The Hokkaido National Agricultural Experiment Station Phytotron

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Introduction

In Hokkaido, which is in the northern part of Japan, the attempt to protect rice and bean plants from damage due to cool weather, "cool injury", has been studied for a long time. Cool injury occurs statistically about every four years, and even after in the postwar years of 1954, '56, '64 and '66, it still occurred. It is caused by low temperature ranging from 12 to 15°C, at flowering time in the summer. Cool injury is of two types, one results in sterility, and the other in insufficient ripening. But, in bean plants, there is a third type of cool injury, the insufficient growth type.

Fig. 1. General view of the phytotron.

Installation which is capable of controlling the environmental factors, i.e., temperature, humidity, light intensity, and air components, etc., independently and with precision, and which makes it possible at any time to make cool weather conditions, has been desired. Its purpose is for making clear the mechanism of cool injury and of devising practical methods of protection. Before the construction of the phytotron, investigation on cool injury in rice plants had been done only by using the cool water irrigation method in paddy fields; in the case of bean plants, there was little investi-

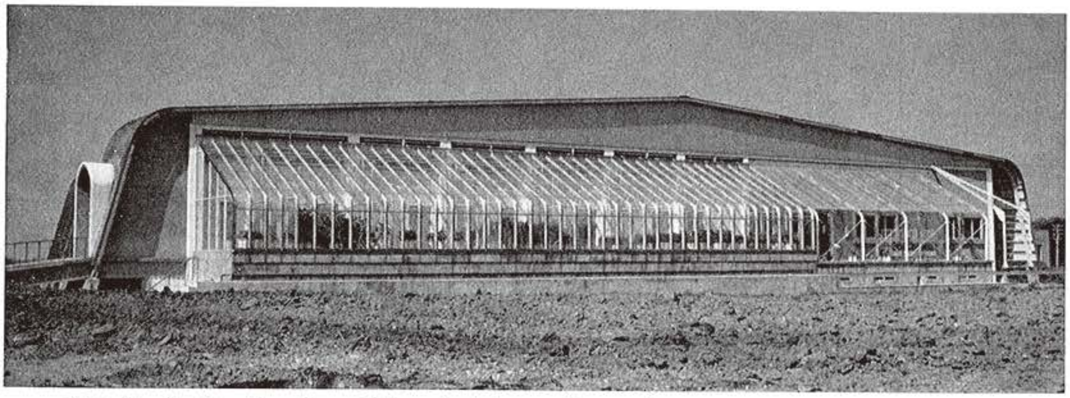

Fig. 2. South side view of the phytotron. Seven glass rooms are seen on the left side and sliding ladder on the rightmost side.

gation, except for the surveying of actual cool injury conditions in the field in a year when cool injury occurred.

The first phytotron consisting of five glass rooms, two artificial light rooms and one dark room, was built at the Hokkaido Agricultural Experiment Station in 1954–1956 and since then has played an important role in the investigation of cool injury for about 10 years.

The necessity of enlargement of the phytotron, in space and facilities, which goes together with the advance of research and experimental methods necessitated the erection of a new phytotron, which was constructed at Hitsujigaoka, Sapporo, in 1966. This was after the cool injury which took place in 1964.

Outline of the floor plan

The main floor of the building (Fig. 3) comprises seven glass rooms, three light rooms, a dark room, a control room, a preparation and laboratory room, a measuring room and offices. The ground floor contains a machinery room which is for the glass room, a boiler-room, a water storage tank for roof-spraying, and equipment for the sending of compressed air through the building, as well as a cellar for spare lamps. The total area of the building, including the main floor to the ground floor, is 1249.6 square meters.

There is a slope and an elevator (lift) which were installed for the purpose of carrying plants grown in the outdoor glass house into the phytotron, and for lifting tools stored on the ground floor to the main floor.

Capacities and area of the controlled plant growing room

The capacities of each room and the area are shown in Table 1. The dimension of the glass room is 4.5 m wide, 4.0 m deep and 2.0 m high on the south side, and 4.5 m high on the north side. The light room is 2.5 m wide and 4.0 m deep and 2.0 m from the floor to the slide sash, which separates the room from the lamp house.

