



Improving Greenhouse Practices

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English version

Who am I?

- Agronomist
- **Instructor at ITA, La Pocatière Campus**
- **Consultant for Climax Conseils**
- Former Production Director (Demers, Lakeside Produces, Savoura)



What is Climax Conseils ?

- 3 associates
 - 2 agronomists
 - 1 technologist
- 90 producers in Quebec
 - 1475 m²
 - 150 m² to 4 ha
 - 52% organic operations
 - Diversified market gardening
- Technical support
- Project management
- SR & ED
- Training



What have I come to do in NB ?

- Invited by DAAF along with ACORN
- 8 producers visited, Aug 2016
- Technical expertise & consulting
- ACORN conferences



Presentation Plan

1. Elements to improve and explanations
2. Priorization of actions
3. Questions



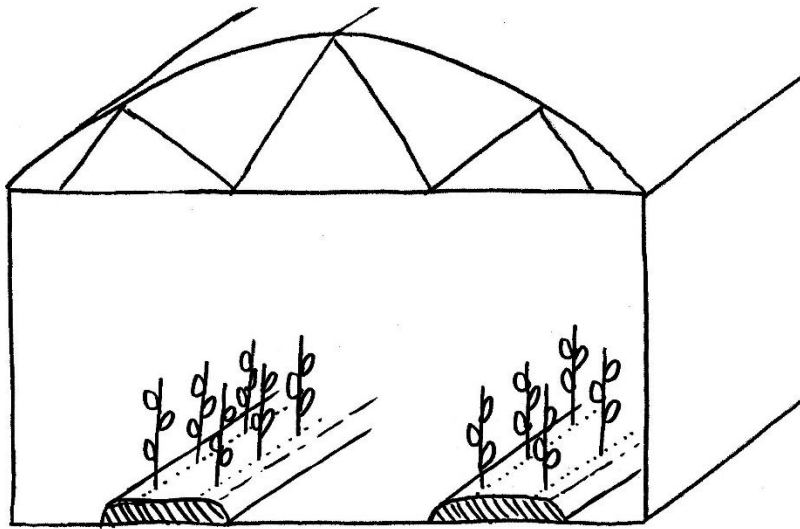
Presentation plan and background

- Greenhouse layout
- Crop density
- Greenhouse coverings
- Ventilation management
- Heating management
- Pollination
- Transplant production and grafting
- Choice of cultivars
- Temperature management
- Irrigation management
- Fertility management
- Work management
- Plant protection

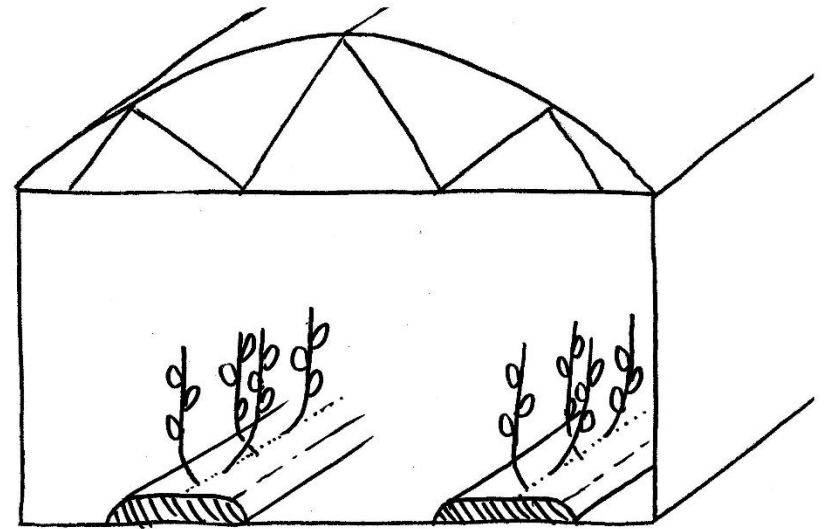


Greenhouse layout

Double rows vs double "V" rows



2 double rows on 2 beds



2 double "V" rows on 2 beds



Greenhouse layout

Single rows vs double "V" rows

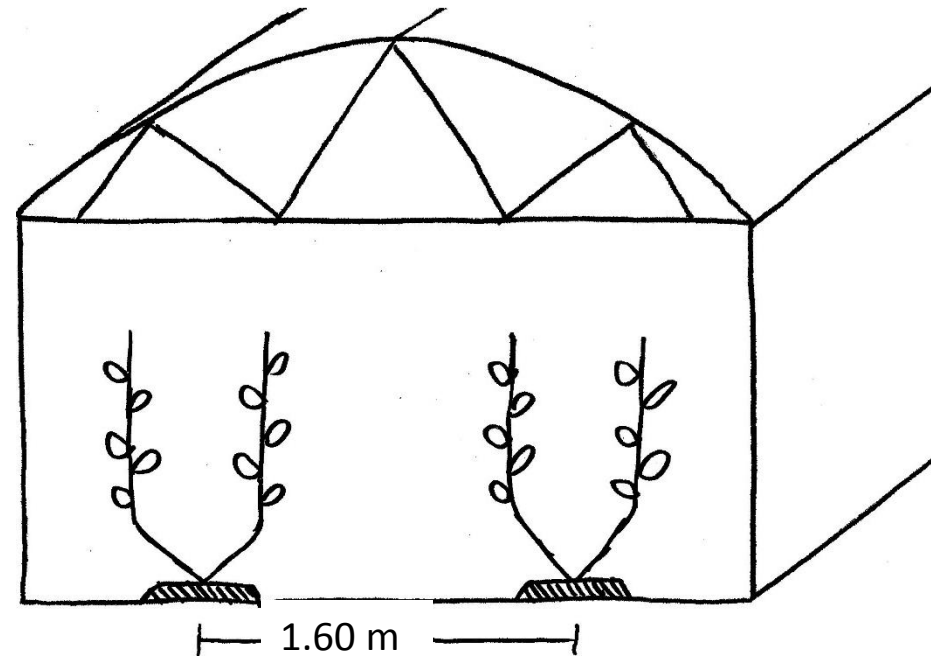
- Advantages of double « V » rows
 - Easier to install **ground covers plastic**
 - More room to apply **solid fertilizer**
 - **Fruits at the base of the plant** are more out of the way
 - Easier to install the **irrigation lines**
 - Easier to arrange **grafted plants**
 - Quicker to **plant**



Greenhouse layout

Distance between the rows

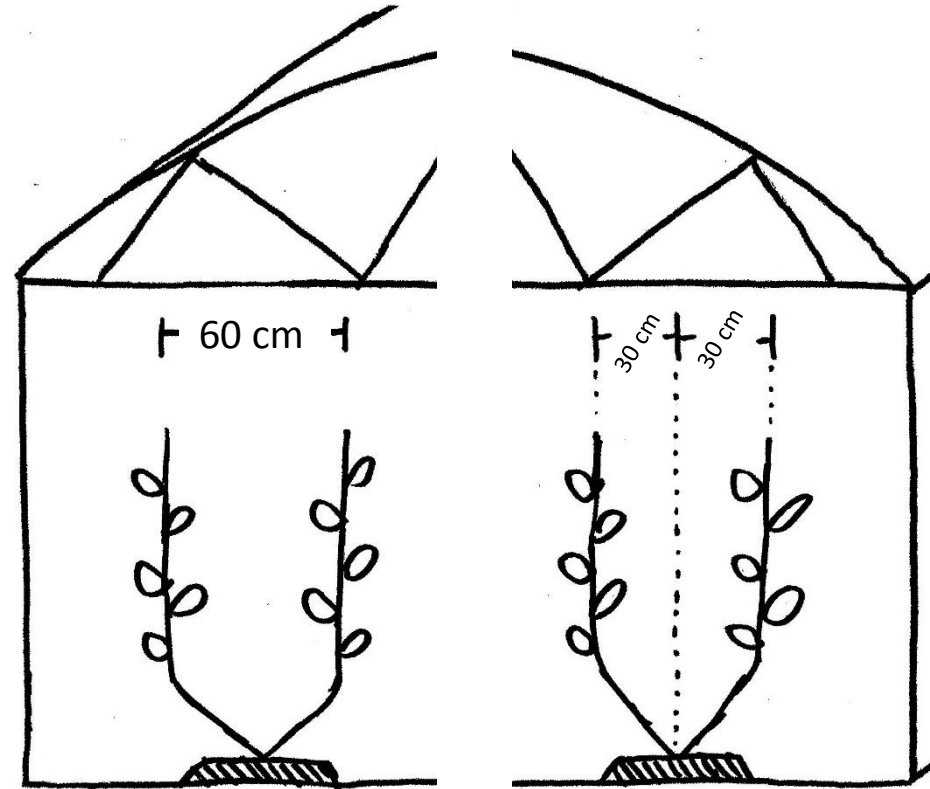
- Measured center-to-center
 - **160 cm minimum**
 - Best **work/productivity compromise**
 - Trend **> 1.60 m**



Greenhouse layout

Double "V" rows and distance between pins

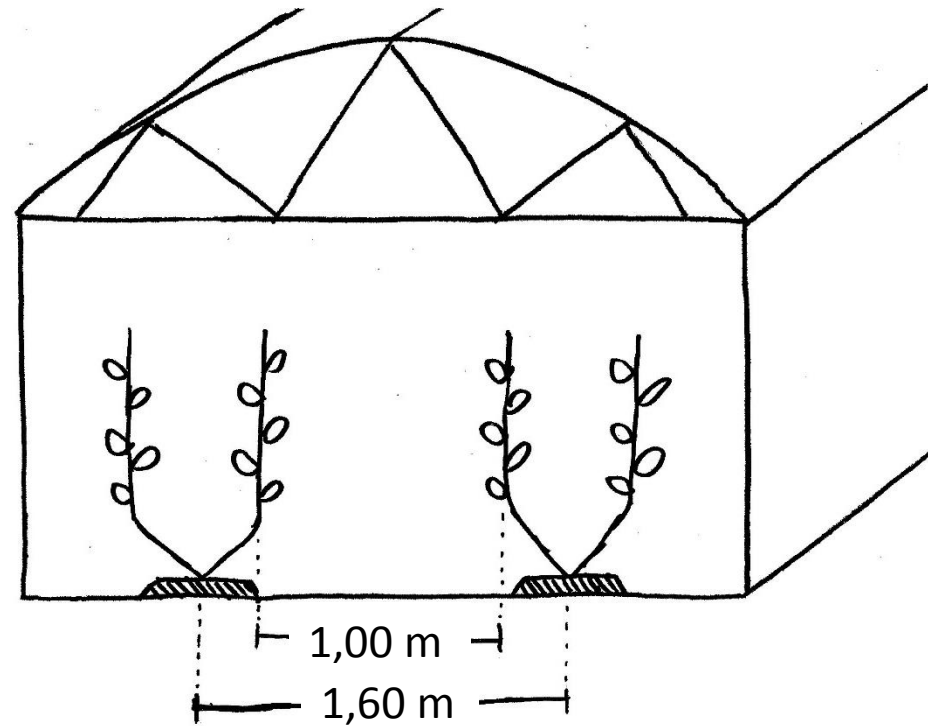
- Single rows and double rows
 - **60 to 70 cm maximum**
 - 70 cm when the rows are spaced >160 cm



