Technology & Product Reports

Development of the Press Extraction Method for Plug Substrate Analysis: Effects of Variable Extraction Force on pH, Electrical Conductivity, and Nutrient Analysis

Holly L. Scoggins,[1]
Paul V. Nelson,[2] and
Douglas A. Bailey[2]

ADDITIONAL INDEX WORDS. soilless media, soil testing, plug nutrition, root medium

SUMMARY. Substrate solution testing is an essential management tool for greenhouse plug production. Current methods of plug solution extraction and testing can be confounded by subjective aspects of their techniques. The press extraction method (PEM) developed at North Carolina State University offers a convenient and timely method of solution extraction. The rooting substrate is brought to container capacity and after a period of one hour, pressing the plug surface with a finger or thumb is sufficient to expel the solution. This series of experiments serves to quantify possible variation that may occur in pH, Electrical conductivity (EC), and nutrient analysis from differing manual extraction forces. A modified press was designed to apply a range of force [53, 71, 89, 106, and 124 N (5.0, 6.7, 8.3, 10.0, and 11.6 lb/inch^2)], and sampling protocol consistency was verified. For all three experiments, the range of extraction forces within a single fertilizer rate did not significantly affect solution pH or EC. When testing included a range of fertilizer rates, results were significantly different among the fertilizer rates, demonstrating the method's ability to detect changes in pH and EC resulting from increases in fertility levels. Nutrient analysis (NO_3^-, NH_4^+, P, K, Ca, Mg, Na, B, Cu, Fe, Mn, and Zn) of solution extracted from two different rooting substrates (peat-based and coir-based) showed no differences within substrates for the range of force treatments.

Department of Horticultural Science, Box 7609, North Carolina State University, Raleigh, NC 27695-7609.

The research reported herein was funded in part by the Fred C. Gloeckner Foundation, Inc., and the North Carolina Commercial Flower Growers' Association. Mention of products does not imply endorsement of this product over similar products by North Carolina State Univ. The authors gratefully acknowledge the technical assistance of Ingram McCall. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Graduate assistant; Virginia Tech, Dept. of Horticulture, 301 Saunders Hall, Blacksburg, VA 24061.

[2]Professor.

Plug production is a rapidly growing and significant sector of the floriculture industry (Styer and Koranski, 1997). On-site testing is crucial for successful plug production (Bailey et al., 1995). The relatively small volume of substrate results in a smaller nutrient reservoir, or conversely, a reduced buffering capacity. Due to this small margin of error, the recommendations are to test substrate pH and soluble salts or electrical conductivity (EC) frequently (Fonteno et al., 1995). Nearly 80% of nutritional problems are due to fluctuations in substrate pH and soluble salts levels that should be monitored on a regular basis (Styer, 1996). However, the rapid production cycle for most plugs of 3 to 5 weeks (from seed to transplant) negates the usefulness of analysis if a lengthy turnaround is involved, as is often the case with analytical laboratories. Thus, there is a need to develop a dependable, yet quick, method of substrate solution extraction (Bunt, 1986) that can be implemented on a regular basis by plug growers.

Analysis of the true, displaced solution best assesses the nutrient status of the growth substrate (Bunt, 1986). The press extraction method (PEM) is a variation of the "squeeze" method introduced by Fonteno et al. (1995). The substrate is brought to container capacity and not further diluted. Pressing the top of the plug and collecting the expelled solution provides an extract that closely resembles the root zone solution. Solution pH and EC can be determined within minutes, and the extracted solution can be sent on to an analytical laboratory for nutrient testing.

The objective of these experiments was to quantify how extraction force may affect solution chemical properties. We investigated the effect of extraction force on solution pH and EC initially with one fertilizer concentration, then over a range of concentrations. We also examined the effect of variable force on the nutrient analysis of coir, an alternative substrate component.

Materials and methods

COMMON TO ALL EXPERIMENTS. Though pressure from a finger or thumb is all that is required to extract the solution, an apparatus was created to apply and quantify the variations in force used to extract the solution from the substrate. Modified manual drill presses (penetrometers or firmness testers) have been used to measure force exerted on the skin of fruit in postharvest experiments (Reid, 1992). For our purposes, a drill press was modified to hold a 150-cm^3 (9.15-inch^3) volume of substrate in a Plexiglas cylinder while a plate 4.45 cm (1.75

inch) in diameter compressed the sample of substrate as force was applied. The expelled solution was collected at the base. Treatments were fixed at 53, 71, 89, 106, and 124 N (5.0, 6.7, 8.3, 10.0, and 11.6 lb/inch^2). This range was determined by measuring the volume of solution that could be expelled manually (by squeezing or pressing) from the same volume of substrate. These volumes were then correlated to the amounts expelled by the apparatus at these forces.