The range of controlled temperature in the glass room is standardized from 10 to 30°C in the daytime and from 10 to 25°C at night, with a little modification of range for the special rooms.

There are three light rooms with the same capacity for all environmental factors that can be controlled, and a wide range of

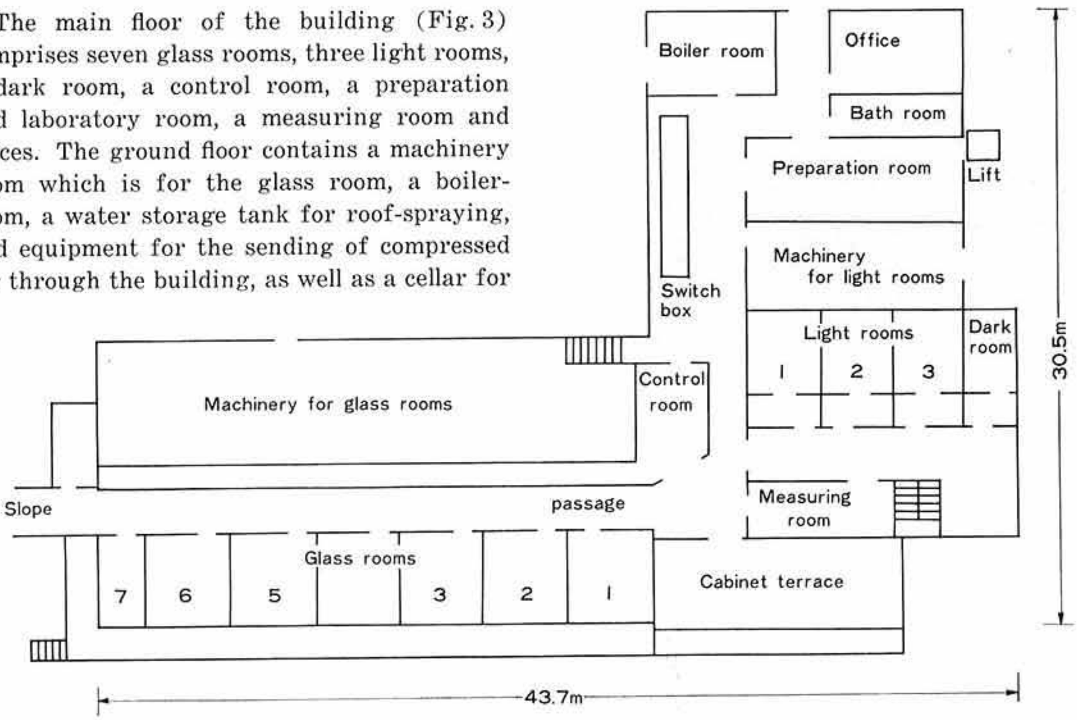

Fig. 3. Plane figure of the phytotron.

Table 1. Capacities and area of controlled plant growing room

Room number	Area (m^2)	Range of temperature*		Humidity** (%)	Light intensity (g cal. cm^{-2}. min^{-1})
		Day (°C)	Night (°C)		
Glass room					
No. 1	18.0	10—35	10—30	70—85	Natural
No. 2	18.0	10—30	10—30	70—85	Natural
No. 3	18.0	10—30	10—25	70—85	Natural
No. 4	18.0	10—30	10—25	70—85	Natural
No. 5	18.0	10—30	10—25	70—85	Natural
No. 6	18.0	10—20	10—15	70—85	Natural
No. 7	9.9	8—10	5—10	not controlled	Natural
Light room					
No. 1	10.0	10—30	10—30	75	0.442
No. 2	10.0	10—30	10—30	75	0.442
No. 3	10.0	10—30	10—30	75	0.442

* Precision of temperature is ±1°C.

** Humidity in the glass rooms is kept from 70 to 85% at any temperature set and in the light room it is constantly kept 75% with a 5% error at any temperature set.

Fig. 4. Inside view of the glass room. Aeration equipment is seen on the right side wall.

the controlling of temperatures as well as the similarity in capacities are one of the characteristics of the phytotron. This system is effective in preventing mishaps to machinery which interrupt experiments. Each room has two refrigerators. Even when one refrigerator is out of order and the room temperature cannot be kept as low as 15°C, it can be kept at 25°C. Therefore, if the temperature condition is exchanged between each room, the experiment can be continued without any trouble.

