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Appropriate Greenhouse Constructions for Mild Climates

Angepaßte Gewächshauskonstruktionen für wärmere Klimate

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1 Introduction

When considering the installation of greenhouse in mild climates one has to distinguish between
- greenhouses for subtropical climates (Mediterranean)
- greenhouses for humid tropical climates
- greenhouses for dry climates.

Plastic-film greenhouses are mainly used in most of the mild climate regions. In addition to the general demands on plastic-film greenhouses the climate conditions prevailing in each region have an influence on the construction design.

Ventilation, humidity control, light transmission, heating, cooling and the collection of rain water for irrigation are functions of climate control which are dependent on the greenhouse construction. The plastic-film greenhouses have been developed in many countries according to national traditions. One often finds very different constructions in climatically comparable regions, but the plastic-film greenhouses should be designed with more regard to climatic conditions and general demands in future.

2 General design criteria

The general design criteria of plastic-film greenhouses can be defined as follows:
- Avoidance of film destruction on the structure by flapping in the wind. Films must be stretched tightly by means of simple stretch devices.
- Simple methods to change the film which require little work.

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- Insulation of those parts of the structure which are heated up by solar radiation and in contact with the film (mainly iron structures).
- Effective ventilation.
- In climates where temperatures can sink considerably in the night, ventilators must be closeable. Avoidance of leakages to prevent a lowering of the temperature in cold nights.
- Greenhouse volume as large as possible.
- Avoidance of drop fall of condensation water from the roof by choice of roof slope, film treatment or anti-dew film.
- Greenhouse with gutters are recommended for collecting rain water for irrigation.
- Vertical side-walls to allow production of high crops near the walls as well as for utilization of machinery for cultivation.
- Sufficient wind resistance.

3 Greenhouses for subtropical climates

The main problems for plant production in greenhouses in subtropical climates (Mediterranean) are:

- low temperatures below the biological optimum in winter nights, necessity of heating for some months;
- high temperatures during the day;
- high humidity at night;
- stability against wind;
- water quality and water storage;
- deficiency of CO_2 in closed greenhouses during day-time.

Greenhouses for subtropical climates should have the following characteristics:

- The design of the construction itself to minimize heat losses even in unheated greenhouses by reducing the heat transfer through the covering material and by reducing the uncontrolled air exchange through leakages.
- Installations for increasing the temperature at night-time. Cheap fossil fuel heating systems of simple solar equipments.
- Effective ventilation. The relation of ventilator opening to greenhouse floor area should be 18 to 25%.
- The light transmission should be as high as possible. The reduction by water condensation in drop-form on the covering material should be avoided.
- Greenhouses with gutters are recommended for collecting rain water.

A large number of plastic-film greenhouses have been developed world-wide. They range from simple constructions made of wood clad with nailed-on plastic-film and round arched tunnels to superior constructions.

The simplest form of plastic-film greenhouse is the round arched tunnel greenhouse. This type can only be built single-span.

Fig. 1 shows a typical 8 m wide tunnel greenhouse. The film is 7 m wide. Openings are provided on each side at intervals of 7 m by parting the overlapping film sheets. The normal length of tunnel greenhouses is 40 to 60 m. In this case the ventilation efficiency is unsufficient.

In some cases the openings for ventilation are obtained by separating the overlapping film sheets on the whole round arched surface, Fig. 2. The ventilation efficiency is better in this case but not always sufficient. Recently developed round arched greenhouses have a rolling-up system for the ventilation openings at the side-wall, Fig. 3.
The round arched tunnel greenhouses presently used in subtropical regions have the following disadvantages:

- The ventilation is not sufficient if only overlapping plastic-films are „opened".
- When tall plants are grown (tomatoes, cucumbers), the arched design of the wall causes about 1 m of ground to be left unoccupied between the side-walls and the first row.
- The plants near the side-wall ventilation and gable grow less than those in the middle of the tunnels. This phenomenon is caused by low inside temperatures during cold nights, by low air humidity near the vents and the gables and by a wind effect.
- The greenhouse volume is small.
- The net greenhouse floor area fit for plant cultivation is small compared to the ground area occupied by the tunnels. The space left between two tunnels can be 2 to 3 m.

Multispan greenhouses have advantages:

- The greenhouse volume is larger and the climatic conditions are better.
- The ventilation with side-wall ventilators can prove sufficiently efficient if the whole structure has a width of 16 to 22 m.
- The drop density is higher and the border effect is less important. Vertical side-walls avoid losses of space along the walls and allow machines to work inside the greenhouse.
- The useable greenhouse area per ground area is higher.
- The ventilation efficiency compares favourably with that obtained in a single-span tunnel.

The width of plastic-film available locally limits the width of individual spans in multi-span greenhouses, if the film is stretched longitudinally.

Different types of saddleroof constructions with plastic-film coverings are built in the subtropical regions, Fig. 4. A closeable rolling-up ventilation is situated at the side-wall and perhaps even at the gables. The stanchions are made of wood, steel or concrete; the roof construction is made of wood. The plastic-film is nailed on with lath wood which is unsatisfactory for the change of the films and their durability.

Steel tube constructions in round and pointed arch shape are also built, Fig. 5. Pointed arched of gothic arched greenhouse constructions have advantages over round arched construction because condensation water can flow off better at the inner side of the film.
The constructions often have gutters to collect rain water and also for fastening the film. The film is fixed and stretched by rolling it on a pipe in the gutter.

The greenhouse shown in Fig. 6 has sloped guy wires to stabilize the construction. The film is rolled up on the sloped rods for ventilation purposes. The ventilation opening is enlarged.

Greenhouse constructions with ridge ventilation can also be equipped with rollable ventilations that can be closed over night, Fig. 7. This construction is a little more expensive.

4 Greenhouses for humid tropical climates

The climatic conditions in humid tropical climates are:
- High monthly precipitation quantities and high average humidity throughout the year or during the rainy season.
- Only little variation of temperature and solar radiation in the course of the year. During dry periods slightly higher temperatures.
- Throughout the year, day and night temperatures are above the biological minimum for plant production.
- Irradiation can be too high.

Greenhouses for humid tropical climates should have the following characteristics:
- Protection of crops from rain, too high solar radiation and wind. Only single covering is necessary.
- Very good ventilation efficiency; no closing of ventilators is necessary. Single-span and multi-span constructions with open side-wall, gable and ridge ventilators. Volume/ground floor area as large as possible.
- Durability of the film for at least one year.
- If necessary, ventilation openings have to be equipped with desease-nettings.
- Rain water collection in regions with dry and wet seasons.
- Wind resistance.

Fig. 8 shows a simple single-span construction built from round timber. The construction has large ventilation openings in the side-walls, gable and at the ridge. The single-span construction is suitable for smaller holdings. On the side-walls and gables, the film reaches about 1 m hight. The film from the side-walls extends over the ground so that the rain water draining off the roof can be collected in a storage reservoir.

As an alternative to the simple wooden construction steel pipes can also be used for the stanchions and other connecting pieces. The choice of the construction materials depends on the local prices for timber and steel.

