A COMPARISON OF SOLUBLE SALTS TESTING PROCEDURES FOR PRODUCTION OF POINSETTIAS IN SOILLESS MEDIA

By

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MEDIA

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PREFACE

This study was conducted to compare and evaluate soluble salt readings of the saturated paste extract method, 1:2 dilution method, and the leachate method of soluble salt testing in order to determine the relative efficiency of each method. In addition growth response of poinsettias including height, plant dry weight, leaf burn, and foliar elemental concentrations were monitered in an attempt to correlate plant response to soluble salt levels.

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A COMPARISON OF SOLUBLE SALTS TESTING PROCEDURES FOR PRODUCTION OF POINSETTIAS IN SOILLESS MEDIA

Key Words: *Euphorbia pulcherrima*, soluble salts, leachate, conductivity, pH, leaf analysis

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ABSTRACT

Soluble salt measurements (millimhos/cm) using saturated paste extract, 1:2 dilution (volume), and leachate methods were compared to determine their relative efficiency and the reliability of existing interpretations. An attempt was also made to define guidelines for interpreting readings for the leachate method. Two soilless media and four levels of 20-4.4-16.6 N-P-K water soluble fertilizer at 100, 300, 500, and 700 ppm N were utilized for production of 'V-14 Glory' poinsettias (Euphorbia pulcherrima) and plants were fertilized at every watering. Three test dates at four week intervals were used. Reduced plant dry weight and height were observed as fertilizer rate in-

creased. Bract necrosis was noted on plants fertilized at 500 and 700 ppm. Tissue analysis indicated that N, P, and K concentrations increased with fertilizer level and Ca and Mg levels were lower at higher fertilization levels. Solution analysis for nutrient content at the third testing date also indicated decreased Ca and Mg levels at higher fertilization levels while N, P, and K levels increased.

pH became more acidic as fertilizer level increased but there was an overall slight increase in pH readings from date 1 to date 3. pH of the media corresponded closely to the pH of the solutions used for the 1:2 and saturated paste methods, but the pH for the leachate method solution was more acidic than for normal medium pH readings.

Solubridge measurements from the leachate test demonstrated the most variability while the 1:2 test showed the least variability. The following guidelines were derived for each method:

<u>Saturated Paste</u>

Safe - below 4.1 millimhos/cm.

High - possible growth inhibition, bract necrosis - 4.1 - 6.0.

Excessive - plants may be severely injured - Above 6.0.

<u>1:2 Dilution</u>

Safe - below 1.5 millimhos/cm.

High - possible growth inhibition, bract necrosis - 1.5 - 1.8.

Excessive - plants may be severely injured - Above 1.8.

Leachate Method

Safe - below 5.7

High - possible growth inhibition, bract necrosis - 5.7 - 7.2.

Excessive- plants may be severely injured - Above 7.2.

INTRODUCTION

Many greenhouse growers today use soilless media that are bark or peat-based with other manufactured ingredients such as perlite or vermiculite. Because artificial media have limited nutrient holding capacity, crops grown in these mixes must be supplied continually with adequate fertilizer. Water soluble and/or controlled release fertilizers are often used and to provide a readily available nutrient supply.

Excessive fertilization may lead to soluble salt accumulation in the medium, especially with inadequate leaching practices. The term "soluble salts" refers to the sum total of all soluble mineral residues in the soil (14). Ions that easily dissolve in water, such as nitrates, phosphate, potassium, calcium, sulfates, chlorides and others, are involved (5). If soluble salt levels in the medium solution accumulate to high or "toxic" levels, water movement into the root may be inhibited along with the uptake of nutrients. According to Nelson (16), symptoms of excessive soluble salts include wilting of the plant even when the medium is moist, death of root tips, leaf necrosis, and eventually various nutritional deficiency symptoms. Substantial crop loss may occur due to these negative effects on the plant. Knowing what salts (and percentages in the soil solution) are present is also important (5).

Soluble salts testing has become a means of monitoring salt levels to prevent excessive accumulation. A common soil test procedure involves the use of distilled or deionized water to remove the soluble salts from the root medium. After enough time has passed with the water and soil in mixture for the soluble salts to move into the water, the electrical conductivity of the solution can be read by placing two electrodes (conductivity meter) in the solution. Nelson (16) states there are three commonly used soluble salts tests varying by the amount of water used to remove the salts from the root medium: 1) The 1:2 dilution method which involves diluting one part dry medium with two parts distilled water (volume to volume); 2) the 1:5 dilution method in which five volumes of water are added to one volume of soil (often used with mineral soils); and 3) the saturated paste extract method in which only enough water is used to barely saturate the sample. This solution is then drawn off by vacuum and tested for electrical conductivity. The "saturation point" for the saturated paste extract method has been defined by Warncke (23) as when the medium will mix easily and just begin to flow when tilted. Three criteria of this "saturation point' have also been described (2). The saturated paste extract method has been claimed to be superior to the 1:2 dilution method for artificial media in work by Waters, Llewelyn, Geraldson and Woltz (24) and also in work by Ingram and Henley (10) The 1:2 dilution method is most often used by growers (12) probably due to the ease of preparation and the fact that no specialized vacuum equipment is required.

A less common soluble salt testing procedure is the leachate method in which leachate is collected from the pot and then analyzed. This method has been demonstrated in work by Yaegar, Wright, and Donohue (25). Other studies that have involved the measurement of soluble salts by testing the electrical conductivity of collected leachate (6,19) demonstrate that this method may be a reliable and easy way to test for soluble salt levels. This method has several advantages to the grower. As with the 1:2 dilution method, no specialized vacuum equipment is needed and extract collection is simple and rapid. Slow-release fertilizer granules are not ruptured since medium is not removed from the container and root systems are not disturbed, so repetitive testing of the same medium is possible.

