VEGETABLE PRODUCTION IN GREENHOUSES

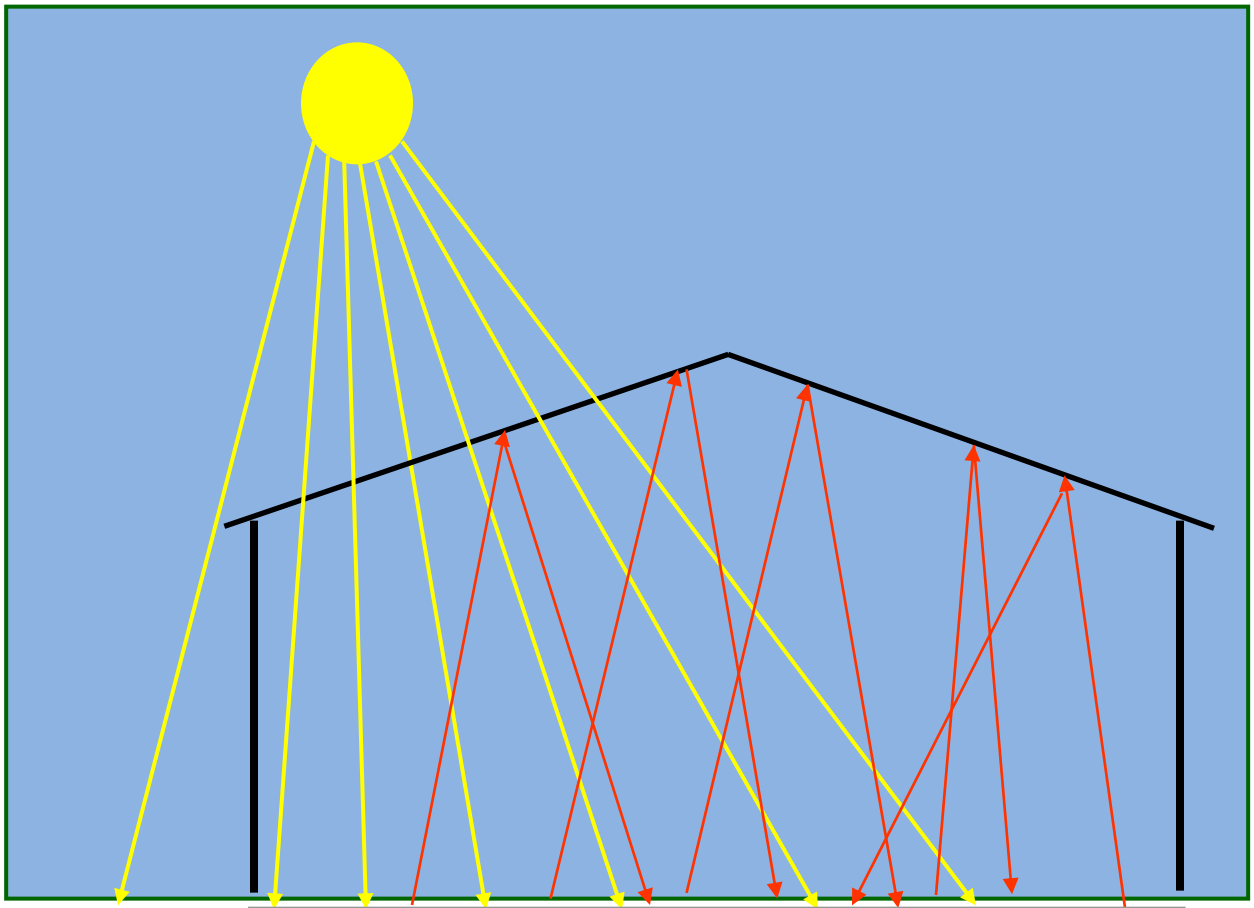
Greenhouse

A greenhouse is a closed construction with the following characteristics:

- It is covered with a material which is transparen to the photosynthetically active radiation,
- Its height is sufficient for a human to enter in standing position,
- It aims at modifying the inside microclimate with reference to the external environment,
- It is used to enable plant cultivation, irrespective of the external climatic conditions.

Greenhouse effect owing to the closed construction.
I. Selective transmittance of the covering material

The transparent covering material is permeable to the ultraviolet, (>400 nm) visible (PAR: 400-720), far-red (720-780) and infra-red radiation (740-2.500 nm)



However the permeability of the transparent covering materials to thermal radiation higher than 2.500 nm is very low or even zero .

Greenhouse effect owing to the closed construction.
II. Obstruction of air exchange

II. Temperature, air humidity, and air composition inside the greenhouse are modified because the air exchange with the external environment is drastically restricted.

Area and production of greenhouse vegetables in Greece (2012)

Crop species	Tall greenhouses										2nd crop	
	Heated greenhouses				Unheated greenhouses				Total (tall greenhouses)			
	Glasshouses		Plastic-covered greenhouses		Glasshouses		Plastic-covered greenhouses					
	area (ha)	prod. (ton)	area (ha)	prod. (ton)	area (ha)	prod. (ton)	area (ha)	prod. (ton)	area (ha)	prod. (ton)	area (ha)	prod. (ton)
Tomato	62.2	11,203	425.2	41,165	23.9	2,510	1,393.0	164,161	1,904.3	219,039	710.9	71,059
Cucumber	11.5	1,405	188.3	28,578	25.4	5,280	895.5	93,178	1,120.6	128,441	317.9	38,582
Zucchini	0.9	41	15.0	729	3.0	240	57.4	2,137	76.3	3,147	31.8	866
Eggplant	0.7	56	16.0	968	3.0	220	155.8	16,884	175.6	18,128	12.3	754
Pepper	11.9	1,570	78.9	4,935	8.3	716	626.9	71,132	725.9	78,353	52.8	3,411
Bean	2.0	50	62.2	1,978	7.5	260	104.4	2,167	176.1	4,455	125.9	3,378
Lettuce	1.8	63	22.4	634	3.0	120	115.8	2,489	143.0	3,306	237.8	4,704
Melon	0.1	0	2.1	85	1.0	20	2.0	100	5.2	205	118.0	8,400
Watermelon	0.2	0	1.6	96	6.0	420	14.5	620	22.3	1,136	685.0	39,150
Strawberry	0.0	0	0.0	0	0.0	0	1,163.0	43,927	1,163.0	43,927	2.0	60
Miscellaneous	2.0	0	16.9	1,135	1.0	15	42.1	772	62.1	1,922	50.9	1,005
Total	93.3	14,388	828.6	80,301	82.1	9,801	4,570.4	397,568	**5,574.3**	502,058	**2,345.2**	171,368

Types of greenhouses

Simple construction: Low cost resulting in low yield. Very common GH type in Mediterranean countries.

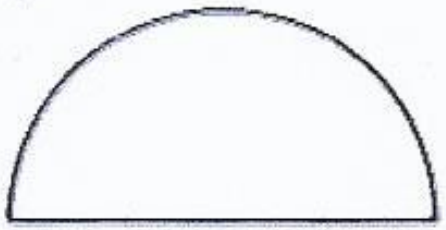
Modern greenhouse combined with hydroponics, resulting in high yields, which requires a high investment.