Greenhouse layout

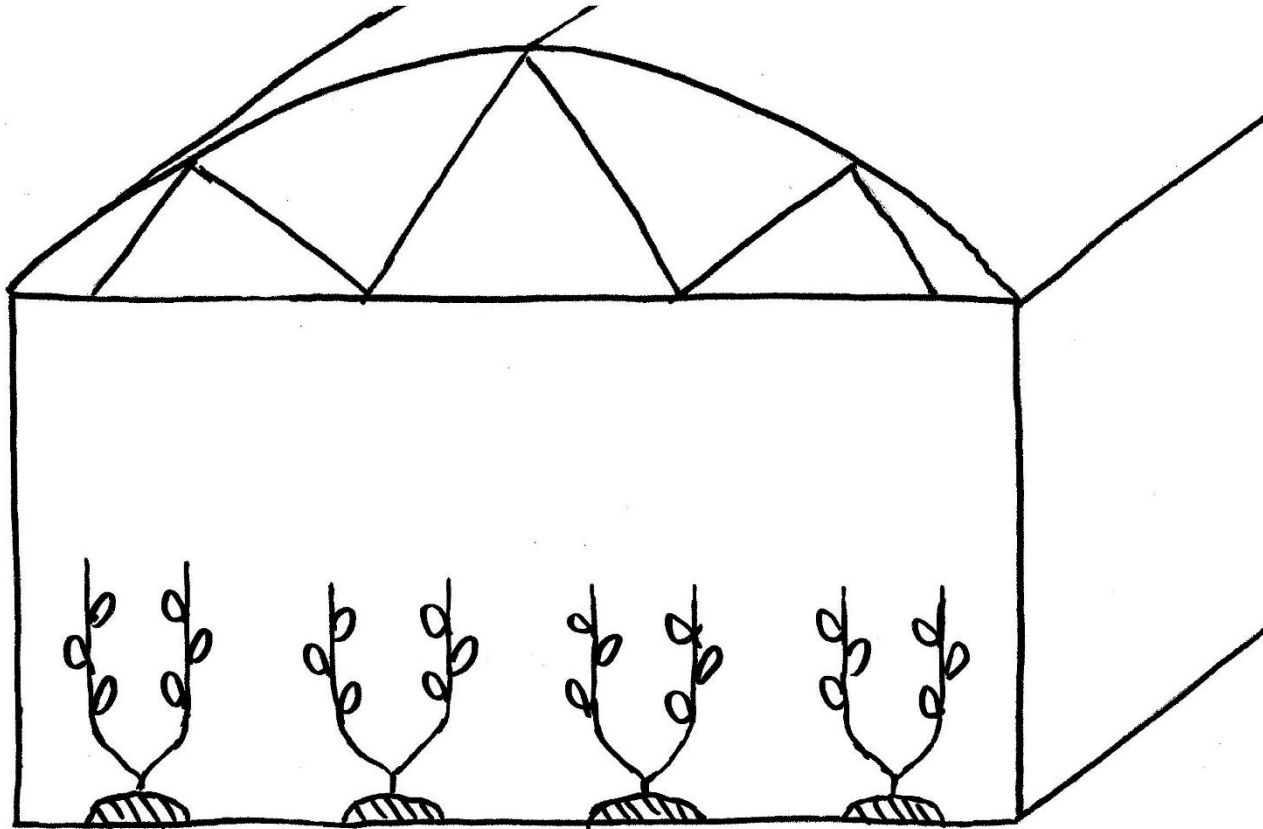
Distance between plants

- Work space
 - Leave **100 cm** for working in the row
 - The length of the leaves **will reduce** this space
 - Trend > **1.00 m**



