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PourThru: A Method for Monitoring Nutrition in the Greenhouse

T.J. Cavins
Horticulture and Landscape Architecture
Oklahoma State University
Stillwater, OK
USA

B.E. Whipker and W.C. Fonteno
Horticultural Science
North Carolina State University
Raleigh, NC
USA

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Abstract

The purpose of this research was to adapt the PourThru nutrient extraction technique, which is a displacement of the bulk solution from the production container without a destructive harvest, to commercial greenhouse production. PourThru is a quick and easy nutrient sampling technique that is done in the greenhouse and can help prevent nutritional problems for growers. Previous PourThru research had focused on techniques for use on large outdoor nursery containers (~3800 cm^3), while this work focused on effects in smaller (~1700 cm^3) containers. Studies were conducted on the relationship of PourThru values to saturated media extract (SME), the variation caused by different irrigation systems, timing effects on PourThru results, as well as the development of recommended influent and leachate volumes to ensure an unadulterated sample. Calibration curves were developed between PourThru and SME values and r^2 values ranged from 0.91 to 0.99 for pH, electrical conductivity (EC), and nutrients. The type of irrigation systems did affect EC values and alternative standard values were developed for irrigation system. Timing of the PourThru was important to ensure adequate leachate was collected for sample analysis. The amount of influent affected EC values and the amount of leachate collected.

INTRODUCTION

PourThru is a bulk solution displacement method that is increasing in popularity (Cavins et al., 2000a,b; Cavins et al., 2001; Whipker et al., 2000). This simple substrate solution extract can be easily performed in the greenhouse and/or sent to commercial or university laboratories for complete nutritional analysis. PourThru substrate solution extraction can be performed in the growing container without special equipment or the need to transport substrate samples to a laboratory. The ability of horticultural producers, consultants, and researchers to save valuable time for nutrient analysis can vastly influence the profitability of a crop. On-site analysis allows fertility regime adjustments in a timely manner.

A major limitation in the use of PourThru monitoring is the lack of recommended floriculture nutrition values based on PourThru extractions. Yeager et al. (1983) compared PourThru and SME values, but results were based on 100% pinebark substrate. Most commercial floriculture substrates are peatmoss-based, which may significantly alter the values. Albeit, Wright (1986) observed no differences between peat:perlite (50:50 v/v) and 100% pinebark when compared without plants in the substrates. Plants growing in the substrate would affect nutrient concentration in the bulk solution (Compton and Nelson, 1997).

The objectives of this research were: 1) to determine the relationship between SME and PourThru extract on NO_3, NH_4, P, K, Ca, and Mg values in the leachate and develop interpretive PourThru standard values based upon the relationship, 2) to determine the effects of water content and time of PourThru extraction on pH and EC values and optimize PourThru protocol to ensure a representative sample, and 3) to determine the effects of over-head-hand-, drip tube-, and sub–irrigation on PourThru pH and EC values and leachate volume.

MATERIALS AND METHODS

PourThru Method

The PourThru (adapted from Wright, 1986) is performed as follows:

1. Irrigate the Crop One Hour before Testing. Make sure the substrate is satiated. If using constant liquid feed, irrigate with fertilizer solution as usual. If using periodic feeding: (A) irrigate with clear water and test a day or two before fertilizing and (B) test on the same day in the fertilizing cycle each time.

2. Place Saucer under Container. After the container has drained for 30 to 60 minutes, place saucers under the containers to be sampled. If you are testing seedlings in bedding plant flats, place one cell pack in each saucer.

3. Pour Enough Distilled Water on the Surface of the Substrate to Get 50 ml of Leachate in the Saucer (10 cm and Smaller Containers Only Require Approximately 30 ml). The amount of water needed will vary with container size, crop, irrigation system, and environmental conditions.

4. Collect and Test the Leachate for pH and EC. Allow the containers to drain for 5 minutes to obtain 50 ml of leachate. Leachate volumes over 70 ml (based on 15.2 cm pot extractions) will begin to dilute the sample and give non-representative EC values.

