N-P-K requirements of individual foliage plant species is still limited. Poole and Conover (5) found that 100-150 mg N, 25 mg P, and 100-120 mg K/10 cm pot at 4 week intervals in 50 ml of solution produced good quality *Aechmea fasciata* Baker. *Aglaonema commutatum* Schott cvs. Fransher and *Pseudobracteatum* (6) receiving 240 mg N, 80 mg P, and 240-360 mg K/15 cm pot monthly produced good quality plants. In a later study (7), Poole and Conover observed that weekly applications of 12.5-37.5 mg N, 5-50 mg P, and 25-50 mg K/10

cm pot produced high quality *Adiantum rad-dianum* K. Presl.

The 2 experiments reported here were conducted to determine the N-P-K requirements of *Dieffenbachia maculata* 'Exotica', *Dracaena sanderana*, *Maranta leuconeura* var. *kerchoviana*, and *Peperomia obtusifolia*.

Experiment 1.

Well-rooted dieffenbachia cuttings (15-20 cm) were potted May 14, 1979, into 13 cm diameter azalea pots containing 2 Florida sedge peat:1 pine bark:1 cypress shavings (v:v:v) amended with 4 kg/m³ dolomite and 1 kg/m³ Perk, a micronutrient blend, and placed in a glasshouse receiving 200 μEm⁻²s⁻¹ maximum natural illumination. Plants were watered twice weekly and temperatures ranged from 20°C minimum to 35°C maximum. Treatments consisted of a 3 × 2 × 2 factorial combination in randomized block design of N, P, and K at 10, 30, or 50 mg N, 5 or 10 mg P, and 10 or 30 mg K/pot at weekly intervals in 100 ml of solution. N was obtained from NH₄NO₃, P from H₃PO₄, and K from KCl. Treatments were replicated 5 times

with 1 cutting/pot as an experimental unit.

Data collected at experiment termination, September 4, 1979, included height from pot rim to tip of leaves, foliar color (1 = light green to 5 = dark green color), and shoot fresh weight. The first mature leaves from the apex of the plant were collected and analyzed for elemental tissue content (4).

Data indicate good quality dieffenbachia can be grown with 50-5-30 mg N-P-K/13 cm pot weekly, a ratio of 10-1-6 (Table 1). Converting this ratio into a commercial formulation of N-P₂O₅-K₂O yields a ratio of 10-2.3-7 (about 4-1-3). Thus the popular and frequently used 1-1-1 ratio fertilizers appear unnecessary, waste energy, and can lead to ground water pollution because of excess fertilizer applied to pots.

Fifty mg N/13 cm pot per week produced slightly better plants than 30 mg N/pot, the suggested level (1) of N, but suggested levels of P and K were slightly higher or equal to levels used in this experiment. Since the levels of P used in this experiment did not affect plant growth, lower than suggested levels of P (1) might be acceptable (Table 1).

Best quality plants had tissue N content of 3.4% which is within the range suggested (3, 4) but 2.7% tissue N found in lower quality plants is also in the suggested range. Calcium level of the best plant was also within the suggested range, but P and Mg tissue content were slightly higher and K slightly lower than suggested levels (Table 1).

Experiment 2.

Well-rooted cuttings of dracaena (15-20 cm), maranta (6-8 cm), and peperomia (10-12 cm) were potted April 25, 1980, into 10 cm diameter square pots containing the same medium as in Experiment 1 and grown under the same conditions. Treatments consisted of a 2 × 3 × 3 factorial combination in randomized block design of N, P, and K. Rates for dracaena were 48 or 96 mg N; 16, 32, or 48 mg P; and 40, 60, or 80 mg K/pot; for maranta 48 or 72 mg N, 16, 24, or 32 mg P, and 24, 40, or 56 mg K/pot; and for

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