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DEVELOPMENT AND APPLICATION OF A HYDROPONIC TECHNIQUE TO INVESTIGATE MOISTURE STRESS IN PLANTS

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SUMMARY

A system to examine moisture stress in plants was devised. It involves a hydroponic technique and uses polyethylene glycol (M.W.1500) to apply the stress when desired. This results in a quick, reliable method of exerting a controlled degree of moisture stress. The technique involves continuous automatic recycling of nutrient solution. Application of the system to moisture deficit studies is discussed.

I. INTRODUCTION

It has been shown that maize suffers extensively from moisture stress at anthesis. Previous attempts to establish the correlation between moisture stress at anthesis and grain yield in maize were partially successful. Nutritional and moisture status of the plants was variable and unco-ordindated stress effects resulted.

It was therefore resolved to use a hydroponic technique to overcome the inadequacies of the previous method, and to use a high molecular weight substance, polyethylene glycol, to induce a rapid osmotic stress in the plants.

The site for the trial was a temporary glasshouse at Hermitage Research Station, near Warwick. To test the technique a number of types of plants were grown in pots filled with sand. When they had attained an advanced vegetative stage, they were stressed for moisture.

I. *Components of System*

A schematic diagram of the system is shown in Figure 1, and a description of the components follows.

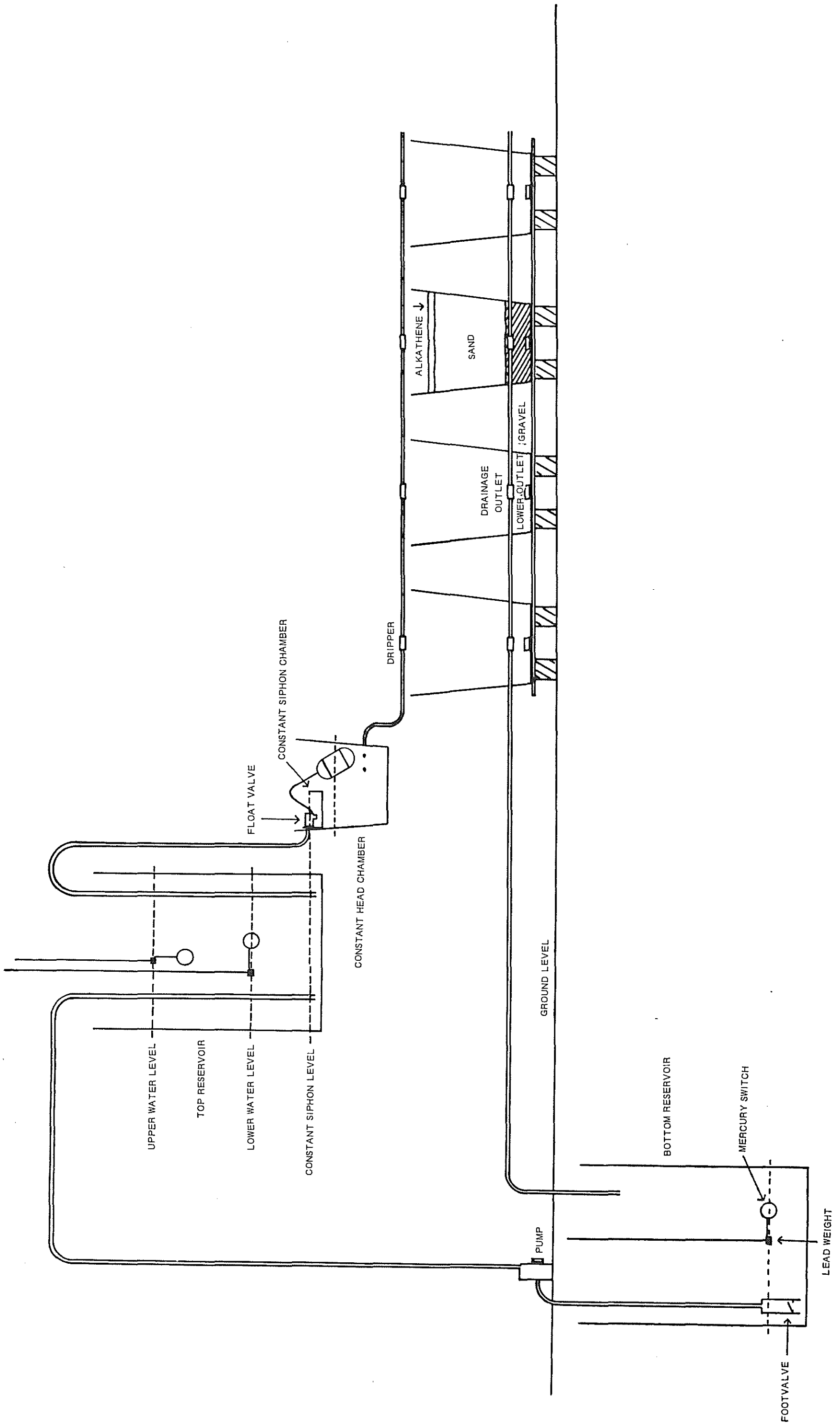

Fig. 1.—Schematic diagram of system.

Top reservoir.—As shown in Figure 2.

This consisted of a 200 litre steel container lined with polythene to obviate corrosion of the metal by the nutrient solution and to minimize precipitation of salts. Light was excluded to prevent algae building up in the nutrient solution. An automatic refilling device was fitted to the top reservoir to ensure a continuous supply to the constant head chamber.

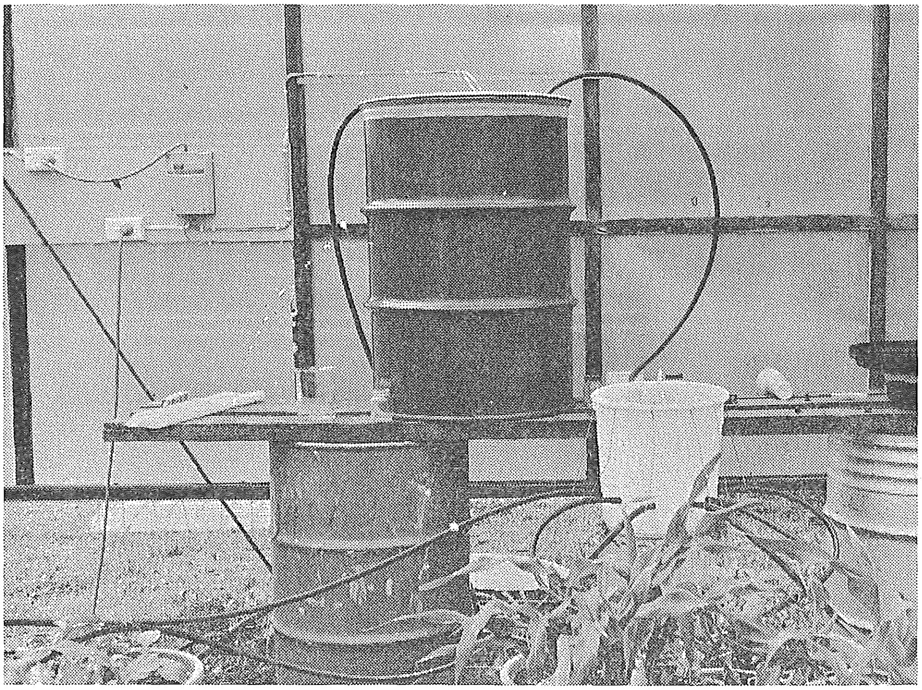

Fig. 2.—Top reservoir and constant head chamber. This view shows the contactor with cables leading to mercury switches in reservoirs. In the centre is the top reservoir with a polyliner. A polythene pipe leads to a constant head chamber which has six outlets.

Constant head chamber.—This is also shown in Figure 2. Its function was to maintain a supply of nutrients to the plants under a constant head, allowing equal quantities of nutrient solution to be issued to each dripper. It was supplied from the top reservoir *via* a 13 mm polythene pipe. One end of the polythene pipe was placed at the bottom of the 200 litre container, and the other end was inserted through the wall of the constant head chamber. A plastic float valve operating at this end ensured that the chamber head was constant (Figure 3). Brass fixtures on the float valve were coated with enamel paint to prevent metal contact with the solution.

