FOR AGRICULTURAL **EXPERTISE** IN PRODUCT DEVELOPMENT

LIGHT, GROWTH and DEVELOPMENT of PLANTS

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Botany B.V.

Introduction Botany B.V.

- Private R&D company 2003
  - Business-to-business
  - Confidential testing
  - Product development
  - Demonstration of innovations
- Located in SE of the Netherlands
  - Campus Greenport Venlo
  - LED R&D facility Brightbox
  - High-Tech Horticulture R&D Lab Innoveins

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Botany B.V. participates in:

- Brightlands Campus Greenport Venlo
- www.brightlands.com/brightlands-campus-greenport-venlo
- Brightbox LED Research & Demonstration facility
  - Philips, HAS University
- http://www.brightbox-venlo.nl/en
- Innoveins R&D Lab for High-Tech Horticulture
  - Blue Engineering, Bluehub
  - LED, robotics, seed technology, water treatment
- http://www.innoveins.co/

Clients in Product Development

CERTIS

BELCHIM Crop Protection

Dow AgroSciences

SUR fa PLUS research & development

BASF The Chemical Company

Arysta LifeScience

KOPPERT BIOLOGICAL SYSTEMS

everris.

grodan® Passionate about Precision Growing

HORTICOOP

Cultilene

BAYER

RHIZOPON®

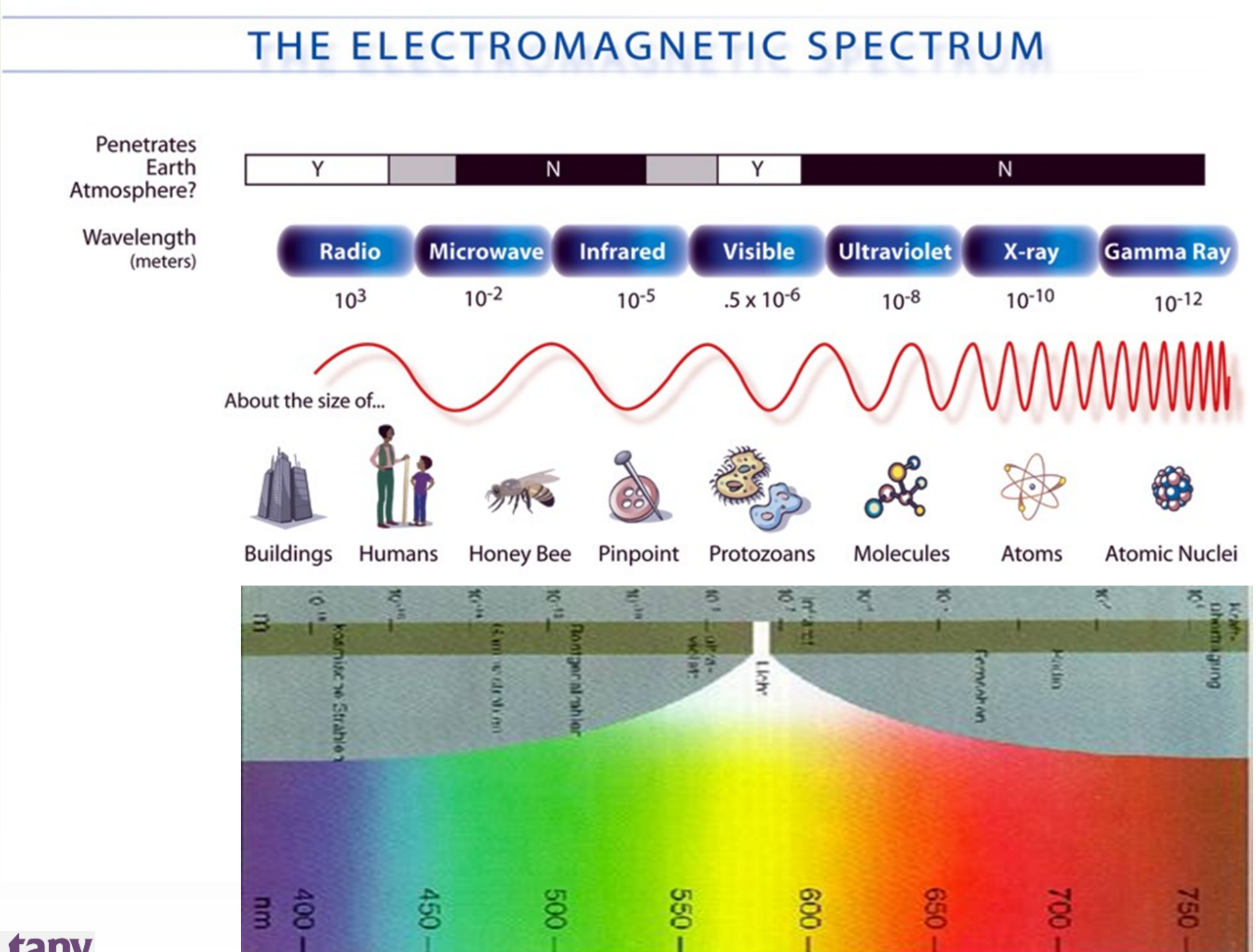
PHILIPS

syngenta

Light: source of life on earth

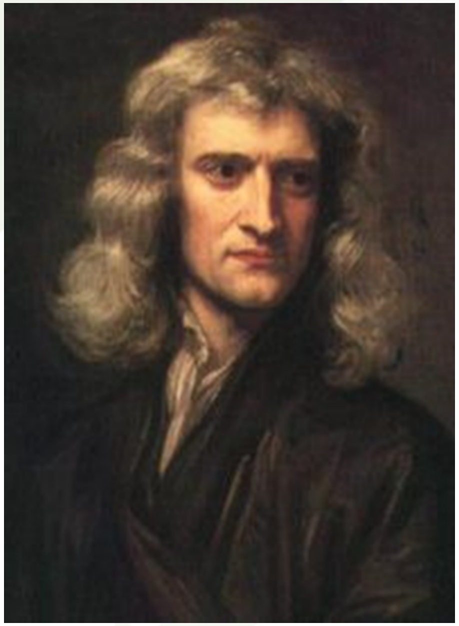
- Solar radiation determines life on planet Earth (and organisms have adapted to that)
- Heat source → driving force for evaporation and condensation of water, allowing life on earth
- Driving force for season changes
- Energy source for photosynthesis: $CO_2 + H_2O \rightarrow$ sucrose + O_2

