Plant behavior through the seasons: An overview of plant phenology

What is phenology?

"Phenology" is derived from the Greek word *phaino*, meaning to show or appear. Phenology refers to recurring, seasonal, plant and animal life cycle stages, such as leafing and flowering, maturation of agricultural plants, emergence of insects, and migration of birds. It is also the study of these plant and animal life cycle stages, especially their timing and relationships with weather and climate. Naturalists, farmers and gardeners, herbalists and hunters have always been attuned to these seasonal changes, and so there is much country lore about annual cycles and co-occurrences. In some European countries, the national weather service collects citizen reports on phenological data about common species, and these data are used in advising farmers about when to plant and harvest. Records of these data have provided important evidence about changes in climate in New England and around the world, and have other scientific value, as well.

This Brief provides basic background about key seasonal changes that are studied ("phenophases") in plants; other Briefs detail specific methods for data collection.

Plant phenophases

In this Brief, we focus on some key phenophases for flowering plants. (For other possible observations on flowering plants, and for phenophases for nonflowering plants such as conifers or ferns, see the USA-NPN Technical Report.) [1]

Note that, owing to plants' modular construction, phenophases do not take place all on the same day — some buds or flowers will open on one part of the plant, and later on others. In fact "all leaves (or flowers) open" is sometimes recorded as a phenophase. Some studies take measurements on several individuals, and compute an average time of appearance, or other statistic based on multiple observations or measurements.

Bud-burst, or bud-break. This is most often used in observing woody plants (trees and shrubs) at the onset of spring. A bud is considered to have broken or burst when the green tip of a new leaf is visible in the bud, but most of the leaf is still hidden behind the bud-scales.

Leaf out. The full shape of the leaf is visible. For most species, the leaf opens and then grows in size to its final "mature" size.

Leaves fully open. Leaves reach the point of full size for the season. Some studies examine the difference in size between first leaf-out and fully-open leaves. This is one of the measurements being taken as part of the Climate Lab.

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[1] USA-NPN National Coordinating Office. 2012. *USA-NPN Plant and animal phenophase definitions*. USA-NPN Technical Series 2012-004. www.usanpn.org.

For example, the observer might record when most of (the majority of) the leaves on an individual are fully open

Flowering. One or more flowers completely open on the plant (ready for pollination). Some studies record "first flower" observed in a location each year, some record the date on which all the flowers on an individual plant are observed to be open. Some studies note the first dates on which pollinators are observed on a species.

Fruit. Fruit first are visible, or first ripe fruit, or majority of fruits ripe. Some studies note when fruits of the target species begin to disperse (fruits fall to the ground, seed pods begin to shed seed, etc.)

Leaf color. One or more leaves turn to their late-season or autumn coloration.

Leaf fall. One or more leaves shed at the turn of the season (e.g. in the fall); or the date on which a tree of a particular species is almost completely bare of leaves.

What does it mean? How does phenology tell us about climate?

Phenological events are triggered by environmental cues taking place during the year. Thus, one year's observations are interesting, but don't tell us about trends. If, however, a phenophase takes place earlier and earlier (or later and later) than reported in the past, it suggests that the organisms are reflecting a real trend or shift. Many plant species in New England and around the world have been shown to respond to climate change with earlier leaf-out, earlier flowering, and later leaf-fall or senescence. Examples range from highbush blueberry and marsh marigold to trees like the red maple or oak. Moreover, some studies have shown that invasive species such as the garlic mustard may be more responsive than some natives, so that the invaders get an earlier start in the seasonal competition for light, space, and soil nutrients. Some species are changing their ranges northwards, but some may not be able to disperse over long distances fast enough to keep up with the shifting growing conditions that are best for them.

Beyond that, there are some species that are able to adjust their behavior to match the change in climate, and some that cannot. This means that seasonal events like bird migration and insect emergence will start to fall out of synchrony with flowering and fruiting. This causes problems for the animals that don't have food when they expect it, but also for plants that may not get pollinated, or may not have their seeds dispersed. Changes in seasonal temperatures can also lead to draining effort put into reproduction at the wrong time, reducing the ability of the plant to reproduce later in the year when success is more likely.