The second advantage of this system is the simplification of maintenance because of the few kinds of parts necessary for preservation as spares, the promotion of the ability to exchange parts, and easy maintenance. The third is the acceleration of the effective employment of the controlled room. The number of rooms which are to be controlled at a certain temperature varies with the season and year. One can determine the number of rooms at desired temperatures according to the demand of the users.

Light intensity in the light room is 0.442 g cal. $cm.^{-2}$ $min.^{-1}$ above 1.5 m from the floor at the lighting of new lamps. The light panel on top of the room is mounted above a sliding

Fig. 5. Inside view of the light room. Soybean plants grown from the seed shown near the ripening stage.

sash which separates it from the plant-growing space. The panel consists of 74 tubes of 110 W. fluorescent lamps, 21 bulbs of 400 W. special improved mercury lamps and 18 bulbs of 100 W. incandescent lamps. The lamp house is cooled by means of a water-to-air heat exchanger with a fan to prevent the temperature from rising above 40°C.

The spectrum in the visible band range of these lamps and the energy contained in each divided band range are shown in Figure 6 and Table 2.

The agronomic characteristics of soybean plants grown under these lamps in the régime of temperature 23°C, 14 hours a day, and 18°C, 10 hours at night are shown in Table 3. The plants grown under the light room conditions are superior in many points, especially the number of pods, weight per 100 seeds and dry

Table 2. Energy contained in each range band of wave length

Range of wave length mμ	Energy contained g. cal. $cm.^{-2}$ $min.^{-1}$	Relative* value
400—450	0.051	81
450—500	0.041	65
500—550	0.074	117
550—600	0.110	175
600—650	0.076	121
650—700	0.049	77
700—750	0.040	64

* Average value of energy contained in each range band of wave length is estimated as 100.

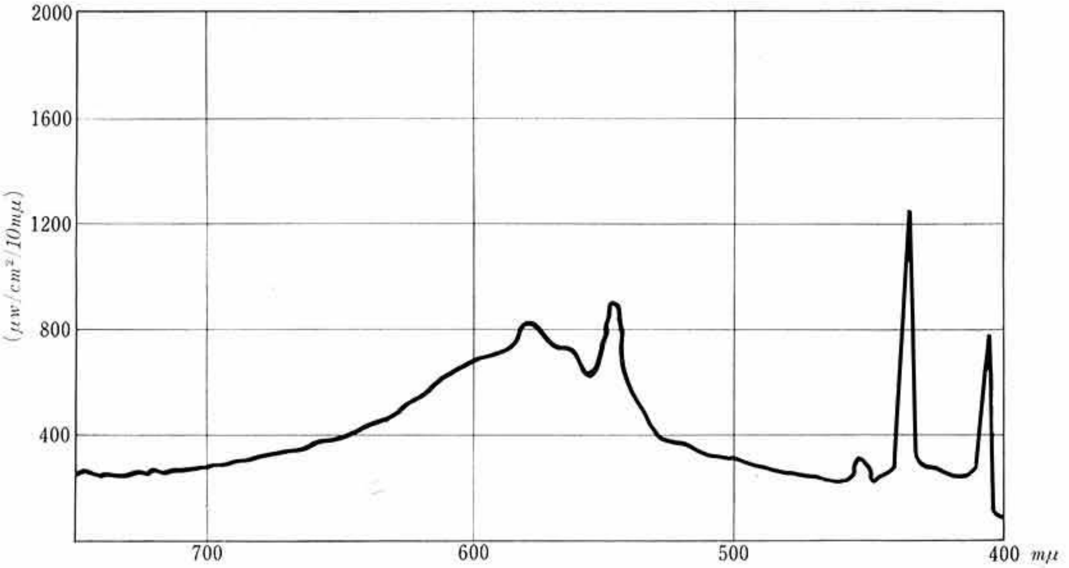

Fig. 6. The spectrum and energy of the lamps in the visible band above 1.5 m from the floor of the light room.

