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INTERPRETATION OF SOLUBLE SALTS AND PH OF BULK SOLUTIONS EXTRACTED BY DIFFERENT METHODS

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Abstract. **Soluble salts (SS) and pH are two easily measured parameters but critically important to the growth of containerized plants. Because different methods are being used for extracting bulk solutions from potting media, SS and pH readings for an identical medium may differ significantly. Until now a relationship had not been established that would allow the correlation of the metered results obtained from one extraction method to another. In this study, three commercial media were used to fill 15.1-cm (6-inch) pots and were fertilized with either a water-soluble fertilizer or a controlled-release fertilizer. Bulk solutions of the media were extracted three times using four commonly used methods: (1) pour through, (2) saturated media extraction, (3) 1:2 and (4) 1:5 (medium: water by volume) dilution. The initial bulk solution extractions were performed one week after golden pothos [*Epipremnum aureum* (Linden & Andre) Bunt.] were transplanted into the media; two additional extractions were conducted at two consecutive two-week intervals. The pH of the bulk solutions was not affected by the extraction methods, but SS readings were extraction-method dependent. Correlation coefficients of SS among the four methods were highly significant ranging from 0.62 to 0.84; thus, equations for converting SS readings from one extraction method to another were calculated.**

Soluble salts (SS) is a measure of all dissolved salts in extracted solutions (bulk solution or leachate) of potting media using conductivity meters and quantified as millimhos per centimeter (mmhos/cm) or deciSiemens per meter (dS/m) depending on particular meter calibrations; thus, SS is also referred to as electrical conductivity (EC). The pH is the measure of hydrogen ion concentration, expressed as a negative logarithm. Since SS levels represent the nutrient status of potting media and pH provides information on media acidity or alkalinity as well as the availability of micronutrients, both parameters have been used widely in ornamental plant production (Poole and Conover, 1983, 1988; Yeager et al., 1983). Recommended ranges for media SS and pH for the growth of potted plants have been published in a variety of journals and textbooks (Handreck and Black, 1994; Nelson, 1998; Stamps, 1999). With the availability of less expensive and portable meters, many growers can monitor potting media SS and pH on site.

Currently, there are four methods being used by growers, extension agents and analytical laboratories for extracting bulk solutions from potting media: (1) 1:2 dilution by volume; (2) 1:5 dilution by volume. One part of air-dried media is mixed with two or five parts of distilled or deionized water; the mix is stirred and equilibrated for 30 min, then filtered using filter paper or several folds of cheese cloth (Lang, 1996); (3) Pour-through (PT) method. Distilled or deionized water is slowly poured over the surface of near saturated container-medium so that about 50 mL of bulk solution can be collected as leachate from drainage holes (Yeager et al., 1983); (4) Saturated media extract (SME) developed by Lucas et al. (1972). About 500 cc of medium is sampled from potting media and mixed with distilled or deionized water until just saturated (medium surface glistens). After equilibrating for 1.5 h, solutions are extracted using a vacuum filter.

Different extraction methods may vary the SS and pH readings of an identical medium (Lang, 1996). Although several studies have been conducted on the reliability of individual extraction methods (Argo et al., 1997; Poole and Conover, 1988; Warncke, 1986; Wright, 1986; Wright et al., 1990), limited research has been done on the comparison of the readings from the different methods (Yeager et al., 1983). Until now relationships had not been established that would allow the correlation of the metered results obtained from one extraction method to another. As a result, growers and extension agents are often confused by the results derived from different extraction methods (Stamps, 1999).

The objectives of this study were: (1) to compare SS and pH readings of bulk solutions extracted by the aforementioned methods using three different media fertilized with either a water-soluble or a controlled-release fertilizer; (2) to determine the relationship of SS and pH of bulk solutions extracted by the four methods; and (3) to develop equations for converting SS readings from one method to another.

Materials and Methods

Potting media. Three potting media were used in this study: (1) two from Fafard, Inc. (Apopka, FL), designated here as FM1 and FM2, and (2) Vergro Container mix A (Verlite Co., Tampa, FL), designated as VM. FM1 contains 40% sphagnum peat, 25% pine bark, 25% coconut coir and 10% styrofoam and FM2 is composed of 55% sphagnum peat, 25% perlite and 20% vermiculite. VM contains 60% sphagnum peat, 20% perlite and 20% vermiculite, supplemented with 4 $kg \cdot m^3$ dolomite.

