bulk solution concentrations of P measured at container capacity throughout the crop cycle are presented in Fig. 2. Initial concentrations began at 250 ppm and quickly fell to 40 ppm, after which the rate of decline was slowed to 1.4 ppm. Concentrations were at all times above the reported threshold value of 0.18 ppm. These values bear a direct relationship to the P sorption isotherm levels; hence comparison to other forms of nutritional research is again permitted through bulk solution analysis. These particular results suggested that no P stress would occur, which, in fact, turned out to be true.

Many other research uses can be served through bulk solution analysis. The column displacement procedure (as presented in this paper) is, however, a destructive and tedious procedure, which precludes its use for routine analyses of commercial samples in its present form.

SUMMARY

The nutritional environment from which most nutrients are derived by the plant is best represented in the bulk solution (that position of the soil solution not influenced by the exchange surface of the root medium components) of root media. Owing to the need for careful control and monitoring of nutrient availability, hydroponic procedures are often mandated in nutritional research. There is a serious problem in relating hydroponic results to the commercial root medium situation. Current soil testing procedures alter the bulk solution, thereby obscuring the relationship between these 2 systems. Unaltered bulk solution analysis offers the needed bridge. A refined column displacement procedure for collecting bulk solution is presented in this paper. This system can be used to collect bulk solution fractions at increasing soil moisture tensions including −30 kPa.

Literature Cited

1. Bennett, A.C. and F. Adams. 1970. Concentration of NH_3 (aq) required for incipient NH_3 toxicity to seedlings. Soil Sci. Soc. Amer. Proc. 34:259–263.
2. Burd, J.S. and J.C. Martin. 1923. Water displacement of soils and soil solution. J. Agr. Sci. 13:265–295.
3. Davies, D.E. and R.I. Davies. 1963. A simple centrifugation method for obtaining small samples of soil solution. Nature (London) 198:216–217.
4. Faber, W.R. 1980. Effects of drying, fertilizer delivery system, and three root media on the composition of the bulk solution during pot mum production. PhD Thesis. North Carolina State Univ., Raleigh.
5. Faber, W.R. and P.V. Nelson. 1984. Evaluation of methods for bulk solution collection from container root media. Commun. Soil Sci. Plant Anal. 15:1029–1040.
6. Mubarak, A. and R.A. Olsen. 1976. Immiscible displacement of the soil solution by centrifugation. Soil Sci. Soc. Amer. J. 40:329–331.
7. Nishimoto, R.K., R.L. Fox, and P.E. Parvin. 1975. External and internal phosphate requirements of field grown chrysanthemums. HortScience 10:279–280.
8. Parker, F.W. 1921. Methods of studying the concentration and composition of the soil solution. Soil Sci. 12:209–232.
9. Pearson, R.W. 1971. Introduction to symposium, the soil solution. Soil Sci. Soc. Amer. Proc. 35:417–420.
10. Reeve, R.C. and E.J. Doering. 1965. Sampling the soil solution for salinity appraisal. Soil Sci. 99:339–344.
11. Soil Science Society of America, Committee Report. 1965. Glossary of soil science terms. Soil Sci. Soc. Amer. Proc. 29:330–351.
12. Wagner, G.H. 1962. Use of porous ceramic cups to sample soil water within the profile. Soil Sci. 94:379–386.

The Pour-through Nutrient Extraction Procedure

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Nutrient absorption and subsequent plant growth is related to an adequate supply of the nutrient in the soil solution. Thus, fertilizer practices in a nursery and greenhouse should attempt to maintain nutrient levels in the soil solution that promote optimal growth (2, 3). Maintenance of nutrients for greenhouse and nursery crops is usually via slow-release fertilizer or frequent additions through the irrigation water, where mass flow rather than diffusion is probably the predominant process by which nutrients move to plant root surfaces. In effect, the container medium serves primarily as mechanical support for the plant, and, in contrast to mineral soil systems, nutrients adsorbed to the medium are insignificant in relation to the rate of nutrient uptake and subsequent plant growth. This is particularly true for macronutrients, although the extent that it applies to micronutrients is still not clear.

