Agric. Chem. Biotechnol. **41**(8), 583-586 (1998)

Article

Technique for Soil Solution Sampling Using Porous Ceramic Cups

Jong-Bae Chung

Department of Agricultural Chemistry, Taegu University, Kyongsan 712-714, Korea

Received August 31, 1998

Porous ceramic cups are used for monitoring ion concentration in soil solutions in various time course and depth. A soil solution sampler was constructed in laboratory by inserting pliable perfluoroalkoxy(PFA) tubings into porous cup through holes in PVC rod segment which plugged top opening of the porous cup. The system was installed in drip irrigated soil in a vertical position, and nitrogen movement below the drip basin was monitored. To collect soil solution, vacuum in the cup was applied with a hand vacuum pump. The samples obtained were sufficient enough to run quantitative analyses for a number of chemicals. Nitrogen transformation and movement could be well defined, and the system seemed to be relevant to the other soil solution samplers in monitoring chemical movement in soil. Although this system has general deficiencies found in the other samplers using ceramic cup, it could be easily constructed at a low cost. Since the tubing was pliable, the cups could be installed in horizontal position, and this allows installations of the cups at more precise depth increments and also more precise samplings of soil solution at each depth.

Key words : *porous ceramic cup, soil water, soil solution sampler.*

Recently, emphasis has been placed on the improvement of the efficiency of nutrients in agriculture in order to alleviate their impact on the environment. The movement of NO_3^- ion in soil has been investigated extensively because its accumulation in ground water supplies can be hazardous to human health. To improve the efficiency, nutrients must be supplied in accordance with plant demand in terms of timing as well as quantity. Also, understanding of contaminant migration in soil landscapes continues to be an important research emphasis embraced by soil scientists.

Methods employed in soil solution sampling can be divided into two main groups: indirect and direct methods. Direct methods include soil coring or the use of ceramic cup, pan, and wick type solution samplers. Indirect methods usually involve the use of electrical conductivity probes[1)] or time domain reflectometry probes.[2)] Soil coring is a good and inexpensive method to determine the chemical composition in a given volume of soil. The removal of soil cores for subsequent extraction and analysis of solutes is perhaps the most intuitive approach to evaluating the spatial distribution of solutes within the soil profile. However, it is a destructive method, requiring a large number of samples, and does not allow for repetitive measurements at the same point, thus limiting its usefulness when monitoring changes with time. Although time domain reflectometry has recently been utilized to monitor transport of conservative tracers,[3-5)] this technology does not have the capability of discerning specific pollutants such as metals, nitrate and pesticides that are currently of interest to research scientists.

Porous cup soil solution samplers have been extensively utilized for monitoring soil solution chemical constituents and contaminant migration for nearly a century.[6-8)] Porous cup solution sampling is a relatively cheap method and useful for continuous monitoring of changes with time at the same point. Although widely used, some of the deficiencies of this device are that the sampled soil volume is not known[9)] and preferential and funneled flows may not be captured with respect to time and space.[10)]

England discussed some of the basic problems in interpreting data collected from ceramic cups.[9)] The concentration and the composition of the soil solution are not homogeneous through out its mass. Thus, water drained from large pores at low suctions may have a chemical quality that is very different from that extracted from micropores. Also, the concentrations of various ions in a soil solution generally do not vary inversely with the soil water content. Total dissolved quantities of some ions increase upon dilution while, concurrently, those of other ions may decrease. There is the problem of adsorption of ions by the ceramic cup itself. Nearly all porous ceramics

*Corresponding author
Phone: 82-53-850-6709; Fax: 82-53-850-6709
E-mail: jbchung@biho.taegu.ac.kr

Abbreviations: PFA, perfluoroalkoxy; PVC, polyvinyl chloride.

have some ion exchange capacity that, in this case, may remove some ions as water enters the cup and possibly affect the composition of subsequent extractions.

The use of porous cup soil solution samplers has been and continues to be a very common method for the sampling of soil solution. Unlike soil coring method, once installed, the instruments can be used to monitor solute concentrations at discrete depths within the soil profile. Therefore, it seems reasonable to conclude that soil solution samples in general, and porous cup soil solution samplers in particular, will continue to be utilized in the near future. In this study a simple soil solution sampler using ceramic porous cup was constructed, and the application of this system in nitrogen transport under drip irrigated soil was demonstrated.