Construction characteristics of greenhouses

- Greenhouse shape
- Greenhouse width
- Greenhouse height
- Greenhouse structure
- Greenhouse covering materials

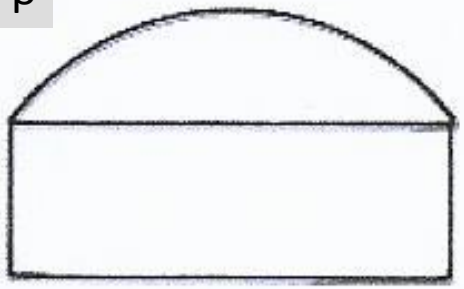
Greenhouse shapes

α



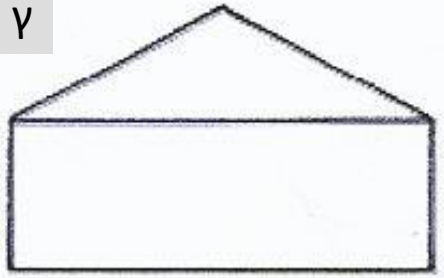
Round arched tunnel

β



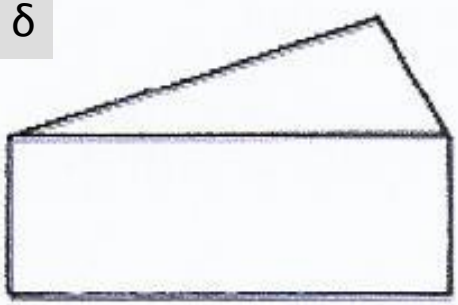
Round arch with vertical side wall

γ



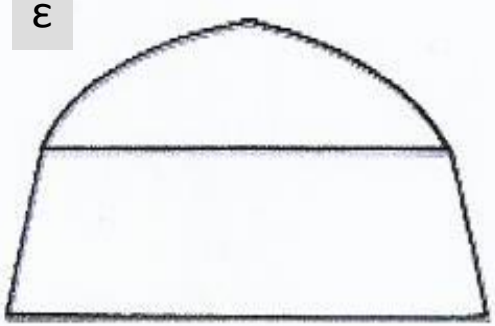
Saddle roof

δ



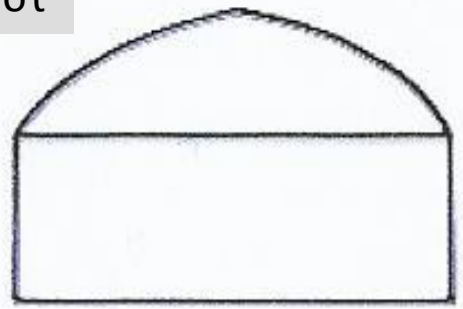
Shed roof

ε



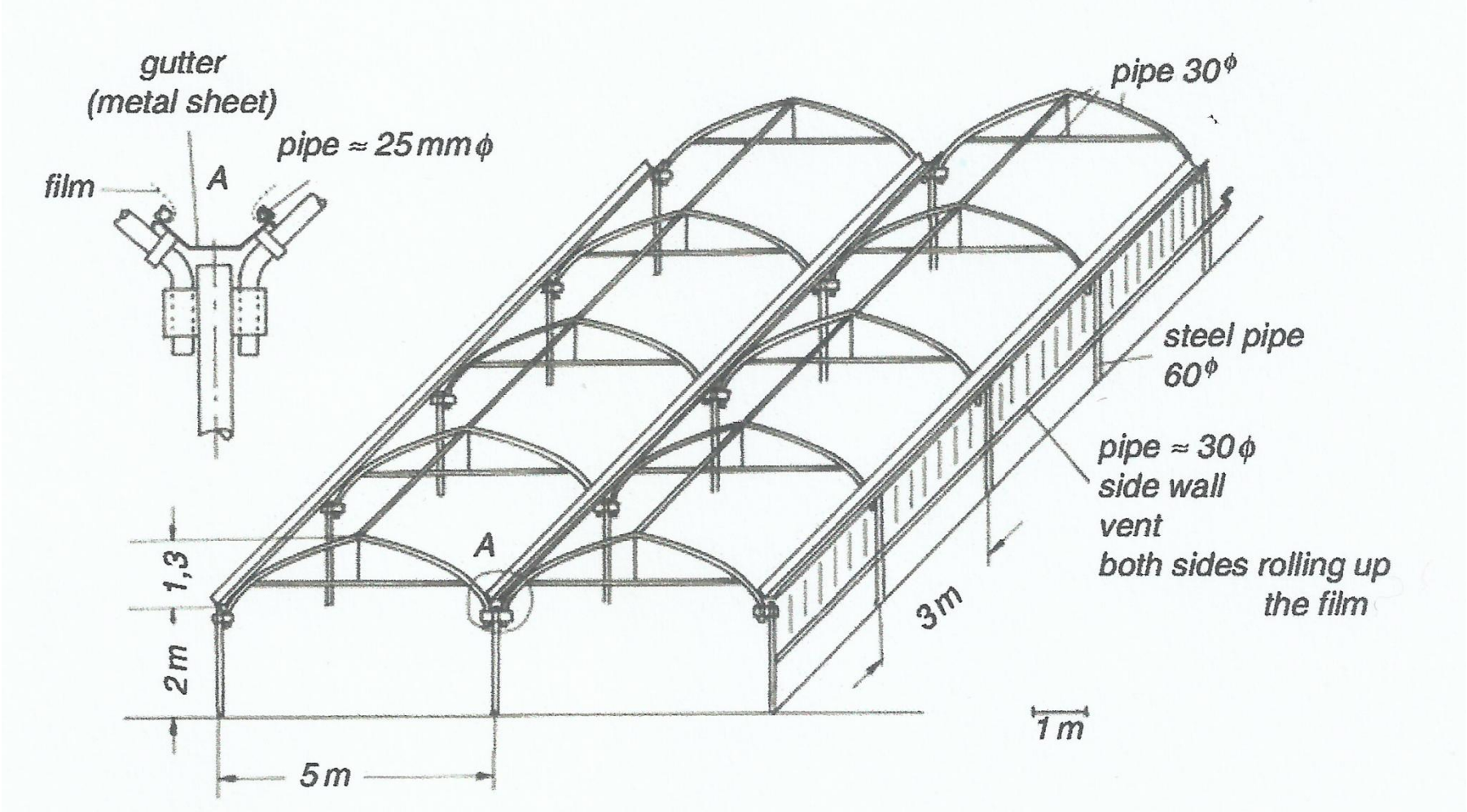