Increased use of soilless media in the floriculture industry there has developed a controversy in soluble salt reading interpretations and recommendations (3,5,10,12,14, 15,16,17,18,21,22,23,24) for both the 1:2 dilution method and the saturated paste extract method. Reliability of the leachate testing procedure and interpretations for this method for greenhouse crops are not currently defined.

Recommendations given for soil-containing media may not accurately reflect the state of a soilless medium (10,18,22,24). In addition, work by Biamonte and Scott (4) demonstrates a variation in soluble salt readings for different soilless media. This work also demonstrates how the number of fertilizations during a growing season affects soluble salt levels. Other studies (1,23) demonstrate the variance in laboratory results between different laboratories and also how individual judgement of the "saturation point" for the saturation extract method can affect results. One study (4) demonstrates soluble salts levels described as "extremely high" and yet no apparent adverse effect on plant quality was reported. How accurate, then, are these readings and interpretations and what do they really reflect in soilless media?

This experiment was designed to compare and evaluate solubridge readings in millimhos/cm of the saturated paste extract, 1:2 dilution method, and the leachate method utilizing poinsettias grown in two soilless media. Soluble salts, height, plant dry weight, bract burn, and foliar elemental concentrations at 4, 8, and 12 weeks into the crop cycle were evaluated. Attempts were made to correlate plant response to the various levels of soluble salts. pH measurements were also recorded for both the media and solubridge testing solutions to determine if accurate pH measurements could be made using the same solution used for soluble salt measurements.

MATERIALS AND METHODS

Terminal stem cuttings of 'Gutbier's V-14 Glory,' approximately 7.6 cm long, were propagated August 7, 1985 from stock plants received earlier, courtesy of Paul Ecke Poinsettias, Encinitas, California. The basal ends of the cuttings were treated with 0.1% Indole-3-Butyric acid powder formulation and stuck into 5.7 cm square pots filled with a half sphagnum peat and half perlite mixture and placed on an intermittent mist bench where a minimum soil temperature of 21°C was maintained. On August 14 the cuttings were soil-drenched with Captan (448ml/378.5 l water), Quintozene (112 ml/378.5 l), and NH_4NO_3 (224ml/378.5 l). Additionally, while on the mist bench the cuttings were fertilized August 21, September 4, and September 10 with a 20-4.4-16.6 fertilizer (Peter's 20-10-20 Peat-Lite Special) at the rate of 300 ppm N, 66 ppm P, and 249 ppm K.

The cuttings were transplanted to 15 cm azalea pots September 10. Two soilless media were used. One half the plants in the experiment, 108 cuttings, were planted into "Mix 1", Metro Mix 360, a commercial soilless medium made by the W. R. Grace Co., Cambridge, MA, containing sphagnum peat moss, vermiculite, processed bark ash, a wetting agent, selected washed granite sand, and a starter nutrient charge. The exact amounts and nutritional ingredients are undisclosed. An additional 108 plants were planted into "Mix 2", containing the following ingredients per 0.77 m^3:

sphagnum peat 0.465 m^3, vermiculite 0.155 m^3, perlite 0.155 m^3, dolomite 4.54 Kg, 0-8.8-0 1.134 Kg, 13.8-0-36.9 680g, Fritted Trace Elements 85g, wetting surfactant 680g. After potting each plant was watered and a 177 ml fungicide drench of ethazol 30% wp and benomyl 50% wp (118.5 ml ethazol and 237 ml benomyl per 378.5 l water) was applied to each pot. This drench was applied monthly thereafter. Two monthly soil applications of aldicarb 10 G were made using 0.45 g per 15 cm pot. The plants were pinched September 20 to 6-7 nodes per plant to promote lateral branching.

Twenty-four experimental treatments were established starting 19 Sept., including four fertilization levels applied at every watering: 100, 300, 500, and 700 ppm (based on N rate) of 20-4.4-6.6 N-P-K fertilizer; two soilless media (mixes 1 and 2, already described); and three soluble salts testing methods: saturated paste extract, 1:2 by volume (medium to deionized water) extract, and the leachate method. A randomized split plot design was used to enable easier fertilization on two centrally located greenhouse benches with three replications and three pots per replication. Plants were spaced 38.1 cm x 38.1 cm and enclosed by buffer plants which were also used to replace harvested plants. Greenhouse temperatures were maintained as close as possible to 16°C nights, 19° days, and 22-25° sunny days. Each pot received 473 ml of fertilizer solution at every watering and all watering dates were recorded. The four fertilization levels utilizing the 20-4.4-16.6 N-P-K water soluble fertilizer (Peter's 20-10-20 Peat Lite Special) were: 1) 100 ppm N, 22 ppm P, 83 ppm K, 0.75 ppm Mg, 0.50 ppm Fe, 0.28 ppm Mn, 0.10 ppm B, 0.081 ppm Zn, 0.05 ppm Cu, 0.05 ppm Mo. Levels 2) 300 ppm N, 3) 500 ppm N and 4) 700 ppn N received 3, 5, and 7 times the levels shown for 100 ppm N, respectively. No plain water was applied throughout the experiment.