Materials and Methods

Construction of porous cup soil solution samplers. Porous ceramic cup assemblies were constructed as shown in Fig. 1. The porous cups used in this study were purchased from the Soil Moisture Equipment Corp., California USA. The cup had an outside diameter of 1.9 cm, an inside diameter of 1.1 cm and length of 6.7 cm. Porous cups are available with several different air entry or bubbling pressure values. The porous cups used in this study had a one-bar air entry value, and the theoretical pore size was 2.9 μm. The pore size did not produce ultrafiltration effect or plug readily with fine materials. Porous cups must be throughly cleansed before use in collecting samples for chemical analyses. In this study, the cups were cleansed by allowing approximately 1 *l* of 8 N HCl to seep through them. This acid treatment was followed by allowing 15~20 *l* of distilled and deionized water to seep through and rinse the cups throughly.

PVC rode was cut in volt shape and made to fit the top opening of the porous cup. Two holes were made to insert the solution sampling and air inlet tubings. Tubings used in this study were Nalgene PFA tubings of an outside diameter of 0.32 cm and an inside diameter of 0.16 cm. Each part was connected and sealed airtight at the joint with epoxy cement. The plastic tubings can be cut in any length. One tubing was inserted to the bottom of the cup (solution sampling tube) and another tubing was inserted to the top of the cup (air inlet tube).

Sample collection facilities at the soil surface consisted of a 15 m*l* conical centrifuge tube and a hand vacuum pump (Fig. 2). Tubings from porous cup and vacuum pump were connected to a rubber stopper fitted to the conical centrifuge tube. Hand vacuum pumps were purchased from Nalge company, USA. Several different models are available with different suction pressures. In this study, pump with 84 kPa positive pressure at the exhaust port was employed.

Installation and sample collection. A hole was drilled to the desired depth with a soil core sampler, and the porous cup assembly was lowered to the bottom of the sampler hole by means of the two tubings. The material augered from the hole was used to backfill the hole to the surface. Only one unit was placed in a hole. The single unit installation has several advantages.[11] Several units can be installed at different depths around the sampling site.

On the soil surface, solution pumping tube and tube from vacuum pump were connected to the 15 m*l* conical centrifuge tube (Fig. 2). Vacuum was applied first with the air inlet tube open, and the solution filled in the porous cup was removed. The air inlet tube was closed, and vacuum was applied to pull the soil solution around the cup. The solution pulled in the cup was then pumped into the sample collection tube on the surface. The amount of

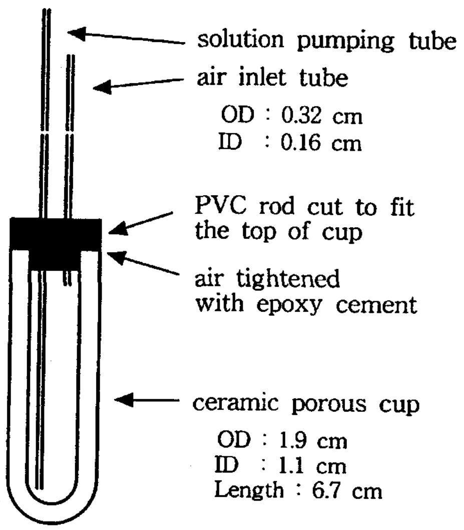

Fig. 1. Details of the ceramic porous cup assembly.

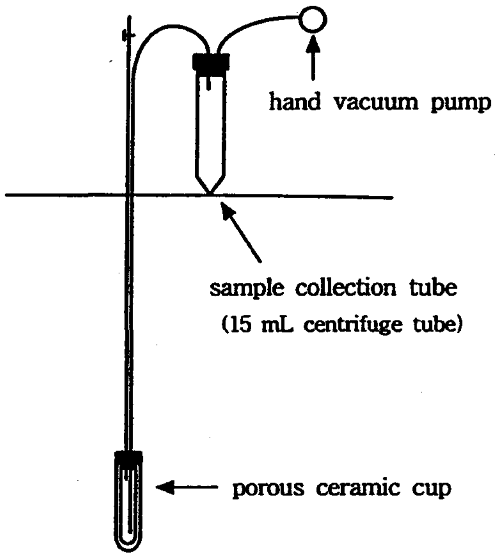

Fig. 2. Installation of the porous cup assembly and arrangement of the surface collection equipments.

solution sampled and time required for the needed amount of solution sampling were dependent on the soil moisture condition.