Table 3. Characteristics of the soybean plants grown under various conditions

	Days to flowering	Days to maturity	Stem length (cm)	Number of pods	Weight per 100 seeds (g)	Grain yield per plant (g)	Dry weight of main stem (g)
Light room	40	107	70.9	67.1	25.8	33.6	11.6
Glass room	48	92	50.1	21.7	23.0	10.6	1.8
Outdoors	59	114	41.9	42.0	22.0	17.4	4.1

Light room; Day temperature is 23°C, 14 hours a day, and 18°C, 10 hours at night.
Glass room; Day temperature is 24°C, 14 hours a day, and 19°C, 10 hours at night.
Sowing date, May 15.
Outdoors; Sowing date, May 15.

matter increment per day, as compared to plants grown under glass room conditions, and even more so with those grown outdoors.

Airflow

The heat which enters the glass room from the outside is removed by a closed-circuit air cooling system, with provision for the infusion of an amount of fresh air three times of the room volume per hour. Diagrams of the air-conditioning system of the glass rooms and of the light rooms are shown in Figures 7 and 8.

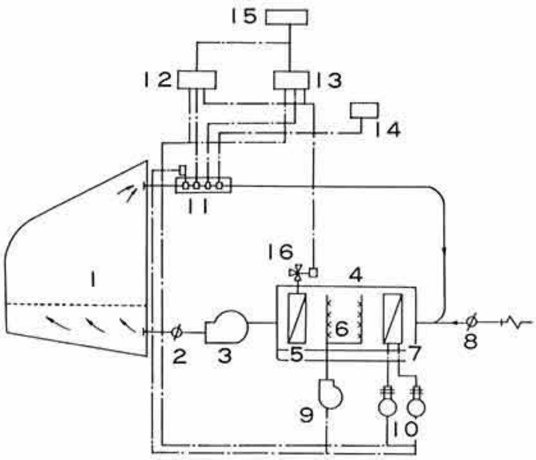

Fig. 7. Diagram of the air-conditioning system of the glass room.
1. Glass room 2. Volume damper 3. Fan 4. Air conditioner 5. Heating coil 6. Spray nozzle 7. Cooling coil 8. Volume damper 9. Fan 10. Refrigerators 11. Detectors 12. Thermal controller for day 13. Thermal controller for night 14. Recorder 15. Time switch 16. Three-way motor valves.

In the glass room, the air flows vertically upwards in the plant growing space, through the iron floor plate, with small holes 8 mm in diameter, and is expelled into the suction duct located on the upper side of the north wall. In the light room, air is put into the room through the perforated side wall and expelled into the opposite wall, which is of the same style. Airflow volume is more than 250 times that of the room volume per hour, both in the glass and light rooms.

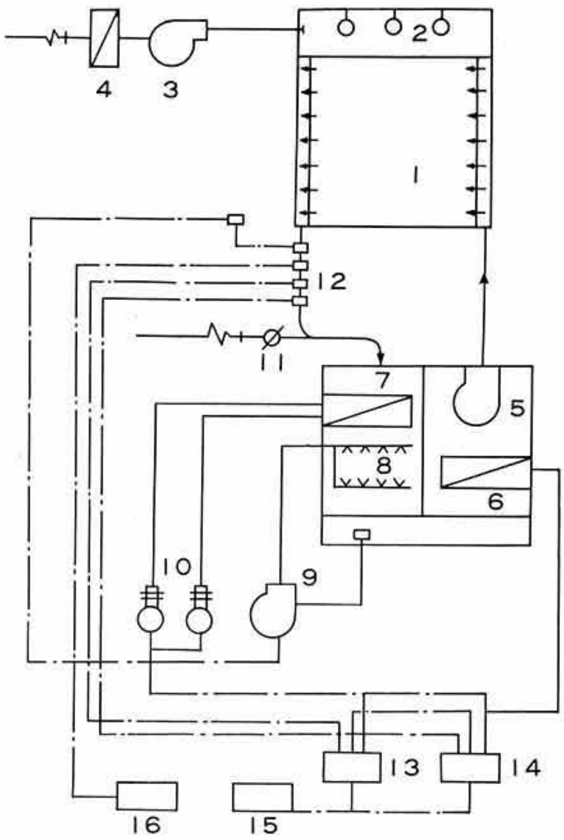

Fig. 8. Diagram of the air-conditioning system of the light room.
1. Growing room 2. Lamp house 3. Fan 4. Water-to-air heat exchanger 5. Fan 6. Heating coil 7. Cooling coil 8. Spray nozzle 9. Fan 10. Refrigerators 11. Volume damper for fresh air 12. Detectors 13. Thermal controller for day 14. Thermal controller for night 15. Time switch 16. Recorder.

