Modern Greenhouse Polyethylene Films and their innovative contribution

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THE ROLE OF PE PLASTICS FOR MODERN GREENHOUSE CULTIVATIONS

- **Greenhouse cover is a media/filter between the sun and the cultivation**
- **Therefore, we can modify its properties in order to maximize its positive influence and minimize its negative one**
- The rapid increase of the global plastics demand during the last 20-30 years has driven relative research in a serious push towards the improvement of greenhouse claddings

TANZANIA
«DUMMEN» 30 ha

AZERBAIJAN
«AZAGRO» 40ha

MEXICO

«EL ROSAL» 140 Ha

MEXICO

«EL ROSAL» 140 ha

MEXICO
«DIVEMEX» 320 ha

PARAMETERS AFFECTING CULTIVATION AND FARMERS CONCERN RELATED WITH PE COVERS

Cultivation

- Favorable microclimatic conditions
  - Light transmittance
  - Heat preservation
  - Relative Humidity → Antidrip ability

Farmers

- Lifetime
- Mechanical strength
- Antidrip without fog
- Contribution to IPM
- Photoselective films

PARAMETERS AFFECTING CULTIVATION

Light properties

- Play the most significant role for the better crop growth and development

Also

- **Properties modifying UV light** → UV-open or UV-blocking films

  Properties modifying the plant → enhance stem elongation or dwarfing, more vivid coloration etc

PARAMETERS AFFECTING CULTIVATION

- **Thermal factors** to retain higher temperatures during cold nights
- **Cooling factors** to keep temperatures lower during hot days
- **Anti-drip/Anti-mist properties** to offer regulated RH for better growth and avoidance of diseases

PARAMETERS CONCERING FARMERS

Apart from the properties concerning cultivations, farmers are also very much interested in:

- **Lifetime:** First property in their mind for cost reasons(*)
- **Mechanical Strength** of the film against unfavorable weather conditions (winds, snow, hail etc.)

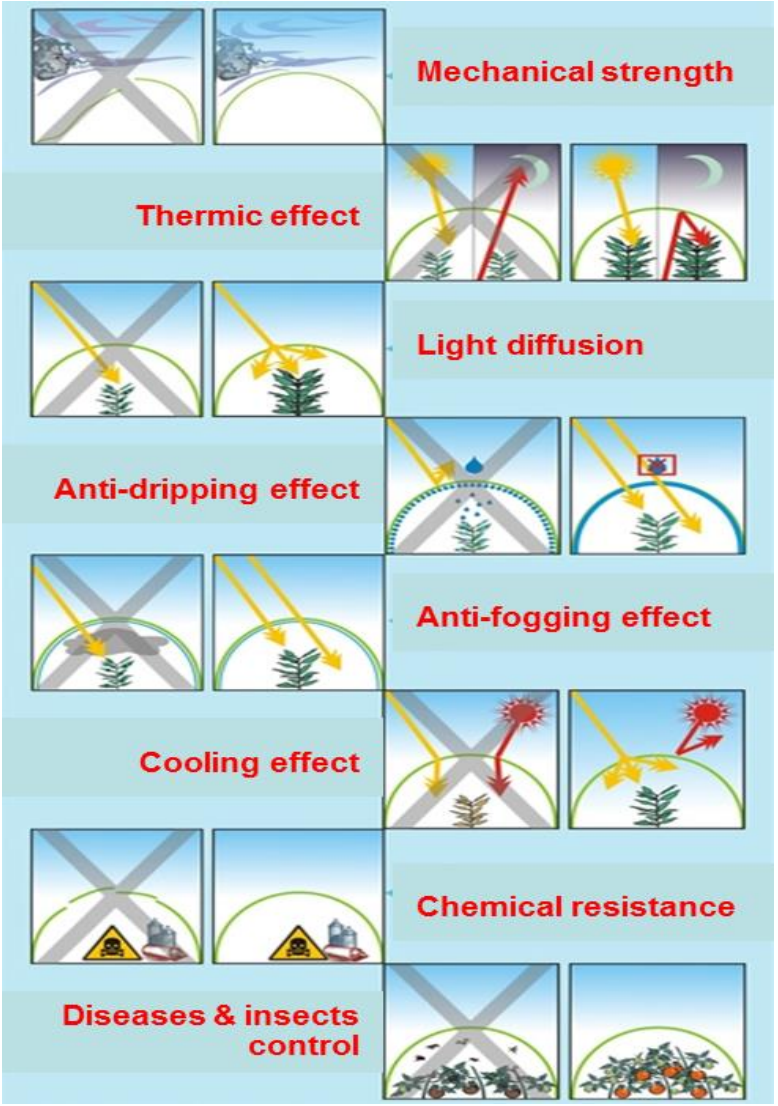
(*) In some countries the labor cost for replacing film covers exceeds the cost of the film itself!

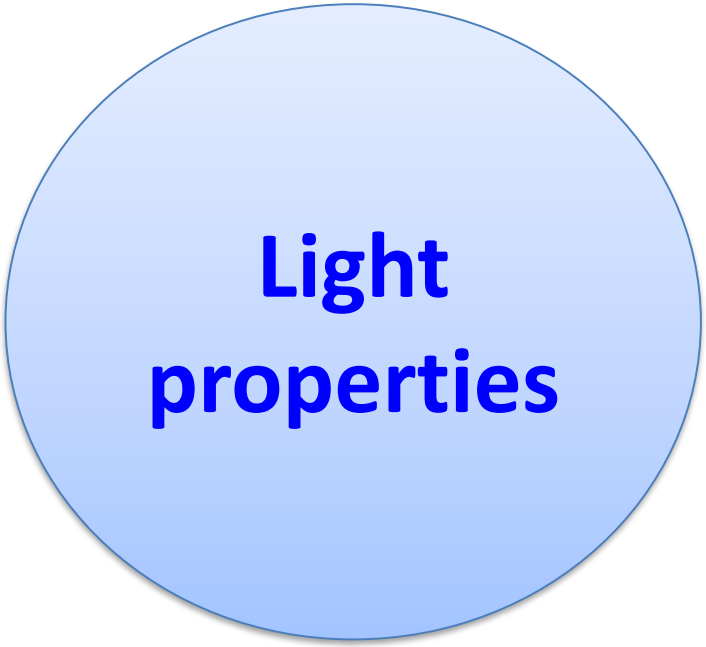
PARAMETERS CONCERING FARMERS

- **Anti-dripping effect** without the undesired phenomenon of fog
- **Contribution to IPM**
- **Photoselective properties**
- **“Smarter” films**

PARAMETERS CONCERING PLANTS AND FARMERS

Summarizing what we want and what we don't want →



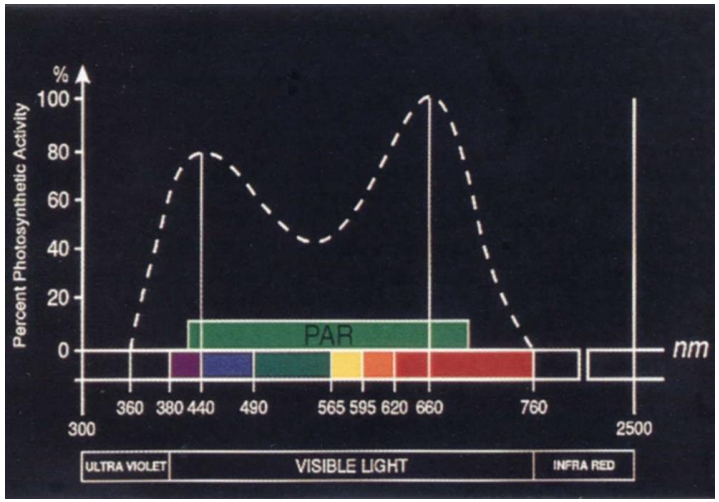


Being aware that you have already heard an analytical presentation of light and its properties, I will try not to repeat same things but I will refer to light when it is related with desirable films properties

Global Light Transmission (GLT)

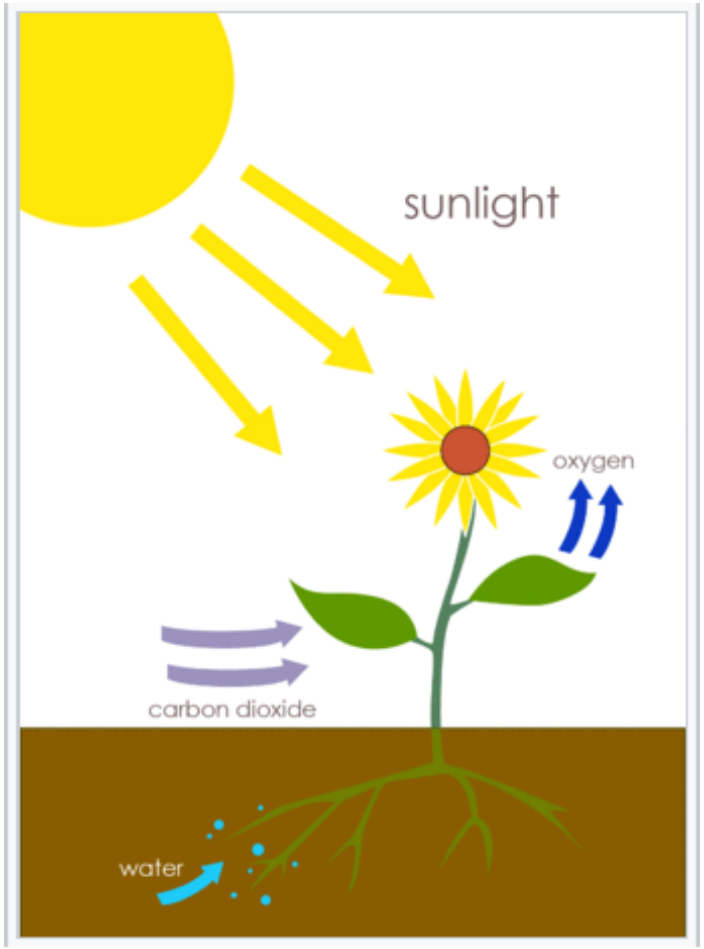
Light spectrum is divided into

UV – VISIBLE (PAR) – NIR – FIR

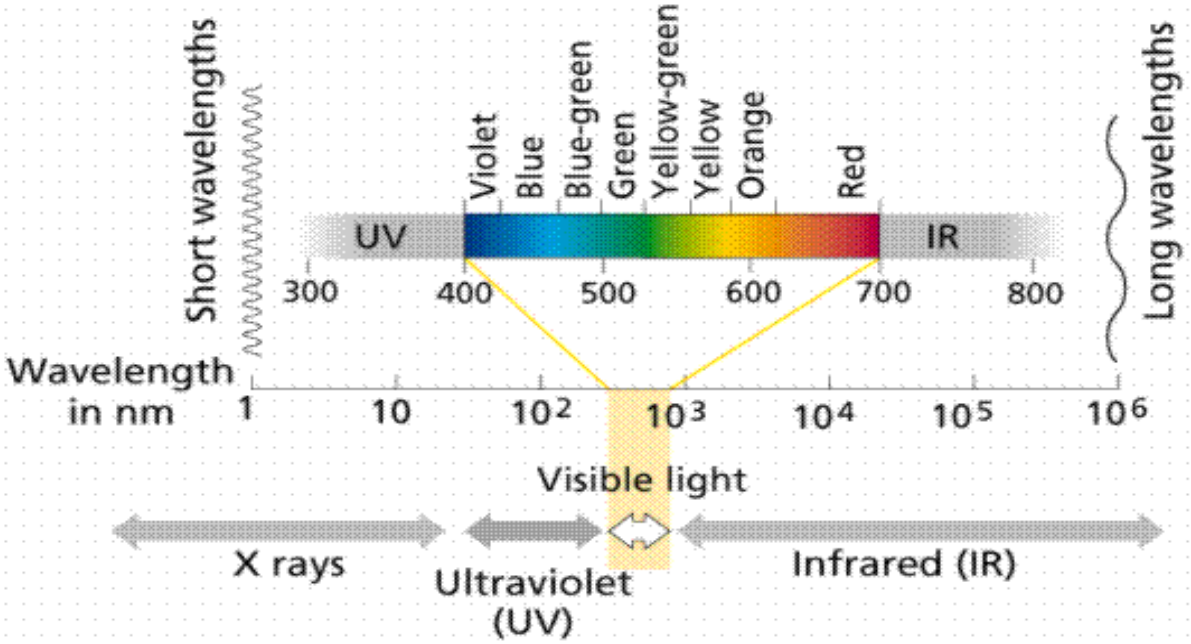


PAR (Photosynthetically Active Radiation) is responsible for the growth and productivity of plants but also **UV and IR zones** play basic role