Comparison of PourThru and SME

Euphorbia pulcherrima 'Freedom Red' Willd. ex Klotzch. rooted cuttings were transplanted on 15 August 2000 into 16.5 cm (1700 $cm^{3)}$ plastic pots with Fafard 4P, a commercial peat and pine bark-based substrate (Conrad Fafard Inc., Anderson, S.C.) and fertigated with 200, 300, or 400 $mg·L^{-1}$ N from a 13N-0.88P-10.8K Cal – Mag fertilizer (The Scotts Co., Marysville, Ohio). Polyethylene covered greenhouses were set at 21/16°C, day/night and the plants were grown under natural days. Substrate samples were collected at 6 and 9 weeks after transplanting rooted cuttings. PourThru extractions were made 1 hour after irrigation using 75 ml of distilled water to displace approximately 50 ml of leachate (Cavins et al., 2000a; modified, Wright, 1986). PourThru samples were tested for pH and EC immediately following extraction. Substrate samples were selected at the same time for SME (modified, Warncke, 1998). Approximately 350 cm^3 of substrate from the middle of the container was saturated with distilled water until "glistening", then allowed to equilibrate for 30 minutes. pH was measured in the slurry. After pH values were obtained, the samples were vacuum filtered through a Buchner funnel using Whatman 40 filter paper and pH and EC were measured in the vacuumed extract. All extractions were preserved by refrigeration (5°C) and the addition of 0.05 ml phenolmercuric acetate saturated solution until the completion of the study. Samples were then analyzed for NO_3^-, NH_4^+, and P photometrically (Cataldo et al., 1975; Chaney and Marbach, 1962; Murphy and Riley, 1962) and for K^+, Ca^{2+}, and Mg^{2+} using atomic absorption spectrophotometry (Christian and Feldman, 1970). There were five replications per treatment. Analysis of variance was obtained using procedure general linear models (α = 0.01); nutritional values were regressed and calibration equations developed using PROC REG (SAS Institute, Cary, N.C.). The experiment was repeated in 2001.

Timing and Leachate Volume

Helianthus annuus L. 'Teddy Bear' seed was sown 15 April 2002 and transplanted on 29 April 2002 into 16.5 (1700 cm^3) or 19.1 cm (2650 cm^3) containers with Fafard 4P (Conrad Fafard Inc., Anderson, S.C.) or Scotts Metro Mix 320 high lime with coir (The Scotts Co., Marysville, Ohio). Glass covered greenhouses were set at 18/24°C, night/day, respectively and plants were fertigated with a 150 $mg·L^{-1}$ N from a 20N-4.4P-16.6K fertilizer (The Scotts Co., Marysville, Ohio). PourThru extractions using 100 ml for the 16.5 cm containers or 125 ml for the 19.1 cm containers of distilled water were performed 15, 30, 60, 120 and 240 minutes after irrigation. Extractions were done at 4, 5 and 6 weeks after transplanting of seedling.

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Extractions were analyzed for pH, EC, and volume. Data collected also included mass wetness (g of water/g dry substrate) of the substrate [(whole container wet weight – shoot fresh weight – substrate dry weight – container weight)/substrate dry weight]. There were five replications per treatment. Data was analyzed by general linear models and means separation was performed using a protected LSD ($P \geq 0.05$) (SAS Institute, Cary, N.C.).

Irrigation System Effects

Geraniums (*Pelargonium* x*hortorum* L.H. Bail.) 'Rocky Mountain Salmon' were grown in 15.4 cm plastic containers using Fafard 4P root substrate (Conrad Fafard Inc., Anderson, S.C.). All containers were placed in hydroponic troughs (Bato Trading B.V., The Netherlands) with drainage holes and plugs for leachate collection to determine leaching fraction and fertigated by hand (333 ml/pot by watering can with breaker), drip tube (350 ml/pot with pressure compensated emitters rated at 95 ml s^{-1}), or sub-irrigation (troughs were filled with fertigation solution to approximately 2.5 cm up the pot side, allowed to equilibrate for 12 minutes and drained) methods with 200 $mg \cdot L^{-1}$ (ppm) N from 13N-0.88P-10.8K (13–2–13) fertilizer (The Scotts Co., Marysville, Ohio). Plants were irrigated when three randomly selected plants from each irrigation treatment averaged 40% of the available water content (Morvant et al., 1997). PourThru extractions were performed at 2, 4, 6 and 8 weeks after planting of rooted cuttings in order to determine pH and EC. There were six replications with six subsamples per treatment. Data were analyzed using procedure general linear models and protected interactive LSD (SAS Institute, Cary, N.C.).

