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THE PHYTOTRON OF THE INSTITUTE OF HORTICULTURAL PLANT BREEDING AT WAGENINGEN, NETHERLANDS

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1. Introduction

In a recent issue of this periodical BANGA (1) discusses the design and activities of the Institute of Horticultural Plant Breeding. He states that modern plant breeding is in the first place based on genetics and cytology but to an increasing extent also on other sciences, e.g. plant physiology.

With this in mind a Physiological Laboratory has been built with the object of providing the Institute with equipment by means of which it would be possible to study the reaction of horticultural plants to environmental conditions, to influence their development by the manipulation of the environment and to study their suitability for growing under certain sets of environmental conditions. For this purpose a number of glasshouses and experimental rooms have been constructed where, within certain limits, temperature and humidity of the air as well as duration and intensity of the light can be controlled. A laboratory provided with the facilities mentioned above is usually called "phytotron" (3, 2). A front view of our phytotron, which was put into service in the spring of 1953, is given in Fig. 1.

In the design of the Laboratory the following points had to be considered. Physiological experiments demand a wide range for each of the factors temperature, humidity, duration and intensity of the light, and at the same time a high accuracy in the maintenance of each factor at a given level. Consequently the experimental rooms should be small, their number considerable and the air-conditioning system extensive and fully automatic.

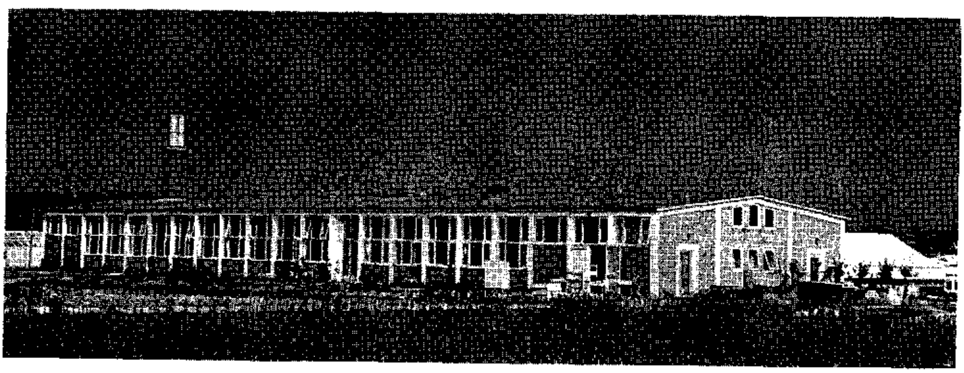

FIG. 1. FRONT VIEW OF THE PHYTOTRON

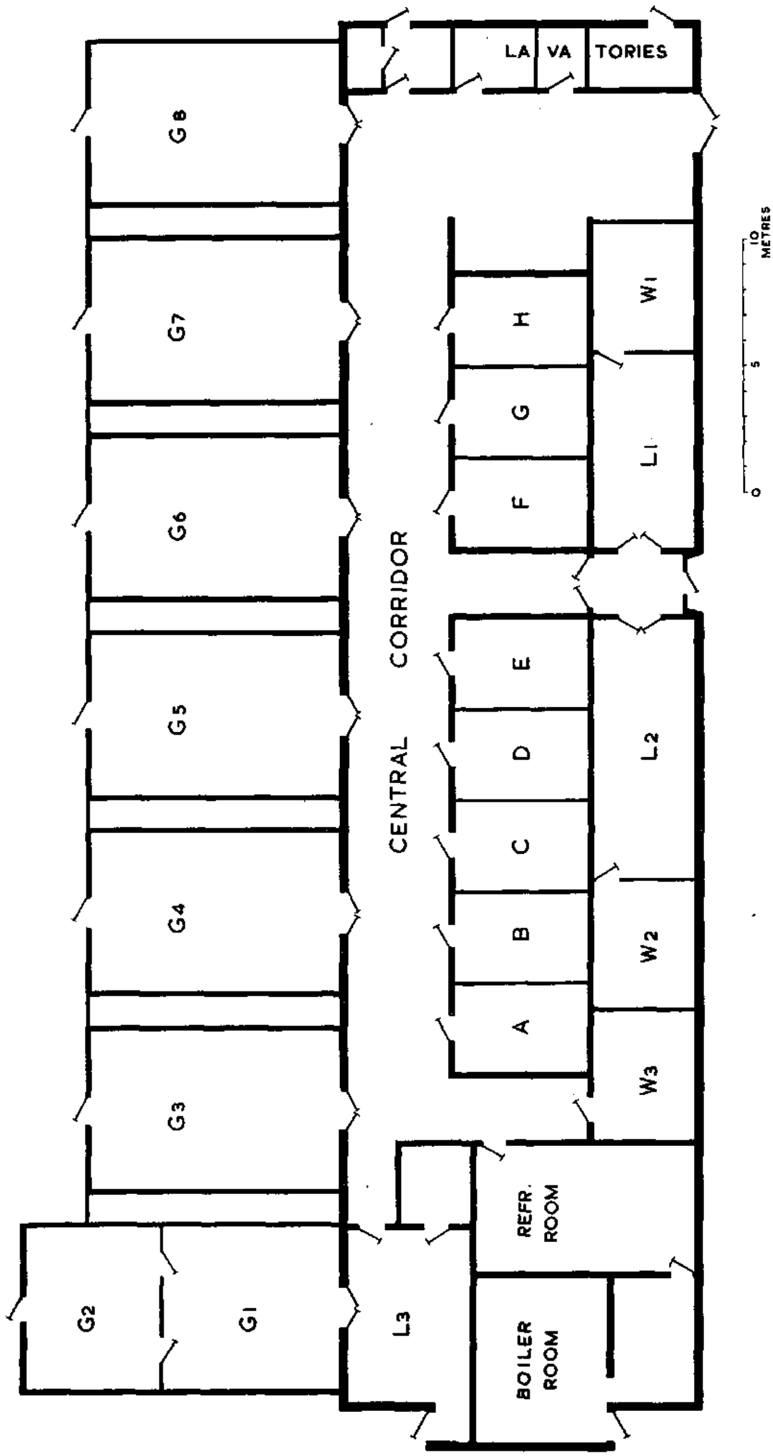

FIG. 2. GROUNDPLAN OF THE PHYTOTRON

In view of the often high heterozygosity in a number of horticultural crops fairly large numbers of plants had to be anticipated in each experiment. This fact, combined with the considerable dimensions of some of the objects (fruit crops) made it advisable to construct large rooms.