Plants in all treatments were harvested and evaluated at 4, 8, and 12 weeks after the beginning of the experiment (19 Sept.). At the end of each four week period the plants to be evaluated were collected and brought into the head-house. All plants had been fertilized 24 hrs prior to harvest. Plants were evaluated for height (pot rim to the point of attachment of the petiole of the tallest leaf); number of branches; above ground plant dry weight; medium pH; pH of the solution used for soluble salts testing; and electrical conductivity utilizing one of the three soluble salts methods. All pH measurements were determined using a Cole-Palmer Digi-Sense pH meter LCD model number 5994-10 with a combination electrode Calomel reference cell type Hg/HgCl model number T-5990-35. Electrical conductivity was measured in millimhos/cm using an El Hamma Digital Field Conductometer model number TH-250 with a conductivity cell model number EHT-24c. Standards for both instruments were prepared and used to monitor the equipment frequently. Growing medium pH was tested with the standard procedure using 17 ml of medium from the central root zone diluted with 30 ml of deionized water. This mixture was stirred and allowed to stand for five minutes before reading.

The plants tested by the leachate method were held over a funnel and the growing medium was watered with 300 ml deionized water. The first 80 ml of leachate were collected below the funnel and immediately tested for electrical conductivity and pH. Those plants to be tested for soluble salts using the 1:2 dilution method had approximately 30 ml of medium removed from their root zone area and placed in clean paper bags to dry at the time of harvest. When the medium collected was air dry 17 ml of medium was diluted with 34 ml of deionized water. This mixture was then stirred three times within a twenty minute period and then allowed to stand ten more minutes. At the end of ten minutes the mixture was stirred again and electrical conductivity and pH were measured. The pot plants to be tested using the saturated paste extract method had approximately 226 g of medium removed from their root zone area and placed in clean paper bags to dry. After the medium was air dry 113 g were placed in a plastic cup and enough deionized water was added to create a soil paste defined as "saturated". Approximately 75 ml of deionized water were required to achieve this saturated state. The paste was stirred well and then allowed to sit for one and a half hours. At this point the paste was again stirred and placed in a 7 cm Buchner funnel containing a Whatman #4 filter paper and fitted by a rubber stopper onto a glass bell jar attached to a Fisher Filtrator apparatus (model 09-788) for vacuum filtration using a small vacuum pump. When enough extract was collected the solution was immediately tested for electrical conductivity and pH.

At the time of harvest six to eight recently matured leaves were collected from each plant and placed in clean paper bags for later foliar analysis. These leaves were dried in a 75°C oven and their dry weight was recorded and added to the dry weight of the remainder of the plant to obtain total dry weight for each plant. The leaves collected for foliar analysis were combined from like treatments in order to obtain enough leaf material for analysis. The leaves of three plants were combined for foliar analysis and re-dried for 24 hours at 75° then ground to pass through a 20 mesh screen in a Wiley Mill. These combined samples were then stored in air tight jars until later analysis. Before analysis the samples were re-dried at 80° for 24 hours. N was determined by the macro-Kjeldahl method, P colorimetrically, and K, Ca, Mg, Mn, Zn and Fe on a Perkin-Elmer 303 atomic absorption spectrophotometer.

On the third testing date, twelve weeks after the beginning of the nutritional programs (12 Dec.), in addition to the usual data collection (at four and eight weeks) data were also collected on bract necrosis and nutrient composition of the various soluble salt extracts from plants grown in Metro Mix 360 only. The number of bract leaves demonstrating any necrotic areas were recorded. Solutions from the four fertilization rates and three soluble salts extraction methods were collected and sent to a W. R. Grace Company laboratory in Fogelsville, PA for solution analysis. Tests of these solutions included soluble salts, pH, NO_3, NH_4, P, K, Ca, Mg, Mn, Fe, Cu, B, Zn, and Mo.

RESULTS AND DISCUSSION

Thirty seven 473 ml fertilizer applications were made to each 15 cm pot during the twelve week testing program. The following data were collected and an attempt was made to correlate plant growth response to soluble salt levels.

Plant Dry Weight

Plant dry weight for both growing media reflected similar patterns (Table I). Plants harvested at test date 1 (17 Oct., four weeks after fertilizer program initiation) demonstrated similar dry weights for all four fertilizer levels, with the plants grown at 300 and 500 ppm showing the highest dry weight accumulation. All plants harvested at the second harvest date (Nov. 14, eight weeks after fertilizer program initiation) were significantly larger than those harvested at date 1. Also, significantly higher dry weight accumulation occurred in plants grown in medium 1 (MM 360). Once again the highest dry weight accumulation occurred in plants grown at 300 ppm and a significant

TABLE I

EFFECT OF FERTILIZER LEVEL, TESTING DATE, AND GROWING MEDIUM ON PLANT DRY WEIGHT

Growing Medium	Plant Dry Weight (g)																				
	4 weeks							8 weeks							12 weeks						
	Fertilizer Level							Fertilizer Level							Fertilizer Level						
	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C
MM 360	8.6	10.9	9.5	9.0	NS	.01	.05	28.3	26.0	28.1	24.3	.05	NS	.05	32.5*	29.6*	25.9	24.6	.01	NS	NS
3:1:1	8.7	9.1	9.7	8.4	NS	NS	NS	25.2	27.9	25.1	20.8	.01	.01	NS	32.6*	30.5	26.3	23.3	.01	NS	NS
significance[y]	NS	.05	NS	NS				.05	NS	.05	.05				NS	NS	NS	NS			

[z]All date 2 means significantly larger than date 1 means.
[y]Denotes significance between means of growing media within fertilizer levels.
*Date 3 significantly different from date 2 (.05 level t-test).

quadratic effect was evident with plants grown at 700 ppm giving the lowest dry weight.

