LIGHT

Stages of Plant Growth
&
Shifting Light Needs

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Crops need light and a specific amount of warmth to achieve optimum characteristics for the market place

Too much light or heat $\longrightarrow$
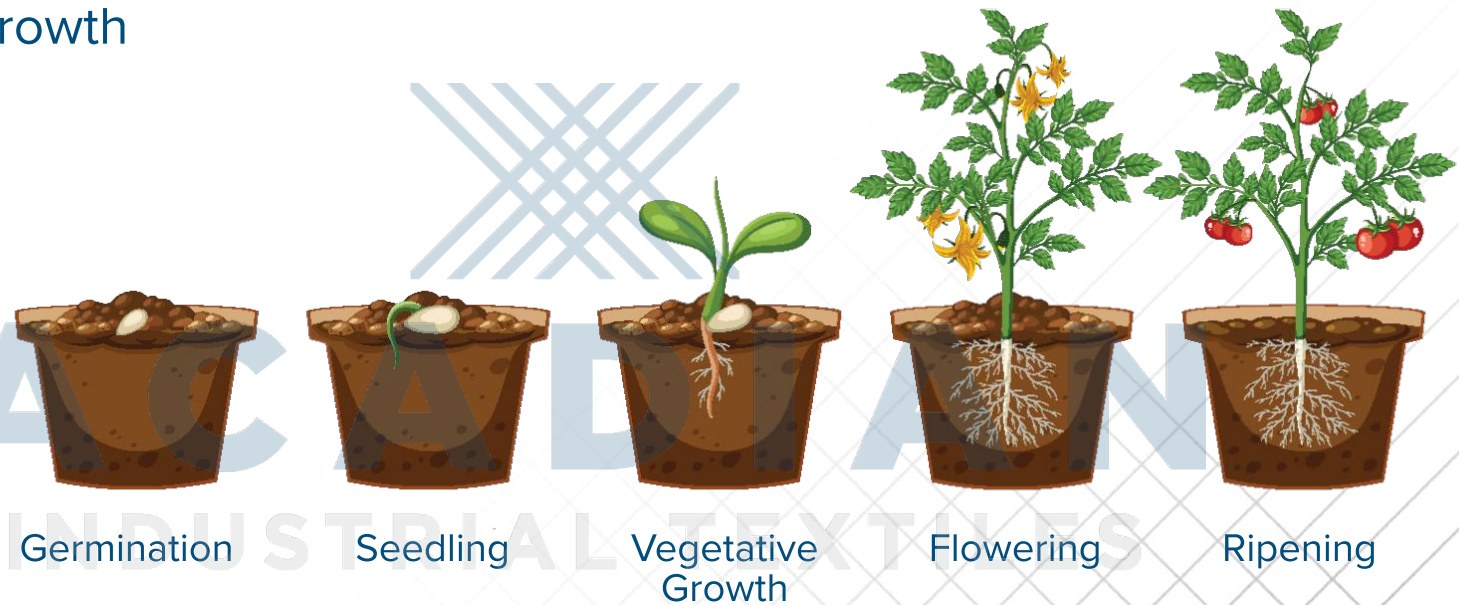
Too little light or heat $\longrightarrow$

Using specific textiles based on location, crop, time of year and crop stage of development, these slides provide guidance to achieve healthy, happy plants.