The magic circle of life



Light Properties



Light is the spectrum of electromagnetic radiation emitted by the sun

It is divided into 3 parts

Ultra-violet (up to 400 nm)

Visible – PAR (400-700 nm)

Infra red (above 700 nm)

Photosynthetically Active Radiation (PAR)

VIOLET	~ 400 nm - 430 nm	**Influence on photosynthesis**
INDIGO	~ 430nm - 450 nm	**Influence on photosynthesis**
BLUE	~ 450nm - 520 nm	**Strong influence on photosynthesis: phototropic curvature in shoots, non-etiolated growth of seedlings, stomata opening, cytoplasmic streaming**
GREEN	~ 520nm - 565 nm	Very small influence on plants
YELLOW	~ 565nm - 590 nm	Practically no influence on plants
ORANGE	~590nm - 625 nm	Small influence on photosynthesis and photoperiodism
RED	~625nm - 700 nm	**Strong influence on photosynthesis & photo-morphogenesis: seed germination, flowering, senescence, dormancy**

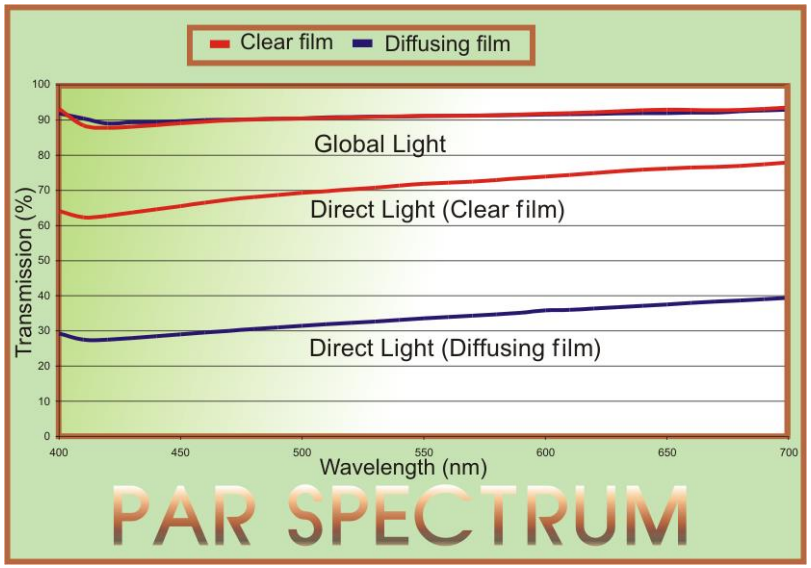
Global Light Transmission (GLT)

- We have to examine light properties **quantitatively as well as qualitatively**
- Modern plastics secure a total light transmission **more than 90%**
- Recent research - decreasing reflectance of PE films - **drives GLT to more than 94%** which actually means that plastic can behave almost like glass

Light Diffusion

- In regions with plenty of light, like Greece and other countries of Med zone, **direct light should be avoided** entering the greenhouse
- Lots of damages can be caused due to direct light → **Burnings, Inhibition of vegetation etc.**

Light Diffusion

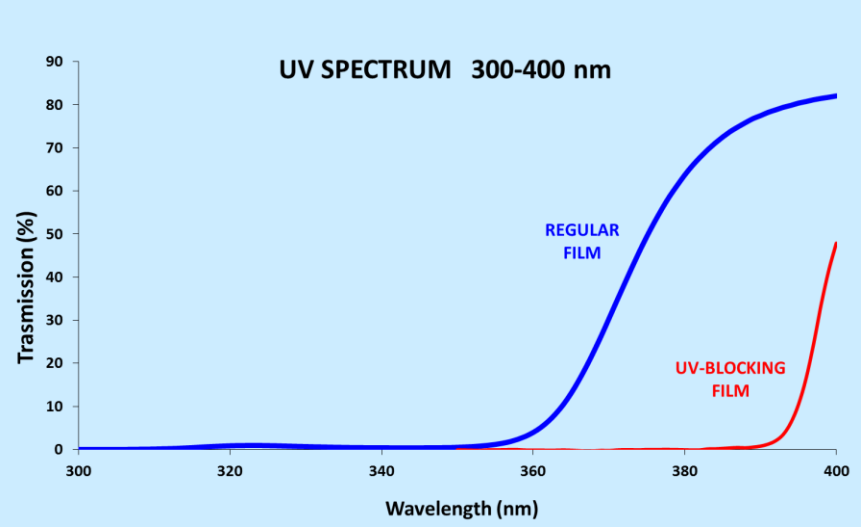


- For this reason **Light diffusion** is necessary around the levels of **50-50** (direct to diffusing light)
- **Diffusion** offers better and more uniform distribution of light, allowing it to reach the lower parts of the plants
- **Light diffusing films do not decrease GLT!**
- **High diffusing films (>65%)** also reflect NIR radiation, offering a moderate “cooling” effect, by reducing heat entering the greenhouse during hot days

Special effects of Light

Disease control (UV blocking effect)

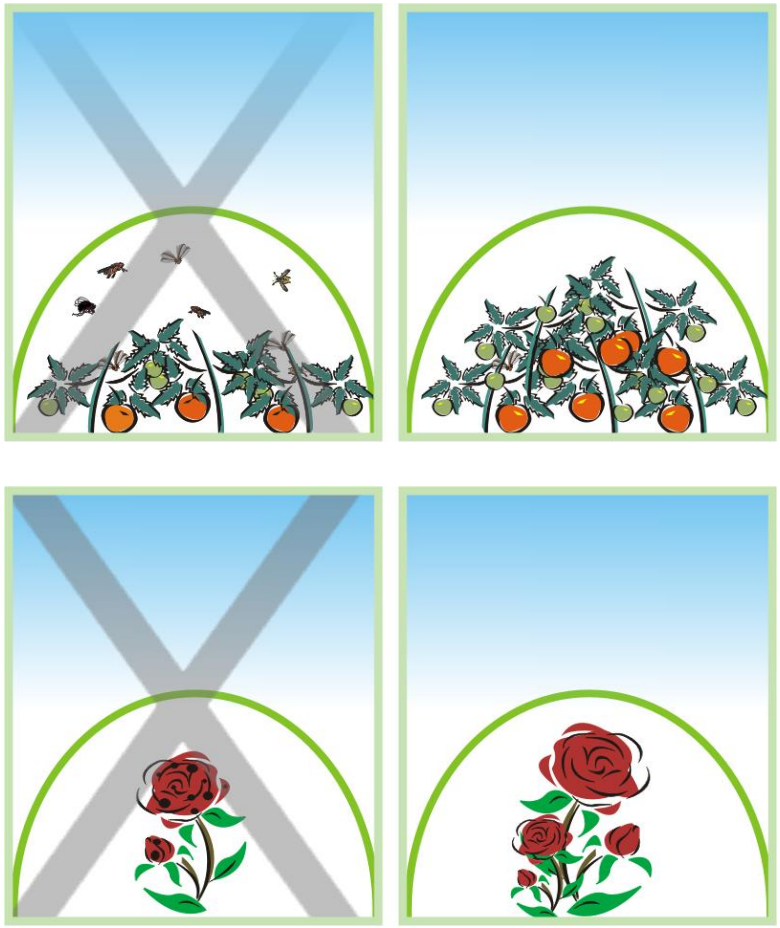
“UV-blocking” films absorb UV-radiation up to 380-390nm



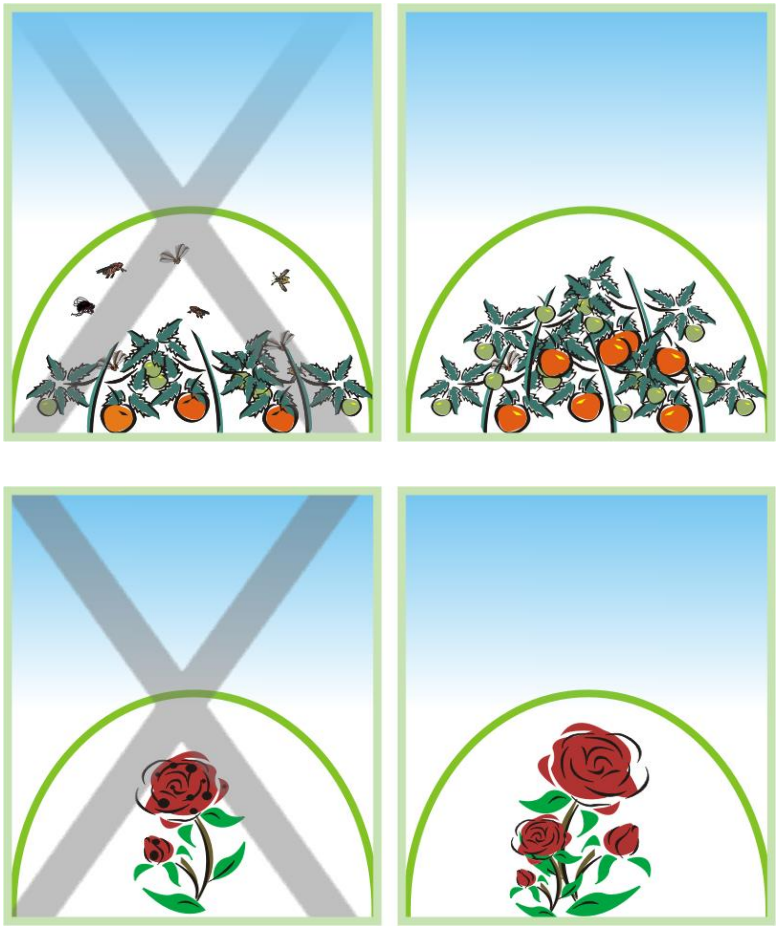
- Contribute efficiently to "Integrated Pest Management"
- Help to reduce the usage of insecticides & fungicides

Disease control effect (UV blocking effect)

- **Reduction** of the population of whiteflies, thrips, miners, aphids and other insects in greenhouses, thereby also reducing the viruses which are vectored by these insects
- **Control** of the spread of certain diseases (such as botrytis), by reducing the sporulation of the relevant pathogenic fungi
- **Reduction** of "blackening" of red rose petals (combination of cold and UV presence), thereby increasing their commercial value



Disease control effect (UV blocking effect)