Greenhouse layout

Greenhouse of 6.40 m (21') with 4 double rows

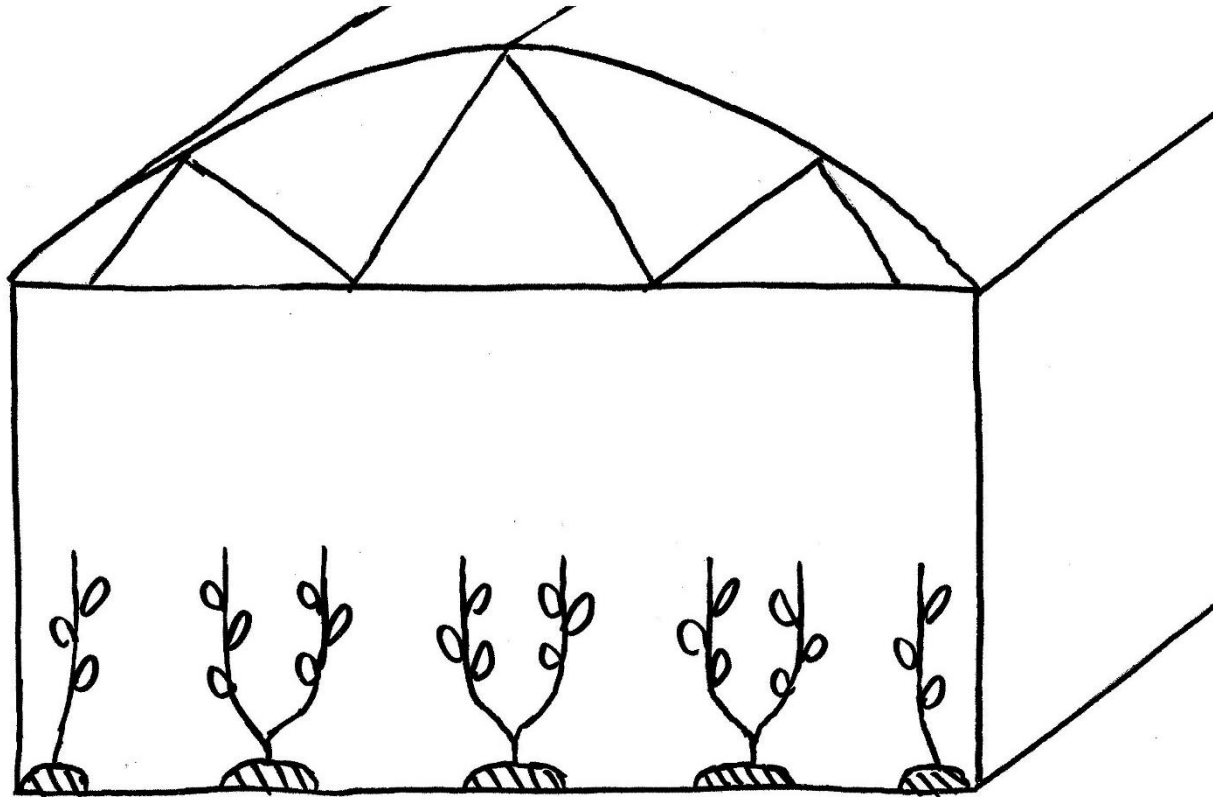


- The spacing between the rows will be = 1.60 m



Greenhouse layout

Greenhouse of 6.40 m (21') with 3 double rows and 2 single rows

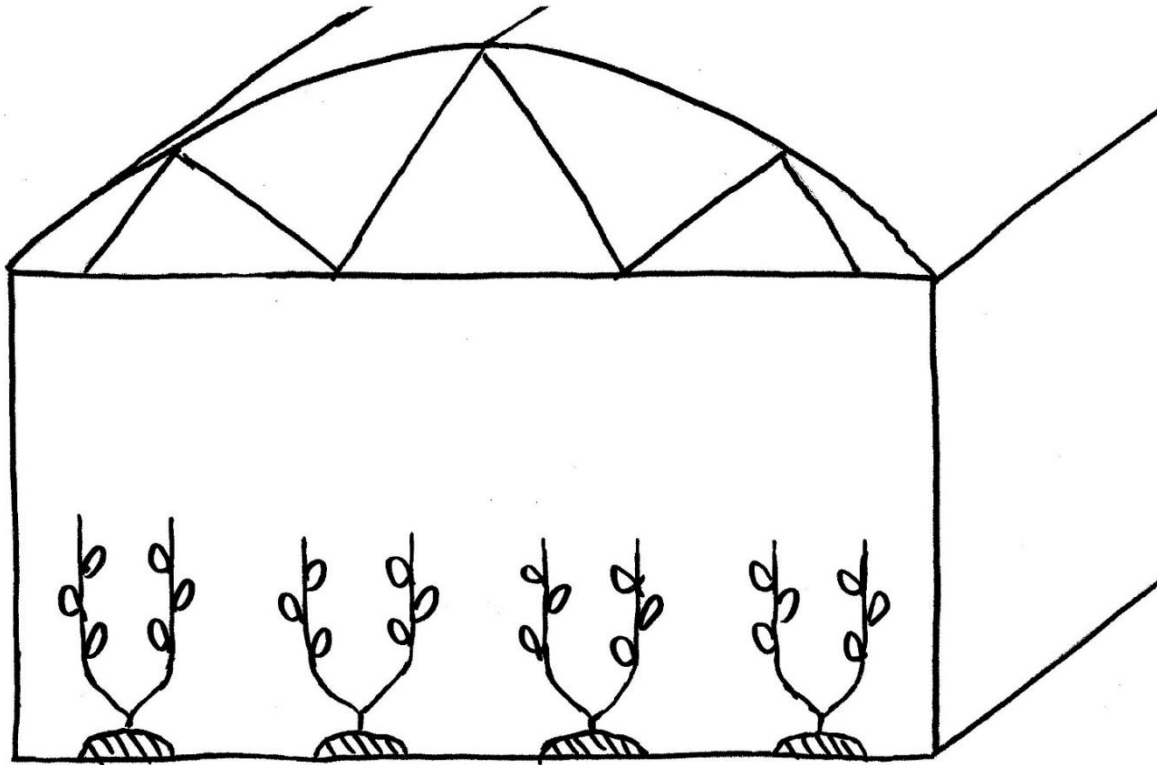


- The spacing between the rows will be < 1.60 m



Greenhouse layout

Greenhouse of 7.31 m (24') with 4 rangs double rows

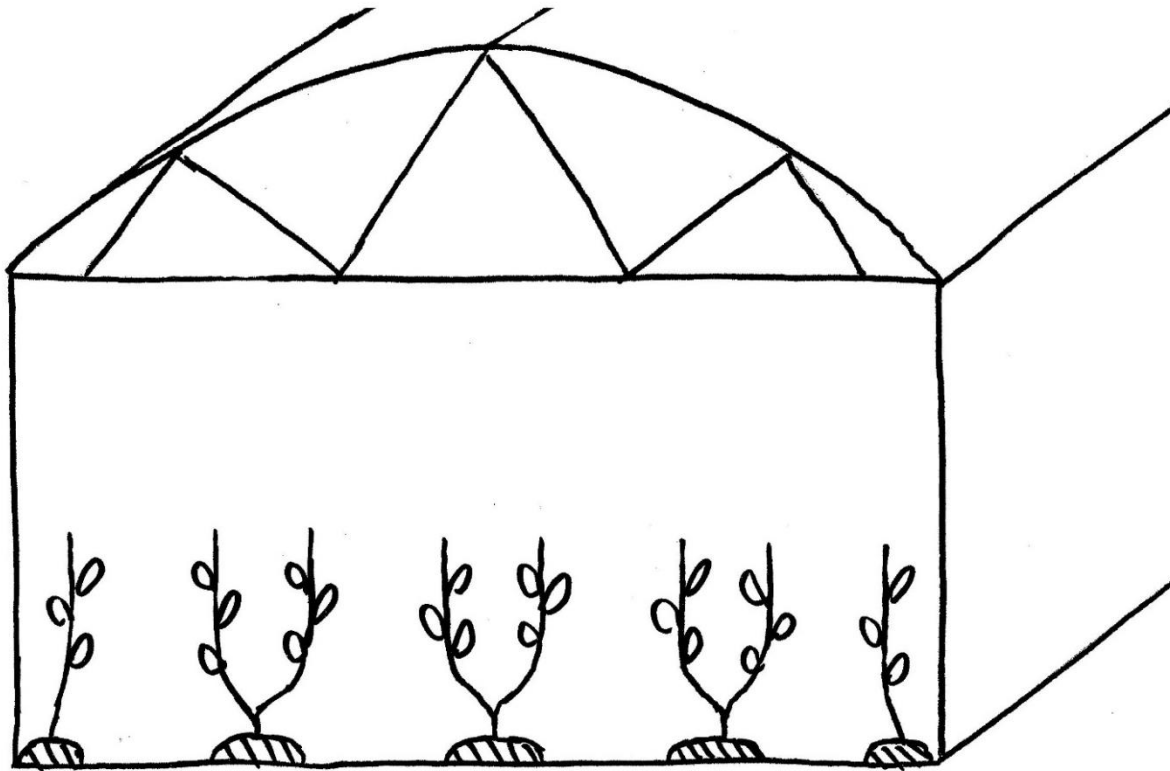


- The spacing between the rows will be = **1.83 m**



Greenhouse layout

Greenhouse of 7.31 m (24') with 3 double rows & 2 single rows

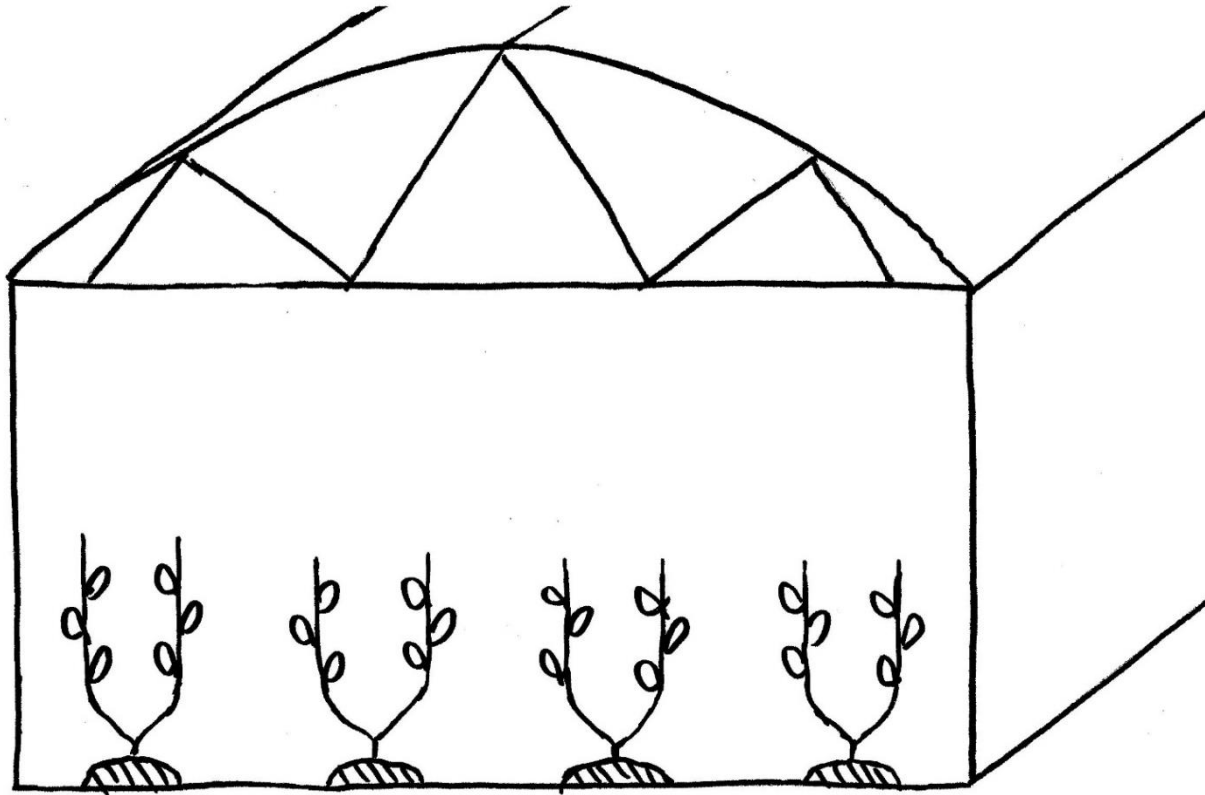


- The spacing between the rows will be < 1.60 m



Greenhouse layout

Greenhouse of 7.62 m (25') with 4 double rows

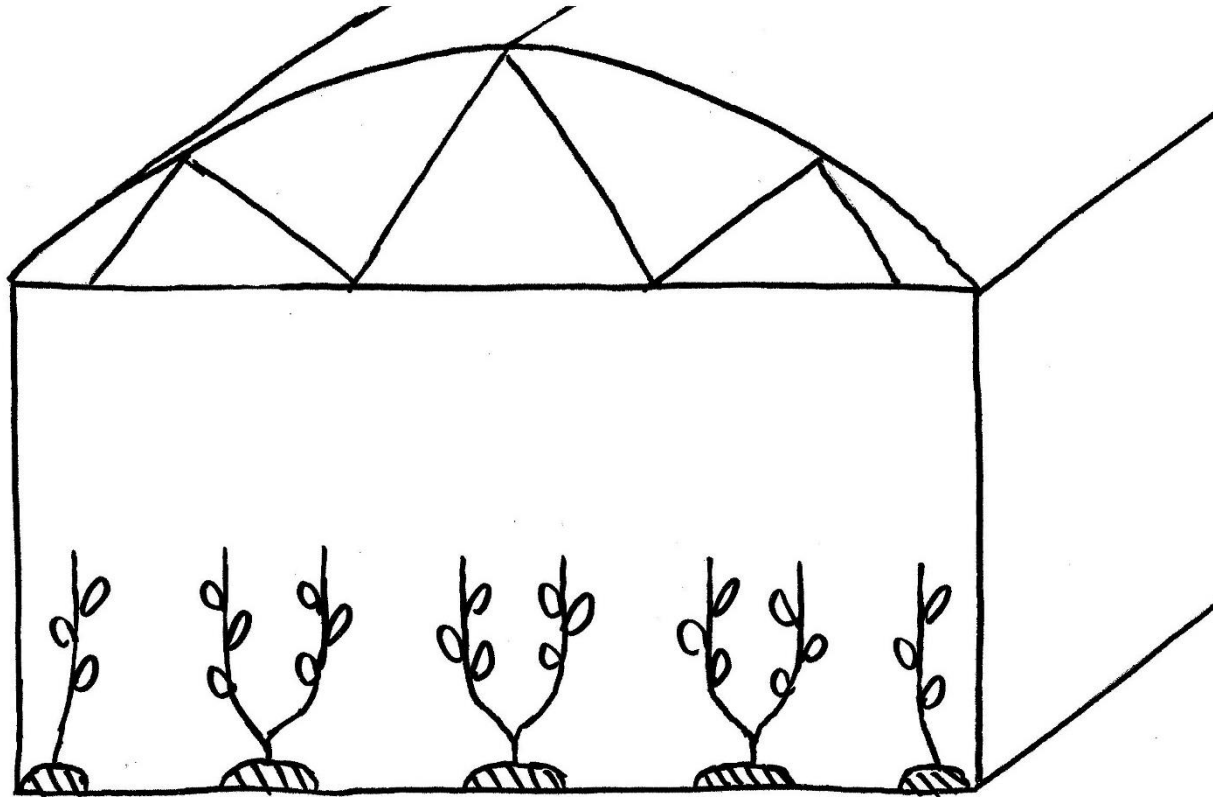


- The spacing between the rows will be = **1.91 m**



Greenhouse layout

Greenhouse of 7.62 m (25') with 3 double rows & 2 single rows

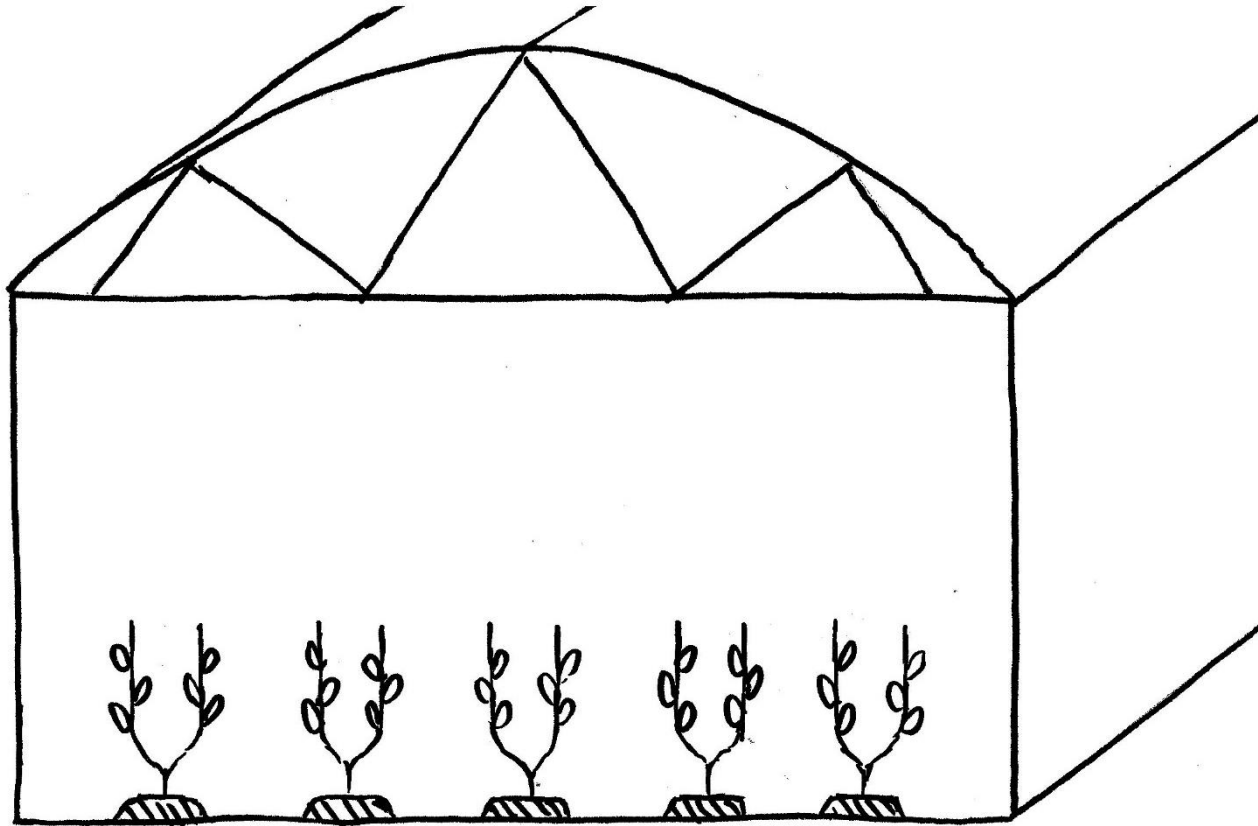


- The spacing between the rows will be ≈ 1.60 m



Greenhouse layout

Greenhouse of 7.62 m (25') with 5 double rows

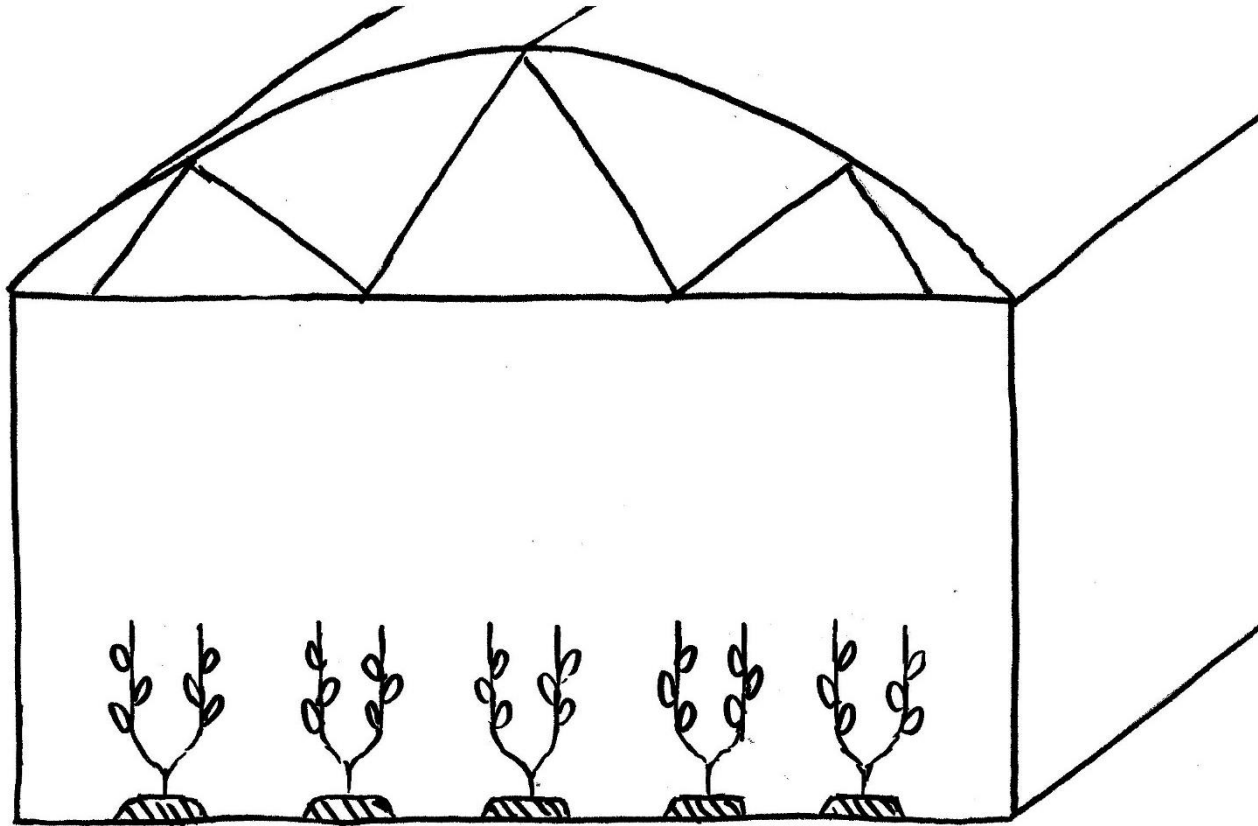


- The spacing between the rows will be = 1.52 m



Greenhouse layout

Greenhouse of 9.14 m (30') with 5 double rows

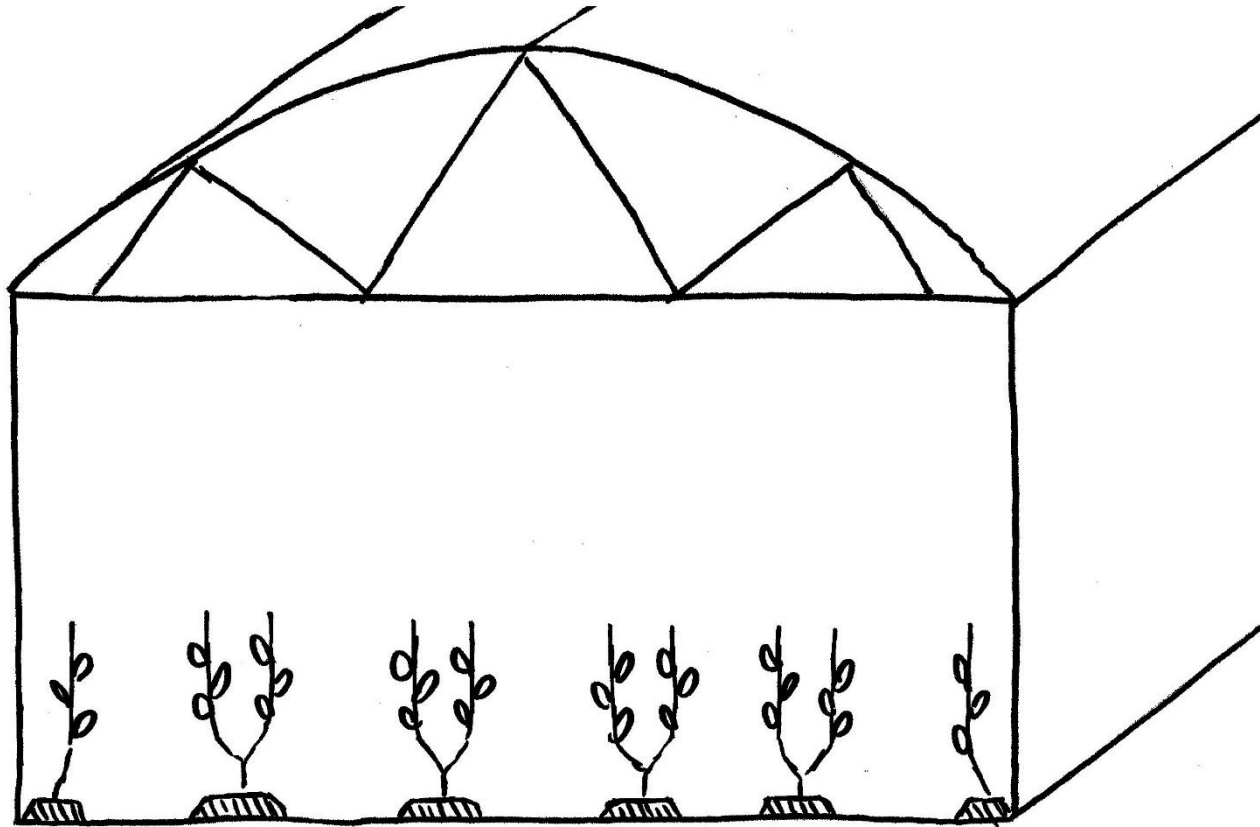


- The spacing between the rows will be = 1.83 m



Greenhouse layout

Greenhouse of 9,14 m (30') with 4 double rows & 2 single rows

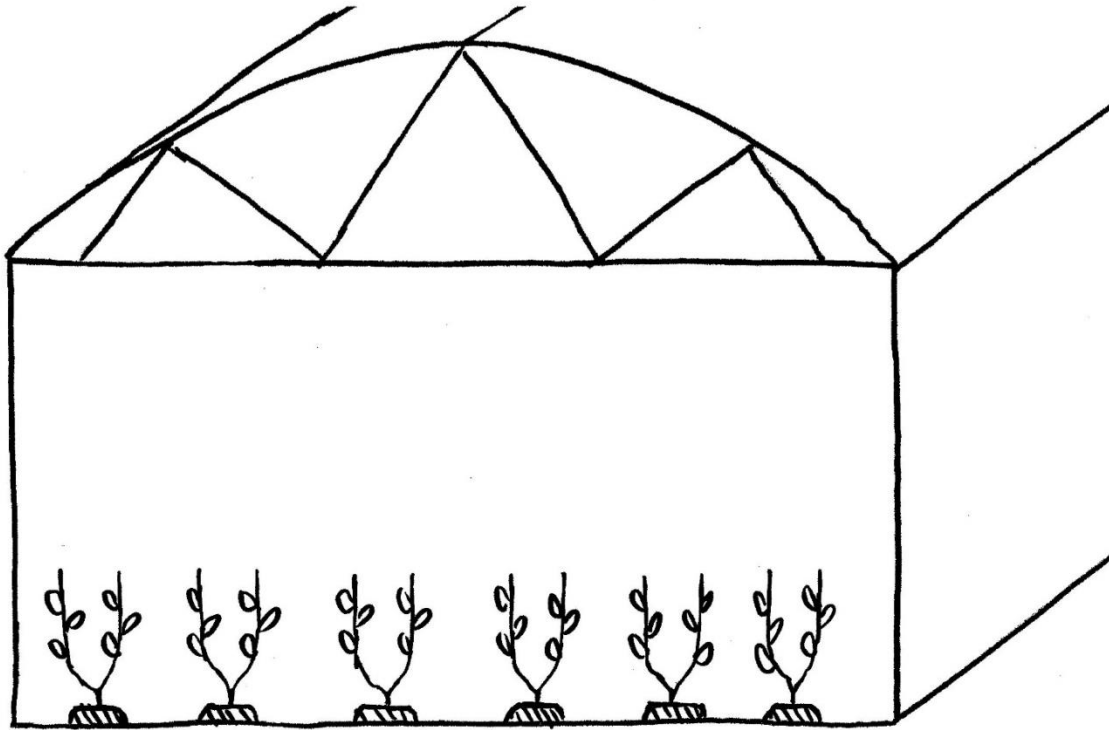


- The spacing between the rows will be ≈ 1.60 m