Fig. 9 shows how a single-span construction can be changed into a multi-span construction by building the greenhouses close to each other. The plastic-film is streched over the space in between and thus serves as a gutter. At the edges of the roof, wires are put up where the plastic-film is fixed.

Fig. 10 shows a saw-tooth construction with gutter. The roof construction consists of vertical and sloped surfaces. The vertical surfaces consist of ventilation openings. Saw-tooth greenhouses are relatively cheap. For a maximum incidence of light the vertical surface have to

face the sun in winter. The sloped construction parts can also be built of flexible woods or bamboo sticks.

Fig. 11 shows a high wooden greenhouse construction with ventilation openings at ridge and gutter. The gables and side-walls are open. At the sides facing the wind, a kind of porch of canopy is built as a mean of protection from wind and rain.

5 Greenhouse for dry climate

Under desert conditions one has to take into consideration the following problems:
- Yearly evaporation rate is higher than precipitation
- High temperatures at day time and possible low temperatures at night, sometimes below 0°C
- Strong winds with dust and sand
- Low outside humidity
- Only brachish or salty water is frequently available which has to be desalinated.

Greenhouses for desert conditions should consequently have the following characteristics:
- Effective ventilators, which can be closed
- Protection from sand storms and low humidity
- Stable constructions
- Avoidance of heat loss at night time
- Possibility of raising the temperature at night-time
- Reduction of border effect by wind and low humidity
- Evaporative cooling if necessary
- Solar water desalination system

There are two trends of greenhouse development for dry, arid climates:
- Greenhouse constructions similar to those constructions for subtropical climates with special equipments for evaporative-cooling. In this case high amounts of water are necessary.
- Special closed-system greenhouses with climate control without active evaporative cooling.

During recent years special closed atmosphere greenhouse systems have been developed and are under investigation.

6 New developments for mild climates

A new closed system greenhouse with integrated solar water desalination was developed and evaluated in the Institute for Horticultural Engineering (1, 2, 3). The greenhouse should fulfill the following demands:
- Protection of plants from wind, dust and low humidity
- Reduction of water use by decreasing transpiration rate and reducing humidity losses through leakages
- Minimizing water consumption by waiving artificial cooling
- Recollection of condensed water from interior greenhouse surfaces

- Desalination of salty water for irrigation
- Independent energy supply by solar cells
- Construction with common greenhouse elements to reduce investment costs.

Fig. 12 shows a cross section of the construction. The shape of the northern roof is designed to reflect the main part of the global radiation during high positions of the sun. The south roof is made from a special selectiv absorbing glass, which absorbes a high amount of the non visible part of the global radiation. The transmission for visible light is reduced not very much. The special shape, the use of selective glass and the outside shading system aim at an inside temperature, which does not exceed suitable conditions for plants, even at high outside radiation and temperature. In the north side wall a fan for a low capacity forced ventilation is installed. To reduce the necessary amount of desalinated water the greenhouse is especially tightened and should be kept closed as long as possible. Thus the water which is evapotranspirated by plants and soil is not lost through leakages and can be recollected. The solar water desalination system is located at the southern side wall. Another simple plastic film greenhouse construction has been developed in Hannover suitable for subtropical climates (4, 5). This construction is shown in Fig. 13. It consists of two independent parts, the load bearing basis construction and the roof construction. The basis construction is a guy-rope construction similar to attent with shaped wire ropes or steel rods (a) connecting the gutter or upper end of the posts, respectively, with the foundation. Within the spans, the stanchions are connected crosswise at the upper ends by steel rods or wire ropes (b). Longitudinally, the stanchions are connected by gutters. The stanchions only absorb pressure forces, the other parts only tractian forces. Therefore, foundations are only necessary at the outside at the shaped rods. Under the vertical stanchions only supporting slabs and no deep foundations are necessary, or the stanchions are put into the soil. In this way, the assembly is simplified considerably and the material costs are reduced. The independent roof construction can be produced in various forms with different steel or wooden profiles and can be fixed at the gutter or the stanchions, respectively. Both parts must have sufficient resistance against wind forces.

7 Summary

In regions of mild climates pastic-film greenhouses are mainly used for horticultural production near urban centres. There are a great variety of designs available on the market. The plastic-film greenhouses should be more adapted to climatic conditions, as well as to the expected future demand.

This paper describes general criteria for the design of greenhouses and examples are given for appropriate constructions in regions of mild climate.

Zusammenfassung

In den wärmeren Klimaten werden vor allem in der Nähe von großen Verbrauchszentren in zunehmendem Maße Foliengewächshäuser zum Anbau von Gemüse eingesetzt. Nicht immer

werden die angewandten Konstruktionen den besonderen Standortverhältnissen dieser Klimate gerecht.

Die vorliegende Arbeit gibt einen kurzen Überblick über die wesentlichen Erfordernisse die von den Foliengewächshauskonstruktionen in wärmeren Klimaten zu erfüllen sind und gibt Beispiele für angepaßte Konstruktionen.

References

1. STRAUCH, K. H., 1985: Geschlossene Gewächshaussysteme mit integrierter solarer Wasserentsalzungsanlage für aride Gebiete. Gartenbautechnische Information, Institut für Technik im Gartenbau Hannover, Heft **22**

2. BAYTORUN, A. N.; C. DUMKE and J. MEYER, 1989: Closed system greenhouse with integrated solar desalination for arid regions. Gartenbauwissenschaft **45 (2)**, 62–65

3. MEYER, J.; C. DUMKE und A. N. BAYTORUN, 1989: Entwicklung, Bau und Erprobung eines geschlossenen Gewächshaussystems mit integrierter solarer Wasserentsalzung für Trockengebiete. Gartenbautechnische Information, Institut für Technik im Gartenbau Hannover, Heft **32**

4. ZABELTITZ, Chr. VON, 1985: New construction of a plastic-film greenhouse. Acta Horticulturae **170**, 25–28

5. ZABELTITZ, Chr. VON, 1984: Plastic-film greenhouses. Desadvantages – Demands – Types. Acta Horticulturae **154**, 305–314

