Gardening 365

Managing Your Hobby Greenhouse

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Plants or People?

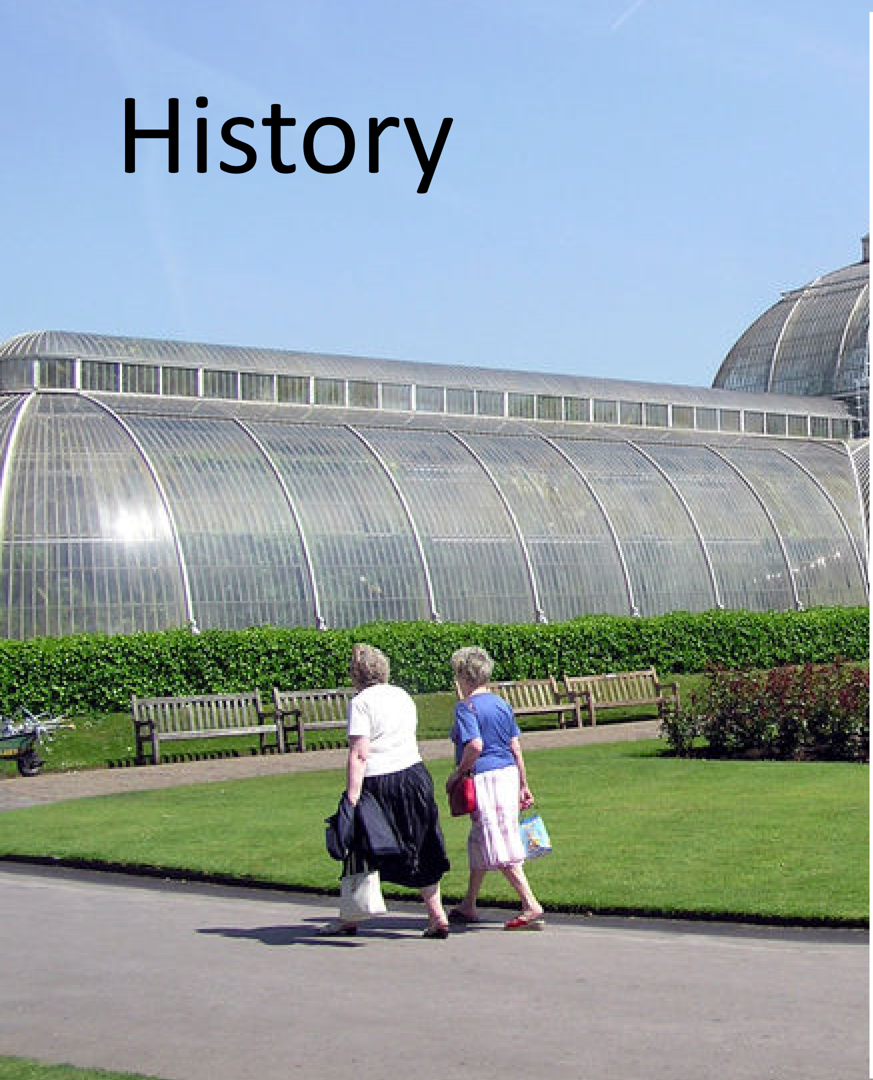
GREENHOUSE

- Growing space for plants
- Sometimes attached to home
- Functional
  - Plants
  - Structure
- Relatively low cost per ft^2

CONSERVATORY

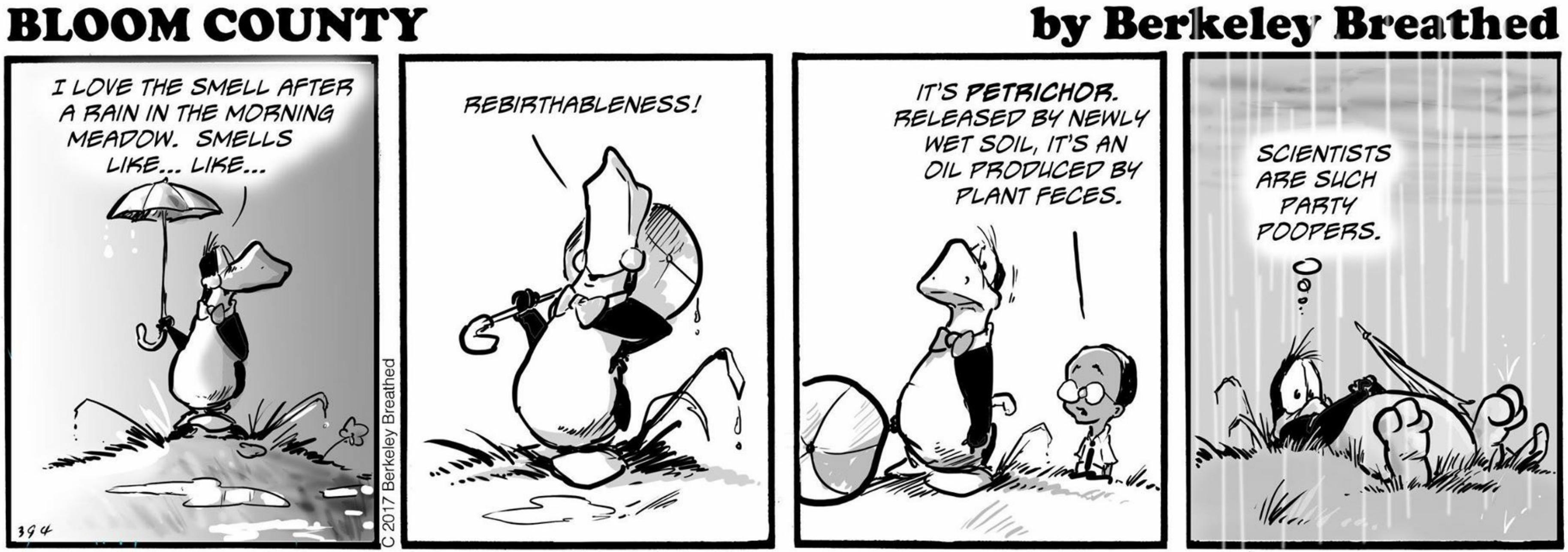
- Living space for people
- Usually attached to home
- Decorative
  - Plants
  - Structure
- Relatively high cost per ft^2