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Phases

1. Germination
2. Seedling
3. Vegetative Growth
4. Flowering
5. Ripening

| Germination | Seedling | Vegetative Growth | Flowering | Ripening |

Phases of growth are generalized to provide basic information across many plant types. Specific varieties/cultivars can vary in development stages.
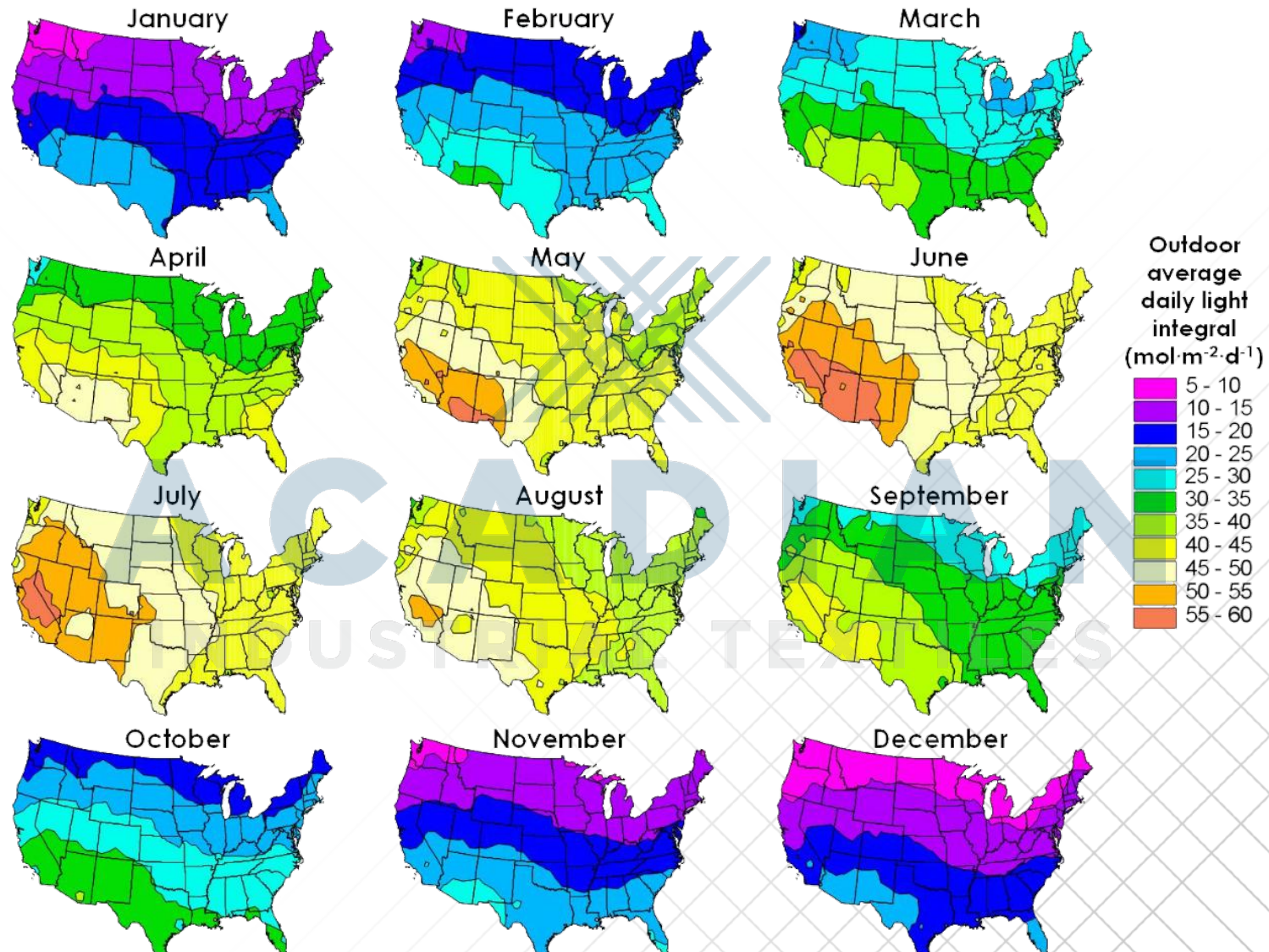
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Key Aspects Defined

- Photosynthetically Active Radiation (PAR):
  - Light needed by crops: full light spectrum (~400 - ~ 700 nm wavelength)
  - Roughly blue to Red
- Photosynthetic Photon Flux Density (PPFD):
  - Amount of PAR light that reaches a specific area
  - Measured in micromoles per square meter per second (mol/m^2/second)
  - Can be measured with a photometer above crops or cell phone app
  - Varies by season and location
- Daily Light Integral (DLI)
  - Amount of PAR light a crop needs for photosynthesis
  - Measured in micromoles per square meter per day (mol/m^2/day)
  - Varies by stage of crop development
- Photoperiodic plants: transition to different development stages based on cues from length of day
- Photoblastic plants: require light for germination

Optimal Light information provides basic information across many plant types. Specific varieties/cultivars can vary greatly in light or heat requirements. To provide examples, common crops with specific needs are listed.