Lastly the available funds put a limit to the number and the dimensions of the rooms as well as to the degree of perfection of the climatic control system. The Laboratory as it has ultimately been constructed must therefore be regarded as a compromise resulting from the often conflicting demands of the above considerations.

A visit by Dr. O. BANGA, Director of our Institute, to Dr. F. W. WENT, Professor of Plant Physiology, California Institute of Technology, Pasadena, U.S.A., during his American trip in 1945–46, has been of great importance for the design of the phytotron in its present form. Our thanks are due to Dr. F. W. WENT for his valuable advice.

2. THE DESIGN OF THE PHYTOTRON

Figure 2 shows the groundplan of the building. On the north side are located laboratory rooms (L1, L2) and working rooms (W1, W2, W3) for the staff. Lavatories and washing rooms fitted with showers are on the west side. A boiler room, a room for the main refrigerating plant, a laboratory room (L3) and a glasshouse consisting of two sections (G1, G2), which have been specially constructed for research on nursery problems and vegetative propagation of fruit crops are on the east side. The experimental section is located on the south side of the building (Fig. 3).

The design of the experimental part is based on the principle of maintaining constant temperature and air humidity in each of the glasshouses and experimental rooms and mobility of the plants. This mobility has been achieved by putting the potted plants on trucks. These trucks have tops of perforated metal plates of 90 × 100 cm and four wheels, two of which are swivel castors (Fig. 4). They can carry a load of 200 kg. There are 50 trucks with fixed tops and 30 of which the top plate can be vertically adjusted.

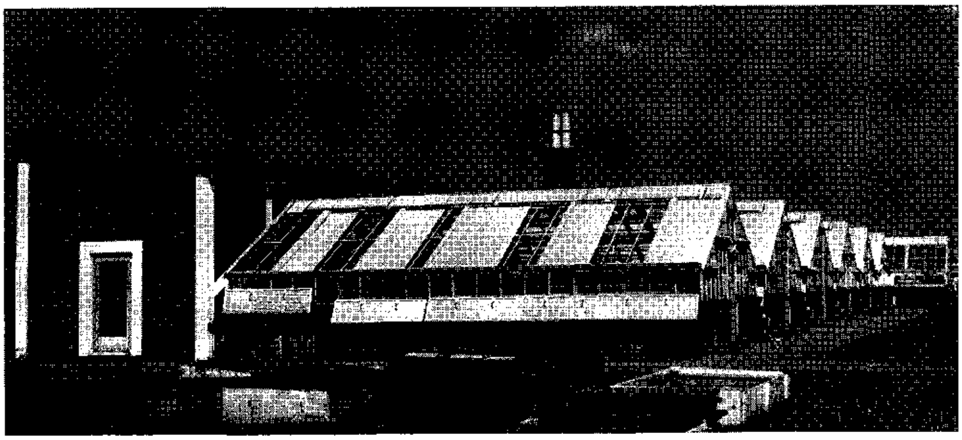

FIG. 3. THE BACK OF THE PHYTOTRON WITH THE GLASSHOUSES

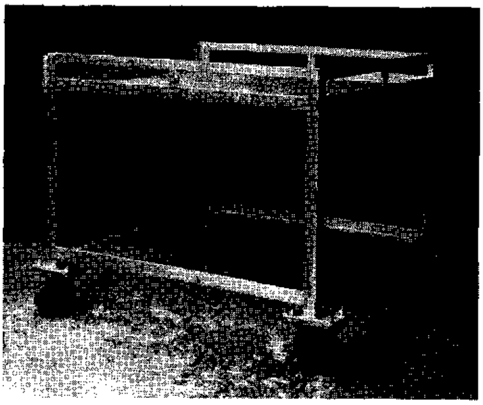

FIG. 4. TRUCK WITH FIXED TOP

The experimental section consists of:

a. A central corridor leading to the glasshouses and experimental rooms (Fig. 5). This corridor is wide enough to permit an easy passage of a large number of trucks and is also used for sowing, pricking and potting plants and for the preparation of plant material for analysis.

b. Eight experimental rooms (A-H) of 3 × 5 metres of which five are "cold rooms" (temperature-range from −15°C to +20°C) and three are "warm rooms" (temperature-

FIG. 5. CENTRAL CORRIDOR, AT THE LEFT DOORS OF THE EXPERIMENTAL ROOMS, AT THE RIGHT WORKING TABLES AND DOORS OF THE GLASSHOUSES (NOT VISIBLE IN THE PHOTOGRAPH)