RESULTS AND DISCUSSION

Comparison of PourThru and SME

The substrate pH did not differ between years or extraction procedures (data not presented). The lack of differences between years indicates that PourThru and SME are reliable, consistent methods for obtaining substrate pH. Surprisingly, no differences occurred among extraction procedures (PourThru, SME slurry, and SME vacuum extract) for pH. Yeager et al. (1983) noted that pH values for PourThru and SME were similar.

Because there were no differences in our study, pH calibration curves were not developed. Calibration curves were established for EC, NO_3, P, K, Ca and Mg (Table 1). Because of the fertilizer used, only minute amounts of ammonium were detected. These values were not affected by the variables in this study (data not shown).

Differences between years were noted with P and Ca, which were attributed to the initial "starter" charge difference in the commercial substrate. The commercial substrates contain an initial nutrient charge to counteract substrate acidity and aid in plant nutrition. The exact contents of these starter charges are proprietary and are frequently adjusted to compensate for differences observed in the substrate chemical properties.

In agreement with Yeager et al. (1983) and Wright et al. (1990), a relationship exists between PourThru and SME values. In our study, PourThru nutrient values (excluding pH and NH_4) were approximately 1.4 to 1.6 times higher than SME values, except for Ca (year one) whose relationship was approximately 1.2 times higher. This was similar to Yeager et al. (1983) who reported PourThru values approximately 1.3, 1.4 and 1.2 times higher than SME values for N, P and K, respectively; albeit, calibration curves were not developed to describe the relationship in their study. Yeager also noted that pH values were similar, which agrees with our findings.

However, we did not find a similar relationship of PourThru and SME values as described by Wright et al. (1990) who noted that PourThru values were nearly double that of SME values. These differences are likely due to variances in testing procedures (water content of the SME) that may have altered nutrient values.

Based on the calibration curves developed in our study and recommended SME values (Warncke and Krauskopf, 1983), recommended-PourThru nutrient values for greenhouse substrates have been developed (Table 2). The calibration curves in Table 1 will allow substrate-testing laboratories to convert PourThru values to SME values and compare those values to established standard values.

Timing Effects on pH, Electrical Conductivity and Leachate Volume

Timing of the PourThru did not affect pH (data not shown). This was likely due to the high volume of substrate, which enhanced the buffering capacity of the system and prevented plant nutrient uptake from altering the soil solution within 240 minutes of irrigation. Therefore, timing was not the dominant factor affecting substrate pH. Conversely, Compton and Nelson (1997) noted that EC and various nutrients decrease rapidly within 4 h of irrigation. However, their results were based upon smaller substrate volumes (6.5 cm^3/plant) than ours (1700 or 2650 cm^3).

The EC was affected by substrate such that Fafard 4P had lower EC values than MM320 (1.43 and 3.27 mS/cm, respectively; $LSD_{0.05}$ = 0.13). MM320 contained coir fiber as a component. Handreck (1993) noted that coir fiber yields higher EC values than conventional peatmoss substrates. MM320 also did not drain as readily as Fafard 4P, which was indicated by its higher container capacity [75 versus 70% (v/v), respectively], that led to more salt accumulation in the substrate. Container size, extraction date, or timing of PourThru did not affect EC (data not shown). Similar to pH, timing of the PourThru likely did not affect EC due to the large substrate volume.