The best way to determine plant nutrient availability (when supplied via mass flow) is to determine the nutrient concentration in the soil solution. The best recognized procedure for extraction of the true soil solution is the displacement soil solution procedure first described by Parker (4). Subsequent studies dealing with the procedure have been reviewed by Adams (1). The pour-through (PT) procedure is a modification of this technique and has been studied by Yeager et al. (6). Nutrient values obtained with the procedure are lower than would be expected with the displaced soil solution procedure, since some mixing of the displacement solution and the soil solution may occur. However, this method is much faster to execute and no specialized equipment is required. Further, relative differences that occur between soils of different fertility should still be apparent, even though the true nature of the dissolved solutes in a soil solution (the ratio of one nutrient to the other) may be changed because of a dilution effect (5).

Description of the PT extraction procedure

1) The container and medium in question is placed on a suitable object to elevate the container bottom of the surface of the collection vessel. The collection vessel should be wide enough to collect leachate from both center and side container holes.

2) Add sufficient distilled water to the surface of the container media so that about 50 ml of water is accumulated in the collection vessel. Applying rates of 75, 150, and 350 ml of water per 1-, 4-, and 12-liter nursery containers, respectively, is normally sufficient. The moisture level of the container should be at or near its water-holding capacity. The moisture level must be similar at the time of each extraction, or the moisture level of the container medium will influence the level of nutrients extracted. About 5 min is sufficient time with most container media for the leachate to drain into the collection vessel.

3) The leachate is then poured into a suitable container and is ready for pH, soluble salts, and nutrient analysis. This analysis may be accomplished on location or sent to an analytical laboratory. Rapid turn-around times of 24 to 48 hr for results can be arranged with analytical laboratories under emergency conditions.

4) Samples should be refrigerated until analysis, and if an extended period of time is to occur before analysis, freezing is recommended.

Effectiveness of the procedure

One might question the effectiveness of the procedure because of the simplicity of the procedure. Some questions that have been asked about the system include:

Table 1. Pour-through extract N, P, K, Ca, Mg, and pH of a pine bark medium (102% gravimetric moisture) as influenced by volume of water applied (6).

Volume applied (ml)	Volume collected (ml)	Extract (ppm)					
		NH_4–N	NO_3–N	P	K	Ca	Mg
40	23	---	16	14	129	36	46
55	39	2.2	15	13	123	35	43
70	51	2.1	16	13	126	35	46
85	65	3.2	16	13	127	33	42
100	78	3.0	16	13	130	36	43
Linear effect		*	NS	**	NS	NS	NS

NS, *, **: not significant, significant at $P = 5\%$ and 1%: data subjected to linear regression analysis.

1) How does the volume of water applied influence the nutrient concentration of leachate?

2) How does moisture level of the medium influence the nutrient concentration of leachate?

3) How well does the nutrient concentration of leachate correlate with nutrient concentration of soil solution?

4) What is the reproducibility of the method in the field?

Results from experiments addressing the first 2 questions have been published by Yeager et al. (6). The volume of water applied to the surface had no influence on the level of nutrients extracted when it ranged from 40 to 100 ml applied to a 1-gal nursery container (Table 1). Even though linear regression analysis indicates a significant response of NH_4 and P to volume of water applied, these differences are not considered realistic from a production viewpoint. The moisture concentration of the container had a significant effect on the concentration of nitrates and soluble salts extracted from the container (Table 2). As the moisture level decreased from 102% (container capacity) to 50% on a gravimetric basis, the level of nutrients extracted decreased. Thus, it is recommended that the PT should be conducted when the moisture level is near container capacity, or, more importantly, the moisture level should be at about the same level each time the extraction is made. In the same way, container moisture levels also influenced the level of nutrients extracted from a container media by the saturated soil extract method (Table 2).

A peat:perlite (50:50 v/v) medium and a 100% pine bark medium were saturated with either a 1 × or 1/3 × complete nutrient solution to determine how well the nutrient level of the leachate from PT correlated with that of the true soil solution. The values obtained from the PT were slightly lower than that applied (Table 3), but the 3-fold difference in the nutrient concentration of extracted solution was similar to the differences between the 2 solutions applied. There were no differences between the extraction of nutrients from the 2 soil media.

Analytical results from 3 solutions sent to a commercial laboratory that had been taken from 3 separate containers in a block of plants were compared to demonstrate the reproducibility of the method under nursery conditions (Table 4; unpublished data). Nutrient levels (except for K and Ca) for each container were similar, demonstrating the consistency of the procedure in extracting the nutrients from a container under field conditions. The difference in nutrient levels obtained with this procedure thus is a reflection of actual nutrient levels in the container and not to errors in the extraction procedure.

