

A LOW-COST SYSTEM FOR CIRCULATING NUTRIENT SOLUTIONS IN POT STUDIES¹

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ABSTRACT

A simple, inexpensive nutrient solution circulation system was developed which could be duplicated in developing countries. The airlift perfusion principle was employed to continuously recirculate nutrient solution within individual pots containing porous medium. The system has proven to be very satisfactory for N studies including a ¹⁵N experiment and an evaluation of the transfer of legume-fixed N to a grass growing in a separate pot.

Additional index words. Perfusion system, N transfer.

A system for supplying nutrient solutions to pot-grown plants should a) provide the solution at a constant rate; b) maintain homogeneity of the solution, or constant concentration of nutrients, or both; c) maintain the integrity of different nutrient treatments; and d) allow adequate aeration in the root zone. Several systems have been devised to accomplish these goals. Mariotte's Bottle (and subsequent modifications) provide for continuously regulating the level of solution in pots or as a constant-head device for continuously-flowing nutrient solutions (3). Mariotte's bottle or more elaborate continuously-flowing nutrient culture solution systems (3) can maintain nutrient concentrations within relatively close tolerances but require large quantities of solution. Compressed air (2, 3) or solution-pump methods (3, 4) (whereby nutrient solution is forced upward into the pots at regular intervals and then allowed to drain back to the reservoir) may require less volume of solution, but usually require sophisticated control equipment for operation.

The NifTAL³ project required a simple inexpensive system which could be easily duplicated in developing countries yet provide sufficient reliability and uniformity for ¹⁵N and other nutrient-response studies. We found that the perfusion system utilized for studies of microbiological activity in soil (1) could be readily adapted to meet these requirements.

DESIGN AND OPERATION

The NifTAL nutrient solution circulation system utilized the following readily available components: a) light duty aquarium air pump (e.g. Metaframe Hush III⁴); b) vinyl tubing, 4.8 mm I.D.; c) rubber tubing, 3.2 mm I.D.; d) polyethylene microtubing, 1.6 mm I.D.; e) glass tubing, 3 mm I.D.; f) rubber stopper, 2 cm diameter with two holes; g) disposable plastic syringe, 1 cc capacity; h) hollow steel needle, 25 gauge X 8 mm long; i) PVC plastic pipe, 13 mm I.D. (for air manifold); and j) pots with provision for a nutrient reservoir at the base and containing porous media.

A schematic of the basic nutrient solution circulation system is shown in Fig. 1, right side. There are three subsections in the system; pot and growth medium, tubing for nutrient circulation, and the air supply. The general view is shown in Fig. 2.

Pot and Growth Media. The size of the pot can be varied according to the need of the experiment, but the pot must be deep enough to provide adequate rooting volume plus capacity for a nutrient solution reservoir at the base. The growth medium employed should be sufficiently porous to allow for both good aeration and free flow of the nutrient solution. Our experience has shown that crushed rock (2 to 5 mm diam) gives good results. If finer textured material is used, slight suction must be applied by elevating the pot above a reservoir which is connected hydraulically to the pot (Fig. 1, left side). A two-hole rubber stopper at the base of the pot allows the insertion of a "sight-glass" 3 mm I.D. glass tubing, plugged with cotton wool if desired) and an outlet for supplying solution to the circulation system.

Circulation System. Solution from the base of the pot flows through a glass tubing into a short section of rubber tubing which is plugged at the opposite end by a glass rod. A short piece of polyethylene microtubing is inserted into the rubber tubing and serves to regulate the flow of solution (the longer the tubing, the less flow) into the rubber tubing at the base of the lifting tube. Air is then introduced into this tubing at a point below the level of solution in the pot. Circulation occurs because the weight of the solution in the lifting tube is less than the effective hydraulic head of the solution in the pot.

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³Acronym for Univ. of Hawaii's program to maximize N₂ fixation by tropical agricultural legumes.

⁴Use of the trade name is for illustrative purposes only and does not imply endorsement or preference for the product so named.

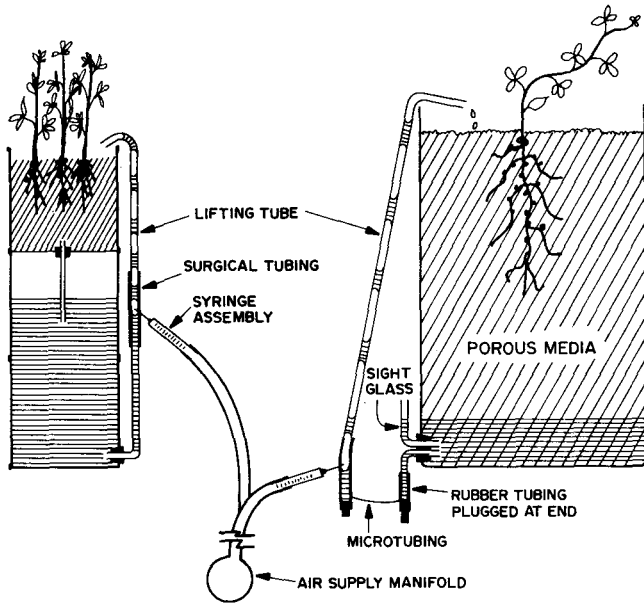


Fig. 1. A schematic diagram of the NifTAL nutrient solution circulation system.