Timing of the PourThru affected leachate volumes (LSD = 7.55) (Fig. 1). No differences were observed between the 15, 30 and 60-minute interval extractions (55.5, 58.3 and 54.7 ml, respectively); however, leachate volumes decreased when 120 (36.0 ml) or 240 (18.7 ml) minutes elapsed between irrigation and sampling. This indicates that samples should be collected 60 minutes after irrigation to ensure a sufficient volume of leachate extraction (Wright, 1986) and representative sample.

Timing of PourThru affected the substrate mass wetness and leachate volume such that the leachate volume decreased when 120 or 240 minutes elapsed from irrigation to sampling (Fig. 1). A correlation mass wetness and volume of leachate did occur indicating that moisture content of the substrate is important (r^2 = 0.70). However, timing did not affect pH or EC. This was likely due to overriding factors such as substrate components and container volume. In contrast, Compton and Nelson (1997) noted EC and nutrients concentrations change within 240 minutes of irrigation in small substrate volume containers.

Based upon the fluctuations in leachate volumes and mass wetness values, we recommend 60 minutes elapse from time of irrigation to PourThru sampling. Sixty-minutes is sufficient time to allow for nutrient equilibration so the greenhouse crop producers can obtain a representative sample of the plant available nutrient status, yet maintain sufficient moisture status to prevent EC shifts due to moisture content variation leachate volumes from becoming too low (Compton and Nelson, 1997; Dole and Wilkins, 1999).

Irrigation System Effects

The pH values for hand irrigated (HI) plants were generally lower than drip irrigated (DI) and sub-irrigated (SI) in corresponding weeks except for SI during week eight, when pH values were similar to HI values (Fig. 2A). Morvant et al. (1997) found similar results such that HI produced lower pH values than SI when comparing only the lower portion of the substrate. Due to the nature of displacement, PourThru only samples nutrient solution from the lowest portion of the container (Bilderback and Fonteno, 1987; Handreck, 1994; Wright, 1986). The lower pH is likely a result of higher water content of HI plants (577.8 g, average weight of container, substrate, plant and water prior to irrigation) versus the DI and SI plants (552.9 and 529.9 g, respectively). A moist substrate condition can promote an increase in N reduction (mineralization) and organic acid release from the substrate, which may account for the lower pH values with HI plants (Morvant et al., 1997; Sparks, 1995).

The pH values were highest for DI during week eight and a pH increase was observed with all irrigation treatments during weeks four to six (Fig. 2A). The higher pH values observed at the end of the crop are a result of the basic residues of the 13N-0.88P-10.8K fertilizer, which has a potential basicity of 155 kg/907 kg calcium carbonate (342 lb/ton).

Hand irrigation produced the highest EC values and the values increased from week two to four and then from six to eight (Fig. 2B). Electrical conductivity values were higher for HI. This may be due to the downward movement of solutes within the substrate from the bulkhead of water formed when overhead-hand irrigating (Argo and Biernbaum, 1995; Morvant et al., 1997). It may also be due to the lower leaching fraction (9.9%) compared to DI (20.5%). A majority of the substrate solution resides in the lower 1/3 of the container (Bilderback and Fonteno, 1987); therefore, the higher EC values may be reflected in the displaced PourThru sample from HI plants.

Values obtained from HI plants were within the EC range (2.0 to 3.5 mS/cm) for geraniums recommended by Whipker (2000). Hand irrigation, DI, and SI had similar heights (12.35, 15.72 and 15.22 cm, respectively), diameters (22.6, 24.8 and 28.27 cm, respectively) and shoot dry weights (22.6, 24.8 and 24.2 g, respectively) (values collected at termination of study, week 8). These similarities indicate that all three irrigation methods provided adequate nutrition despite variation in EC values.

Drip tube and SI treatments had similar trends such that EC decreased from weeks two to six and then increased form week six to eight (Fig. 2B). The depletion of nutrients from plants in the rapid vegetative state of growth led to the initial decline in EC values (Whipker and Hammer, 1997). The evaporation of water from the surface of DI and SI containers would be higher compared to the HI containers (which were sufficiently rewetted with every irrigation). Albeit adequate nutrients were supplied, this could cause increased stratification of solutes (Argo and Biernbaum, 1995; Morvant et al., 1997) which could result in lower EC values in the lower 1/3 of the containers where PourThru displacement occurs.