Plug flats [288 cells, cell volume 6 cm^3 (1.22 inch^3)] were filled with screened substrate consisting of 3 peat : 1 perlite (by volume) (unless otherwise specified), amended with dolomitic lime at a rate of 6 g·L^{-1} (10.1 lb/yd^3) and placed on a greenhouse bench. Fertilizer was added via subirrigation. Testing was done 1 h after an irrigation event as recommended by Compton and Nelson (1997). This timing allows for nutrient equilibrium within the substrate to produce an adequate amount of solution for analysis. Data were subjected to analysis of variance using the general linear model (SAS Institute, Cary, N.C.). When model analysis showed a significant force (treatment) or fertilizer rate effect, means were subjected to trend analysis.

EFFECT OF EXTRACTION FORCE ON PH AND EC (EXPT. 1). Three plug flats were filled with substrate, placed in trays, subirrigated with 20N–4.3P–16.6K (Peter's Peat Lite Special; Scotts, Marysville, Ohio) at 75 mg·L^{-1} (ppm) of N, and allowed to equilibrate for 24 h. Flats were subirrigated with water to obtain container capacity 1 h before testing, then removed from trays to allow drainage of excess moisture. The contents of the flats were removed and gently combined to help insure uniformity of the samples. Each sample weighed 35 g (1.23 oz) (±5%), predetermined as the sample size necessary to produce at least 20 mL (0.67 fl oz) of expelled solution.

Measurements included pH and EC of the extracted solution (Twin pH meter B-213 and conductivity meter B-173, Horiba, Inc., Kyoto, Japan). To verify consistency of our samples and cylinder packing technique, substrate sample wet weight (WW) and dry weight (DW) were measured to calculate percentage recovery of moisture ([WW–DW] ÷ WW) × 100) (Fonteno, 1996). Samples were weighed at the time of testing (filling the press cylinder) and again after drying at 105 °F (41 °C) for 24 h. The five treatments were replicated eight times for a total of 40 experimental units.

EFFECT OF EXTRACTION FORCE ON PH AND EC AT THREE N RATES (EXPT. 2). The same methods were used as established in the previous experiment but the plug flats were subirrigated with 20N–4.3P–16.6K at 75, 125, and 175 mg·L^{-1} of N (three flats per rate) and allowed to equilibrate for 24 h. Flats were subirrigated with water one h before testing. Contents of the three flats for each rate were carefully combined to reduce sample variability. The five treatments—53, 71, 89, 106, and 124 N of force—were replicated six times for each of the three fertilizer rates for a total of 90 experimental units. The pH and EC of the extracted solution were measured.

EFFECT OF EXTRACTION FORCE ON NUTRIENT ANALYSIS OF PEAT SUBSTRATE (EXPT. 3). The same methods were used as in the prior experiments but extracted solution was also analyzed for NH_4^+, NO_3^- (LACHAT QuickChem, Milwaukee, Wis.), P, K, Ca, Mg, B, Cu, Fe, Mn, Na, and Zn (Jarrell Ash ICAP 9000, Franklin, Mass.) content. Flats were filled with a commercial soilless germination mix (2-P; Fafard, Anderson, S.C.) and subirrigated twice (within 48 h) with 20N–4.3P–16.6K at 125 mg·L^{-1} of N to insure measurable levels of nutrients. Flats were allowed to equilibrate for 24 h and then were subirrigated with water 1 h prior to extraction. The contents were combined to reduce sample variability. The five treatments (force) were replicated five times for a total of 25 experimental units for the peat-based germination mix.

EFFECT OF EXTRACTION FORCE ON NUTRIENT ANALYSIS OF COIR SUBSTRATE (EXPT. 4). The substrate tested was 3 coir : 1 perlite (by volume) (screened coconut husk fiber; Crystal Co., St. Louis, Mo.). Again, flats were subirrigated twice (within 48 h) with 20N–4.3P–16.6K at 125 mg·L^{-1} of N. The procedures used were the same as in the previous experiment, with one exception. The lowest force treatment of 53 N was not used on the coir (insufficient amount of solution for testing was extracted), leaving four treatments with five replications each for a total of 20 experimental units. After pH and EC were measured, the extracted solution was analyzed for NH_4^+, NO_3^-, P, K, Ca, Mg, B, Cu, Fe, Mn, Na, and Zn content.