Sampling depth. Since 1:2, 1:5 and SME methods require removing portions of medium from pots, the first experiment was to determine if SS and pH readings at various depths within the same pots were different. The three media were used to fill 15.1-cm (6-inch) tapered pots with an 8-cm depth, after which rooted golden pothos cuttings were transplanted. Plants were fertigated with a Peter's water-soluble fertilizer 24.0N-3.5P-13.3K (1 g dissolved in 1 L of deionized water) at 150 mL per pot once a week. No additional water or fertiliza-

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tion was needed. The experiment was set up as a completely randomized design with three replications. Plants were grown in a shaded glasshouse under a light intensity of 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and a temperature range from 20 to 32°C. Three weeks after plant addition, media samples were taken at three media depths within the pots: top (0 to 2 cm from media surface), middle (2 to 5 cm down) and bottom (5 to 8 cm down). Bulk solutions were extracted using the 1:2 dilution method. Both soluble salts and pH of bulk solutions were measured after 30 min of equilibration using a Fisher Accumet Selective Ion Analyzer, Model 750.

Equilibration time. Samples taken using either the 1:2, 1:5 or SME methods should be equilibrated with distilled or deionized water before bulk solution extraction. To determine whether the equilibration time affected the reading of SS and pH, media samples were taken four weeks after golden pothos transplanting from pots described above (three replications). Using the 1:2 method, the samples were equilibrated with water for 0.5, 1, 2, 3, 4, 5 and 6 h prior to bulk solution collection. Soluble salts and pH of the collected solutions were measured.

Water volume-PT method. The amount of water poured onto the surface of the potting medium during leachate collection is a variable that could affect meter readings. To study the volumetric effects, the 15.1-cm pots were filled with three media to which water-soluble fertilizer was applied weekly. There were no plants grown in these media but a near saturated moisture level was maintained. Two weeks after fertilization, 200, 250, 300, 350 and 400 mL of deionized water were poured slowly over the surface of the pots (three replications), and SS and pH of the collected leachates were measured.

Soluble salts and pH levels utilizing the four extraction methods. The three media were used to fill 15.1-cm pots in which single rooted golden pothos cuttings were transplanted. Plants were grown under the identical environmental conditions as described above and fertigated using either the same concentration and application rate of Peter's water-soluble fertilizer 24.0N-3.5P-13.3K (24-8-16) as described above or a Scotts' controlled-released fertilizer 18.0N-2.6P-10K (18-6-12) at 5 g per pot. Bulk solutions were collected one week after golden pothos transplanting and every two weeks thereafter for four weeks using 1:2, 1:5, PT and SME methods. Samples were taken from the middle level (3 to 5 cm from media surface) of media and allowed to equilibrate 1 h before solution extractions began. For the PT method, 250 mL of deionized water were slowly poured over the surface of the near saturated media and leachates were collected. Soluble salts and pH of the bulk solutions were measured.

All means, standard errors and correlation coefficients were calculated using the means and correlation procedures of SAS (SAS Institute, Inc., 1992, Cary, NC). Corresponding equations for converting SS readings from one extraction method to the other three were calculated using the regression procedures of SAS.

Results and Discussion

Sample depth. Soluble salts and pH of bulk solutions extracted from samples at three media depths are presented in Fig. 1. Soluble salts between the middle and bottom layers were similar in all three media, however, differences were found between top and middle or bottom layers (Fig. 1a). Soluble salts levels were low in the top, but higher in the middle and bottom layers of FM1 and FM2, whereas SS of VM were high in the top, but low in the middle and bottom. There were no differences in pH of the bulk solutions extracted from the three depths (Fig. 1b). Lang (1996) studied SS distribution in New Guinea Impatiens (*Impatiens hawkeri*) media and found that SS in the upper one third were markedly different from those in the lower two thirds of the potting media and that readings from the lower two thirds were more stable. In general, the majority of roots are distributed in the lower two thirds of the pots; samples taken from the middle of pots appeared to be reliable.

