Nordic Hydrology (1971), II, 79–92
Published by Munksgaard, Copenhagen, Denmark

LYSIMETERS WITH RAINFALL AND SOIL WATER CONTROL

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The lysimeter installation described comprises 36 concrete tanks each with a soil surface of 4 m^2. The installation is useful for plant growth experiments under natural conditions involving different treatment combined with various controlled water supplies. The ground installation is at least 20 cm below the soil surface and tillage can be done with field implements. The lysimeter tanks are provided with a drainage system which can drain the soil at the bottom (100 cm depth) to a tension of up to 100 cm. A constant ground-water table at less than 100 cm soil depth can also be maintained. The soil moisture content at different depths is determined from an underground tunnel by use of gamma radiation equipment in metal tubes horizontally installed in the soil.

Rainfall is prevented by a movable glass roof automatically operated and controlled by a special rain sensor. Water is applied to the soil surface with a special trickle irrigation system consisting of a set of plastic tubes for each lysimeter tank and controlled from the tunnel. Fertilizers in controlled amount can be applied with the irrigation water.

For plant growth experiments involving water control and measurements, lysimeters are often used. Several lysimeter installations exist and some are described in the literature. A rigid lysimeter installation has recently been described by Keitera & Maasilta (1970). Weighable lysimeters of the monolith type are described by Makkink (1953). Each lysimeter tank can be weighed by a movable weighing machine running on rails. Weighable and continuous recording installations are described by, among others, Pruitt & Angus (1960), Aslyng & Kristensen (1961), and Van Bavel & Myers (1962). An evalution of the hydrology by monolith lysimeters is given by Harrold & Dreibelbis (1967). In 1964 a lysimeter installation was built by the Hydrotechnical Laboratory, The Royal Veterinary and Agricultural University, Copenhagen, on the University experimental farm "Højbakkegård" about 20 km west of Copenhagen. For effective control of the water supply a movable automatically operated glass roof and an irrigation installation were established 1966/67.

THE LYSIMETERS

The lysimeter installation consists of 36 lysimeter tanks each 2 by 2 m and 1 m deep. The tanks are placed in two rows divided by a 2 m wide and 44 m long underground tunnel, Fig. 1. All the lysimeter parts, except the tunnel entrance and the ventilation shafts, are 20–25 cm below the soil surface. The installation is made of reinforced concrete. The tunnel walls and bottom are 25 cm, the walls and bottoms of the tanks are 15 cm thick. The roof is 12 cm thick and intensively reinforced by iron bars.

The tank bottoms are slightly tilted toward the tunnel wall. The outlet consists of a vertically mounted iron pipe, 95 cm long and 11.4 cm in diameter. This pipe continues in a 90° bending through the tunnel wall and ends with

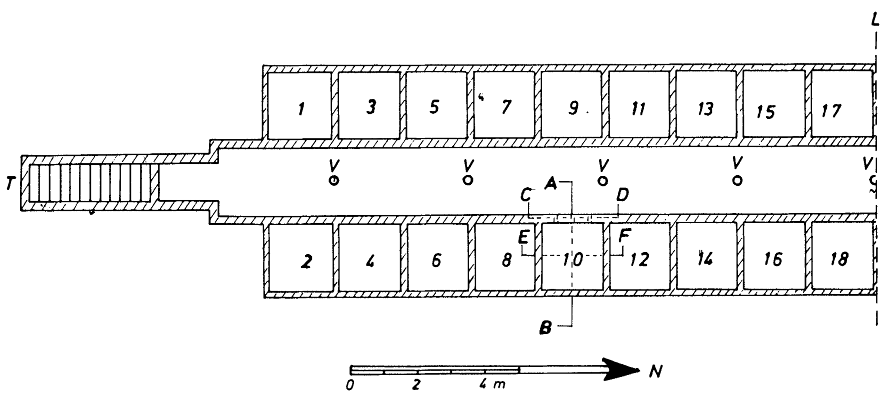

Fig. 1
The lysimeter installation seen from above.
T = tunnel entrance. V = ventilation shaft. L = line of symmetry, see also Figs. 2 and 3.

a stopcock in the tunnel, on the tank bottom is placed a 5–10 cm layer of fine sand (dune sand). The sand extends through the vertical part of the outlet pipe, while the bent part is filled with gravel. Sand and gravel are divided by fibre glass material, Fig. 2. The purpose of the sand is to facilitate drainage and to obtain a certain suction in the lysimeter soil. The maximum tension in the lower part of the soil is 100 cm. By connection to an elevated container with constant water level, less tension can be obtained or constant ground-water level can be maintained.