History



The Secret Garden (1911)

Vision


BLOOM COUNTY
by Berkeley Breathed
I LOVE THE SMELL AFTER A RAIN IN THE MORNING MEADOW. SMELLS LIKE... LIKE...
REBIRTHABLENESS!
IT'S **PETRICHOR**. RELEASED BY NEWLY WET SOIL, IT'S AN OIL PRODUCED BY PLANT FECES.
SCIENTISTS ARE SUCH PARTY POOPERS.
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- Inspiration
- What can you do?
- What you can do

DC Smith Greenhouse UW-Madison

Photo: Jeff Miller

My Vision

How to Grow Plants

Genotype x Culture → Phenotype

Genotype		**Culture**		**Phenotype**
Species		Light		Growth
Cultivar		Temperature		Development
		Water		
		Nutrients		
		Gases		
		Care		

Blackman's *Principle of Limiting Factors*

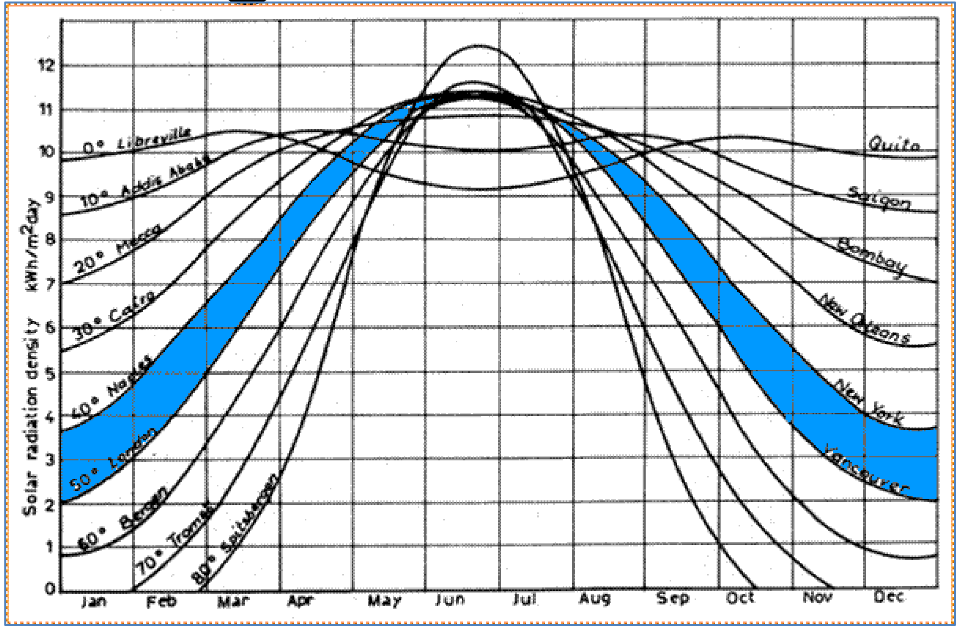
the rate of a process influenced by many separate factors is limited by the pace of the slowest factor