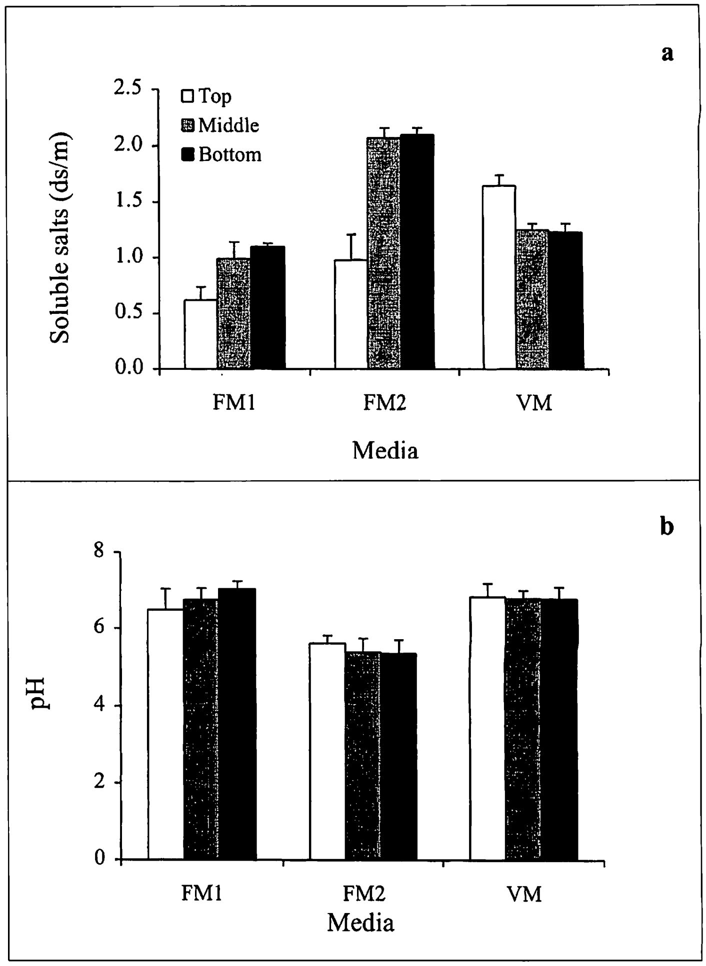

Figure 1. Soluble salts (a) and pH (b) of bulk solutions extracted using 1:2 dilution method from media samples taken from pots at top (0 to 2 cm from medium surface), middle (2 to 5 cm down) and bottom (5 to 8 cm down) layers of pots containing Fafard Mix 1 (FM1), Fafard Mix 2 (FM2) and Vergro Container Mix A (VM) fertilized with a Peter's water-soluble fertilizer (see text for details of media components). Bars represent means ± S.E., n = 3.

Equilibration time. Equilibration for 30-min to 6 h showed no distinctive difference in SS readings across all three media (Fig. 2a). However, equilibration for 5 to 6 hours caused a significant decrease of pH in the three media (Fig. 2b). These data lend support to the adequacy of a 30-min time period for sample equilibration (Lang, 1996).

Water volume-PT method. The amount of water used to collect bulk solution influenced SS readings when the PT method was used (Fig. 3a). No matter which media were used, pouring 200 mL of water into the 15.1-cm pots resulted in higher SS readings than using 250 mL or more, and no pronounced differences occurred in readings when FM1 and VM