Pointed arch with sloping side wall

στ



Pointed arch with vertical side wall

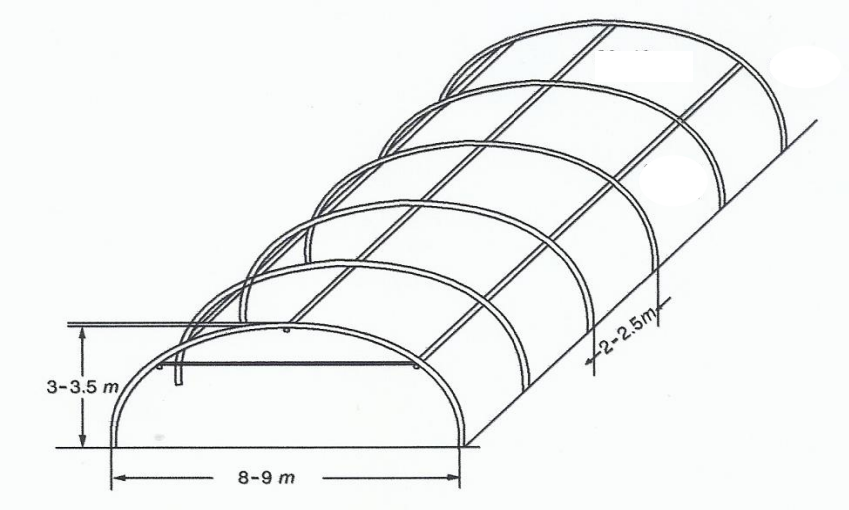
Structure of a greenhouse



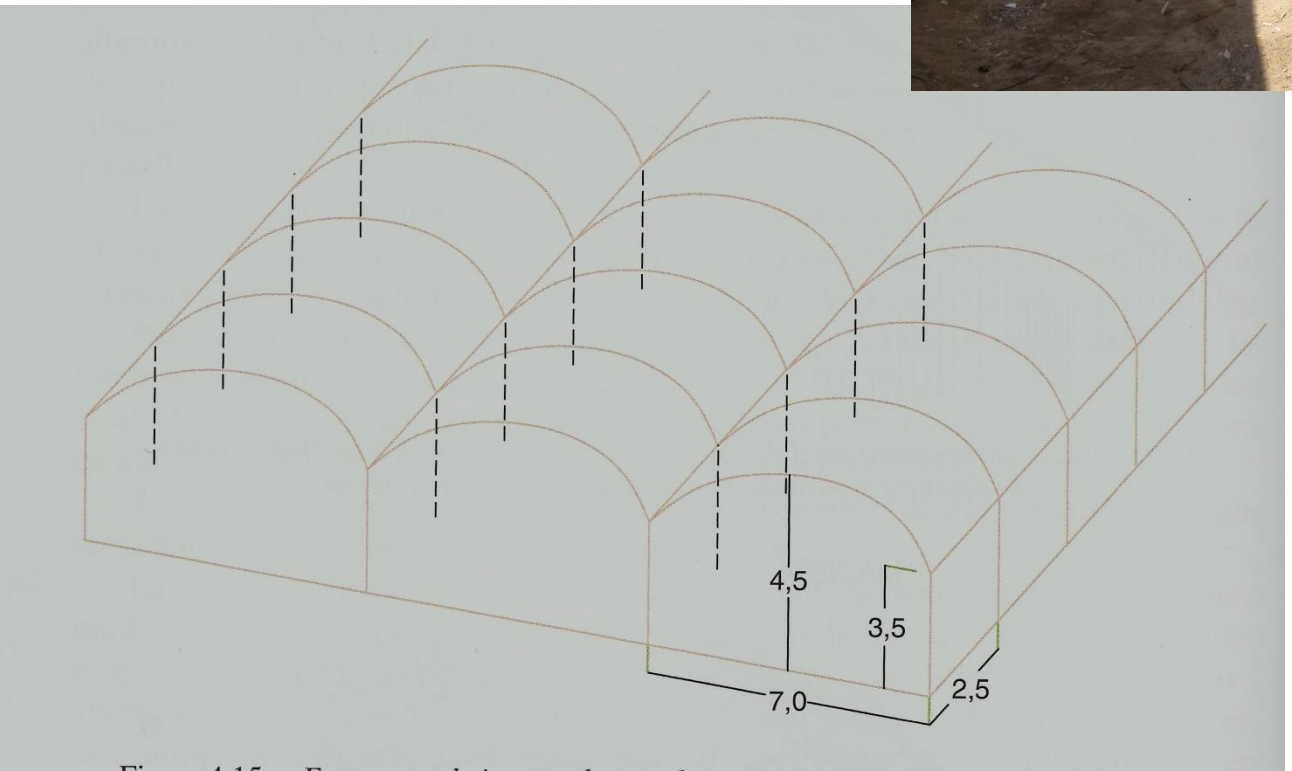
Single-line greenhouse

Multiple-line greenhouse

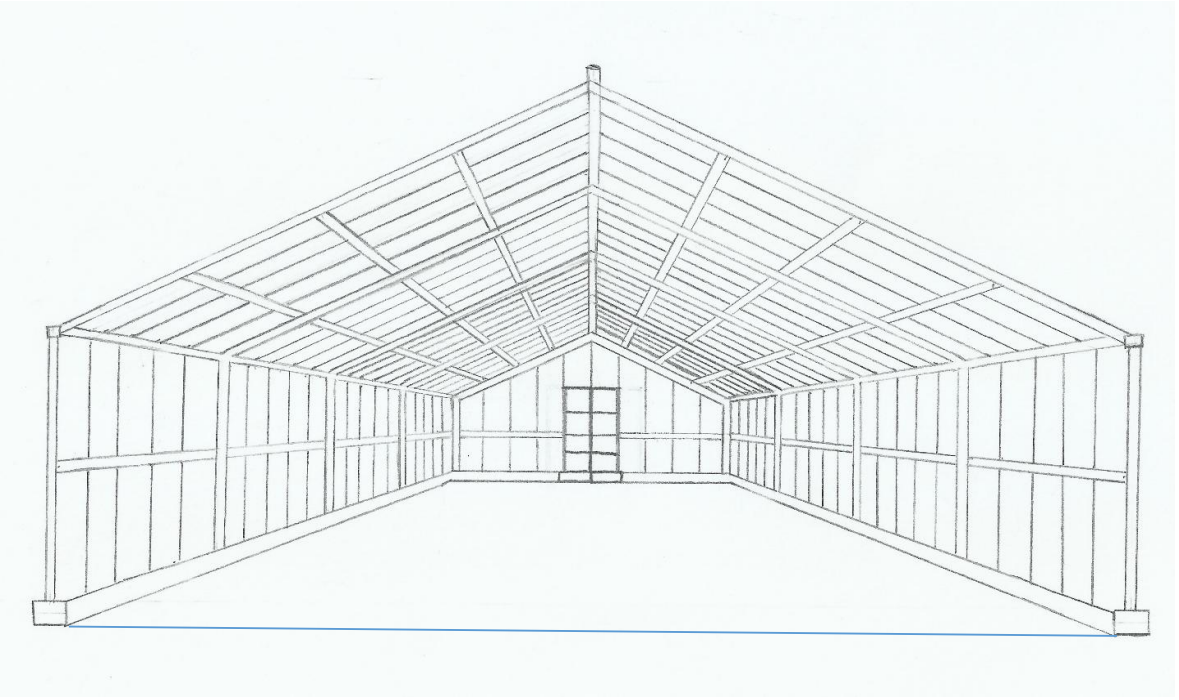
Round arched tunnel



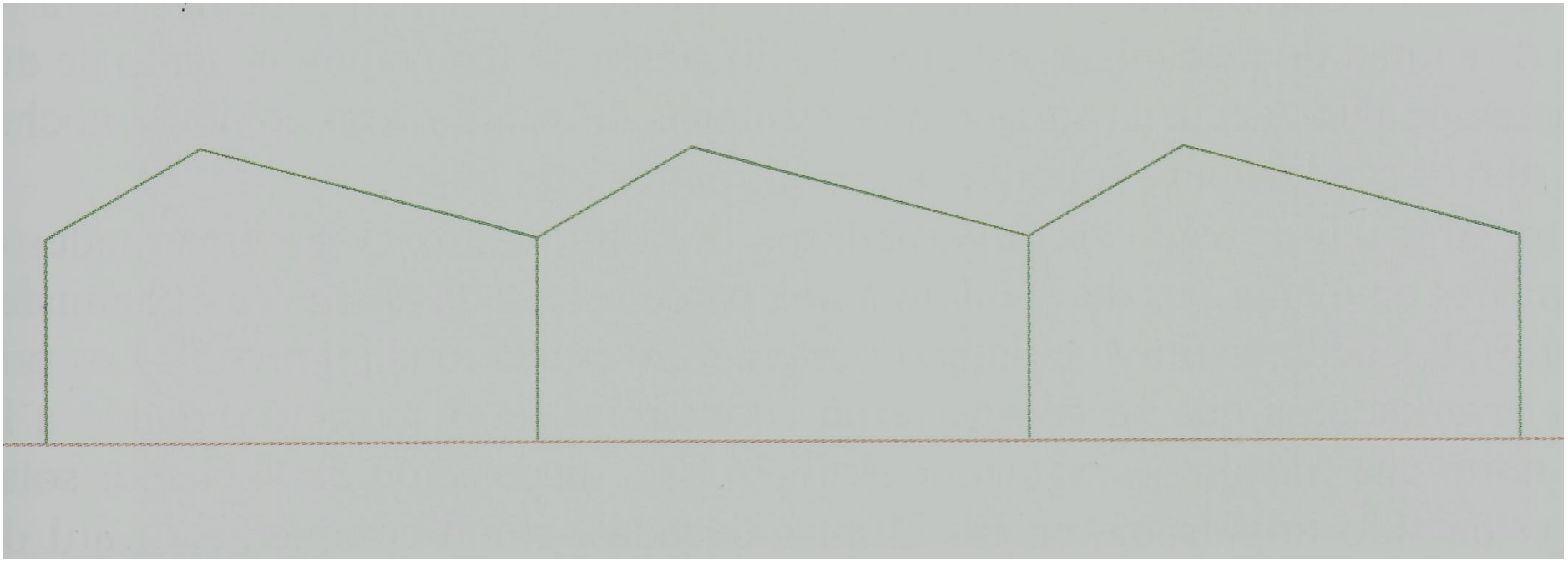
Round arch with vertical side wall



Saddle roof with one roof per construction unit (wide-span type)

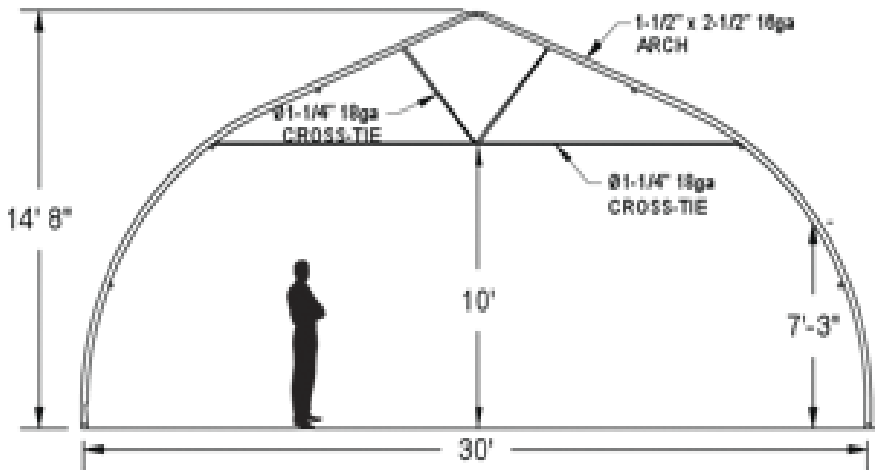


Saddle roof with two roofs per construction unit (Venlo type)