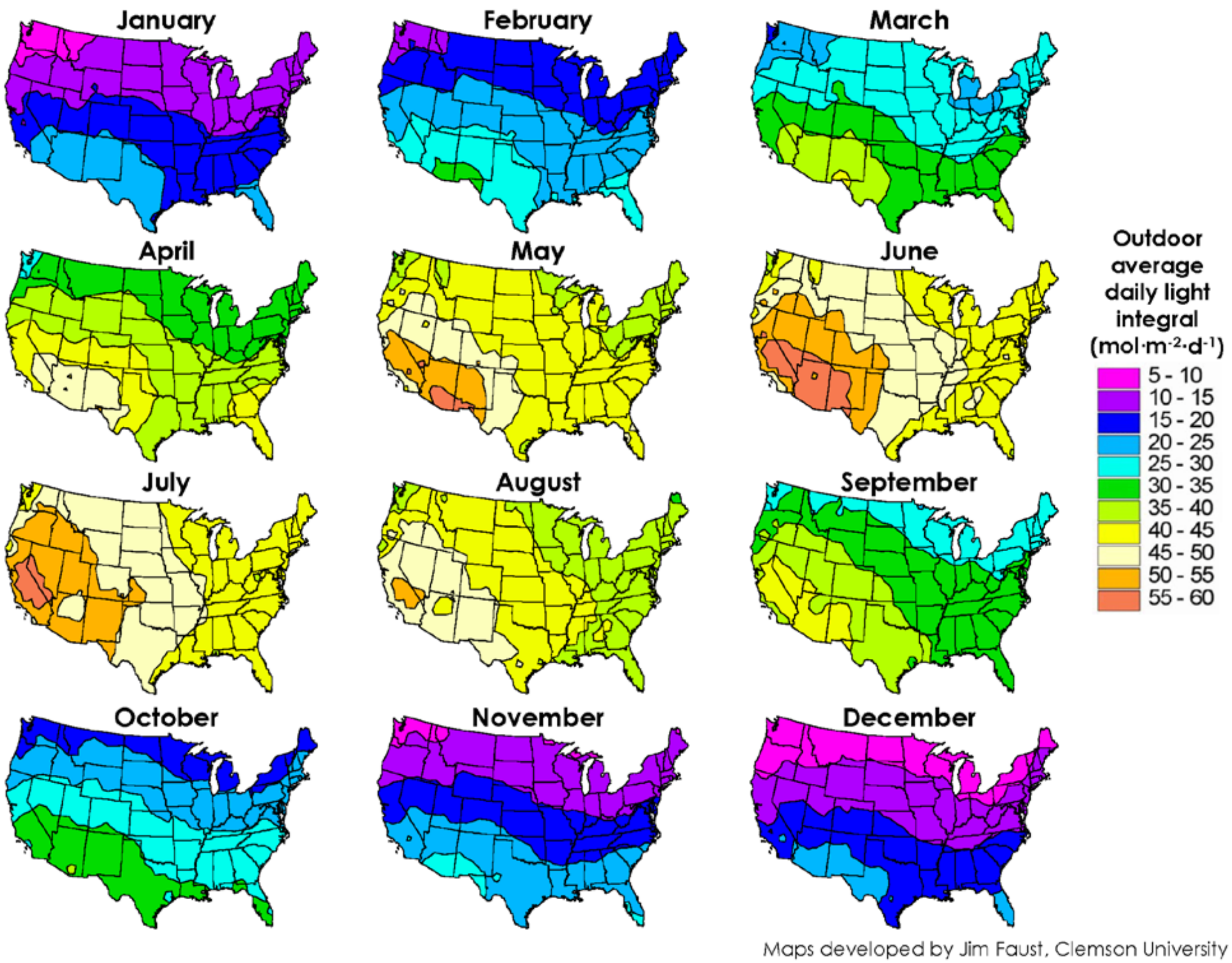
Exterior rated materials and systems

Abiotic Factors

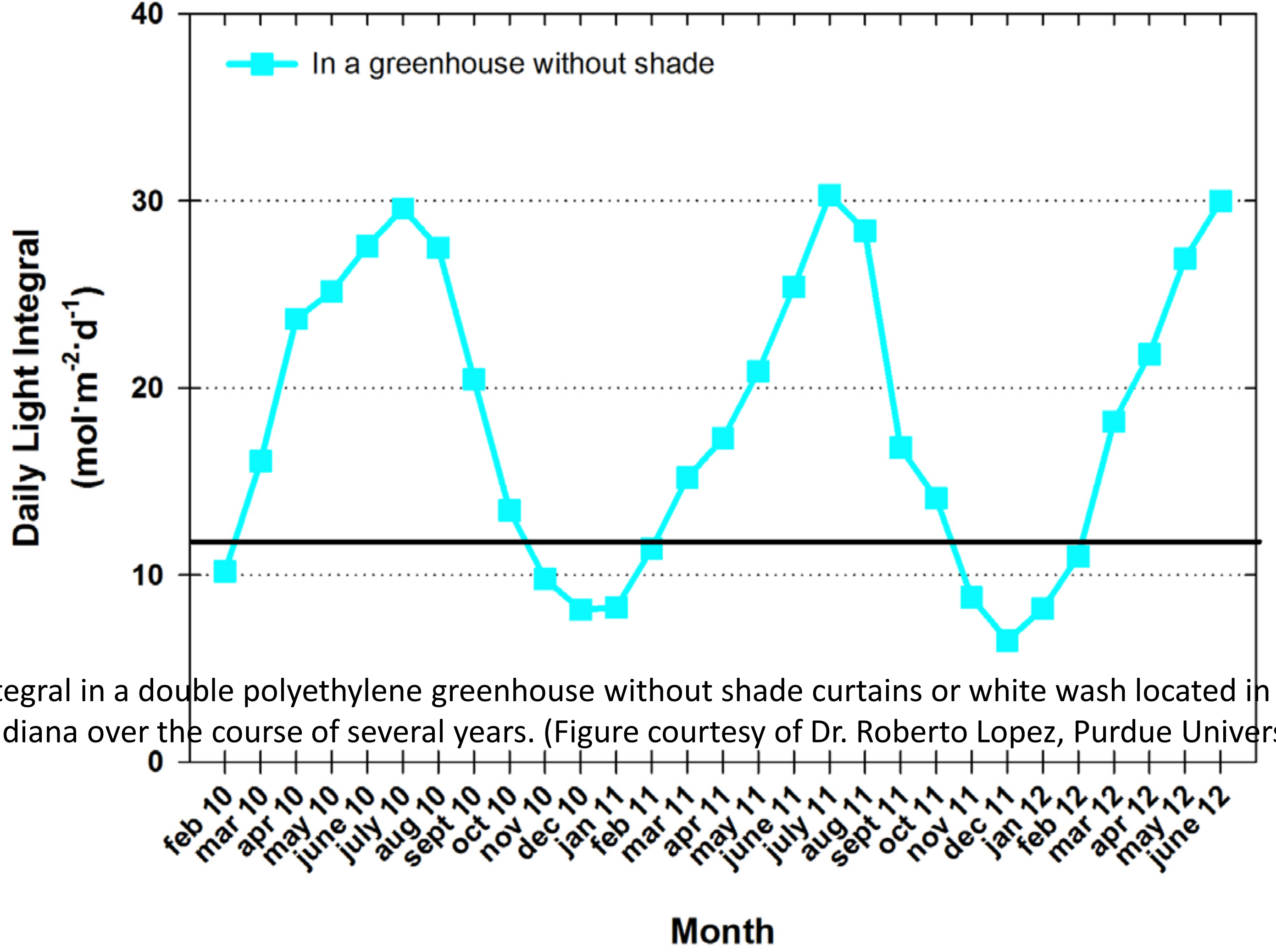
Natural Causes of Light Variation

- Latitude
  - Radiation density (quantity)
  - Length of exposure (photoperiod)
- Air Quality
  - Radiation density (quantity)
- Location
  - Radiation density due to altitude
  - Photoperiod due to light pollution





Outdoor daily light integrals across the continental United States over the course of one year.
(Figure courtesy of Dr. Jim Faust, Clemson University.)



Daily light integral in a double polyethylene greenhouse without shade curtains or white wash located in West Lafayette, Indiana over the course of several years. (Figure courtesy of Dr. Roberto Lopez, Purdue University.)