Results and discussion

EFFECT OF EXTRACTION FORCE ON PH AND EC (EXPTS. 1 AND 2). For plug flats subirrigated with 75 mg·L^{-1} of N, the pH, 5.4 ± 0.06 (mean ± SD), and EC, 0.65 ± 0.04 dS·m^{-1} (mmho·cm^{-1}), of the substrate solution were unaffected by differing extraction forces. After extraction, the remaining percent moisture content (87.1 ± 0.5%), of the substrate samples was not significantly different, verifying consistency in our sampling techniques.

The pH and EC of solution extracted from substrate treated with three N rates was not affected by the range of extraction forces within each fertilizer rate, therefore, data were pooled within N rates. The pH and EC were significantly different among the fertilizer rates as presented in Table 1. These data help demonstrate the method's ability to detect changes in pH and EC resulting from increases of at least 50 mg·L^{-1} of N in fertility levels.

EFFECT OF EXTRACTION FORCE ON NUTRIENT ANALYSIS (EXPTS. 3 AND 4). Within each substrate (peat or coir), levels of nutrients did not differ among the extraction forces. Consistent with the previous experiments, solution pH and EC were unaffected by extraction force for either peat or coir substrates. Therefore, data were pooled within each substrate. EC levels were relatively high (with associated lower pH levels) due to two applications of the fertilizer without leaching. Though not an initial objective, comparisons of

Table 1. Electrical conductivity (EC) and pH of extracted solution. Extraction force treatments were not significant (data pooled within fertilizer rates) (Expt. 2).

Fertilizer rate (mg·L^{-1} of N)^z	pH	EC (dS·m^{-1})^y
75	5.97 ± 0.1^x	0.93 ± 0.2
125	5.77 ± 0.1	1.84 ± 0.1
175	5.63 ± 0.1	1.98 ± 0.2
Significance	L**	Q**
r^2	0.58	0.82

^{z}1 mg·L^{-1} = 1 ppm.
^{y}1 dS·m^{-1} = 1 mmho·cm^{-1}.
^{x}Mean ± standard deviation n = 25.
**Significant at $P \leq 0.01$; L = linear, Q = quadratic.

Table 2. Analysis of solution extracted from different substrates. Force treatments were not significant, data are pooled means (Expts. 3 and 4).

	Substrate base	
Variable	Peat	Coir
pH	4.8 ± 0.05[z]	5.0 ± 0.06[y]
	$dS \cdot m^{-1}$ ($mmho \cdot cm^{-1}$)	
EC	3.2 ± 0.2	3.2 ± 0.1
	$mg \cdot L^{-1}$ (ppm)	
NO_3^-	295 ± 26.4	234 ± 7.3
NH_4^+	69.5 ± 5.0	31.0 ± 2.2
P	39.2 ± 5.3	40.3 ± 1.2
K	303 ± 39.5	644 ± 19.5
Ca	165 ± 25.2	26.3 ± 2.8
Mg	125 ± 17.2	21.7 ± 1.2
Na	47.6 ± 5.4	195 ± 6.2
Fe	2.3 ± 0.3	0.7 ± 0.02
Mn	1.1 ± 0.2	0.5 ± 0.03
Cu	0.06 ± 0.02	0.2 ± 0.02
Zn	0.3 ± 0.05	0.3 ± 0.01
B	0.2 ± 0.02	0.4 ± 0.01

[z]Mean ± standard error for peat-based substrate, n = 25.
[y]Mean ± standard error for coir-based substrate, n = 20.

the nutrient analysis between the peat-based and coir substrates revealed differences that may be inherent in the nutrient holding and exchange capacities as well as product source (Table 2). Elevated levels of K and Na are common due to the source of coir (W.C. Fonteno, personal communication). Other analyses of coir versus peat substrates have yielded significant differences in pH (Handreck, 1993), EC, and nutrient content (Evans et al., 1996; Evans and Iles, 1997; Meerow, 1994). Determination of substrate chemical properties is advised and amendments and fertilizer regimes should be adjusted accordingly.