The third testing date (12 Dec., twelve weeks after fertilizer program initiation) shows a reverse linear effect in dry weight accumulation for both growing media with the plants grown at 100 ppm having the highest dry weight and those at the 700 ppm level having the lowest dry weight recordings. The only date 3 dry weights significantly larger than the date 2 dry weights occurred at the 100 and 300 ppm levels. The highest recorded dry weight accumulation for the entire experiment occurred at the 100 ppm level, third testing date.

Soluble salt relationships to dry weight and other growth parameters will be discussed later.

Vegetative Plant Height

Vegetative plant heights were similar in both media (Table II). In general, plant height responses were similar to dry weight accumulation response for all three test dates. Plants harvested at test date 1 were all very similar in height with plants grown at 700 ppm being smallest. Test date 2 plant heights were all signficantly taller than date 1 plant heights. Both the plants grown at 100 and 300 ppm were taller than those grown at 500 and 700 ppm with the plants grown at 700 ppm being the shortest. Test date 3 shows a reverse linear effect in plant height for both growing media with the plants grown at 100 ppm being the

TABLE II

EFFECT OF FERTILIZER LEVEL, TESTING DATE, AND GROWING MEDIUM ON PLANT HEIGHT

Growing Medium	Plant Height (cm)																				
	4 weeks							8 weeks							12 weeks						
	Fertilizer Level							Fertilizer Level							Fertilizer Level						
	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C
MM 360	15.5	15.9	15.1	13.9	.01	NS	NS	24.1	26.1	22.4	21.2	.01	.01	.01	28.7*	27.5	24.3	22.3	.01	NS	NS
3:1:1	15.6	14.9	14.8	14.4	.05	NS	NS	25.3	23.7	21.8	20.8	.01	NS	NS	26.7	25.7	24.1	23.0	.01	NS	NS
significance[y]	NS	NS	NS	NS				NS	.05	NS	NS				.05	NS	NS	NS			

[z]All date 2 means significantly larger than date 1 means.
[y]Denotes significance between means of growing media within fertilizer levels.
*Date 3 significantly different from date 2 (.05 level t test).

tallest and those at 700 ppm being the shortest. The only date 3 height significantly taller than date 2 height occurred at the 100 ppm level in medium 1 (MM 360). The tallest plant height for both media were at the 100 ppm level, third testing date.

<u>Number of Breaks</u>

No significant differences in number of breaks per plant was observed. Number of breaks per plant ranged from 6.8 to 7.9.

<u>pH</u>

Medium pH readings obtained from normal soil testing procedures tended to follow the same patterns in both media. pH generally decreased from basic to acidic levels as fertilizer levels increased (Table III). Although all pH readings ranged from 5.7 to 7.0 the general trend was for pH readings to increase linearly from date 1 to date 3. This increase in pH readings from date 1 to date 3 may be attributed to dolomite availability and/or Ca and Mg levels in the water used to prepare fertilizer solutions (3). There were also a few cases where readings from medium 2 were significantly different from medium 1 readings.

pH readings taken of solutions used for soluble salt testing followed the same patterns as normal pH test results (Table IV, V). Those readings taken from solutions used for the leachate method of soluble salt testing were

TABLE III

EFFECT OF FERTILIZER LEVEL, TESTING DATE, AND
GROWING MEDIUM ON SOIL pH

Growing Medium	4 weeks							8 weeks							12 weeks						
	Fertilizer Level							Fertilizer Level							Fertilizer Level						
	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C	100	300	500	700	L	Q	C
MM 360	6.6	5.8	5.8	5.7	.01	.01	.01	7.0*	6.2*	5.9	6.0*	.01	.01	.01	6.7**	6.1**	6.0	6.2	.01	NS	NS
3:1:1	6.7	6.1	5.9	5.8	.01	.01	NS	6.7	6.4*	6.3*	6.2*	.01	NS	NS	6.7	6.2	6.5	6.5**	.01	NS	NS
significance[z]	NS	NS	NS	NS				.05	NS	.05	.05				NS	.05	.05	.05			

[z]Denotes significance between means of growing media within fertilizer levels.
*Date 2 significantly different from date 1 (.05 level t-test).
**Date 3 significantly different from date 2 (.05 level t-test).

TABLE IV

SIGNIFICANT EFFECTS OF TESTING DATE ON pH OF SOLUTION USED FOR SOLUBLE SALT CONDUCTIVITY READINGS

	MEDIUM 1							
	Fertilizer Level							
	100		300		500		700	
Sol. salt test	L	Q	L	Q	L	Q	L	Q
Sat. Paste	NS	NS	NS	NS	NS	.01	.01	.05
1:2	NS	.01	NS	NS	.01	.01	.01	NS
Leachate	NS	.01	.05	NS	NS	NS	NS	NS

	MEDIUM 2							
	Fertilizer Level							
	100		300		500		700	
Sol. salt test	L	Q	L	Q	L	Q	L	Q
Sat. Paste	.05	NS	NS	NS	.01	NS	.01	.05
1:2	.05	NS	NS	NS	.01	NS	.01	.05
Leachate	NS	.01	NS	NS	.05	NS	.01	NS

TABLE V

SIGNIFICANT EFFECTS OF FERTILIZER LEVEL ON pH OF SOLUTION USED FOR SOLUBLE SALT CONDUCTIVITY READINGS

Sol. salt test	Medium 1								
	4 weeks			8 weeks			12 weeks		
	L	Q	C	L	Q	C	L	Q	C
Sat. Paste	.01	NS	NS	.01	.01	NS	.01	.01	NS
1:2	.01	.01	.01	.01	NS	NS	.01	.05	NS
Leachate	.01	.01	NS	.01	.01	NS	.01	NS	NS