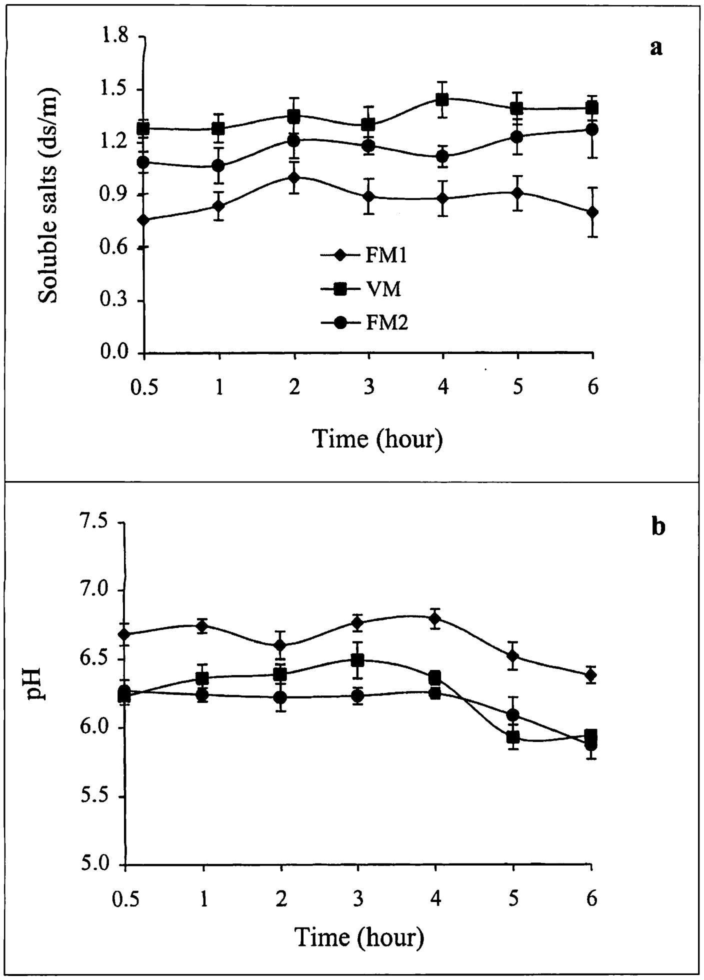

Figure 2. The effects of equilibration time between water and media samples on soluble salts (a) and pH (b) readings of bulk solutions extracted using 1: 2 dilution method from Fafard Mix 1 (FM1), Fafard Mix 2 (FM2) and Vergro Container Mix A (VM) fertilized with a Peter's water-soluble fertilizer (see text for details of media components). Bars represent means ± S.E., n = 3.

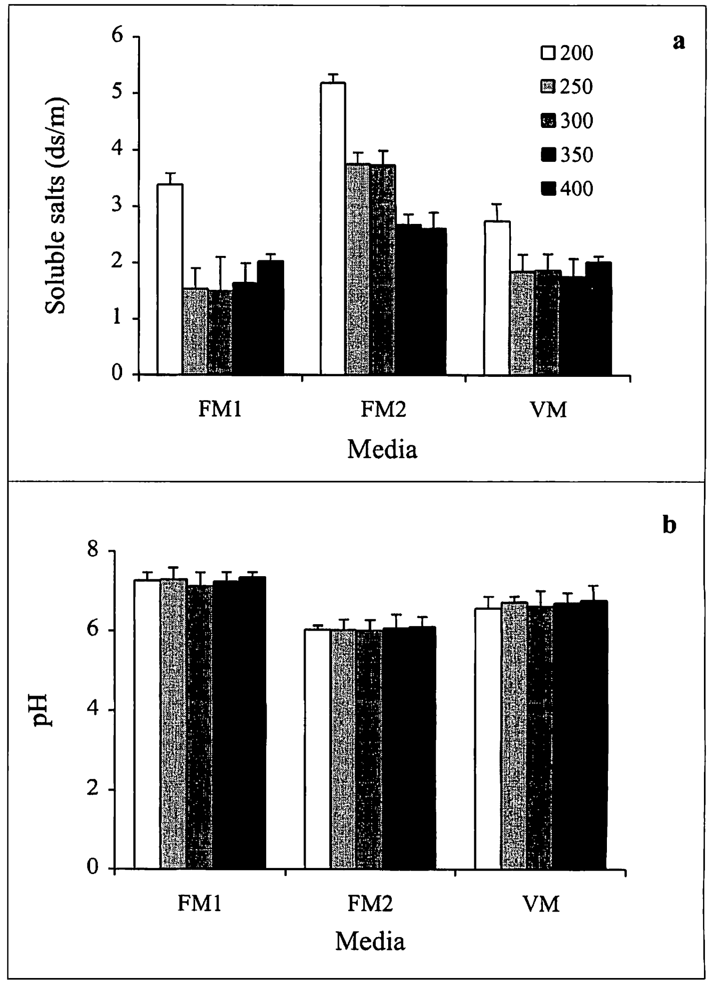

Figure 3. The effects of water volume on soluble salts (a) and pH (b) readings of bulk solutions extracted from Fafard Mix 1 (FM1), Fafard Mix 2 (FM2) and Vergro Container Mix A (VM) fertilized with a Peter's water-soluble fertilizer (see text for details of media components). Bars represent means ± S.E., n = 3.