The edges of the outer tank walls are tilted away from the lysimeter and the edges of the dividing walls are tilted equally to both sides. For each lysi-

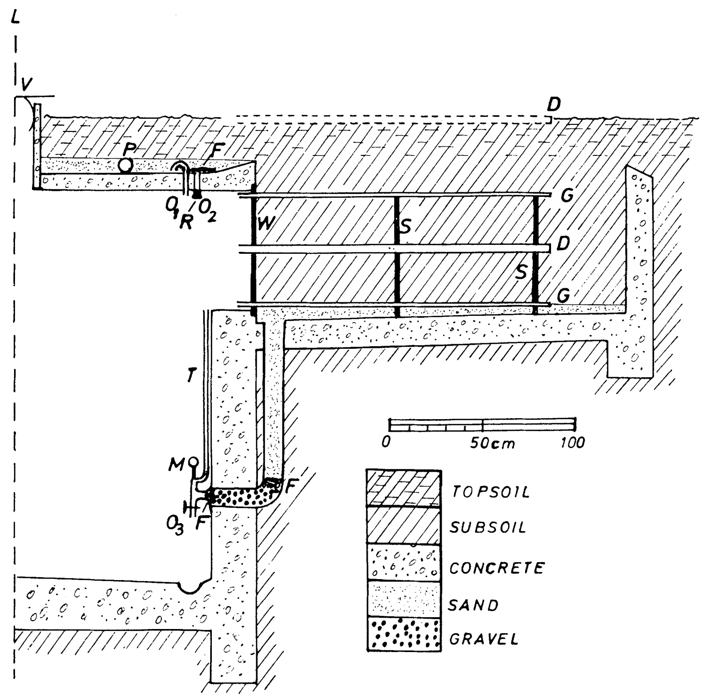

Fig. 2.
Cut A-B in Fig. 1.
L = line of symmetry. V = ventilation shaft with shield. P = perforated plastic tube for subirrigation. O_1 = outlet pipe for ground water at the roof of the tunnel. O_2 = outlet pipe for total drainage. O_3 = main outlet with stopcock. F = fibre glass filter. R = rubber stopper. G = access pipes for gamma ray source. D = access pipes for gamma ray detector. W = plastic window. S = supports for the access pipes. T = water table regulation.

meter tank there are three access openings in the wall facing the tunnel. Each of the openings is 10 by 70 cm, and closed by a plastic plate, allowing moisture measurements and sampling of soil air, etc., Figs. 2 and 3. As a permanent installation three iron pipes are mounted horizontally in the middle access opening for noting changes in water content estimated from measurements of soil density changes by use of the gamma transmission method, e.g. Jensen & Overgaard (1966). The lower pipe rests in the sand layer. The distance between the pipes supported by the plastic plate and a plastic support is 30 cm.