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Outdoor Daily Light Integral (DLI) Maps
developed by Jim Faust, Clemson University

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What's Occurring (mostly applicable to vegetables, legumes, nuts)

- Seeds absorb water
- Begin metabolic and initial root processes
- Once seeds open photosynthesis starts
- Shoots are reaching for light; typically need a lot of bright, indirect light

Light Color Impact:

- Red, Far Red Light: can trigger their germination in photoblastic seeds

Role of Shade Cloth, Polyfilm or Curtain:

- Keep environment dark until seeds sprout shoots
- Deliver Far Red or Red light through Rose colored Shade

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Role of light:

Generally, the heat generated by light plays a larger role than light itself

- Beets and Spinach: 4-6 hours direct light (photoblastic crops)
- Peppers and Tomatoes don't need light
- Spinach needs some warmth but does best in temperatures under 70F

Specific Crops and their Textiles:

- Beets and Spinach: Need PAR light either directly or through film/ curtain
- Peppers and Tomatoes: May need darkness
- Dense shade cloth 70% or higher
    - Opaque, black out or panda film/ curtain that can be easily changed or moved for seedling phase to allow light

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What's Occurring?

- Most plants are using photosynthesis to make food
- Roots deepen
- Shoots flourish as leaves open
- Plants shift from using nutrients in seed to gathering their own

Light Color Impact:

- Red/blue balance (Rose) in low intensity promote:
  - Stem and root growth
  - Leaf expansion
  - Increase in number of tomato, which improves photosynthesis efficiency
- Blue light plays largest role in chlorophyll creation
- Daily light requirements are generally lower than in later development phases

Role of Shade Cloth, Polyfilm or Curtain : Temporarily limits light received by plant until vegetative phase

- Cloth:
  - Low shade amount allows bright light while limiting indirect light
  - White or Silver cloth can reflect excess heat away
- Greenhouse curtain or Polyfilm: Limit transmission of light reaching plants

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Role of light:

How much needed per day by crop and possible shade needs

- Beets: Early stage: 6 - 10 mol/m^2/day, later stage: 10-15 mol/m^2/day
- Peppers: 8-16 mol/m^2/day. 50% shade in mid-west
- Spinach: 8 - 12 mol/m^2/day 60% shade or higher
- Tomatoes: 8-16 mol/m^2/day unde 40% shade

Specific Crops and their Textiles:

- Beets, Peppers, Tomatoes: Clear film or curtain with over 70% or even 80% shade transmission allows to reach plants
- Spinach:
  - White or silver/grey shade reflects excess heat
  - Shade of 50% or more depending on geographic location and time of year
- Tomatoes: Opaque Hail or Bird net (low shade %)
  - Protects plant from inclement weather
  - Allowing light through

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What's Occurring?

- Roots continue to grow while majority of growth is in the leaves and stems
- Maximize photosynthesis possible by expanding available surface area (leaves are where most photosynthesis occurs)

Light Color Impact:

- PAR (full light spectrum): need at crop specific daily light integral (DLI)
- Blue Light: Supports Chlorophyl production
- Red/Blue balance (Rose) in low intensity promotes:
    - Structural growth: stem and roots
    - Leaf expansion

Role of Shade Cloth, Greenhouse curtain or polyfilm: Select shade % or light transmission level based on crop DLI /PPFD

- Prevent leaf burn and stunted growth by reducing:
- Heat experienced by plant is reduced
- Controls crop exposure to light based on crop DLI or PPFD requirements
- Prevent premature flowering in specific crops by reducing day light hours for crops grown in early spring
- White or Silver shade cloth reflects excess heat away
- Spread light around tunnel/greenhouse when there are various canopy levels
- Greenhouse curtain or Polyfilm can reduce heating costs with IR additive and prevent condensation from collecting on walls or ceiling with Anti drip additives

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Role of Light: How much per day or at a given moment per crop (estimates)

- Beets: 12-20 mol/m^2/day, PPFD 200- 400
- Peppers: 20-30 mol/m^2/day, PPFD up to 600
- Spinach: 14-16 mol/m^2/day, PPFD up to 250
- Tomatoes: 22- 30 mol/m^2/day, PPFD up to 800

Specific Crops and their Textiles:

- Protection from adverse weather
- Beets: Canopy may benefit from diffusion above 30% in Polyfilm or curtain
- Peppers: 50% shade/transmission or lower prevents too much light on tender parts of plant
- Spinach: Keep temperatures below 80F and amount of light (PPFD) on plant under 400 µmol/m^2/s
- Tomatoes: Bird/hail, insect netting, or curtain generally provides protection from animals and pests while transmitting ≥ 70% light

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What's Occurring? Energy use shifts from leaf and root expansion to flower and seed development

