AIRFLOW-CONTAINED AEROPONIC NUTRIENT DELIVERY FOR A MICROGRAVITY PRANT GROWTH UNIT

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出版情報：BIOTRONICS. 21, pp.33-38, 1992-12. Biotron Institute, Kyushu University
バージョン：
権利関係：

BIOTRONICS ***21***, 33–38, 1992

AIRFLOW–CONTAINED AEROPONIC NUTRIENT DELIVERY FOR A MICROGRAVITY PRANT GROWTH UNIT

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(Received January 9, 1992; accepted May 6, 1992)

Hessel M. I., Jr., Richert G. E., Jr. and Nevill G. E., Jr. *Airflow–contained aeroponic nutrient deliveery for a microgravity plant growth unit.* BIOTRONICS **21,** 33–39, 1992. Paper presents a new approach to nutrient delivery and control for microgravity plant growth. Nutrients are delivered by aeroponic misting of roots and leakage is prevented by flowing air. Plant germination and growth are explored for several seed holder concepts and found to be sensitive to holder material and configuration.

Key words: microgravity; nutrient delivery; plant growth

INTRODUCTION

As man explores deeper into space, regenerative closed–loop life support becomes increasingly attractive. Because of mass restrictions and containment problems in microgravity, soil is a poor choice for a plant growth medium (*4*). There are numerous alternatives to a soil medium (*2*). Not all alternatives are compatible with microgravity. Only systems which prevent the water and nutrients from escaping into the environment and which provide adequate aeration of roots are feasible. Additionally, it has been shown that plants grown aeroponically are as healthy as plants grown hydroponically or in soil (*3*). Researchers with the Bionetics Corp., located at Kennedy Space Center, are working on a porous growth medium in the form of tubes and trays. The porous growth medium system utilizes a concept proposed by Wright and Bausch (*5*) for containing the nutrient solution and allowing it to pass by capillary action through a microporous, hydrophilic membrane to the roots (*1*). An aeroponic system, unlike the porous growth mediun system, would contain the nutrient solution with airflow. The need for an alternative approach, such as the project to be described, results directly from the difficulties associated with refurbishing porous growth medium systems.

MATERIALS AND METHODS

The alternative proposed here is a simply constructed system that eliminates root growth on porous surfaces and does not require disassembly to refurbish. A chamber contains the roots which are misted with a nutrient solution. The stems and leaves of the plants grow out of the chamber, while the roots grow in. The three layer root plane is comprised of two plates and an air gap (Figs. 1 and 2). The bottom plate is perforated and is designed to distribute air flow uniformly; while the top plate is solid, except for the airflow inlets and seed holder ports. The combination allows for the creation of a low pressure zone in the root chamber (Fig. 1).

To retain the seeds in the system during germination, and support the plants later, seed holders are placed in the seed holder ports, which are holes in the two plates (Figs. 1 and 2). Nutrient nozzles emitting a 360° horizontal spray pattern are mounted on the root chamber side of the root plane (Fig. 3).

The nutrient solution is constantly removed from the root chamber by the pressure and velocity gradients of the flowing air. Complete sealing of the root chamber is not necessary; although there are many gaps through which the fluid might escape, the low pressure zone in the root chamber causes a steady inward airflow which contains the solution. Controlling the nutrient fluid in this manner is desirable in microgravity, where surface tension forces are the predominate forces that may cause leakage. It is believed that the friction between the moving air and the water will overcome the forces of surface tension at the edges of the holes, where the water will try to come out.

To evaluate the system in earth's gravitational field certain assumptions where made. To verify the containment of nutrient solution, the assumption was made that if the system was successful when gravity tended to cause leakage, it would also be suceessful in microgravity where only surface tension forces will cause leakage. These tests were accomplished by placing the system in an orientation (upside down) such that the airflow was required to move the nutrient solution from a lower to higher potential state. For any given root chamber pressure, the quantity of nutrient solution in the root chamber reached an equilibrium volume.

Although nutrient solution containment is vital, germination and growth in the system are equally significant. To test the system's ability to germinate and grow plants, the assumption was made that if gravity strongly influences orientation during germination, it could be temporarily produced in microgravity. The results of the experiment proved to be particularly sensitive to the type of seed holders used, therefore, the seed holder type become the critical variable. The first two seed holder designs were constructed of filter paper and perforated plastic sheet (Fig. 2A). These materials were cut into cross shaped pieces that, when installed, suspended the seed in a position accessible to the nutrient solution. The third seed holder was a cylindrical sponge with a small hole punched through the center in which the seed rested (Fig. 2B); the nutrient solution was transferred to the seed through the sponge. The final

