Neth. J. agric. Sci. 23 (1975): 238-247

The climate glasshouse at Naaldwijk*

J. van de Vooren[1] and R. Koppe[2]

[1] Glasshouse Crops Research and Experiment Station, Naaldwijk, the Netherlands
[2] Technical and Physical Engineering Research Service, Ministry of Agriculture and Fisheries, Wageningen, the Netherlands

Summary

The technical outfit of a glasshouse of 24 compartments is described. A process computer with peripheral units is used to control the glasshouse climate and to record the climatic data inside and outside the glasshouse. The analysis of the results of the experiments is discussed.

Introduction

For many years there has been a need for climatically controlled rooms in which the effects of climatic factors such as light and temperature on the growth and development of the plant could be studied. In the 1950's this led to the introduction of the phytotrons or growth chambers (e.g. Went, 1957; Chouard et al., 1972; Doorenbos, 1964; Commissie Fytotrons TNO, 1972). However, all the information obtained in this way (Lang, 1963) was valid only for individual plants growing under certain constant conditions.

The task of applied agricultural research is to relate this information to the crop as it is produced in agriculture under often sharply fluctuating conditions. In the case of glasshouse horticulture this crop research should be carried out in glasshouses in which the environmental conditions can be controlled by methods which are within the present and future economic reach of growers.

In England compartmented glasshouses were built to study the interaction of a number of climatic factors (Sheard, 1965). The scope of an existing glasshouse with six compartments at the Naaldwijk Research Station proved to be too limited, and it was decided to build the climate glasshouse described in this article. During the 1960's the glasshouse temperature control equipment used in practical horticulture developed into glasshouse climate control equipment. The control actions of this equipment are determined by climatic factors in and outside the glasshouse (Germing, 1969; Bokhorst et al., 1972; Strijbosch et al., 1973; Heyna, 1973). It became necessary to find an answer to the question which control procedures are most likely to provide the optimum climate for the crop. This means that the relationship between the climate outside, the glasshouse climate and the growing crop needs to be studied.

---

* Publikatie van het Proefstation voor de Groenten- en Fruitteelt onder Glas te Naaldwijk No 209.

Lay-out

A climate glasshouse should consist of several compartments in which crops can be grown under practical conditions. The new climate glasshouse at Naaldwijk has 24 compartments, each with a surface area of about 50 m². The compartments were built in a Venlo block bordered on two sides by corridors and by other glasshouse compartments on the other two sides to eliminate fringe effects. Each compartment is regarded as a separate unit, equipped with flexible heating and irrigation systems suitable for both flower and vegetable crops, ventilators on two sides, CO_2 equipment, facilities for artificial irradiation and permanent underground steam sterilization and soil heating systems (Anon, 1972b). A computer system was found to be necessary to control the climatic conditions in each of the 24 compartments.

This system is also used for continuous recording of a number of climatic factors and for the daily control of the glasshouse climate and the positions of the final control elements (Anon., 1972a).

Construction

The climate glasshouse was built on the site of the Glasshouse Crops Research and Experiment Station, Zuidweg 38, Naaldwijk. The soil consists of light loam drained