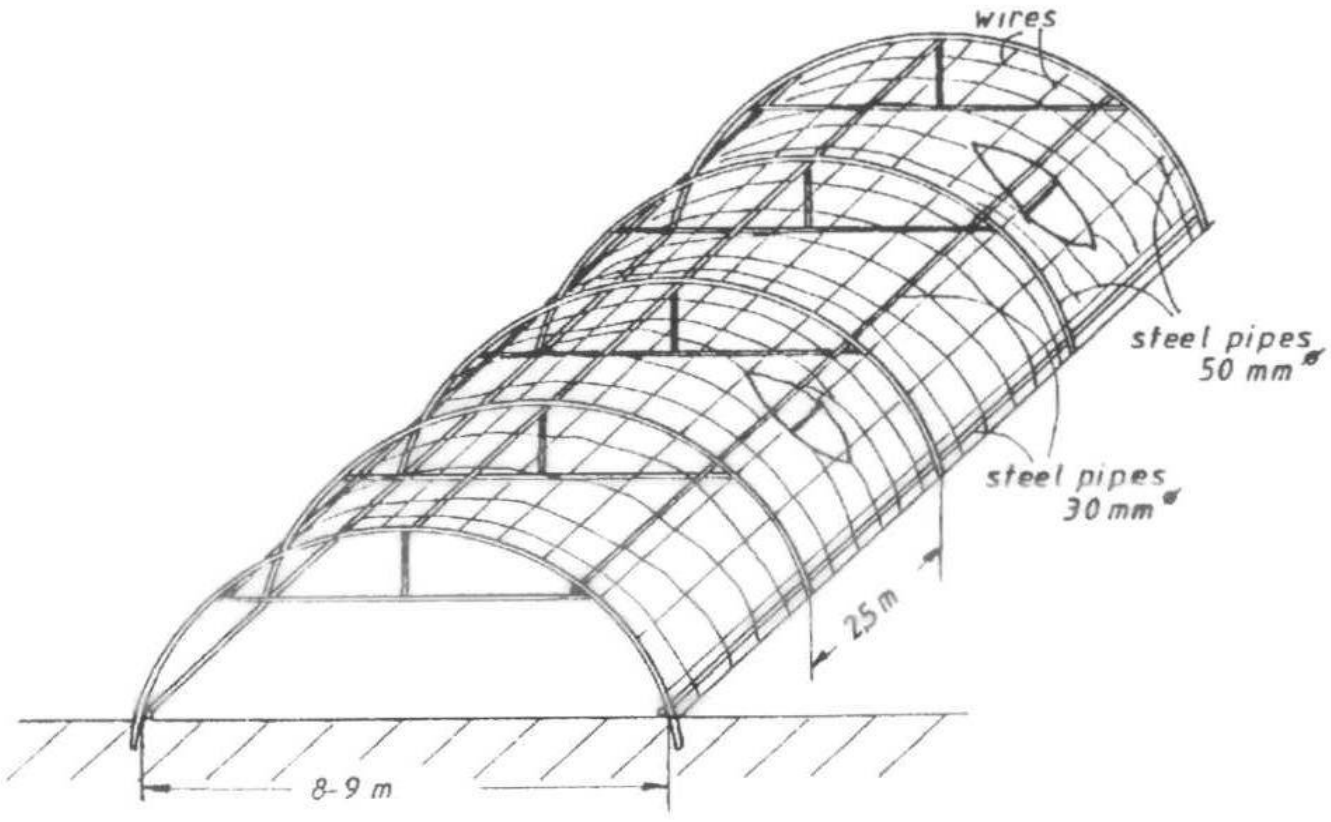

Fig. 1: Tunnel-greenhaus with conventional ventilation.

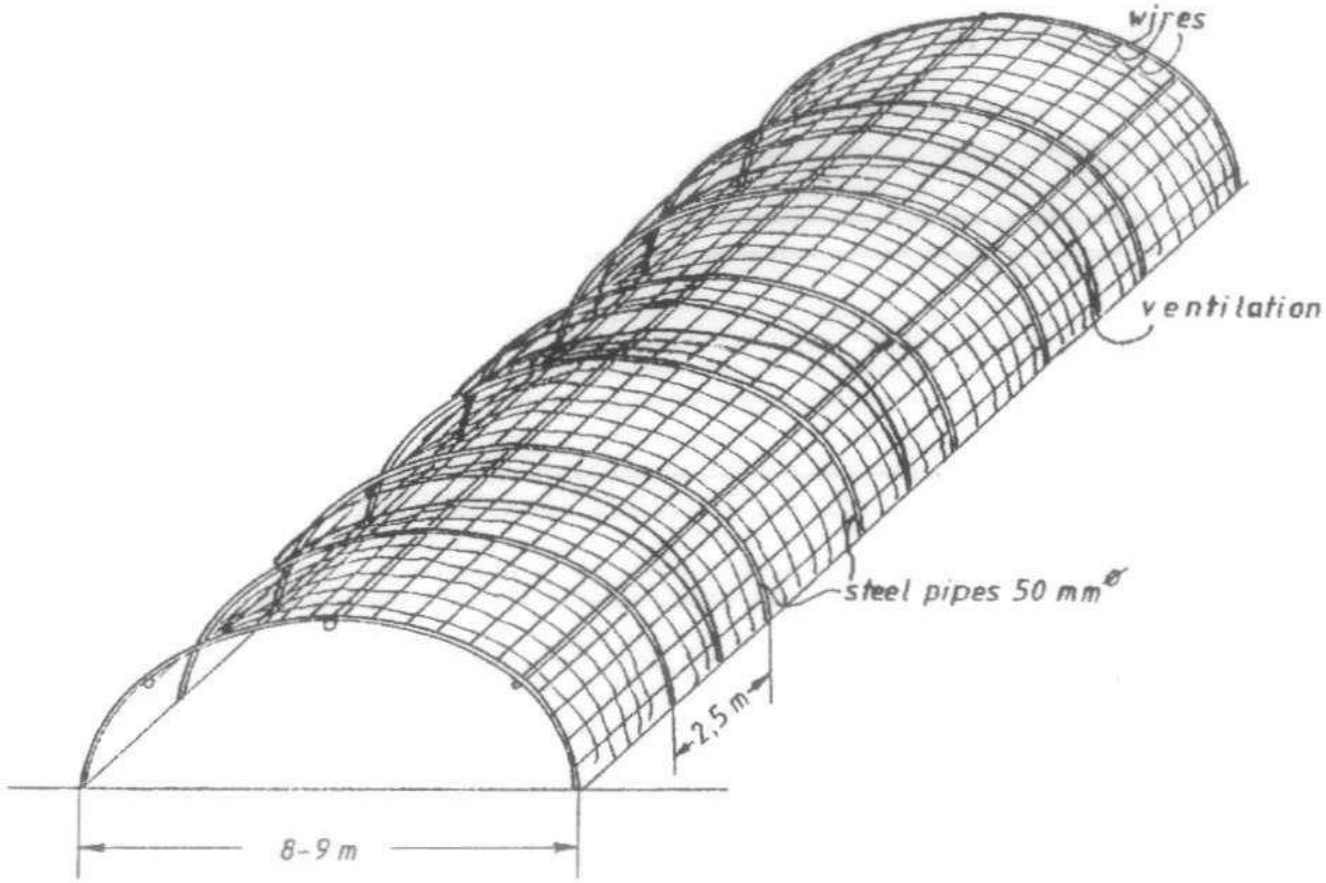

Fig. 2: Tunnel-greenhouse with improved ventilation.

