REPORTS & NOTES

HortScience 19(2):216–217. 1984.

Phosphorus Leaching from ^{32}P-superphosphate-amended Soilless Container Media

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Additional index words. pine bark, moss peat, sand, media columns

Abstract. **Polyvinyl chloride columns (4 × 15 cm) containing by volume either 2 pine bark : 1 moss peat : 0 sand, 2 pine bark : 0 moss peat : 1 sand, 0 pine bark : 1 moss peat : 1 sand, or 2 pine bark : 1 moss peat : 1 sand amended with 3 kg m^{-3} of ^{32}P-superphosphate (8.7% P) were leached daily with 16 or 32 ml of deionized water (pH 5.5) in 1 hour. Irrigation rate did not affect ^{32}P leaching nor was there a media rate interaction or difference in the percentage total ^{32}P and dissolved ^{32}P leached. Medium 2:1:1 had the greatest percentage (76%) of ^{32}P leached during the 3-week experimental period, however, 55% of the ^{32}P amendment leached from each medium the 1st week.**

A common nursery practice is to amend soilless container media with superphosphate (9% P). The rationale is that P is not leached from mineral soil and, therefore, is available for plant growth throughout the growing season. However, considerable P leaching from soilless container media may occur due to porosity of the media, daily irrigation, and media components such as pine bark (15), peat (1, 13), and sand (13). Although soil and nursery media differ chemically and physically, containerized media can be viewed as structurally similar to porous sandy soils where P leaching depends on the rate of water moving through the soil and P concentration of the soil solution (7). Ozanne et al. (9) determined 17% to 81% of P applied as superphosphate (10.5% P) leached from the surface 10 cm of several loamy sand soils. Other researchers (6, 8, 11) also have determined P leaches when applied to sandy soils.

Spinks and Pritchett (12) compared columns of topsoil (Arredondo fine sand), topsoil and peat (v/v), peat, and a 1 peat : 1 shavings : 2 topsoil (v/v/v) medium and determined that P leached to a greater depth in the peat. Larsen et al. (5) similarly observed that a leached virgin muck soil retained less P than a leached mineral soil. Organic soils do not contain the quantity of Fe and Al commonly found in mineral soils (4), consequently, less P is adsorbed by organic colloids and adsorbed P in organic soils is more water soluble than adsorbed P in mineral soils (4). Decomposition products of organic matter may react also with Al or Fe and reduce P fixation (3).

Based on previous research with organic and sand soils, it is possible that P leaches from container media composed of sand and/or organic constituents. Yeager and Wright (14) determined that water-soluble P levels of a pine bark medium amended with superphosphate decreased rapidly; however, the quantity of P leached was not determined. Undissolved superphosphate particles may also leach from container media. Consequently, the effectiveness of superphosphate as a P source for container plants would be short-lived. The purpose of this study was to determine the influence of container media and irrigation regime on the leaching of P from superphosphate-amended media.

Nursery media composed by volume of 2 pine bark : 1 moss peat : 0 sand, 2 pine bark : 0 moss peat : 1 sand, 0 pine bark : 1 moss peat : 1 sand, or 2 pine bark : 1 moss peat : 1 sand with an air space and particle distribution as given in Table 1 were used for this study. Air space was determined according to procedures of Self and Pounders (10) and particle distribution by shaking 3 replicate samples on a Tyler Portable Sieve Shaker (W.S. Tyler, Inc., 8200 Tyler Blvd., Mentor, OH 44060) for 20 min. Each medium was amended with 4.2 kg m^{-3} of dolomitic limestone.

We placed 26, 125, 184, and 93 g of oven-dried 2:1:0, 2:0:1, 0:1:1, and 2:1:1, respectively, which was 170 cm^3 of each medium, in 8, replicate plastic bags and ^{32}P-superphosphate (8.7% P) was added to each bag at a rate equivalent to 3 kg m^{-3}. Superphosphate particle sizes ranged from 1.0 to 3.4 mm with a specific activity of 31 μCi g^{-1} of P. Each bag was hand-shaken for 1 min, then deionized water (22, 20, 20, and 19 g, respectively) was added and the bag was again shaken for 1 min to moisten each medium before leaching. Media were placed in polyvinyl chloride columns (4 × 15 cm) with cheesecloth secured by a rubber band around the column bottom. Six pieces of #42 filter paper were placed on top of each medium for water dispersion and a plastic cap,

Received for publication 5 Aug. 1983. Florida Agricultural Experiment Station Journal Series No. 4905. The authors thank Tennessee Valley Authority, Muscle Shoals, AL 35660 for supplying radioactive superphosphate under contracts TV-58105A, TV-58118A, and TV-58123A. We are also grateful to Dr. Hannah for assistance with scintillation counting and Robin Reddick for typing this manuscript. Trade names are mentioned with the understanding that no discrimination is intended and no endorsement by the authors or Univ. of Florida is implied. 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.