Light: visible part of solar radiation

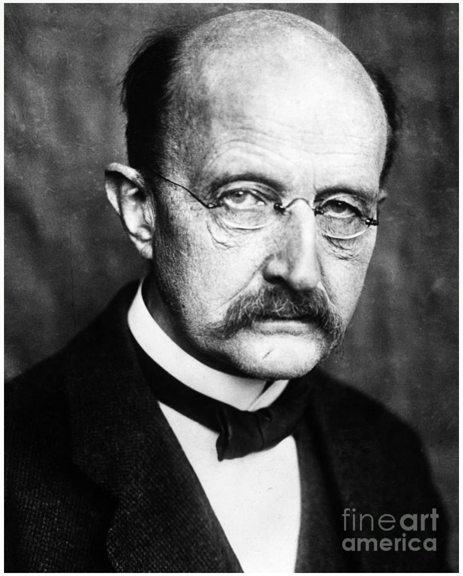


Physical nature of Light

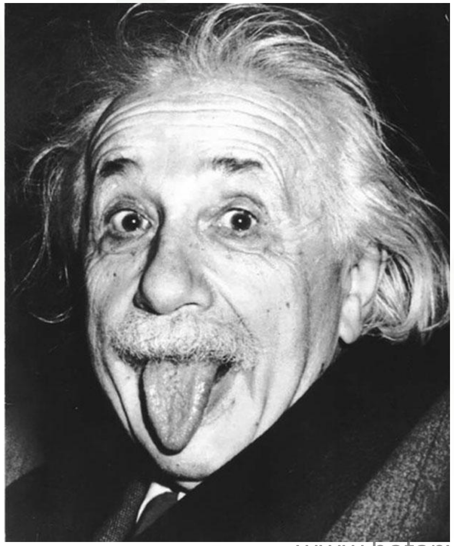
- Christiaan Huijgens (1629 – 1695), 1690: Wave → Energy → Interference



- Isaac Newton (1643 – 1727), 1670: Particles → Energy → Reflection and refraction



- Max Planck (1858 – 1947), 1900: Light is energy particle (photon) and wave! Longer wavelength = lower energy (Nobel prize 1918)



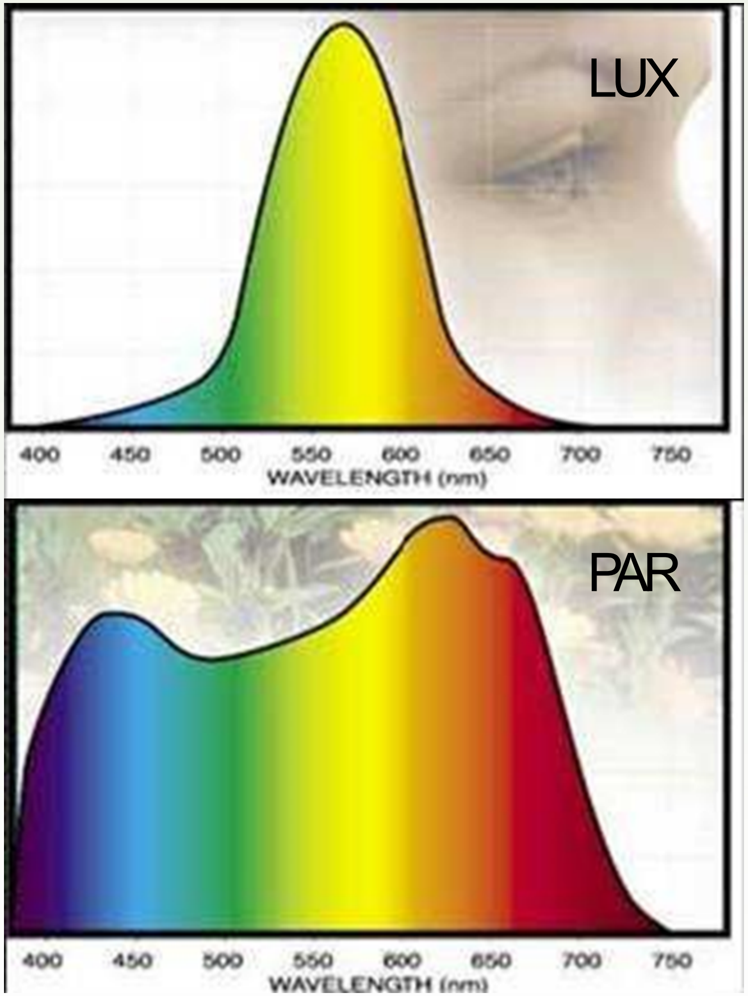
- Albert Einstein (1879 – 1955), 1905: Photo-electric effect (Nobel prize 1921)

How to quantify light?

- Light energy flux: Watt/m^2
- For detection by the human eye: Lumen
  - Lux = Lumen/m^2
- Photon flux density:
  - Number of photons/surface/time: µmoles/m^2/s
  - 10.000 lux = 27 W/m^2 = 125 µmoles/m^2/s
  - 400 J/cm^2/day outside = 10 hrs of 15.000 lux

Difference in sensitivity human eye/plant

- At equal photon flux per wavelength



- At equal photon flux per wavelength
- Light in horticulture:
  - µmol/m^2/s between 400-700 nm (PAR) important, Lux unfit for use!
- Light HPS-lamps is yellow-orange: highest sensitivity of human eye