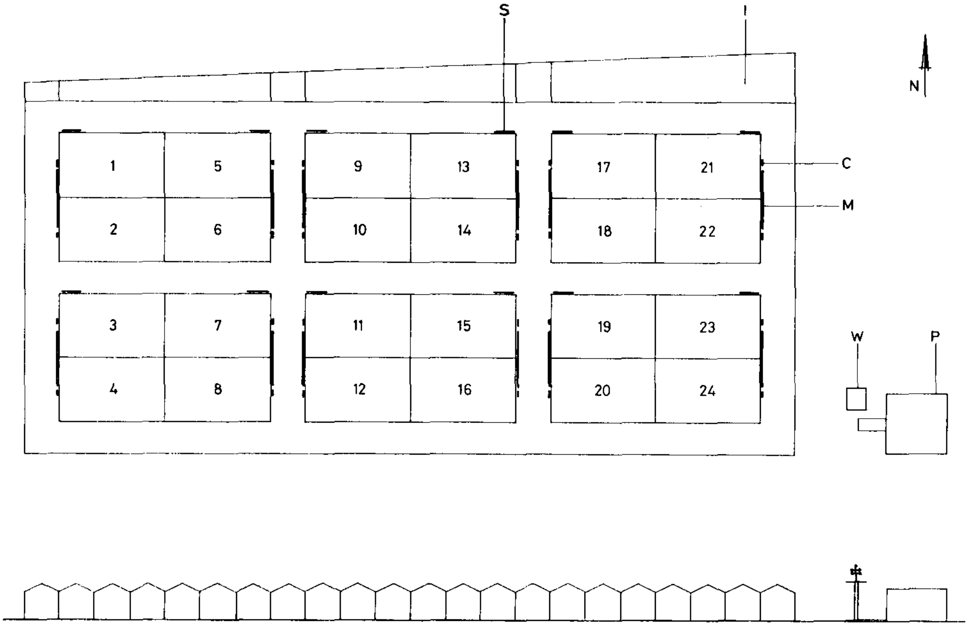

Fig. 1. Plan and front view of the climate glasshouse with computer centre (P) and weather mast (W). Also shown are the position of the irrigation installation (I), manifolds (M), the control and switch cabinet (S) and the connection cabinets for mV signals (C).

Fig. 2. Aerial view of the climate glasshouse.

to a depth of 75 cm. In a Venlo glasshouse block of about 2500 m^2 24 compartments were constructed with glass partitioning (Fig. 1, 2).

On the North side of the complex is the central irrigation installation consisting of an irrigation pump, heat exchanger, a liquid feed diluter installation with concentration meter and the irrigation control equipment. The installation has been planned in such a way that each compartment can be irrigated for a predetermined length of time with water and liquid feed of a certain temperature. Three rotating agricultural sprinklers have been mounted on the roof of the glasshouse block to clean the glass.

Manifolds for heating, irrigation, pure CO_2 and steam has been installed in the North-South corridors. There is one manifold for every two compartments. There are also connection boxes with built in temperature reference units for thermocouple signals (Fig. 3) and other low level signals (mV) obtained from measuring equipment (Table 2).

In the East-West corridors there is one cabinet for every two compartments with the switches, relais and controllers for heating, ventilation and irradiation and with the connections for collecting high level signals (V) obtained from ventilator and valve positioners and from the measuring apparatus (Fig. 1).

Underneath the corridors is a channel covered with concrete slabs in which the majority of the piping and the electrical cables are housed.

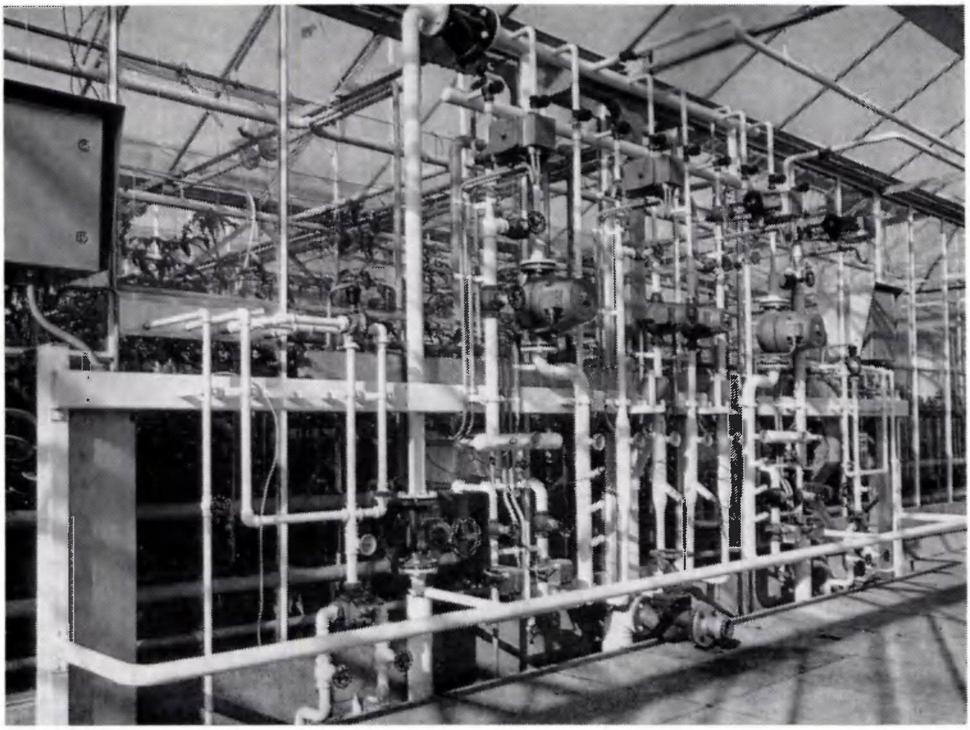

Fig. 3. Manifold for heating irrigation, pure CO_2 and steam sterilization equipment. Connection cabinet for mV signals obtained from measuring instruments.