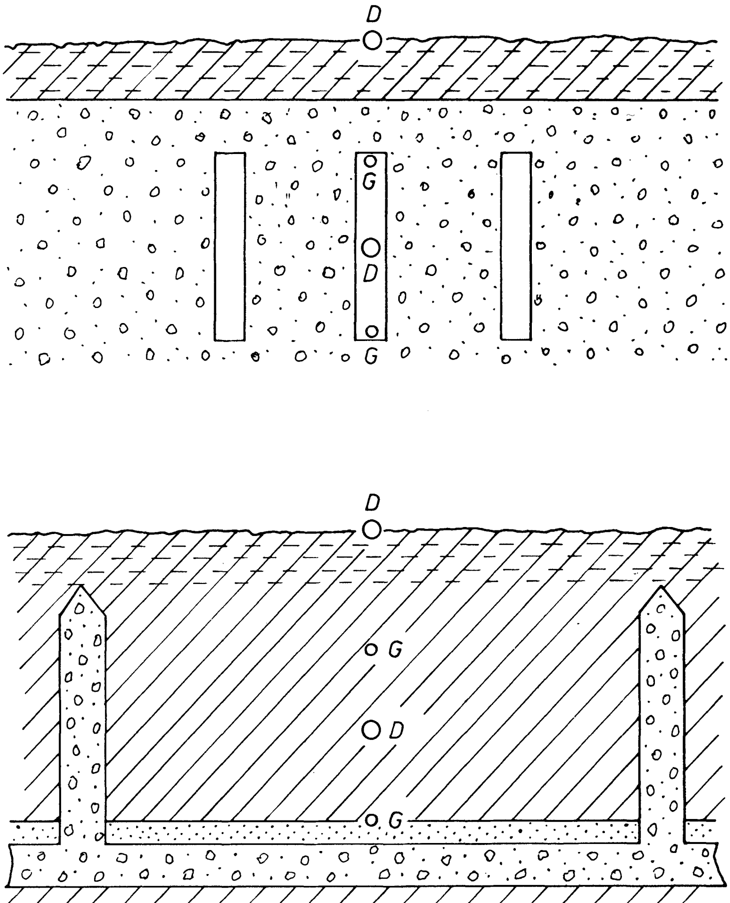

Fig. 3.
Cut C-D and E-F in Fig. 1. Explanations as Fig. 2.

A fourth pipe may be placed on the soil surface in order to make measurements in the upper 40 cm soil layer, Figs. 2 and 3.

The tunnel roof is also covered by a thin layer of fine sand, and is supplied with water inlets for subsoil irrigation and water outlets for either total drainage or for maintaining a 2–3 cm layer of water in the sand, Fig. 2.

Tanks 1–6 were filled with coarse sand resembling poor sandy soil. The remaining tanks (7–36) were filled with the local clay loam soil, excavated during the construction. The sand is homogeneous material with no division between topsoil and subsoil. The clay loam soil was during excavation divided into two types (topsoil, upper 30 cm; and subsoil, 30–100 cm). Each of the two soil types was mixed and the tanks were filled with subsoil, so that 30 cm was left for topsoil. The textural composition of the soils is given in Table 1.

THE MOVABLE ROOF

The roof is a green house roof reinforced with spars of iron pipes 4 m apart. On these spars are mounted supporting and guiding wheels. The roof rests and runs on iron rails consisting of 120 mm H-iron. The rails are about 2 m above the soil surface, carried by 100 mm H-iron, mounted 4 m apart in concrete blocks extending about 1 m below soil surface.

Fig. 4 shows the underpart of the roof construction from above (upper), in profile (lower left), and as a vertical cut along the line A–A (lower right). A cut through one of the gables is shown in Fig. 5, and some construction

Table 1.
Textural composition of the lysimeter soils (%/o by weight).

	Clay loam		Sand
	Topsoil	Subsoil	
Clay (0–2 μm)	16	20	2
Silt (2–20 μm)	17	17	1
Fine sand (20–200 μm)	40	43	45
Coarse sand (ca. 200 μm)	24	20	52
Organic matter	3	0	0