Managing Light

- Maximize Light by
  - Orientation
  - Materials

Orientation

- Shadows
  - Exposure
  - Trees
- Make the most of what you have
- Balance your priorities

Glazing Materials	% Light Transmission	Heat Loss BTU/hr/ft²	Cost ($/ft²)	Lifespan (years)
Glass				From Nelson, 2011
Single Pane Float	88	1.13	0.80	25+
Tempered	90-92	1.13	0.95	25+
Laminated Float	77	0.95	3.00-4.00	25+
Film Plastic				
Single Wall Polyethylene	87	1.10	0.09	3-4
Double Wall Polyethylene	78	0.70	0.18	3-4
Rigid Plastic				
Acrylic, twin walled, 8mm	84	0.56	1.90-2.60	20+
Polycarbonate, twin, 8mm	81	0.58	1.50	10-15

Shades

- What to do with too much light?

Reasons to reduce light levels

- Seasonal control (March 21 to September 21)
- Low light crop preference
- Acclimatize crop to low light levels

Methods to reduce light levels

- Shading compound
- Shade cloth
- Retractable curtain systems

Ways to increase Light quantity

Reasons to increase light levels

- Increase photosynthesis rates (and growth)
- Hasten flowering (facultative irradiation response)
- Frequently used in greenhouse vegetable, rose, and plug production
- Night time illumination

Ways to increase light levels

- Incandescent
- Fluorescent
- HID
- LED

Light Fixtures

Managing Temperature

- Balance
- Heat in/out

What is Temperature?

Measure of heat energy

- Celsius - international standard
- Fahrenheit – typical in US greenhouses
- BTU – British Thermal Unit - used to describe output of heating equipment and structural heat loss

What is temperature?

Movement of heat energy

- Conduction
  - Diffusion through a continuous medium
- Convection
  - Diffusion between two dissimilar materials
- Radiation
  - Electromagnetic radiation leaves one object and is intercepted by another

Greenhouse Temperature Variation

- **Heat Gain**
  - Solar gain (the Greenhouse effect)
- **Heat Loss**
  - Glazing and Framing materials
  - Greenhouse profile (American vs European)
- Influence of vegetation (humidity) on greenhouse temperature

In the greenhouse we want to reach our optimum temp and then add/subtract heat at the rate it is lost/gained.

Cooling

GREENHOUSE COOLING

Avoiding Solar Gain

Shade Cloth

- Densities 10 to 90% light reduction
- Position inside or outside
- Can be automated

Shading Compound

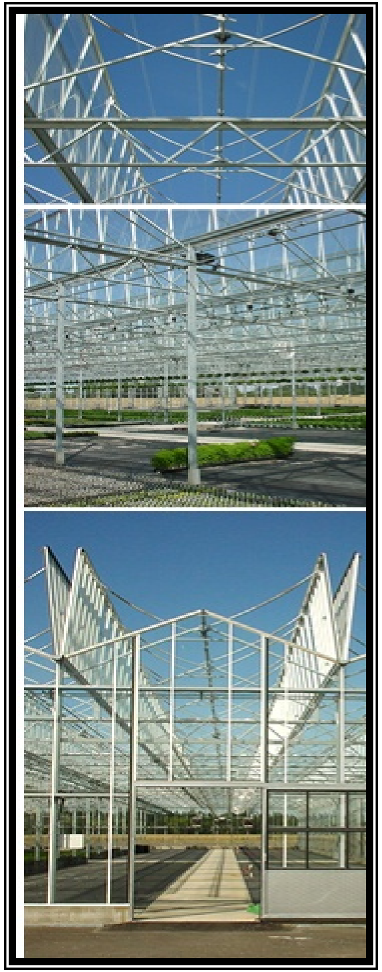
White compound applied to outside glazing

- Specific for greenhouses
  - White latex paint used, not recommended
- Wears off "naturally" over time
- Scrubbed off after frost or freeze

Greenhouse Cooling

Natural cooling

(passive ventilation)



http://www.paulboers.com/images06/interface/openroof_left.jpg

Warm air rises exits vent, cool air settles

- Ridge Vent
- Side Vent
- Open Roof

Disadvantages

- Cool and warm spots
- Hard to control

Greenhouse Cooling

Natural Ventilation - Roll-up side walls

- Cross ventilation – open location
- Typically single wall glazing
- Increases infiltration
- een

Greenhouse

Mechanical Ventilation

Fans & Louvers

- Thermostatically controlled
- Louvers and fans at

opposite ends of greenhouse

- Number of units must be accurately calculated for air volume
  Summer cooling needs
  - 0.75 to 1 air changes/minute

Cooling Comparison

	Outside Temp	Inside Temp
No Cooling	95 °F	140 °F
Natural Ventilation	95 °F	115 °F
Fan and Louvers	95 °F	105 °F
Fan &Louver With shade curtain	95 °F	98 °F
Evaporative cooling (Fan & Pad)	95 °F	80 °F

Reference: http://www.igcusa.com/greenhouse_cooling_information.htm

Balance

- Structure
- Keeping in the heat
- Insulated foundation

Greenhouse Heating

Heat Loss

- Conduction
  - Glazing, walls, floor
- Infiltration
  - Air leakage
- Radiation/Transmission
  - Radiant heat loss
- Convection
  - Currents within the greenhouse

In the greenhouse we want to add heat at the rate it is lost.

Greenhouse heating

Avoiding Heat Loss

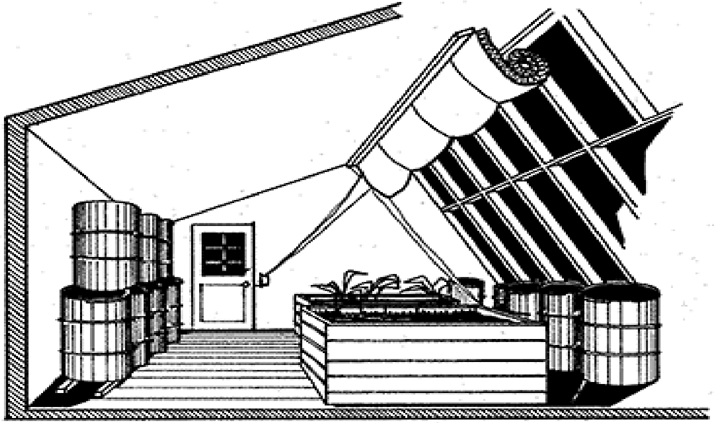
Thermal curtains reflect radiant energy back into the greenhouse

Greenhouse Heating

Passive Solar Greenhouses

Engineered to maximize solar energy and do without supplemental heat sources.