Sol. salt test	Medium 2								
	4 weeks			8 weeks			12 weeks		
	L	Q	C	L	Q	C	L	Q	C
Sat. Paste	.01	NS	NS	.01	.01	NS	.01	NS	NS
1:2	.01	NS	NS	.01	.05	NS	.01	NS	NS
Leachate	.01	NS	NS	.01	.05	NS	.01	NS	NS

generally more acidic than the solutions of the other two testing procedures (Table VI). In most cases the readings collected from the solutions used for the 1:2 soluble salt test were closest to the normal pH test readings (Table VI). The saturated paste extract solution pH readings were also quite similar to normal pH test readings but the leachate test solution pH readings appeared more acidic than normal pH test readings. This indicates that pH readings could probably be accurately taken from solutions prepared for the 1:2 soluble salt test and perhaps from the saturated paste extract solution.

Foliar Nutrient Analysis

Both media followed similar elemental concentration trends. N concentrations demonstrated a curvalinear response at all three testing dates from 100 to 700 ppm. A significantly higher N level was noted in medium 2 in some cases (Table VII). N levels remained within the normal mineral analysis range for poinsettias described by Ecke (7) although levels approached the toxic range of > 7.3 at 700 ppm, third testing date (Table VIII, IX).

P levels remained similar at test date 1 from 100 to 700 ppm. A curvalinear response is apparent in both media at test dates 2 and 3 with the 100 ppm level having the lowest P concentrations. The P level increased linearly at 700 ppm from date 1 to date 3 while the plants grown at 100 ppm demonstrate a decreased P level at dates 2 and 3.

TABLE VI

EFFECT OF SOLUBLE SALT TESTING PROCEDURE ON pH OF SOLUTION USED FOR SOLUBLE SALT CONDUCTIVITY READINGS

Growing medium and sol. salt test	4 weeks				8 weeks				12 weeks			
	Fertilizer Level				Fertilizer Level				Fertilizer Level			
	100	300	500	700	100	300	500	700	100	300	500	700
MM 360 sat. paste	6.77	5.92	5.84	5.7	6.62[*]	6.13[*]	5.54[*]	5.69[*]	6.6	6.06	5.94	6.15
3-1-1 sat. paste	6.89	6.01	5.87	5.6	6.73	5.96[*]	5.89[*]	5.7[*]	6.63	6.15[*]	6.32[*]	6.32[*]
significance[z]	NS	NS	NS	NS	NS	NS	.05	NS	NS	NS	.01	NS
MM 360 1:2	6.5	5.95	5.8	5.74	6.97	6.24	5.63	5.82	6.7	6.1	6.29	6.1
3-1-1 1:2	6.35	6.04	5.81	6.0	6.69	6.37	6.08	6.18	6.64	6.28	6.52	6.83
significance	NS	NS	NS	NS	.05	NS	.01	.01	NS	NS	NS	.01
MM 360 Leachate	6.55	5.24[*]	5.24[*]	5.3[*]	7.04	5.43[*]	5.44[*]	5.34[*]	6.57[*]	5.55[*]	5.47[*]	5.4[*]
3-1-1 Leachate	6.44	5.65[*]	5.33[*]	5.42[*]	6.8[*]	5.95[*]	5.64[*]	5.66[*]	6.45[*]	5.84	5.82[*]	5.79[*]
significance	NS	.01	NS	NS	NS	.01	NS	.01	NS	.01	.01	.01

[z]Denotes significance between means of growing media.
[*]pH of soluble salt testing solution significantly different from soil pH.

TABLE VII

SIGNIFICANT EFFECTS OF GROWING MEDIUM, FERTILIZER LEVEL, AND TESTING DATE ON ELEMENTAL CONCENTRATION OF PLANTS

	Medium 1								
	4 weeks			8 weeks			12 weeks		
Element	L	Q	C	L	Q	C	L	Q	C
N	.01	.01	NS	.01	.01	NS	.01	.01	NS
P	NS	.01	NS	.01	.01	.01	.01	.01	.01
K	NS	NS	NS	.05	NS	.01	.01	.05	NS
Ca	.01	.01	NS	.01	NS	NS	.01	.01	.05
Mg	.01	.01	NS	NS	NS	.01	.01	.05	NS
Fe	.01	.01	NS	.01	NS	NS	.01	NS	NS
Mn	.01	NS	NS	.01	NS	NS	.01	NS	NS
Zn	.01	NS	NS	NS	NS	NS	.01	.01	NS

	Medium 2								
	4 weeks			8 weeks			12 weeks		
Element	L	Q	C	L	Q	C	L	Q	C
N	.01	.05	NS	.01	.01	.01	.01	.01	.05
P	.05	.01	NS	.01	.01	.01	.01	.01	.01
K	NS	NS	.01	.01	NS	NS	.01	.05	NS
Ca	NS	NS	NS	.01	NS	NS	.01	.01	NS
Mg	.01	NS	NS	.01	NS	.05	.01	NS	.05
Fe	.01	NS	NS	.01	.01	.01	.01	NS	NS
Mn	.01	NS	.05	NS	NS	NS	NS	NS	NS
Zn	NS	NS	NS	.05	.01	NS	.01	NS	.01