Table 2. Pour-through (PT) and saturated soil extract (SSE) soluble salts and nitrates of a pine bark medium at 3 moisture levels (6).

Gravimetric moisture (%)	Soluble salts (ppm)		Nitrate (ppm)	
	PT	SSE	PT	SSE
50	418	284	31	25
76	578	316	42	26
102	621	454	53	40
Linear effect	**	**	**	**

**Significant at $P = 1\%$: data subjected to linear regression analysis.

Table 3. Pour-through extraction[z] of nutrients applied to a pine bark medium.

	Soluble salts (ppm)	Nutrient level (ppm)			
		NH_4	NO_3	P	K
Applied					
1 ×	434	51	55	16	29
1/3 ×	154	14	15	4	11
Extracted					
1 ×	396	38	47	14	24
1/3 ×	143	11	14	4	9

[z]75 ml of H_2O applied to 1-liter containers.

Table 4. Pour-through extraction of nutrients from pine bark–sand medium for Burford holly in 3-gal containers

Nutrient extracted	Nutrient level (PPM)			
	Sample number			
	1	2	3	SE
NO_3-N	56	53	56	1.7
NH_4-N	30	26	30	2.3
P	5	5	7	1.2
K	26	36	44	9.0
Ca	52	40	44	6.1
Mg	18	14	20	3.1
Fe	0.1	0.1	0.1	0.0
Mn	0.3	0.3	0.4	.6
Cu	0.01	0.02	0.02	0.005
Zn	0.19	0.24	0.26	0.04

Table 5. Pour-through soil solution elemental and soluble salt levels associated with vigorous growth of *Ilex crenata* and other nursery species growing in a pine bark medium.

Element	level in leachate (ppm)
N	75–100
P	10–15
K	30–50
Ca	10–15
Mg	10–15
Soluble salts	0.6–2.0 $mmho \cdot cm^{-1}$

Comparing PT with other procedures

Other methods of nutrient extraction for soilless container media use the addition of water to a volume of medium. Procedures vary from saturating the medium (saturated soil extract method) to adding different amounts of water to a known volume of soil (2:1, 3:1, or 5:1, etc.). All of these procedures entail the removal of the medium from the container with subsequent extraction in the laboratory. The advantages of the PT procedure are that no medium is actually handled, there is no danger of rupturing slow release fertilizer particles (causing erroneously high nutrient readings), no specialized equipment is required for extracting the solution from the medium, and time required for each extraction is much reduced.

Application of PT procedure

The PT procedure should be especially valuable to nurserymen and greenhouse operators interested in monitoring soluble salts on a regular basis. It is effective in obtaining a complete nutrient analysis of the soil solution in conjunction with commercial laboratories, since the laboratories can make direct readings on the solution. This reduces turn-around time to 24–48 hr, which can be critical to nursery and greenhouse operators when correcting a nutrient imbalance.

Based on results from test with 'Helleri' *Ilex crenata* nursery crops, nutrients in the soil solution extracted with PT should be about that shown in Table 5. These levels may vary between different crops—especially azalea—but many nursery crops have been shown to grow rapidly at those levels.

Literature Cited

1. Adams, F. 1974. Soil solutions. p. 441–482. In: E.W. Carson (ed.). The plant root and its environment. Univ. Press of Virginia, Charlottesville.
2. Hiatt, A.J. and J.E. Leggett. 1974. Ion interaction and antagonism in plants. p. 101–134. In: E.W. Carson (ed.). The plant root and its environment. Univ. Press of Virginia, Charlottesville.
3. Niemiera, A.X. and R.D. Wright. 1982. Influence of medium nitrogen level on growth periodicity of *Ilex crenata* Thunb. 'Helleri'. Scientia Hort. 17:81–87.
4. Parker, F.W. 1921. Methods of studying the concentrations and composition of the soil solution. Soil Sci. 12:209–232.
5. Reitemeir, R.F. 1945. Effect of moisture content on the dissolved and exchangeable ions of soils in arid regions. Soil Sci. 61:195–214.
6. Yeager, T.H., R.D. Wright and S.S. Donohue. 1983. Comparison of pour-through and saturated pine bark extract, N, P, K, and pH levels. J. Amer. Soc. Hort. Sci. 108:112–114.