media were leached using up to 400 mL. However, leaching FM2 with 350 to 400 mL of water substantially reduced the SS readings compared to those leached with 250 to 300 mL of water. Our data do not completely agree with previous studies conducted by Poole and Conover (1988) wherein 160 mL to 460 mL of water used to extract bulk solution from 15.1-cm pots did not greatly affect SS readings. Based on the results of this study, a minimum of 250 mL of water was required for extracting bulk solution from 15.1-cm pots containing these media when the PT method was used.

The relationships between SS and pH readings and the four extraction methods. Means and standard errors of pH and SS readings of bulk solutions collected three times using the four extraction methods were computed. The pH readings of the bulk solutions ranged from 5.2 to 7.6 depending on individual media and fertilizer applications, but were not significantly affected by the extraction methods. Soluble salts readings, however, varied substantially according to method no matter what fertilizers were used or when samples were taken (Table 1). This variability is mainly due to finite dissolved salts diluted by the amount of water outlined by the methodology. Expressly, water volume used by the PT method only partially displaces existing medium solution, whereas, SME, 1:2 and 1:5 rely on a dilution of sampled medium, which will lower SS readings depending on dilution. Thus, the SS readings for bulk solutions extracted from an identical medium using the four methods should be in this order: PT>SME>1:2>1:5.

To determine the relationship of the SS readings resulting from the four methods, data were grouped by method and regression analyses were conducted. The correlation coefficients among the four methods were highly significant with r values ranging from 0.62 to 0.84 (Table 2). As a result, equations for converting the SS readings of one method to another were calculated (Table 2). Since three representative media with basic components combined with water-soluble or controlled-release fertilizers were used in this study, the developed equations should be applicable to a wide range of potting media and production conditions.

Each extraction method has its merits and drawbacks. We have concluded that the PT method is the most practical one for container-grown plants, due to: (1) its simplicity and ease of use; no medium is removed from pots or handled and no specialized extraction equipment needed, and (2) its reliability; the readings are comparable to other methods as indicated in this study and others (Poole and Conover, 1988; Yeager et al., 1983; Wright et al., 1990). The PT method may partic-

Table 1. Soluble salts readings of bulk solutions collected three times using 1:2, 1:5, pour through (PT) and saturated media extract (SME) methods from three potting media fertilized with either a controlled-release or a water-soluble fertilizer.