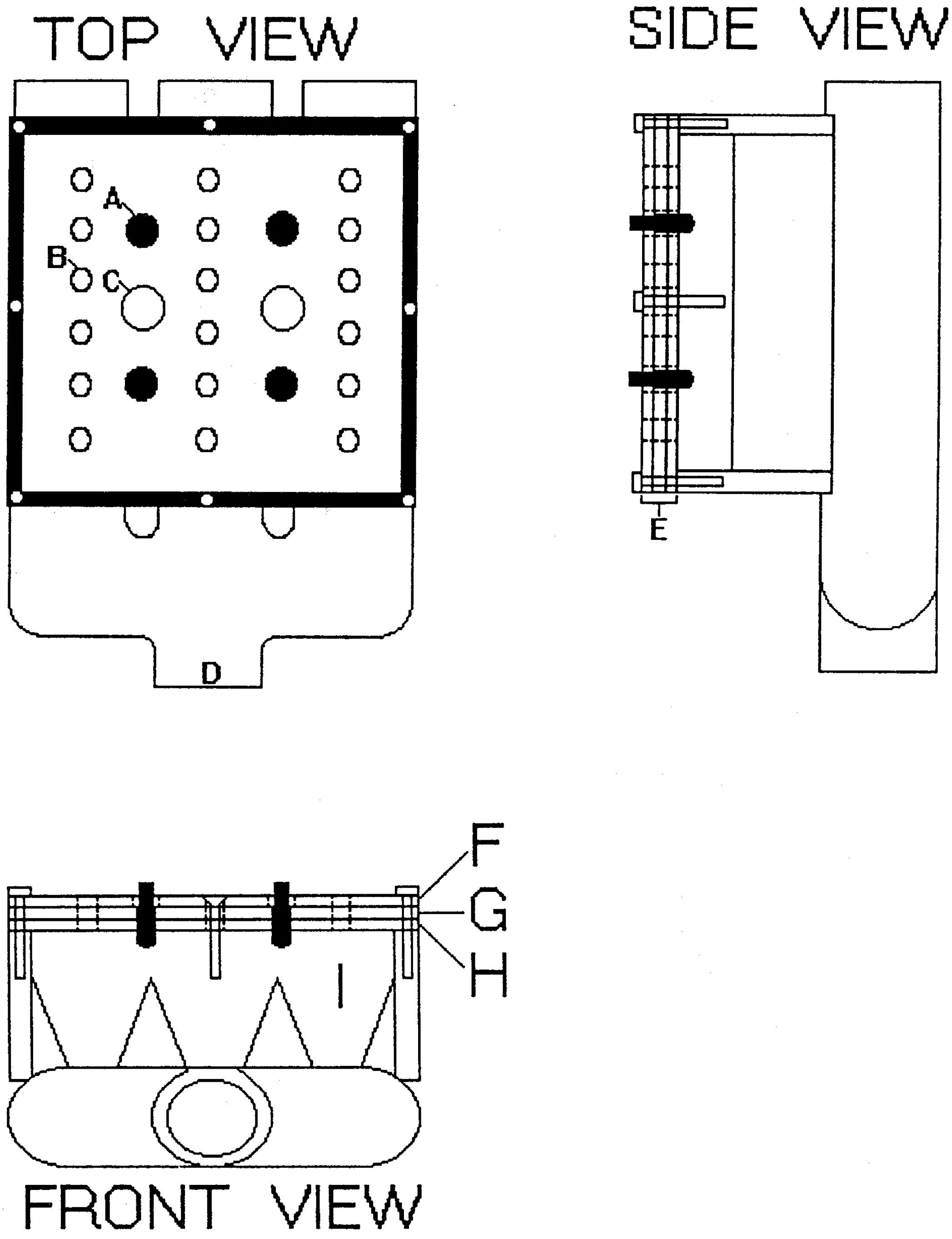

Fig. 1. Plant growth unit that uses induced air flow to contain nutrient solution. A. Nutrient nozzle. B. Seed holder port. C. Air flow inlet. D. Air and nutrient solution outlet. E. Three layer root plant. F. Top plate. G. Air space. H. Bottom plate. I. Root chamber.

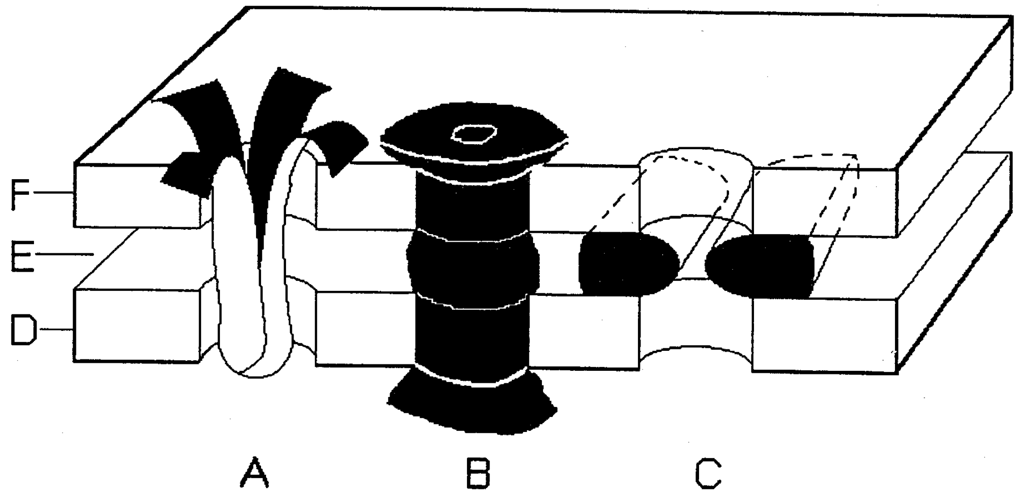

Fig. 2. Seed holder configurations tested in the plant growth unit. A. Filter paper Seed holder. B. Sponge Seed holder. C. Neoprene Seed holder. D. Top plate. E. Air space. F. Bottom plate.