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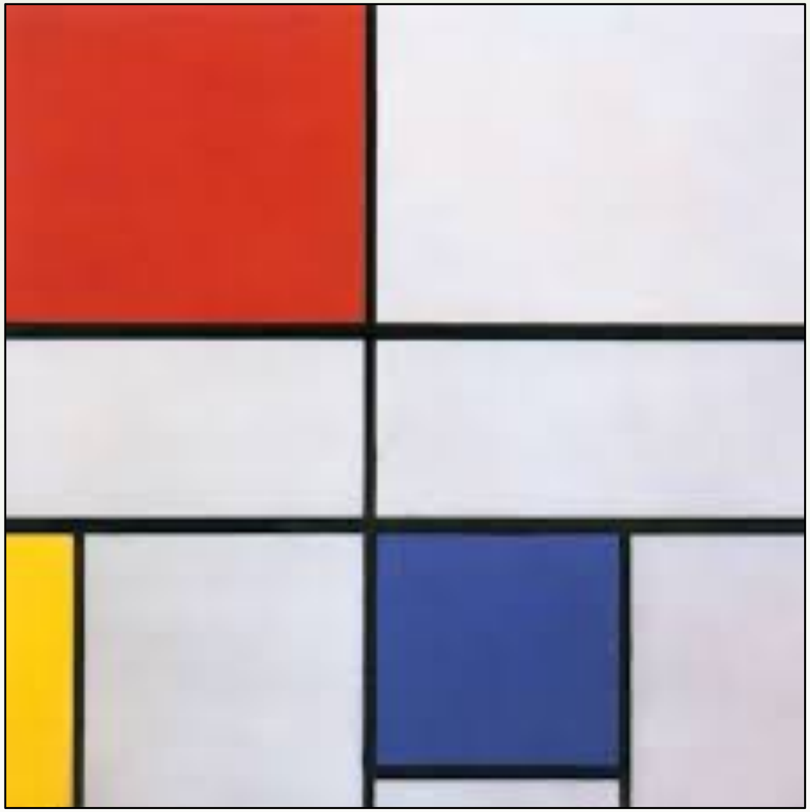
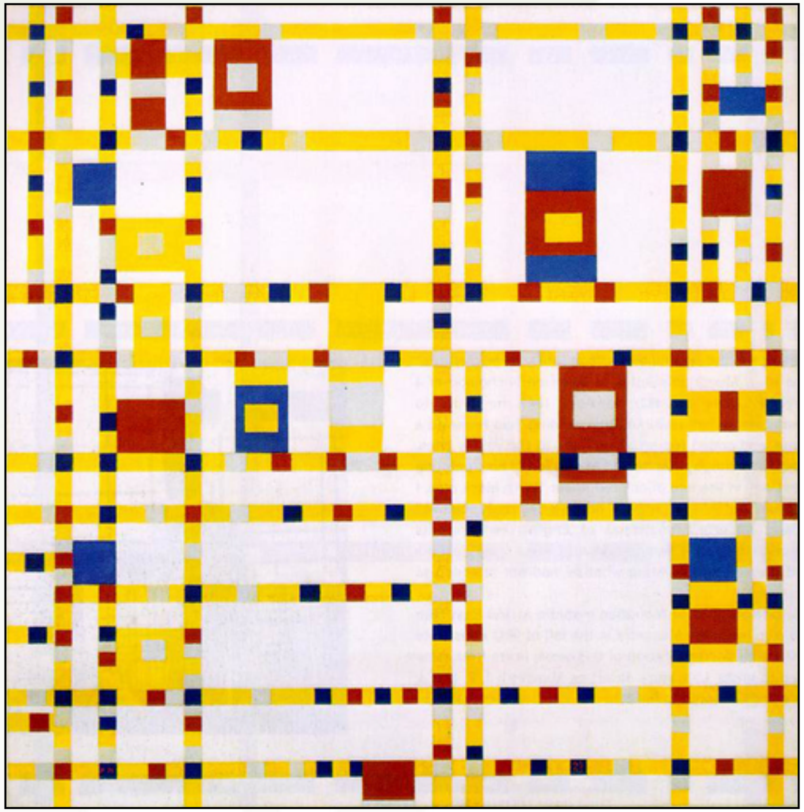
Piet Mondriaan was aware of this





- *Natura artis magistra* – Nature teaches the arts

Role of light in plants 1

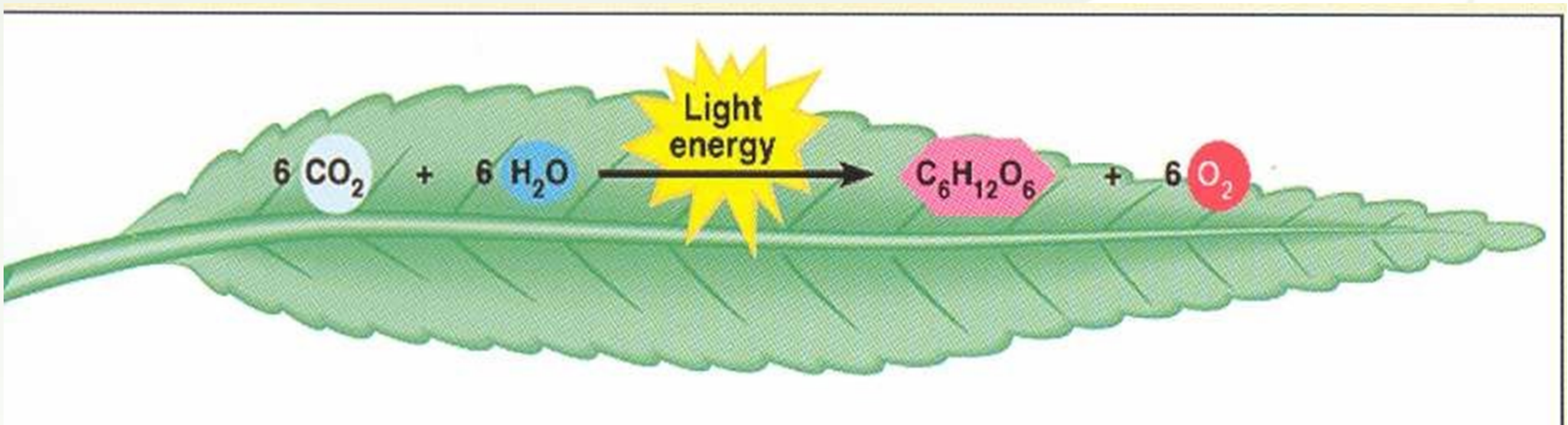
- Light quantity: energy supply for photosynthesis
  - Daily light integral basis for growth (mass increase)
- Light quality (light colour, wavelength)
  - Plant shape, axillary bud break, bud abortion, dormancy breaking, other developmental processes
- Light period:
  - Flowering, flower induction, dormancy induction, growth

Light: essential for growth and development

Sun flower: germination under low light

1. Light quantity

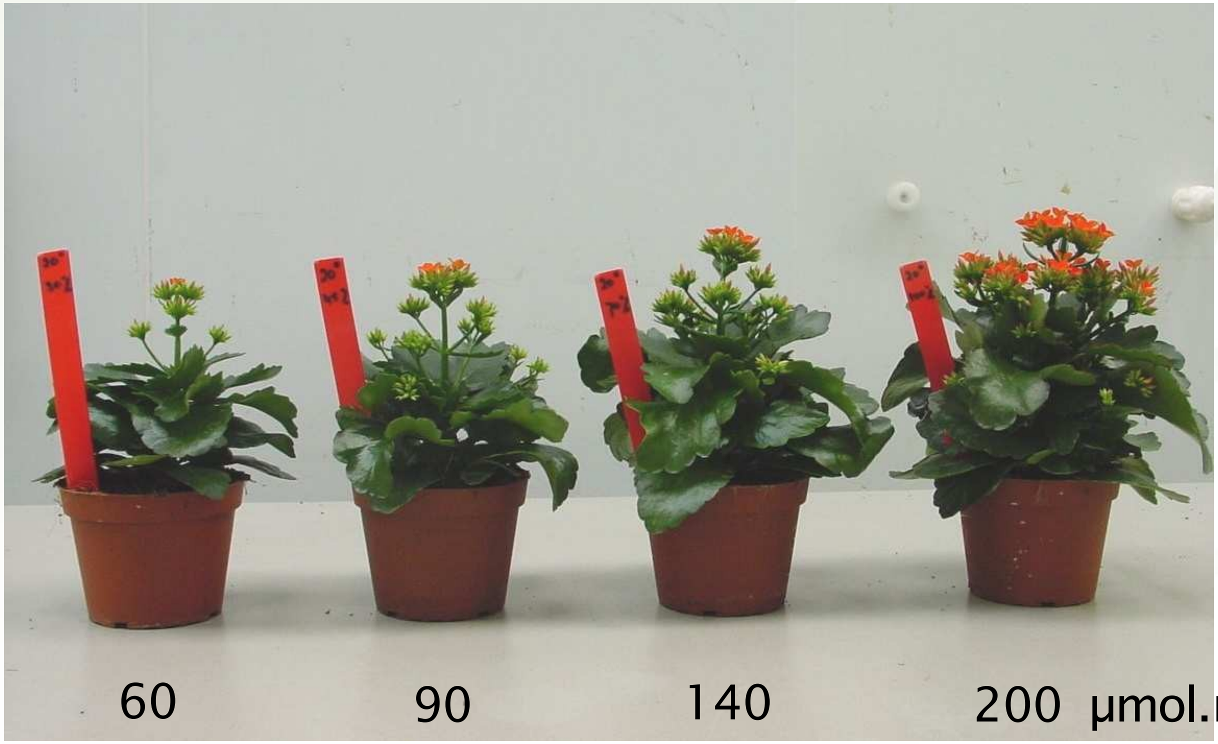
- Energy source for photosynthesis → production of assimilates → growth