Greenhouse layout

Greenhouse of 9,14 m (30') with 6 double rows

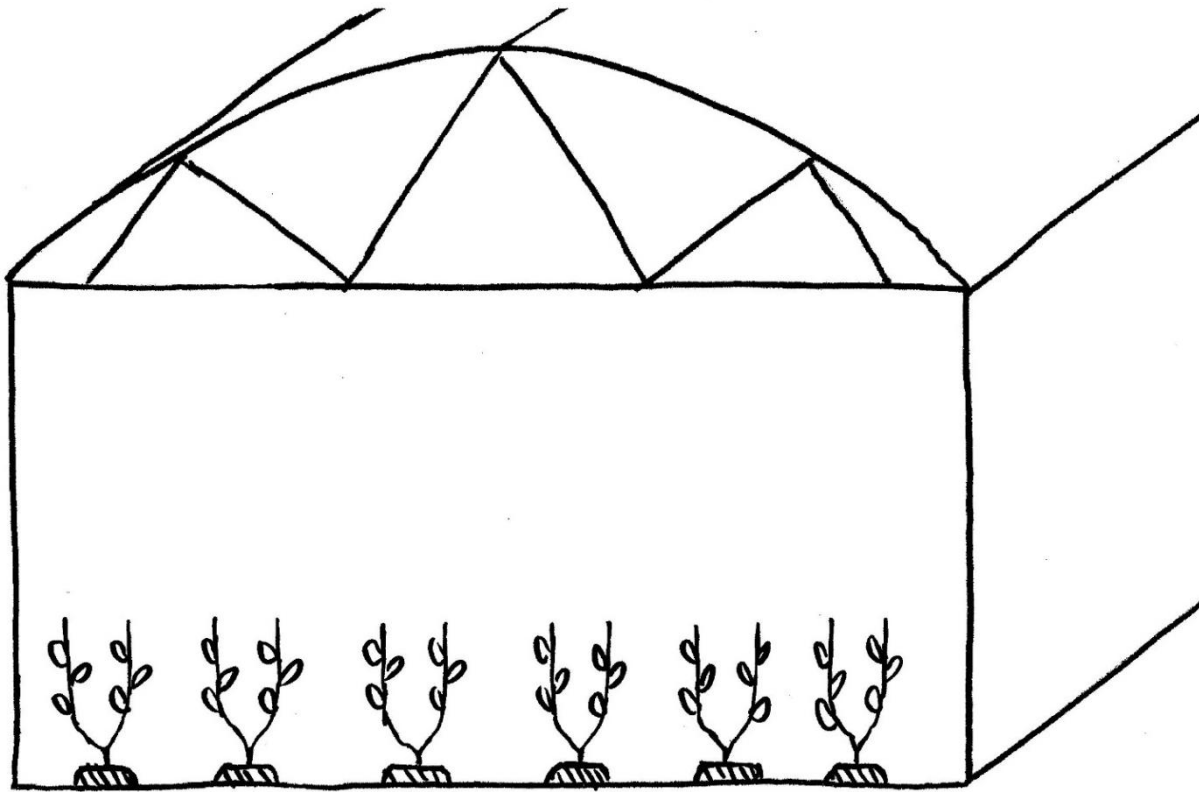


- The spacing between the rows will be = 1.52 m



Greenhouse layout

Greenhouse of 9.60 m (31'4") with 6 double rows

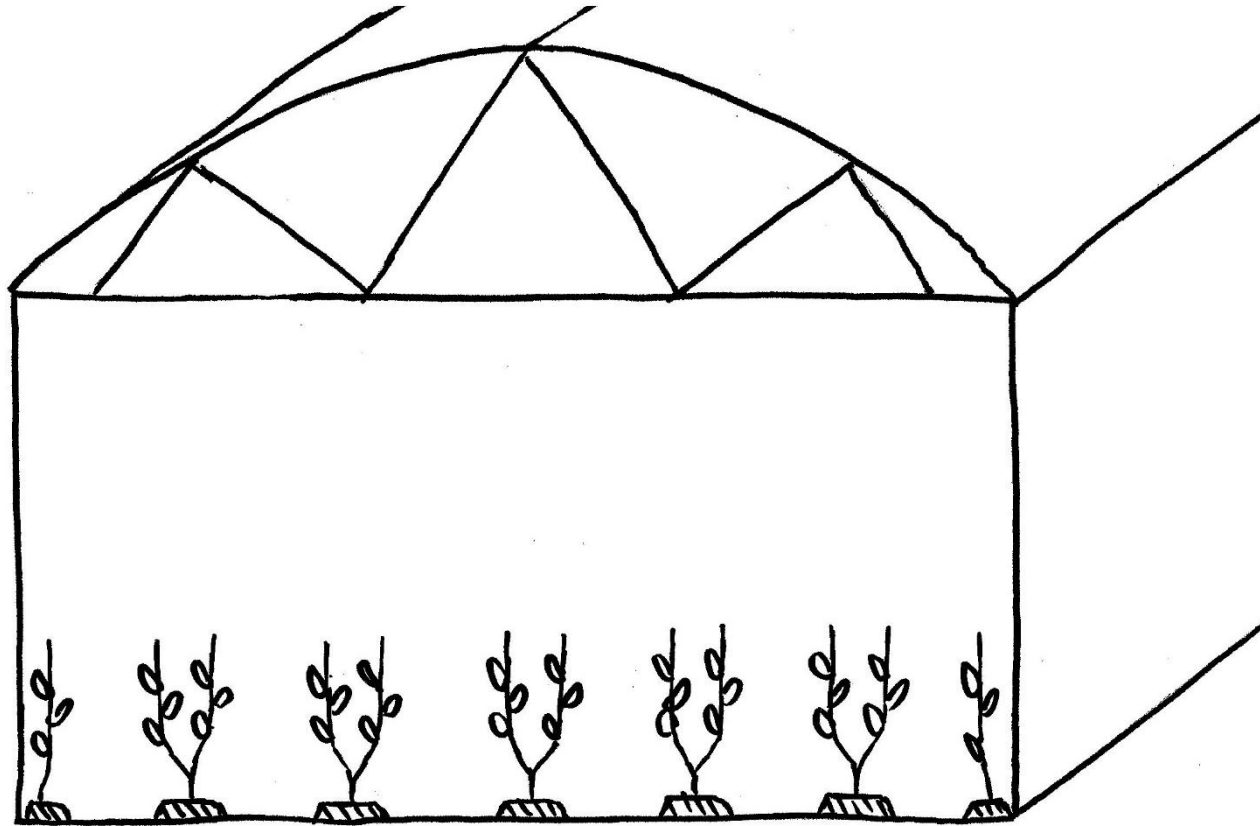


- The spacing between the rows will be = 1.60 m



Greenhouse layout

Greenhouse of 9.60 m (31'4") with 5 double row & 2 single rows

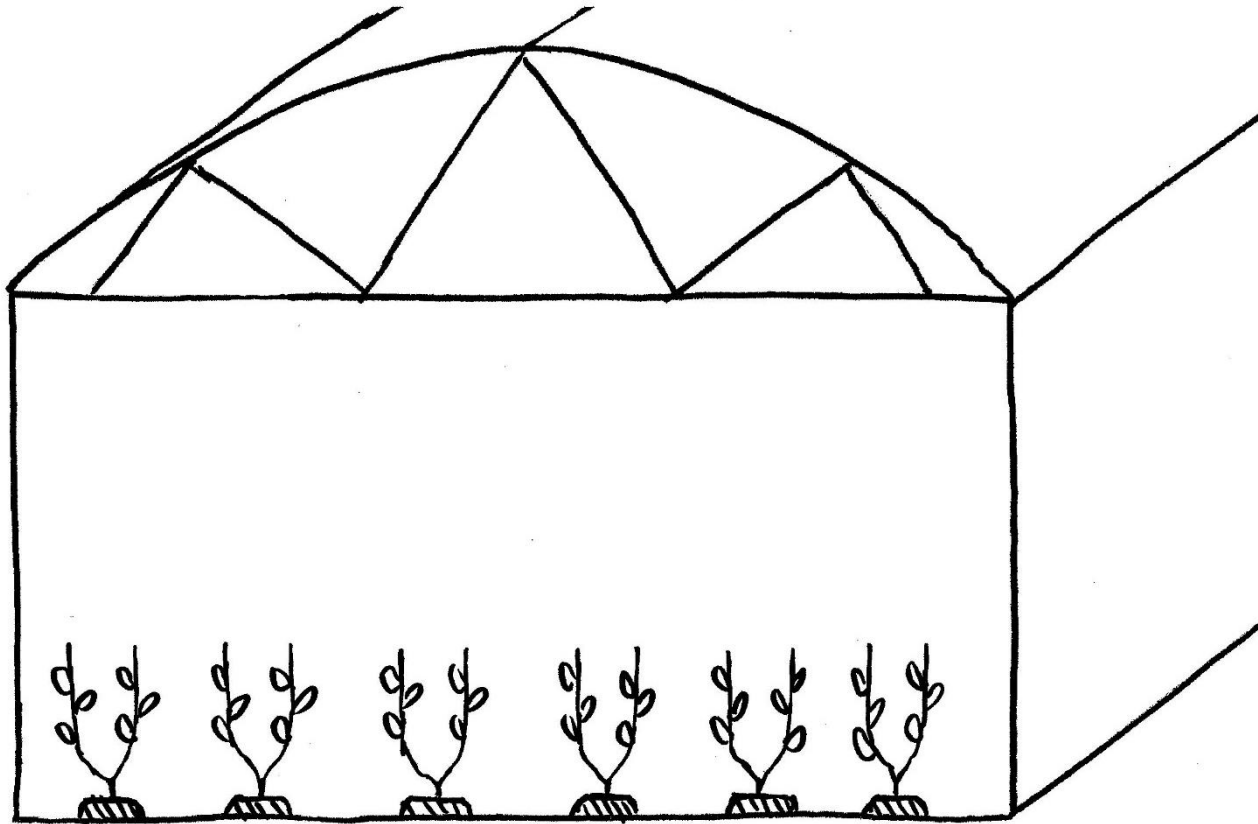


- The spacing between the rows will be < 1.60 m



Greenhouse layout

Greenhouse of 9.75 m (32') with 6 double rows

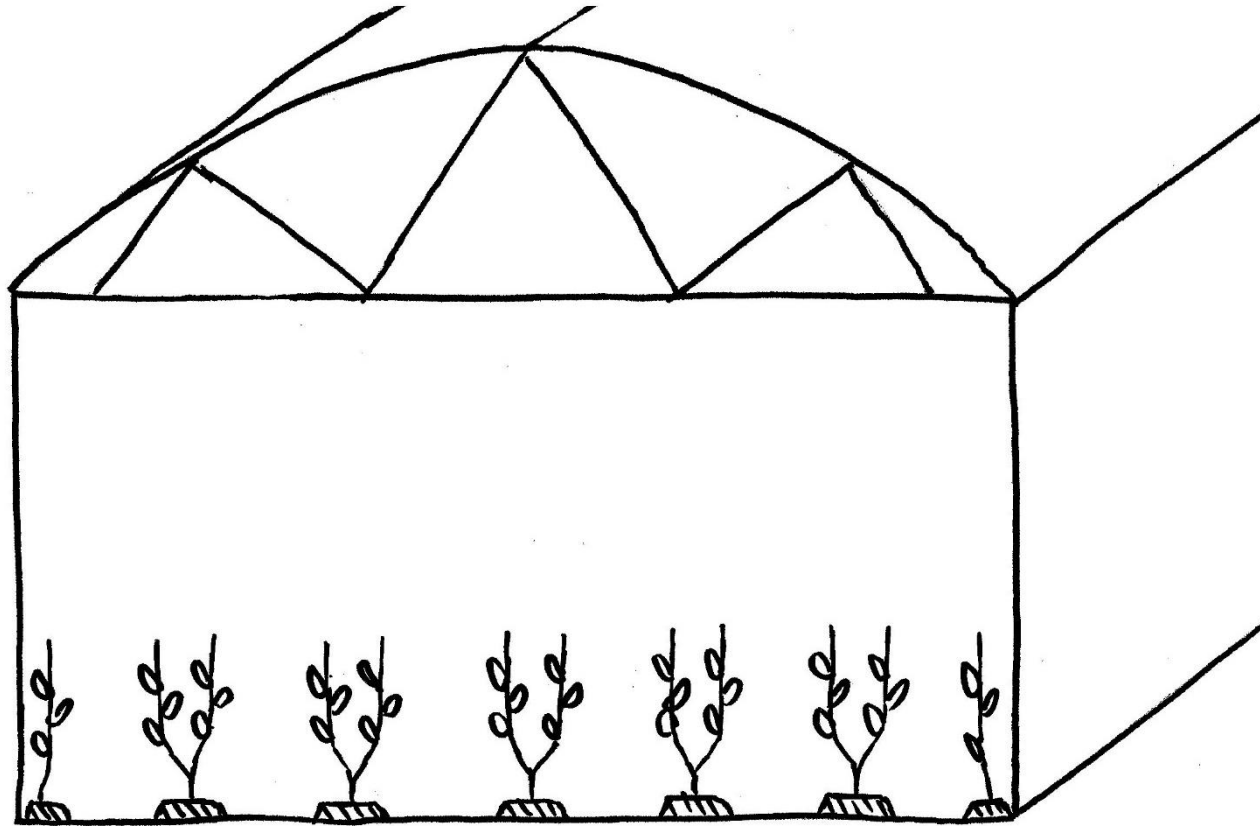


- The spacing between the rows will be = 1.63 m



Greenhouse layout

Greenhouse of 9.75 m (32') with 5 double rows & 2 single rows



- The spacing between the rows will be < 1.60 m



Greenhouse layout

Arrangement of crops

Size of greenhouse	Number of double rows possible	Variations
*6.40 m (21')	4 (1.60 m)	• 3 double rows and 2 single rows on borders
7.31 m (24')	4 (1.83 m)	• 3 double rows and 2 single rows on borders
7.62 m (25')	4 (1.91m) 5 (1.52 m)	• 3 double rows and 2 single rows on borders • 4 double rows and 2 single rows on borders
9.14 m (30')	5 (1.83 m) 6 (1.52m)	• 4 double rows and 2 single rows on borders
*9.60 m (31'6")	6 (1.60 m)	• 5 double rows and 2 single rows on borders
9.75 m (32')	6 (1.63 m)	• 5 double rows and 2 single rows on borders

*Horticultural greenhouses usually have a multiple width of 0.80 m.



Suggested crop densities