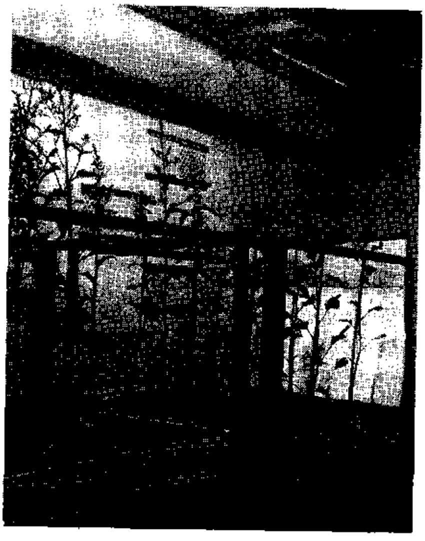

FIG. 6. VIEW OF A COLD ROOM

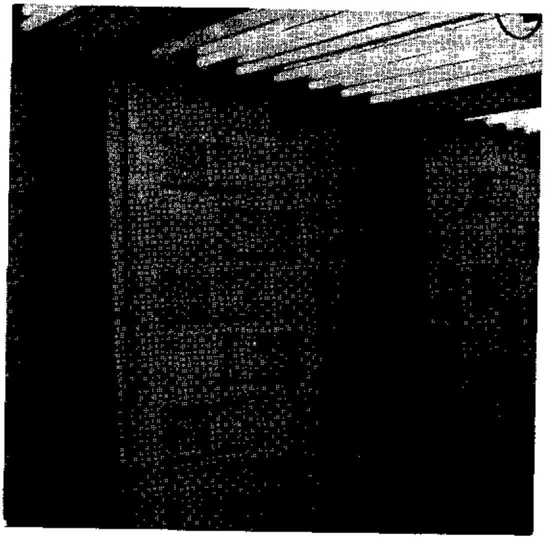

FIG. 7. VIEW OF A WARM ROOM

range from + 18°C to +30°C). Both in the cold rooms (Fig. 6) and warm rooms (Fig. 7) plants can be artificially illuminated.

c. Six glasshouses (G3–G8) of 6 × 10 metres with fixed side benches and a central space for trucks (Fig. 8).

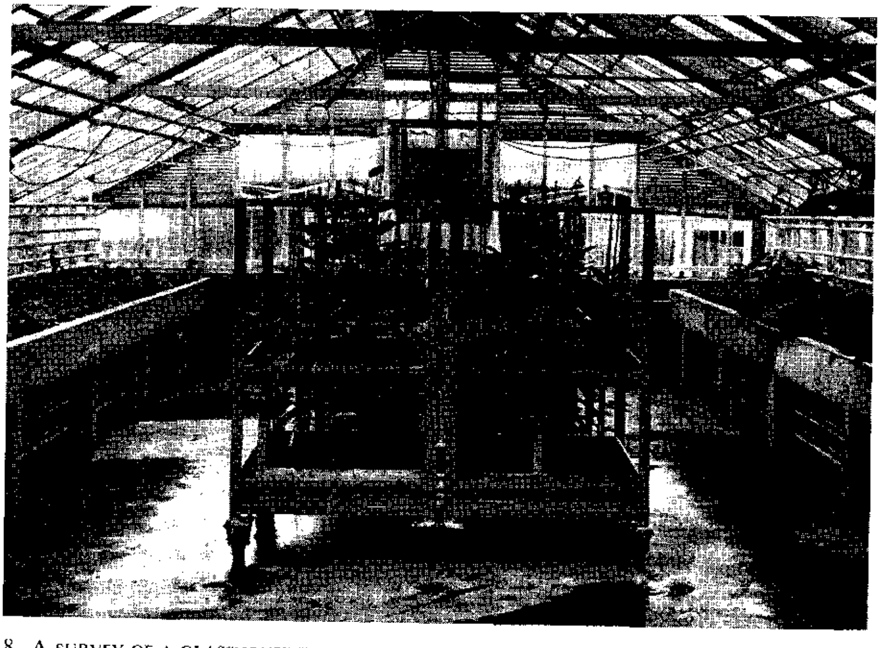

FIG. 8. A SURVEY OF A GLASSHOUSE WITH SOME TRUCKS OF WHICH THE TOP PLATE CAN BE VERTICALLY ADJUSTED

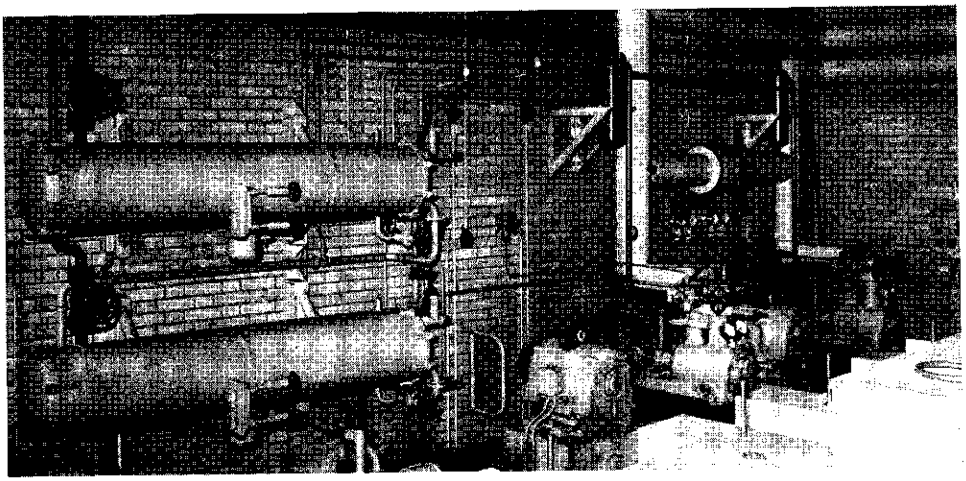

FIG. 9. PART OF THE REFRIGERATING ROOM. AT THE RIGHT THE TWO COMPRESSORS, AT THE LEFT THE TWO CONDENSORS

Heating is provided by hot water pipes connecting with two boilers in the basement. These burn light fuel oil, which is stored in two 10,000 litre tanks.

The boilers are identical, their combined capacity is 450,000 kcal/h. Except on very cold days in winter, one of the two can carry the load alone.

