A CONVENIENT SAND-CULTURE APPARATUS

ROBERT W. WARD

With plate 177 and one text figure

ONE of the essential requirements in nutritional studies on higher plants is a culture apparatus in which replications of an extended series may be studied simultaneously. It is also always desirable, if not actually necessary, that the time expended in the routine operations of watering and feeding the plants be reduced to a minimum. The most important consideration, however, from the physiological point of view is that the component parts of the apparatus with which the plants, medium, or nutrient come in contact be constructed of materials which are chemically resistant, as well as non-porous, and capable of affording leak-proof connections.

An apparatus which seems to satisfy these requirements better than any heretofore described has been designed and put into use by the writer in a study on physiological disorders of apple trees.

The apparatus consists primarily of an inverted, bottomless, one-gallon jug connected to an inverted, standard, one-half-gallon jug by means of rubber- and glass-tubing (Fig. 1[4]). The bottomless jug B, in which the plants are grown in white silica sand, is of standard dimensions but lacks both bottom and handle and has the neck grooved so that the rubber stopper may be wired in position. It is glazed externally according to standard requirements with a white glaze and internally with a special acid-resistant glaze. The sand found satisfactory for apple culture is a mixture of 5 parts of Columbia No. 4, a coarse, angular, silica sand, and 6 parts of Ottawa No. 20, a silica sand having almost spherical grains. The lower part of the jug, as shown in the illustration, is provided with the Columbia No. 4 sand to ensure good drainage. The sand is prevented from entering the glass tubing by the use of a small circle of Monel metal screening, No. 32 mesh, laid against the rubber stopper. The nutrient solution is placed in the one-half-gallon jug A, from which it is flooded into the sand by elevating this jug to the proper height and into which it is later drained by lowering again. The connecting tubings H are of heavy-walled gum rubber and standard Pyrex glass. As much of the latter is used as is conveniently possible (Plate 177). The tubing J, which facilitates movement of air in the nutrient jug, may also serve as a suction tube to which a very weak suction pump may be attached if more aëration of the sand culture medium is desired than can be obtained by normal drainage of the nutrient solution. As many of these pieces of apparatus as are necessary or can be used conveniently are assembled on a wooden stand, as shown in Fig. 1, in which the culture jugs B...B are placed in twin beds C, C and the nutrient jugs A...A in a movable rack E. The writer was thus enabled to set up twenty-four cultures in triplicate, seventy-two cultures in all, on one greenhouse bench.