- More assimilates → higher quality or production
  - More fruits, more flowers, more branching, easier rooting of cuttings
  - Total Daily Light Sum

Example: *Kalanchoe blossfeldiana*

- Supplemental light in autumn and winter
  - Faster flower induction under high DLI
  - More and heavier inflorescenses with more flowers under high DLI

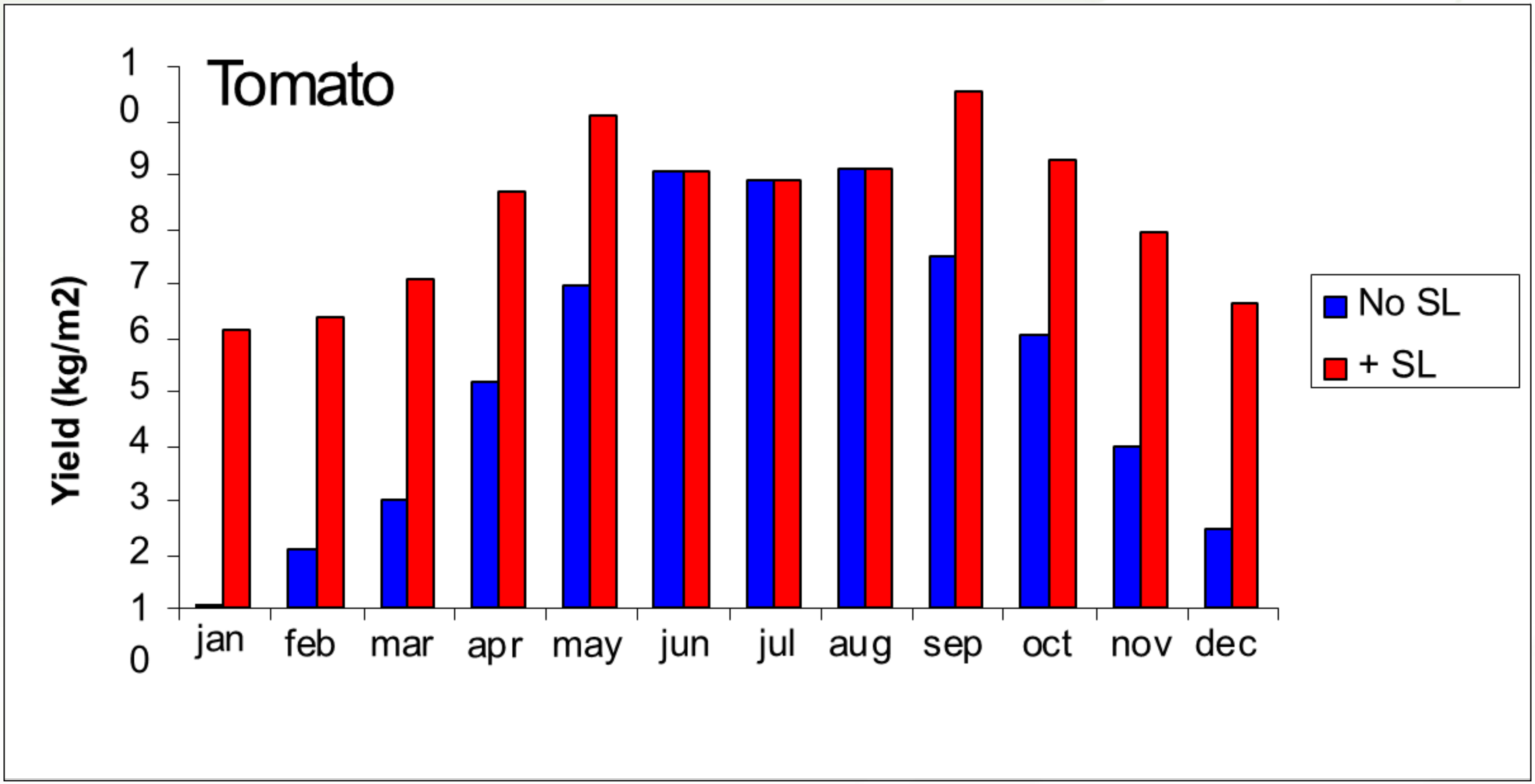


$\mu mol.m^{-2}.s^{-1}$

Heuvelink E. and L. Marcelis, 2007

Example: Tomato production

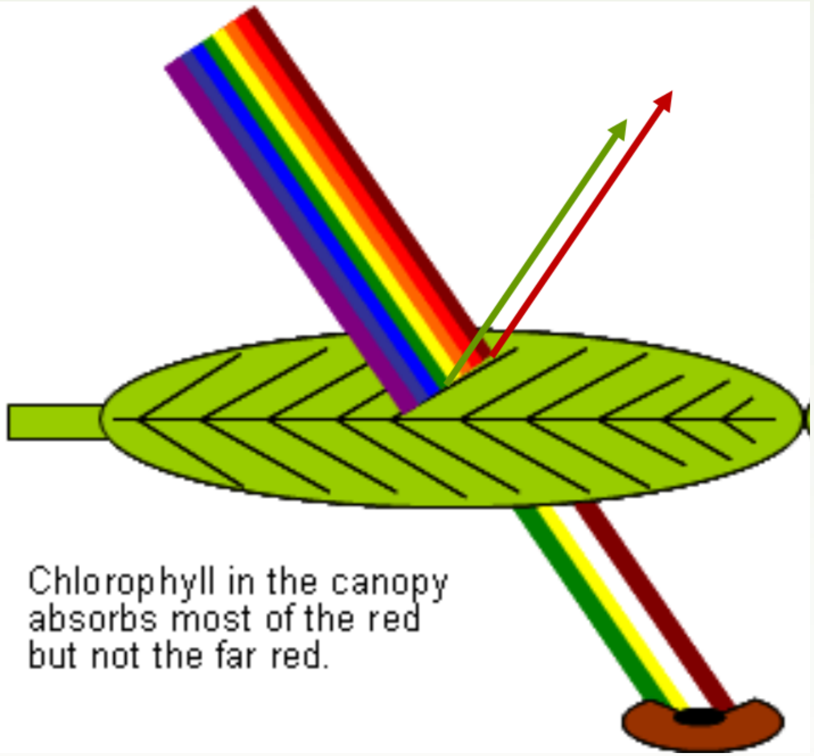
- More uniform production with Supplemental Light
  - 188 µmol/m^2/s (≈ 14.500 lux)