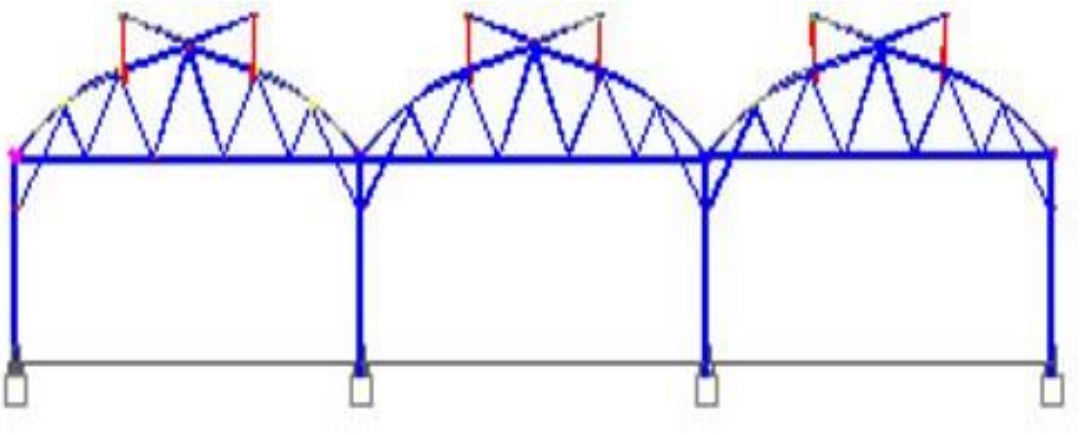


Shed roof greenhouse

Pointed-arched (gothic-arched) structures with sloping side wall



Pointed arched (gothic-arched) with vertical side walls



Greenhouse height

High constructions (7-7.5 m) are suggested

Advantages:

- Larger volume per area unit and thus a higher buffering to temperature changes during the 24-hours cycle.
- A lower fluctuation in CO_2 concentrations during the 24-hours cycle.
- More vertical space for the development of high plants