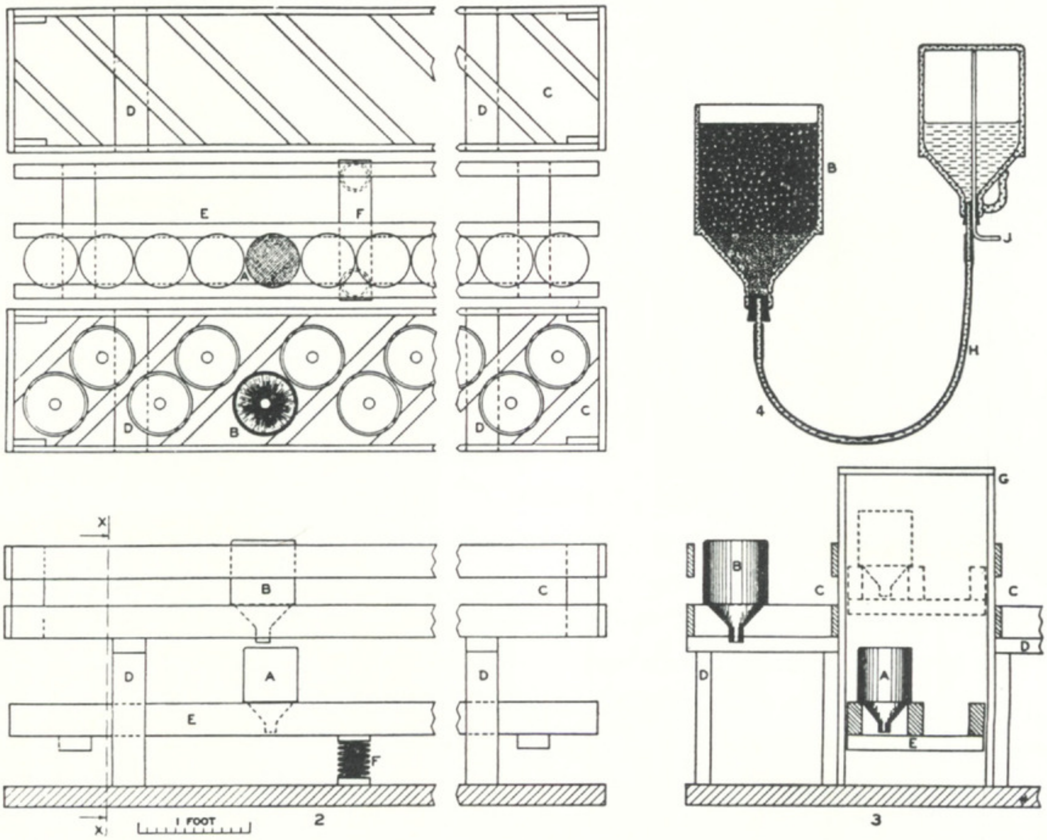


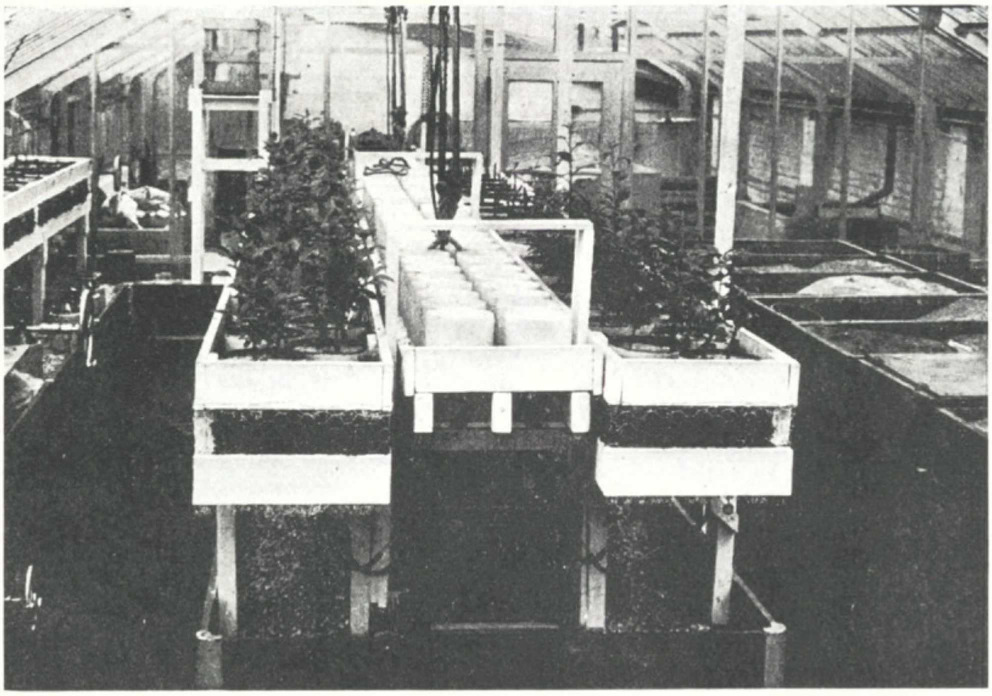
FIGURE 1. SAND CULTURE APPARATUS. 1, 2, 3. Working drawings of stand and assembled jugs. 4. Vertical section of jugs in flooding position.

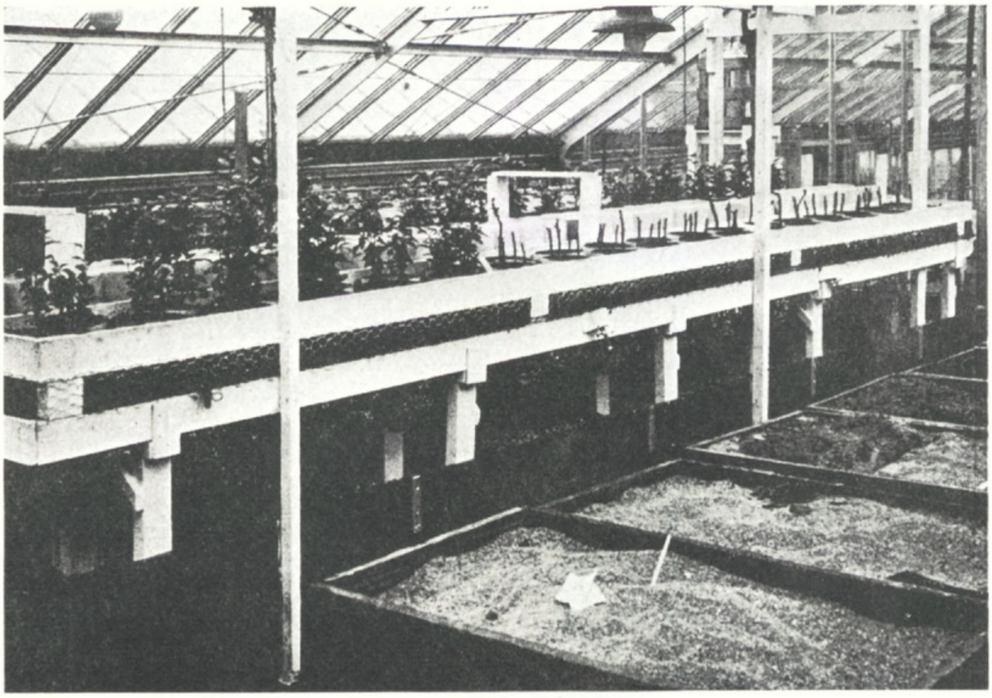
The wooden stand which holds the jugs has been designed to fit on an ordinary greenhouse bench (Fig. $1^{1,2,3}$; Plate 177). It is composed of twin beds C, C resting on horses D...D, placed about four feet apart, and a movable median rack E, which, in the raised or flooding position, rests on removable horses of a predetermined height, placed about eight feet apart (Plate 177) and which later, in the lowered or draining position, comes to rest on two stout spiral-spring blocks (Fig. $1^{1,2,F}$). The beds are fastened firmly to their respective horses and the ensemble is made immovable by use of the upright structures G...G (Fig. 1^{3}; Plate 177), which also serve as guides for the rack E. The lumber used in the construction of the stand is "western fir," 2 inches by 4 inches, and white pine, 1 inch by 4 inches. All exposed parts are painted with a good white waterproof paint.