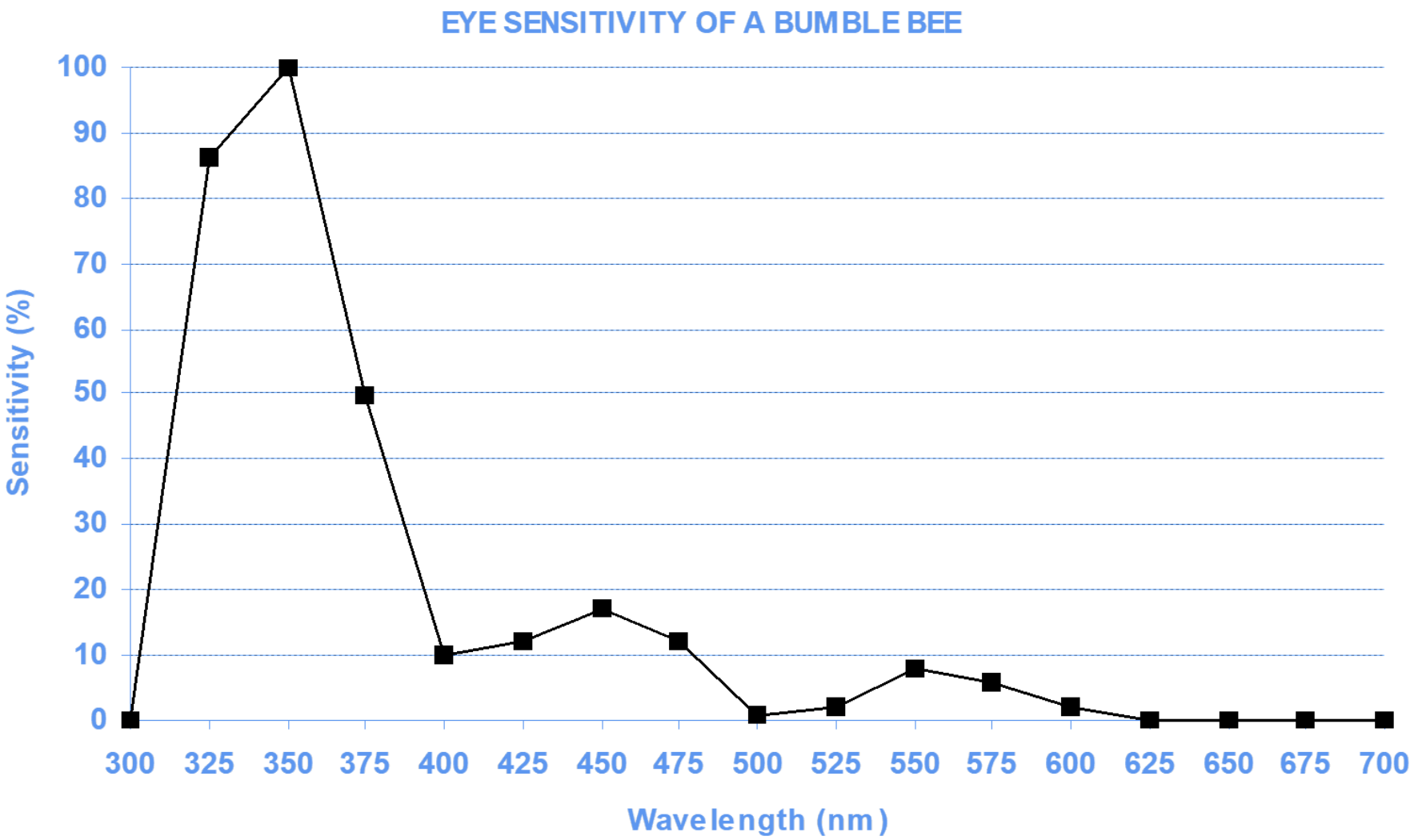


WARNING

UV blocking films should be used after testing when

- **Cultivate purple flowers & fruits**
- **Bumble bees are used for pollination**
- **Beneficial insects are used against harmful insects and mites**

Behavior of bumble bees under UV light



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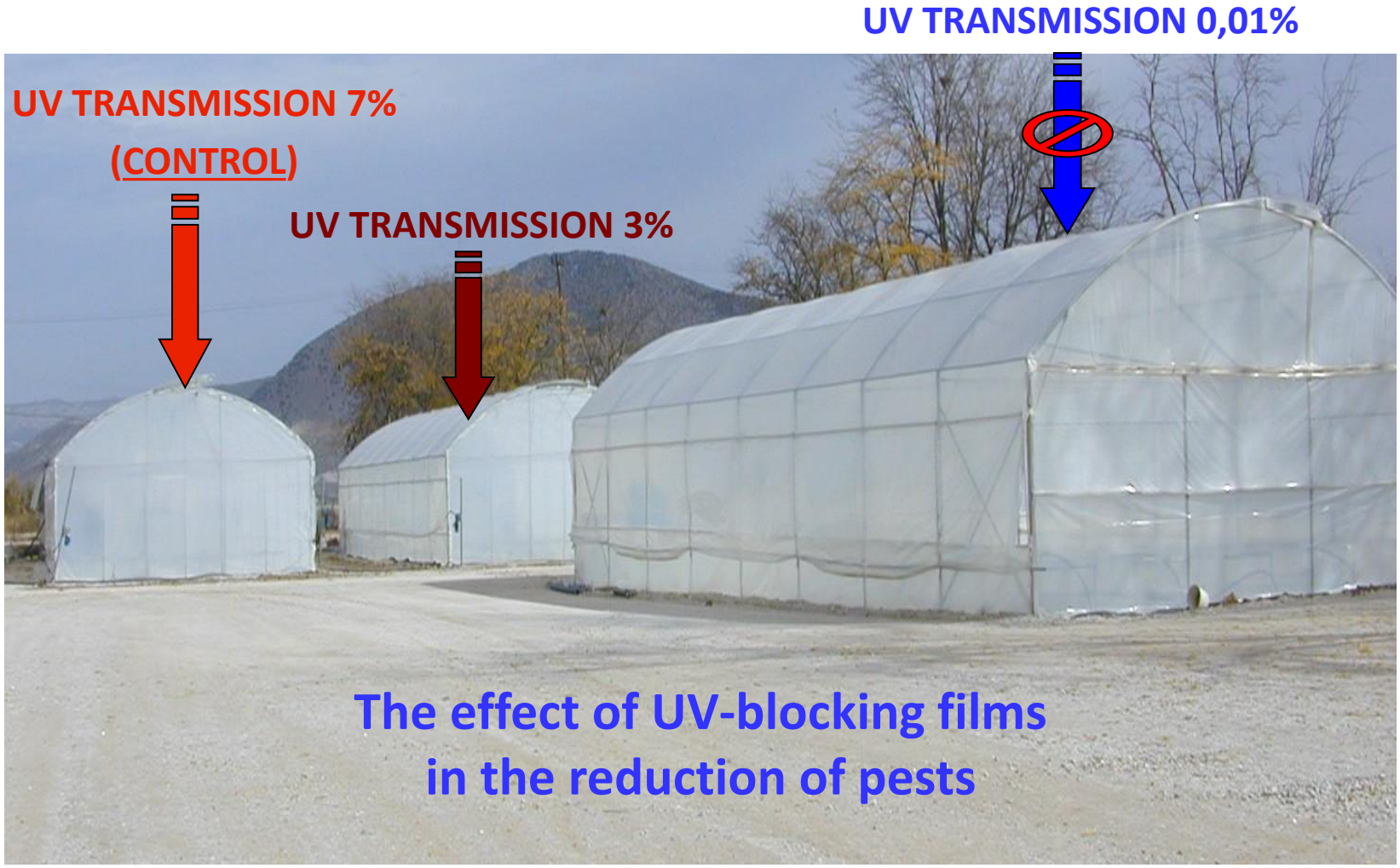
UV blocking Films Experiments



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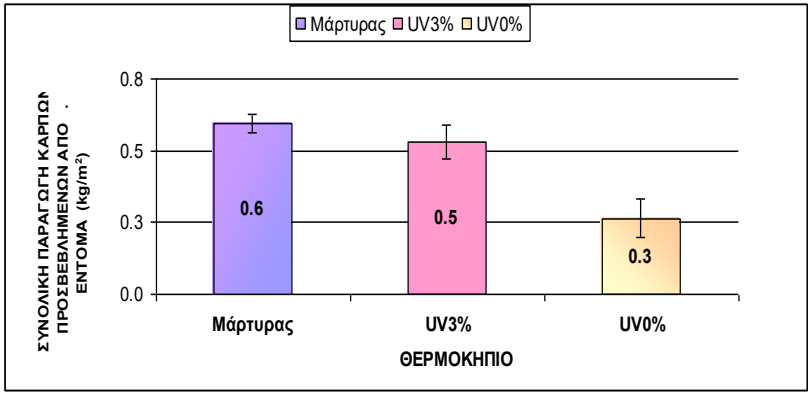
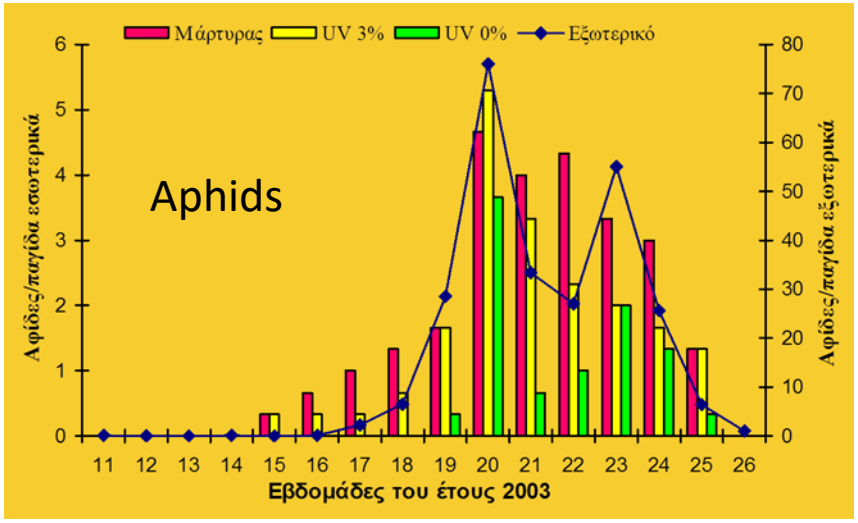
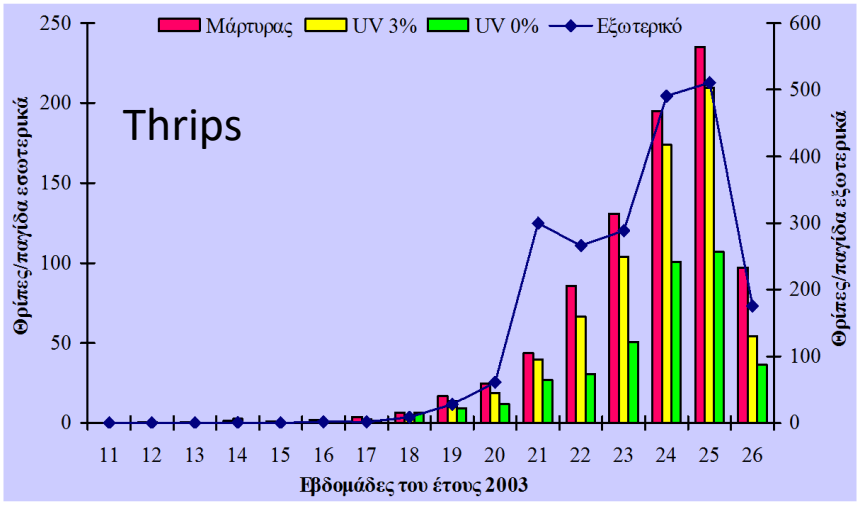
UV blocking Films Experiments

- Significant reduction in the population of harmful insects inside greenhouses
- Improving the quality of the products produced and the most important "cleaner products“
- Slight increase in production