Table 1. Air space and particle distribution of 4 nursery media.

	Media			
Variable	2:1:0[z]	2:0:1	0:1:1	2:1:1
	% of volume			
Air Space	20	21	12	20
Particle size	*Distribution (% of dry wt)*			
<0.5 mm	31.8	43.2	47.9	44.6
0.5–1.4 mm	26.2	36.5	37.7	34.3
1.4–4.0 mm	38.2	18.8	12.9	18.6
4.0–6.4 mm	3.8	1.5	1.5	2.5

[z]2:1:0 = 2 pine bark : 1 moss peat : 0 sand, 2:0:1 = 2 pine bark : 0 moss peat : 1 sand, 0:1:1 = 0 pine bark : 1 moss peat : 1 sand, 2:1:1 = 2 pine bark : 1 moss peat : 1 sand (v/v/v).

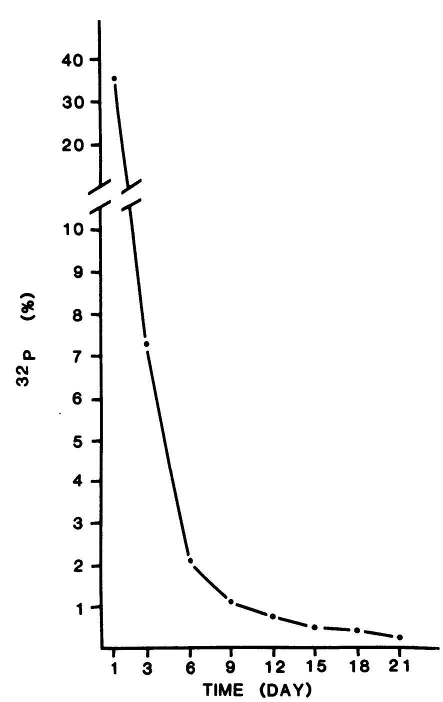

Fig. 1. ^{32}P leached from a 2 pine bark : 1 moss peat : 1 sand medium amended with 3 kg m^{-3} of superphosphate (8.7% P). Data are average of 1.25 and 2.5 cm·hr^{-1}·day^{-1} rates of deionized water (pH 5.5).

Table 2. Phosphorus leached from columns of nursery media (percentage of ^{32}P applied)[z].

Media[y]	P leached (%) Days 1 to 21	Days 2 to 21
2:1:0	66 a[x]	36 a
2:0:1	72 b	37 a
0:1:1	72 b	52 b
2:1:1	76 c	39 a

[z]Forty-eight ml of deionized water (pH 5.5) were applied in 3 or 1.5 hr on day 1 and as 16 or 32 ml hr^{-1}, respectively, on days 2 to 21. Data are averages of irrigation rates equivalent to 1.25 and 2.5 $cm \cdot hr^{-1} \cdot day^{-1}$.
[y]2:1:0 = 2 pine bark : 1 moss peat : 0 sand, 2:0:1 = 2 pine bark : 0 moss peat : 1 sand, 0:1:1 = 0 pine bark : 1 moss peat : 1 sand, 2:1:1 = 2 pine bark : 1 moss peat : 1 sand (v/v/v).
[x]Means separated within columns by Duncan's multiple range test, 5% level.

with a 3.2-mm hole in the center to accommodate the water delivery tube, was placed on top of each column. The columns were supported by a metal frame in the laboratory (21° to 26°C). Deionized water with pH adjusted to 5.5 using HC1 and NaOH was delivered to columns by peristaltic pump. The 1st day 4 columns of each medium received 48 ml of water in 3 hr and the remaining 4 received 48 ml in 1.5 hr. This is a common practice following the potting of container plants and it thoroughly wets the media. From days 2 to 21, the columns that received water for 3 and 1.5 hr on day 1, received daily 16 and 32 ml, respectively, applied in 1 hr. This corresponds to 1.25 and 2.5 cm of water per hr, respectively. The experimental design was a split-plot with irrigation rates as main plots and media as subplots. Each column was an experimental unit.

Leachates from each column were collected daily, the volume recorded, and pH determined by Corning Model 12 pH meter (Corning Glass Works, Medfield, MA 02052). An aliquot was taken from each leachate and filtered through a 0.2-μm Acrodisc filter (Gelman Sciences, Ann Arbor, MI 48106) to remove undissolved ^{32}P (V.A. Berkheiser, personal communication). An aliquot of each leachate fraction, total and dissolved ^{32}P, was placed then in a scintillation vial containing 10 ml of scintillation cocktail. The cocktail was composed of 2 parts Toluene Scintanalyzed (Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219) to 1 part by volume Triton × 100 Scintanalyzed, with 3 g per liter of 2,5-diphenyloxazole (PPO) and 0.1 g per liter of 1,4-bis (2-(5-phenyloxazolyl)) benzene (POPOP). Radioactivity in each sample was determined by liquid scintillation spectrophotometry. Corrections were made for background and decay. The quantity of total and dissolved ^{32}P leached from each column per day was calculated as a percentage of the total ^{32}P initially placed in each column.