Solution sampling at drip basin. The porous cup assemblies were installed in a peach orchard, and water was supplied using drip irrigation system. Two drip basins of 20 cm in diameter were constructed in a row on each side of the trees at a distance of 50 cm from the tree trunks. Porous cup assemblies were installed at 5, 20, 30, 40, and 60 cm depths immediately below the drip basin. The systems were stabilized for one month before the soil solution sampling. During the experiment, water was supplied at the level of 20 kPa soil tention at 20 cm depth with the drip irrigation system. A tensiometer was installed, and soil moisture condition was continuously monitored. Nitrogen was applied with 50 g of ammonium sulfate (21% NH_4-N) for each drip basin, and soil solution samples were collected at 3, 8, 15, and 24 days after N application. The solution samples were refrigerated in the field with ice and stored at 4°C until nitrogen could be analyzed. After filtering the samples using 0.45 μm membrane filters, the concentrations of NH_4-N and NO_3-N in the solution were determined by conductimetric analysis.[12]

Results and Discussion

Samples of sufficient quantity for chemical analyses were extracted by the ceramic porous cup soil solution sampler designed in this study. Although moisture contents throughout the soil profile varied depending on the irrigation schedule, the soil below the drip basin was wet enough to collect 5 to 10 mL samples of the soil solution within 20 minutes after vacuum was applied. The solutions were clear with no visible residues left on the membrane filters after they were passed through. Clogging was not a problem with the soil solution sampling system.

Figs. 3 and 4 show the changes in concentration profiles of NH_4-N and NO_3-N with time under drip irrigation system. The applied NH_4-N rapidly moved down, and the highest concentration was found at 20~30 cm depth. The concentration declined very rapidly after one week of N application. After 24 days, NH_4-N concentrations throughout the soil profile were near the level of no N treatment. The rapid decline of NH_4-N in soil would be due to a radial movement,[13,14] plant absorption, and nitrification. Nitrate-N concentration increased with time, and the highest concentration was found at 40 cm depth. The concentrations were quite lower than the NH_4-N concentration found after 3 days of N application. This could be due to the plant absorption or rapid radial movement of nitrate in the soil profile. Vertical movement of NH_4-N and NO_3-N was limited above 60 cm depth. Although the movement and transformation of applied N in the soil were not studied in detail and only used to demonstrate

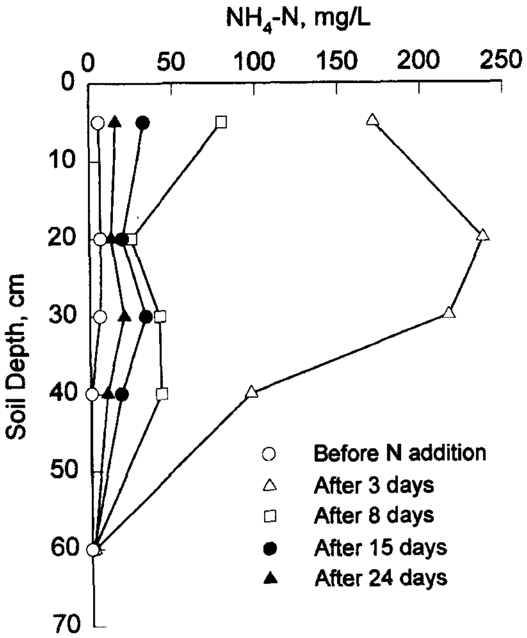

Fig. 3. Changes in ammonium ion levels with time at five mean soil depths immediately below the drip basin.