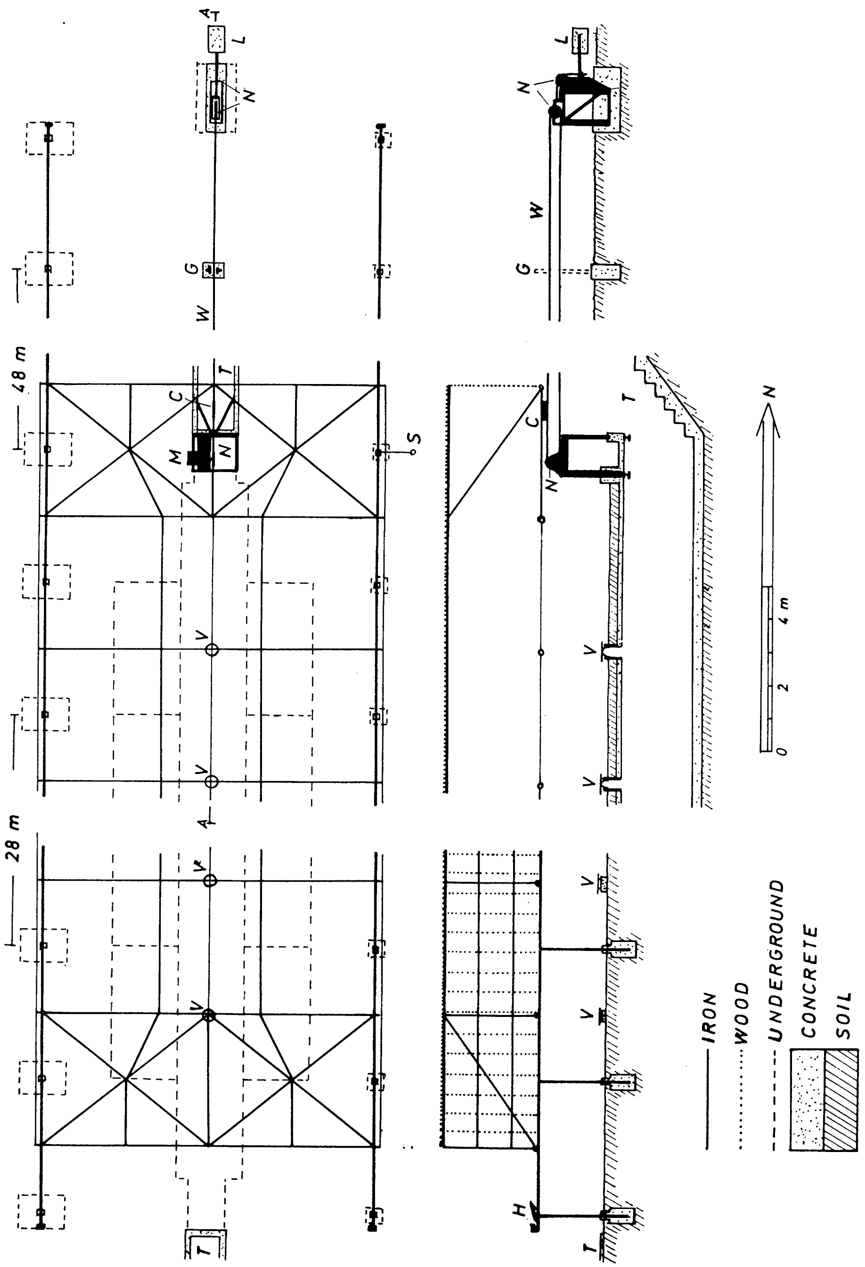

Fig. 4.

Sketch of the movable roof in position covering the lysimeters. Upper part shows rail niveau. Lower left, as seen from the side. Lower right, a cut through A-A.
T = tunnel entrance. V = ventilation shafts. M = electric motor. N = notched wheels for the pulling wire. W = pulling wire. C = wire connection to the roof. G = wire guide. L = load for tightening the wire. H = safety hook and emergency stop.

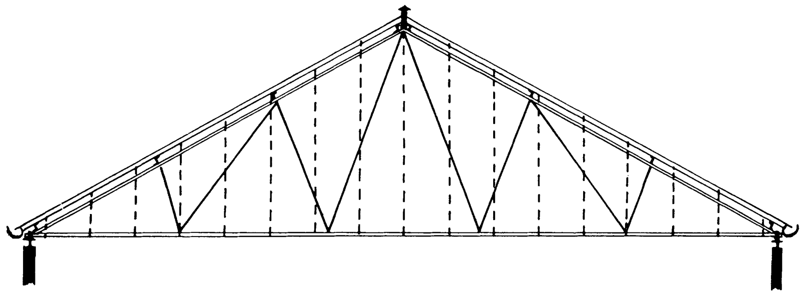

Fig. 5.
Cut through one gable showing rafter and rafter supports. The vertical wooden rafters carrying the glass cover are shown as broken lines.

details of the bearing and supporting system in Fig. 6. Fig. 7 shows part of the lysimeter installation with the roof in parking position. A rain gauge and irrigation implements can also be seen from Fig. 7. The roof is pulled by a 1.5 hp geared electric motor. The motor can be operated both manually and automatically.