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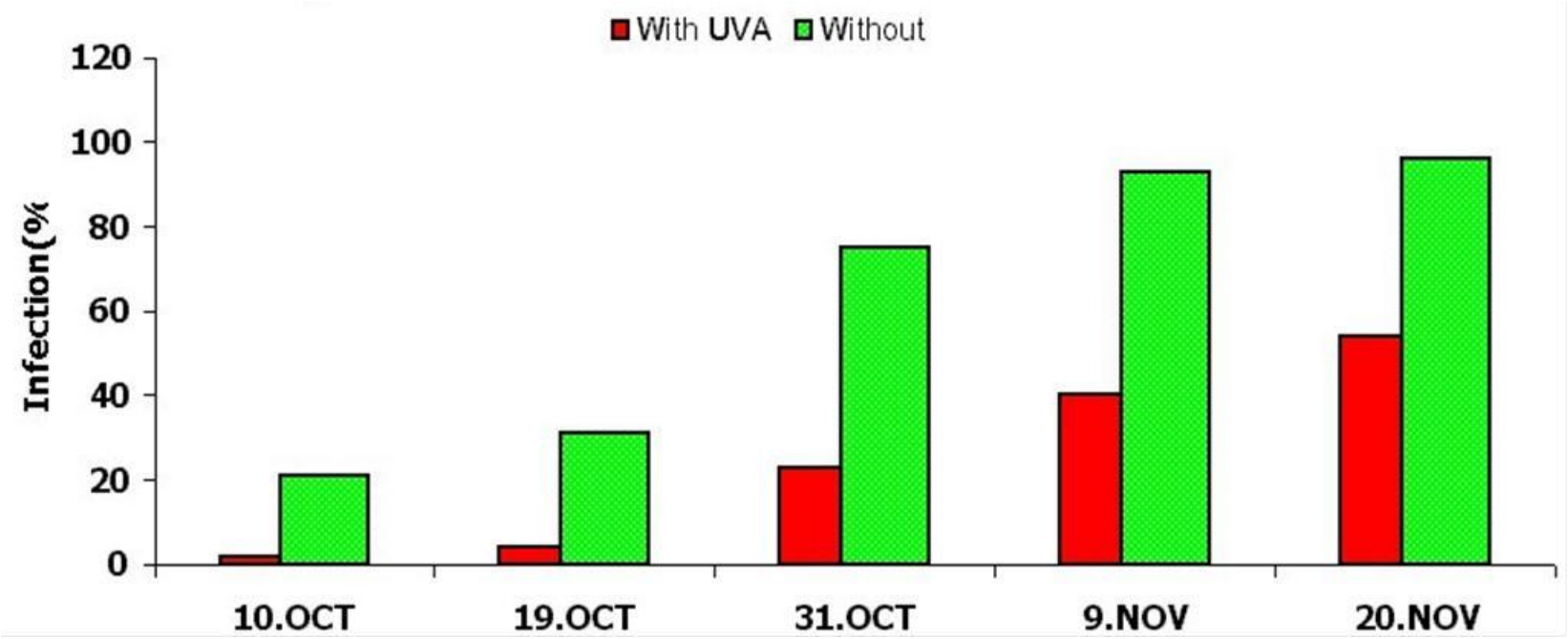
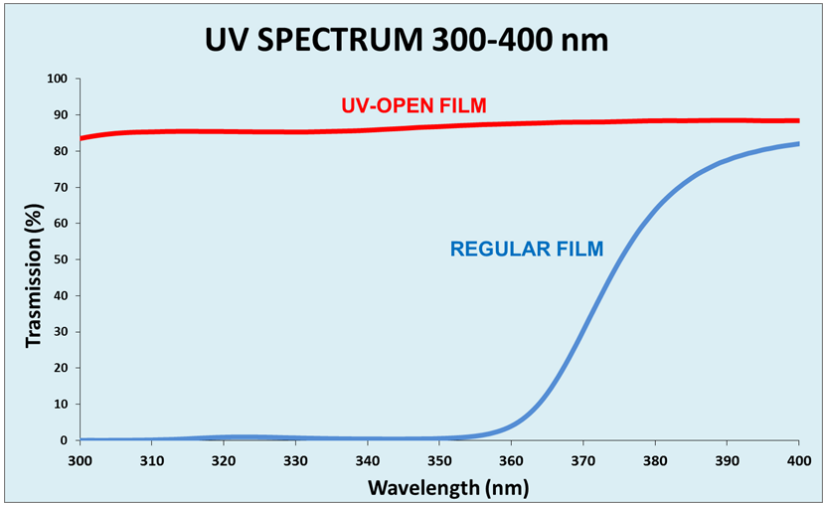
UV blocking Films Experiments

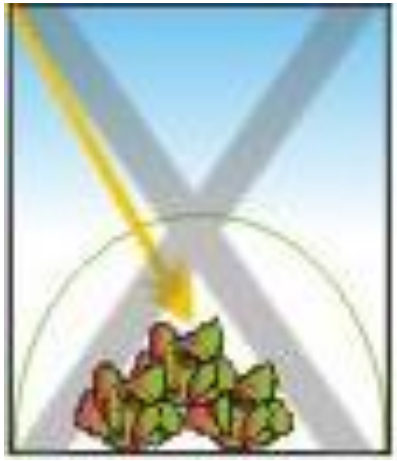
Cumulative infection of TYLCV



UV open films

- **Films that allow the full spectrum of UV-A & UV-B radiation to enter the greenhouse**
- Enhance color formation of red salads, strawberries and certain varieties of roses which require intense UV-light to develop their characteristic color





UV open films

Effect of UV radiation in coloration of red salads

Normal film (with UV)

UV open film

UV open films

UV open films

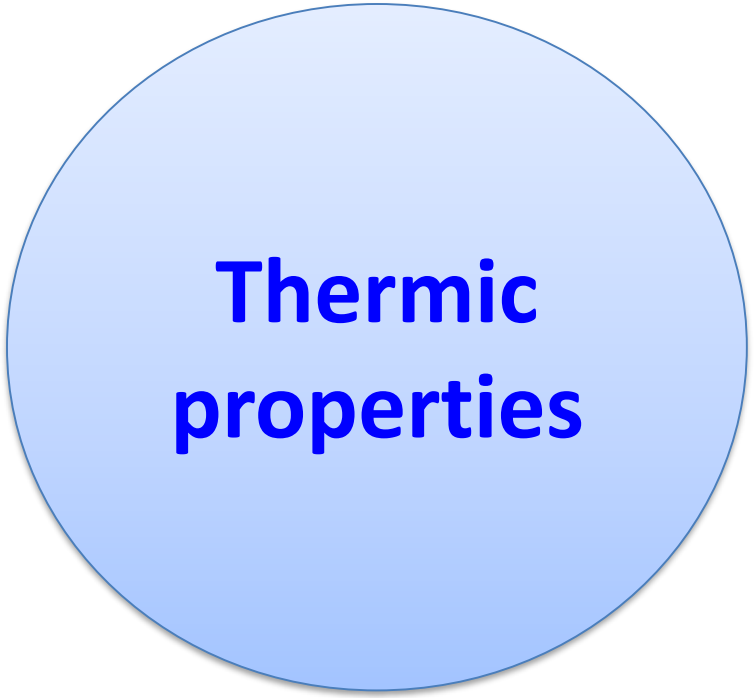
Photoselective films

- Special films incorporating selected additives and pigments, are used to modify the light spectrum entering the greenhouse
- **Changing the growth behavior of plants (photosynthesis and photomorphogenesis)**
  - **increase the yield**
  - **promote or retard the growth**
  - **cause elongation or dwarfing of the stems**
- The short duration of pigments doesn't allow extended use of such films…

Photoselective films

- Absorbed UV radiation is converted into red light, thus increasing the rate of useful radiation for photosynthetic activity
- **The R/FR ratio is considerably increasing**
- **Recommended mainly for flowering crops**
- Manufacturers of such PIGMENTS report that in relative experiments in Europe, America, Africa, Asia there was an increase in the production of red roses by up to 25% (!!! ???)

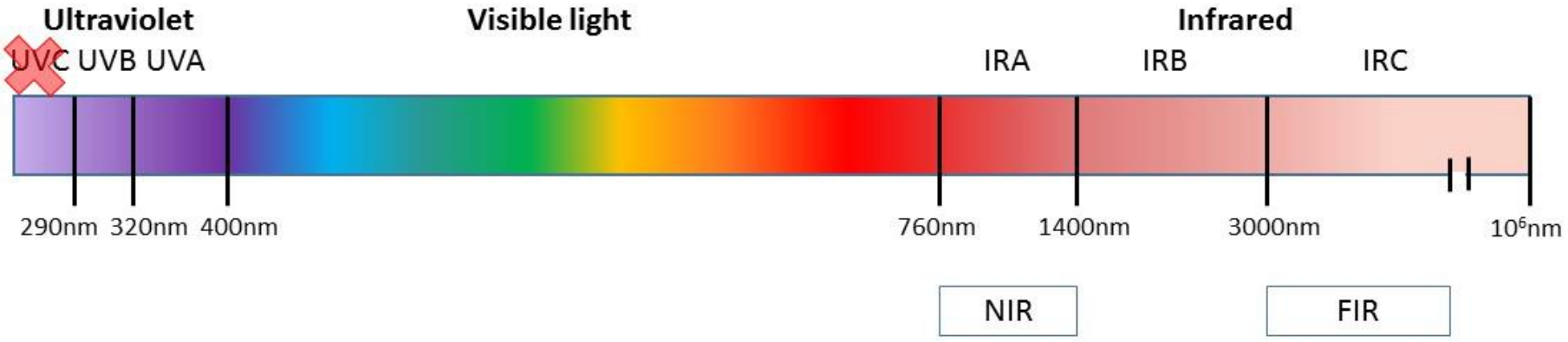
- Still very expensive (2-3 times more than conventional films)


Thermic
properties

Thermic effect
Infra-red radiation

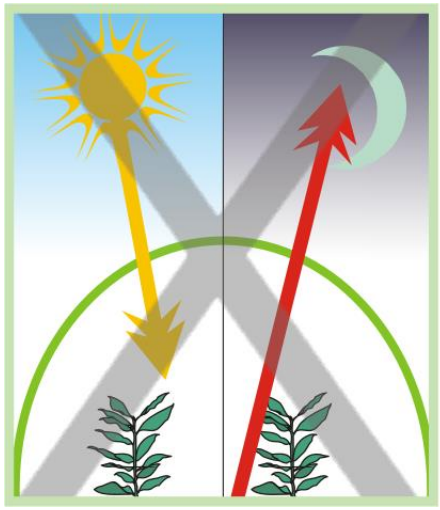
NEAR INFRA- RED (1)	700-800 nm	Influences photomorphogenesis, hence affecting the growth process
NEAR INFRA- RED (2)	800-1300 nm	Useless for plants. Transfers heat inside the greenhouse during daytime
FAR INFRA- RED	> 1300 nm	Transfers heat. Radiation from 7 to 14 mic. and above is responsible for heat losses from a greenhouse during night

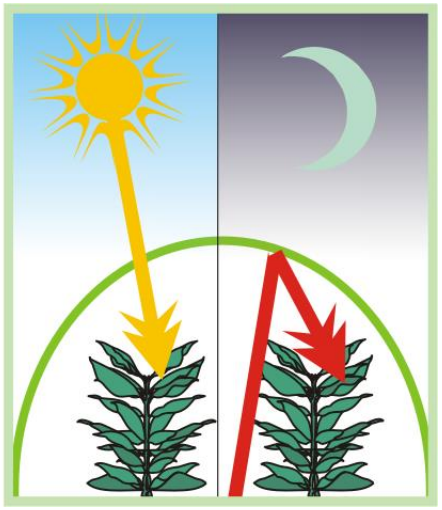
Solar spectrum



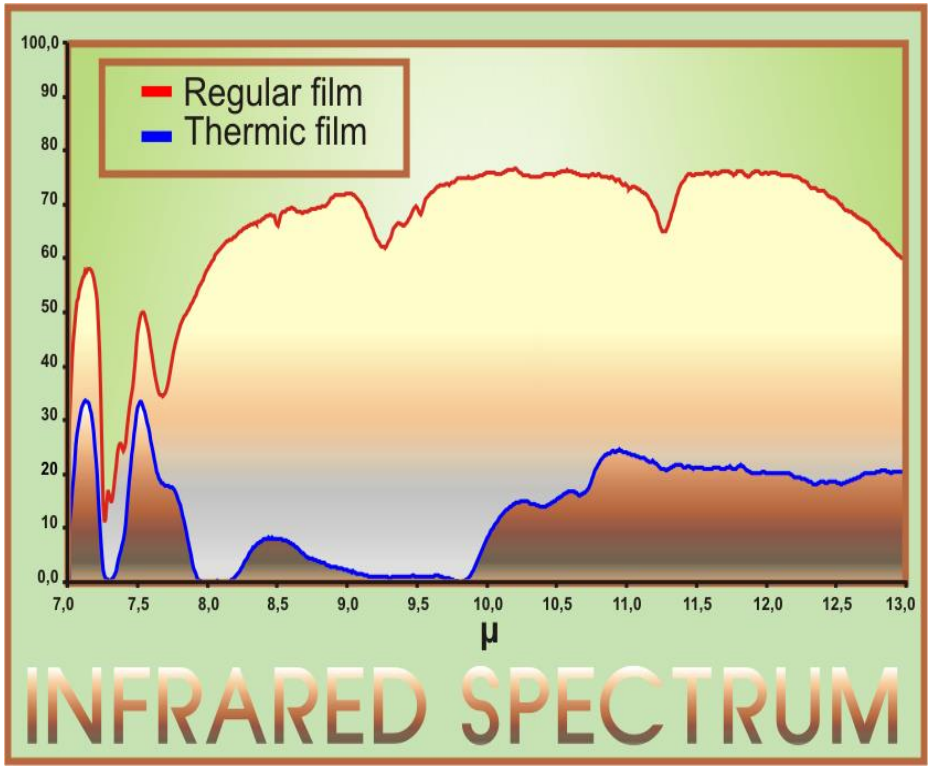
Thermic effect

- Special raw materials like **EVA and/or additives (IR factors)** can be added inside the film in order to achieve:
  - **Increased night temperatures (2-4˚C)**
  - **Smoother temperature drop during night**
- Therefore protect crops from cold in unheated structures
- Provide energy saving in heated ones





