Medium Temperatures Effect on Geranium and Poinsettia Root Initiation and Elongation[1]

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Abstract. Root promotion and root inhibition were measured for geranium and poinsettia cuttings during and after treatment at medium temp of 5 to 35°C at 5°C increments for 1 to 5 days. Optimum root initiation and elongation temp from 1 day of treatment were 15 to 30°C with reduced root initiation after 5 and 35°C and inhibition of root elongation after 5, 10 and 35°C treatments. Medium treatments for 3 or 5 days at 25 and 30°C increased root initiation and elongation which continued at accelerated rates during a 5 day period following treatment. Medium temp 5, 10, 15, and 35°C for 3 or 5 days reduced root initiation and elongation during treatment, and inhibition continued after treatments of 5, 10, and 35°C. Roots became brown for both species during 35°C treatment, while roots at 25°C and below remained white. After treatment root tip vascular and cortical cells varied in size but were anatomically similar. Distances from the root tips to the 1st xylem element were largest at 25°C allowing more cortical cells in the meristematic region.

The effects of soil medium temp on root initiation and elongation vary with the plant species. From data based on seedling root weights, Brouwer (2) found that some species have optimum root growth ranges from 20 to 25°C, while others have a broad optimum range exceeding 25°C. Numerous adverse plant responses have been reported from reduced root activity at unfavorable soil temp (1, 7, 8). Kofranek (6) found poinsettias at a constant soil temp of 5°C wilted severely and abscised leaves and bracts. Previous research has measured temp effects during long periods of root treatment, but root recovery after short periods of adverse temp has received less study. Richardson (9) found max root elongation of silver maple seedlings at 20°C, but plants given 2 days at 3, 7.5, or 10°C and returned to 20°C were slow in recovering their previous root growth rate. The purpose of this study was to measure temp effects for 1, 3, or 5 days on the number of roots initiated from callused geranium and poinsettia cuttings and to determine the root growth rates during and after temp treatment.

Materials and Methods

Three trials to determine the short-term effect of temp on root development of callused geranium and poinsettia cuttings, and 3 trials to measure temp effects on root elongation were conducted from September 1970 to May 1971. Callused, 7.5 cm, terminal stem cuttings of *Pelargonium hortorum* Bailey cv. Irene and *Euphorbia pulcherrima* Willd. cv. Eckespoint D-3 were removed from an initial propagation area after 14, 16, or 18 days for treatments of 5, 3, and 1 days respectively. Cuttings were transplanted to 7.5 cm clay pots in a 1:1 peat-Turface medium and placed at temp from 5 to 35°C at 5°C intervals. Fifteen callused geranium and poinsettia cuttings were treated for 1, 3, and 5 days at each temp. Refrigerated containers each held 45, 7.5 cm pots at constant medium temp of 5, 10, 15, or 20°C. Temperatures were maintained at 25, 30, and 35°C by pumping heated water from controlled temp water baths through flat-sided rubber tubing encircling each pot. Perlite provided insulation around pots and on medium surfaces. Air temp were maintained at 24°C day and 18°C nights at 12 hr daylengths. Medium temp measurements were made during 4 half-hour periods daily using thermocouples on a 24-point portable recording potentiometer. Following treatment the cuttings were removed and root counts and lengths were determined, after which the cuttings were replanted and given similar medium temp of 25°C days and 18°C nights for 5 days. Cuttings again were removed and root counts, lengths, and root fresh and dry wt measured.

Post root initiation temp responses were studied with terminal stem cuttings of the geranium and poinsettia cultivars in a second study in which cuttings were removed from the propagation bench when root lengths were 6 to 12 mm. Root numbers and lengths were measured prior to treatment. Fifteen cuttings of each species were treated 1, 3, and 5 days at each medium temp from 5 to 35°C using the systems previously described. Root numbers and length were determined after treatment, and after 5 days at 24°C day and 18°C nights; root numbers, lengths, and fresh and dry wt were measured. Data were summarized for each trial using analyses of variance with separation of the means using Tukey's w procedure (10). The data in Tables 1 and 2 were pooled from 3 experiments.