The temperature of the water coming from each boiler can be automatically maintained at any temperature-level between 20°C and 90°C. It is circulated through hot water pipes in the building by one of two centrifugal pumps. The pumps are placed

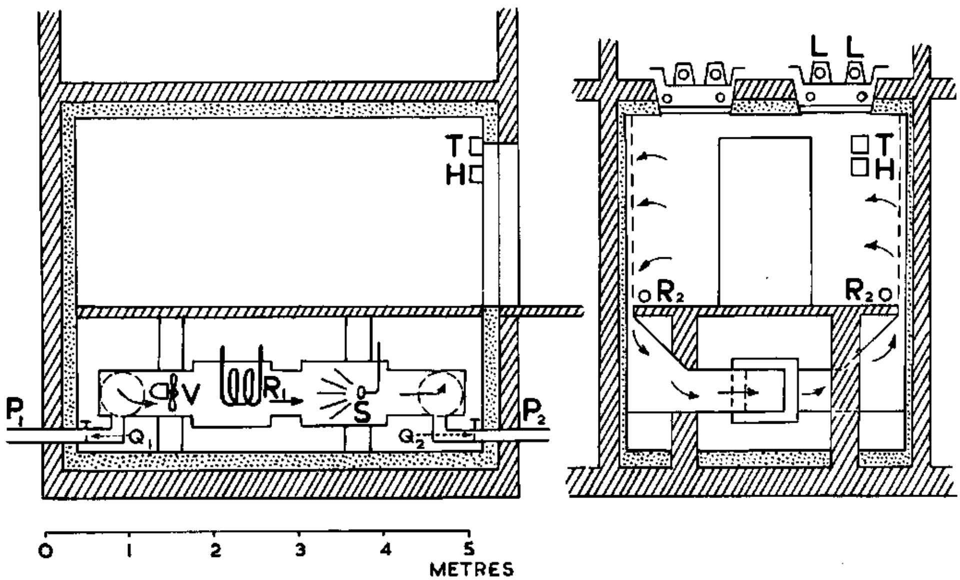

FIG. 10. LONGITUDINAL SECTION AND CROSS SECTION OF A COLD ROOM

parallel and each is directly connected with a 1 h.p. motor. In case of a defect the boilers as well as the pumps can replace each other.

Cold brine serves as the main means of cooling for the experimental section. The brine, a concentrated solution of $CaCl_2$, is cooled by the expansion of ammonia in two storage tanks of 1500 litres each in the refrigerating room. Two refrigerating units each with a 19 h.p. compressor (Fig. 9) have an expansion coil submerged in the brine. The compressed ammonia is cooled by groundwater of 11 °C. The capacity of either compressor amounts to 12,500 kcal/h at -25 °C evaporating temperature and + 20°C. condensing temperature. During cold weather one of them can carry the total heat load, but as a rule they have to work simultaneously. The temperature of the brine in each tank can be kept constant at any level between +10 °C and -25 °C.

3. Control of temperature and air humidity

a. Cold and warm rooms

Figure 10 shows a longitudinal section and a cross section of one of the cold rooms. Each room has an experimental chamber with a door opening on to the central corridor, and a cellar with the air-conditioning apparatus. The walls, ceiling and floor of the room are covered on the inside with an insulating layer of cork. The air-conditioner in the cellar consists of an airduct with a ventilator V, a heat exchanger R 1 and spray chamber S. Each end of the conditioner is connected with one of the two spaces formed by placing perforated partitions at a distance of 12 cm parallel to the longitudinal walls of the experimental chamber. Cold brine circulates through the coils of the heat exchanger.

The ventilator, with a capacity of 2500 m^3/h, forces the air over the coils of the heat exchanger, where it is cooled, and through the spray chamber where it is moistened by a sprayer. The air then enters the experimental chamber by apertures of the partition on one side, moves across the room in a mass, passes out through the holes in the partition on the other side and is returned to the conditioner. By opening the dampers Q1 and Q2 outside air is introduced into the air-circulation and at the same time used air is removed. Temperature is controlled by thermostat T which starts the pump of the cold brine circulation, each time the temperature of the experimental space rises above the chosen level.

In the air circulation system of each room are two electric heaters R2 of 1250 W capacity. This compensating source of heat is needed to reach and maintain the higher levels in the temperature range and to flatten out the oscillations in the temperature curve that tend to appear at these levels. Both heaters are regulated by the same thermostat T which controls the pump of cooler R1.

Humidity is controlled by the humidistat H which opens the solenoid valve of the sprayer as soon as the air becomes too dry.

Figure 11 shows a longitudinal section and a cross section of one of the warm rooms. The air in these rooms is conditioned in the same manner as in the cold rooms with this difference that the air is heated when circulating over the coils of heat exchanger R3. Moreover, a re-heating coil R5 is fitted behind the spray chamber S. To ensure a satisfactory control of the temperature range each room also has a small refrigerating unit with a capacity of 3500 kcal/h at +5 °C evaporating temperature and +25 °C

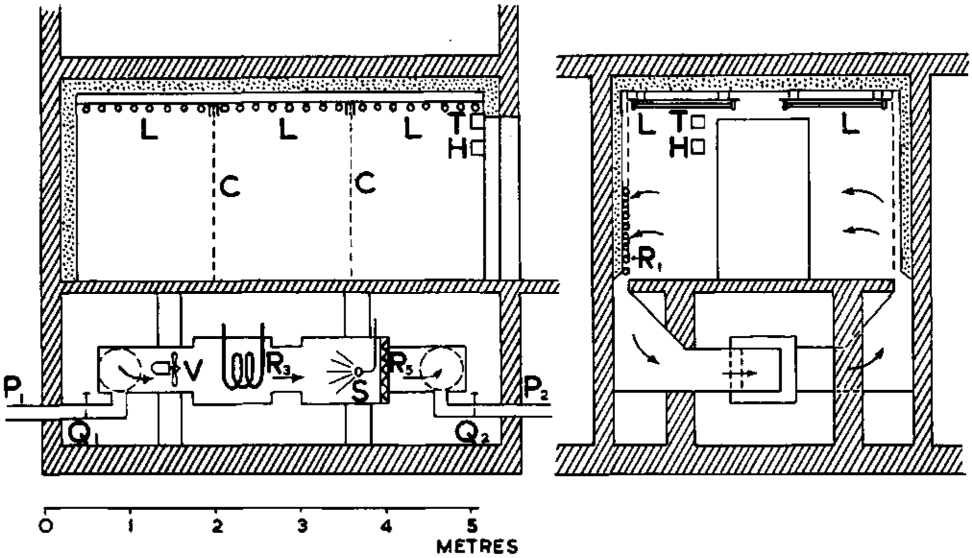

FIG. 11. LONGITUDINAL SECTION AND CROSS SECTION OF A WARM ROOM

condensing temperature. Cooling is effected by direct expansion of freon in the coils R_1. The thermostat T controls both the cooler R1 and the heater R3.

b. The glasshouses

Figure 12 shows a cross section of one of the glasshouses. Thermostat T1 operates the motor valve in the hot water supply, thus controlling the circulation of hot water through the pipes R5 running under the side benches and along the vertical side walls and the glass of the roof. By this simple arrangement temperature levels lying above the outside air temperature can be satisfactorily maintained.