The observed EC increase from week six to eight was probably due to salt accumulation (Fig. 2B). Over time, the solute build up in the top of the container presumably migrated downward. Therefore, the high EC values were detected in the PourThru leachate as it was obtained from the lower 1/3 of the container. The EC values obtained for DI and SI were below the recommended values (2.0 to 3.5 mS/cm) noted by Whipker (2000) for actively growing geraniums.

Even with different PourThru EC values, plant heights, diameters and dry weights were similar for all three irrigation treatments. Consequently, alternative EC recommendations were developed for DI and SI systems (Table 3).

PourThru leachate volumes were generally greatest for HI containers, except during week six (Fig. 2C). The higher leachate volumes were due to more uniform moisture contents for the HI containers versus the DI and SI containers (Argo and Biernbaum, 1995; Morvant et al., 1997). In our study, HI containers generally had higher moisture volumes (577.8 g, weight of container, substrate, plant, and water) prior to irrigation versus DI or SI irrigated plants (552.9 and 529.9 g, respectively).

Sub-irrigated containers appeared to be the most consistent for leachate volumes. A decrease in PourThru leachate volume was observed between weeks two and four; however, weeks four, six, and eight were similar. This indicates that SI was the most uniform irrigation treatment in our study.

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Tables

Table 1. Inverse ca
extraction value
represented as de

Parameter
EC
NO_3
P[1]
P[2]
K
Ca[1]
Ca[2]
Mg

[1] Equation is based upon
[2] Equation is based upon

Table 2. Recommen
values.

Parameter
pH[2]
EC (mS/cm)
NO_3 ($mg·L^{-1}$)
P[3] ($mg·L^{-1}$)
K ($mg·L^{-1}$)
Ca[3] ($mg·L^{-1}$)
Mg ($mg·L^{-1}$)

[1] Values adapted from Wa
[2] pH values are equivalen
[3] Values based upon year

Table 3. PourThru el
irrigation systems

Irrigation / extraction
Overhead / hand[1]
Drip tube or subirriga
SME[1]
1:2VS[3]

[1] Whipker, 2000.
[2] Overhead / hand or subi
[3] Dole and Wilkins, 1999.

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Tables

Table 1. Inverse calibration equations for PourThru and SME comparisons. PourThru extraction values are represented as independent variable (x) and SME values are represented as dependent variable (y).

Parameter	Equations	Adjusted r^2
EC	$y = 0.74x - 0.05$	0.98
NO_3	$y = 0.71x - 25.13$	0.98
P[1]	$y = 0.69x - 1.74$	0.97
P[2]	$y = 0.63x - 23.39$	0.99
K	$y = 0.70x - 4.66$	0.99
Ca[1]	$y = 0.84x - 73.43$	0.94
Ca[2]	$y = 0.63x + 1.55$	0.97
Mg	$y = 0.59x + 12.17$	0.91

[1] Equation is based upon values obtained in year one.
[2] Equation is based upon values obtained in year two.

Table 2. Recommended PourThru substrate values transformed from SME[1] substrate values.

Parameter	PourThru	SME
pH[2]	5.6 – 6.0	5.6 – 6.0
EC (mS/cm)	2.8 – 4.8	2.0 – 3.5
NO_3 ($mg \cdot L^{-1}$)	180 – 320	100 – 199
P[3] ($mg \cdot L^{-1}$)	11 – 16	6 – 9
K ($mg \cdot L^{-1}$)	220 – 360	150 – 249
Ca[3] ($mg \cdot L^{-1}$)	330+	200+
Mg ($mg \cdot L^{-1}$)	100+	70+

[1] Values adapted from Warncke and Krauskopf, 1983.
[2] pH values are equivalent for both extracts.
[3] Values based upon year one data.

Table 3. PourThru electrical conductivity recommended values for geraniums based upon irrigation systems and non-irrigation specific SME and 1:2 VS values.