Tomato, cucumber, pepper & eggplant

Species	Type	Minimal density (heads/m ²)	Maximal density* (heads/m ²)
Tomato	Fleshy (Beefsteak)	2.20	3.25
	Cluster	2.45	3.50
	Cherry/Cocktail	3.00	4.50
Cucumber (umbrella style pruning)	English	1.40	1.80
	American	1.60	2.00
	Lebanese /Cocktail	2.20	2.80
Pepper	Blocky	5.50	7.00
Eggplant	Medium/Large	4.90	6.00

*The densities are increased if the production factors allow (luminosity, CO₂, experience, etc.).



Greenhouse covering

Properties of polyethylenes

- Characteristics of plastic films
 - **Thickness:** Weight and **price** of the film.
 - **mechanical resistance and durability.**
 - **Anti-condensation (AC):** Additives incorporated to reduce the surface tension between the water and the film. Instead of the droplets, formation of a thin film **that flows off easily** if:
 - The **slope** is sufficient
 - There are no **obstacles**
 - The AC effect lasts a **maximum of 2 seasons**

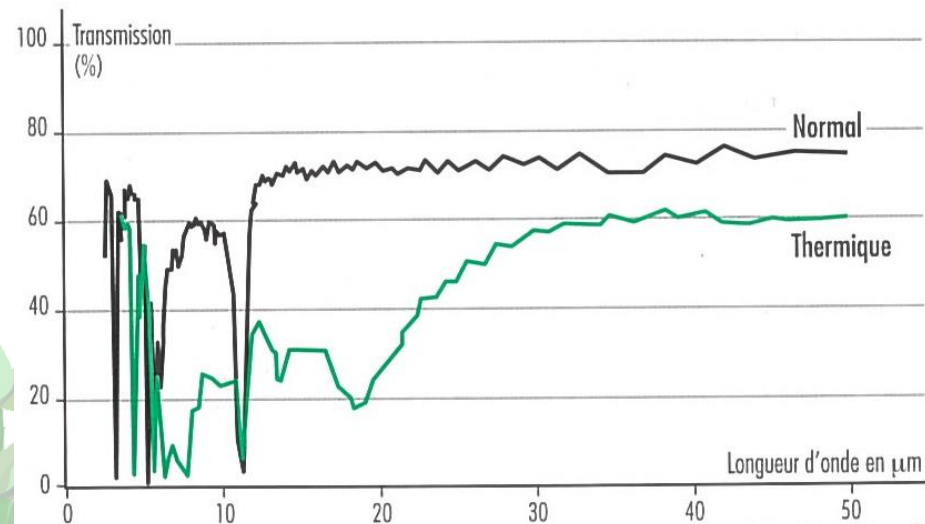




Coverings

Properties of polyethylenes

- Characteristics of plastic films
 - **Thermicity (IR):** Mineral fillers and vinyl acetate (EVA) added
 - **More opaque** at far infrared
 - **Keeps** the heat in the greenhouse



Coverings

The right polyethylenes for the right structures

	Plastic greenhouse	Large tunnel	
		Hot climate plant	Cold climate plant
Mechanical resistance	Average	Maximal	
Anti-condensation (AC)	Yes	If the slope is sufficient (usually not the case)	
Thermicity (IR)	Yes	Yes	No