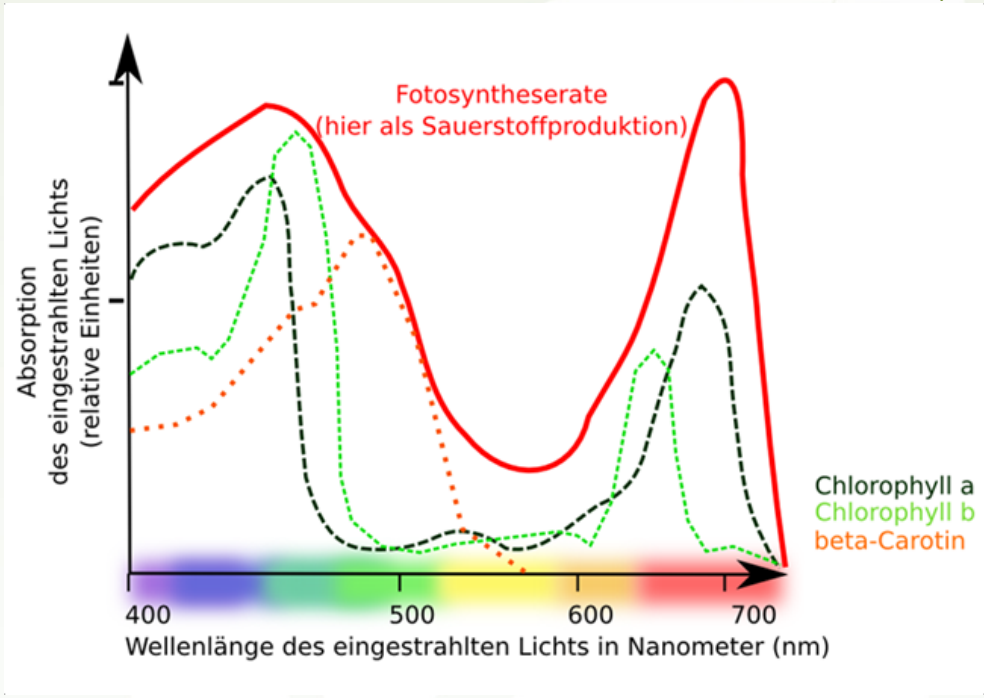


Heuvelink E. and L. Marcelis, 2007

Role of light in plants 2

- What wave lengths are used by the plant?





Photosynthesis: peaks at 400-500 nm and 600-700 nm

Role of light in plants 3

- Growing under LEDs: red and blue are sufficient

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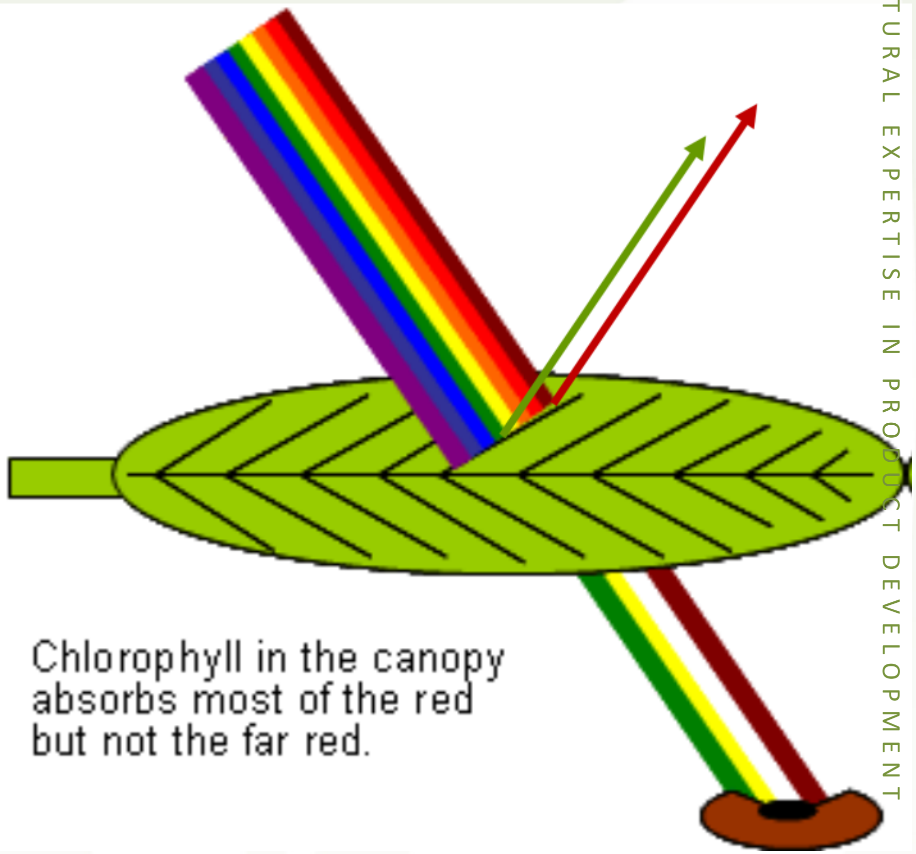
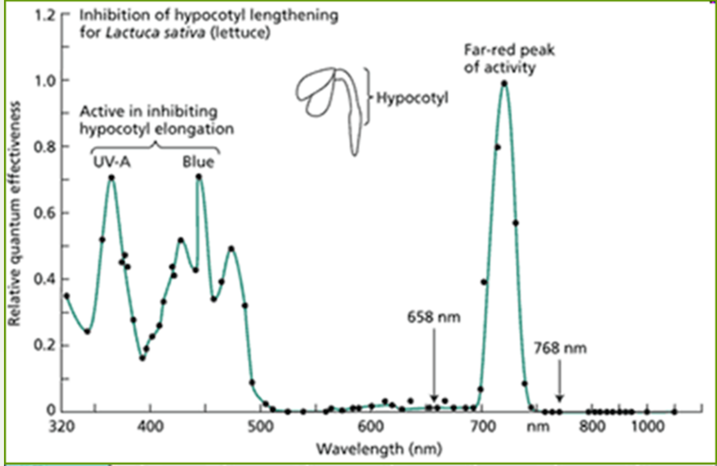
Receptors for light colour