Thermic effect

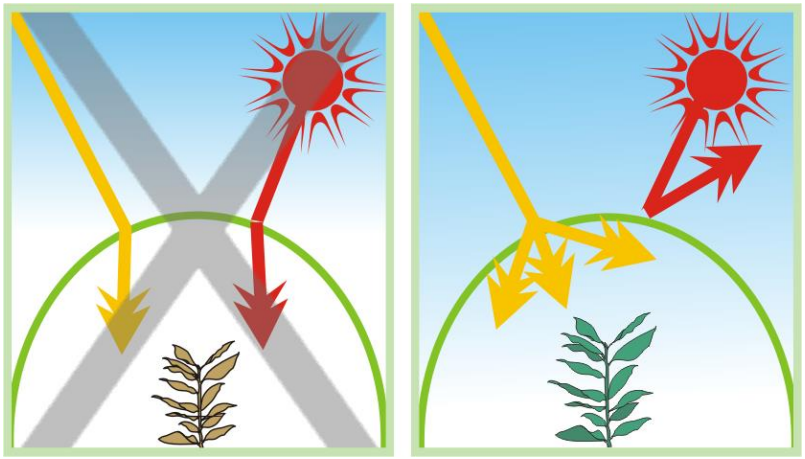


- Recommended for areas with night temperatures below 14°C
- Ensures increased yield and better quality of crops

Thermic effect
Energy screens

- Special thin films (25-40 mic) used as **internal screens in greenhouses and glasshouses** to limit heat losses during night and reduce heating costs
  - ✓ **Very high transparency**
  - ✓ **Thermic with EVA resin or non-thermic**
  - ✓ **With or without anti-dripping effect**

Cooling effect



- In order to extend growing seasons, farmers are obliged to find solutions for overcoming unfavorable high summer temperatures
- Therefore plastics industry should provide films that offer:
  - **Less temperature fluctuations during day and night**
  - **Decrease of evapotranspiration**
  - **Decrease of relative humidity**
  - **More favorable environment to the workers**

Cooling effect

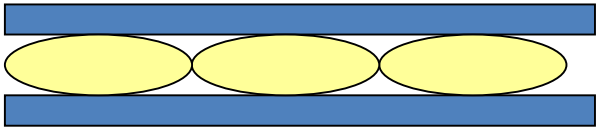
- Special films have been developed reflecting or absorbing NIR:
  - ***Silver cooling films with Aluminum particles***
  - ***Films with bubbles inside***
- The higher the sun radiation the higher the temperature difference between cooling and regular films

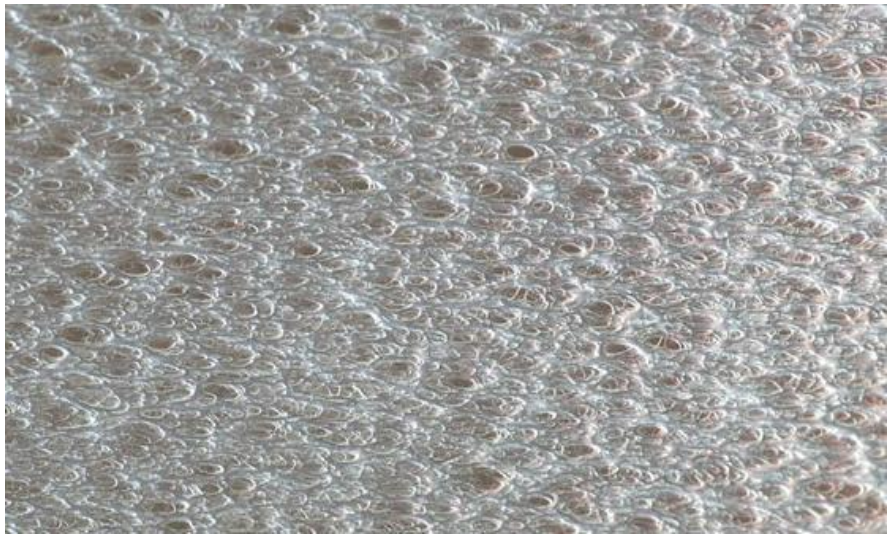
Cooling effect

Bubble film

Bubbles inside the film reduce thermal conductivity to half

regular layer
bubble layer
regular layer





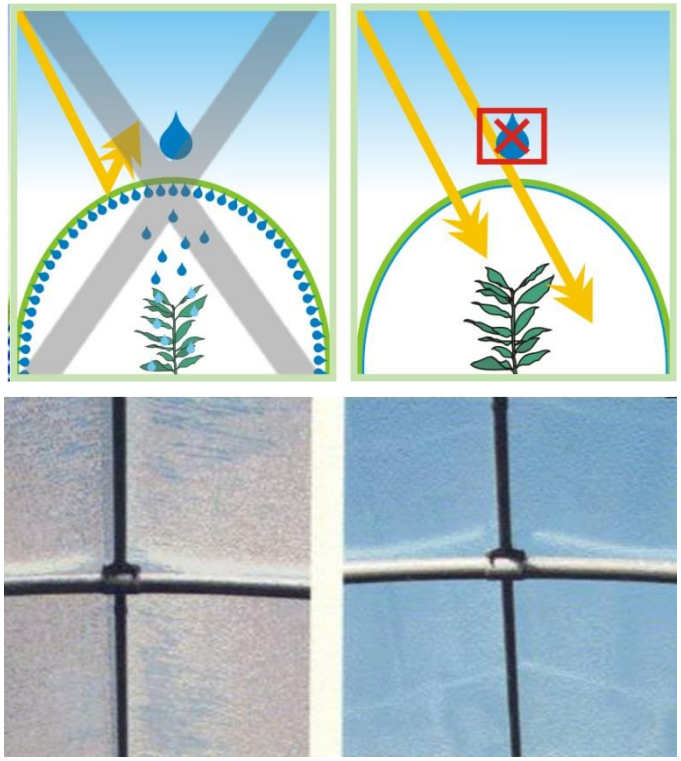
Silver cooling film

Tiny aluminum particles that reflect NIR radiation, offering cooling during hot days and better heat retention during cold nights (because Al has also thermic properties)


Antidripping
Antifogging
Properties

Antidripping effect

- Droplets on the film cover are created due to water and plastic affinity. Also cover is the coldest part of the greenhouse

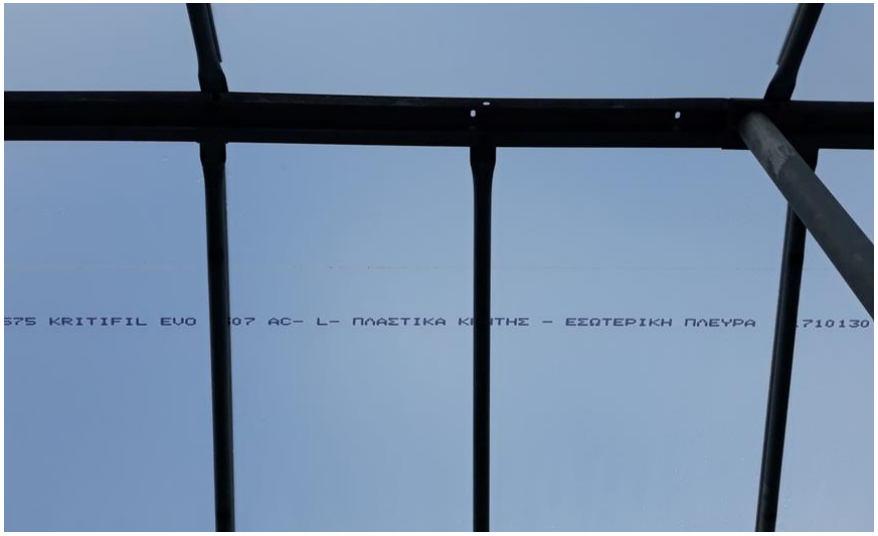


- This phenomenon leads to:
  - **Decreased light transmission**
  - **More diseases**
  - **Leaves and fruits burnings**

Antidripping effect

Advantage

Special additives help avoiding droplets **driving the water like a small river to the gutters**



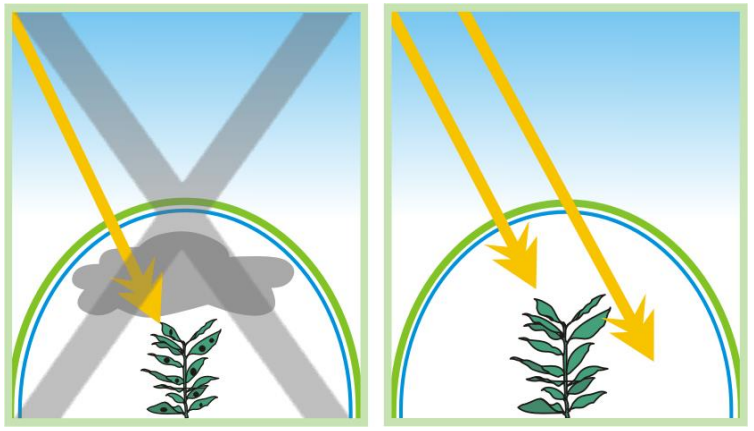
Disadvantage 1

Gradual migration of additives from the mass of the film results into the **loss of the anti-drip property within 18-24 months**

Antidripping effect

Disadvantage 2

- Inside greenhouses covered with anti-dripping films the **creation of fog** is very common



- **When temperature drops below dew point, vapor inside greenhouse is transformed into fog**