TABLE VIII

ELEMENTAL CONCENTRATIONS OF PLANTS GROWN IN
GROWING MEDIUM 1, MM 360

		% Dry Weight					Mg/g Dry Weight		
Testing Date	Fertilizer Level	N	P	K	Ca	Mg	Fe	Mn	Zn
4 weeks	100	4.8[z]	.71	3.5	.56	.49	88	54*	35*
	300	6.1	.84	3.8	.62*	.54*	128	76*	43
	500	6.3	.81	3.6	.51	.50*	149	81*	47
	700	6.3*	.76	3.5	.40	.41	124	89*	45
8 weeks	100	3.8	.47	2.5	.59	.39	60	33*	21*
	300	5.3*	.87	2.9	.47	.46	80	37	27*
	500	6.1*	.75	2.6*	.36	.39	90*	47	25
	700	6.7	.83	2.9*	.32	.39	110	64	28
12 weeks	100	4.4	.55*	2.4	1.25	.74	78	80*	20*
	300	5.9	.97*	2.5	.82	.67	98	94*	28*
	500	6.6	.87	2.5	.64*	.61*	129	111	35
	700	7.0	.89	2.9	.45	.46	129	102*	31*

[z]Each figure is the mean of 3 samples.
*Significant difference between medium 1 and medium 2 (.05 level t-test)

TABLE IX

ELEMENTAL CONCENTRATIONS OF PLANTS GROWN IN GROWING MEDIUM 2, 3:1:1

		% Dry Weight					Mg/g Dry Weight		
Testing Date	Fertilizer Level	N	P	K	Ca	Mg	Fe	Mn	Zn
4 weeks	100	4.9[z]	.66	3.6	.51	.50	94	94*	50*
	300	5.9	.78	3.9	.49*	.47*	103*	104*	47
	500	6.6	.78	3.5	.44	.44*	132	141*	52
	700	6.8*	.73	3.6	.47	.42	125	132*	49
8 weeks	100	3.8	.46	2.7	.55	.40	59	55*	26*
	300	6.3*	.83	3.0	.45	.44	81	55	36*
	500	6.6*	.79	2.9*	.35	.37	142*	64	41
	700	7.1	.82	3.3*	.30	.34	95	72	32
12 weeks	100	4.5	.47*	2.6	1.22	.75	77	143*	28*
	300	6.1	.86*	2.5	.78	.64	105	141*	37*
	500	6.7	.87	2.5	.51*	.47*	109	127	32
	700	7.0	.84	2.9	.45	.42	121	144*	40*

[z]Each figure is the mean of 3 samples.
*Significant difference between medium 1 and medium 2 (.05 level t-test).

Plants grown at 300 and 500 ppm show similar P levels at all 3 testing dates. There was a significantly lower P concentration in medium 2 in some cases. Most P levels fell within the normal range for poinsettia although some levels exceeded the described toxic level of > .7 (7).

K levels remained similar for all fertilizer levels at date 1. Date 2 and date 3 K levels remained quite similar also, with the plants grown at 700 ppm showing slightly higher K concentrations at both dates. At the 100 ppm level, K levels decreased from date 1 to date 3 with a curvalinear response. The same trend is evident at 300, 500, and 700 ppm levels. This may be attributed to higher N levels in fertilizer solutions (11). K levels were found to be slightly higher in plants grown in medium 2 in some cases. All K levels fell within the normal range for poinsettias (7).

Accumulation of Ca and Mg followed similar patterns (Table IX). At date 1, levels remained similar for all four fertilizer levels. However a linear decrease from 100 to 700 ppm is evident at dates 2 and 3. At 100 ppm concentrations of both Ca and Mg remained similar at dates 1 and 2 and increased greatly at date 3. Plants grown at 300, 500, and 700 ppm followed this pattern also although a smaller increase in concentration occurred at the third testing date as fertilizer level increased. Both Ca and Mg concentration appeared significantly lower in medium 2 in some cases. Mg concentrations fell in the normal range while Ca levels appeared at the critically low level of $<$ .5 at the higher levels of fertilization (7). These lower levels of Ca and Mg occurring at the high fertilization levels and later test dates may be attributed to higher levels of K in fertilizer solution due to K competitively inhibiting the uptake of Ca and Mg (11,13).

Zn concentrations at test date 1 were in the same range for all four fertilizer levels. Test date 2 and 3 showed a similar pattern. Plants grown at all four fertilizer levels tended to decrease in Zn concentration from date 1 to date 3. This decrease in Zn concentration at the final test date can be attributed to higher fertilization levels of P at this point (11,21). Plants grown in medium 2 appeared to be significantly higher in Zn concentrations than those grown in medium 1. All values of Zn concentrations fell into the normal range for poinsettia (7).

Accumulation of Fe and Mn followed similar patterns. All three test dates showed a general increase in elemental concentrations from 100 to 700 ppm. The plants grown at all four fertilizer levels demonstrated high concentrations at date 1 followed by low concentrations at date 2 and high concentrations again at date 3. All Fe and Mn levels fell within the normal range for poinsettias (7). Mn concentration is significantly higher in plants grown in medium 2 than those grown in medium 1.

Soluble Salts

All three soluble salt testing procedures produced similar trends (Table X). Soluble salt readings increased linearly from 100 ppm to 700 ppm in all tests and at all dates (Table XI). Readings from plants grown in both media were also similar. Soluble salts readings generally increased linearly from date 1 to date 3 with the leachate test demonstrating the most variability (Table XII).