Coverings

Polyethylenes on the market

- **Trends**

- Polyethylene vinyl acetate (**EVA**) at a **thickness > 180 μm** (7.2 mil)
- **AC** (5 to 20% more luminosity), **IR** and **UV**
- Films of **150 μm** used **2-3 seasons**
- Films of **180 μm** are kept for **3-4 seasons**

- **In the future:**

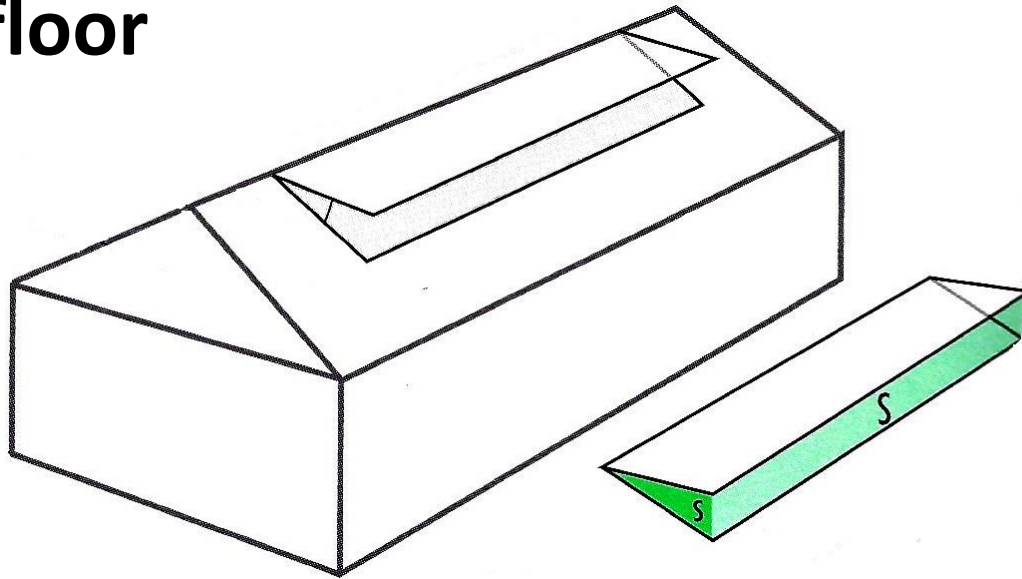
- **Photo-selective** films, translucent films (**diffusion**)



Ventilation management

Minimum opening ratios for natural ventilation

- Ratio obtained by measuring the **open surface of the openings** and dividing it by the **surface of the floor**



Ventilaton management

Minimum opening ratios in natural ventilation



Ventilation management

Minimum opening ratios in natural ventilation



Ventilation management

Minimum opening ratios in natural ventilation

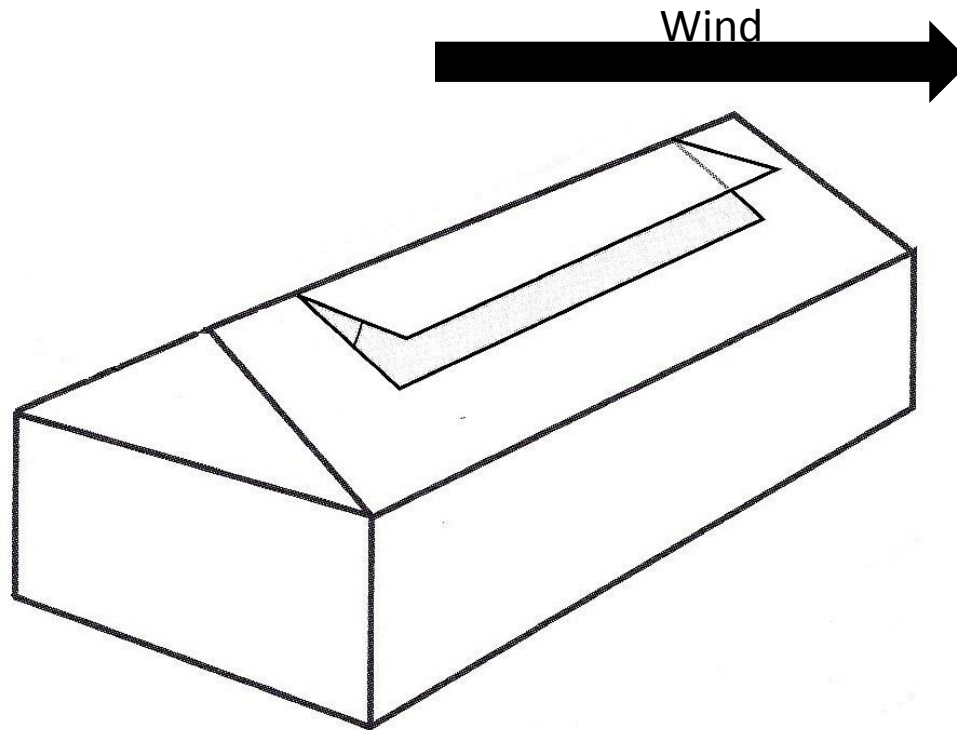
	Individual plastic greenhouse	Multi-bay plastic greenhouse	Large tunnel
Opening ratio	25 to 33%	20 to 30%	10 to 15%

- Careful with **restrictive** elements
 - Anti-insect **nets**
 - **Windbreaker** nets



Ventilation management

Ventilation positioning



- The opening is positioned in the **direction opposite to the prevailing wind**
 - Generates a negative pressure, a suction effect, amplifies the chimney effect



Ventilation management

Dymanic ventilation

- For a greenhouse of:
 - **6.40-7.62 m** (21-25') wide and
 - **30.48 m** (100') long
- Requires:
 - 1 ventilator (fan) or **0.91 m** (3')
 - 1 ventilator (fan) of **1.22 m** (4')



Heating management

Heating needs

- Furnace power
 - \cong **24 BTU/h per m²** of surface per **1°C of $\Delta T^{\circ}C$**
- April
 - 200 m² (2150 '²)
 - T° of 20°C
 - \cong **140 000 BTU/h (41 kW)**

Month	Minimum T° (°C)
March	-22.5
April	-9.9
May	-3.0
June	1.0
July	6.1
August	6.2
September	1.3
October	-3.0
November	-8.5

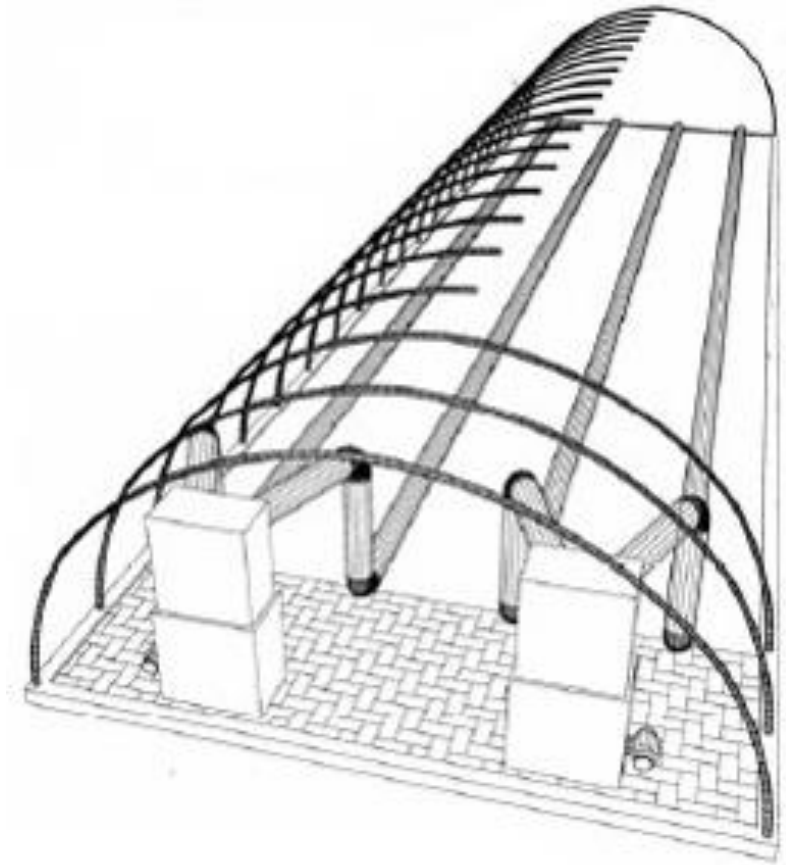
Environment Canada, Moncton 2000-2005



Heating management

Heat distribution

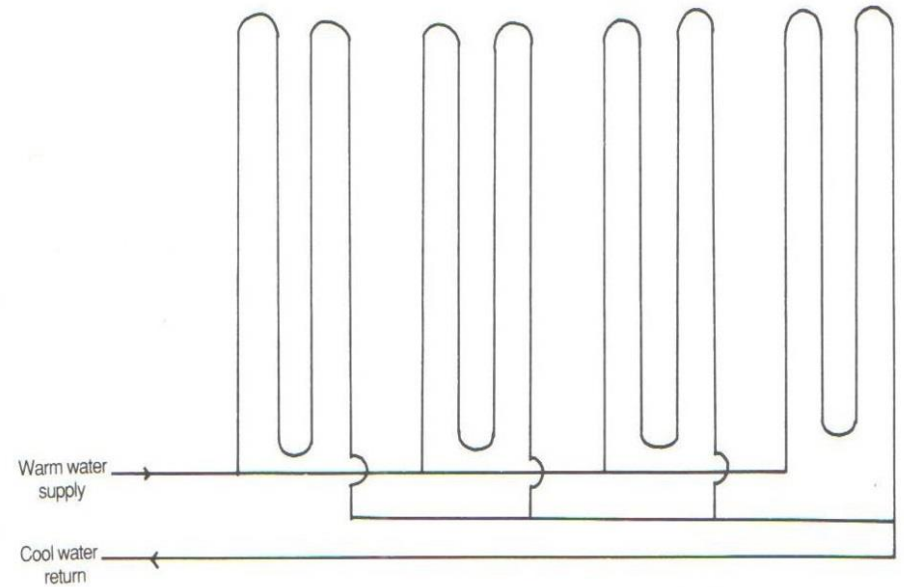
- **As many** poly tubes as rows
 - **Walls** very important
- Place furnaces at the **North end**



Heating management

Heating the floor (and the irrigation water)

- In **soil** cultivation, the soil must be heated
 - **Flexible pipes buried**
30-40 cm (12-18')
 - Circulate hot water (35-55°C)
- In **substrate and soil cultivation**, the irrigation water is heated: 18-20°C



Pollination

- The **tomato** is slightly anemogamous
 - The pistil is enclosed in the stamina tube
 - We **reduce** the influence of the wind in the greenhouse
- **Cucumbers and peppers**
grown in the greenhouse
do not need additional pollination

Natural pollination



Pollination

Manual pollination

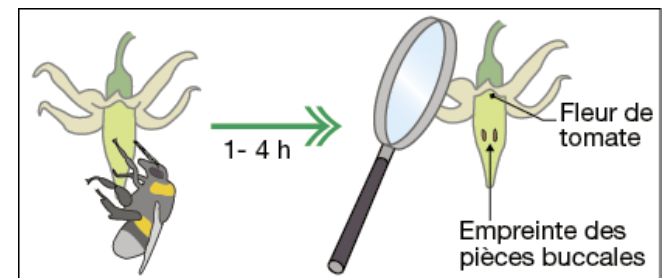
- **Manual pollination**
 - **Everyday**
 - When flowering is maximum (noon)
- **With vibrating device**
- **By tapping the crop wires**
- **Blower**



Pollination

Pollination by bees

- Pollination by bees is **very advantageous**
 - Fruits with more seeds, **more size (+ 20%)**
 - More uniformity in size, **better shape**
 - **Better quality**
 - **Less expensive and pollination more reliable**



Transplant production

Basic principles

- **Planning seed requirements**

	N^{bre} de plants nécessaires	N^{bre} de graines commandées
Tomate	10 000	12 000–13 000
Concombre	6 500	7 500*
Poivron	10 000	12 000–13 000
Laitue	1 000	1 100–1 200

** Les semences de concombres offrent en général des taux de germination et de levée plus élevés.*

**Cucumber seeds generally have higher germination and emergence rates*



Transplant production

Basic principles

- Ideal **temperatures** and **times** for germination

Culture	Température du milieu de croissance (°C)
Tomate	25
Concombre	27
Laitue	16–18
Poivron	26