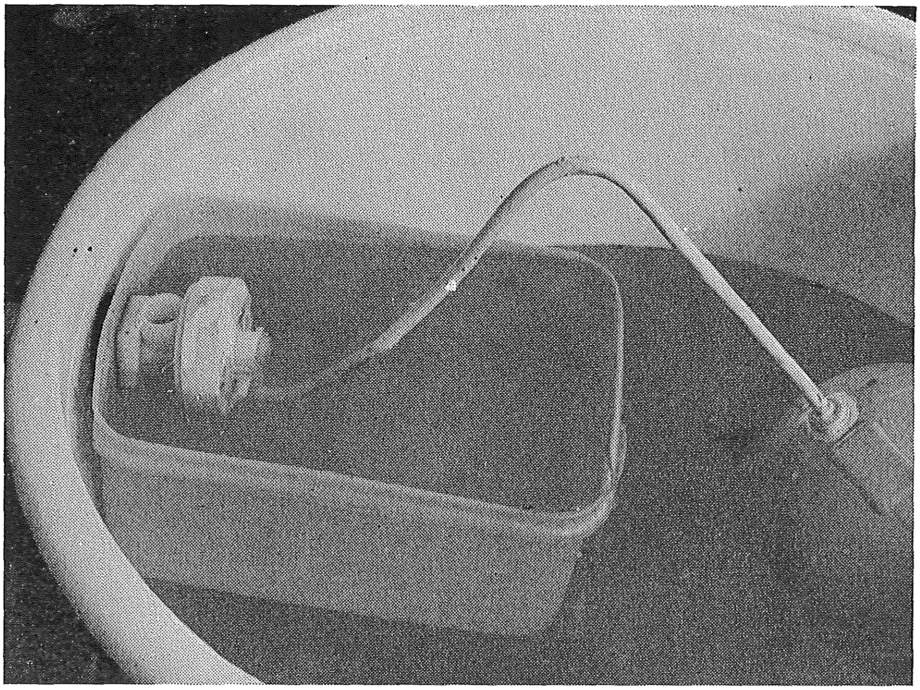

Fig. 3.—Constant head chamber. Inside view shows plastic float valve assembly with syphon chamber. Note brass fittings coated with enamel.

To avoid breaking the syphon from the top reservoir, a small overflow chamber was fitted to the inlet on the constant head chamber. Light was excluded from the constant head chamber, which had a capacity of approximately 16 litres.

Six outlets were drilled into the constant head chamber in a hemispherical pattern facing towards the pots. They were situated 7 cm from the base to enable settling of any foreign material that would have clogged the drippers. Grommet take-offs (13 mm) were inserted into these outlets, and lengths of 13 mm polythene tubing were attached to the take-offs.

Drippers.—For the purposes of this experiment, there were six rows of seven pots, with a length of polythene tubing per row. Black tubing was used to prevent algal growth in the tubes. A 13 mm dripper supplied each pot. The drippers were cleanable and had a maximum capacity of 2·3 litres per hour.

The hydraulic head used on the drippers was 40 cm and the output per dripper was 100 ml/hr. This ensured adequate nutrient solution for actively growing plants. Equilibration of the drippers was carried out after all the air had been excluded from the tubing and the ends of the tubes sealed. Supports were used to keep the drippers at an equal height.

Pots.—Plastic pots with a capacity of 45 litres were used in the experiment. Two holes were drilled into each pot, one at the base and the other 8 cm above the base (Figure 4). Into each of these holes was inserted a 13 mm grommet take-off.

Fig. 4.—Lower parts of pots, showing upper outlets leading to bottom reservoir and stoppered lower outlets.

The pots were then filled with 9·5 mm bluemetal to a depth of 10 cm. This provided adequate drainage for both holes with no loss of sand. Thirty-two litres of sand were put over the gravel. The sand was thoroughly washed with rain water to remove as much debris as possible.

Before planting, black alkathene granules were spread on the surface of the sand to a depth of 2 cm. This provided a mulch to minimize moisture loss and to promote consistent wetting across the surface of the pots. It also prevented light from reaching the sand and causing algal growth.

Tee pieces were connected to the grommet take-offs in each pot. The lower outlets were corked, and the upper outlets were joined to each other by polythene tubing. One end of the polythene line was stoppered and the other end emptied into the bottom reservoir. (Figure 1).

The function of the two outlets was as follows. Throughout the normal growing phase of the plants, the upper outlet was used to drain the excess nutrient solution into the bottom reservoir. This meant that there was a supply of nutrient solution 8 cm deep in the bottom of the pot that the plant could draw on if there was a breakdown in the supply system. When the plants were ready to be stressed, the upper outlets were stoppered and the polyethylene glycol fed into the system. After the polyethylene glycol had stressed the plants the lower outlets were opened to allow the chemical to be flushed out of the system and the plants resumed growth.