In automatic position the roof is controlled by a rain sensor, which basically consists of a piece of filter paper connecting two conducting wires in a second-

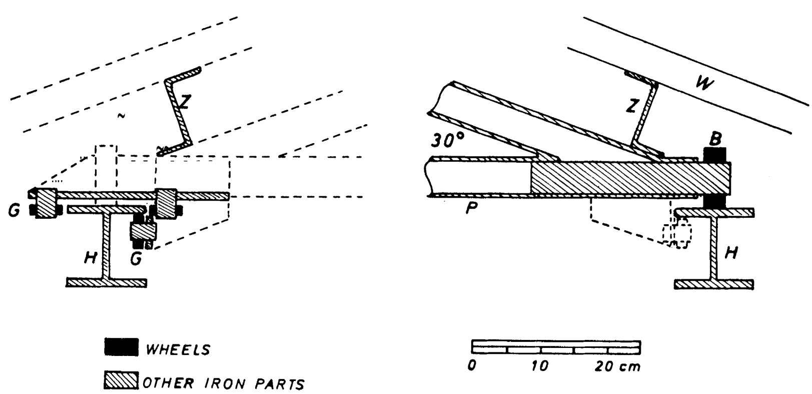

Fig. 6.
Cut through roof supports.
B = bearing wheels. G = guiding wheels. P = 6×10 mm iron pipe. H = 120 mm H-iron profile. Z = 100 m Z-iron profile. W = wooden spars.
Details shown as broken lines are behind the cut plane.

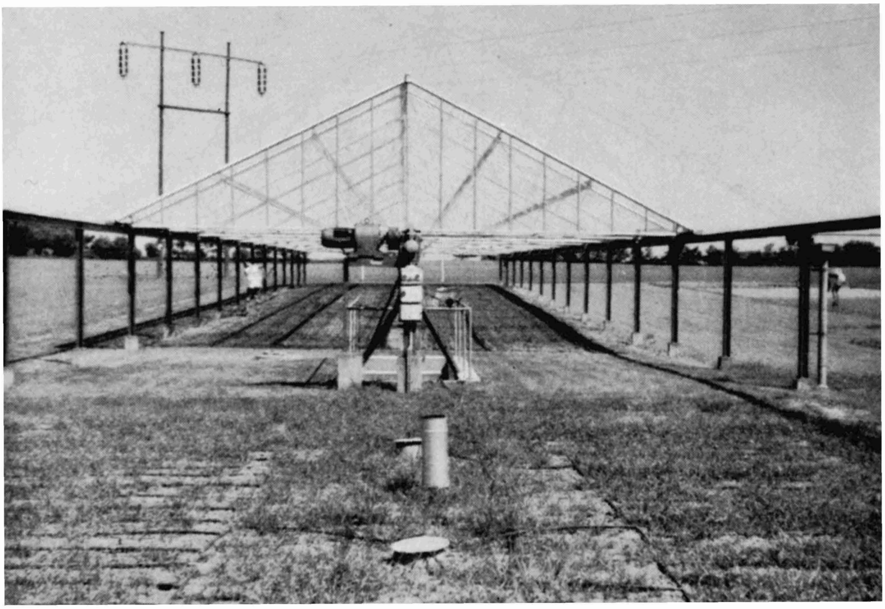

Fig. 7.
Photograph showing the movable roof in parking position. The electric motor and part of the lysimeter area with a rain gauge and trickle irrigation implements on the ground can be seen.

ary electrical circuit with low voltage (24 volts). When the filter paper is dry, its electrical conductivity is very low. When wetted by rain, its conductivity raises to a value high enough to operate a relay which switches on the current to the driving motor.

The roof then moves to a position covering the lysimeter installation. In completely covering position the current to the driving motor is broken, and the polarity of the motor is changed by a switch operated by the roof. When the filter paper of the sensor is dry again, the relay returns to its original position, and the current is switched on. The roof now returns to its parking position where the current is broken and the motor polarity is again changed by a switch operated by the roof.