A weather mast (Fig. 1) of about 5 m height provides the necessary meteorological information (Table 2).

The control and recording centre has been housed in an air-conditioned building

Table 1. Configuration of the Siemens computer system.

- Process computer – 330 –, memory 64 K words of 16 bits, 16 standard registers, cycling time 650 ns.
- In and output device – PE 3600 –, process coupling element for 760 analog input signals, integrating analog digital converter-speed 30 ms/measuring point; 76 digital input signals, 361 digital output signals.
- Moving head storage device – 3941 –, capacity 4.8 M bytes, average entry time 47.5 ms, transfer speed 312 K bytes/s.
- Operator console – 3911 – typewriter with line width of 100 characters and a speed of 18 characters/s, paper tape in and output device-speed 18 characters/s.
- Paper tape input device – 3921 –, speed 120 characters/s.
- Magnetic tape unit – 3957 –, 9 tracks, transfer speed 60 K bytes/s, density 800 b.p.i., tape length, 2.400 ft.
- Graphical colour display – 3973 – 4 curves with accompanying text, picture about 18 s.
- System software – ORG PPII – assembler – AS30 –, macro-compiler – SM30 –, test programme TEPOS, user programme (Scheider et al., 1973).

Fig. 4. View of process computer and peripheral units.

(Fig. 1) and consists of a process computer with peripheral equipment (Fig. 4, Table 1; Offer et al., 1973).

Each growing compartment has a surface area of 56 m^2. Tile drainage has been installed consisting of clay pipes with a diameter of 50 mm. The soil heating system consists of a double network of 13-mm galvanized steel pipes and the permanent steam sterilization system consists of 50-mm clay pipes.

The drainage system, connected to a central pump, maintains the water-table at a constant level. The water temperature of the soil heating system in each compartment is separately controlled by a regulating valve and a thermostat with a range of 0 to 40 °C. The steam sterilization system in each compartment can be connected

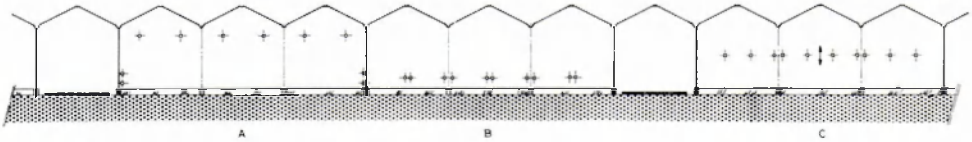

Fig. 5. Possible combinations of the heating systems.

