Root Research Phytotron

By KIYOSHI SHIMURA

Chief, 1st Crop Laboratory, Upland Farming Division,
Tokai-kinki National Agricultural Experiment Station

Studies on upland irrigation, such as water consumption of crops and mechanism to bring about irrigation effects, have been pursued at our Upland Farming Division, and satisfactory results have been obtained from these studies.

It is believed, however, that in order to get more effects of irrigation the importance of conducting studies on roots which absorb water must be taken into consideration.

Furthermore, in western Japan, very little humus is found in the soil, it being predominantly fine clay type with very little water content and most of the soil is in too shallow layers to assure good development of the root system.

Therefore, it is especially desirable to develop a method to let roots grow more deeply in order to improve the effectiveness of irrigation.

From these points of view, the need for laying more emphasis on root study was felt very keenly, and based on the preliminary tests conducted since 1964, it was decided to establish the Crops Roots Physiological Experiment Laboratory, which can be described as a small-size phytotron, and finally in the autumn of 1969, the laboratory was completed. (Fig. 1)

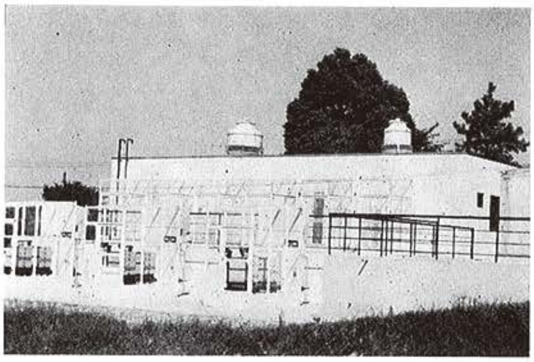

Fig. 1. Outside view of phytotron.

Since that time, there have been repeated trial operations and its full-fledged use has just been started. The following is an outline of the laboratory.

Description of buildings

The laboratory consists of spray culture facilities without soil, growth cabinet adjustable for both temperature and humidity, and a green house with movable roof. The roof of the green house automatically closes when rain falls and opens again when the weather is clear. The floor is made of bricks placed with narrow splits. By permitting water to flow in the splits, excessive rise in temperature around such culture base as pots can be avoided. Explanations will be made on the two other parts of the laboratory, showing their plane figure in Fig. 2 and side view figure in Fig. 3.

The ground is about 250 m^2 wide. Outside the ground floor, 6 top cabinets for spray culture and 3 growth cabinets are installed. Air conditioners, recording panels, gas bombs storage, and a preparatory room are on the ground floor. Air conditioners, gas analyzers,

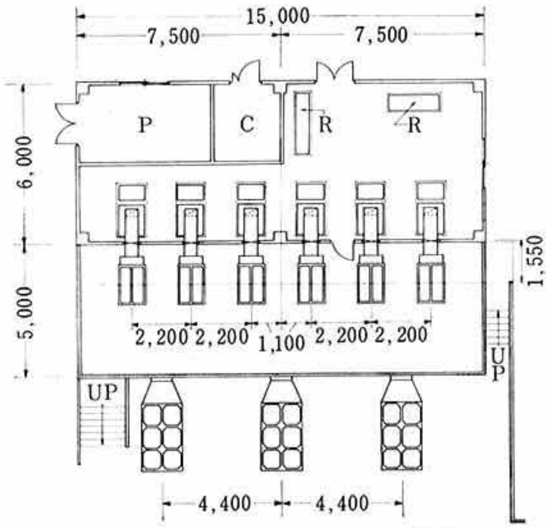

Fig. 2. Plane figure of ground floor.
S: Spray culture cabinet.
G: Growth cabinet.
R: Recorder.
C: CO_2 gas store room.
P: Preparatory room.

etc., and root cabinets for spray culture are found in the basement.

Spray culture equipment

As seen in Fig. 2, there are 6 spray culture equipment of the same capacity. Each of them has a 5 cm thick floor with 12 holes of 50 mm in diameter for planting crops, and this floor constitutes the partition between the top and root cabinets. The top cabinet is 100 cm × 150 cm × 250 cm (height) in dimensions. Pair glass is used, except its northern side, to avoid the lower light intensity because of dews formed on the pane in case of high humidity.

The root cabinet is 100 cm × 150 cm × 250 cm (height) in dimensions. Around the inner walls of the cabinet, 45 nozzles for spraying nutrient solution are installed in five different heights to enable spraying from an adequate height depending upon the root growth stage.

A part of the bottom floor forms a ditch for storing nutrient solution with 50 *l* capacity. No metal is used for those equipment as well as the pump and pipes in order to avoid pollution from harmful matter due to corrosion by nutrient solution especially attributed to melted heavy metals, but all is made of hard polychloride vinyl.

The diagram of environmental conditioning

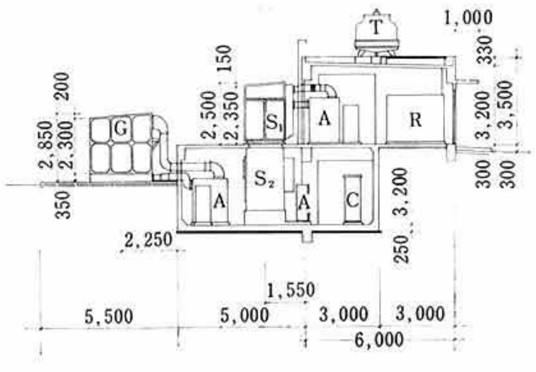

Fig. 3. Side view figure.
S_1: Top cabinet of spray culture. S_2: Root cabinet of spray culture. G: Growth cabinet. A: Air conditioning apparatus. C: CO_2 and O_2 analyzer. R: Recorder. T: Cooling tower.