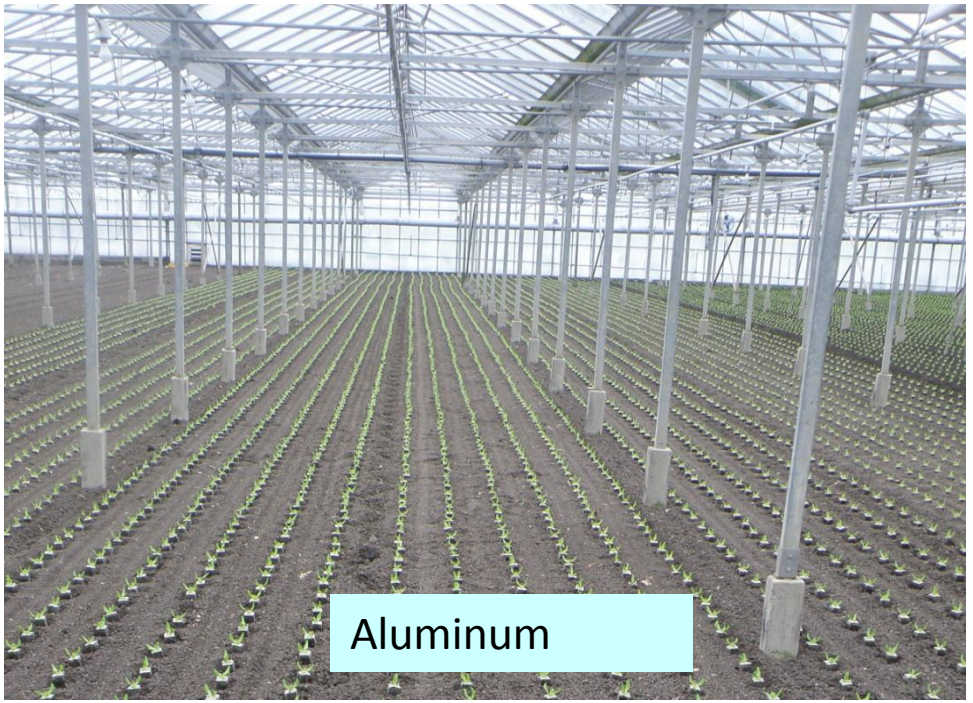
Greenhouse orientation

PAR transmittance through two similar greenhouses at the same location differing in the orientation

Date	East - West	North - South
January 2	379	293
January 4	426	322
February 6	578	530
March 10	1,243	1,226
April 14	1,955	2,104
June 20	2,720	2,969

Impact of greenhouse orientation on daily PAR interception (Wh m^{-2}) in Dutch greenhouses at different dates during the year.

Structure material



Greenhouse covering materials

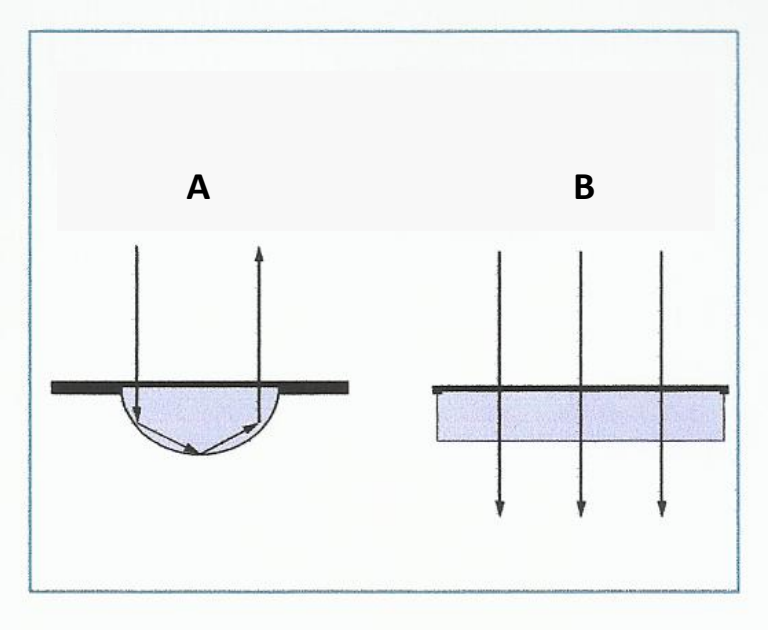
Three groups of covering materials are used in greenhouse:

- soft plastic,
- rigid plastic,
- glass.

Special types of plastic covering sheets

- **Stabilized sheets**
- **UV-blocking plastic sheets**
- **IR-radiation blocking plastic films**
- **Plastic films reflecting the NIR radiation**
- **Plastic films increasing the diffusion of the solar radiation**
- **Ant-drop plastic films**
- **Anti-fog plastic films**

Increase of light transmittance by using anti-drop films



Greenhouse equipment

- Ventilation systems
- Heating and energy saving systems
- Dehumification systems
- Shading systems
- Cooling systems
- Carbon dioxide (CO_2) enrichment systems
- Artificial lighting systems

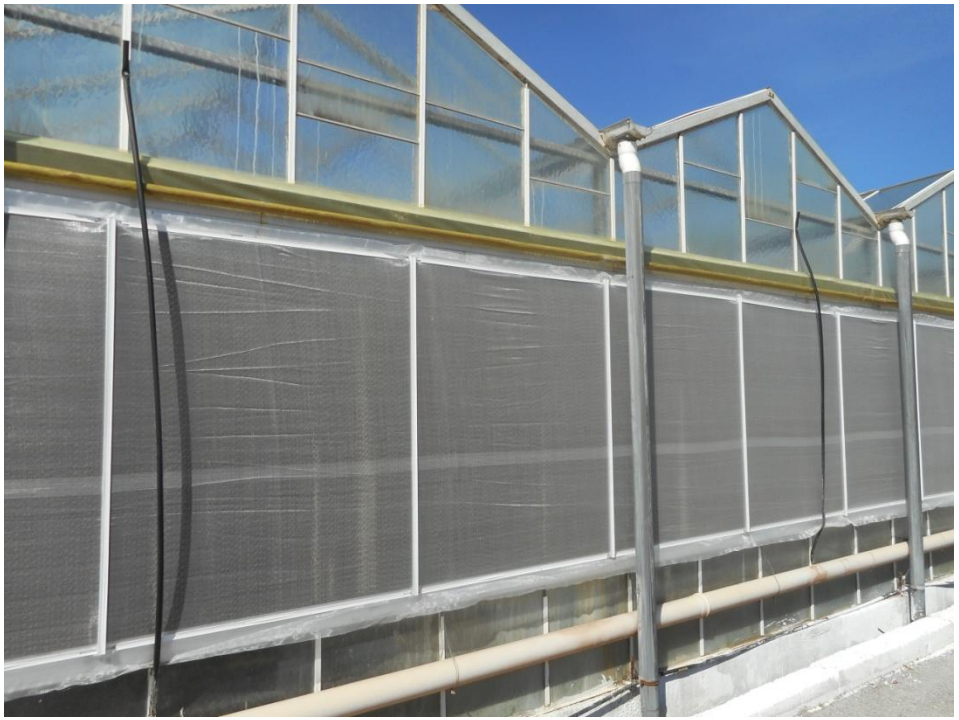
Natural ventilation by opening ventilators at side walls, gables ridge or roof area