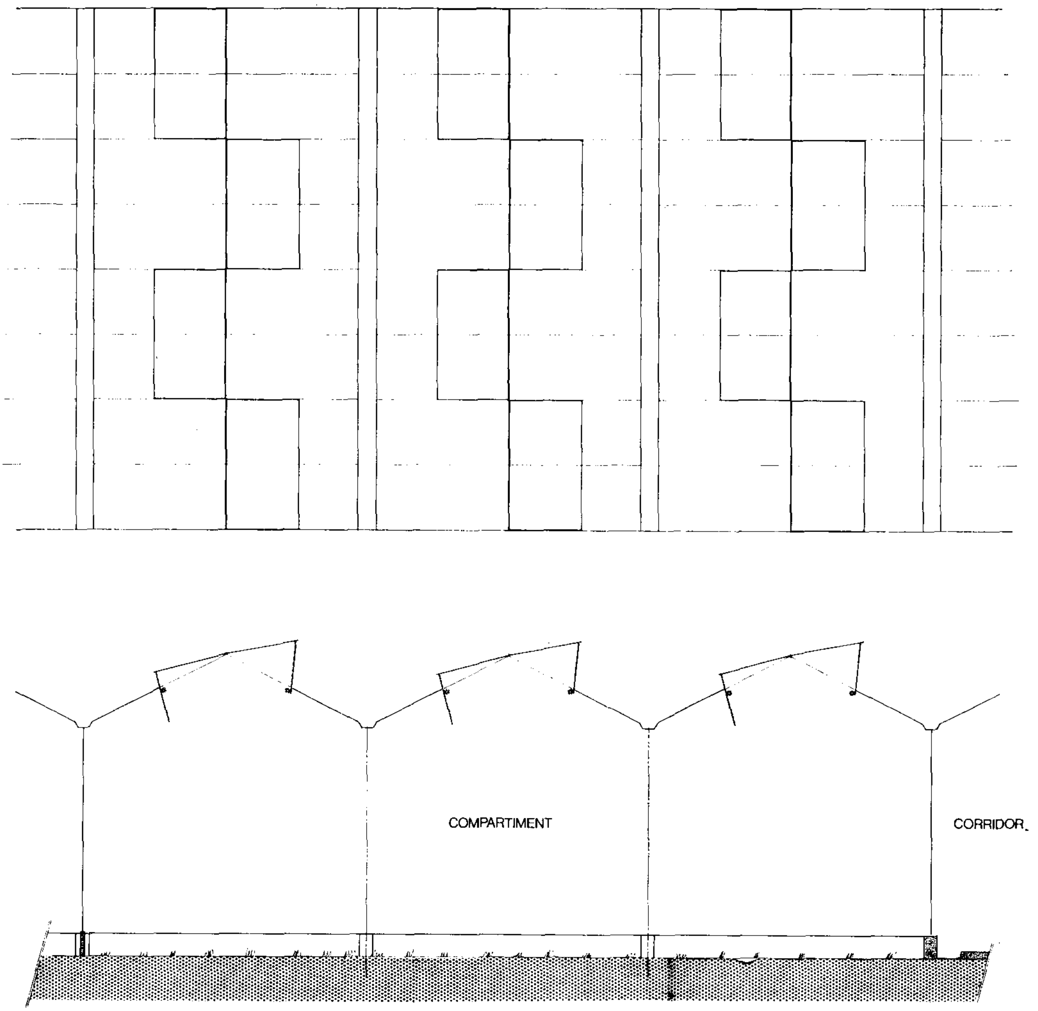

Fig. 6. Configuration of ventilators in one compartment.

to a mobile steam generator. Two pipe heating systems – made of 51-mm steel pipes – have been installed in each compartment, fixed pipes along the gables and at gutter level and a vertically and horizontally adjustable pipe system lower in the house (Fig. 5).

The water temperature in the heating system is controlled with the aid of regulating valves operated by the computer system. This type of control system is known as direct digital control (DDC). Both the upper and lower pipe heating systems are activated with on/off valves by DDC. The ventilation system consists of 12 ventilators (Fig. 6).

Table 2. List of signals recorded.

Variable	Signal	Method	Location	Number	Physical unit
Time	digital clock	digital	computer	1	d, h, s
Radiation	solarimeter	analog 0-10 mV	weather st.	1	J cm^{-2} h^{-1}
Outside temperature	thermo-couple	analog 0-10 mV	weather st.	1	°C
Wind speed	tachogenerator	analog 0-10 mV	weather st.	1	m/s
Relative atmospheric humidity outside	potentiometer	analog 0-10 mV	weather st.	1	%
Wind direction	potentiometer	analog 0-10 V	weather st.	1	°
Rain	relais	digital	weather st.	1	–
Glasshouse air temp. dry bulb	thermo-couple	analog 0-10 mV	compartment	72	°C
Glasshouse air temp. wet bulb	thermo-couple	analog 0-10 mV	compartment	72	°C
Glasshouse air temp.	thermo-couple	analog 0-10 mV	compartment	48	°C
Pipe temperature supply	thermo-couple	analog 0-10 mV	compartment	24	°C
Pipe temperature return	thermo-couple	analog 0-10 mV	compartment	24	°C
Soil temp. at 0-50 cm	thermo-couple	analog 0-10 mV	compartment	120	°C
Plant temperature	thermo-couple	analog 0-10 mV	compartment	24	°C
CO_2 content	infra-red gas analyser	analog 0-10 V	compartment	24	% v/v
Setting heating valve	potentiometer	analog 0-10 V	compartment	24	%
Setting western vents.	potentiometer	analog 0-10 V	compartment	24	%
Setting eastern vents.	potentiometer	analog 0-10 V	compartment	24	%
Setpoint heating back up controller	potentiometer	analog 0-10 V	compartment	24	°C
Setpoint vent. back up controller	potentiometer	analog 0-10 V	compartment	24	°C
Spare 1		analog 0-10 mV	compartment	72	μV
Spare 2		analog 0-10 V	compartment	48	V
Valve setting lower pipe network	relais	digital	compartment	24	–
Valve setting upper pipe network	relais	digital	compartment	24	–
Lighting on/off	relais	digital	compartment	24	–
Test signal 1	DC power supply	analog 0-10 mV	computer	8	μV
Test signal 2	multiplex	analog 0-10 mV	computer	8	μV