In 2 studies comparisons were made of the poinsettia root anatomy at each medium temp from 5 to 35°C. Ten cuttings with root lengths 3 to 5 mm were exposed to each treatment for 10 days, after which longitudinal root sections were prepared (5). Cortical cell numbers were determined from the meristem to 0.4 mm and from 0.4 to 0.8 mm, and the distance from the meristem to the first observable xylem element also was measured for roots of all treatments.

Results and Discussion

Root initiation. Treatment of callused terminal cuttings of geranium and poinsettia at temp from 5 to 35°C for 1, 3, or 5 days between the 14th and 18th day after propagation significantly influenced the numbers of initiating roots (Table 1). Treatment for 1 day (18th day after propagation) reduced root initiation for both species at the 5 and 35°C medium temp and increased root initiation at 30°C. Callused cuttings of both species receiving medium temp of 15°C or lower or 35°C between days 16 and 18 or 14 and 18 had fewer roots, whereas 25 and 30°C treatments increased root numbers.

Post-treatment effects on root initiation varied with the medium temp during treatment and its duration (Table 1). Maximum root initiation for both plant species occurred during a 5-day period after 20 and 25°C medium temp, and reduced root initiation resulted following 1 day at medium temp of 5 and 35°C. Root initiation was significantly reduced during the 5 day period after 3 or 5 days at temp of 5, 10, 30, or 35°C. Longer periods of initial treatment at those unfavorable temp resulted in larger reductions in root initiation following

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Table 1. Effect of 5 to 35°C medium temp on geranium and poinsettia root number and elongation during treatment and a 5 day post-treatment.

Days of treatment	Treatment temp °C						
	5	10	15	20	25	30	35
				Geranium root number/cutting			
				Treatment effect[z]			
1	4.3^{ax}	5.1^{ay}	5.2^{ay}	4.9^{ay}	5.4^{ay}	6.1^{az}	4.4^{ax}
3	2.8^{bx}	3.4^{bx}	4.1^{ax}	5.6^{ay}	5.7^{aby}	6.5^{aby}	2.9^{bx}
5	0.2^{cx}	1.2^{cx}	1.6^{bx}	4.8^{ay}	6.3^{by}	7.1^{by}	0.4^{cx}
				Post-treatment effect			
1	10.2^{ax}	11.4^{axy}	12.3^{ay}	13.4^{ayz}	14.1^{az}	14.3^{az}	8.0^{ax}
3	8.9^{abx}	9.6^{abx}	13.6^{ay}	16.1^{bz}	18.5^{bz}	17.2^{abz}	5.4^{bx}
5	6.2^{bx}	6.4^{bx}	13.0^{ay}	17.8^{by}	26.2^{cz}	20.3^{bz}	2.8^{cx}
				Poinsettia root number/cutting			
				Treatment effect			
1	4.0^{ax}	4.6^{axy}	4.8^{axy}	5.5^{ayz}	5.1^{ay}	6.0^{az}	4.3^{ax}
3	1.1^{bx}	1.4^{bx}	3.1^{abxy}	5.9^{ay}	8.5^{bz}	8.2^{bz}	2.9^{bx}
5	0.0^{bx}	0.3^{bx}	2.4^{bxy}	5.8^{ay}	14.6^{cz}	9.3^{bz}	0.7^{cx}
				Post-treatment effect			
1	9.1^{ax}	11.2^{axy}	11.8^{ay}	13.0^{ay}	12.5^{ay}	11.7^{axy}	8.6^{ax}
3	5.1^{bx}	9.3^{ay}	11.2^{ayz}	12.6^{ayz}	13.4^{az}	9.1^{aby}	3.4^{bx}
5	0.5^{cx}	4.0^{by}	12.6^{az}	14.1^{az}	12.9^{az}	5.8^{by}	1.6^{bx}
				Geranium root elongation (mm)			
				Treatment effect			
1	0.4^{ax}	0.7^{ax}	1.9^{ax}	4.4^{ay}	5.2^{ay}	6.3^{ay}	2.7^{axy}
3	0.8^{ax}	1.6^{abx}	3.7^{bx}	7.2^{by}	13.5^{bz}	14.3^{bz}	3.8^{bx}
5	0.7^{ax}	2.5^{bx}	5.0^{bx}	10.9^{cy}	17.1^{bz}	19.2^{bz}	4.6^{bx}
				Post-treatment effect			
1	9.3^{ay}	9.5^{ay}	15.4^{az}	18.2^{az}	19.0^{az}	17.5^{az}	4.2^{ax}
3	8.3^{aby}	7.2^{abxy}	18.1^{ayz}	24.2^{bz}	17.4^{ay}	14.3^{aby}	2.2^{bx}
5	7.8^{bxy}	5.6^{bx}	17.9^{ay}	22.9^{bz}	18.3^{ayz}	13.7^{by}	1.4^{bx}
				Poinsettia root elongation (mm)			
				Treatment effect			
1	0.2^{ax}	0.5^{ax}	1.1^{axy}	1.7^{ay}	3.0^{az}	2.1^{ayz}	1.8^{ay}
3	0.4^{ax}	1.0^{ax}	1.8^{ax}	3.1^{by}	9.1^{bz}	5.9^{by}	2.6^{abxy}
5	0.7^{ax}	1.3^{ax}	3.5^{bxy}	7.9^{cy}	20.2^{cz}	11.4^{cy}	3.9^{bxy}
				Post-treatment effect			
1	3.2^{ax}	3.8^{ax}	4.3^{ax}	6.2^{ay}	6.7^{ay}	5.9^{ay}	4.8^{axy}
3	0.8^{bx}	2.6^{abx}	4.6^{ay}	4.5^{ay}	9.0^{bz}	7.5^{byz}	1.6^{bx}
5	0.5^{b}	1.8^{bx}	4.0^{ay}	5.4^{ay}	12.1^{cz}	7.8^{by}	1.2^{bx}