Antifogging effect

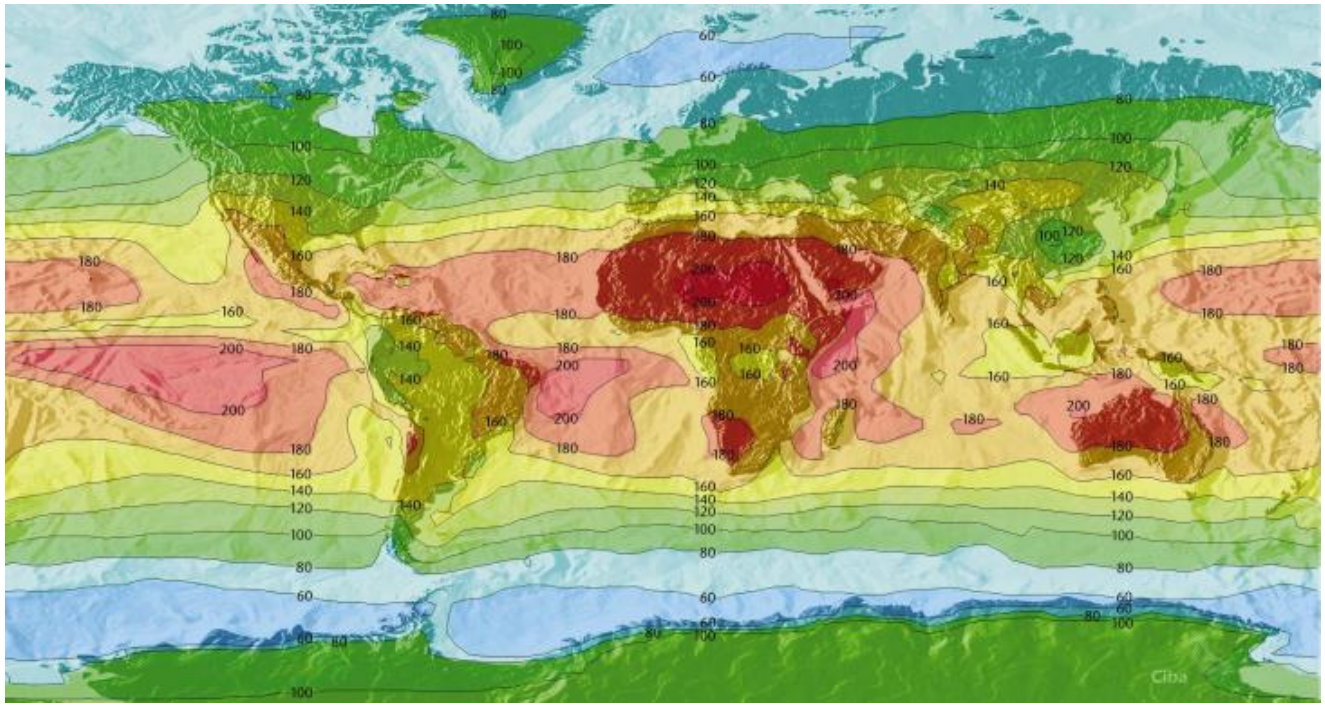
With special additives it's possible to significantly decrease the undesirable phenomenon of fog: **Anti-fogging films**

Antidrip film without Anti-fogging agent

With Anti-fogging agent


Lifetime

Factors affecting lifetime
1. Geographical Region



- **Greenhouse films should be adjusted depending on**
  - The intensity of light received by each area around the world measured by kglys(*)
  - The solar radiation (UV part)

(*) One langley is 1 thermochemical calorie per square centimetre

Factors affecting lifetime
2. UV light and chemicals

- **Weathering: Natural ageing coming from the harmful effect of UV light (300-390 nm)**
- Photochemical reactions inactivate polymers
- PE film without any UV-protection lasts maximum some few months (6-7)

- **Early premature failure**
- There are also other factors destroying PE films
- **Sulphur** and chemicals containing it destroy its UV-stabilizers
- **Halogens** (mainly chlorine) destroy UV-stabilizers and the polymer the same

Factors affecting lifetime

Apart from the previous

(certain region, use of chemicals and adjusted UV stabilizers package)

We should also pay attention to the following:

- Greenhouse type
- Installation
- Points of contact

Factors affecting lifetime

- Researchers and manufacturers pay great concern in increasing the **guaranteed LT**
- **i.e. in Med zone:**
  - **Decade of 70's 1 year**
  - **Decade of 80's 2 years**
  - **Decade of 90's 3 years**
  - **Nowadays 4 and 5 years**
- **Actual LT** exceeds the above and reaches much more years

Typical ageing coming from film contact with the frame (wires)

Factors affecting lifetime

- In recent years and mainly due to the ban of dangerous spraying chemicals and disinfectans (MBr)
  - The use of more innocent but less efficient chemicals has been increased i.e.
  - **Sulphur and sulphur-containing chemicals have been increasingly used (1, 3)**
  - **Techniques have been changed in many countries (2)**

(1) The dense cloud of sublimated Sulphur

(2) Crops close to the sprayed plastic

Factors affecting lifetime

(3) The detrimental effect of burnt Sulphur

Sulphur has acidic behavior.

Hals Stabilizers have an alkaline one.

Reaction between them

→ inactivates HALS

→ early premature failure

Factors affecting lifetime

How to obtain maximum lifetime?

- Select a film with a high level of an effective UV-stabilizers system
- If there is intensive use of pesticides, especially Sulphur & halogen compounds, choose a film with improved chemical resistance
- Prevent direct contact of pesticides with the film

- Ensure good ventilation
- Paint the film white where it touches the structure

UV stabilizers systems

- Nowadays, with modern recipes and new stabilizers combinations, **outstanding film duration can be reached**

- For example, film guaranteed for 3 seasons in Crete (the hottest region in Greece) can last up to 6,7,8 years, with some exceptions of even up to 12 - 13 years!

- Of course, a film guaranteed for 3 seasons in Crete can be guaranteed for 5 and 6 years in northern climates (Germany, Poland etc.)

UV stabilizers systems

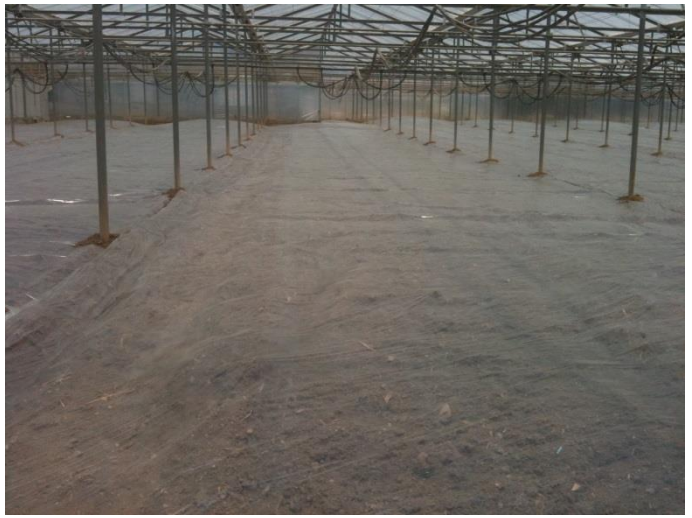
- **Ni-Quenchers (yellowish color):** Old generation of stabs. Resistant to sulphur. Not to chlorine which destroys also the polymer the same
- Not desirable today because of **low GLT (<86%)**
- Environmentally not friendly

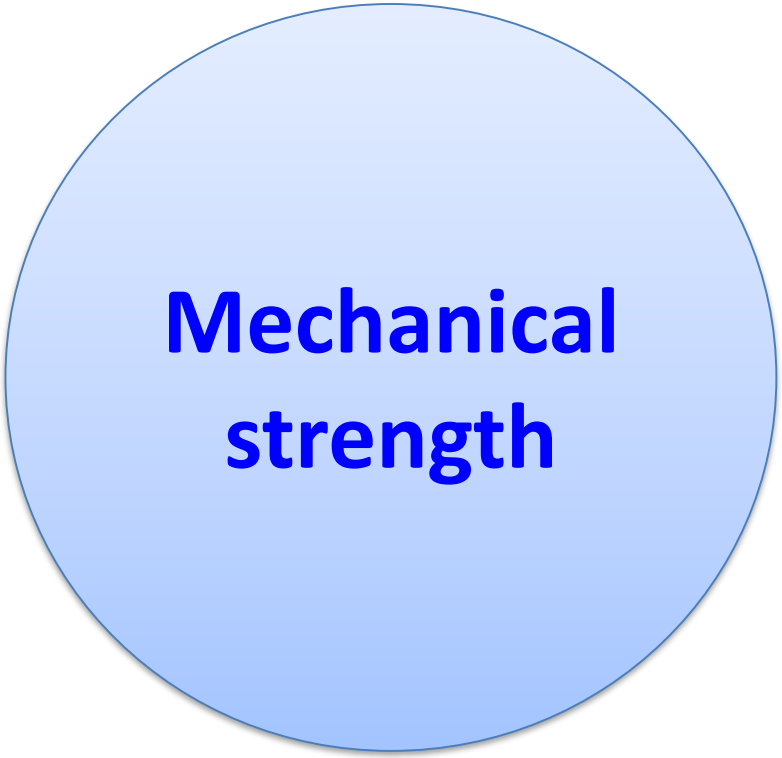
- **HALS stabilizers (colorless):** New generation with outstanding properties (GLT> 89%)
- Special packages resistant to sulphur and chemicals containing it up to 2-3000ppm

Additional factors affecting lifetime

- Barrier films can be used to avoid harmful evaporation of soil disinfectants containing Sulphur and/or Chlorine

- **Virtually Impermeable films (VIF)**
- **Totally Impermeable films (TIF)**




Mechanical
strength

Mechanical Strength

Depends on:

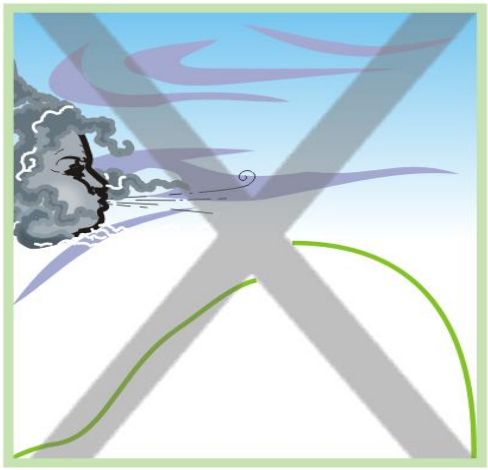
- Selection of suitable raw materials
- Quality of equipment
- Processing conditions
- Thickness & thickness uniformity
- Fold strength

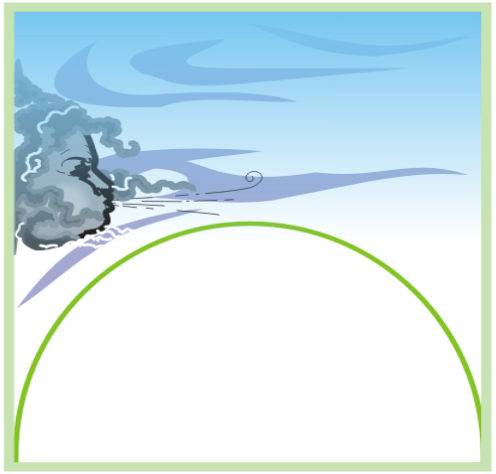
Mechanical Strength

- A new generation of super-tough films has been introduced in recent years using special high-strength polymers

Offer

- **additional safety in areas with very strong winds**
- Significant economy as they can be produced at lower thickness than regular films while maintaining the same or still higher strength





Superior mechanical properties

Property	Units	Traditional PE thermic film	Metallocene thermic film	Ultra-strong 7-layer film
Thickness	mic.	200	180	150
Tensile strength	N/mm2	22	27	40
Tensile stress	N/mm	4,4	4,8	6,0
Tear stress	gf	1200	1800	2600
Impact strength	gr	800	1250	2000
Light transmisison	%	90	91	92
Diffusion (*)	%	22	18	16
IR transmittance	%	15	18	21

