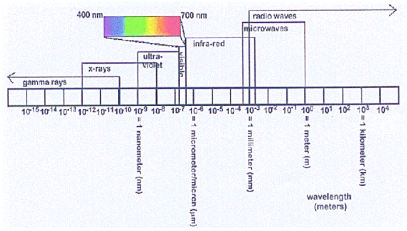
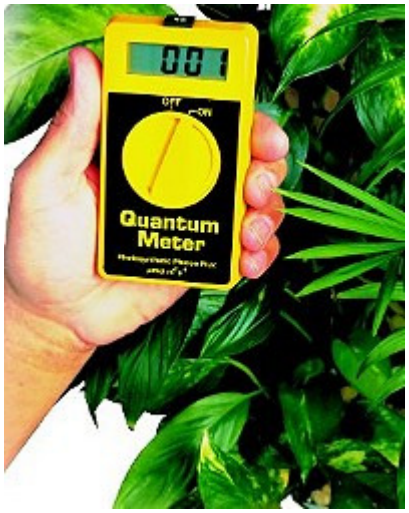
2.5 Light nature and measurement

Fact sheet objectives

- To discuss light
- To describe light measurements
- To illustrate applications



The electromagnetic spectrum showing the portion made up by photo synthetically active radiation (PAR).



A commercial handheld PAR light sensor

Spectrum
http://www.specmeters.com/Light_Meters/Quantum_Light_Meter.html

Nature of light

Light is a form of electromagnetic energy, similar to radiant heat and radio waves. Light is generally described as energy flow in the form of an electromagnetic wave, but in some applications a description of light as a flow of particles called **photons** is more useful.

Light has both colour and intensity. What our eyes sense as colour corresponds in technical terms to the **wavelength** of the light (usually expressed in millionths of a metre or nanometres). In general light is a mixture of wavelengths, known as a **spectrum**. Our eyes see a fairly narrow spectrum, and do not respond equally well to all wavelengths within this optical band.

Light is critical for plant growth, and plants respond to a similar range of wavelengths as our eyes. However plant response across this spectrum of wavelengths is different from the human eye response.

Light measurement

Photometry is the measurement of visible radiation; sensor response to different wavelengths is matched to the human eye response. **Luminous flux** is the amount of radiation coming from a light source per unit time, with units of **lumens** (lm). **Illuminance** is the density of luminous flux shining on a surface, measured in **lux** (lx, = lumen/m^2).

Radiometry is the measurement of light energy, regardless of the light wavelength, so power and energy units are used. **Radiant flux** is the amount of radiation coming from a source per unit time, measured in **watts** (W). **Irradiance** is the intensity of radiant flux shining on a surface, measured in W/m^2. Over a period of time (for example a day) the total amount of energy per unit area falling on a surface is measured in **joules** (J/m^2). In the case of sunlight the daily energy total is in the **megajoule** range (MJ/m^2).

In plant science, light is sometimes measured as **photosynthetically active radiation** (PAR), defined as radiation in the 400 – 700 nm band. Because photosynthesis is a light induced chemical reaction, units for PAR are taken from chemistry. The **einstein** (E) is equivalent to a mole of photons, and PAR is measured in micromoles or microeinsteins per second per square metre (μmol/s/m^2 or μE/s/m^2).

There is no simple conversion between photometric, radiometric and PAR units because of their dependence on wavelength. The conversion is different under fluorescent light compared with metal halide light, for example. However as a rule of thumb, full summer sun around the middle of the day on a horizontal surface is about 100,000 lux, 1000 W/m^2, and 2000$\mu E/s/m^2$.

Light incidence is affected mainly by cloud cover, solar angle (which is in turn affected by latitude and season) and air quality. Light incidence can be assumed to be reasonably constant on a scale of 5-10 km, at which local variations in cloud cover can be assumed to be small. For this reason it should be possible to obtain meaningful light incidence data from regional weather data loggers. All of the main HortResearch research station weather stations record light incidence.

Ultraviolet light

Ultraviolet (UV) light covers radiation extending from the blue end of the visible spectrum (400nm) to the x-ray region (100nm).

UV-A (400-315nm), also known as black light, represents the bulk of natural UV light and is the less energetic component.

UV-B (315-280nm) is the more aggressive component of natural UV responsible for sunburn. It is partially blocked by the ozone layer.

UV-C (280-100nm) is completely blocked by the earth's atmosphere, and hence is encountered only from artificial light sources.

Infrared light

Infrared (IR) light covers radiation extending from just beyond the red end of the visible spectrum at about 780nm (near infrared) through to wavelengths approaching microwave at about 10,000nm (far infrared). Far infrared waves are the radiant heat we feel from the sun or a fire. We do not detect near infrared as heat. Near infrared light has industrial and domestic applications such as TV remote controls and camera automatic focussing.