[z]Means, within a given column for abc and within a row for xyz, with the same letters do not differ significantly at the 0.05 level when tested with the Tukey-w procedure.

treatment. Geranium receiving medium temp of 25 and 30°C for 3 or 5 days continued initiating more roots during the 5 days following treatment, but this was not true for poinsettias.

Root elongation. Root increases in length for geranium and poinsettia were found to vary greatly from temp treatments of 5 to 35°C for 1, 3, or 5 days (Table 1). The increments of root increase during 1 day of treatment were significantly smaller for both species at 35°C and 15°C and below. Reductions in root elongation increased as the durations of treatment at 5, 10, 15, and 35°C were extended to 3 and 5 days. Optimum root elongation temp for geranium and poinsettia was 25 and 30°C, while only limited elongation occurred at 5 and 10°C.

The root elongation rates found during treatment continued for the 5-day period after treatment (Table 1). Geranium root elongation recovered after 5 and 10°C treatment, but root elongation was largest for plants continuously at 20 and 25°C soil medium temp. Reduced geranium root elongation was found at 1 day of 35°C treatment, and limited elongation occurred during a 5-day period following treatment. The longer the duration of 35°C treatment the slower the root elongation recovery rate after treatment. Poinsettia root elongation almost ceased during treatment at 5°C and did not begin during a 5-day period at warmer temp following 3 and 5 days at 5°C. Poinsettia root elongation also was reduced after 3 and 5 days at 35°C.

Root anatomy. The distance of the first xylem element of poinsettia roots from the root tip varied with the medium temp (Table 2). The distance from the root tip to the first xylem element was largest (2.5 mm) for roots grown at 25°C. This distance was found to become progressively smaller as medium temp declined from 25 to 5°C or increased from 25 to 35°C. Cortex cell counts from root sections showed the largest cell numbers from the root tip to 0.4 mm and 0.4 mm to 0.8 mm for roots grown at 25°C. Cell counts declined slightly as medium temp decreased from 25 to 5°C, but dropped abruptly as temp increased from 25 to 35°C.

The effect of adverse temp in reducing root initiation and elongation is not well understood. Richardson (9) believed low

Table 2. Comparison of mm from root tip to first xylem element and cortical cell number of poinsettia roots developing at medium temp from 5 to 35°C.