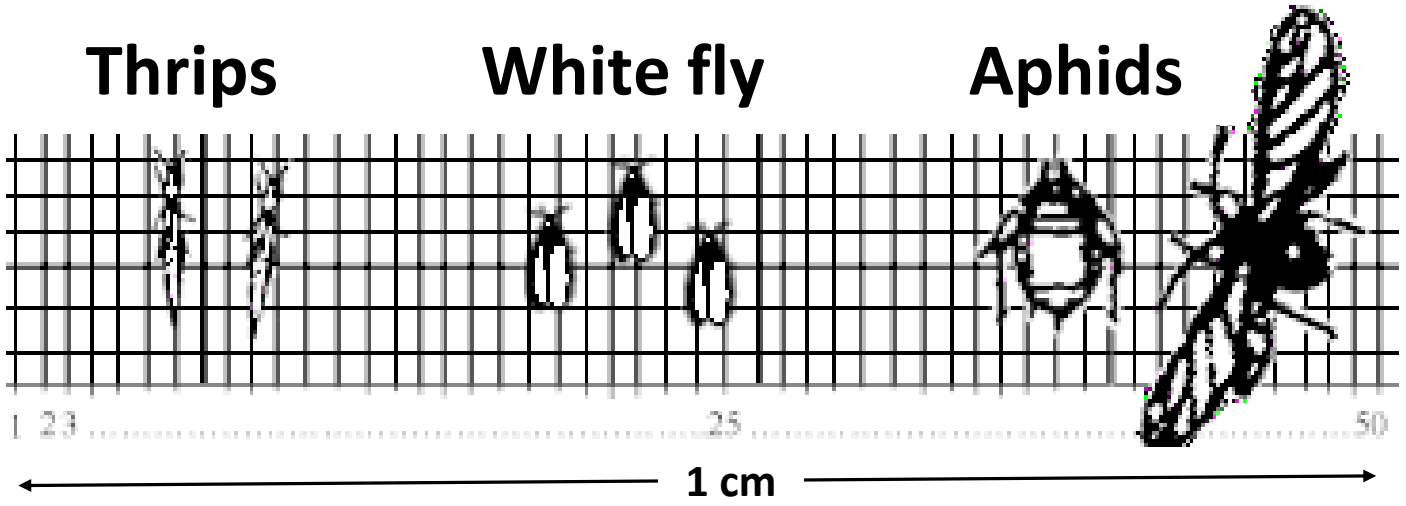
Flap ventilators

Roll-up ventilators

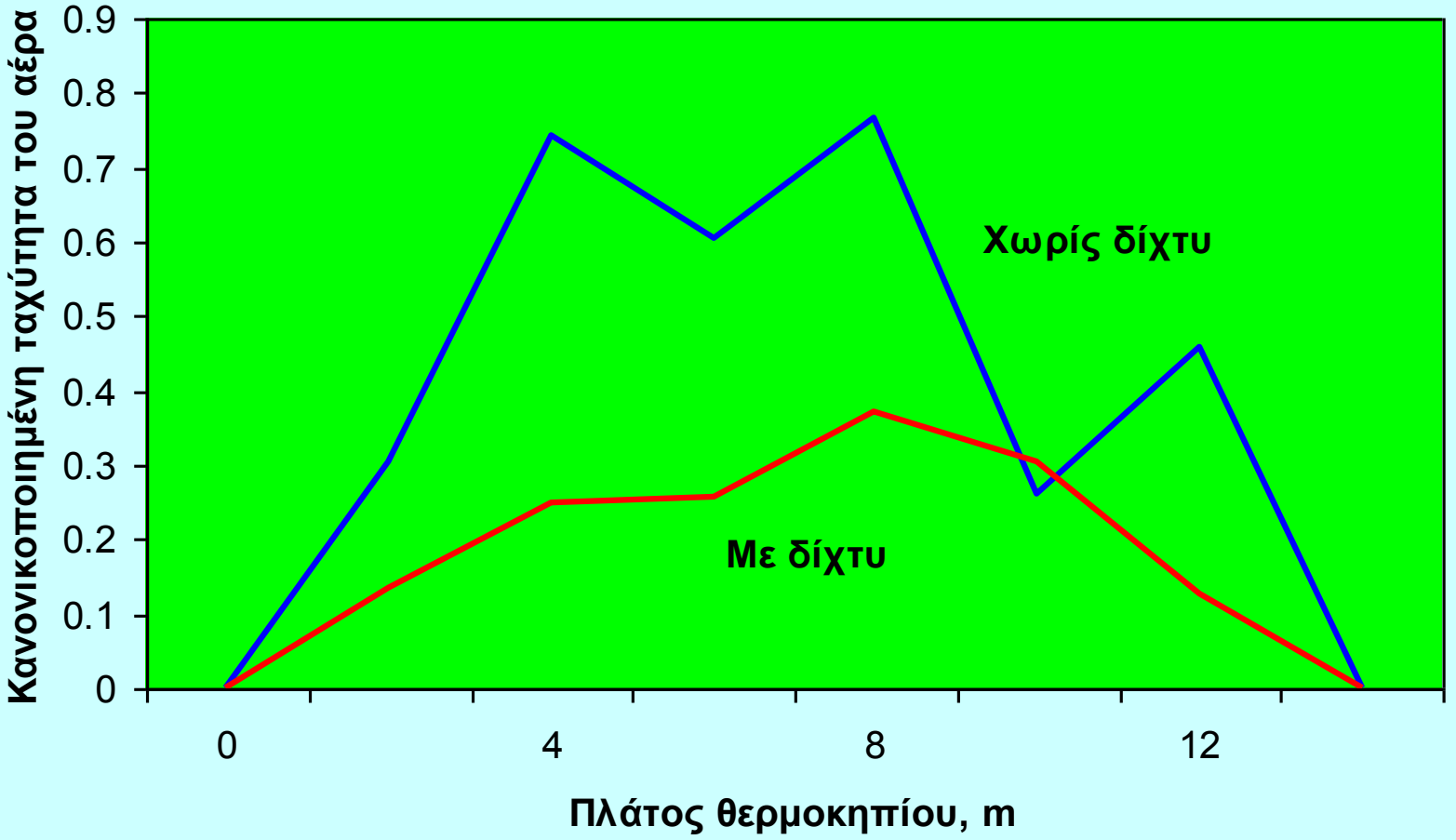
Forced ventilation by fans

Insect-proof screens





Impact of insect proof screens on greenhouse ventilation



Heating and energy saving systems

They are distinguished according to the following characteristics:

- Heat (energy) source
- Heat generator (heating system)
- Heat distribution system.

Energy source for heating

- Combustion of fossil fuels, oil, gas, coal
- Combustion of biomass (wood, straw, husks, etc.)
- Geothermal energy
- Waste heat from industry
- Solar energy

Heating systems

- Central warm water boiler
- Decentralised warm water boiler
- Directly fired air heater

Central warm water boiler

Directly fired air heater

Heat distribution systems

Recirculation of warm water via metallic pipes

Recirculation of vapor via metallic pipes

Corrugated plastic tubes for warm water recirculation

Perforated plastic tubes for air heating systems

Thermal screens

Thermal screens are capable of reducing the energy consumption for heating by 35-40%.