The sensitivity of the rain sensor can be increased by preparing the filter paper with a hygroscopic salt, e.g. LiCl. The drying period after rain can be shortened by placing heating elements in the rain sensor.

The actual rain sensor consists of a cylinder about 5 cm in diameter and a metal bar in the centre, both serving as conductors. A circular piece of filter paper connects these two conductors as sketched in Fig. 8. To avoid mechanical damage by rain drops, the filter paper is supported by a sheet of glass fiber cloth. A photograph of the rain sensor in operating position is shown in Fig. 9.

The roof moves from parking position to full cover of the lysimeters in about 4 minutes. As rain is required to affect the rain sensor, some rain will fall on the lysimeters, the amount depending on the intensity prior to full cover. As the amount of rain varies along the lysimeter, three rain gauges are placed above the tunnel, one at each end (N and S) and one at the middle (M) of the lysimeter installation.

At N, which is covered less than one minute after start of the roof, from 0.1 to 0.9 mm rainfall has been recorded on rainy days. At S the maximum rainfall for one day amounted to 1.2 mm in 1970.

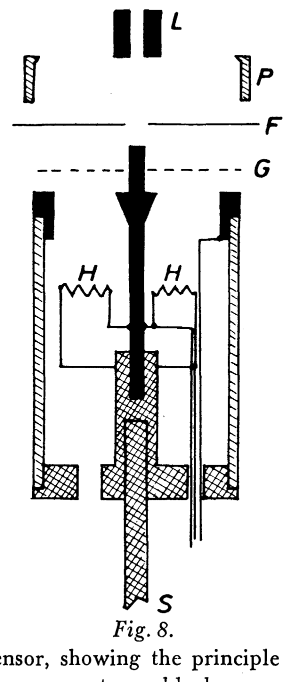

Fig. 8.

Exploded view of the rain sensor, showing the principle of operation. The conducting parts are black.

L = load for contacting filter paper to centre conductor. P = plastic ring for contacting filter paper to outer conductor. F = filter paper. G = fibre glass cloth. H = heating elements. S = bar for supporting the sensor.

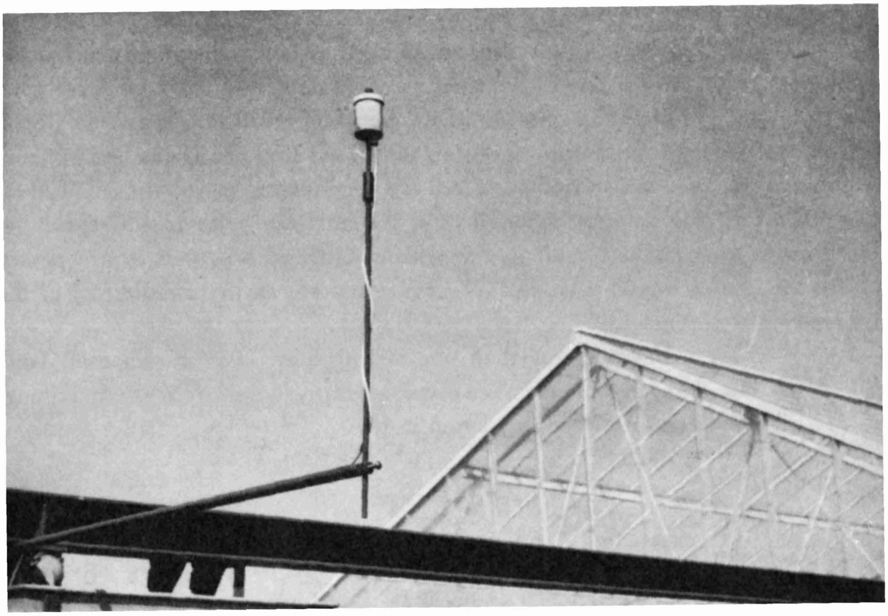

Fig. 9.
Photograph showing the rain sensor mounted and the roof in parking position.

THE IRRIGATION AND FERTILIZING SYSTEM

Water can be supplied to the lysimeter either by keeping the roof at its parking position during rainy periods or by irrigation. A special irrigation system is used in experiments involving different irrigation.