Treatment	mm to 1st xylem element	Mean cortex cell no.	
		meristem to 0.4 mm	0.4 mm to 0.8 mm
5°C	0.5	22	11
10°C	0.7	24	12
15°C	1.3	27	13
20°C	2.1	30	14
25°C	2.5	33	15
30°C	2.0	29	8
35°C	0.3	13	5

temp reduced root respiration and carbohydrate utilization and high temp decreased carbohydrate translocation. Domanski et al. (4) reported that temp induced effects on rooting result from changes in levels of endogenous growth regulators and possible co-factors. Our research showed geranium and poinsettia root initiation and elongation were reduced during 1 to 5-day periods at high or low temp, and the inhibition continued for 5 days after treatment. Since high temp induced root inhibition was found after 1 day treatment and the change from favorable to inhibitory temp occurred within the 5°C interval from 30 to 35°C, the adverse effects are probably not related to reduced carbohydrate levels. Studies in progress have shown a measurable reduction in root elongation for both plant species after 12-hr treatments at 5 and 35°C.

Geranium and poinsettia roots were white and appeared normal after 5 days of treatment at 5 to 25°C. Slight browning of poinsettia roots was noted following 5 days at 30°C, but geranium roots remained white. Root browning of both species resulted from treatment at 35°C. The browning became more extensive as the duration of treatment increased from 1 to 5 days, and some roots after 5 days appeared to have highly suberized root tips. The distance from the root tip to the first xylem element progressively increased for temp treatments from 5 to 25°C, and declined with treatments from 25 to 35°C. Poinsettia roots at 25°C had more cortical cells in the meristematic region than roots grown at lower (5 to 20°C) or higher (30 to 35°C) temp. Roots in the 35°C treatment had a very short region of cell elongation and a rapid increase in cortical cell size within 0.2 to 0.3 mm from the root tip.

Greenhouse medium temp decline below the optimum for root growth when cold irrigation water is applied (3) and rises above the optimum range when sunlight warms the soil or container surface. Further studies are required to determine the extent to which adverse medium temp affect root growth and hence crop production in the greenhouse.

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Levels of Hydrogen Sulfide Toxic to Citrus Roots[1]

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Abstract. The toxicity level for H_2S, generated under waterlogged conditions, is a concn-time relationship associated with the dissolved molecular H_2S concn in the root rhizosphere. A molecular concn of 2.8 ppm for 5 days is one toxicity threshold for significant root injury in controlled tests with rough lemon (*Citrus jambhiri* Lush.) seedlings. Rapid bacterial generation of H_2S in the root rhizosphere was indicated by a doubling of the concn every 24 hr. Sulfides were present in root tissues that died.

Hydrogen sulfide can usually be detected under O_2 deficient conditions when the citrus root environment becomes waterlogged. The presence of H_2S has been associated with citrus root injury in the poorly drained flatwoods areas of Florida (4). Citrus roots can tolerate O_2 deficiency *per se* longer than when H_2S is present (2). From a practical standpoint, the presence of H_2S is being used to evaluate the need for additional drainage in problem areas. A handful of disturbed soil and roots from the waterlogged zone is smelled to detect H_2S (4). The determination of toxic levels for H_2S and the interaction with time of exposure has been difficult to establish because of the many complex reactions occurring in the root rhizosphere under anaerobic conditions.

Materials and Methods

A multicelled apparatus capable of being monitored and controlled under anaerobic conditions (2) was used to measure the rate of sulfide production in the root rhizosphere and to establish a toxicity threshold for citrus seedlings at a root temp of 23°C.

The solution circulating apparatus handled simultaneously 6 plants for each of 2 solution treatments or a single treatment of 12 plants (Fig. 1). Rough lemon (*Citrus jambhiri* Lush.) seedlings, uniform in size and root density, and grown under conditions where the watering source contained sulfate reducing organisms, were planted in the apparatus using a medium of washed, graded, sterile white sand. Solution sampling tubes, terminating within 2 mm of a feeder root were installed in each cell to sample the solution abutting the root system. Four hundred ml of sterile solution containing 3 ppm total sulfides

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