Thermal screens are made of materials with low heat conductivity which reduce the heat exchange between the inside air and the outside environment

Installation of thermal screens

- In most cases they are placed at the top of the greenhouse

- In these cases they are used also as shading screens during the summer.

In greenhouse located in cold-climate areas the thermal screens cover also the side walls.

Shading systems

The shading of the greenhouse is aimed at reducing the income of solar radiation, thereby reducing the greenhouse temperature whenever ventilation is not sufficient in reducing the inside air temperature.

On the other hand, shading affects also two other climatic parameters, i.e.:

- The relative humidity which increases with increasing shading
- The interception of PAR by plants which may result in yield losses.

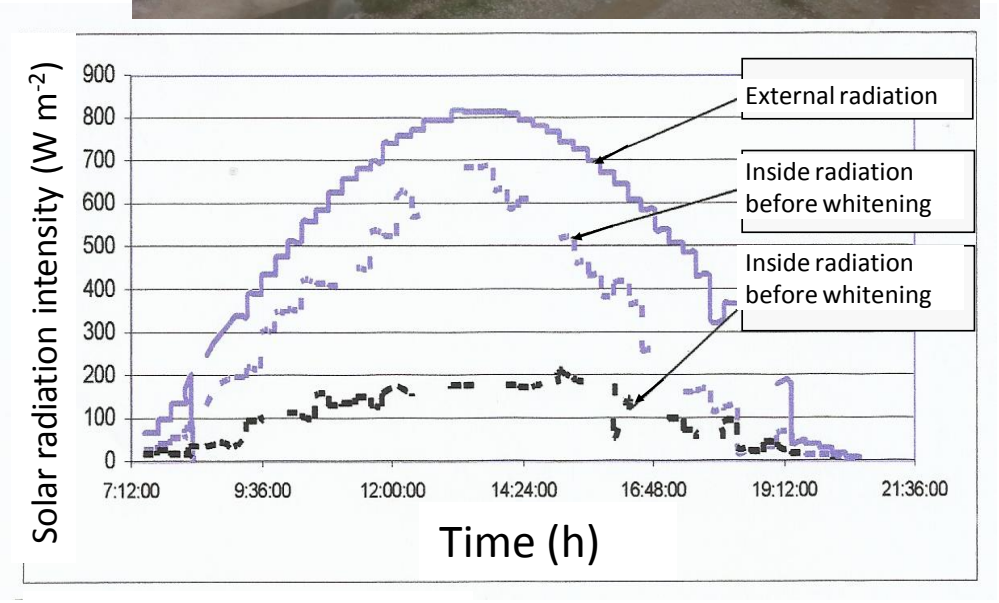
Methods of greenhouse shading

- Whitening of the covering material
- Net shading
- Shading screens

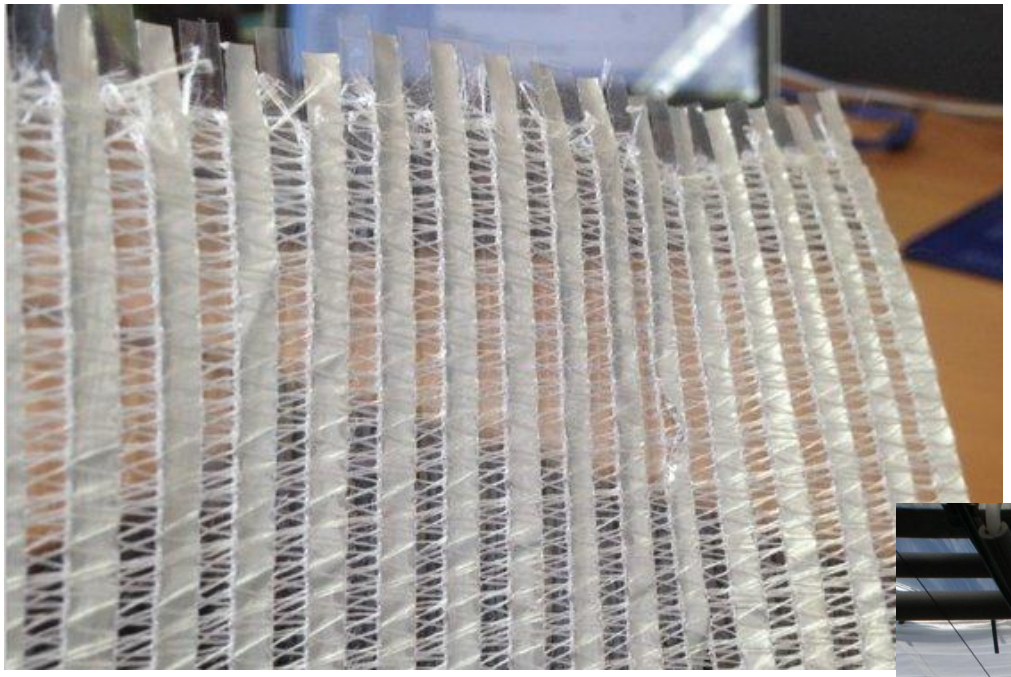
Shading by whitening

Whitening of greenhouses

- Impact of whitening on light transmittance



Shading screens



Cooling systems

I. Fog system

A fog cooling system consists of:

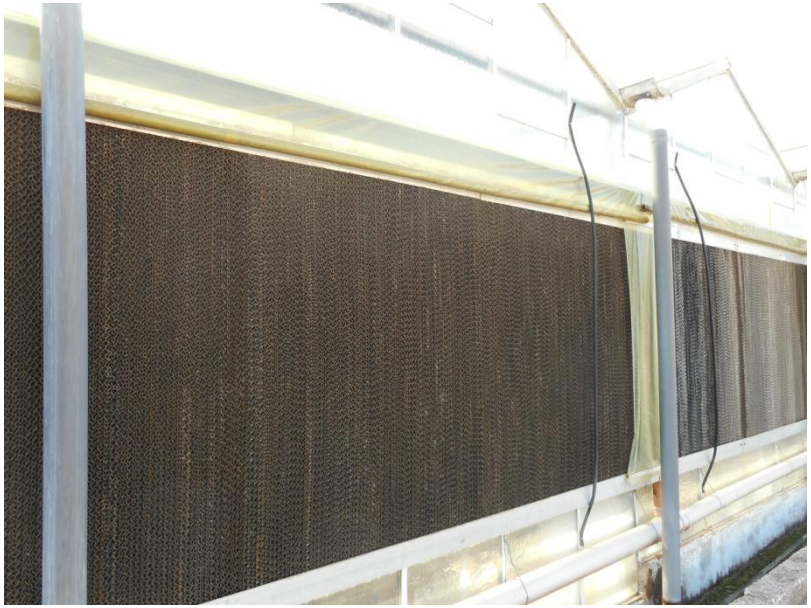
- a water softener,
- good filters to prevent nozzle clogging,
- a water reservoir,
- pumps,
- pressure regulation valves,
- tubes with nozzles above the crop.

Prerequisites for high efficiency:

- The air must be moving inside the greenhouse,
- The air has to be continually renewed through passive ventilators.