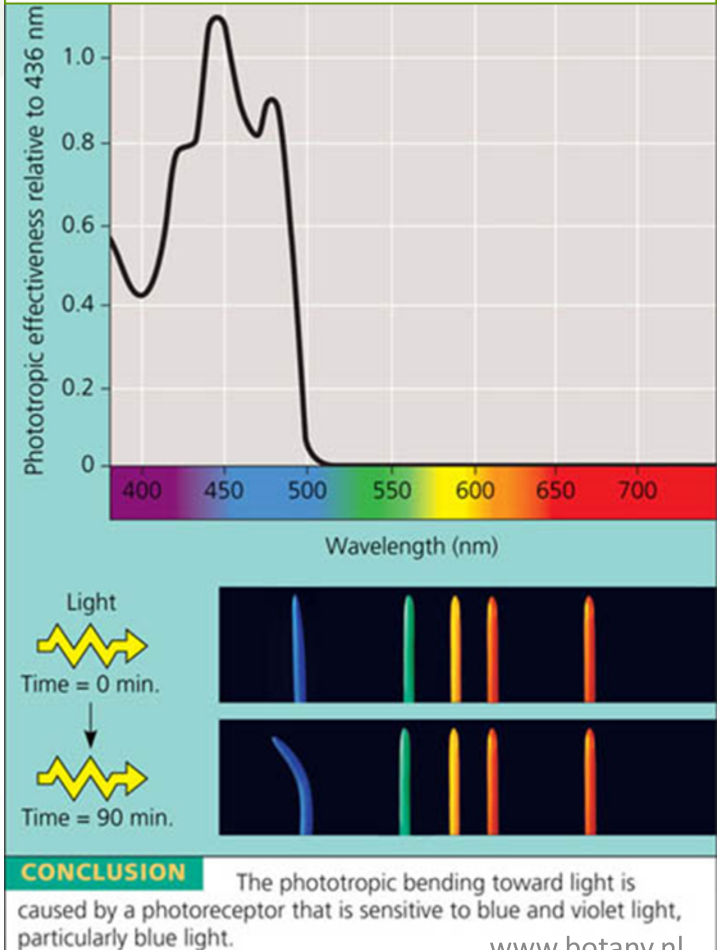
- In all green parts
  - Leaf
  - Stem
  - Buds
- Blue, red
  - Fully absorbed
- Green, far-red
  - Partly transmitted
  - Partly reflected



Response to light quality

- Light colour affects development
- Each program depends on specific wavelength & specific light receptor (pigment)
- Blue light: 3 pigments
  - Phototropin: bending towards light
  - Cryptochrome: hypocotyl elongation
  - Zeaxanthin: opening stomata
- Red & Far red: 1 pigment
  - Phytochrome





BLUE Light

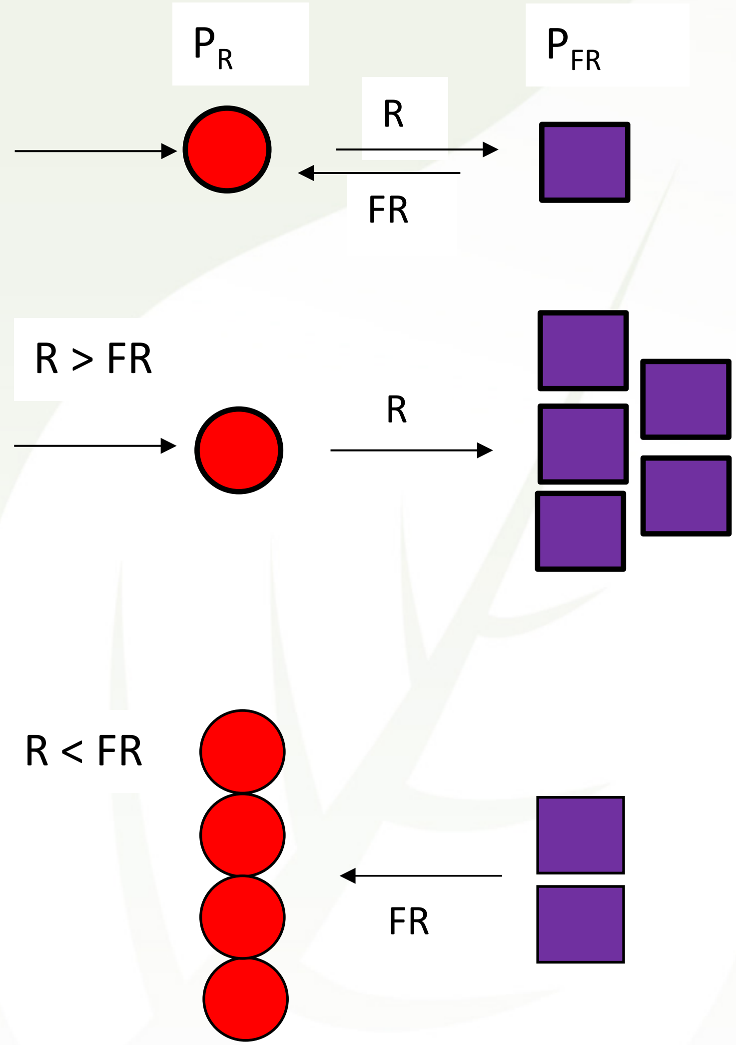
- High blue = open habitat = few neighbours
  - Compact growth: short internodes, smaller and thicker leaves
- Reduction of % blue light in spectrum stimulates stem elongation
- Blue light stimulates:
  - Opening of stomata
  - Anthocyanin synthesis

RED & FAR-RED Light

- Ratio of R:FR is important
- R:FR sun light= 1.2 → normal plant development
  - Increase in axillary shoots (branching)
  - Low flower & fruit abortion
- R:FR under leaf canopy = 0.13
  - Etiolation ('shade avoidance')
  - Increase in leaf surface, decrease in leaf thickness, lower branching and bud break
  - No germination of light-dependent seeds
- R:FR at sunset = 0.9-1.0

RED & FAR-RED receptor: Phytochrome

- Phytochrome: 2 isomers
- Inactive isomere P_R converted into active P_{FR} by RED light
- P_{FR} re-converted into P_R by FAR-RED light and in darkness
- Plant detects P_{FR} concentration → reacts according to its developmental program