The greatest within treatment variability was noted for the leachate test readings (Table XIII). This variability tended to increase with fertilizer level increase and testing date. The saturated paste method and 1:2 dilution method both demonstrated less variability, with the saturated paste readings becoming more variable at higher fertilization levels than the 1:2 test readings. This may indicate that the leachate test is not as reliable an index of soluble salt levels as the 1:2 method or saturated paste method. This greater variability may be partially due to soil interactions and moisture state of the medium. The distilled water poured through the pot and then collected may not reflect the soluble salts level accumulating in the medium as well as a test such as the saturated paste and 1:2 methods in which the distilled water is allowed to mix with the medium and remove salts that were bound there. The leachate test may be more of a reflection of the current status of the medium (i.e. how much liquid fertilizer is in the medium when the distilled

TABLE X

EFFECT OF FERTILIZER LEVEL, TESTING DATE, AND GROWING MEDIUM ON SOLUBLE SALT READINGS UTILIZING THREE SOLUBLE SALT TESTING PROCEDURES

	Soluble Salts (mmhos/cm)											
	4 weeks				8 weeks				12 weeks			
Growing medium and sol. salt test	Fertilizer Level				Fertilizer Level				Fertilizer Level			
	100	300	500	700	100	300	500	700	100	300	500	700
MM 360 Sat. Paste	1.34	2.6	3.73	5.5	1.51	3.46	4.12	5.17	2.58	5.69	6.6	7.67
3-1-1 Sat. Paste	1.17	2.92	4.51	6.1	1.1	3.41	4.58	4.76	1.93	5.40	7.03	9.60
significance[z]	NS	NS	NS	NS	.01	NS	NS	NS	NS	NS	NS	.05
MM 360 1:2	0.48	1.08	1.87	1.69	0.40	0.98	1.53	1.88	1.28	1.71	2.22	3.67
3-1-1 1:2	0.32	0.83	1.21	1.72	0.40	0.88	1.31	1.46	0.76	1.56	1.79	2.69
significance	NS	.01	.01	NS	NS	NS	.05	.01	.05	NS	NS	.05
MM 360 Leachate	0.99	5.46	7.91	9.18	0.96	4.25	5.70	7.77	1.94	4.84	7.24	10.5
3-1-1 Leachate	0.87	3.86	6.25	9.08	0.84	3.39	6.39	7.14	0.92	3.95	7.21	10.3
significance	NS	.01	.05	NS	NS	.01	NS	NS	.01	NS	NS	NS

[z]Denotes significance between means of growing media.

TABLE XI

SIGNIFICANT EFFECTS OF FERTILIZER LEVEL ON SOLUBLE SALT READINGS

	Medium 1								
	4 weeks			8 weeks			12 weeks		
Sol. salt test	L	Q	C	L	Q	C	L	Q	C
Sat. Paste	.01	NS	NS	.01	.01	NS	.01	.01	NS
1:2	.01	.01	.01	.01	NS	NS	.01	.05	NS
Leachate	.01	.01	NS	.01	.01	NS	.01	NS	NS

	Medium 2								
	4 weeks			8 weeks			12 weeks		
Sol. salt test	L	Q	C	L	Q	C	L	Q	C
Sat. Paste	.01	NS	NS	.01	.01	NS	.01	NS	NS
1:2	.01	NS	NS	.01	.05	NS	.01	NS	NS
Leachate	.01	NS	NS	.01	.05	NS	.01	NS	NS

TABLE XII

SIGNIFICANT EFFECTS OF TESTING DATE ON SOLUBLE SALT READINGS

	MEDIUM 1							
	Fertilizer Level							
	100		300		500		700	
Sol. salt test	L	Q	L	Q	L	Q	L	Q
Sat. Paste	.01	.05	.01	.05	.01	.05	.01	.05
1:2	.01	.01	.05	.01	.01	NS	.01	.01
Leachate	.01	.01	.05	.01	NS	.01	.05	.01

	MEDIUM 2							
	Fertilizer Level							
	100		300		500		700	
Sol. salt test	L	Q	L	Q	L	Q	L	Q
Sat. Paste	NS	.05	.01	.01	.01	.01	.01	.01
1:2	.05	NS	.01	.01	.01	NS	NS	.01
Leachate	NS	NS	NS	NS	NS	NS	.05	NS

TABLE XIII

WITHIN TREATMENT VARIABILITY FOR
SOLUBLE SALTS TESTS

	4 weeks			8 weeks			12 weeks		
Sol. Salt. test	Sat. Paste	1:2	Leachate	Sat. Paste	1:2	Leachate	Sat. Paste	1:2	Leachate
Fertilizer level									
100	0.0407	0.0319	0.1155	0.0027	0.0085	0.067	0.0207	0.0056	0.0581
300	0.9036	0.0563	0.3068	0.0085	0.0169	0.0277	0.2596	0.1096	0.2958
500	0.1850	0.0604	0.5661	0.0002	0.0032	0.0347	0.1648	0.0912	0.6196
700	0.6546	0.1021	0.7842	0.0106	0.0197	0.2676	2.4254	0.4335	0.6245

water is poured through) rather than the long term accumulation of salts in the medium.

Analysis of solutions used for soluble salt testing show that a higher amount of most nutrients in the 1:2 dilution solution was generally noted. The saturated paste extract solution had the next highest levels in general and the leachate test usually had the lowest amounts of all nutrients (Table XIV). Nitrate, NH_4, P, K, Mn, Fe, Cu, B, Zn, and Mo levels increased in solutions as fertilizer level increased in all three testing solutions. Ca and Mg levels, however, decreased significantly at the 500 and 700 ppm levels. These decreased levels of Ca and Mg at the higher fertilization levels can be explained by replacement of these cations with increased levels of K and NH_4. This displacement would lead to the leaching of these cations and thus lower levels occurring at higher fertilization rates and this is reflected in the solutions (8,23).