There are other methods of substrate analysis suitable for production floriculture. However, there has been little documentation of these methods (or accompanying standards) for their use in plug production. These methods include suspension analysis of various water to substrate ratios (e.g., 2:1, 6:1) (v/v), and the saturated media extract method (SME). For both methods, the substrate is removed from the container and water is added, resulting in significant and variable dilution that has to be considered when comparing to standards for pH and EC (Wright, 1986). In the case of the suspension analysis technique, the substrate packing density is subjective, while in the SME procedure, the amount of water added during extraction is subjective. The suspension analysis technique has an additional disadvantage in that the diluted extract can only be used for measuring pH and EC—the degree of dilution can reduce micronutrients to undetectable levels, hence labs in the United States have not developed standards for interpreting this method. The lack of significant dilution and uniformity in results regardless of extraction force dispels two potential sources of subjectivity for the PEM.

Another method of extraction is the pour-through or Virginia Tech Extraction Method (VTEM) wherein a known volume of water is added to the substrate surface and the displaced solution is collected at the base (Wright, 1986). The pour-through method has become the method of choice for the container nursery industry and shows potential for floriculture pot crops, but the nature of plug flats limits its suitability for plug production. The short substrate column limits the gravitational flow which is necessary to displace the root-zone solution (Fonteno, 1996). This results in a perched water table that does not drain rapidly enough for easy on-site solution collection.

The PEM is appealing since it is extremely easy, may be used at any stage of plug growth, and requires no special equipment (Fonteno et al., 1995). We have demonstrated that variability in extraction force did not affect the solution chemical analysis for either peat-based or coir soilless substrates. This method is especially suited for on-site testing of root-zone solution pH and EC. The use of specific ion meters for on-site nutrient testing could also be of value to growers. Portable specific ion electrodes have been developed for NO_3^- and K^+ testing, though little work has been done to assess accuracy of these instruments (Rosen et al., 1996). This study provides a foundation for further development of this simple, alternative, on-site technique for grower monitoring of the root-zone status of plug crops.

Literature cited

Bailey, D.A., P.V. Nelson, W.C. Fonteno, J.W. Lee, and J.S. Huang. 1995. Plug pH—The make or break factor in nutrition. GrowerTalks 59(9):6–13.

Bunt, A.C. 1986. Problems in the analysis of organic and lightweight potting substrates. HortScience 21:229–331.

Compton, A.J. and P.V. Nelson. 1997. Timing is crucial for plug seedling substrate testing. HortTechnology 7:63–68.

Evans, M.R. and J.K. Iles. 1997. Growth of *Viburnum dentatum* and *Syringa ×prestoniae* 'Donald Wyman' in Sphagnum peat and coir dust-based substrates. J. Environ. Hort. 15:156–159.

Evans, M.R., S. Knoduru, and R.H. Stamps. 1996. Source variation in physical and chemical properties of coconut coir dust. HortScience 31:965–967.

Fonteno, W.C., D.A. Bailey, and P.V. Nelson. 1995. Squeeze your plugs for simple, accurate nutrient monitoring. GrowerTalks 59(9):22–27.

Fonteno, W.C. 1996. Growing media: Types and physical / chemical properties, p. 93–122. In: D.W. Reed (ed.). Water, media, and nutrition for greenhouse crops. Ball, Batavia, Ill.

Handreck, K.A. 1993. Properties of coir dust, and its use in the formulation of soilless potting media. Commun. Soil Sci. Plant Anal. 24:349–363.

Meerow, A.W. 1994. Growth of two subtropical ornamentals using coir (coconut mesocarp pith) as a peat substitute. HortScience 29:1484–1486.

Reid, M.S. 1992. Maturation and maturity indices, p. 21–28. In: A.A. Kader (ed.). Postharvest technology of horticultural crops. 2nd ed. Univ. of Calif. (Oakland) Div. Agr. and Nat. Resources Publ. 3311.

Rosen, C.J., M. Errebhi, and W. Wang. 1996. Testing petiole sap for nitrate and potassium: A comparison of several analytical procedures. HortScience 31:1173–1176.

Styer, R.C. 1996. Key factors of water media and nutrition [for plug production]. GrowerTalks 60(9):22–30.

Styer, R.C. and D.S. Koranski. 1997. Plug and transplant production: A grower's guide. Ball , Batavia, Ill.

Wright, R.D. 1986. The pour-through nutrient extraction procedure. HortScience 21:227–229.