To counteract a rise of temperature each glasshouse is provided with a ventilation system which consists of a ventilator V and two airducts D running lengthwise under the side benches. As soon as the temperature rises above the level set on thermostat T2, outside air is blown into the ducts by the ventilator. Through apertures over the whole length of the ducts it flows into the glasshouse to replace the hot air which escapes through the windows W in the top. The capacity of the ventilator in each glasshouse amounts to 3000 m^3/h enabling 20 air changes per hour or one every three minutes.

Air humidity is controlled by the humidistats H1 and H2. Humidification of the air is effected by a fine water spray produced by 6 nozzles and regulated by the humidistat H1 which controls the electromagnetic valve in the water supply to the sprayers. A lowering of humidity by the introduction of outside air is effected by humidistat H2 which controls the switch of the ventilator V.

Additional cooling of the air is achieved by the interaction of humidity and temperature control. On sunny days the outside air is usually dry and becomes even drier when its temperature has been brought to the desired level after introduction into the glasshouse. The humidity control system then raises the relative humidity to the level

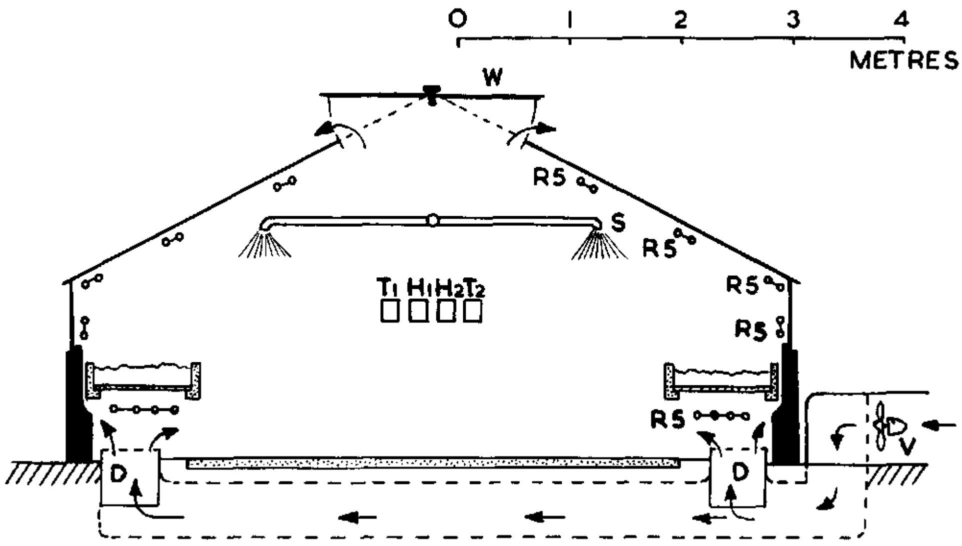

FIG. 12. CROSS SECTION OF A GLASSHOUSE

maintained in the glasshouse. The uptake of heat accompanying the evaporation of the necessary amount of water results in a lowering of the air temperature.

In one glasshouse, numbered G3 on the plan of Figure 2, a switch-over is possible from cooling by means of ventilation to cooling by means of refrigeration. Here the airducts under the side benches have their ends connected with an airduct running lengthwise in the top of the house. A ventilator draws the air through the apertures of the upper duct and forces it over two brine-cooled heat exchangers (Fig. 13). The cooled air is then reintroduced into the glasshouse through the apertures of the two lower ducts, from where it rises again to the duct at the top.

The thermostat T1, which controls the hot water heating system of this glasshouse also operates the circulation pump of the two coolers. Here humidity control is identical with that of the other 5 glasshouses. During summer the temperature in this house can be kept at 17 °C, provided shades are used during sunny periods.

4. CONTROL OF THE LIGHT FACTOR

In the 5 cold rooms artificial illumination is possible up to an intensity of about 30,000 m W/m^2. As a main source of light Philips high pressure mercury vapour lamps HO 450 W are used. To compensate the deficiency in the red part of the spectrum of the mercury lamps, incandescent lamps have been added in a ratio of 1/3 of the total capacity.

Figure 10 shows that the lamps are mounted outside the experimental chamber over the glasswindows in the ceiling. By this arrangement combined with a 2 cm layer of running water on the glass panes the convection heat as well as the heat radiation of the lamps is prevented from entering the experimental chambers. This allows an effective control of temperature even at high light intensities.