- Oriented to optimize solar heat gain
- Thermal mass to store heat
- Well-insulated
- Advantages
  - Free heat
  - Environmentally friendly
- Disadvantages
  - Achieving fine control and balance is difficult



Greenhouse Heating

Designing a Heating System

- Parameters based on meeting most extreme heating requirement
  - In Madison, WI our **design temperature** is -7º F
    - In Fresno, CA it's 30ºF
  - Desired **indoor air temperature** ~ 70º F
  - The difference (**ΔT**) describes the conditions under which the heating system should operate.

design temperature - indoor air temperature = ΔT

Greenhouse Heating

Calculating Greenhouse Heat Loss (**Q**)

Transmission Heat Loss $\quad Q = UA\ (\Delta T)$

- U = Heat Transmission Coefficient (the U-value) of the specific Covering
- A = Exposed Area (in Square Feet) of the specific Covering

Infiltration Heat Loss $\quad Q = 0.018NV\ (\Delta T)$

- N = Design Air Changes (the U-value) of the specific Covering
- V = Greenhouse Inside Air Volume (in Cubic Feet)

Structure and materials are key

Managing Gases

Air Quality - Harmful Gases

By-products of combustion

- Malfunctioning vented heaters (incomplete combustion)
- Impurities in Fuel

Ethylene – colorless & odorless

- Delayed effect
- Distorted growth
- Increase fruit ripening
- Accelerates floral senescence

and abscission

Ethylene injury

Sulfur Dioxide

- leaf curl, necrotic spots on leaves

Carbon Dioxide Injection

- Increases growth and yields
- Only used when <u>little or no ventilation</u> is required for temperature control
- CO_2 is only utilized during daylight hours
- Increasing air movement in canopy (100 fpm) has same affect as 50% enrichment
- CO_2 supplied by
  - Bottled gas, dry ice
  - CO_2 Generator
    - Propane or Natural gas

Air Flow

Greenhouse heating

Air Stirring / heated air distribution

Air Movement

- Reduce temperature variations – linearly
- Reduce temperature stratification - vertical
- Increase drying speed of plant leaves
- St


Managing Water

Humidity

Drainage

MEDIA

Water

Air

Support

Nutrients

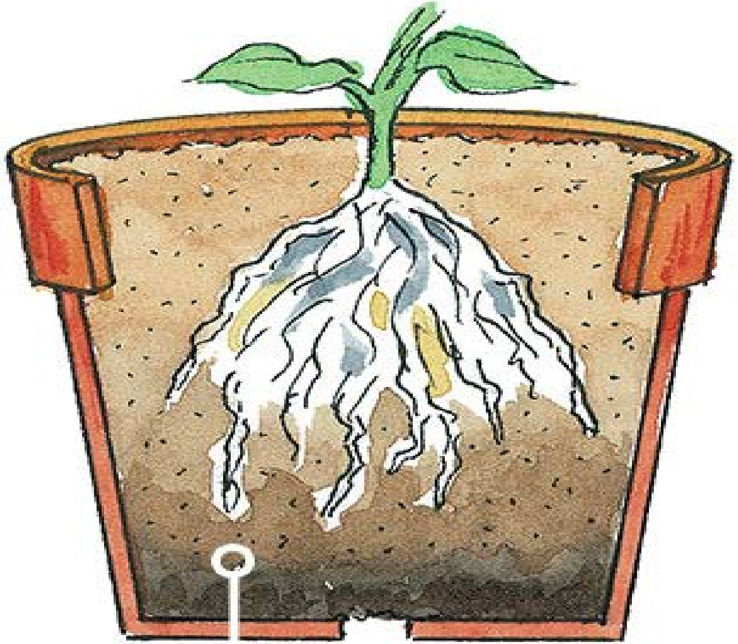
Characteristics of Good Media

Physical Properties

- Structure
  - Promotes drainage and lifespan of media
- Porosity
  - Allows for drainage
- Water Holding Capacity (WHC)
  - Retains moisture

Chemical Properties

- Cation Exchange Capacity (CEC)
  - Holds nutrients available to plant
- pH
  - 5.4-6.2 preferred
  - Nutrient availability



The wettest soil is at the bottom.

Gravel moves the wettest soil up in the pot, closer to the roots, which can lead to rot.

Container choice affects soil volume and WHC

Components of Potting Mixes

Organic Matter (55-85%)

- WHC
- CEC
- Structure
- Porosity
- pH

Particulates (15-45%)

- Structure
- Porosity
- pH

Additives

- Wetting Agents
- Fertilizers
- Beneficial organisms (symbiotic fungi)
- Fungicides or pesticides

Media

Cation Exchange Capacity

- Ability of the media to hold/release ions
  - Minerals important in plant nutrition
- EC: Measure of soluble salts (TDS)
  - Use to estimate salt (nutrient) level in media
  - Does not specify which salts
- Minerals (salts) are left behind and accumulate in media as water leaves the root environment

Root environment interactions

Keys to Creating a Healthy Root Environment

- Media Choice
  - Inherent characteristics: CEC, pH, porosity, structure, WHC
- Container Choice
  - Drainage: container shape and size affect water retention
- Initial Media Handling
  - Absorption/wettability: Media should be moist at filling
  - Compaction: loss of pore space = loss of available water/air
- Initial Watering
  - Saturation: water new transplants thoroughly

Irrigation

Watering recommendations

Light level x Temperature = water use

- Greenhouse
  - Check daily
- Indoors
  - Check weekly
- Outdoors
  - Sunny and warm: Check daily
  - Windy too: Check more often
  - Cloudy and cool: check less frequently

Usually best to let media dry between watering.