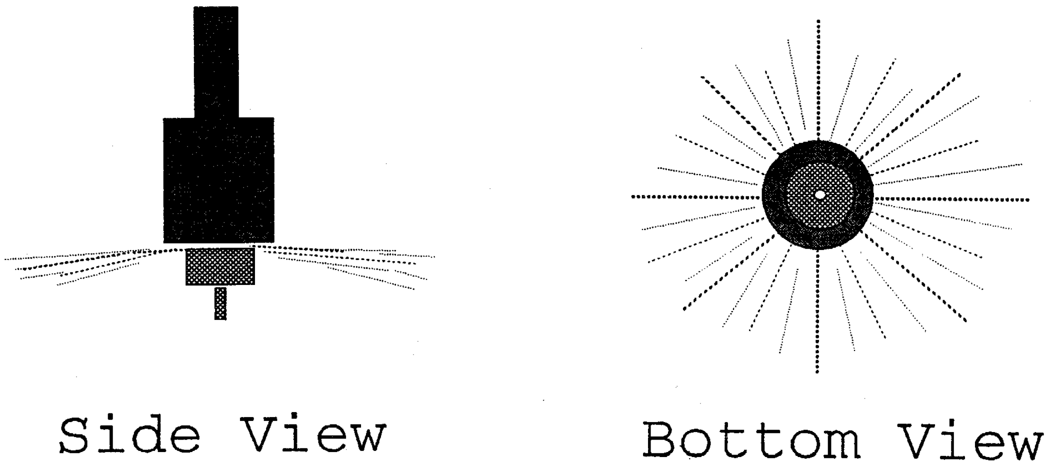

Fig. 3. Nozzles with 360° horizontal spray patterh.

seed holer used in the experiment consisted of two pieces of neoprene held between the two plates that make up the root plane. The seed is held in the crevice created by the two neoprene pieces (Fig. 2C).

RESULTS AND DISCUSSION

The first significant result of the tests was the complete containment of the nutrient solution with unit in any orientation with respect to gravity. Thus, the airflow was able to counteract both surface tension and gravity. Therefore, it can be confidently concluded that this system will be able to contain the solution in microgravity.

To test for germination and initial growth, radish seeds were inserted in the 18 seed holders of the system and tested with airflow. In parallel, 18 seeds were placed in a petri dish on filter paper as a control. The four seed holder types were effective at germinating seeds to varying degress. The control seeds had close to 100% germination. The filter paper seed holder allowed 66% of the seeds to germinate and 33% to grow to a height of 2 cm. The obvious problem with this seed holder was mineral salt build-up along the top which eventually led to a chemical burning of the seedling. It was expected that the perforated plastic seed holder would absorb no fluid, therefore, reducing the amount of mineral salt build-up. For unexplained reasons, the perforated plastic performed even worse, germinating only 50% of the seeds and not allowing any growth. An additional complication of the first two seed holders was the possible inability of the roots to penetrate into the root chamber.

To provide a more direct pathway to the root chamber, the previously described sponge seed holder was tested. Anticipating saturation of the sponge seed holder, the frequency of nutrient solution application was reduced. This test resulted in 77% germination and some minimal growth. After reviewing these results, it is believed that moisture and mineral salt build-up on the seed holder are two key factors which may inhibit growth. To avoid problems associated with the first three seed holder types, the final seed holder was designed not to absorb but to be a barrier to the nutrient solution, therefore minimizing mineral salt build-up. This resulted in a significant decrease in the build-up of mineral salt. This was the most successful seed holder allowing 89% germination and growth of three seedlings to a height of 8 cm. In this test, the control seeds showed signs of decreasing root development, possibly stemming from the age of the seeds. Therefore, new seeds were acquired and the tests were repeated. Again, 89% of the seeds germinated. Although the plants did not grow to full maturity, four plants grew to a height of 9 cm. One plant developed four leaves and grew to a height of 11 cm. This leads to the conclusion that the final seed holder tested is reasonably effective, but the search for a better seed holder should continue.

Two important characteristics of a plant growth system to be used in microgravity are the containment of the nutrient solution and the ability to germinate and grow plants. The system described was tested and proved to be capable of completely containing the nutrient solution. Testing the systems, ability to germinate and grow plants was extremely difficult due to sensitivity to the seed holder type and seed viability. Germination and growth occurred to varying degrees throughout the testing and were sensitive to both the seed holder configuration and material. The limiting factor at this point is believe to be the seed holder. Further work to develop an immproved seed holder is believed justified.

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