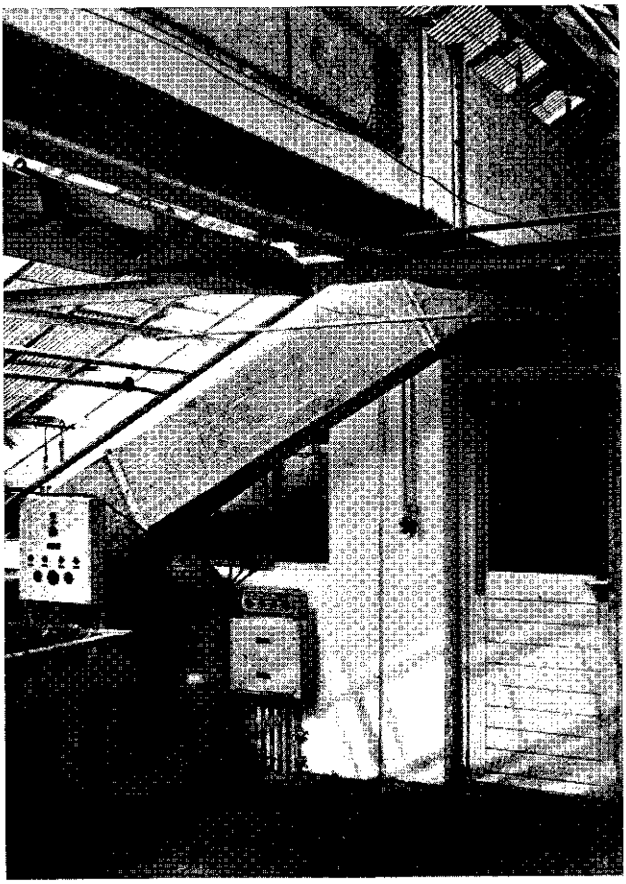

FIG. 13.
COOLED GLASSHOUSE WITH AIR-DUCT AND VENTILATOR IN THE TOP. AT THE LEFT ONE OF THE BRINE-COOLED HEAT EXCHANGERS. NEXT TO IT A FIXED BOX CONTAINING REACTANCE COILS AND CONDENSERS FOR HIGH PRESSURE MERCURY VAPOUR LAMPS; ON THE FLOOR TWO MOVABLE BOXES.

In the 3 warm rooms Philips fluorescent tubes are mounted inside the experimental chambers which can be divided into 3 compartments by means of curtains (Fig. 7). This light source offers the possibility of varying the spectral composition of the light by using different types of lamps. In these rooms artificial illumination is possible up to an intensity of about 15,000 m W/m^2.

Also in the glasshouses natural daylight can be intensified or its duration lengthened by artificial illumination. Here again the high pressure mercury vapour lamp HO 450 W is used, because it combines high light intensity with relatively modest dimensions. With this type of lamp therefore an adequate illumination of the plants can be achieved without the drawback of intercepting a large part of the daylight. To this end each glasshouse is fitted with two fixed boxes each containing reactance coils and condensers for four high pressure mercury vapour lamps. An additional set of movable boxes is available for increasing the number of these lamps from 8 to 20 (Fig. 13). Moreover, supplementary illumination can be supplied from incandescent lamps.

In all experiments the duration of artificial illumination is controlled automatically by time clocks.

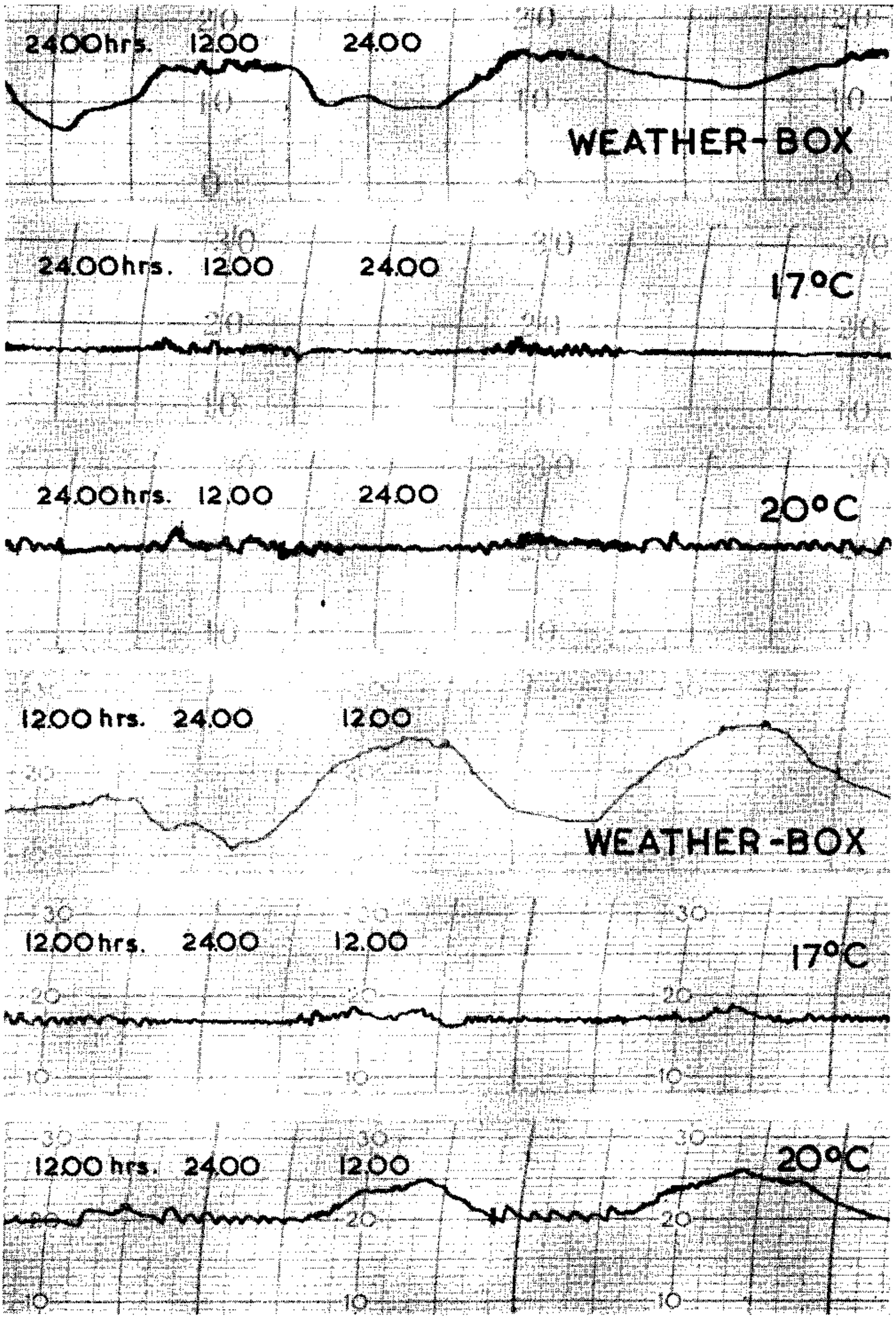

FIG. 14. THERMOGRAMS OF TWO GLASSHOUSES KEPT AT 17 °C AND 20 °C RESPECTIVELY TOGETHER WITH THERMOGRAMS FROM THE WEATHER BOX IN THE CORRESPONDING PERIOD. NOTICE THAT ON EXCEPTIONALLY HOT DAYS THE TEMPERATURE IN THE 20 °C GLASSHOUSE RISES TO ABOUT 25 °C IN THE AFTERNOON