- Vegetables are often harvested before flowering
- Flower buds develop
- Prepare for pollination
- Fruit Set: Fertilized flower develops into fruit

Light Color Impact:

- Signal to begin flowering often based on length of day/ sunlight availability (photo periodic)
- Plants highest light needs are generally during this phase, leading towards sugar and ethylene development
- Red and Far right red shade colors can trigger flowering and increase amount and size of flowers/ fruit

Role of Shade Cloth, Greenhouse Curtain, Polyfilm:

- Prevent sunburn and provide cooling in very warm climates or temporary cover at specific times of day
- Mechanism to modify light colors: Even balance of red and blue can prevent shade avoidance behaviors (stem elongation)
- Crop protection from weather or pests
- Insect netting use can keep pollinators close to crops and pests away
- Greenhouse curtain or Polyfilm with diffusion above 30% can get light to various canopy levels

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Role of Light:

- For crops that flower, red and far red light stimulate flowering and fruit production
- Most crops need at least moderate light to flower; Poinsettias flower after daily light declines

Specific Crops and their Textiles:

- Allows plant to see daily light cycles
- Peppers: ≥ 50% shade or ≤ 50% transmission to reduce light in areas with long days
- Tomato: protect from animals and weather

What's Occurring?

- Enhancement of color, scent, flavor and texture
- Further development of flavanoids
- Increase in sugar content

Role of light: Completion of the development cycle

- Enhance colors, flavors and nutrition
- Blue Light supports synthesis of anthocyanin pigments responsible for the red, blue, and purple colors in many fruits

Role of Shade Cloth:

- Keep plants cool / avoid sunburn with Low Shade or white

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Percent Shade Recommendation by Crop Zone and Plant Type

Zone			Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
Average DLI*			5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
Plant Type	**Plant**	**Ideal DLI***											
Vegetables	Beets	12-20	N/A	N/A	N/A	20%	45%	50%	55%	60%	65%	70%	70%
	Broccoli	15-35	N/A	N/A	N/A	N/A	N/A	20%	20%	25%	35%	40%	45%
	Lettuce	14-16	N/A	N/A	N/A	20%	40%	50%	55%	65%	65%	70%	75%
	Spinach	12-18	N/A	N/A	N/A	20%	40%	50%	60%	65%	65%	70%	75%
Fruit	Bell peppers	20-30	N/A	N/A	N/A	N/A	N/A	20%	30%	40%	45%	50%	55%
	Bell peppers (seedling)	8-18	N/A	N/A	20%	45%	50%	55%	60%	65%	65%	70%	75%
	Blackberries	8-14	N/A	N/A	20%	40%	50%	60%	65%	70%	75%	80%	85%
	Cucumbers (seedlings)	5-15	N/A	N/A	N/A	30%	60%	65%	75%	75%	80%	80%	80%
	Cucumbers	20-30	N/A	N/A	N/A	N/A	N/A	20%	30%	40%	45%	50%	55%
	Oranges	22-30	N/A	N/A	N/A	N/A	N/A	20%	30%	40%	50%	50%	55%
	Peaches	8-14	N/A	N/A	35%	40%	50%	60%	65%	70%	75%	75%	80%
	Strawberries	17-28	N/A	N/A	N/A	N/A	N/A	25%	35%	45%	50%	55%	60%
Flowers	Chrysanthemums	10-14	N/A	N/A	35%	50%	60%	65%	70%	75%	75%	80%	80%
	Lilies	4-14	N/A	20%	45%	60%	65%	75%	80%	80%	80%	85%	85%
	Orchids (high light)	8-18	N/A	N/A	20%	40%	50%	60%	65%	70%	75%	80%	85%
	Orchids (low light)	4-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Orchids (mid light)	4-8	N/A	40%	60%	70%	75%	80%	80%	85%	85%	90%	90%
	Petunias	16-18	N/A	N/A	N/A	15%	30%	40%	50%	55%	60%	65%	70%
	Roses	18-22	N/A	N/A	N/A	N/A	20%	35%	40%	50%	55%	60%	65%
Cannabis	Seedlings	12-16	N/A	N/A	20%	30%	45%	55%	60%	65%	70%	70%	75%
	Vegetative	20-45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20%	25%	35%	40%
	Flowering	30-40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A%	20%	30%	35%

* DLI (Daily Light Integral) is the measure of how much light a given location recieves in 1 day

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