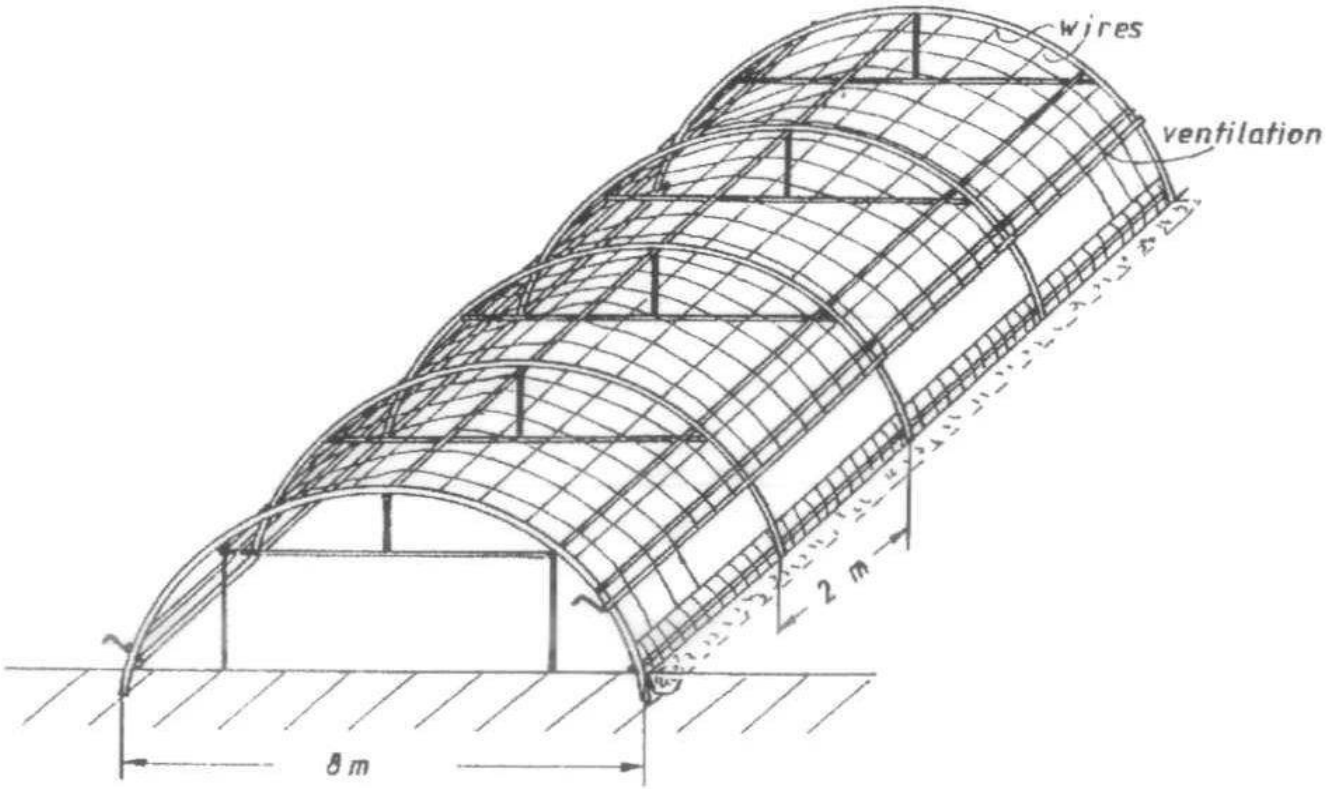

Fig. 3: Tunnel-greenhouse with rolling-up ventilation.

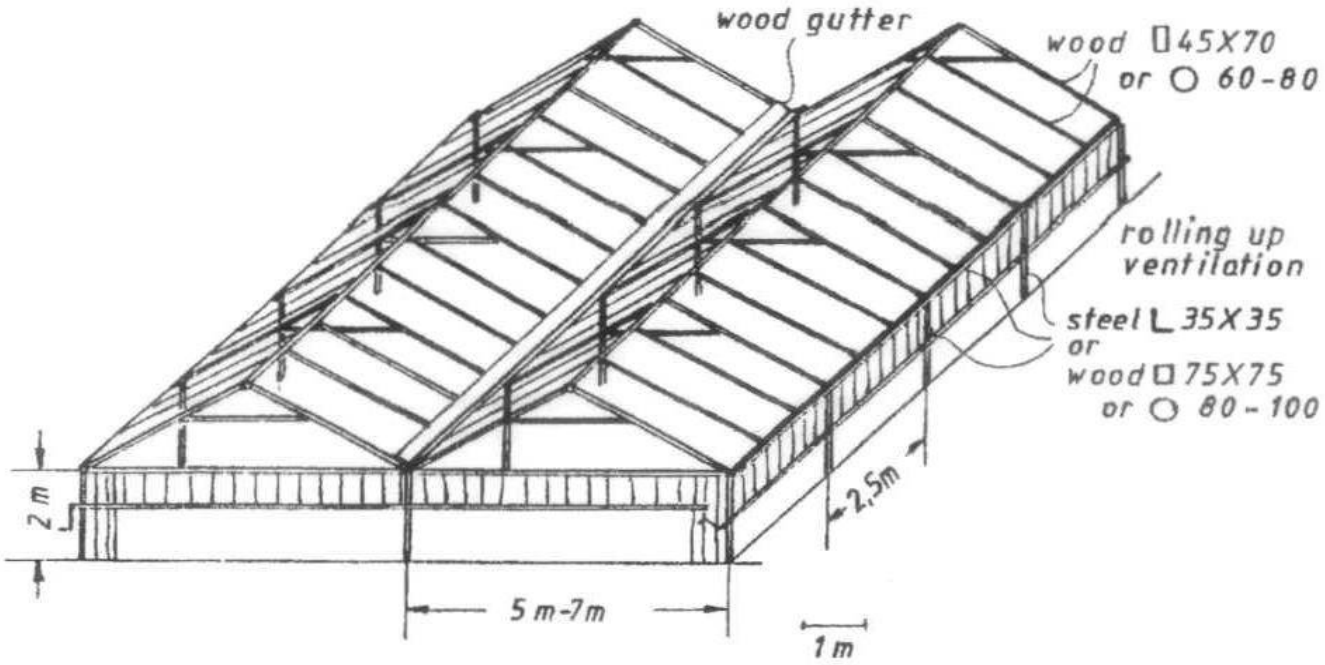

Fig. 4: Saddle-roof greenhouse construction.