1st traditional generation

2nd improved generation

3rd latest generation

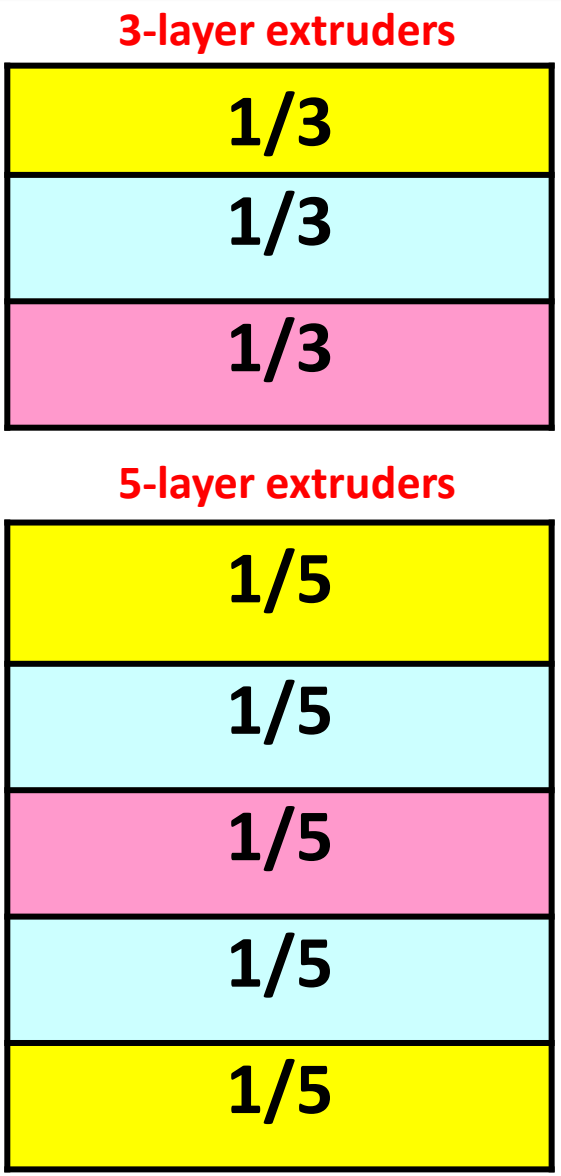
Extruding PE films

Manufacturing possibilities

- Early 1950s the first use of polyethylene film (mono-layer films)
- Early 1980s introduction of multilayer films with 3-layer technology
- 1990s 5-layer films
- Latest development of 7-layer technology

Balanced Technology

- 3- or 5-layer extruders consist of equal layers each (3X33% or 5X20%)
- Limited choices, esp. when you should use expensive raw materials or additives



Barrier Technology

- **7-layer technology** permits the production of innovative products

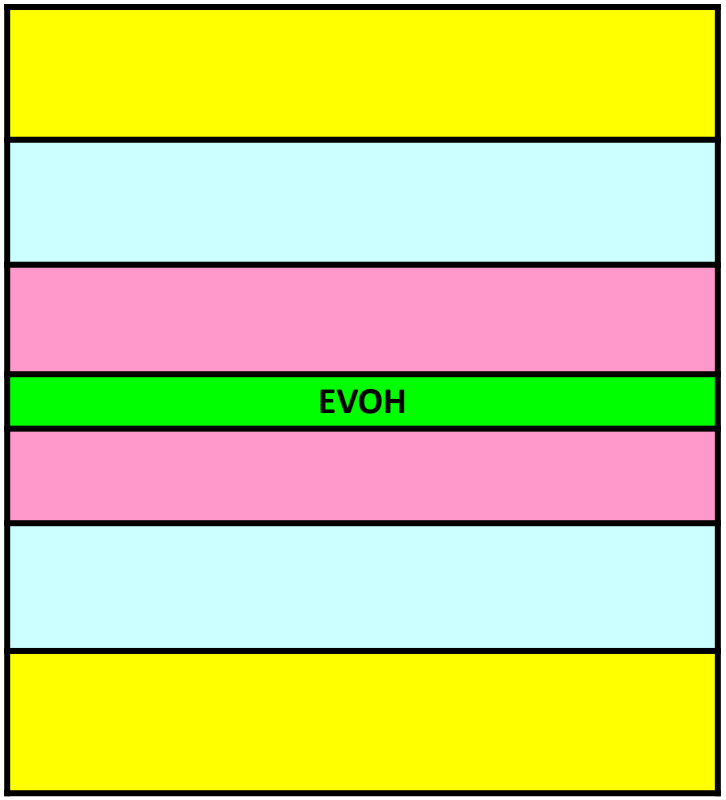
- Each layer can be of different thickness (even 2-3 mic) contributing to the increased quality of the film

- Specially designed for incorporating barrier polymers like EVOH

Barrier Technology

Why barrier technology?

- To use expensive materials for sophisticated products
- To prevent loss of gasses
- To face detrimental effect of Sulphur
- To separate two different films (delaminatable films)
- To improve light properties



Polyethylene films extrusion

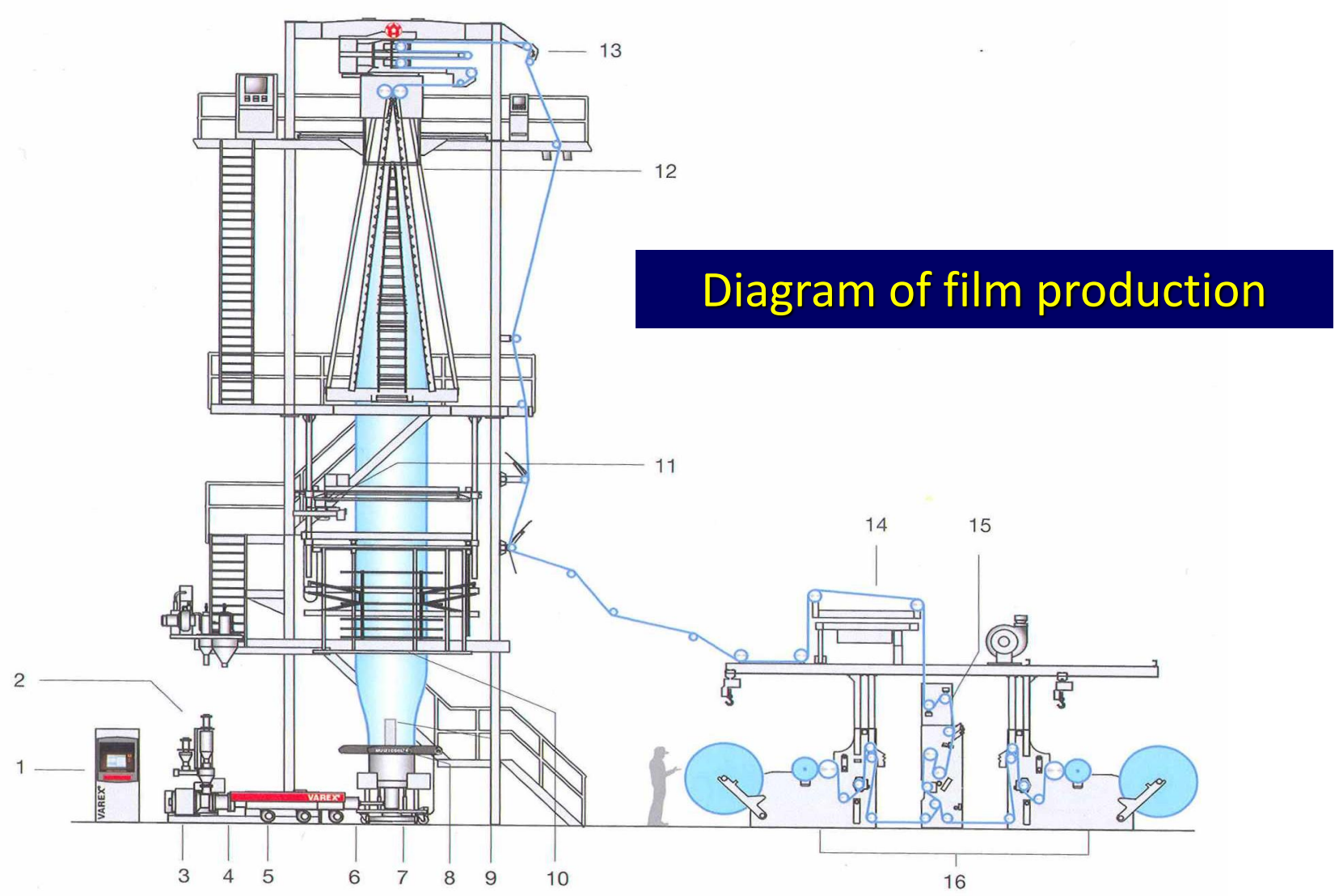
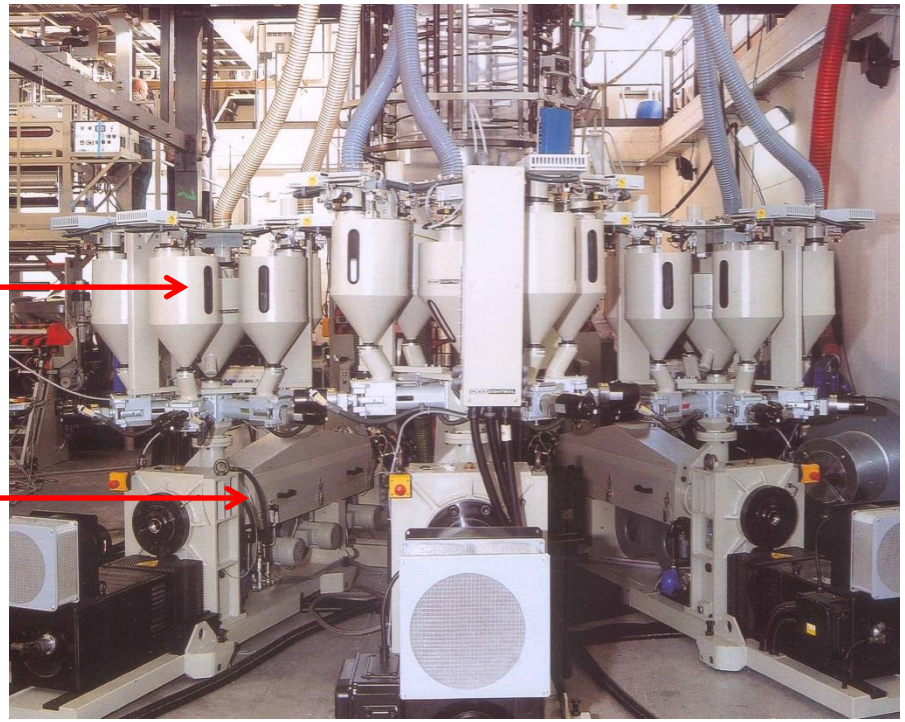