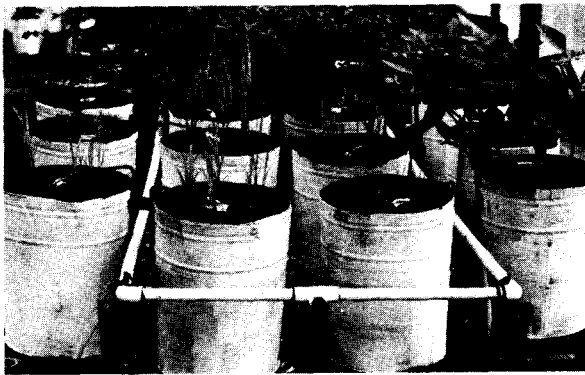


Fig. 2. General view of bench layout of the NifTAL pot nutrient circulation system.

Air Supply. Air from the pump is channeled through a plastic pipe (PVC) manifold and then *through* vinyl tubing which slips tightly over the barrel of a 1 cc disposable syringe. The syringe in turn provides a convenient mounting for a steel injection needle which regulates the volume of air delivered to each pot subsystem.

Using the sizes of needles, microtubing, etc. specified, one air pump can circulate the nutrient solution in at least 64 separate pots, each of 18-liter capacity, at a flow rate of 5 ml/min/pot.

SYSTEM MAINTENANCE

Since the needle tips are exposed to nutrient solution, corrosion may occur. A clogged or partially-clogged needle can be detected easily by dipping the tip of the needle in water and observing the rate of air bubbling. Clogged needles may be flushed with a cleaning solution or replaced. Our experience is that ordinary disposable needles have a life of approximately 3 weeks before occasional problems begin to occur. At this point all needles in the system should be replaced. Rubber tubing may crack after long usage and should be replaced as soon as cracking or splitting is observed in order to avoid loss of solution. Glass tubing should be coated with opaque paint or wrapped with aluminum foil to prevent the growth of algae.

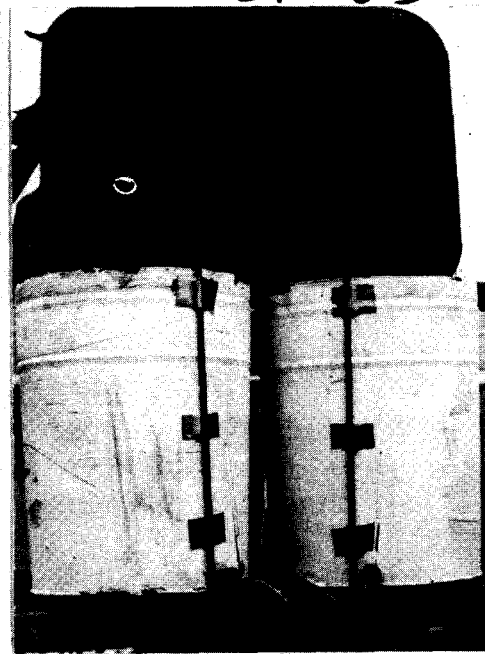


Fig. 3. Closeup of the double crossover nutrient circulation system showing cowpea (*Vigna unguiculata*) on the left and *Setaria anceps* on the right.

PERFORMANCE

The modified perfusion system has proven to be very satisfactory for solution-culture experiments conducted by the NifTAL Project; involving legume nutrition studies, N transfer from legumes to grasses, and ^{15}N studies with grass-legume mixtures.

A strong advantage of the system is that each pot makes up an integral unit and cross-contamination is thereby minimized. However, this tends to restrict the total volume of solution in each pot, with consequent depletion of nutrients during rapid plant growth (especially nitrate). This problem can be reduced by frequent changes of solution, frequent adjustments of nutrient concentrations, using higher initial nutrient concentrations, and/or increasing reservoir capacity (e.g. Fig. 1, left side). Using the tall-reservoir system with sand medium, 6 liter reservoir capacity, and three soybean plants per unit; P depletion was serious only at very low levels of P. At initial levels of P, 0.02, 0.2 and 2.0 ppm, concentrations were reduced to approximately 8%, 6% and 34% within 24 hours. Coefficient of variability (CV) for soybean dry weight yields was 11.7%, for this experiment. At normal levels of solution P (≥ 8 ppm) depletion would be minimal over a much longer period.

In the N transfer experiment, a double crossover system was employed in which solution from a legume pot was lifted into a grass pot and vice versa (Fig. 3). In this experiment six legumes were grown paired with a grass, *Setaria anceps*, each in 18-liter pots. The grass was cut on three occasions to monitor the N released by the legume. In the first two harvests CV's were 15.8%, and 20.0%, for dry matter yield and 13.5%, and 9.7%, for grass heights, respectively. Variability was much greater at the final harvest due to uneven development of N deficiency, but even then, the C for height was only 17.2%.

The basic system is sufficiently flexible that it can be modified further to meet a wide variety of experimental situations.

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