A study by Sanderson, et. al., on leachate solution nutrient content (19) demonstrates higher Ca and Mg levels in leachate taken from pots irrigated half as many times as other treatments grown at the same fertilizer levels. This same study showed that Ca levels appeared to drop as fertilizer rate increased and Mg levels were also affected although not to the same extent as Ca.

According to recommendations for solution analysis of saturated paste extract solutions by Warncke (23), plants grown at fertilizer levels of 300, 500 or 700 ppm contained

TABLE XIV

ANALYSIS OF NUTRIENT CONTENT OF SOLUTIONS USED FOR SOLUBLE SALT TESTING, THIRD TESTING DATE, MEDIUM 1 ONLY

Fertilizer level and sol. salt test	PPM											
	NO_3	NH_4	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
100 ppm												
Sat. Paste	118.0	1.1	5.96	107.5	82.55	65.65	0.3065	2.76	0.3135	0.2085	0.470	0.0275
1:2	221.0	7.92	11.75	164.5	138.0	79.5	0.2745	1.46	0.0965	0.7125	0.470	0.0275
leachate	46.15	4.01	4.74	43.7	28.2	18.0	0.0035	0.6945	0.0615	0.2615	0.1970	0.035
300 μpm												
Sat. Paste	482.5	136.5	99.5	744.0	120.0	97.75	1.229	8.67	0.4380	0.7155	0.711	0.0305
1:2	656.0	128.5	92.8	766.5	162.0	126.5	3.245	7.1350	0.4965	1.95	0.171	0.0665
leachate	201.0	35.9	32.5	258.0	43.8	34.6	0.0715	2.30	0.1460	0.4365	0.545	0.0440
500 μpm												
Sat. Paste	485.0	234.5	136.5	760.5	76.15	60.45	1.7650	8.30	0.4620	0.7580	0.7505	0.0325
1:2	755.0	240.0	143.0	964.5	117.5	92.2	3.32	6.78	0.5220	1.32	1.41	0.0550
leachate	241.0	89.0	46.5	345.0	16.85	13.8	0.3215	1.835	0.1515	0.4625	0.381	0.1110
700 ppm												
Sat. Paste	644.0	381.0	206.0	1051.0	73.0	53.9	2.87	10.605	0.565	1.0255	0.898	0.435
1:2	781.0	362.5	184.0	1074.0	49.5	38.15	3.485	4.76	0.4955	1.265	1.155	0.1755
leachate	290.0	134.0	68.0	414.0	13.9	10.55	0.6360	1.6	0.1385	0.5425	0.328	0.2030

excessive levels of NO_3, P, and K in their medium solutions. Ca levels appeared lower than recommended optimum rates at all four fertilization levels and Mg levels were also too low except at 300 ppm fertilization.

Plant response to soluble salt levels was evident in dry weight (Table I), height (Table II), and bract necrosis data (Table XV). Growth suppression became apparent at date 2 for plants grown at 500 or 700 ppm and is even more apparent at date 3. Bract necrosis occured on plants grown at these levels at test date 3 and indicate toxic soluble salt levels or possible Ca suppression. Bract necrosis levels were higher at 700 ppm than at 500 ppm and were higher for medium 2 than medium 1. Bract necrosis has been attributed to Ca deficiency by Harbaugh and Woltz (9). The levels of fertilization demonstrating bract necrosis are also levels reflecting Ca deficiency in tissue analysis results. Ca levels were close to the same for mix 1 and mix 2 although Mg levels appeared lower in mix 2. Therefore the following guidelines may be set for soluble salt readings based on this data: Good growth and development may be expected at soluble salt readings of <4.1 millimhos/cm with the saturated paste extract method. Levels greater than 4.1 and less than 5.7 are stunting and approaching toxic levels. Readings of greater than 6.0 may be considered dangerous and bract necrosis is very likely. These results are similar to another interpretation (12), but too low when compared to Nelson's interpretation (16).

TABLE XV

AVERAGE NUMBER OF NECROTIC BRACTS PER PLANT
AT THE FINAL TESTING DATE
IN BOTH GROWING MEDIA

Average Number of Necrotic Leaves Per Plant				
	Fertilizer Level			
Growing Medium	100	300	500	700
MM 360	0[z]	0	1.8	4.2
3:1:1	0	0	3.4	6.7

[z]Each figure is the mean of 9 plants.

Soluble salt readings less than 1.5 may be considered safe with the 1:2 dilution method. Levels greater than 1.5 and less than 1.8 may be considered dangerous and growth inhibiting with levels greater than 1.8 indicating possible toxicity. These levels would be considered acceptable by some (5,16) but too high by others (12).

The leachate test deomonstrated safe growth levels at less than 5.7 with growth inhibition at levels greater than this and less than 7.2. Levels greater than 7.2 may be considered toxic and bract necrosis is probable. These levels correspond well with those demonstrated in work by Poole (18) on various crops but more research in leachate testing would be necessary in order to define set guidelines for soluble salt interpretations. Various species may respond differently to the same soluble salt levels.

The leachate test may prove to be more valuable a tool for measuring soluble salts in fertilization programs utilizing controlled release fertilizers. The leachate readings may be used to examine the current statuus of soluble salts in the medium and give the grower a means of monitoring their levels in order to adjust leaching practices or supplemental liquid fertilizer programs. In addition, this method is simple and rapid and does not upset the growing medium of ongoing crops. Slow release capsules are not removed with the medium and would not influence readings as with methods like the saturated paste extract or 1:2 dilution. More research is needed on the best time (or soil moisture content) to test. The saturated paste extract and 1:2 dilution methods both accurately reflect soluble salts in soilless media and would therefore be suitable for monitoring their levels especially with constant liquid fertilization programs.

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