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40. **Floor, J.** Proeven met vermeerdering door entstekken. October 1952 . . . . *f* 1,25
41. **Banga, O.** Some factors in the growth rate of red garden beets. November 1952 . . . . *f* 0,45
42. **Sneep, J.** Practijkproeven met Westlandse Boerenkool 1949–1950 en 1950–1951. December 1952 *f* 1,—
43. Een bos enthoutjes. Januari 1953 . . . . *f* 1,35
44. **Banga, O.** Practijkproeven met Ronde Rode Radijs 1951–1952. Februari 1953 . . . . *f* 0,65
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46. **Kronenberg, H. G.** De veredeling van Klein-Fruit in de Ver. Staten van Amerika . . . . *f* 0,65
47. **Banga, O.** en **M. Keuls.** Practijkproeven met Berlikumer Wortel 1949. April 1953 . . . . *f* 0,65
48. **Gerritsen, C. J.** Welke kersen moeten we planten. April 1953 . . . . *f* 0,45
49. **Banga, O., M. Keuls** en **M. Wattel.** Practijkproeven met Flakkeese Winterwortel 1950–1951. Mei 1953 . . . . *f* 0,90
50. Algemene Veredelingsdagen 1952. Verslag van voordrachten en discussies. Juni 1953 . . . . . . *f* 1,50
51. **Sneep, J.** Practijkproeven met Spitskool 1949–1950 en 1950–1951. Juli 1953 . . . . *f* 0,65
52. **Boom, B. K.** Internationaal reglement voor de naamgeving van gekweekte planten . . . . *f* 0,75
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54. Veredingsdag Groentegewassen 1953. Verslag van voelrdrachten en discussies. December 1953 . . *f* 1,—
55. **Floor,oJ.** Planten in plastic. Januari 1954 . . Uitverkocht
56. **Banga, O.** Taproot-problems in the breeding of root vegetables . . . . *f* 0,25
57. **Jensma, J. R.** en **A. Kraai.** Practijkproeven met Rode Kool 1950–1951. Juni 1954 . . . . *f* 1,10
58. **Jensma, J. R.** en **A. Kraai.** Practijkproeven met Spruitkool 1950–1951. Juli 1954 . . . . *f* 0,85
59. Veredelingsdag Fruitgewassen 1954. Verslag van voordrachten en discussies. Augustus 1954 . . . . . . *f* 0,95
60. **Kraai, A.** The use of Honey-bees and Bumble-bees in breeding work. September 1954 . . . . *f* 0.45
61. **Jensma, J. R.** en **A. Kraai.** Practijkproeven met Witte Kool 1952–1953. Februari 1955 . . . . *f* 1,35
62. **Banga, O.** en **J. W. de Bruyn.** Selection of Carrots for Carotene Content. Februari 1955 . . . . *f* 0.25
63. **Kronenberg, H. G.** en **L. M. Wassenaar.** Practijkproeven met aardbeirassen 1952–1954. April 1955 . *f* 0.90
64. **Keuls, M.** and **J. W. Sieben.** *Two statistical problems in plant selection.* April 1955 . . . . *f* 0,35
65. **Banga, O.** The Institute of Horticultural Plant Breeding. April 1955 . . . . *f* 0,25
66. **Banga, O.** Uienveredeling met gebruikmaking van inteelt en herstel door heterosis. Juni 1955 . . . . *f* 0,30
67. **Banga, O.** Carrot yield analysis. September 1955 . *f* 0,30
68. **Banga, O., J. W. de Bruyn** and **L. Smeets.** Selection of carrots for carotene content. II Sub-normal content at low temperature. September 1955 . . . . *f* 0,25
69. **Braak, J. P.** Effect of temperature and light on June Yellows in strawberries. September 1955 . . . . . . *f* 0,25
70. **Banga, O.** De ontwikkeling van de rassensituatie bij groentegewassen. Oktober 1955 . . . . *f* 0,25
71. **Bruyne, A. S. de.** Tendenzen in de ontwikkeling van het *Nederlandse fruitsortiment. Oktober 1955* . . . . *f* 0,40
72. **Banga, O.** Praktijkproeven met Knolselderij 1953–1954. November 1955 . . . . *f* 0,30
73. **Floor, J.,** Proeven met stekken onder waterverneveling. April 1956 . . . . *f* 1,—
74. **Andeweg, J. M.** en **J. H. Ruyten.** Praktijkproeven met Tomaten 1954–1955. April 1956 . . . . *f* 0,40
75. **Andeweg, J. M.** en **A. van Steenbergen.** Praktijkproeven met Stoksnijbonen 1953–1954. Mei 1956 . . . *f* 0,35
76. **Banga, O.** en **J. L. van Bennekom.** Praktijkproeven met Ronde Witpunt Radijs 1953–1954. Mei 1956 . . . *f* 0,55
77. **Smeets, L.** and **Hester G. Kronenberg.** Runner formation on strawberry plants in autumn and winter . .
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78. **Smeets, L.** Influence of the temperature on runner production in five strawberry varieties. Juni 1956 . . . *f* 0,25
79. **Smeets, L.** and **L. M. Wassenaar.** Problems of heat spot in Fragaria vesca L. when indexing strawberry selections for viruses. Juni 1956 . . . . *f* 0,50
80. **Banga, O.** and **J. W. de Bruyn.** Selection of carrots for carotene content. III Planting distances and ripening equilibrium of the roots. Juni 1956 . . . . *f* 0,35
81. **Banga, O.** International conference on the improvement and on the standardization of vegetable varieties at Wageningen, Netherlands, on August 26 and 27, 1955. August 1956 . . . . *f* 0,75
82. **Floor, J.** Proeven met vermeerdering van houtige gewassen. September 1956 . . . . *f* 0,80
83. **Gerritsen, C. J.** Improvement of the cherryv arieties used in the Netherlands. Oktober 1956 . . . . *f* 0,35
84. **Gerritsen, C. J.** Research offered new possibilities for nut growing in the Netherlands. Oktober 1956 . . . *f* 0,25
85. **Andeweg, J. M.** The breeding of scab-resistant frame cucumbers in the Netherlands. Oktober 1956 . . . *f* 0,30
86. **Zeilinga, A. E.** An improved acetic orcein squash method for serial cytological preparations. Oktober 1956 . *f* 0,20
87. **Braak, J. P.** and **L. Smeets,** The Phytotron of the Institute *of Horticultural Plant Breeding at Wageningen, the Netherlands.* Oktober 1956 . . . . *f* 0,30