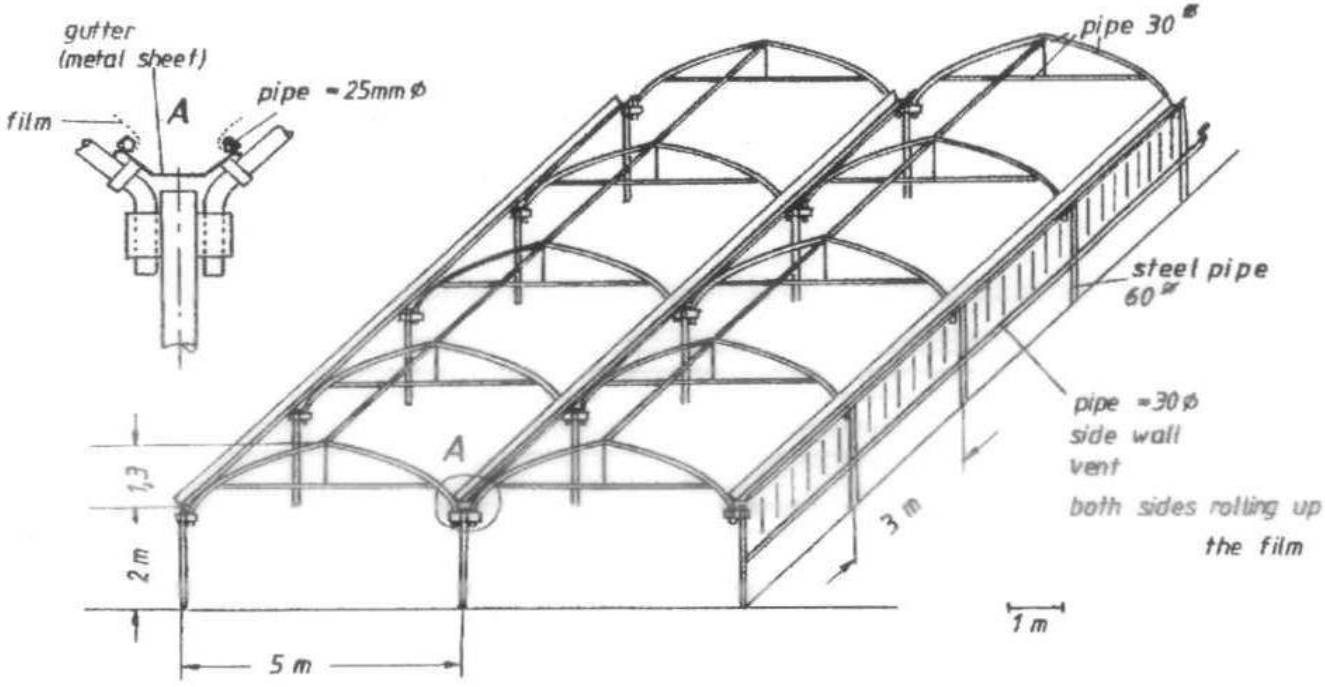

Fig. 5: Steel tube construction with gothic arch.

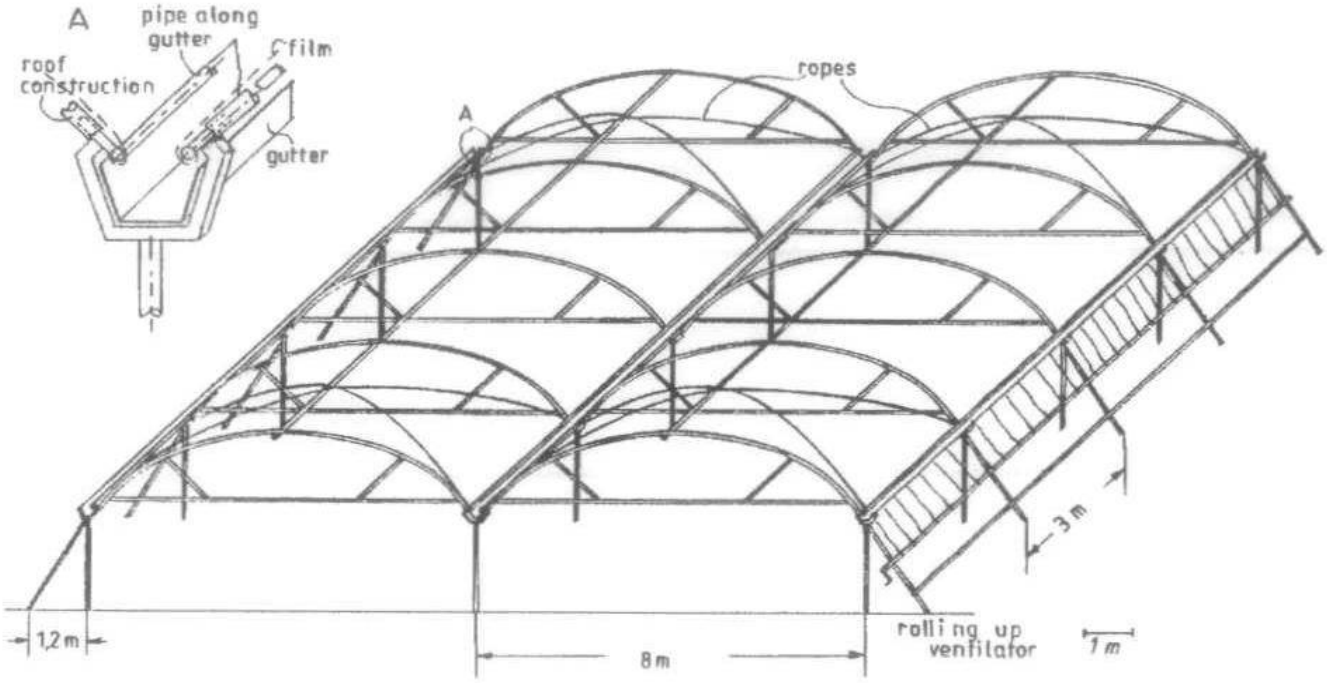

Fig. 6: Greenhouse construction with sloped sidewall.