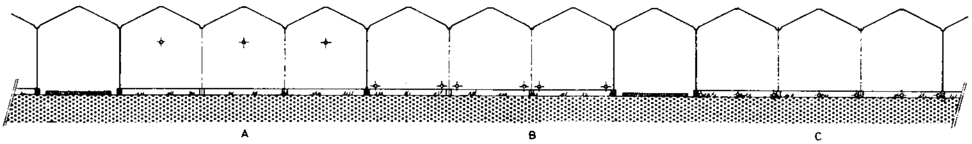

Fig. 7. Possible configurations of the irrigation systems.

The ventilators are operated by the computer system via two ventilator motors installed in each compartment. If necessary, the ventilators can also be opened and closed manually. There is a choise of two irrigation systems. One consists of a 32-mm aluminium pipe fitted with five stem nozzle sprinklers per bay, the other system consists of two 32-mm PVC tubes fitted with 7 bow sprinklers (Fig. 7).

Enrichment with pure CO_2 is applied through 13-mm perforated tubes, one of which is installed in each bay. The time of enrichment is controlled with on/off valves by DDC.

Power points have been fitted for crop irradiation at a capacity of 175 W/m^2. The switches are operated by DDC or, if necessary, manually. Many climatic factors are measured and recorded (Table 2).

Temperatures are measured with copper constantan thermo-couples. The relative and absolute atmospheric humidity is calculated from dry and wet bulb measurements. The weather station measures the relative atmospheric humidity with a hair hygrometer, the wind speed with a cupanemometer, the wind direction with a wind vane and global radiation with a Kipp solarimeter. The CO_2 levels in the 24 compartments will be measured by three infra-red analysers. The synchronization of

Table 3. List of digital output signals.

Variable	Location	Number
Heating computer back up controller	compartment	24
Heating control valve, opening	compartment	24
Heating control valve closing	compartment	24
Valve lower heating network open/closed	compartment	24
Valve upper heating network open/closed	compartment	24
Setpoint heating back up controller higher	compartment	24
Setpoint heating back up controller lower	compartment	24
Ventilation computer back up controller	compartment	24
Ventilation east/west	compartment	24
Ventilators opening	compartment	24
Ventilators closing	compartment	24
Setpoint ventilation back up controller higher	compartment	24
Setpoint ventilation back up controller lower	compartment	24
Valve CO_2 enrichment open/closed	compartment	24
Valve CO_2 measurement open/closed	compartment	24
Lighting on/off	compartment	24
Alarm on/off	computer	1

sampling and analysing will be controlled by the computer.

All the signals recorded (Table 2) are converted to physical values with the aid of conversion functions. Every minute the values are recorded on magnetic tape. At any given time the data recorded from a maximum of 256 measuring points over a maximum period of four days may be visualized on the graphical display unit (Bindewald et al., 1973). Tables containing the climatic data collected in the 24 growing compartments over a 24-hour period and the meteorological data are produced by the printer every day. The current value at each measuring point can be called up instantaneously by means of the typewriter. The physical values measured make it possible to guard valve and ventilator settings as well as the measuring systems such as the thermo-couples and the solarimeter.

The climatic control procedures has been laid down in a programme (Hendriks, 1974; van de Vooren, 1973) which, together with the physical values recorded, are used by the computer in carrying out control operations with the aid of digital output signals (Table 3).

The programme is based on the existing analog climate controllers (Bokhorst et al., 1972; Strijbosch, 1973, 1974). The position of the ventilators and the temperature of the water in the heating system are determined not only by the temperature of the glasshouse air, but also by the atmospheric humidity in the glasshouse, the incidence of rain, the global radiation, the outside temperature, the wind speed and direction of the wind. The programme has been compiled in such a way that adjustments are easily made. In case of breakdown of the computer, the glasshouse temperature is regulated by back-up electronic controllers.

Discussion

The research facilities described have been planned in order to carry out experiments in which climatic factors like temperature, CO_2 content and atmospheric humidity can be controlled at pre-determined levels. The resulting glasshouse climates are recorded accurately and related to the crop growth and development. It should then become possible to decide which set of conditions would be best for the crop. However, it should be noted that a certain setting of the controls will not produce the same glasshouse climate, nor the same crop development, in every year and every season. The results of the experiments will therefore have limited validity only. More extensive analyses could produce information of more general use.