Bottom reservoir.—The upper outlets from the six rows of pots drained into the bottom reservoir (Figure 5). Its structure was identical to that of the top reservoir—it had a capacity of 200 litres, was polythene lined and had a lid to minimize algal contamination.

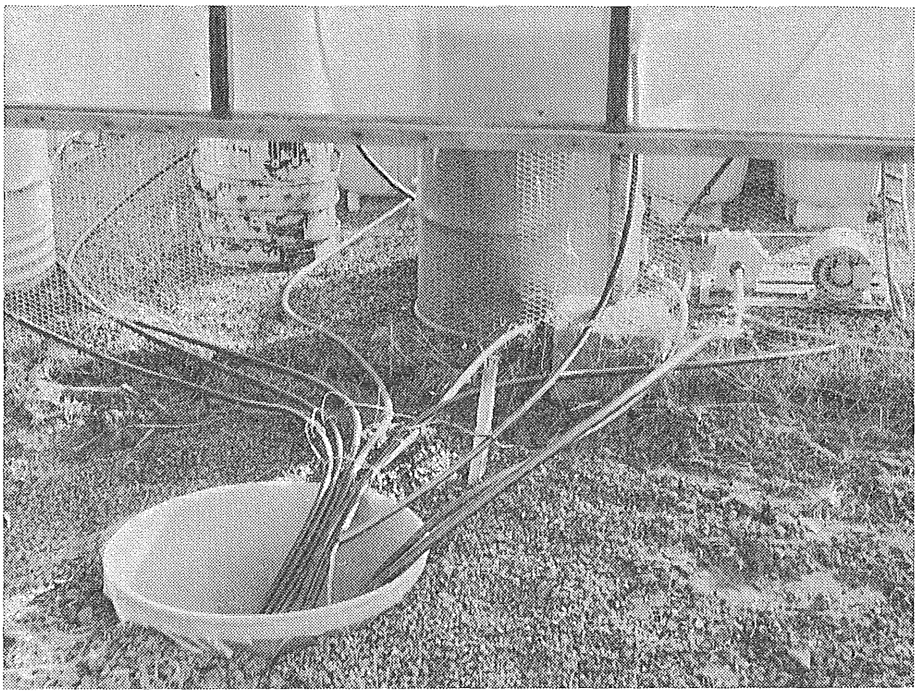

Fig. 5.—Bottom reservoir. Drainage pipes lead to bottom reservoir. Note plastic envelope to ensure protection from corrosion. 18 mm polythene tubing leads from the footvalve at the bottom of the drum to the fibreglass pump.

Refilling system.—A feature of the design of this system was an automatic replenishment circuit for the top reservoir from the bottom reservoir. From the bottom reservoir, an 18 mm polythene tube fitted with a footvalve led to a fibreglass centrifugal pump (Figure 5), driven at 1 440 r.p.m. by an 0·25 kW electric motor. The 13 mm outlet emptied into the top reservoir. The footvalve was fabricated from PVC connections with a flap of rubber attached. It worked on a principle similar to a "clapper valve" in a windmill.

Automation of the system was achieved by a circuit in which were placed several mercury switches. These worked on the principle that they were enclosed in a spherical float and were suspended in the container with a lead weight 20 cm from the sphere (Figure 6). The lead weight was coated with resin to eliminate contamination of the solution.