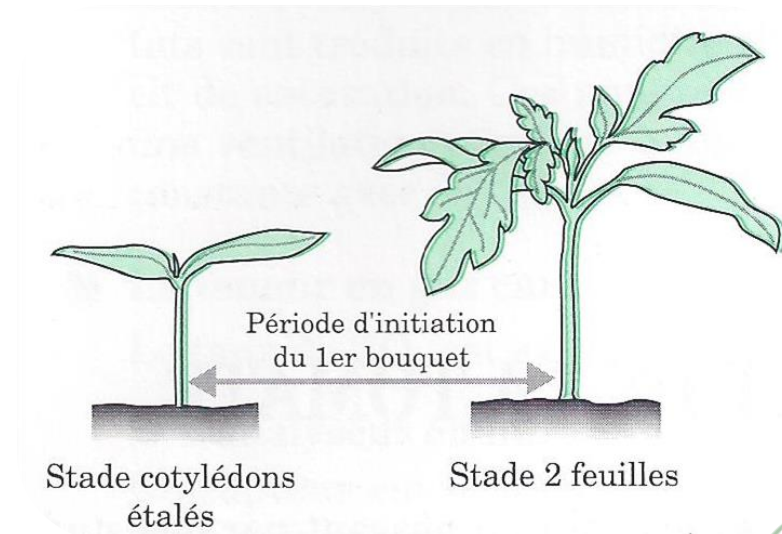
Culture	Temps de germination (en heures)
Tomate	
Bonne germination	72
Germination médiocre	96
Poivron	72–96
Concombre	48–60
Laitue	72



Transplant production

Initiation of the first cluster on the tomato plant

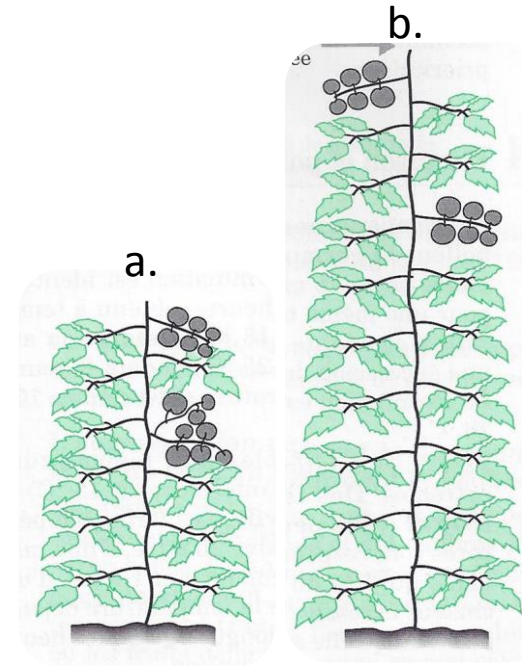
- **Initiation of the first cluster** takes place between the **cotyledon stage** and the **appearance of the first 2 true leaves**



Transplant production

Initiation of the first cluster in the tomato

- **Temperature control at this time results in:**
 - The **early** appearance of the first cluster (a.)
 - **Cool T, elevated luminosity**
 - The **late** appearance of the first cluster (b.)
 - **Hot T, weak luminosity**



Transplant production

Transplant production schedule

Species		Number of days in the nursery	Stage*
Tomato	Normal	35	8-10 true leaves
	Pinched	42-45	
	Grafted and pinched	49-55	
Cucumber	Normal	21-24	3-4 true leaves
	Pinched	28-31	
Pepper		56	5 true leaves

*It is possible to bring the seedlings into the greenhouse/tunnel before this stage



Transplant production

Pinching the heads of the tomato and cucumber plants at the cotyledon stage



Transplant production

Pinching the heads of the tomato & cucumber plants at the 2nd true leaf stage



- Advantages
 - Easier
 - Faster recovery
 - (5-7 days vs 7-10 days when pinched at the cotyledon stage)
- Disadvantages
 - First cluster sometimes arrives later
 - Requires more space in the nursery at the start



Transplant production

Allowing the development of a sucker below the first cluster



- Advantages:
 - Shorter prep period in the nursery
 - Lower seed cost
- Disadvantages:
 - Less productive first harvests



Transplant production

Pinching the head of the tomato plant



Greenhouse pepper and eggplants are always grown with at least two heads per plant.



Grafting

Basic principles

- Technique that dates back 50-60 years
 - Resistance to **root diseases**
 - Corky root (*Pyrenochaeta lycopersici*)
 - **Stronger** plant
 - Better **recovery** of the plant during heatwaves
 - Less **blossom end rot** in times of stress
 - For **tomatoes and eggplants**



Grafting

- Blades
 - Scalpel, razor blade
- Silicone grafting clips
- Domes
- Sprayer
- Tents



Material



Grafting

Technique



Grafting

Conditions for success

- Humidity
 - 90-95%
- Temperature
 - 21-22°C
- Luminosity
 - Very **low** during the grafting, then back to normal



Grafting

Points to improve

- The plants are transplanted **too deeply**
 - Leave 2-3 cm below the grafting point
- The suckers of the rootstock **must be removed**
 - Disease susceptibility



Planting Depth



Suckering



Choice of cultivars

- Cultivar selection criteria
 - **Indeterminate** growth (greenhouse)
 - **Determinate** growth (large tunnels)
 - **Taste**
 - **Size**
 - **Shape of fruit**
 - **Colour** (diversity)
 - **Disease resistance** of (scion and rootstock)



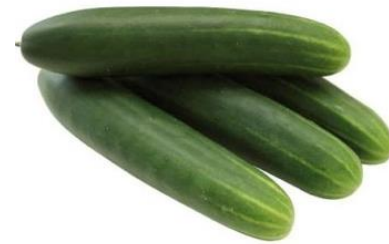
Tomato



Choice of cultivars

Cucumber

- Cultivar selection criteria
 - **Parthenocarpy**
 - **Resistance**
 - **Size (length)**



Choice of cultivars

Peppers

- Cultivar selection criteria
 - **Type** of pepper
 - **Taste**
 - Size (size of the fruit)
 - **Colour**
 - Growth speed
 - Disease resistance



Temperature management

Basic principles

- The ideal **growth temperature** is high for tomatoes
 - **Earlier** harvest
 - **Superior** yields
- Temperature management during the **seedling stage** is paramount

Stage	Ideal average (24 hour) T° (°C)	
Young seedling	High luminosity	Low luminosity
	23-25	18-21

Stade	Ideal average (24 hour) T° (°C)	
Mature plant	High luminosity	Low luminosity
	21-23	16-18



Temperature management

Basic principles

- And **even higher** for cucumbers
 - **Earlier** harvest
 - **Superior** yields

Stage	Ideal average (24 hour) T° (°C)	
Young seedling	High luminosity	Low luminosity
	25	20-22

Stage	Ideal average (24 hour) T° (°C)	
Mature plant	High luminosity	Low luminosity
	23-24	18-20



Irrigation management

Hiling the rows

- Hiling the rows up to **20 cm (8")** high



Irrigation management

Soil mulch, ground cover

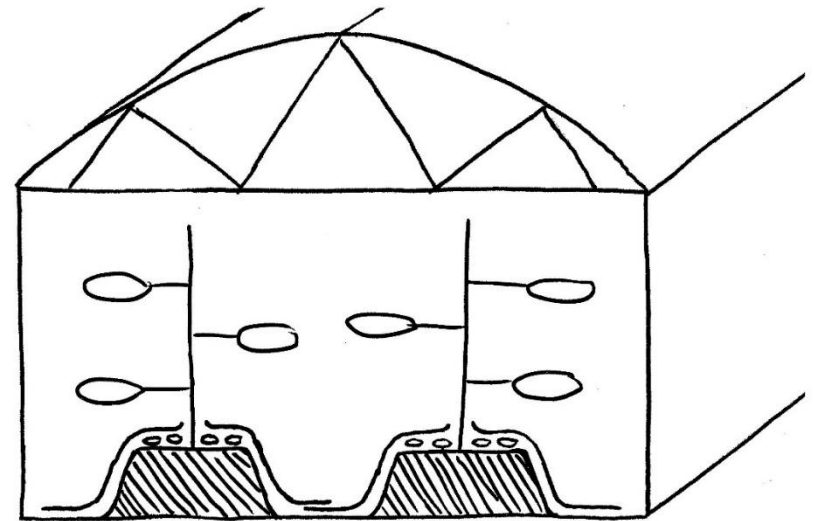
- An **opaque plastic** floor allows:
 - **Weed control**
 - **Humidity in the soil** and not in the air
 - Improved **fertilizer degradation**
 - Control of certain **pests** (*Thrips*)



Irrigation management

Irrigation lines

- Ideally
 - **> 4 irrigation lines** per bed
 - **Close distance** between drippers (**10 cm/4 "**)
 - **Valve** on the 2 central lines



Irrigation management

Irrigation lines



Irrigation management

Irrigation lines



Irrigation management

Water needs for crops

- Water needs for crops
 - In summer, crops need up to **6000 ml/m²/day**
- With a plastic ground cover
 - In summer, **6 irrigations of 1000 ml/m²**



Fertility management

Fertilizers used

Options

- **Compost (1-1-1)**
 - Mixing element and trace elements
- Composted **chicken manure (5-3-2)**
- **Feather meal (13-0-0)**
- **Magnesium sulphate of potash (0-0-22)**
- **Potassium sulfate (0-0-50)**



Fertility management

Fertilization recommendation

- Typical fertilization recommendation (multiple ingredients)
 - For **staked** crops, when basic soil test indicate adequate soil pH and a high level of fertility
 - Based on annual yields
 - Beefsteak tomato > **50 kg/m²** (heated greenhouse system, long season)
 - Cucumber > **120 fruits/m²** (heated greenhouse system, long season)

Fertilizer needs (kg/week/100m ²)	
Actisol (5-3-2)	3.60
Feather meal (13-0-0)	1.94
Sul-Po-Mag (0-0-22)	0.77
Potassium sulfate (0-0-50)	0.61

Many growers will mix these ingredients together before application



Fertility management

Fertilization recommendation

- Fertilizers applied
 - **Every 2 weeks**
 - **Under** the plastic ground cover
 - **On** the irrigation lines
 - **Alternate** the sides of the row
- **SSE** (or **SME**) greenhouse soil analysis
 - To validate fertilization plan
- **Tissue testing**
 - To identify and confirm a nutrient deficiency



Fertility management

Fertilization recommendation



Plant protection

Prevention

- **Preventive measures**
 - Insects predators with **bunker plants**
 - *Dicyphus* in **the mullein plant** for tomato
 - *Aphidius* in **grasses** for peppers
 - Predatory mites **with misting system**
 - *Phytoseiulus* in cucumber



Bunker plant example

Prevention



The mullein plant



Plant protection

Prevention

- Nets/Mosquito nets
 - Against the tarnished plant bug on cucumber
 - Against the striped cucumber beetles on cucumber
 - Against the wind
- Dehumidification
 - Against gray mold
- Humidification
 - Against powdery mildew



Plant protection

Pesticides

- **More pesticides allowed in organics**
 - Dormant oil
 - Against several insects
 - Milstop
 - Against powdery mildew
 - Sulfur
 - Against powdery mildew and mites



Work management

Size of tomato plants

- Leave **fewer fruits** per cluster
 - Maximum of **4 fruits** per cluster for beefsteak tomatoes
- Remove **old leaves**
 - Maximum of **18 mature leaves** per plant