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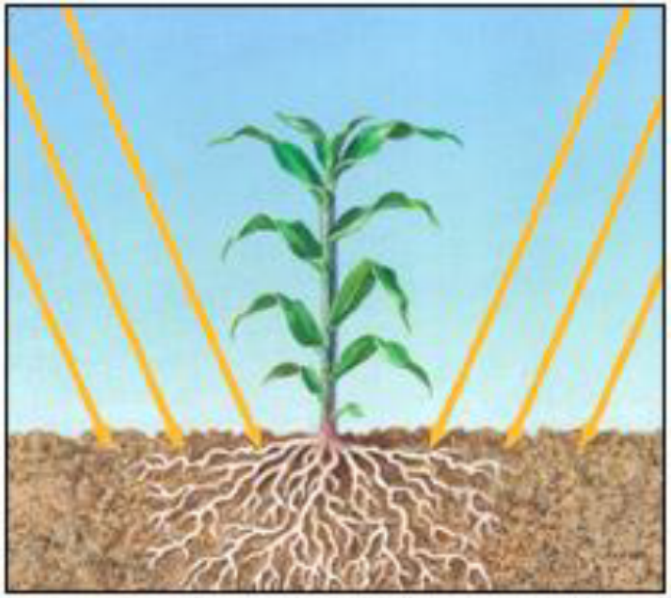
Shade avoidance reaction

- R:FR > 1.2 (sun light): normal plant development
- R:FR < 0.8
  - Under leaf canopy or from reflection by neighbouring plants
  - Etiolation
  - All energy to aerial parts
  - Decrease in root mass, making plants vulnerable to drought



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Light-dependent seed germination

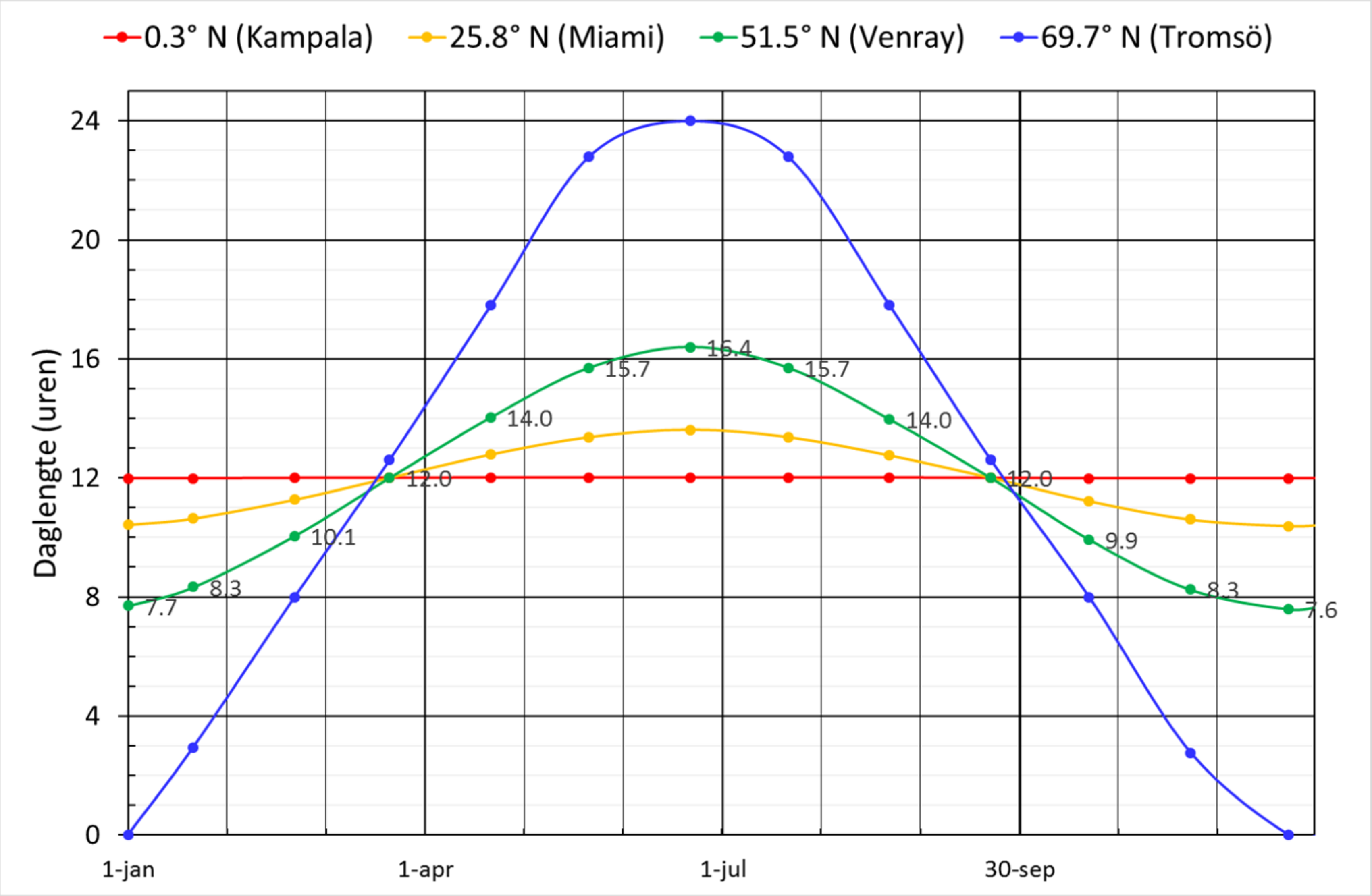
- Light germinators such as *Calluna vulgaris* or *Digitalis purpurea* require high P_{FR} for germination
- Under leaf canopy or in soil R:FR < 0.2 → low P_{FR}, high P_R
- Tree felling or soil disturbance brings light to seeds → increase in P_{FR} → germination

Light period (day length)