Problems in the Analysis of Organic and Lightweight Potting Substrates

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Most potting mixes currently used for raising greenhouse crops, vegetable transplants, and hardy ornamental shrubs in containers do not contain mineral soil; these mixes are often known as "soilless", "lightweight", or "artificial" media. Their popularity has increased steadily over the last 3 decades, principally for reasons of convenience or economic advantage. The chemical and physical characteristics of these media are, however, very different from those of the traditional potting mixes based on mineral soil.

Consequently, methods that had been successfully used for the chemical analyses of field soils and soil-based potting mixes are generally considered to be inappropriate for the new soilless mixes. New procedures are required to obtain the maximum understanding and benefit from chemical analyses of the new-type mixes.

PURPOSE OF ANALYSES

The reasons for making the analysis, together with the anticipated numbers and frequencies, largely will determine which method is chosen. Different objectives and priorities may well apply if the analysis is required for research rather than extension or advisory work.

Consideration should be given to the following in choosing a method for a research project: 1) accuracy; 2) results should relate directly to the conditions experienced by the plant (e.g., the ability to relate a soluble salt determination to osmotic pressure); 3) the method should allow determination of both concentration and balance of major nutrients (for example, the relationship of calcium to other cations in blossom-end rot of tomatoes).

For extension purposes, points for consideration should include: 1) speed (i.e., the ability to handle a large number of samples per day in order to give a quick service to the grower); 2) simplicity of method (i.e., one that is largely independent of individual operator skill); and 3) suitability of the method for a diverse range of materials (e.g., peat, bark, expanded minerals, etc.).

At present, many different methods are used to analyze potting media, often with minor variations. Some rationalization of the methods now in use in different laboratories and countries would be mutually beneficial in providing a greatly enlarged pool of standardized experience from which to make recommendations to growers. The procedures most commonly used for chemical analyses of potting media can be grouped as in Fig. 1. In Western Europe, saturated media extracts and displaced soil solutions are used only for research work. One of the suspension methods is invariably used for extension purposes, largely for reasons of speed and convenience. Some advisory centers process 40,000 samples each year. The principal requirements of the different systems of analysis, with their advantages and disadvantages, are discussed below.

Suspensions

With any of the suspension methods, it is first necessary to decide whether the substrate is to be air-dried, ground, and then sieved before sampling, or whether it is to be extracted in the fresh state.

Drying. Drying can result in the separation of ingredients of different densities, e.g., peat and sand, thereby causing sampling errors (3). Drying reduces the amounts of NO_3-N, P, K, Ca, and Mg that are extracted (13) and also may increase the amount of NH_4-N. Organic materials such as peat and bark are difficult to re-wet after drying, and this difficulty may introduce errors in the analysis. When pine bark is air-dried, large amounts of the added NO_3-N become trapped in the small capillary pores in the bark and then are difficult to extract (15). Even when the air-dry sample was first placed under vacuum for 24 hr and then shaken for 30 min, less than 40% of the applied NO_3-N was recovered.

Grinding. Grinding changes the structure of the medium and increases its bulk density. It can also create problems of interpretation when slow-release fertilizers are used; some of these fertilizers (e.g., Nutricote and Ficote) are more difficult to grind than others (e.g., Osmocote). Mixes containing polystyrene flakes or mineral wool also are very difficult to grind.

Sampling. Media can be sampled by weight or by volume. The accuracy of weighing a sample exceeds that of a volume measurement, but other considerations show the ultimate accuracy, reproducibility, and interpretation of an analysis based on volume sampling of media is greater than sampling by weight with mixes of low- and variable-bulk densities (3, 6, 9). Traditional soil-based potting mixes have a bulk density of about one g per ml: the bulk density

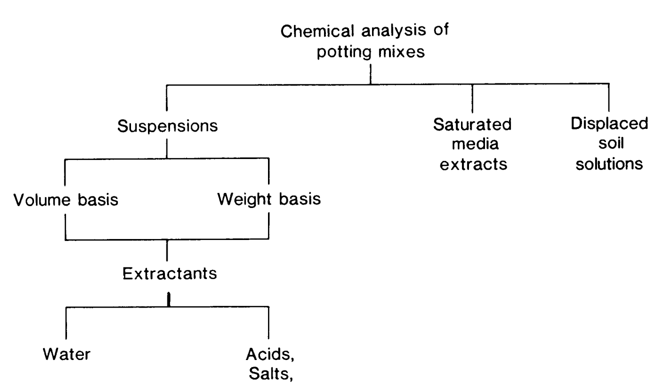

Fig. 1. Classification of methods used to analyze potting mixes.