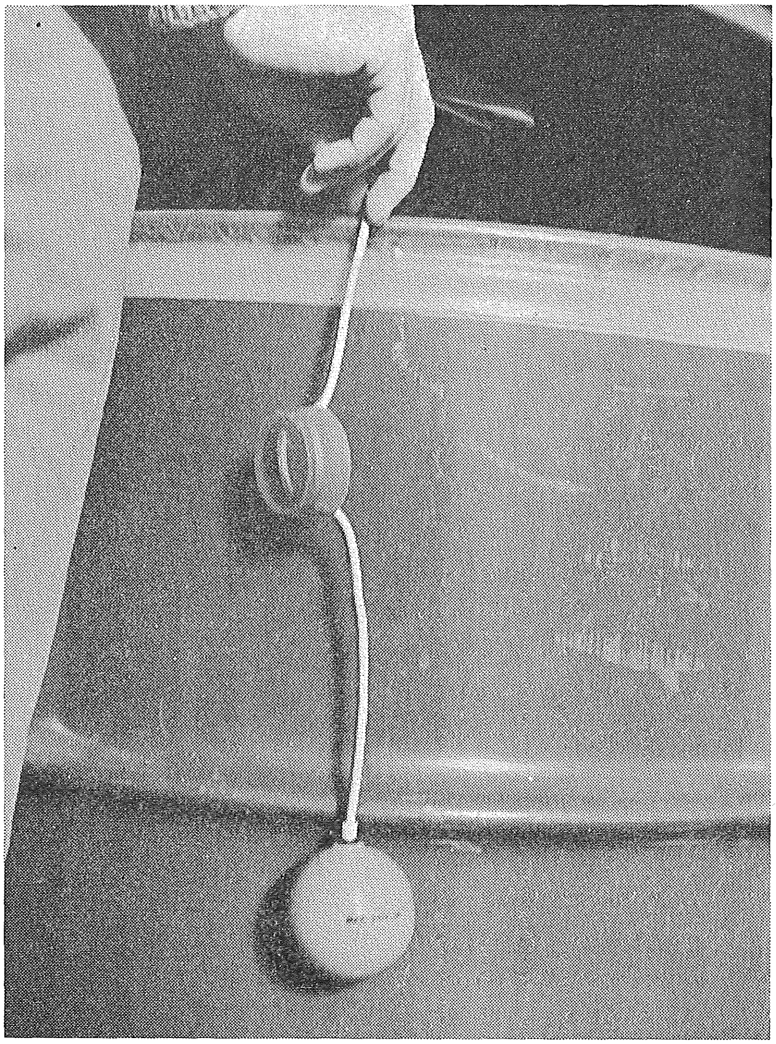

Fig. 6.—Mercury switch. The lead weight is encased in epoxy resin.

As the level of the solution rose, the float was displaced, causing mercury to flow within the sphere and make or break contact. This contact operated the electric motor.

Two switches were suspended in the top reservoir (Figure 7). One of these was situated 15 cm from the top and the other just above the lower limit supply level. These were arranged so that, before the reservoir was drained, the contact on the bottom sphere would close and start the pump.

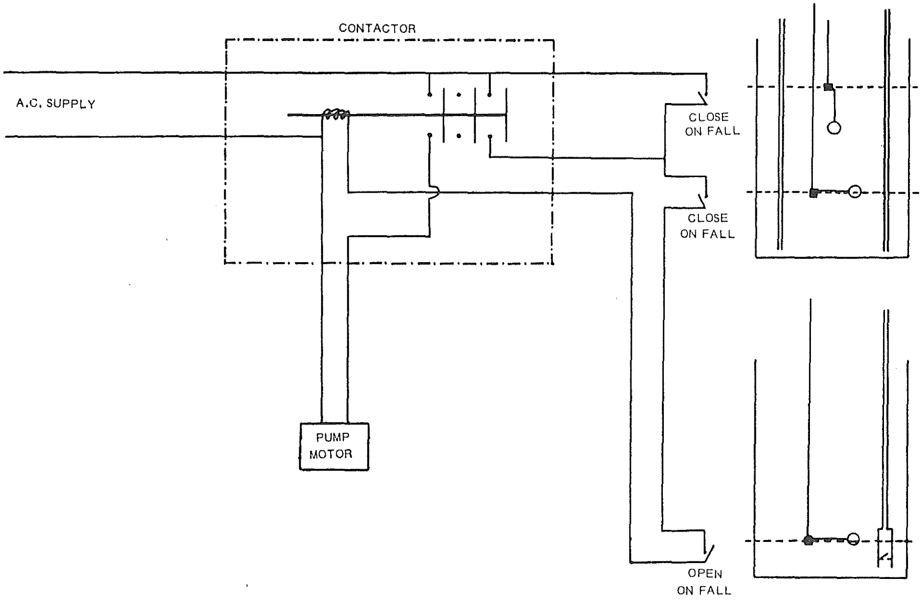

Fig. 7.—Electric circuit for mercury switch.

When the top container was almost full, the top sphere floated up, the mercury flowed and broke contact, and the pump stopped. This rendered the refilling of the top drum completely automatic, provided there was always enough solution in the bottom reservoir.

To safeguard the pump running dry if there was not enough solution in the bottom reservoir, a third sphere was placed in the bottom reservoir, 15 cm from the base. This was so placed in the circuit that, if the sphere dropped below 15 cm, the contact was broken and the pump stopped. Similarly, if the level of the bottom reservoir was initially lower than 15 cm, the pump would not start, regardless of the nutrient level in the top reservoir.