- Bean plant grown at 12 hrs DL under dim light

- Plant displays sleep-wake rythm

At higher latitudes, long days in summer

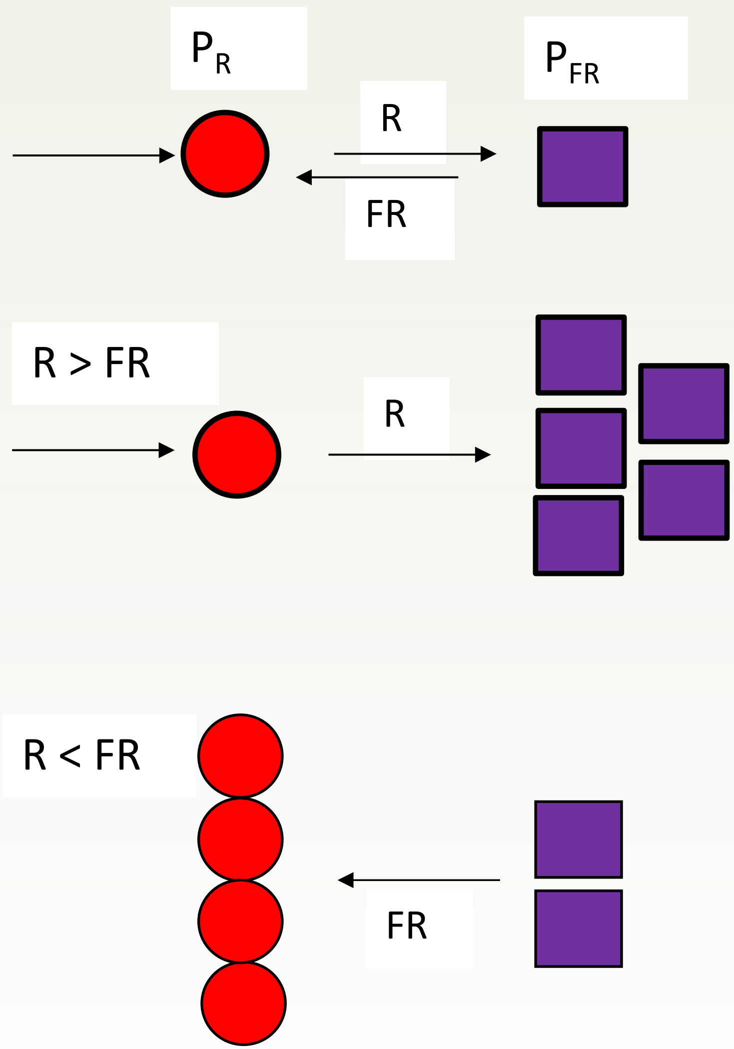


Whereas other climate factors vary each year..

- On each latitude the photoperiod is constant from year-to-year!

- Survival strategy at higher latitudes!
  - Shortening photoperiod → winter is approaching
  - Increasing photoperiod → summer is coming
- Many plant species and animals regulate their growth and reproduction cycle on photoperiod
- Sensing of day length mediated by Phytochrome

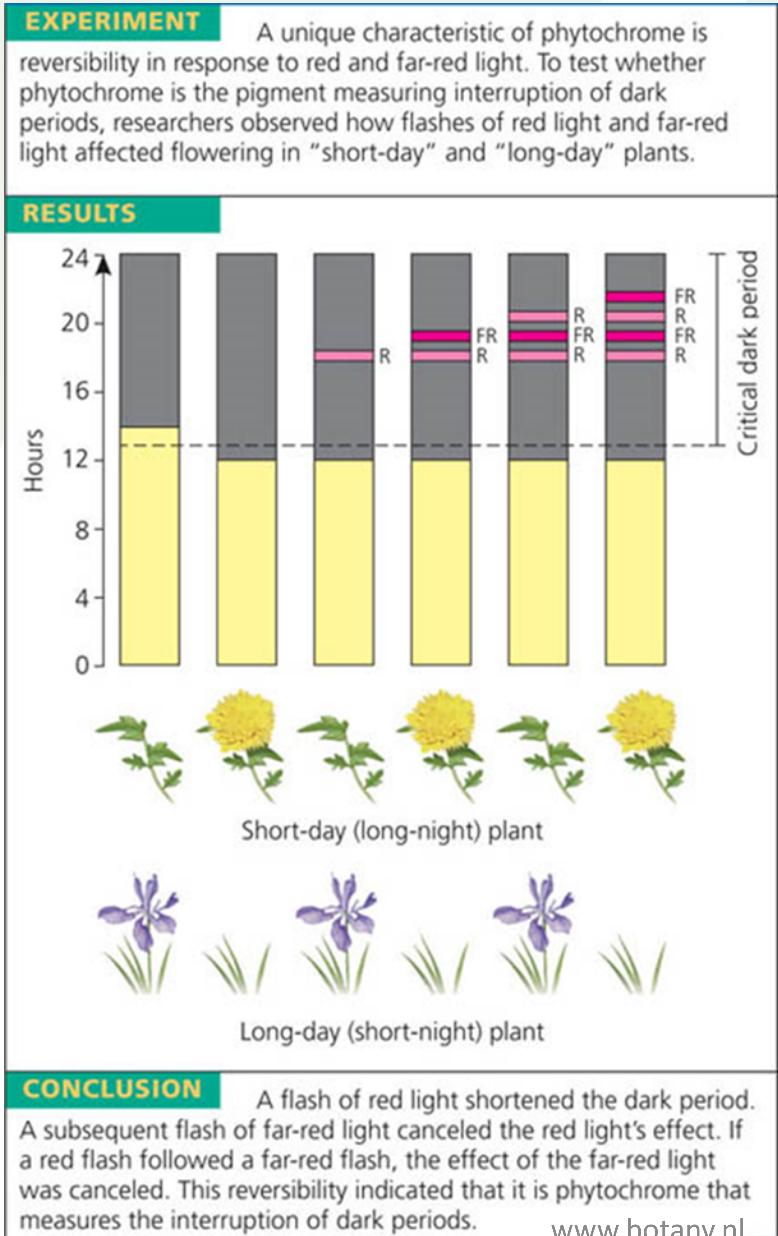
RED & FAR-RED receptor: Phytochrome



- P_{FR} re-converted into P_R by FAR-RED light and darkness
  - R:FR at sunset = 0.9-1.0 → changes P_{FR}-P_R ratio
- Plant detects decrease in P_{FR} and counts hours to next increase at sunrise
- A short flash of RED light during night will shift the P_{FR}-P_R ratio towards P_{FR}

Day length and flowering

- LDP will not flower at low P_{FR} → short night necessary for sufficient level of P_{FR}
- SDP will not flower at high P_{FR} → long night necessary to lower level of P_{FR}
- Short flash with RED will induce flowering in LDP and inhibit flowering in SDP
- Last flash counts!



Summary

- Light quantity = Energy for Photosynthesis = Growth = Basis for Food Chain
    - Chlorophyll, carotene (400 - 700 nm)
- Light quality = Developmental Program
    - Plant shape, elongation, branching, germination
    - 350-450 nm (UV-Blue) and 680-770 nm (Red-FR)
    - Cryptochrome, Fototropin, Zeaxanthanin, Phytochrome
- Light period (day length)
    - Internal clock, flowering, reproduction, dormancy, bud break
    - 680-770 nm (Red-FR), Phytochrome

Acknowledgements

- Dagmar De Greef, Min. of Education Flanders (B)

- Roger P. Hangarter, Dept of Biology, Indiana University, Bloomington IND, USA
  - Motto Indiana University: Lux et veritas = Light and Truth
  - http://plantsinmotion.bio.indiana.edu/plantmotion/starthere.html

- Ep Heuvelink and Leo Marcelis, Wageningen University and Greenhouse Horticulture