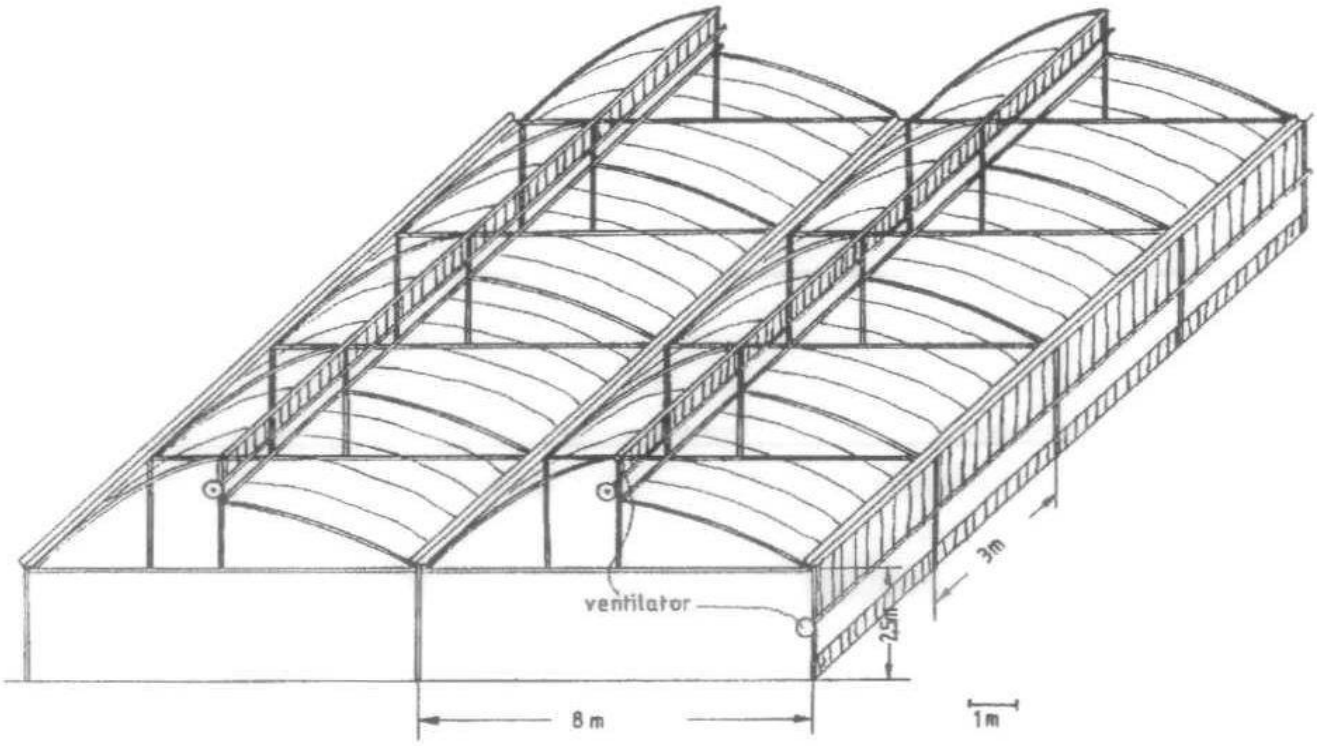

Fig. 7: Greenhouse construction with ridge ventilation.

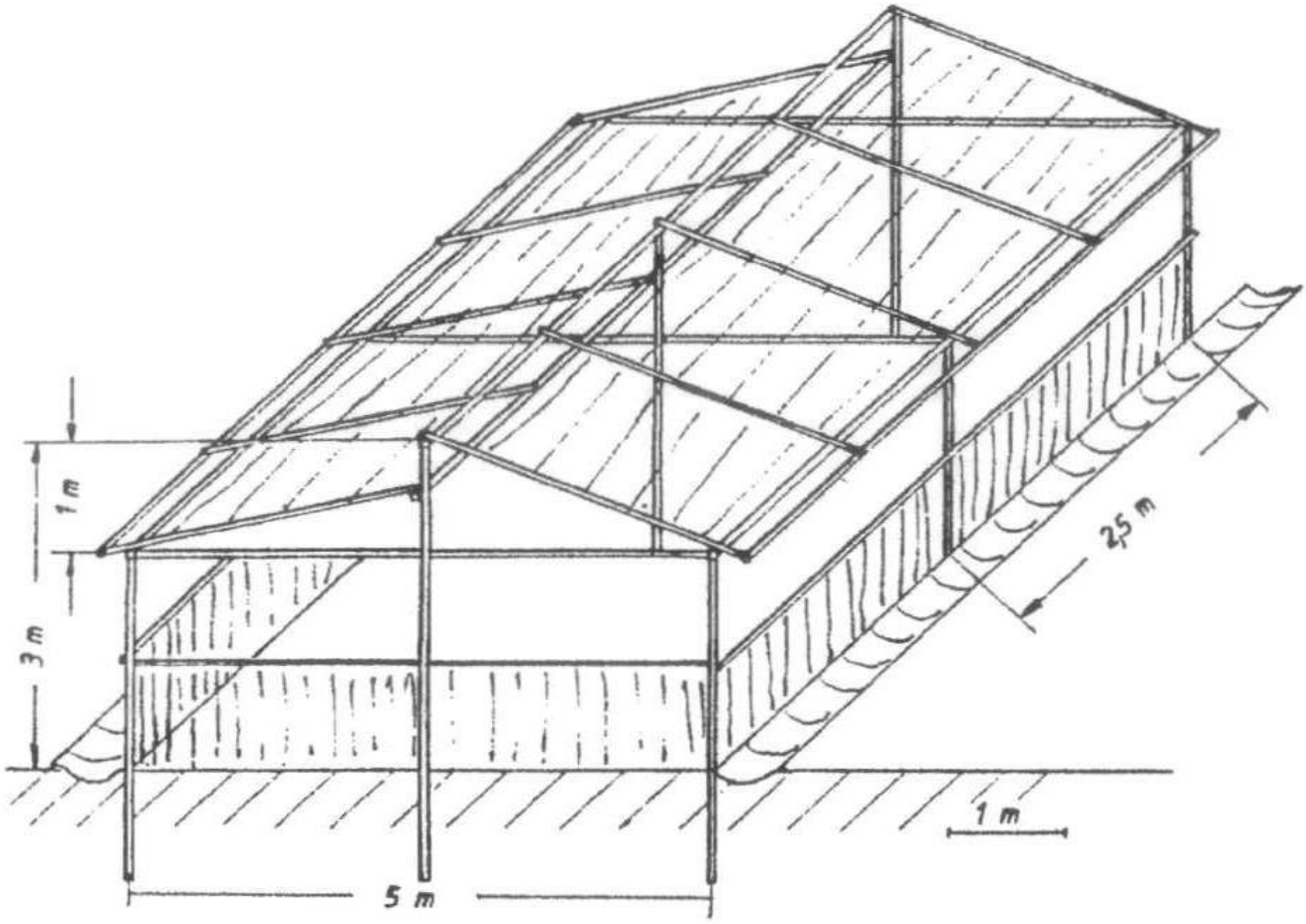

Fig. 8: Single span construction for tropics.

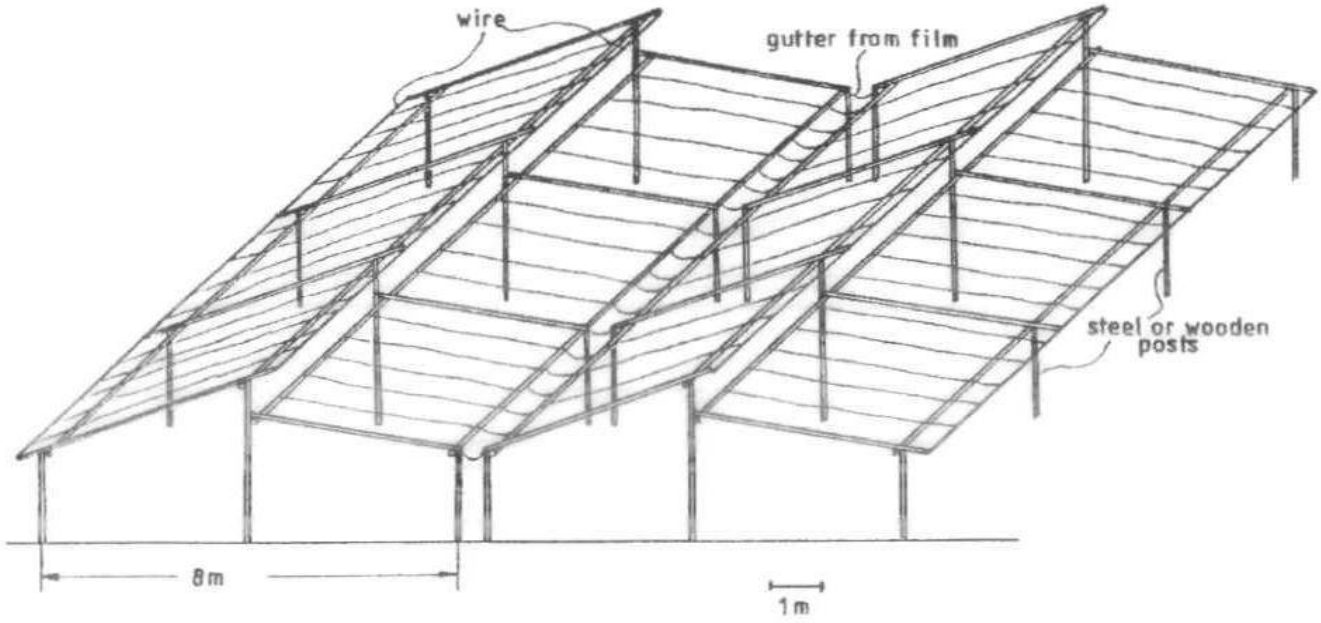

Fig. 9: Simple multispan construction.

