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A method of growing young fruiting apple trees in water culture

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SUMMARY

A water culture method was developed to study the nutrition of apple trees. The method had to allow ease of solution sampling for uptake studies whilst ensuring good growth and fruit production.

The trees were cultured in large horizontal plastic tubes, through which the solution circulated; the solution was therefore thoroughly mixed. Four trees were mounted on each tube. To prevent root attack by pathogens, extra aeration was provided and root temperature was kept low. Root temperature was also regulated in relation to the stage of development.

In experiments with plants, when it is necessary to have exact control over nutrient supply, a choice can be made between different methods; soilless growth in an inert substrate, water culture and spray or mist culture have all been utilized for tree species.

In comparison with culture in sand or gravel, the latter three methods have the following advantages:

the root-system can readily be observed;
total tree weight can be determined at any time;
determination of absorption of both nutrients and water is easy.

Water culture

One of the problems previously encountered in growing apple trees in water culture has been the occurrence of root infection by pathogenic organisms. These infections were affected by aeration, temperature and type of rootstock.

When growing apple trees in an unaerated solution bacterial and fungal growth on the roots was observed, accompanied by poor growth and ultimately death of the trees (Barker, 1920; Bird and Ruck, 1956; Pearse, 1936). Good growth was, however, achieved in experiments when adequate aeration was provided (Pearse, 1936, 1940).

At higher root temperatures, growth retardation is apt to occur earlier, probably because the roots are more sensitive to infection. Bolas and Ruck (1955) observed that growth was better at a root temperature of 8–14°C than at 20–25°C when using the stock M.9. Sensitivity towards high root temperatures was found to differ between stock types. Nelson and Tukey (1956) observed that the stocks M.1, M.2 and M.9 were less tolerant of high root temperatures than M.7 and M.16 stocks or seedlings. To achieve a low root temperature the vessels containing nutrient solution were often sunk in the soil, as in the experiments of Bolas and Ruck (1955) and Mori (1966).

Spray and mist culture

These methods have the advantages that a better supply of oxygen is available to the root system, because it is not immersed in the solution, and bacteria and fungi are washed off the roots. A disadvantage is that the nutrient solution is supplied less uniformly over the total root system. The method also requires relatively elaborate equipment. If failure in the application of the nutrient solution occurs, there is a chance of damage to the trees within a short time, especially during warm weather (Doeksen, 1966; Roach *et al.*, 1957).

After consideration of the advantages and drawbacks of the different methods, a water culture technique was chosen as the basis of a method suitable for growing apple trees under well-defined conditions.

DEVELOPMENT OF THE METHOD

In view of the importance of maintaining nutrient concentrations at the root surface (Asher *et al.*, 1965) the nutrient solution was circulated rapidly in large plastic tubes. Following the ideas of Steiner (1965) efficient aeration was achieved by dropping the solution freely through air. The large volume of solution (150 l) utilized for four trees obviated early depletion of nutrients.

Infections of the root system by fungi or bacteria were quite troublesome at first. Improvements were therefore devised to ensure better disinfection of the tree's root system, including severe root pruning and treatment with a disinfectant. The absorbing root system during the period of culture thus consisted mainly of young roots. In the light of published data, aeration was further improved and the root temperature lowered.

The technique presented thus combines several advantages, i.e. the large, rapidly circulating volume of solution, maximal aeration, and low root temperatures, which are favourable to growth. The ultimate result was reasonable tree growth during culture periods of about five months each, during which up to 20 apples per tree were harvested.

METHOD

Planting material

The experiments were mainly carried out using Cox's Orange Pippin trees on M.9 stock about two years old. These trees were utilized in three growth periods lasting from flowering till harvest. To shorten the period between experiments the trees were given a cool treatment at 4–5°C for two to three months to induce flowering (Doeksen, 1966; Roach *et al.*, 1957). During cool storage the trees remained in nutrient solution or were put into a vessel containing moistened peat. A single experiment was carried out using James Grieve on four-year-old M.9 stock.

Before placing the trees in water culture the roots were heavily pruned. The remaining root system was then disinfected by treatment with 0.01 % chloramine T solution (sodium-tosylchloramine). The trees were then mounted in the lids on the tubes in such a way that the graft joint remained above the solution.

Nutrient solution

The nutrient solution was prepared according to specifications given by Steiner (1961). Fresh solution was supplied each week, after draining off the old solution by means of an outlet at the bottom of the tube.

Circulation system

The whole apparatus is shown in Figure 1; it consists of a double-walled vessel A and a tank E for collecting the overflowing solution after passage through the tubular inner vessel. It is constructed using a non-transparent grey plastic (polyvinylchloride). From E the solution is returned to A by pump H. At point K the solution drops freely into A allowing oxygen to be absorbed. Absorption can also occur at E, where the solution drops from channel D.