Diagram of film production

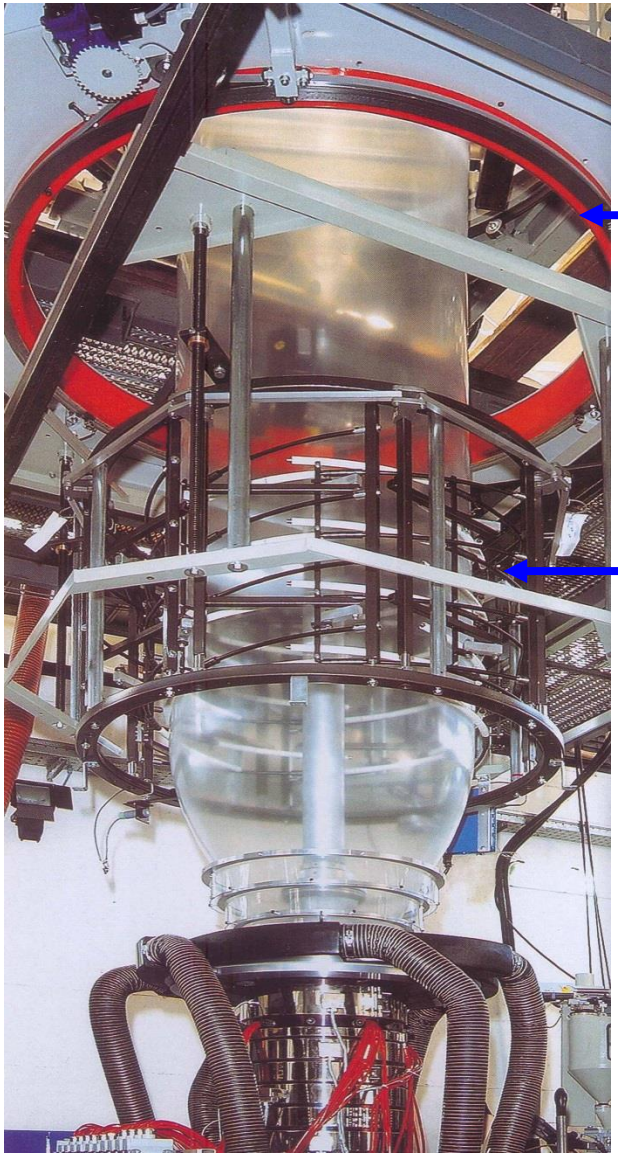
Polyethylene film extrusion

Feeders

Extruders



Polyethylene film extrusion

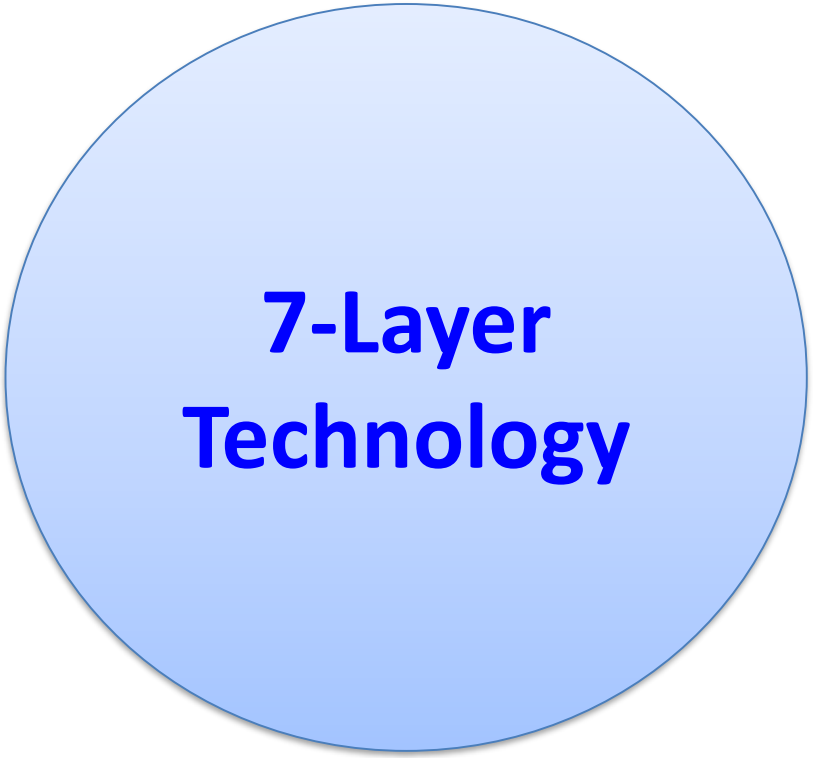


Width control system

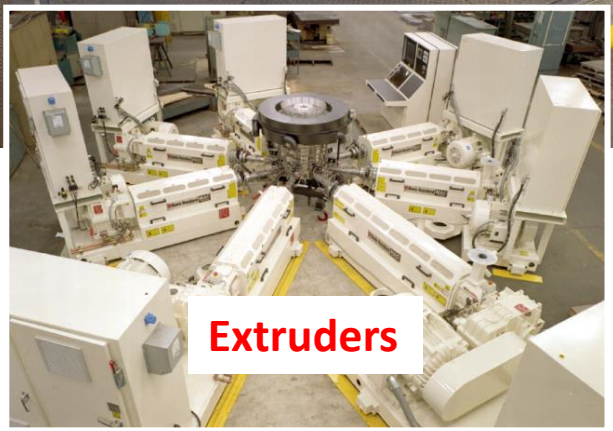
Thickness control system

Polyethylene film extrusion

Folders


7-Layer
Technology

7-layer technology



7-layer technology

7-layer technology

EVO® greenhouse films

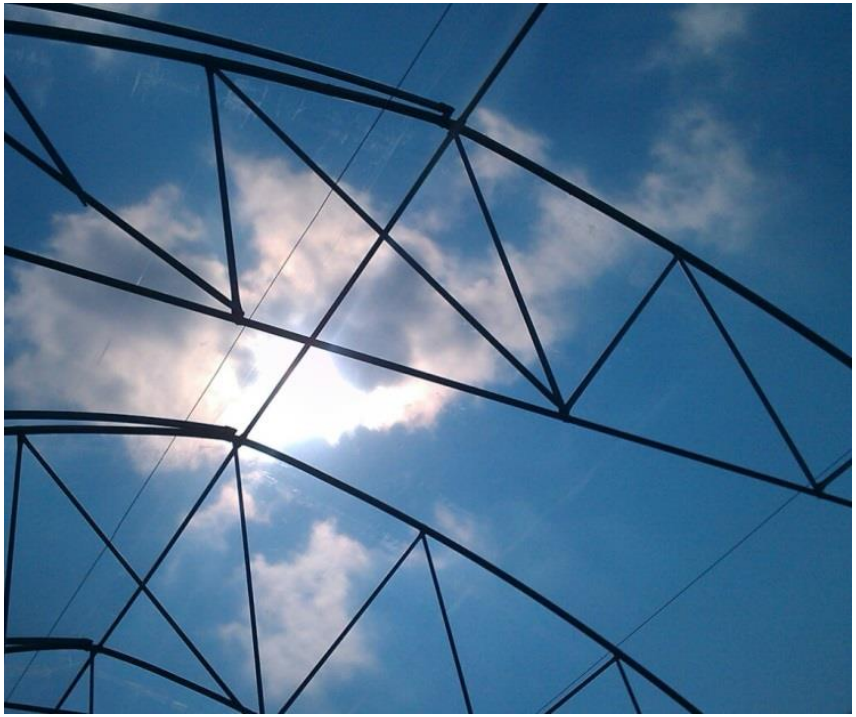
VIF/TIF soil fumigation films

True gas barrier geomembranes & liners

Barrier silage films

Flexitanks & container liners

7 layer greenhouse films



- Films with very long-lasting anti-drip and anti-mist activity
- Combining 7-layer technology with a new system of introducing the anti-dripping additives into the film **extends AD function almost until the end of the film without any sign of fog!**

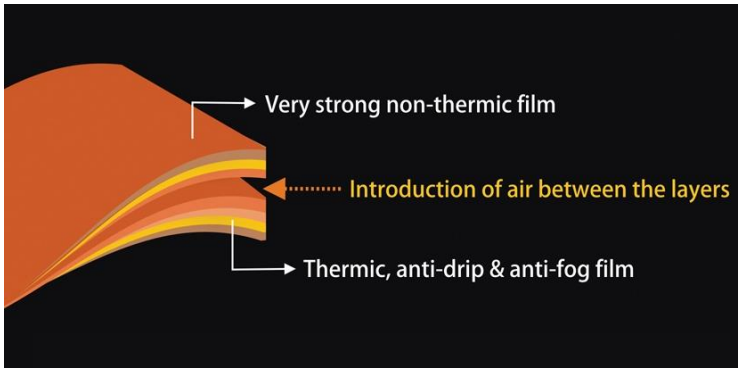
Double inflated Greenhouses

Traditional methods

- Outer film:
  - Transparent (up to 25%), high strength, non-thermic, no AD
- Inner film:
  - Transparent (up to 25%), high strength, thermic, AD / AF
  - Film with 40-50% diffusion, thermic, AD / AF

Delaminatable films

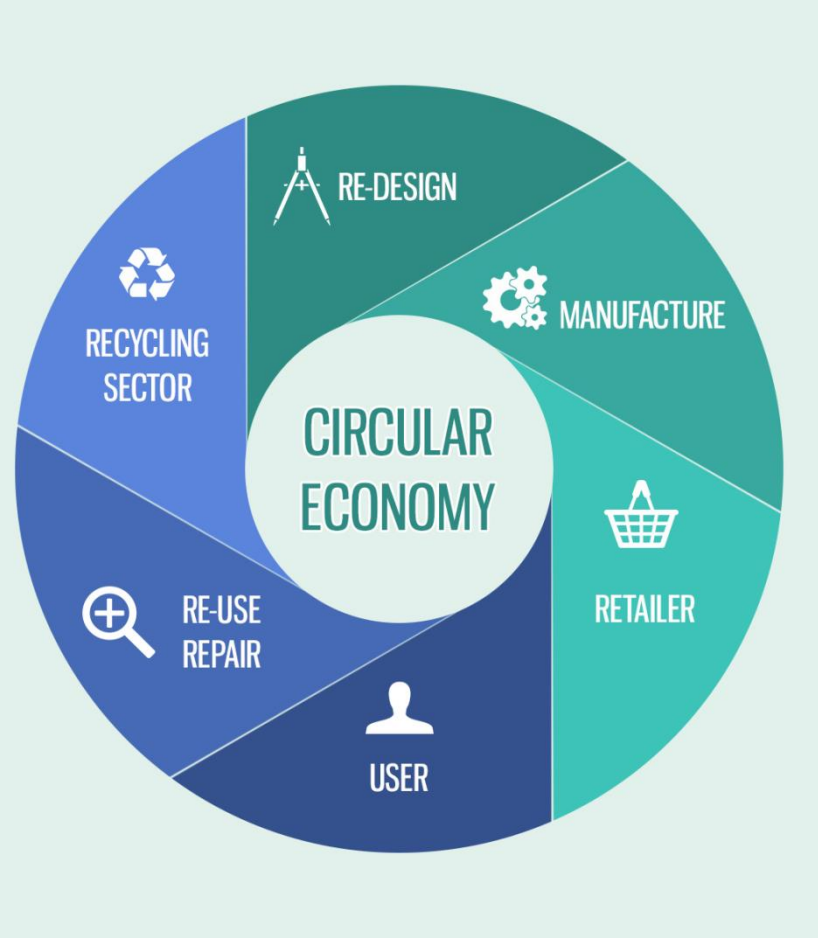
- 7-layer films which are separated into 2 films by introduction of air between the layers
- After the film has been placed and securely fastened on the roof of the greenhouse



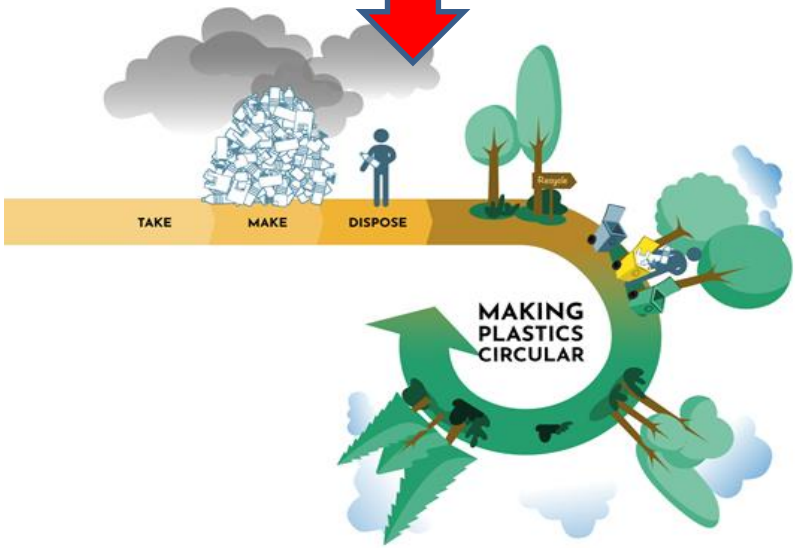
Double inflated Greenhouses

Circular Economy – from waste to resource

- The protection of the environment and the conservation of resources of our planet is a major concern
- Plastics can be “circular” by:
  - **Increasing the useful life of all plastic products**
  - **Replacing disposable products with reusable ones**
  - **Recycling all plastics after use**
  - **Finding smart solutions for reusing recycled materials**



Circular Economy – from waste to resource



- Although recycled material from used greenhouse films can not be reused for greenhouse covers
- It is possible to be used in the production of other plastic products (garbage bags, building films etc.)

Circular Economy – from waste to resource

Thank you!!!

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25-09-2018

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