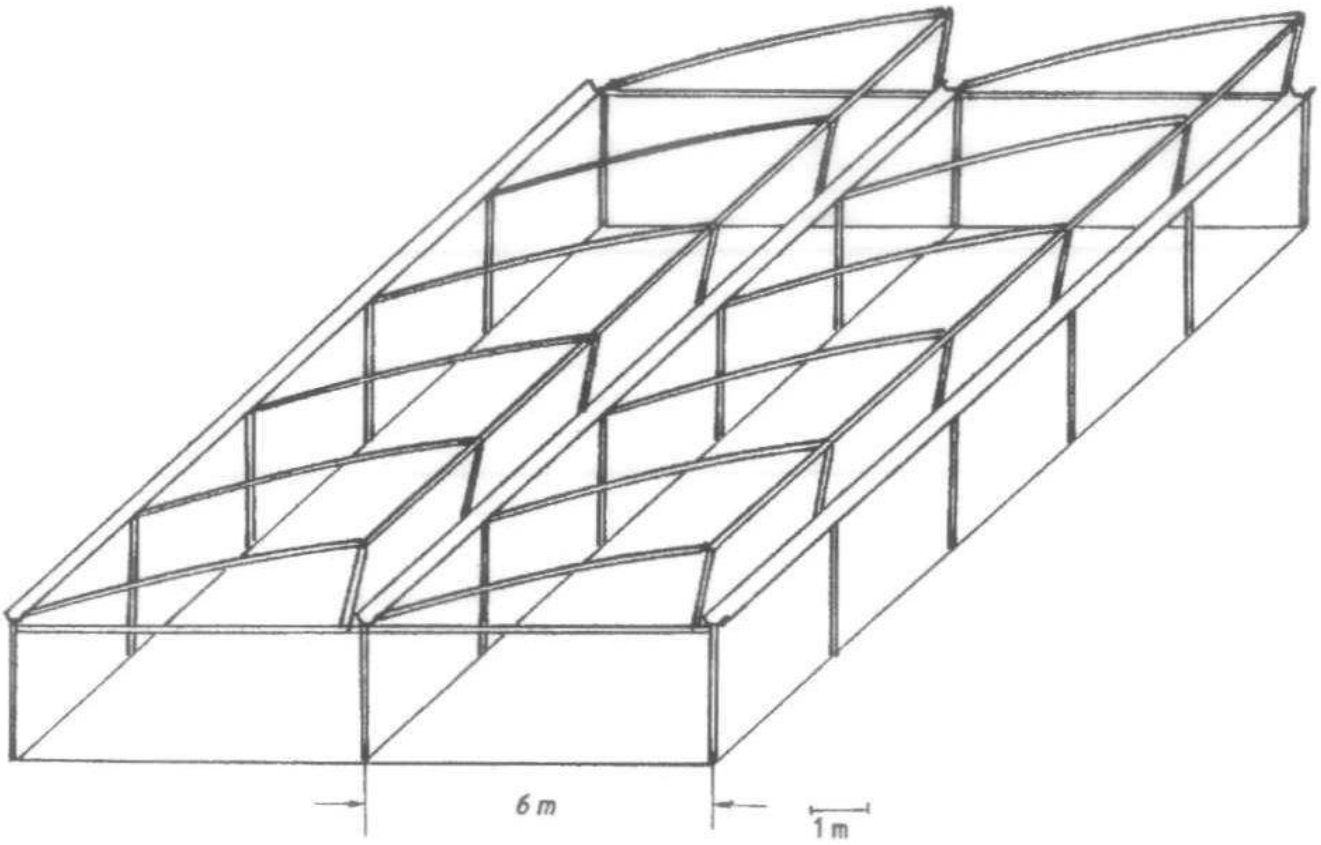

Fig. 10: Saw-toth construction with gutter.

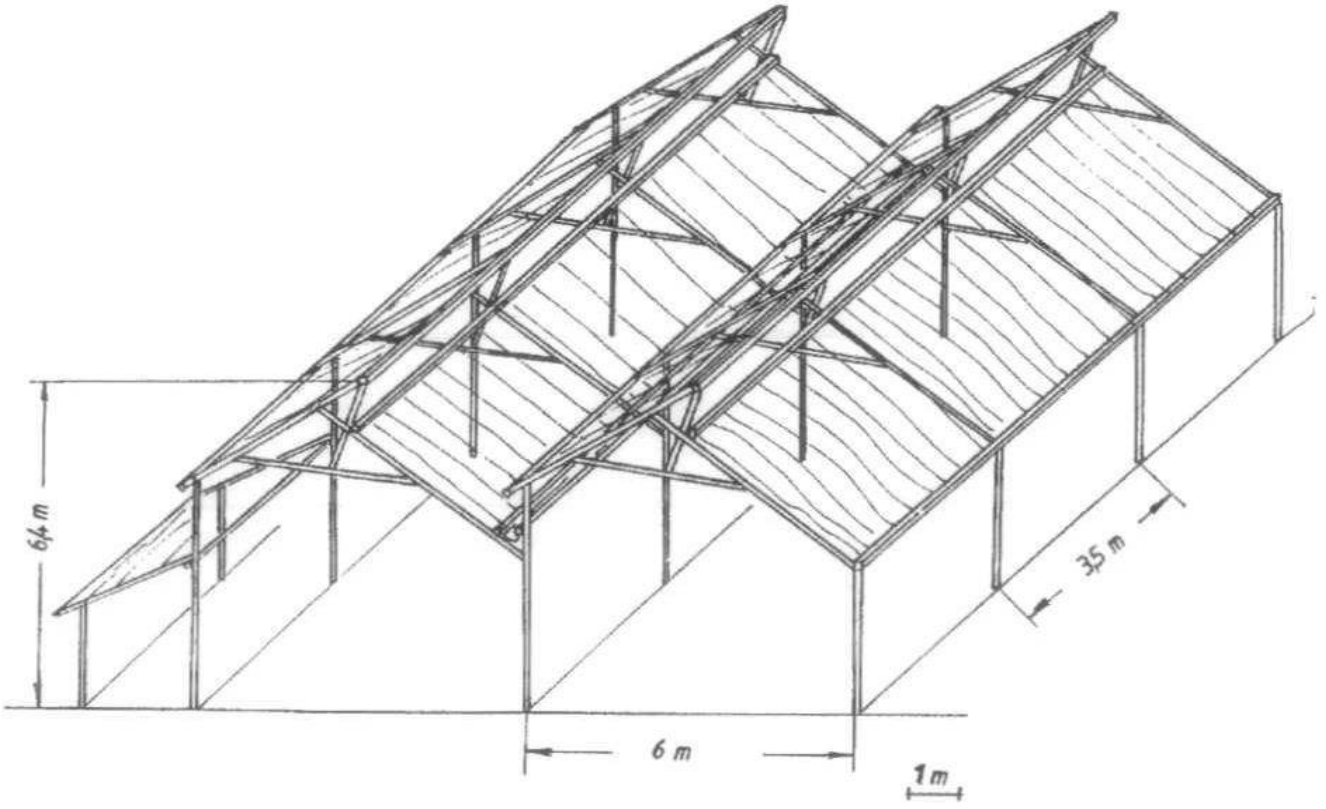

Fig. 11: Wooden construction for tropics.