Air conditioning

Day and night temperatures are kept under separate control by means of electronic controllers mounted in the central controlling board. For heating in the glass rooms, hot water is used with control by a proportional three-way motor, and for the light room, including glass room No. 7, electric power is used with a step control system.

For cooling, a direct expansion system controlled by a step control system, is used. The power of the refrigerator for the light room is 3.75 KW and 7.5 KW for the glass room, and two refrigerators are set for each room.

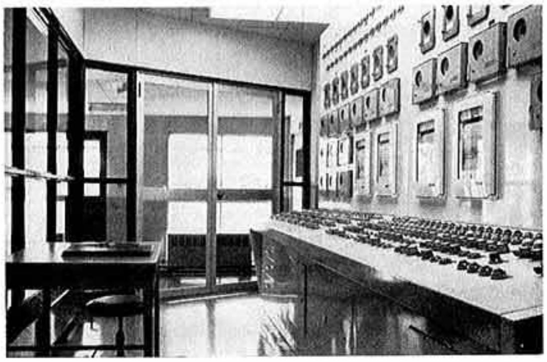

Fig. 9. Central controlling room.

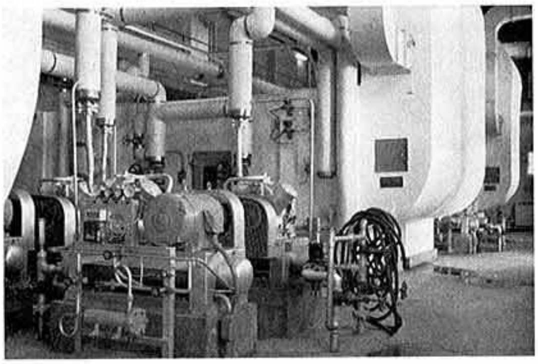

Fig. 10. Machinery room for the glass rooms.

The circulating air washer system is adopted to keep the relative humidity more than 70 per cent. Detectors for temperature and humidity are set in the air return duct, as it is considered that there is little difference in temperature between the recorder and plant growing zones because of the large amount of airflow volume, as much as 250 times per hour.

Special installations

1) Equipment for controlling soil temperature

This equipment is able to control the soil temperature from 5 to 35°C, independent of the room temperature. This shifter can be transferred in front of a certain room, and can be jointed with rubber pipes through the sleeves at the wall to the water case, which is located in the room to soak the pots.

2) Dehumidifying equipment

Four dehumidifiers were installed in the corridors in front of the growing rooms to prevent the wall and ceiling from becoming covered with dew.

3) Other equipment

There are an autoclave for soil sterilizing, aeration equipment for water-culture, and other types of equipment which may be used for experimentation as needed.

Reliability

The machinery for each room forms a group system and is separated from the other machinery to prevent any trouble from extending from the other systems. The duplication system for electricity and water supply, and a replacement system for the boiler, refrigerator and motor and so on, are adopted, where possible. An emergency diesel engine generator, 450 KVA is available to operate the phytotron in the event of a total power failure, and has sufficient capacity for maximum demand.

A certain amount of regular attention everyday, and overhauling during the winter are carried out by five expert officials. The phytotron is under the care of an expert, even during the night, so as to increase the reliability factor in carrying out experimentation.

Conclusion

A phytotron can never be considered as a completed installation. With the advance of phytotronics and with the coming of manifold demands from the research workers, corresponding to the advance of their research, increased precision and complexity of the controlled factors will be required. The expenses, therefore, needed for the improvement of the phytotron must always be supplied to keep it in the best condition for conducting research.

In contrast to former times, plant growing in light rooms has remarkably improved due to the new type of mercury lamp devise. It is, therefore, desirable to increase the number of light rooms, considering that light rooms are more usable than glass rooms, due to being kept in a constant environmental condition all year round. The ratio of light rooms to glass rooms is now three to seven in number, but it is expected in the future that the ratio will be changed to half and half.