Work management

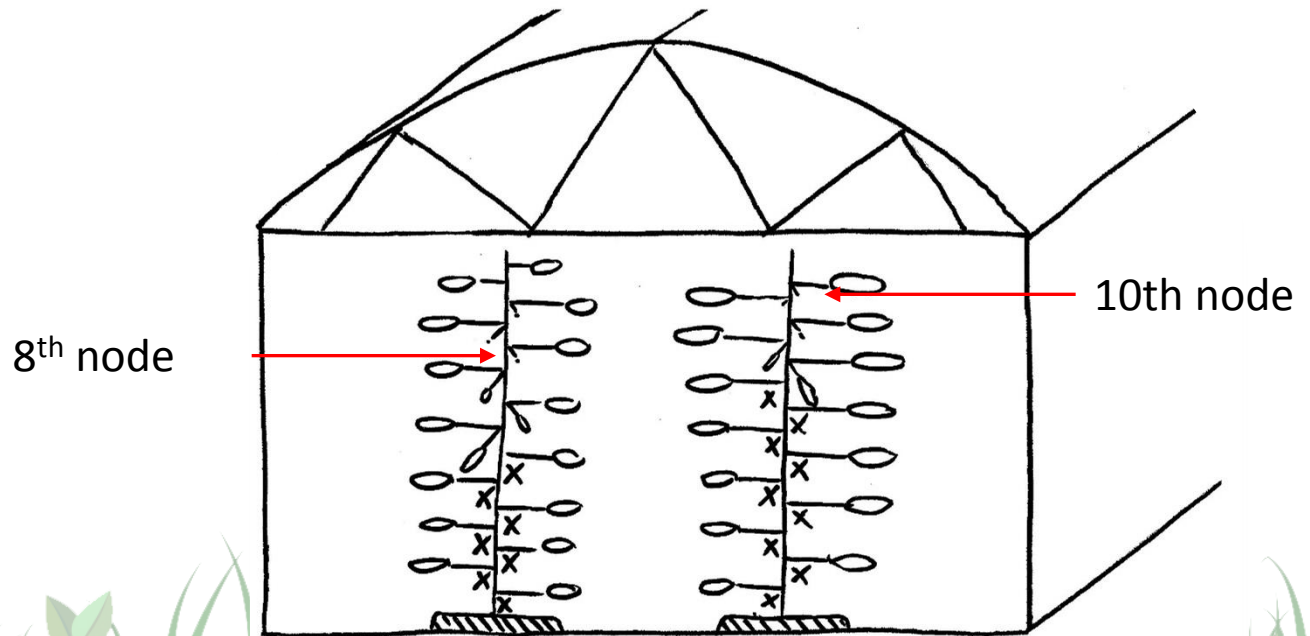
Size of tomato plants



Work management

Cucumber fruit size

- Do not load the plant too quickly
- For higher yield and extended harvest:
No fruits before the **8th or 10th node**



Work management

Cucumber fruit size

- **English**

- 1 fruit/2 nodes

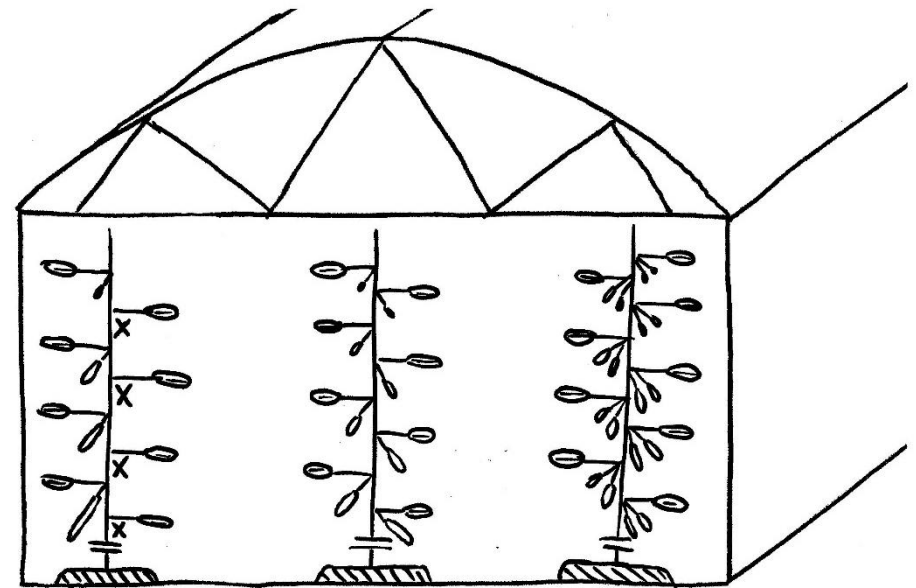
- **American**

- 1 fruit per node

- **Lebanese**

- 2 fruits per node (typically)

- If only 1 fruit per node is growing, allow a 2nd fruit to grow from the sucker that is growing from same node, and do not forget to de-head the sucker.



English

American

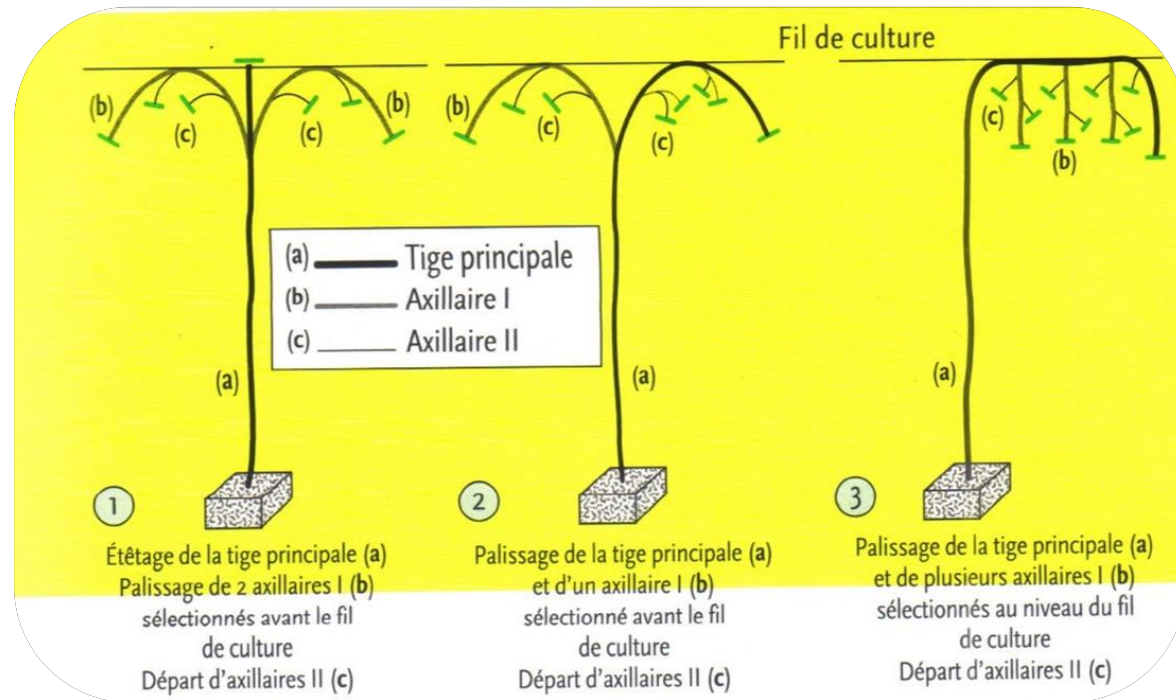
Lebanese



Work management

Cucumber plant size

- **Umbrella style pruning**
 - **Not much work**
 - **Hanging harvest**
 - **≈ 12 weeks**



Work management

Cucumber plant size

- **Umbrella style pruning**



Work management

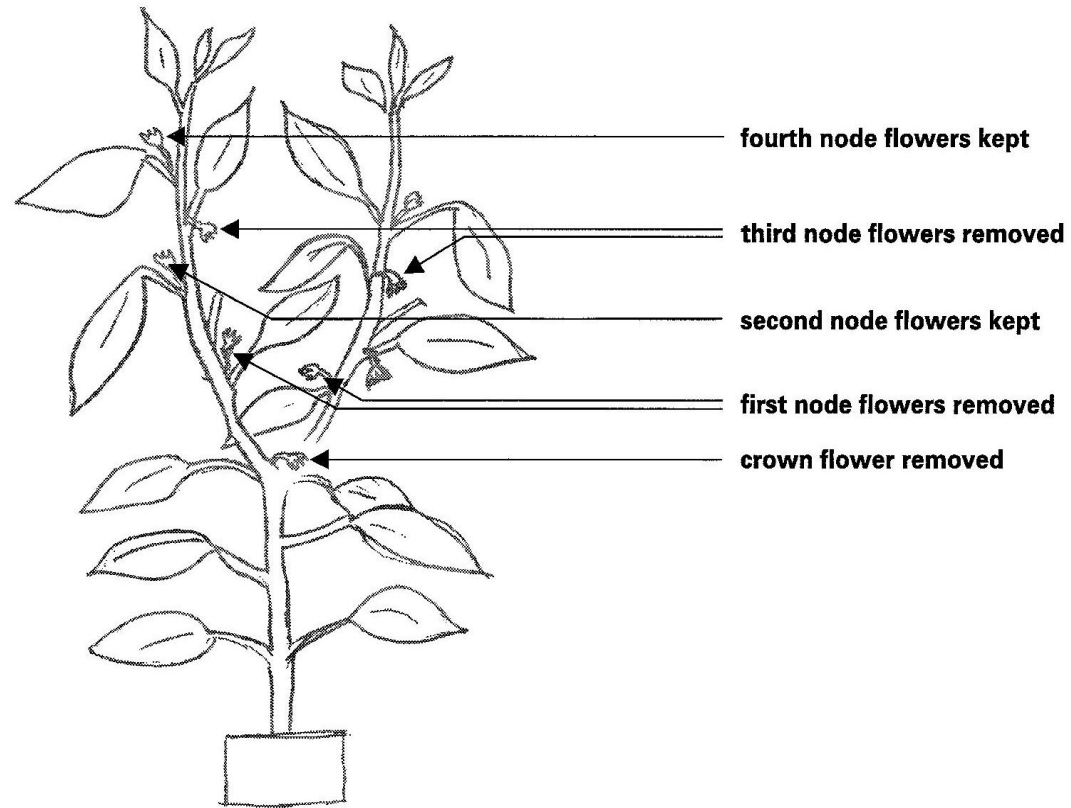
Cucumber plant size

- **Umbrella style pruning**



Work management

Pepper size



For higher yield and an extended harvest:

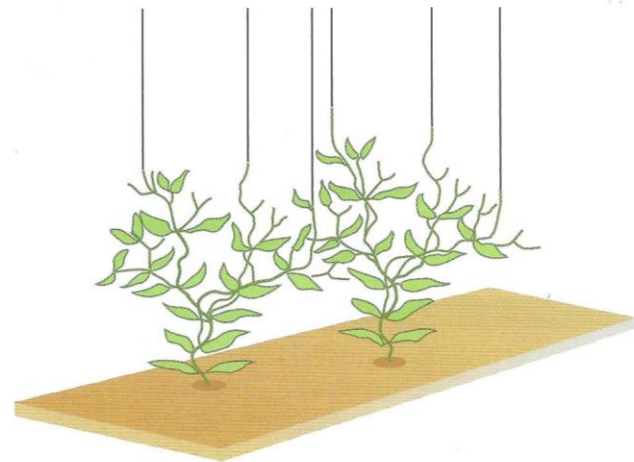
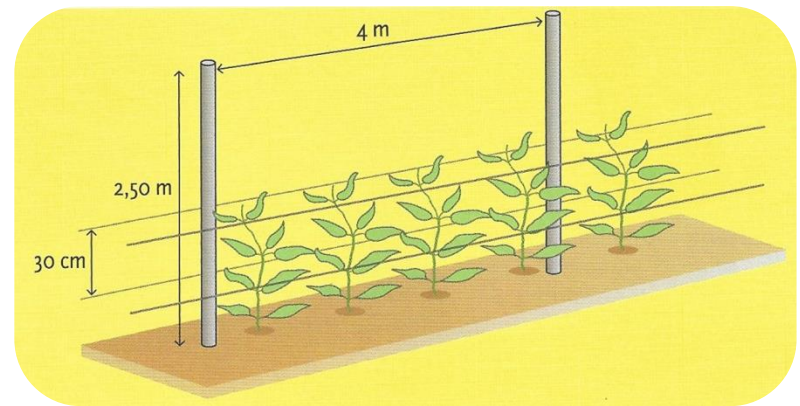
- Remove the fruit from the **fork** and
- Keep the first fruits starting at the 3rd node.



Work management

Staking of pepper plants

- **Diversified market gardening producer**
 - «stake and weave»
- **Greenhouse pepper producer**
 - «hanging string»



Work management

Staking of pepper plants



Work management

Staking of pepper plants



Prioritization of actions

My recommendations

- In the short term (**next season**)
 - **Pollination** by bees
 - **Crop arrangement**
 - **Adapted densities**
 - **Well-chosen cultivars**
 - **Staking techniques** and adequate **size**
 - **Improved temperature management**
- In the **medium term** (things to think about now)
 - Adequate **greenhouse coverings**
 - **Improved plant protection**



Thanks!