Nutrient solution.—The solution used was Hoagland's solution made up with a domestic water supply. Distilled water was not necessary as the level of ions was not critical for the successful running of the trial. It is thought, however, that for continued use of the system, distilled water would be desirable.

As an added source of iron, several 7 cm nails were placed in the constant head chamber. Change of the solution was effected every 2 weeks. This eliminated differential uptake of the solution by the plants and helped to keep the system clear of debris.

Polyethylene glycol.—Polyethylene glycols (PEG) are high molecular weight polymers produced by the reaction of ethylene glycol and water. The molecular weights range from 200 to 20 000 and have wide use in industry.

Molecular weight 1500 was chosen for this trial because of its reasonable solubility in water and its ability to induce osmotic stress readily. This is done by decreasing the osmotic potential of the rooting medium. Uptake of M.W. 1500 by plants is minimal.

Plants used.—Six varieties of plants were established: Hunter River brown onions, telephone peas, Imperial Triumph 615 lettuce, Round Red radish, Hill soybean and PX 616 maize. Growth of the plants was good under the prevailing artificial environment (Figure 8), except that there was a growth differential across the pot related to distance from the dripper. This could be corrected by planting equidistant from the dripper.

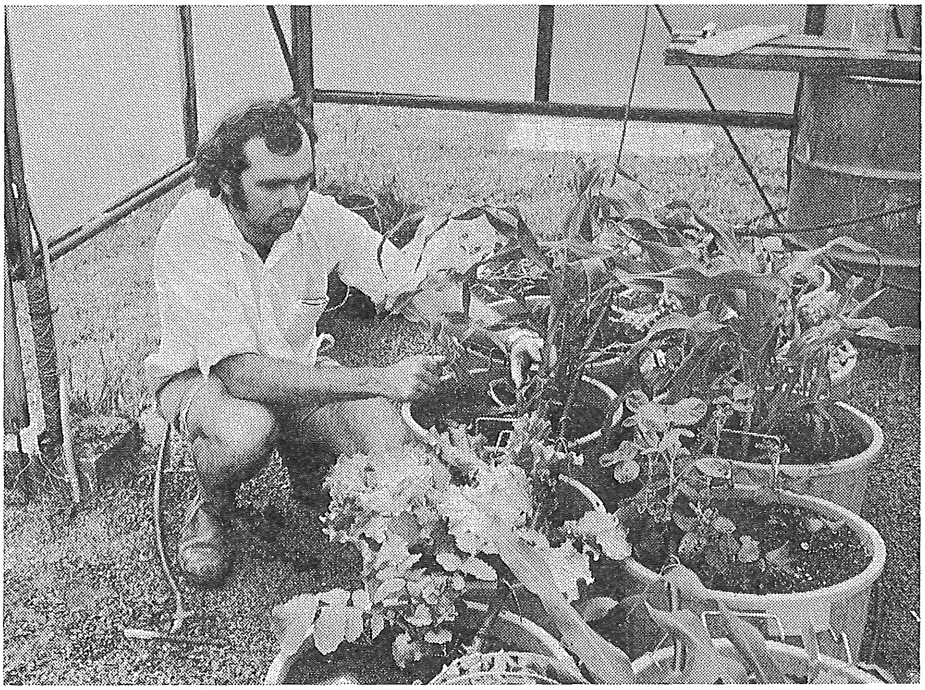

Fig. 8.—Plant growth. This view shows plant growth achieved after several weeks. Note varying size of plants across the pot.

When the plants had reached an advanced vegetative stage, the pots were allowed to drain for several days. The drain holes were stoppered and the pots irrigated with PEG solution. After several hours during which the plants wilted satisfactorily, the pots were flushed out with water through the lower drain holes. These were then sealed, nutrient solution was admitted and the plants resumed growth.

II. APPLICATION

High molecular weight compounds inducing moisture stress have been used successfully by Doley (1970) and Singh, Paleg and Aspinall (1973), but detailed accounts of the techniques used have been rather limited.

The system outlined above can be used in any situation (where systemic diseases can be controlled) to produce a range of controlled moisture stresses. This can be achieved by sealing off each pot and applying different concentrations of PEG.

III. ACKNOWLEDGMENTS

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