Although details of construction of the stand are obvious in the accompanying working drawings (Fig. 1) there are several important features to be noted. First, the scantlings supporting the inverted bottomless jugs B...B in the beds C, C are mitered instead of being inserted at right angles or parallel to the sides of the bed. This makes it possible to adjust the beds to the proper width so that the ensemble of beds and rack may be accommodated on the greenhouse bench. The mitered angle of the scantlings depends naturally on the width of bed desired. The scantlings are also spaced accurately, both in the beds and rack, so that the inverted jugs may rest snugly on their shoulders between adjacent pieces. Secondly, an intermediate portion of the upright part of the beds and the entire bottoms are covered with galvanized wire netting of a coarse mesh. This permits the bottomless jugs in the beds to be packed in wet sphagnum moss, an arrangement which tends to keep the cultures at a uniform temperature due to the regulatory properties of evaporating water. Thirdly, the horses D...D supporting the beds must be of sufficient height to allow proper and adequate drainage of the cultures. Finally, it is imperative that at least two sets of heavy spiral springs F...F, of the shock-absorber type be placed in such a position under the rack E as to give the latter maximum support when fully loaded. This precaution is necessary to prevent shock and probable damage to the glass tubing when the rack with its heavy load of nutrient jugs and attached glass- and rubber-tubings are lowered to the draining position.

The operations of raising and lowering the rack and nutrient jugs are accomplished by means of two quadruple, self-locking block and tackle sets. These are attached to the rack at the proper supporting points and to a solid superstructure directly above the rack, the slings in each case being of Manila rope or some equally reliable material. The single operation of raising or lowering the rack can be accomplished by one operator and occupies about three minutes.

The height to which the rack should be raised for proper flooding of the cultures is determined in the following manner. Two liters of water are placed in the nutrient jug A, which is then set in the rack and connected to its respective culture jug B by means of the rubber- and glass-tubing H described above. The rack is then raised until the water level reaches exactly to the surface of the sand (Fig. 1^4). This height is carefully recorded and light-weight wooden horses are constructed to support the rack when raised to this position (Plate 177).





Sand Culture Apparatus with Apple Trees in Culture.
(Photos by A. B. Hatch)

At this time tests are made with several of the units to determine the average volume of water retained in the sand after drainage. Later, when the culture solutions are made up, this volume is taken into consideration.

The routine daily care of the cultures resolves itself briefly into the following operations. The rack is raised to the flooding position and, after a lapse of a few minutes to allow adjustment of the liquid level, distilled water is added directly to the sand to compensate for loss by evaporation and transpiration, until the original level at the surface of the sand is reached. Thus the original volume of the culture solution is retained throughout the course of the experiment. When the cultures have been flooded for a sufficient length of time the rack is lowered, allowing the sand to be drained and aërated naturally at the same time.

For purposes of convenience, the writer placed a carboy of distilled water on a high stand at the rear of the beds. Leading from this, along either of the outer sides of the beds, were two lines of 12 mm. glass-tubing provided with several outlets (Plate 177). A short length of rubber-tubing was attached successively to these outlets and by this means the complement of distilled water was added to the cultures directly from the carboy.

The frequency with which the culture solutions should be renewed depends upon the technique of the operator and the plants in culture. Since all of the nutrients can be accounted for, either in the plants or in the solutions, it is possible to make periodic analyses of the latter and adjust the time of renewal according to the interpretation of the results obtained.

This apparatus was designed and constructed in the laboratory of Professor J. H. Faull of the Arnold Arboretum, Harvard University, in connection with investigations carried on under his direction. This research was made possible through scholarships from the Harvard Forest and the Arnold Arboretum. The writer wishes to express his sincere thanks to Professor Faull for the facilities afforded and his continued interest. Much credit is due Professor P. R. Gast of the Harvard Forest, who contributed the basic principle of the apparatus devised from his own researches and assisted in many ways with time and equipment. Grateful appreciation is expressed to my former laboratory associates, Drs. A. B. Hatch and J. D. MacLachlan for their many constructive criticisms.

Laboratory of Plant Pathology,
Arnold Arboretum, Harvard University and
Division of Horticulture,
Central Experimental Farm, Ottawa, Canada.