The irrigation implement consists of a specially designed trickle irrigation framework for each lysimeter. The framework consists of plastic tubes (18 mm outer diameter, 1.5 mm wall thickness) in which narrow plastic tubes (3.7 mm o.d., 1.0 mm w.th.) all of the same length (850 mm) are introduced at fixed intervals (200 mm). A sketch of a framework is shown in Fig. 10. The irrigation implements rest on the soil and can remain during the growing period. Details of the irrigation implement may be seen from Fig. 8.

The tunnel roof can be irrigated either by maintaining a ground-water table in the sand layer or by a separate trickle irrigation system. The area between the lysimeter tanks and the roof-supporting iron bars is partly irrigated by the irrigation framework mentioned above and partly by a separate trickle irrigation system. Consequently these areas can serve as border areas for the lysimeters. The water used for irrigation is from the public water supply system. The supply pressure of about 30 m water column is reduced to about 3 m by plastic tubes before entering the trickle irrigation system.

Each irrigation frame covers an area of 6 m². The total number of outlets is 150. The theoretical distances between outlet points are 20 and 22 cm. With the combinations of resistance and water pressure used, the irrigation intensity is about 20 mm (= 120 litres) per hour. The amount of water is controlled by leading the water from one of the narrow tubes into a graduated jar in the tunnel. As 1 mm of irrigation equals 6 litres (6,000 ml) and this is given by 150 tubelets, each single tube delivers 6000/150 = 40 ml per 1 mm of irrigation.

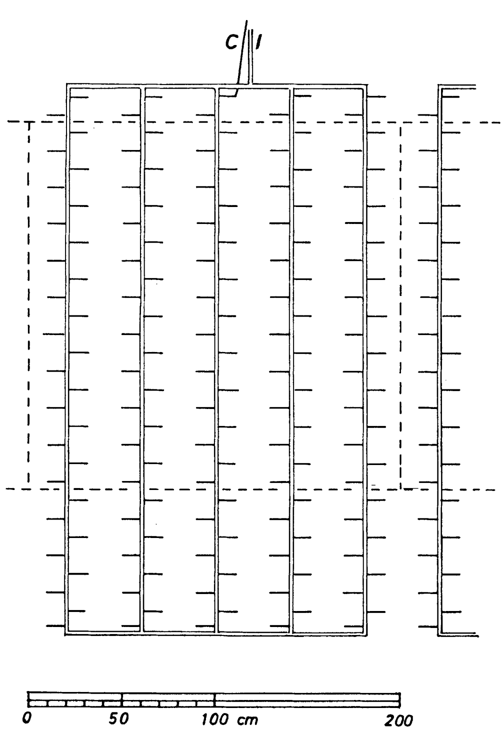

Fig. 10.

Sketch of the trickle irrigation system. The main tubes are shown as double lines. The trickle tubelets, extending about 10 cm to the side from the main tubes, are shown as single lines.

I = water inlet tube. C. = control tubelet.

The broken lines show the position of the lysimeter tank.

Fertilizer can be supplied with the irrigation water, which often is necessary as salts spread on the surface may not be properly dissolved and carried into the soil by irrigation. The amount of fertilizers desired for each lysimeter is dissolved and the solution filled into a 1 litre glass bottle. The bottle is connected to the irrigation system in such a way that the solution is supplied at a rate of 1 litre solution to 120 litres total irrigation. The amount of fertilizer given can within the solubility limits be graduated by varying the concentration of the solution. The principle of the irrigation and fertilization system appears from Figs. 11 and 12. Part of an actual installation appears in Fig. 12.