WATER

Root Health

- Water availability
- Water quality

Transpiration

Water Quality

- Electrical Conductivity
  - Measure of soluble salts (TDS)
  - 0.1 to 0.5 mS preferred
- pH
  - 6.0-7.0 preferred
- Alkalinity
  - Measure of carbonates and bicarbonates ($CaCO_3$)
- Other Nutrients
- Contaminants

Water quality comparison

DC Smith Greenhouse	pH	Soluble Salts	Alkalinity
		dS/m	mg$CaCO_3$/L
Rainwater	5.8	0.03	5
Tap water	7.5	0.72	305
Preferred	6.0-7.0	0.1-0.5	0

ppm of	P	K	Ca	Mg	S	Zn	B	Mn	Fe	Cu	Al	Na
Rainwater	<0.05	0.10	1.22	<0.003	1.00	0.25	<0.02	0.01	0.01	<0.005	<0.05	0.22
Tap water	<0.05	1.45	82.73	42.78	7.70	0.02	<0.02	0.004	0.01	0.08	<0.05	14.30

Water treatment

Reverse osmosis

membrane purification

- 90 to 95% pure
- Low microorganisms
- Energy inefficient
- Waster water produced
- Expensive

Water softening

- Replaces ‘hard’ Ca and Mg ions with Na or K
- Doesn’t reduce EC or change pH
- Only use K in plant production!

Water Tr

Filters and UV treatment
for recirculated water

- Removes pathogens and small particles
- Leaves dissolved solids and bicarbonates
- Does not affect pH

Microfilters

UV Treatment

Water Treatment

Leaching

Flush salts from **media**

- Used when wate
  alkalinity
- Wastes water

and fertilizers

Irrigation

Hand watering

- Hoses
- Shut-off valves
  - Control flow, conserve water
- Wands
  - Extend reach
- Breakers
  - Soften pressure of water
- Mist nozzles
  - For small seeds and maintaining humidity

Managing Plant Nutrients

- Media EC and pH management

Plant n

- Macronutrients
  - **NPK**
- Micronutrients
  - Ca, Mg, S, Fe, Mn, B, Mo, Zn, Cu
- Sources
  - Water Soluble fertilizers
  - Non-soluble amendments
  - Synthetic and Natural sources
- Other essential elements?

Controlling Plant nutrition

Water Soluble Fertilizers

- Convenience
  - Supply fertilizer along with irrigation water
  - Small volumes of concentrated stock solutions
- Flexibility
  - Changes to nutrient levels can be made at any time during crop production
- Accuracy
  - Consistent nutrient levels
  - EC readings allow nutrient levels to be tested and corrected
  - Manufacturers list expected EC values for dilute fertilizer

Back Flow Preventer or air gap is essential to prevent contaminating water source with Ag Chemicals.

Controlling the Environment

Environmental Control Systems

- Sensor (Input)
  - Detects change in variable
  - Produces a signal (measured value)
- Signal Receiver/Translator
- Comparator
  - Compares signal to set value
  - Determines demand for action
- Operator (Output)
  - Responds with increases or decrease in supply

Operating Equipment

Manual Operation

- Curtains
- Vents
- Switches
- Valves
  - Irrigation water
  - Heating pipes

Self-automating equipment

Operating Equipment

Automated Operation

- Motors
  - Fans
  - Vents
  - Curtains
- Pumps
  - Irrigation water
  - Heating water
  - Fog/Mist Systems
  - Pad Cooling Systems

Automatic Controller

Step Controller

- Usually single input (Temperature)
- Variable multi-stage control of outputs
- Add steps to equipment operation
  - Open vents by stages
  - Open vents, then add fans
  - Open vents, add fans, turn on cooling pads or fog

Integrated controller

Microprocessors

- Multiple inputs and outputs
- Integrate indoor and outdoor sensor readings
- Capable of advanced calcula

Computer and software

- Data logger
- Graphical Tracker
- Convenient Interface

Image: Greenhouse Grower Magazine

Alarm Systems

Triggered by

- Preset Max/Min
- System Failure
- Power Failure

Output

- Audible alarm
- Visual alarm
- Dial phone number

Biotic Factors

Crop? Type

- Tropical foliage plants
- Food plants
- Flowering plants
- Mushrooms
- Starting seeds