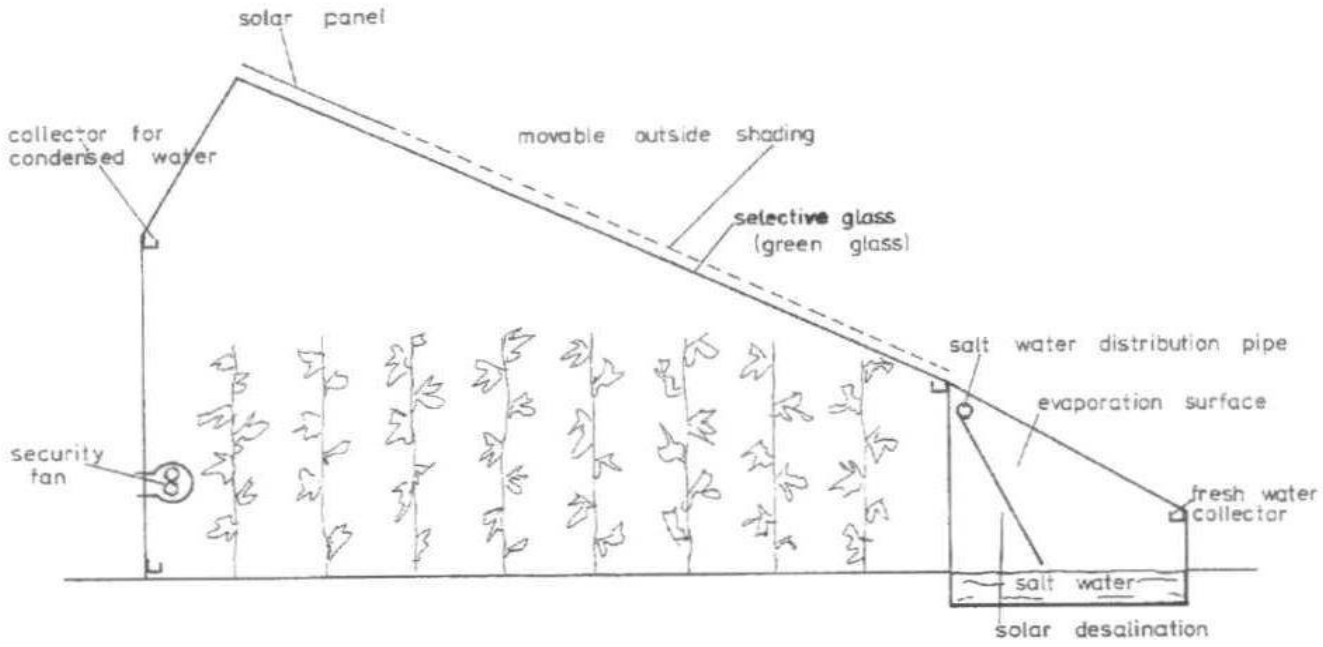

Fig. 12: Closed system greenhouse.

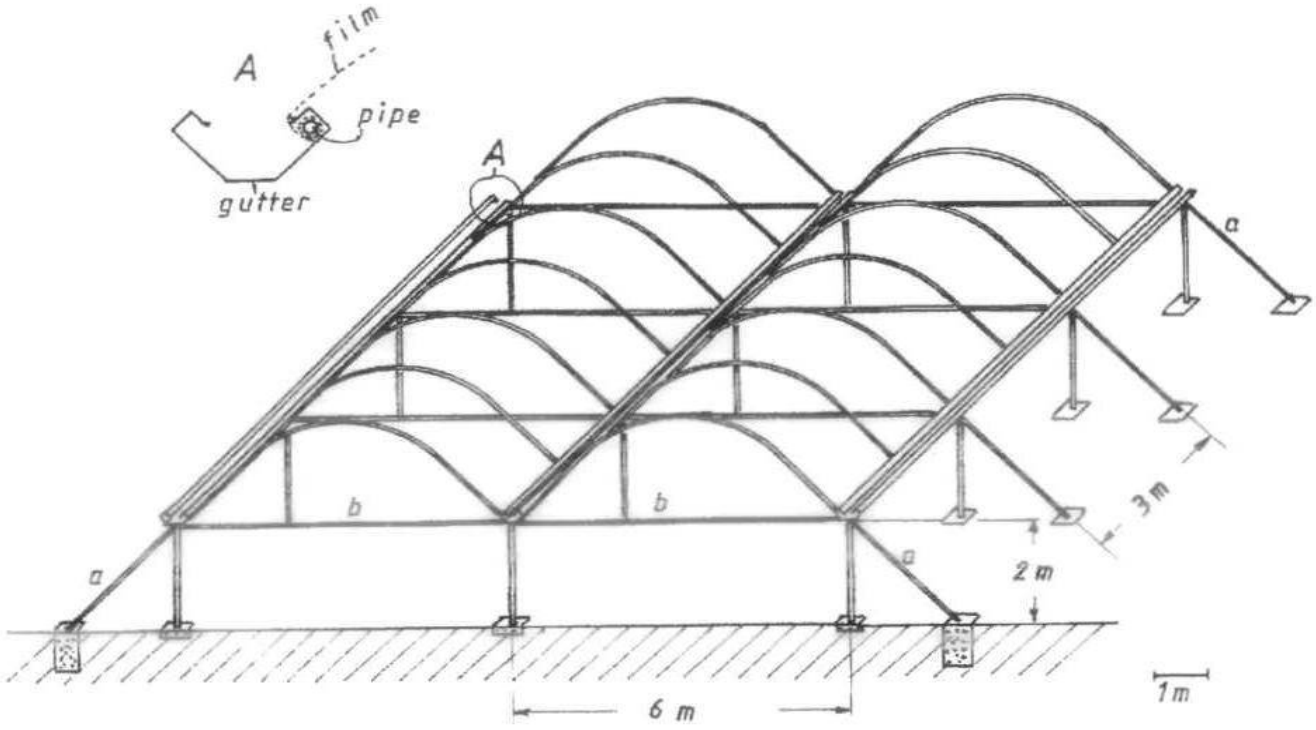

Fig. 13: Greenhouse construction for subtropical climate, developed in Hannover.