When emptying the container holding the solution, fresh water is delivered to the top of the solution. The inlet in Fig. 11 is shaped so that water is spread toward the container wall and no mixing occurs. Because of density differences

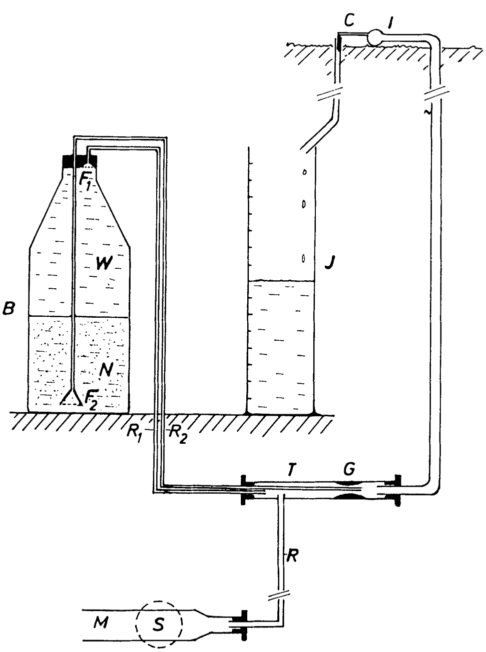

Fig. 11.

Sketch of the water and nutrient supply system.

M = main water supply. S = stopcock. R = plastic tube resistor. B = 1 litre bottle for nutrient solution. R_1 = inflow tube to B. R_2 = outflow tube from B. F_1 = filter funnel for spreading water at bottle inlet. F_2 = filter funnel for cleaning the nutrient solution before entering the irrigation system. W = fresh water. N = nutrient solution. T = tube section for water division. G = gate for pressure reduction. I = irrigation implement on the soil surface. C = control outlet. J = measuring jar.

the solution and the fresh water will remain sharply divided during the irrigation time. This can be controlled by adding colouring matter (e.g., methylene blue) to the nutrient solution.

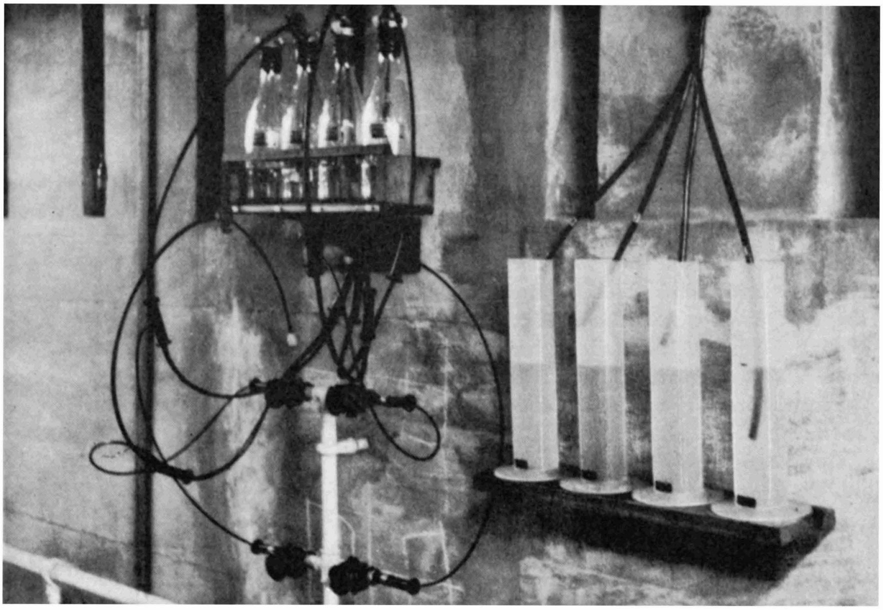

Fig. 12.
Photograph showing the access openings (windows) and details of the irrigation and nutrition supply installations for 4 lysimeter tanks.

ACKNOWLEDGEMENT

The ground concrete parts were built by Mr. O. Fredborg, constructor, Albertslund. The roof was designed and built by O. H. Brödsgaard Engineering Co., Charlottenlund. The automatic rain sensor devices were made by "Dansk Gartneri Teknik" (Gartek), Brøndby Strand. Electrical installations including the automatic devices were made by the engineers of the University. The irrigation and nutrient system (trickle irrigation system) was designed and constructed by "Volmatic", Ballerup.

Valuable help and suggestions prior to and during the construction were given by Dr. agro. B. Friis-Nielsen and Lic. agro. H. E. Jensen, Hydrotechnical Laboratory.

The authors hereby express their thanks to the persons and companies mentioned.

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Received 23 January 1971