The possibilities of carrying out statistical analyses of the results of multifactorial experiments are limited as there are only 24 growing compartments (Jakobs, 1974). However, it is probable that answers may be found to questions of a limited nature.

A greater general validity may be expected from reasoned analyses. Because of the mass of data and the interacting factors, such analyses will have to be carried out with the aid of automatic processing systems. There may be possibilities in the use of simulation techniques (de Wit, 1970) and mathematical models (Heyna, 1970). Besides extensive recording of climatic data for analyses of outside climate – glasshouse climate – crop systems, crop recording is also necessary. So far, this has been done manually, but instruments should now be developed which are capable of measuring crop growth automatically and at frequent intervals.

Acknowledgments

Thanks are due to the Ministry of Agriculture and Fisheries, the Technical Service of the Research Station at Naaldwijk, the Technical and Physical Engineering Research Service at Wageningen and the IWIS – TNO at The Hague.

References

Anonymous, 1972a. Motivering computer klimaatkas en programma van wensen computer klimaatkas. Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk. 22 pp.

Anonymous, 1972b. Programma van eisen van de te bouwen klimaatkas. Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk. 21 pp.

Bindewal, K. & H. Kürner, 1973. Graphical colour display Terminal 300 for process computers. *Siemens Rev.* 90 (1): 14-18.

Bokhorst, D., A. van Drenth & G. P. A. van Holsteyn, 1972. [Light dependent control systems for glasshouses.] Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk, Report 20. 80 pp. (in Dutch).

Chouard, P., R. Jacques & N. Bilderling, 1972. Phytotrons and phytotronics. *Endeavour* 31 (112): 41-45.

Commissie Fytotrons TNO, 1972. Van proefveld naar klimaatkamer. *Res. Mgmt Stud.* 5. 67 pp.

Doorenbos, J., 1964. [The phytotron of the Laboratory of Horticulture, State Agricultural College, Wageningen.] *Meded. Dir. Tuinb.* 27 (9): 432-437 (in Dutch).

Germing, G. H., 1969. [Developments in the control of the glasshouse climate.] *Pub. Inst. TuinbTech., Wageningen* 46. 17 pp. (in Dutch).

Hendriks, P., 1974. Prestatiebeschrijving van de applicatie programmatuur ten behoeve van de klimaatkas op het terrein van het Proefstation voor de Groenten- en Fruitteelt onder Glas te Naaldwijk. Stichting Technische en Fysische Dienst voor de Landbouw, Wageningen. 41 pp.

Heyna, B. J., 1970. [Calculation of climate conditions in glasshouses.] *Pub. Inst. TuinbTech., Wageningen* 55. 36 pp. (in Dutch).

Heyna, B. J., 1973. Symposium Silsoë. *Acta Hort.* (in press).

Jacobs, P. J. J., 1974. Enkele kanttekeningen bij de te verrichten onderzoeken in de klimaatkas van het Proefstation voor de Groenten- en Fruitteelt onder Glas te Naaldwijk. Instituut voor Wiskunde, Informatieverwerking en Statistiek TNO, Den Haag. 20 pp.

Lang, A., 1963. Achievements, challenges and limitations of phytotrons. In: L. T. Evans (Ed.), Environmental control of plant growth. Academic Press, New York. p. 405-419.

Offer, U. & U. Scheider, 1973. Siemens 330 Process Computer – hardware and main fields of application. *Siemens Rev.* 40 (9): 397-403.

Scheider, U. & B. Simang, 1973. System software for the Siemens 330 process computer. *Siemens Rev.* 40 (12): 549-552.

Sheard, G. F., 1965. A glasshouse unit for multifactorial experiments. *Rep. Glasshouse Crops Res. Inst.* 1964: 155-159.

Strijbosch, Th., 1973. Regeling van de ventilatie in de klimaatregeling in kassen. *Bedrijfsontwikkeling* 4 (5): 515-518.

Strijbosch, Th., 1974. Beter overweg met de klimaatregeling. Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk, Report 25. 16 pp.

Strijbosch, Th. & J. van de Vooren, 1973. Symposium Silsoë. *Acta Hort.* (in press).

Vooren, J. van de, 1973. Programma van eisen voor de software van de klimaatkas te Naaldwijk. Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk. 15 pp.

Went, F. W., 1957. Plant growth under controlled conditions. *Chronica bot.* 1. 343 pp.

Wit, C. T. de, 1970. Dynamic concepts in biology. In: Prediction and measurement of photosynthetic productivity, p. 17-23. Pudoc, Wageningen.