PERSBERICHTEN UITSLAGEN PRACTIJKPROEVEN

10- 3-'50.	Uitslag Practijkproeven Wortel Berlikumer 1949.	Zijn geplaatst in diverse tuinbouwbladen.
29-11-'50.	Uitslag Practijkproeven Bak- en Zomerwortelen 1949–1950.	
29-11-'50.	Uitslag Practijkproeven Platronde en Ronde Kroten 1949–1950.	
22-12-'50.	Uitslag Practijkproeven Pronkbonen 1950.	
11- 3-'51.	Uitslag Practijkproeven Westlandse Boerenkool 1949–1950.	
3- 9-'51.	Uitslag Practijkproeven Spitskool 1950–1951.	
7-12-'51.	Uitslag Practijkproeven Flakkeese Winterwortel 1950–1951.	
23- 1-'52.	Uitslag Practijkproeven Vroege en Herfst Rodekool 1950–1951.	
31- 3-'52.	Uitslag Practijkproeven Spruitkool 1950–1951.	
4-11-'52.	Uitslag Practijkproeven Ronde Rode Radijs 1951–1952.	
4-11-'52.	Uitslag Practijkproeven Vroege Rijspeulen 1951–1952.	
25-11-'52.	Uitslag Practijkproeven Lange Kroten 1951–1952.	
23- 1-'53.	Uitslag Practijkproeven Radijs Ronde Scharlakenrode Extra Kortloof 1951–1952.	
13- 5-'53.	Uitslag Practijkproeven Bewaar Rode Kool 1951–1952.	
10- 9-'53.	Uitslag Practijkproeven Vroege Witte Kool 1952–1953.	
18-12-'53.	Uitslag Practijkproeven Herfst Witte Kool 1952–1953.	
3- 6-'54.	Uitslag Practijkproeven Bewaar Witte Kool 1952–1953.	
17-11-'54.	Uitslag Practijkproeven Stoksnijbonen 1953–1954.	
2-12-'54.	Uitslag Practijkproeven Ronde Rode Witpunt Radijs 1953–1954.	
12- 2-'55.	Uitslag Practijkproeven Knolselderij 1953–1954.	
1- 9-'55.	Uitslag Practijkproeven Vroege Groene Savoye Kool 1954-1955.	
14-11-'55.	Uitslag Practijkproeven Tomaten 1954-1955.	
27 12-'55.	Uitslag Practijkproeven Witlof vroege trek 1954-1955.	
2-3-'56.	Uitslag Practijkproeven Witlof middelvroege trek 1954-1955.	
5-3-'56.	Uitslag Practijkproeven Schorseneren 1954-1955.	
28- 5-'56.	Uitslag Practijkproeven Savoye Kool 1954-1955.	
28- 5-'56.	Uitslag Practijkproeven Witlof koude kuil en meilof 1954-1955.	
30- 7-'56.	Uitslag Practijkproeven Tuinbonen 1955-1956.	
1- 9-'56.	Uitslag Praktijkproeven Amsterdamse Bakwortel 1955-1956	
1- 9-'56.	Uitslag Praktijkproeven Vroege Rode Kool 1956	
1- 9-'56.	Uitslag Praktijkproeven Platronde Kroten 1955-1956	

RASSENLIJSTEN [1]
UITGEGEVEN DOOR HET INSTITUUT VOOR DE VEREDELING VAN TUINBOUWGEWASSEN

Achtste Beschrijvende Rassenlijst voor Fruit. 1957. . . f 1,75

Achtste Beschrijvende Rassenlijst voor Groentegewassen. 1956. Redacteur Dr. O. Banga . . . . f 1,75

JAARVERSLAGEN [1]
VAN HET INSTITUUT VOOR DE VEREDELING VAN TUINBOUWGEWASSEN

Jaarverslag 1950. 1 (1951) . . . . Uitverkocht
Jaarverslag 1951–1952. 2 (1954) . . . . f 3.50

PUBLIKATIES VAN HET INSTITUUT VOOR DE VEREDELING VAN TUINBOUWGEWASSEN IN ANDERE ORGANEN OF IN BOEKVORM EVENTUEEL IN SAMENWERKING MET ANDERE INSTELLINGEN [2]

De publikaties, waarvan prijs èn uitgever worden vermeld zijn verkrijgbaar in de boekhandel. Overigens wende men zich tot de opgegeven bronnen of tot de bibliotheek van het I.V.T.

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[1]) Zolang de voorraad strekt kunnen deze publikaties franco worden toegezonden, na ontvangst van het vermelde bedrag op giro no. 425340 van het Instituut voor de Veredeling van Tuinbouwgewassen, S. L. Mansholtlaan 15 te Wageningen onder vermelding van wat verlangd wordt; ook bestaat de mogelijkheid deze publikaties uit de bibliotheek van het I.V.T. te lenen.

[2]) Eerder verschenen publikaties zijn vermeld achterin in de Mededelingen nos 1 t/m 70.

DRUK: H. VEENMAN EN ZONEN, WAGENINGEN