Crop Requirements

- Look it up

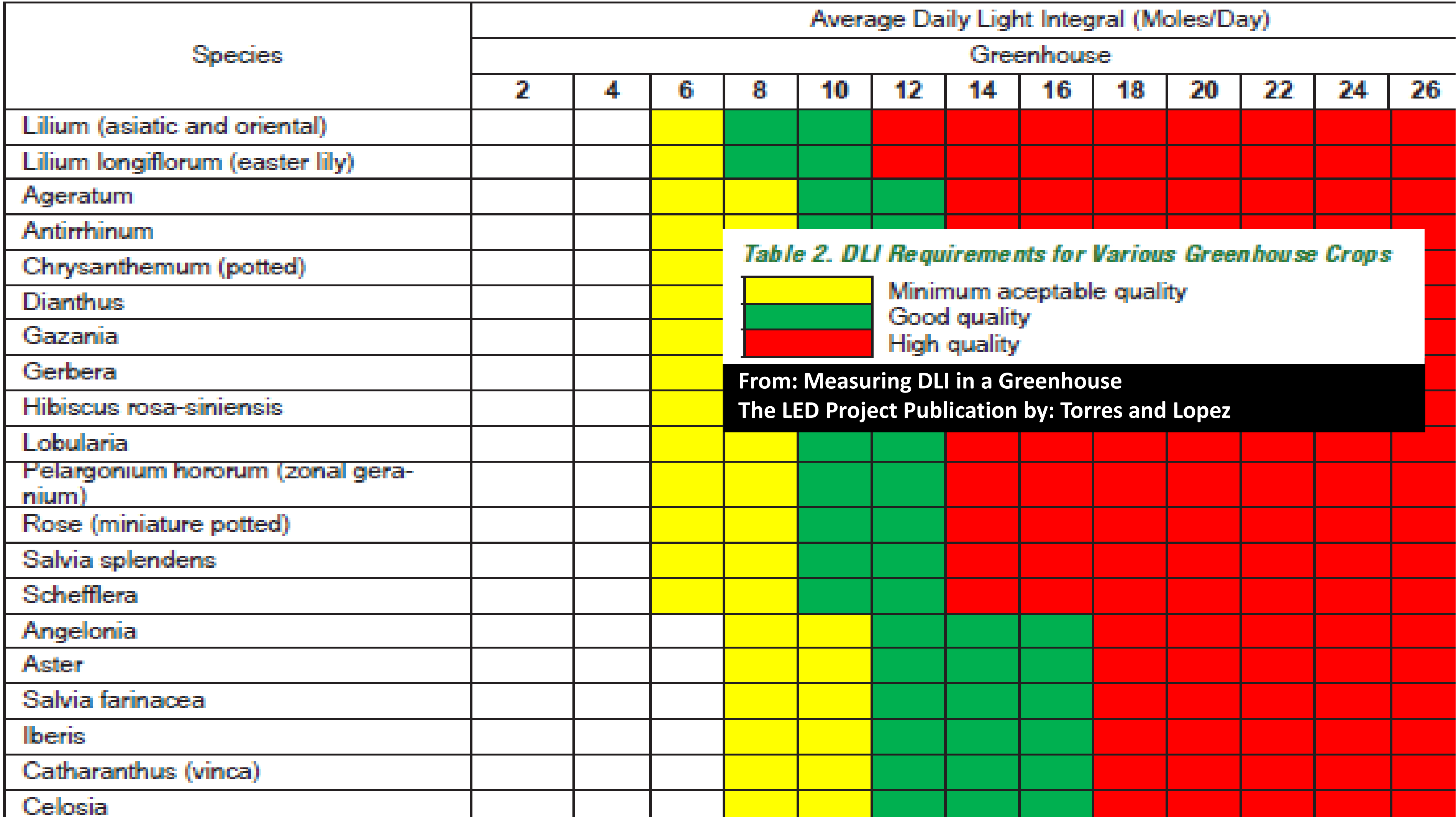


Table 2. DLI Requirements for Various Greenhouse Crops

From: Measuring DLI in a Greenhouse
The LED Project Publication by: Torres and Lopez

Light Quality

Height Control

- A balance of Red and Blue wavelengths has been shown to reduce stem elongation

Images Courtesy of Bjorn Karlsson: UW Biotron

Light Quality

Blue wavelengths encourage phytochemical production

Red Far Red/Red Red+Blue Fluorescent Green Blue

Images Courtesy of Bjorn Karlsson: UW Biotron

Ways to affect light quality

Maintain Plant Quality in Low Light Conditions

- Incandescent
  - Reds for flowering
- Fluorescent
  - Blues for foliage color and compact growth
- LED
  - Specific wavelengths

Lengthen Dark Period >12 hours

- Blackout Curtains
- Turn off lights
- Use natural day-length variation
- Automation
  - Timers
  - Motorized curtains

Shorten dark period <12 hours

- Lights with far-red spectra (~730

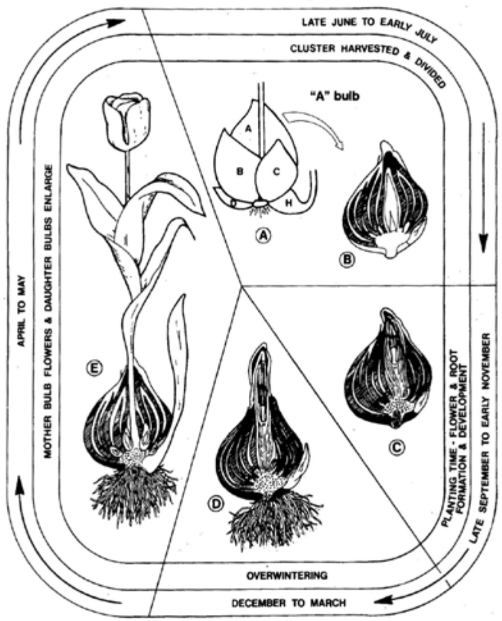
Poinsettia: Light leaking under the cover resulted in green leaves instead of red bracts on the first row of plants

Temperature and plants

Vernalization

- low temperature and moist conditions promote floral initiation
- Can be obligate or facultative
- Natural plant adaptation to seasonal temperature variation.
- Used in the greenhouse to manipulate timing of crops.

  Forcing winter flowers
  - Bulbs
  - Shrubs
  - Potted flowering plants



Source: Holland Bulb Forcer's Guide

Water

pH

Nutrients

Managing Pests

- What can you live with?


PESTS
PLANTS
PEOPLE

Integrated Pest Management (IPM)

Integrated Pest Management is a decision making process that utilizes various pest management strategies to prevent economically damaging pest outbreaks and reduce the risk to human health and the environment.

What are my Control options?