Percentage of total and dissolved ^{32}P leached was not different in any of the combinations as determined by paired *t* test (data not shown), indicating leaching occurs after dissolution of superphosphate. Dissolution occurred rapidly with an average of 30%, 35%, 20%, and 37% ^{32}P leached on day 1 from 2:1:0, 2:0:1, 0:1:1, and 2:1:1, respectively. Because of the large percentage of ^{32}P leached on day 1, the ^{32}P leached during days 2 to 21 was calculated also and expressed as percentage of ^{32}P applied. Leaching progressed rapidly until day 7 when about 55% of the ^{32}P amendment had leached from each medium. A leaching profile for 2:1:1, which is representative of the other media, is shown in Fig. 1. Irrigation rate did not affect ^{32}P leached during days 1 to 21 or 2 to 21 and there was no medium/rate interaction for either time period.

The larger percentage of ^{32}P leached from 2:0:1 rather than 2:1:0 on day 1 and resulted in a greater percentage of ^{32}P leached from 2:0:1 during days 1 to 21. However, the percentage of ^{32}P leached during days 2 to 21 was similar for the 2 media (Table 2). Even though the percentage of ^{32}P leached during the entire experiment was different for the 2 media, the difference is not commercially important because the percentage of ^{32}P leached from both media was very large. Therefore, the substitution of sand for moss peat was apparently not an important factor in reducing ^{32}P leaching. The same percentage of ^{32}P leached from 2:0:1 and 0:1:1 during days 1 to 21, yet 15% more ^{32}P leached from 2:0:1 on day 1 while the reverse was true for days 2 to 21. The greatest percentage of ^{32}P leached for all media was from 2:1:1 during days 1 to 21. The percentage of ^{32}P leached during days 2 to 21 was similar to that of 2:1:0 and 2:0:1, indicating moss peat and sand in combination with pine bark do not influence ^{32}P leaching. This concurs with the findings of others (1, 13, 14, 15) that P leaches from media containing pine bark, peat, or sand.

The fact that more ^{32}P leached from 0:1:1 than from other media during days 2 to 21 is not a result of the volume of leachate collected during this period. Leachate collected from 0:1:1 during days 2 to 21 for the 16 and 32 ml rates was 169 and 473 ml, respectively, compared to 170 and 480 ml from 2:1:0, a medium where less ^{32}P leached. A further indication that percentage of ^{32}P leached was not dependent upon leachate volume is that more ^{32}P leached from 2:1:1 than from 2:1:0 during days 1 to 21, yet 195 and 482 ml of leachate were collected from 2:1:1 and 197 and 506 ml collected from 2:1:0 for the 16 and 32 ml rates, respectively.

Spinks and Pritchett (12) determined that more ^{32}P leached from unlimed (pH 3.8) than limed (pH 6.2) peat media while Chaiwanakupt and Robertson (2) determined that lime had little effect on P leaching from muck. In our study, leachate pH for 2:1:0, 2:0:1, 0:1:1, and 2:1:1 was 4.2, 4.1, 4.7, and 4.2 on day 1 when a large percentage of ^{32}P leached. However, it is unlikely that pH is totally responsible for the quantity of ^{32}P leached on day 1 since average pH during days 1 to 21 for 2:1:0 (pH 5.2) and 2:0:1 (pH 5.3) was lower than 0:1:1 (pH 5.6) and 2:1:1 (pH 5.5), yet more leaching occurred from 2:1:1.

Leachate ^{32}P concentrations of 0:1:1 ranged from 1236 ppm on day 1 for the 16-ml rate to 4 ppm on day 21 for the 32-ml rate. Leachate ^{32}P concentrations of each medium for the 32-ml rate during days 15 to 21 were below 10 ppm, a level previously determined optimum for *Ilex crenata* Thunb. 'Helleri' (14).

Superphosphate appears to be an inefficient P amendment for media composed of pine bark, moss peat, and/or sand. Additional research is needed to characterize P chemical reactions with media components in order to elucidate the factors influencing P leaching. Dalton et al. (3) postulated that organic substrates contain chemicals which complex with Fe and Al, thus increasing P leaching. However, 2:1:0 contained the greatest quantity of organic components and ^{32}P leached the least. Furthermore, alternative P sources which reduce P leaching and maintain a stable growing medium P level need to be developed so efficient P fertility programs can be implemented by the nursery industry.

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