Sunshine hours

Sunshine hours are an older measurement of the sun's radiation, traditionally recorded by adding segments of a trace burned on special paper by the sun shining through a glass sphere.

Sunshine hours have fallen out of favour as a scientific measurement, but still have an appeal as a quantity that can be readily visualised.

Sunshine hours can be estimated from an electronic radiometric sensor, or recorded electronically by a specifically designed instrument.

A handheld Ceptometer PAR light sensor featuring a line of sensors on a bar that can be used by to estimate crop leaf areas.

Decagon Devices Inc.

http://www.decagon.com/accupar/APquests.html

Typical PAR light sensor used on modern dataloggers

Plant growth and development

Sunlight is vitally important for fruit tree productivity. However, most of the incoming energy from the sun is lost over the course of a year. Reasons for this loss are illustrated in the figure on the next page and include, among others, inefficiencies of photosynthesis and reflection of sunlight from leaves and other vegetation. More information on the importance of light can be found in the fact sheets on fruit quality.

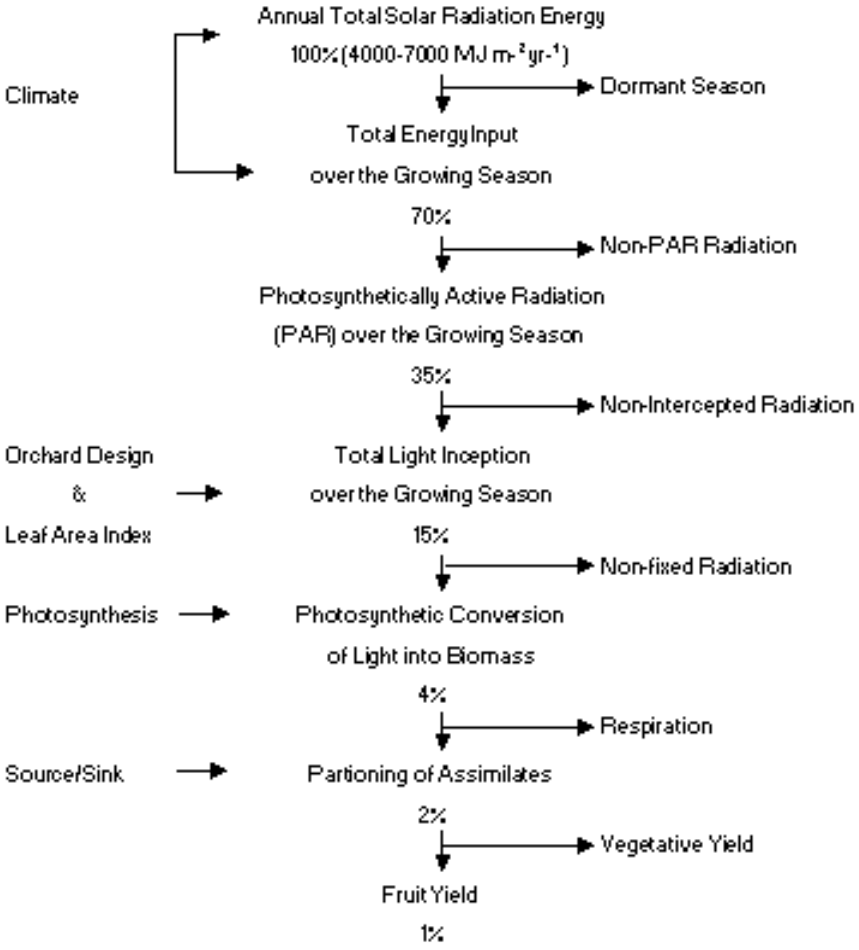


Figure: Annual total solar radiation and the factors which limit the efficiency of the conversion of light energy into fruit yield (estimates for apples). From Wunsche, J.N. 1993 (see web reference).

Summary Information

- Light radiation is part of the electromagnetic spectrum. Photosynthetically active radiation (PAR) used by plants to convert light energy into fruit yield is in the wavelengths 400-700nm
- Light measurements are an important tool in crop production research. Many different light sensors are now commercially available, but their practical use in crop management is still limited
- As the incidence of radiation is relatively consistent within regions, useful PAR records can be obtained from regional weather recording stations

Useful Websites

Sunlight, shoot type and crop load - how they affect apple yields

http://www.hortnet.co.nz/publications/science/jwunche.htm

A MAF Sustainable Farming Fund Project:

Sustainable Farming Fund
www.maf.govt.nz/sff

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