The construction of A is clearly shown in Figure 1—III. It consists of a large tubular vessel (diameter about 38 cm) mounted in a rectangular case; the space between being filled with an insulating substance (Tempex). Four large lids B are located along A, each in turn carrying a smaller lid C, which consists of two pieces. The trees are mounted in the holes L and fastened with foam plastic. As lid C is divided into two parts, the trees can easily be taken out of the tube even if they have a reasonably large root mass. The holes M in the lids are provided for observation of the roots and can be closed by rubber bungs.

The total content of the main vessels and connecting tubes is about 150 dm^3. The capacity of the pump for circulating the solution is 32 dm^3 per minute. Transpirational losses can be made up by filling up to a mark in tank E.

Extra aeration is provided by a number of porous blocks, O, supplied with air through tube N. The porous blocks are fastened on to a plastic ring, fixed inside the tube.

The circulating solution is cooled by means of a copper spiral in E. If the temperature in vessel A rises too high the contact thermometer P switches on a pump, which circulates coolant through coil F; the temperature can be controlled using thermometer R.

Ambient temperatures

The temperature of the nutrient solution is varied during the growth period; during the first month it is kept at 10–12°C, at 14°C for the second and third month, 16°C for the fourth month and in the last month at 17°C.

Air temperature in the controlled glasshouse is set at the following day and night values: in the first month 10–15°C and 10–12°C, in the second month 20°C and 14°C, and in the third, fourth and fifth months 25°C and 15°C.

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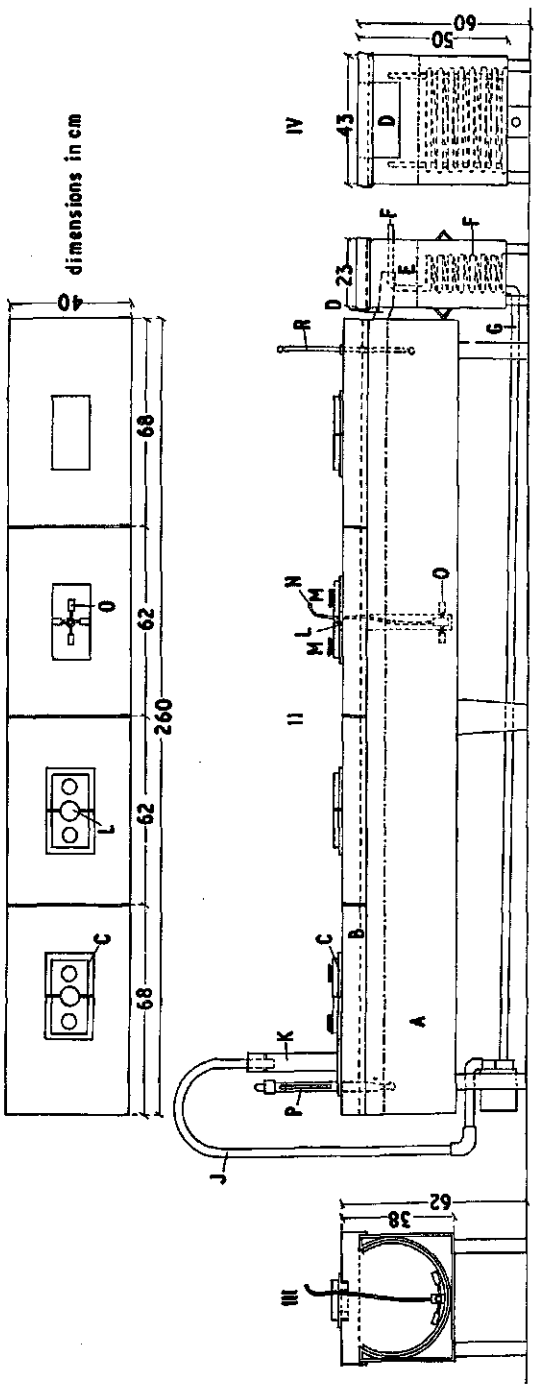

FIG. 1
Schematic drawing of the culture vessel (dimensions in cm).
I View from above
II Front view
III Transverse section at the point of insertion of a tree
IV Side view
A = main culture vessel (tubular); B, C = lids; D = outlet for overflow to E; E = cooling tank; F = cooling spiral; G, J, K = tubes; H = pump; L = hole for insertion of the trees; M = observation hole; N = aeration tube; O = porous block; P = contact thermometer; R = control thermometer; —·—·— level of the solution.

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