Cooling systems

II. Fan and pad cooling



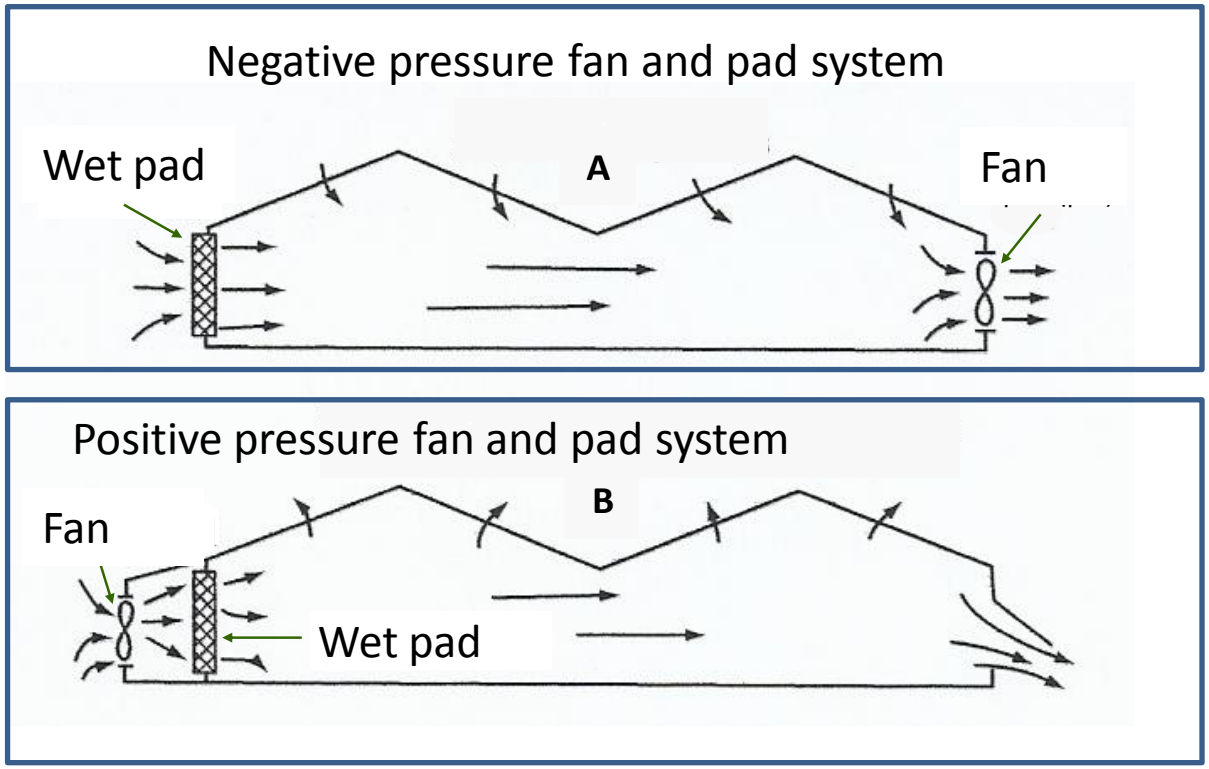
Air from outside is blown or sucked through pads with a large surface.

The pads are kept permanently wet by sprinkling water that evaporates on the surface of the pad and cools the air down.

The fans suck the air:

- either from outside to the inside (positive pressure),
- or from inside to the outside of the greenhouse (negative pressure).

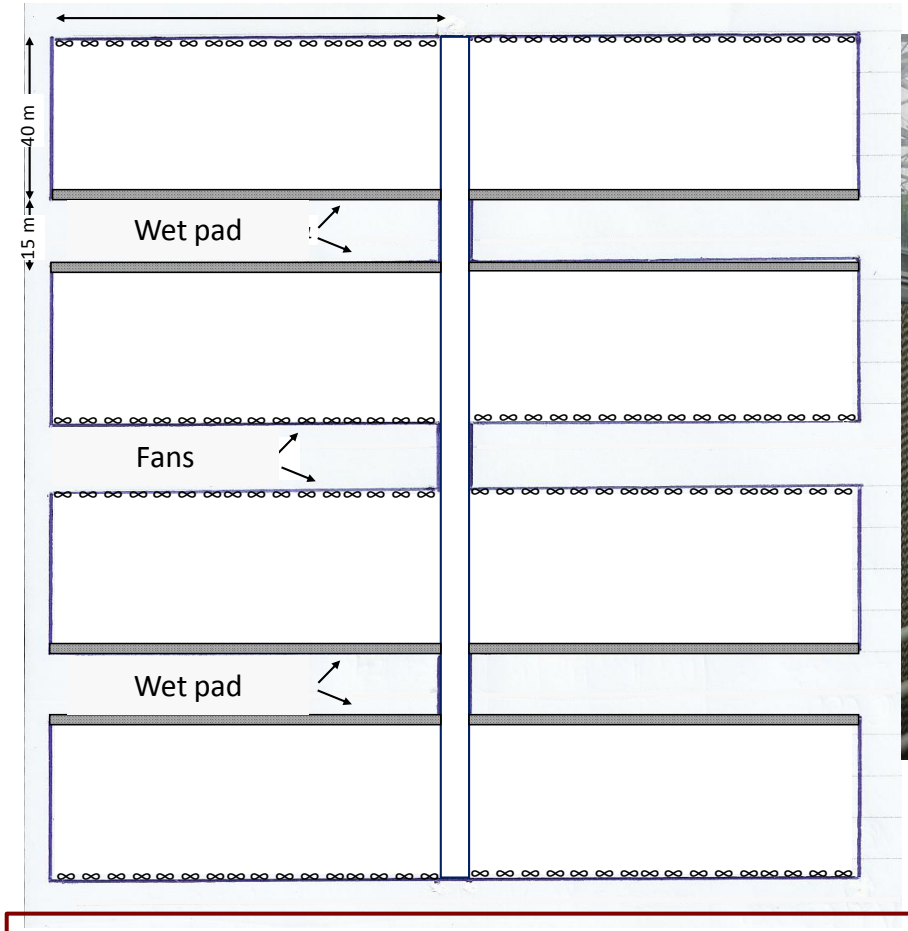
Negative *versus* positive pressure fan and pad systems



<u>Negative pressure fan and pad system.</u> The fans suck the air through the pad and greenhouse.

<u>Positive pressure fan and pad system.</u> The fans and pads are located on one side and vents on the other side. The fans blow the air through the greenhouse so that an overpressure occurs.

Installation of fans and pads in large greenhouse units



The distance between the wet pads and the fans or the vents should not exceed 50-60 m but preferably it is advised to be up to 40 m.

CO_2 enrichment systems

Technical carbon dioxide kept under pressure in liquid form in bottles or tanks

Exhaust gases from:

- gas burner or,
- directly fired air heater with gas burner.

Simultaneous heat production takes place.

CO_2 distribution inside the greenhouse

The CO_2 is distributed to the greenhouse air via perforated plastic tubes.

Artificial lighting to increase photosynthetic assimilation

HPS: high-pressure sodium

LED (light emitting diode)