Cultural/Mechanical Controls

- Exclusion
- Sanitation
- Removal of infected material
- Use of resistant plant varieties
- Environment
  - Good for plants
  - Bad for pests and diseases

Labor intensive

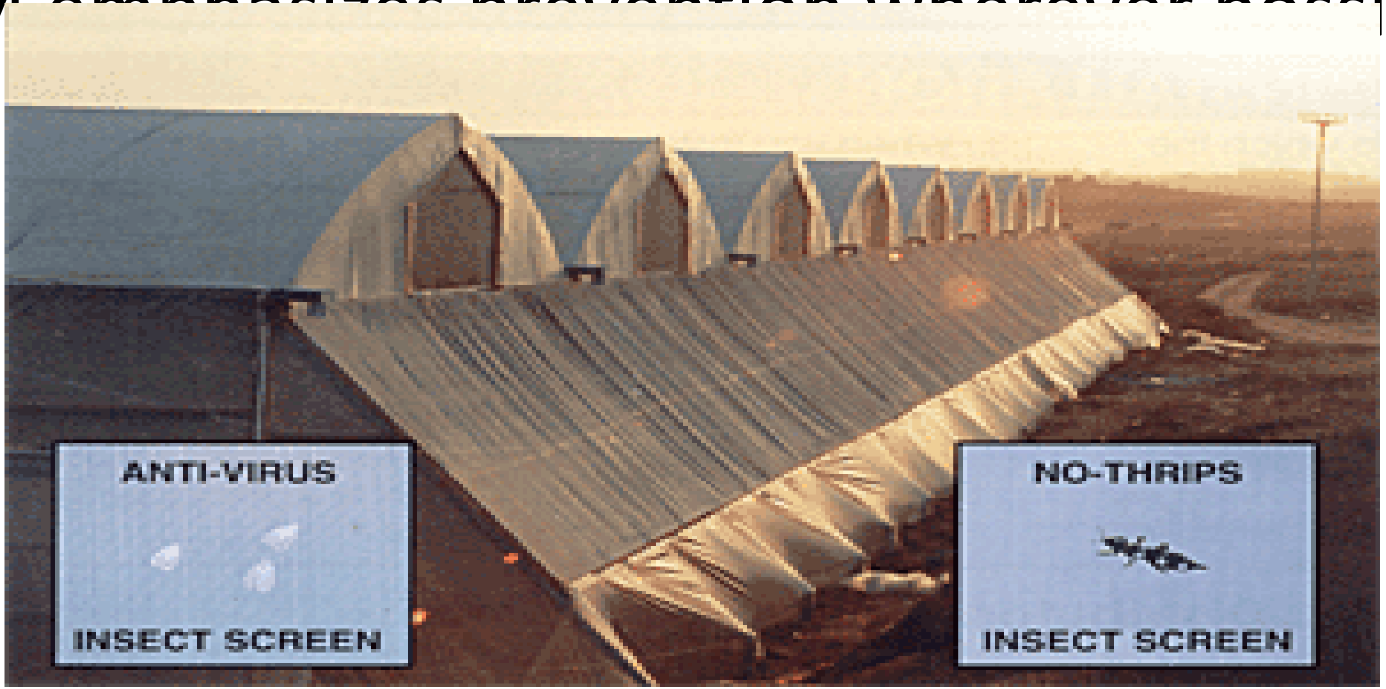
Usually inexpensive

An ounce of prevention…

Pest Management Tools: Cultural

The first line of defense

- IPM emphasizes prevention wherever possible



What are my Control options?

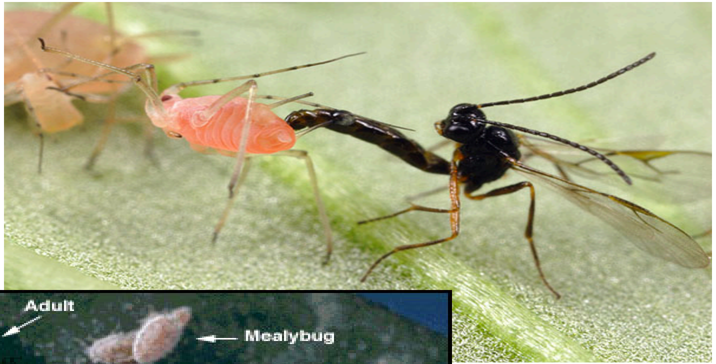
Biological Control (beneficial organisms)

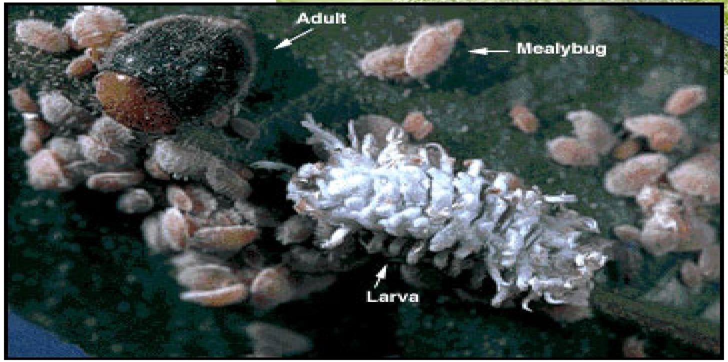
- Natural enemies (predators and parasites)
- Pathogens
- Control is not immediate
- Control is not 100% effective
- Compatibility with
  - Environment
  - Other beneficials
  - Chemical controls

Pest Management Tools: Biological

The Foot Soldiers of IPM

- Natural enemies





- Pathogens

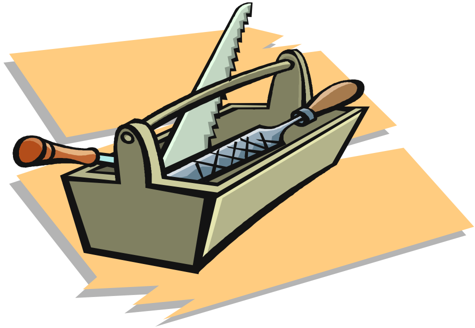
What are my Control options?

Chemical Controls (pesticides)

- Effects are usually quick
- Effectiveness may vary
  - good coverage and residual effect
- May need repeated applications
  - not all life stages are susceptible
- Rotate Mode of Action to prevent resistance
- Cost varies by product
- Consider cost to health and the environment
- Some pesticides are registered for organic use

Pest Management Tools:

A successful IPM program will integrate these tools in the most effective manner possible.



Individual IPM programs will vary according to the priorities and goals of each facility.

Do You DIY or Hire it Out?

- Cost ranges/ft^2

To contact Johanna Oosterwyk or find links and materials from today's talk

https://DCSmithgreenhouse.cals.wisc.edu