Irrigation / extraction system	Electrical conductivity (mS/cm)
Overhead / hand[1]	2.00 – 3.50
Drip tube or subirrigation[2]	1.00 – 1.70
SME[1]	1.50 – 3.00
1:2VS[3]	0.75 – 1.25

[1] Whipker, 2000.
[2] Overhead / hand or subirrigation EC x 0.49.
[3] Dole and Wilkins, 1999.

Figures

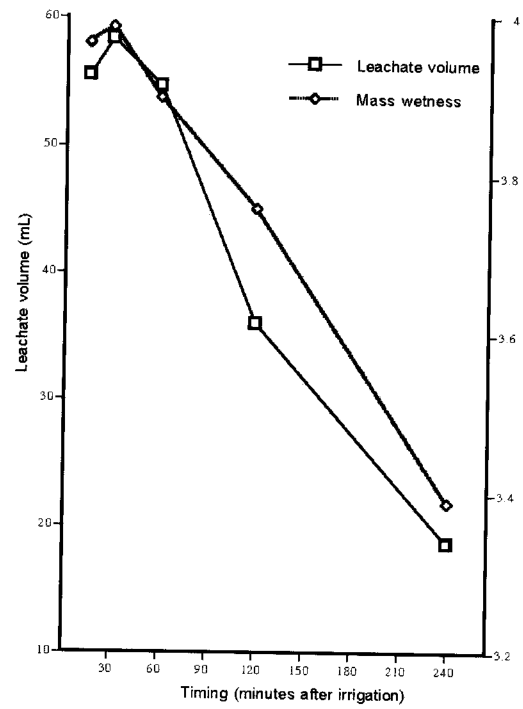

Fig. 1. PourThru timing affects leachate volume and mass wetness. Means are an average of five replications per treatment.

Fig. 2. Irrigatio
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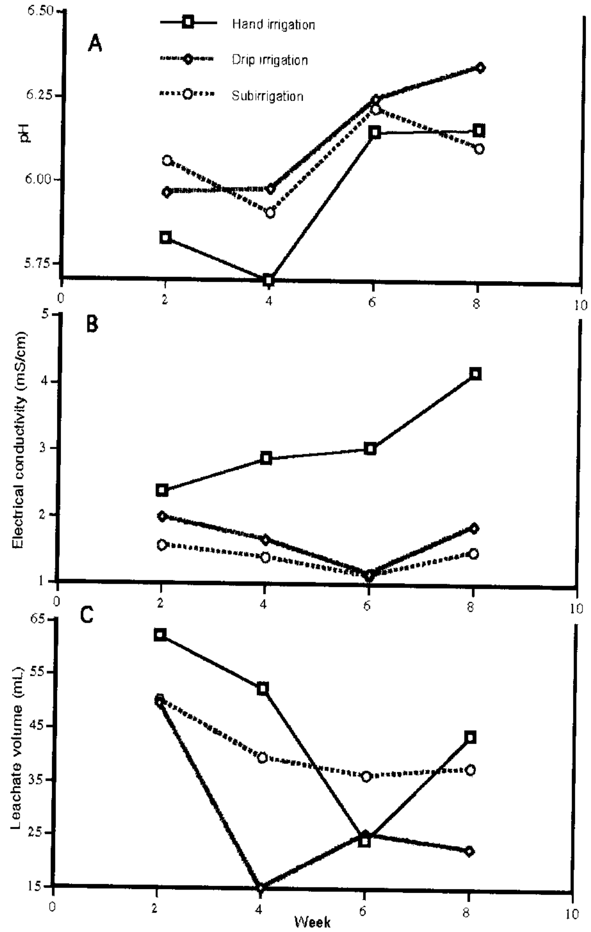

Fig. 2. Irrigation system effect on (A) pH ($LSD_{0.05}$ = 0.09), (B) EC ($LSD_{0.05}$ = 0.17), and (C) leachate volume ($LSD_{0.05}$ = 7.44). Data points represent means of six replications with six subsamples each.