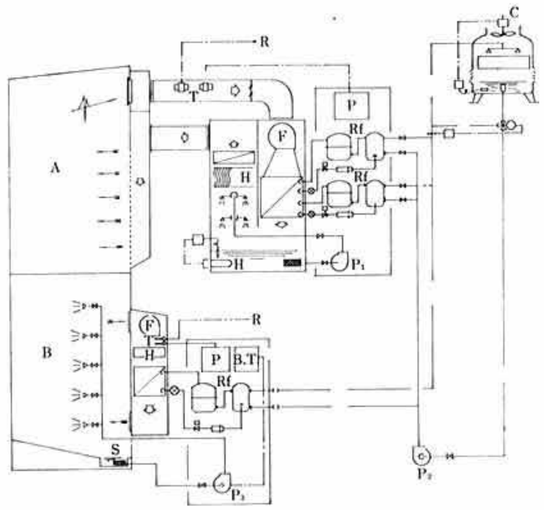

Fig. 4. Air conditioning system of spray culture cabinet.
A: Top cabinet. B: Root cabinet. T: Thermo bulb. R: Recorder. H: Heater. F: Fan. Rf: Refrigerator. P: Operative plate. B.T.: Bell timer for controlling spray frequency. P_1: Pump for humidifier. P_2: Pump for cooling refrigerator. P_3: Pump for spraying nutrient solution. C: Cooling tower. S: Nutrient solution tank.

is shown in Fig. 4 and the controllable ranges in Table 1.

Table 1. Controllable environments and the ranges in spray culture cabinets.

Environmental factors	Ranges
Top cabinet	
Temperature	7~40°C±1.0°C
Relative humidity	60~85%±7% at 15°C 45~85%±7% at 25°C 40~80%±7% at 35°C
Root cabinet	
Temperature	7~40°C ± 1.0°C.
Spray frequency	5~60 sec. at interval of integral number times 5 min.
O_2 concentration	5~21%
CO_2 concentration	0.03~21%

The temperature and humidity of top cabinet and the temperature of root cabinet are adjusted and recorded, and necessary adjustment can be made for day and night time.

The spraying time for nutrient solution can be varied from the minimum 5 seconds to 60 seconds. The intervals between sprayings can be selected by every 5 minutes, or by the multiplication of 5 minutes by integral numbers and varied according to the time of the day or night.

The oxygen density in the root cabinet is analyzed and recorded by a magnetic oxygen analyzer for each root cabinet one by one. According to the results, the magnetic valve which is connected with the pulse timer is opened, so that the oxygen density is adjusted by releasing nitrogen gas supplied from the nitrogen liquefaction tank.

The pressure in the cabinet is maintained at the normal atmospheric pressure with the exhaust trap. The adjustment precision can be maintained at about ±0.5% by adjusting the pulse timer and bypass valve, even when the oxygen analyzer is set at 5% O_2 concentration.

Carbon dioxide density is adjusted by operating two infra-red carbon dioxide analyzers, one for low density (which adjusts either to 0~1% and 0~5%) and the other for high density (0~25%).

The atmosphere in each cabinet is analyzed and recorded one after another, and just as in the case of oxygen, the amount of carbon dioxide is adequately adjusted by letting in carbon dioxide from the bombs.

Density of oxygen and carbon dioxide can be adjusted either singly or simultaneously.

Growth cabinent

As seen in Fig. 2, there are 3 growth cabinets of equal capacity. One cabinet is 150 cm × 250 cm × 250 cm (height) in dimension.

Explanation on the air-conditioning system will be omitted since it is exactly the same as in the top cabinet for spray culture, except that upward ventilation is made from the holes on the bottom.

Inside the growth cabinet, there is an automatic irrigator as a special feature of the cabinet. This system is diagrammed in Fig. 5.

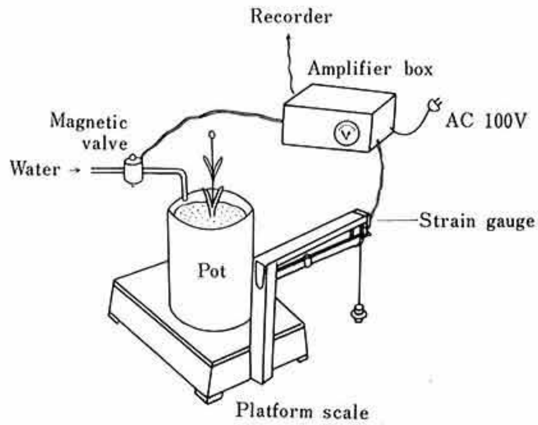

Fig. 5. Automatic irrigator.

A pot in which crops are planted and all the preparations made for the test, is put on the platform scale and after balancing it with the weight, the strain gauge and the beam of platform scale are fixed.

When there is any change in the load due to transpiration and evaporation, pressure is added to the strain gauge. This pressure is then changed into electric signals within the amplifier box and the signals are recorded.

When the change in the pressure reaches the value previously determined in the amplifier, the magnetic valve connected with the water source opens, and water is supplied until the initial stage is restored. Under this system, it is possible to vary the range of water content, depending upon the value of change in the load for automatic supply of water.

The above are the cardinal points about which we paid special consideration in the construction of the phytotron. In the future, utilizing the facilities, studies will be made on effects of top and root environments, such as temperature, humidity, water content to be irrigated and composition of root atmosphere on root development.