How Plants Tell Time

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Seasonal Flowering and Growth

- Garden plants show a seasonal flowering pattern, with some species flowering in the spring, others in the summer or fall, and some all summer long. So, how do plants know when to flower seasonally? How do they tell time?
- I have previously discussed the roles of different plant pigments - chlorophyll (green leaf), carotenoids (carrot colour-like), and anthocyanins (blue flower), with the former two involved in photosynthesis and the latter in the transport of compounds within plants.
- There is one other pigment present in leaves– phytochrome, which simply means "plant pigment", and this shape-shifting pigment influences seasonal plant activities.

Phytochrome

- When this pigment is in the dark for a period of time, it slowly reverts to a from that is called phytochrome red, or P_r for short.
- This reflects this pigment's capability to absorb red light, which after absorption, causes the pigment to more rapidly change into another form called phytochrome far-red, or P_{fr} .
- It's the plant equivalent of a "mood ring", but is is triggered by sunlight rather than the skin heat generated by different emotions.
- So what is far-red light? In a rainbow, there is red at the top and violet at the bottom in the visible light, but there are wavelengths beyond what we as humans can see – ultraviolet wavelengths below and far-red wavelengths above.

Far-red Light

- Although we cannot visually see this wavelength, plants can sense its presence.
- Far-red wavelengths are not used in photosynthesis, although red light is.
- This difference is what makes far-red light useful to plants, as leaves and other tissues contain a lot of it, and it is the ratio of P_r to P_{fr} that is present that is important to plants.
- If there is a lot of sunlight, i.e., red light, then most of the phytochrome will be in the P_{fr} form because red light fairly rapidly converts P_r to $P_{fr.}$
- However, if there is more far-red light than red light available, such as might occur beneath a dense canopy of actively photosynthesizing leaves above the plant, the phytochrome will mostly be in the P_r form.
- Simply put, the ratio of phytochrome forms tells plants whether there is enough of the right kind of light for photosynthesis, and plants respond accordingly.

Photodormancy Response to the P_r/P_{fr} Ratio

- A thick layer of mulch can prevent weeds from growing, but if you push some aside, weeds may suddenly explode in occurrence.
- Many plants have very small seeds, which aids in their dispersal by either wind or water, but this also means they have a small food reserve.
- To grow and survive, they need sufficient sunlight to get photosynthesis going before their stored food reserve is depleted.
- So, small seeds tend to be photodormant, meaning they will not grow unless they are exposed to photosynthetically-useful light.
- Below mulch, the P_r form is dominant, which stops growth even if sufficient water, oxygen and nutrients are present, sometimes for years, until a time when exposure to sufficient light occurs.
- That is why tiny garden seeds should be barely covered with soil before planting, while large seeds like beans or corn seeds can be buried more deeply.
- These latter seeds have sufficient food reserves to not be so influenced by light levels.
- This is another reason not to till soil excessively before seed planting, as not only does tilling negatively affect soil microorganisms but it also can expose small buried weed seeds to light, thereby triggering them to start growing.

Seasonal Dormancy

- Many small-seeded plants are also seasonal in their natural emergence, some being spring annuals (e.g., wild onions), while others are late summer plants, that may even grow through the winter.
- Seeds of seasonal plants can sit in full sun even with sufficient water and temperature and not germinate if the season is not appropriate.
- Such plants need to know what season it is, and this is where phytochrome becomes important.
- The ratio of P_r/P_{fr} also changes on a 24-hr timeframe, or photoperiod, and almost all plants and animals have an internal clock or circadian rhythm.
- In the northern hemisphere at our latitude, Dec 21 is the shortest day, with 8 hr of sunlight here. June 21 is the longest day, with about 18 hr of sunlight. On March 21 and Sept 21, there is about 12 hr of sunlight each day.
- This is the exactly the same every year, and it's this ratio of light and dark that phytochrome ratios can indicate to plants. The P_{fr} form changes to P_r either by far-red light (a rapid process) or by darkness (a slow process). In the summer plants have an abundance of P_{fr} in their tissues, while in the winter P_r dominates, and it's this change in the seasonal ratio of these compounds that allows annual seeds to know when to germinate.
- This is only part of the the alarm clock, though, even if it's the main one, as warm temperatures, sufficient water, and other factors can also be important determinators of exactly when a seed will germinate.

Circadian Rhythm

- Internal clocks are important not just for waking up but also for when to go to sleep, i.e., when to become dormant.
- Dormancy can be in anticipation of or response to temperature change to either cold winter temperatures or to very high summer temperatures. There may be occasional warm winter days or cooler summer days, and so seasonal dormancy allows plants to ignore these relatively short unseasonal temperature fluctuations.

The Seasonal Growth Pattern in Rhododendrons

- In the spring, flowers are the first to emerge from buds, most vigourously when the weather is warmest.
- As trusses fade, leaf buds expand and vertical growth is added through the spring.
- By midsummer, plant growth has virtually stopped and photosynthesis is being maximized, with next year's flower and leaf buds developing.
- By autumn, bud scales begin hardening to protect the plant from harsh winter conditions.
- Inside rhododendrons after June 21, they begin to start preparing for winter, as the gradually changing phytochrome ratio tells them that winter is on its way.
- The biochemical processes that get plants ready for winter are complex and time consuming (remember, the role of the anthocyanins in chemical transport) and must start long before the fall arrives, so that when the temperatures does dip low, the final touches to become fully cold hardy can be realized.

To Bloom or Not to Bloom

- Plants have been categorized as short day (autumn, winter and spring bloomers), long day (summer bloomers) or day neutral (continuous bloomers) plants based on their normal flowering times.
- However, it turns out that it was not day length that triggered blooming, but rather the length of the dark period, especially an uninterrupted dark period, which is measured within the plant by the phytochrome ratio.
- Short day plants such as chrysanthemums are more accurately long night plants, and it has been shown that even short interruptions (such as shining a bright flashlight on them for a short time) would increase the P_{fr} proportion, and if done over many nights, would prevent the critical P_{fr}/P_r ratio that initiates flowering to occur.
- Long night plants generally need at least 12-14 hours of uninterrupted darkness to flower, while short night plants generally need less than 10-12 hours of uninterrupted darkness to flower.
- Day neutral plants are really night neutral, and will flower whenever other environmental conditions are beneficial. Roses and dandelions are examples.

Human Sabotage of the Internal Clock

- Photochrome conversion is not sensitive to moonlight and starlight levels.

- However, incandescent lightbulb, fluorescent tube and high-intensity street lamps have the potential to influence phytochrome conversion.
- Solar-powered LEDS don't seem to have an effect on phytochrome.
- These effects may explain some of the odd flowering times of specific plants that may occur in our garden or home.
- Lights can also delay plants preparing for winter dormancy, which may cause tender tissue damage by winter freezes.
- Christmas cactus are long night plants that can be easily affected by lights in the home at night if they are too bright, which can prevent or minimize their flowering
- Poinsettias are even more sensitive to light, and require absolute darkness (not even a short turning on of lights, such as with a flashlight) for 12-14 hours before they begin flowering.