Extraction method	Media[z]								
	FM1	FM1/WSF	FM1/CRF	FM2	FM2/WSF	FM2/CRF	VM	VM/WSF	VM/CRF
	Soluble salts (ds/m)								
	Week 1								
1:2	0.13 ± 0.03[y]	0.73 ± 0.09	0.24 ± 0.03	0.16 ± 0.02	0.60 ± 0.08	0.18 ± 0.03	0.20 ± 0.02	0.95 ± 0.14	0.22 ± 0.05
1:5	0.08 ± 0.01	0.35 ± 0.06	0.13 ± 0.01	0.08 ± 0.02	0.43 ± 0.01	0.09 ± 0.01	0.12 ± 0.01	0.39 ± 0.01	0.11 ± 0.01
PT	1.30 ± 0.04	6.04 ± 0.17	1.73 ± 0.15	2.34 ± 0.29	8.54 ± 1.43	2.65 ± 0.47	1.65 ± 0.25	4.97 ± 0.26	1.63 ± 0.16
SME	0.18 ± 0.01	1.28 ± 0.35	0.24 ± 0.05	0.34 ± 0.05	1.58 ± 0.01	0.49 ± 0.05	0.32 ± 0.04	1.48 ± 0.21	0.29 ± 0.05
	Week 3								
1:2	0.12 ± 0.01	0.38 ± 0.09	0.17 ± 0.02	0.15 ± 0.01	0.81 ± 0.13	0.32 ± 0.01	0.19 ± 0.03	0.90 ± 0.10	0.32 ± 0.01
1:5	0.07 ± 0.01	0.27 ± 0.06	0.13 ± 0.03	0.07 ± 0.01	0.38 ± 0.01	0.15 ± 0.01	0.14 ± 0.02	0.43 ± 0.10	0.19 ± 0.04
PT	0.69 ± 0.03	3.55 ± 0.31	0.92 ± 0.07	0.87 ± 0.12	8.57 ± 0.95	1.86 ± 0.37	0.88 ± 0.20	3.98 ± 0.34	1.47 ± 0.09
SME	0.22 ± 0.01	0.82 ± 0.29	0.25 ± 0.04	0.33 ± 0.07	1.61 ± 0.24	0.91 ± 0.22	0.50 ± 0.05	1.34 ± 0.01	0.83 ± 0.15
	Week 5								
1:2	0.25 ± 0.01	0.80 ± 0.17	0.26 ± 0.03	0.25 ± 0.02	0.92 ± 0.23	0.57 ± 0.09	0.35 ± 0.05	1.28 ± 0.08	0.44 ± 0.07
1:5	0.11 ± 0.01	0.31 ± 0.10	0.15 ± 0.01	0.12 ± 0.02	0.38 ± 0.03	0.22 ± 0.04	0.18 ± 0.01	0.45 ± 0.04	0.20 ± 0.02
PT	0.51 ± 0.03	2.95 ± 0.36	0.78 ± 0.04	0.61 ± 0.13	7.88 ± 0.83	1.81 ± 0.35	0.86 ± 0.11	4.36 ± 0.12	1.53 ± 0.13
SME	0.43 ± 0.02	1.59 ± 0.14	0.47 ± 0.08	0.55 ± 0.01	2.89 ± 0.25	1.27 ± 0.14	0.59 ± 0.07	1.76 ± 0.16	0.89 ± 0.10

[z]Fafard mix 1 (FM1), Fafard mix 2 (FM2) and Verlite mix (VM) with a water-soluble fertilizer (WSF) or a controlled-release fertilizer (CRF), respectively.
[y]Mean ± S.E.

Table 2. Simple correlation coefficients (r) of bulk-solution soluble salts extracted by 1:2, 1:5, pour through (PT) and saturated media extract (SME) methods and equations for converting soluble salts readings from one extraction method to another.

Extraction method	1:2		1:5		PT		SME	
	Equation	r	Equation	r	Equation	r	Equation	r
1:2			$Y_{1:2} = -0.002 + 2.07\ X_{1:5}$	0.84**	$Y_{1:2} = 0.21 + 0.08\ X_{pt}$	0.62**	$Y_{1:2} = 0.08 + 0.41\ X_{sme}$	0.83**
1:5	$Y_{1:5} = 0.06 + 0.34X_{1:2}$	0.84**			$Y_{1:5} = 0.10 + 0.04\ X_{pt}$	0.74**	$Y_{1:5} = 0.07 + 0.16\ X_{sme}$	0.81**
PT	$Y_{pt} = 0.75 + 4.61\ X_{1:2}$	0.62**	$Y_{pt} = -0.11 + 13.56\ X_{1:5}$	0.74**			$Y_{pt} = 0.4 + 2.73\ X_{sme}$	0.74**
SME	$Y_{sme} = 0.14 + 1.67\ X_{1:2}$	0.83**	$Y_{sme} = 0.02+ 4.02\ X_{1:5}$	0.81**	$Y_{sme} = 0.32 + 0.20\ X_{pt}$	0.74**		

**Significant at P ≤ .0.01, n = 81.
Example:
Suppose a SS reading of 1.5 ds/m is obtained from the PT method. To convert this reading to the equivalent 1:2 reading, use the equation:
$Y_{1:2} = 0.21 + 0.08\ X_{pt}$
$= 0.21 + 0.08 \times 1.5$
$= 0.33$
Therefore, if the 1:2 method is used to extract bulk solution from this medium, the SS reading should be 0.33 ds/m or 0.33 mmhos/cm.

ularly be more applicable to media where controlled-release fertilizers are used because the other three methods require the removal of media from pots in which fertilizer granules may be lost or collected as a part of sample, which can lead to erroneous readings of SS. Sampling can also damage roots and cause media loss.

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