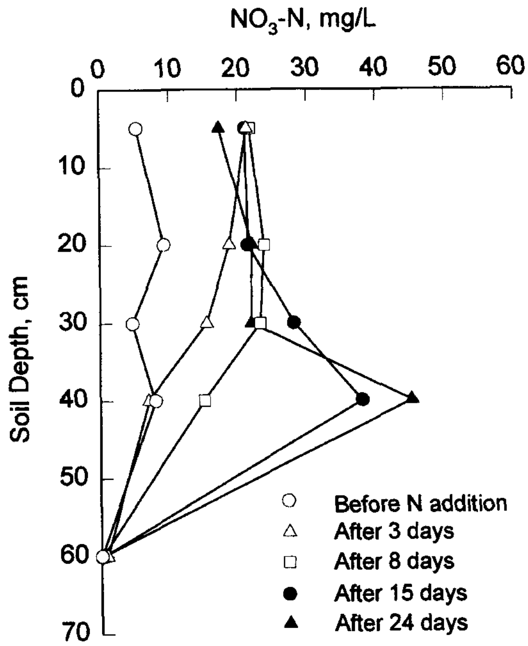

Fig. 4. Changes in nitrate ion levels with time at five mean soil depths immediately below the drip basin.

the applicability of the designed soil solution sampling system, the results showed a representative distribution pattern of nitrogen in drip irrigated soil profile.[13]

Although the general deficiencies of ceramic porous cup soil solution sampler mentioned in the introduction were not considered in detail, the system seems to work as well as other ceramic porous cup soil solution samplers in monitoring the nitrogen transformation and movement in soil. The ceramic porous cup soil solution sampling system of this study not only can be easily constructed at a low cost but has also another advantage; since the tubing connected to the ceramic cup is pliable, the porous cup can be installed in a horizontal position. This allows installations of the cups at more precise depth increments and also more precise samplings of soil solution at each depth. With commercially available suction lysimeters in which rigid plastic pipe is connected to ceramic cup, the installation of this porous cup is limited to only in a vertical position.

Acknowledgments. This research was supported by the Taegu University Research Grant, 1998.

References

1. Rhodes, J. D. and Oster J. D. (1986) Soluble salts. In *Methods of soil analysis: Part I, Agron. Monogr. 9,* Klute, A. (ed.) pp. 985-1004, ASA and SSSA, Madison, WI.
2. Dalton, F. N. and van Genuchten, M. Th. (1986) The time-domain reflectometry method for measuring soil water content and salinity. *Geoderma.* **38**, 237-250.
3. Ward, A. L., Kachanoski, R. G. and Elrick. D. E. (1994) Laboratory measurement of solute transport using time domain reflectometry. *Soil Sci. Soc. Am. J.* **58**, 1031-1039.
4. Risler, P. D., Wraith, J. M. and Gaber, H. M. (1996) Solute transport under transient flow conditions estimated using time domain reflectometry. *Soil Sci. Soc. Am. J.* **60**, 1297-1305.
5. Hart, G. L. and Lowery, B. (1997) Axial-radial influence of porous cup soil solution samplers in a sandy soil. *Soil Sci. Soc. Am. J.* **61**, 1765-1773.
6. Wagner, G. H. (1962) Use of porous cups to sample soil water within the profile. *Soil Sci.* **94**, 379-386.
7. Bruce, R. R., Leonard, R. A, Thomas, A. W. and Jackson, W. A. (1985) Redistribution of bromide by rainfall infiltration into a Cecil sandy loam landscape. *J. Environ. Qual.* **14**, 439-445.
8. Fermanich, K. J., Bland, W. L., Lowery, B. and McSweeney, K. (1996) Irrigation and tillage effects on atrazine and metabolite leaching from a sandy soil. *J. Environ. Qual.* **25**, 1291-1299.
9. England, C. B. (1974) Comments on "A technique using porous cups for water sampling at any depth in the unsaturated zone" by Warren W. Wood. *Water Resour. Res.* **10**, 1049.
10. Barbee, G. C. and Brown, K. W. (1986) Comparison between suction and free-drainage soil solution samplers. *Soil Sci.* **141**, 149-154.
11. Wood, W. W. (1973) A technique using porous cups for water sampling at any depth in the unsaturated zone. *Water Resour. Res.* **9**, 486-488.
12. Carlson, R. M. (1978) Automated separation and conductimetric determination of ammonium and dissolved carbon dioxide. *Anal. Chem.* **50**, 1528-1531.
13. Haynes, R. J. and Swift, R. S. (1987) Effect of trickle fertigation with three forms of nitrogen on soil pH, levels of extractable nutrients below the emitter and plant growth. *Plant Soil* **102**, 211-221.
14. Levin, L., Assaf, R. and Bravdo, B. (1979) Soil moisture and root distribution in an apple orchard irrigated by tricklers. *Plant Soil* **52**, 31-40.