

Science
FINDINGS

INSIDE

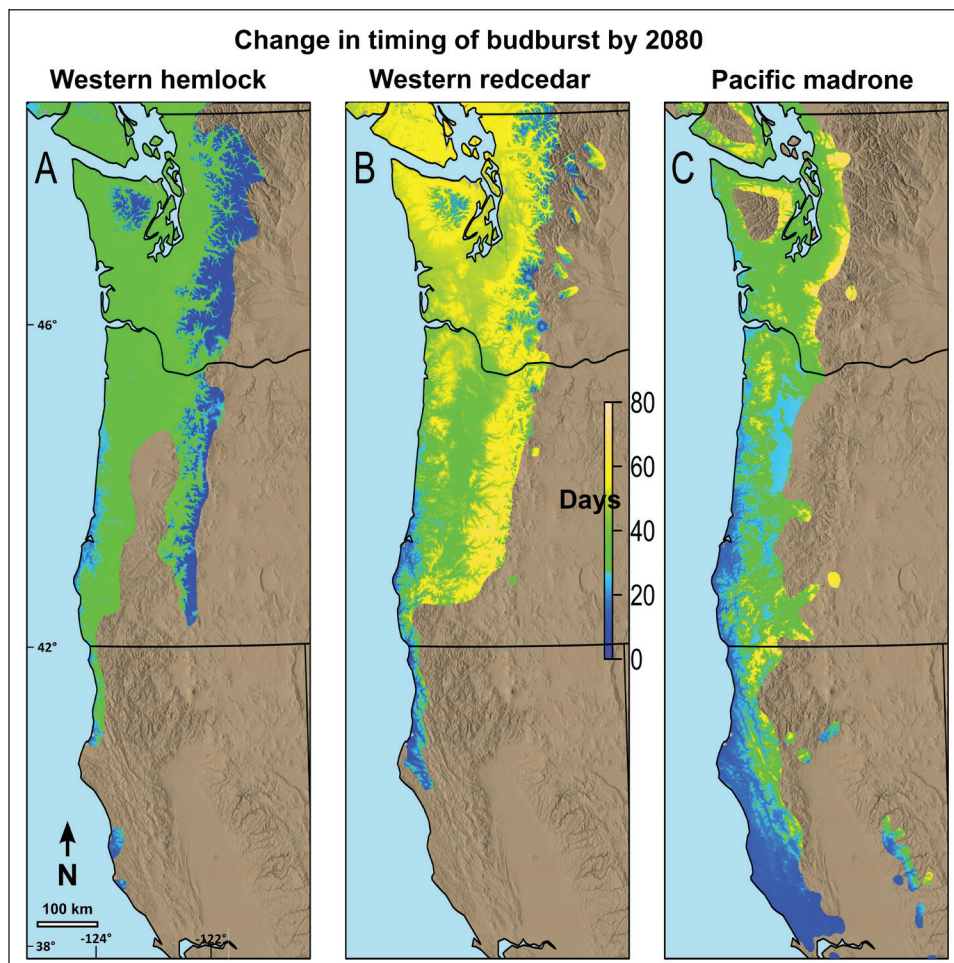
Tracking the Passage of Winter.....2
 Budburst Now and in 2080.....4

issue one hundred eighty three / march 2016

"Science affects the way we think together."

Lewis Thomas

Rise and Shine: How Do Northwest Trees Know When Winter Is Over?



Climate change will lead to changes in the timing of budburst for many tree species. These maps show how many days earlier budburst is projected to occur by 2080 within the native ranges of (A) western hemlock, (B) western redcedar, and (C) Pacific madrone.

"Spring is sooner recognized by plants than by men."

—Chinese proverb

Trees help mark the passage of the seasons: their new flush of leaves in spring; full leafy canopies in summer, cones and seeds that litter the ground in fall, and bare branches and steadfast evergreen

IN SUMMARY

Trees bursting forth with new leaves signal the arrival of spring. Budburst for most temperate tree species occurs after a tree has been exposed to a sufficient number of chilling and forcing hours over the winter. Waiting until these chilling and forcing hours have accumulated is a survival mechanism.

If a tree bursts bud prematurely, delicate tissue may be damaged by a late frost. Conversely, if a tree bursts bud too late in the spring, it will be unable to achieve substantial height growth before summer drought sets in. Although most Northwest tree species require a combination of chilling and forcing hours to promote budburst, the number of hours needed differs by species.

To identify the chilling and forcing requirements of 11 common Pacific Northwest tree species, scientists with the U.S. Forest Service, Pacific Northwest Research Station exposed seedlings to various combinations of chilling and forcing temperatures. They tracked the timing of budburst and created possibility lines that describe the combination of chilling and forcing hours required by each species. As the climate changes, the timing of budburst is also expected to change, so the scientists developed landscape models to predict when a species' budburst would likely occur in 2080.

boughs signal winter. And even as the leaves begin to cover sidewalks, next year's small buds await the arrival of spring.

In temperate climates, it is often assumed that winter dormancy is triggered by the cold. However, "The initiation of dormancy in the fall is not temperature driven; it's primarily triggered by shortening day lengths," explains Connie Harrington, a research forester with the U.S. Forest Service, Pacific Northwest (PNW) Research Station. "Trees will go dormant even in warmer winters. Dormancy is also triggered faster when the trees are under stress, such as when they experience extended periods of drought."

Budburst marks the end of dormancy, when the growing leaves literally burst through their protective bud scales. Cultures around the world have tracked the budburst of a variety of species from one year to the next, and these observations are examples of one of the oldest types of environmental sciences, phenology. This branch of science is derived from the Greek words *phaino* (to show or appear) and *logos* (to study). One famous phenology record is the flowering of the cherry trees in Japan, and the Chinese are credited with having the oldest phenology records, which date back to 974 B.C.

However, observing when a tree bursts bud does not reveal how the tree knows when winter is over. "There have been thousands of studies on dormancy on many plants, including fruit trees and agricultural plants, and which genes are activated as part of going into

KEY FINDINGS	
• Trees have mechanisms that sense the passage of winter by tracking the accumulation of chilling (cool temperatures) and forcing (warm temperatures). Species have evolved to require different combinations of chilling and forcing hours to promote budburst.	
• Most tree species in the Pacific Northwest require a minimum amount of chilling to successfully burst bud. Well-chilled plants require fewer hours of warm temperatures for budburst than plants that have received less chilling.	
• The number of chilling and forcing hours required by a tree species to promote budburst can be modeled as its possibility line. Comparing the possibility lines of different species predicts the relative timing of budburst by species under a range of conditions.	
• The timing of budburst will likely change in the future as the climate warms, but differences in timing will vary by species and location of a population within its range. Although budburst is generally predicted to occur earlier in 2080 than today, budburst in some tree species in low-elevation coastal locations in the southern portions of their ranges may occur later due to a lack of chilling. As a result, these trees may be unable to complete their height growth before droughty conditions occur.	

and out of dormancy," Harrington explains. "But what we still really don't understand is how plants keep track of the winter temperatures and know when to break dormancy."

During dormancy in the Pacific Northwest, trees experience a wide range of temperatures, from below-freezing to mild 55 °F degree

days. For many tree species, they "need to experience a certain amount of chilling before they are able to come out of dormancy," says Peter Gould, formerly a research forester with the PNW Research Station and now a research analyst with the Washington Department of Natural Resources.

TRACKING THE PASSAGE OF WINTER

Just as dormancy is not triggered by cold temperatures, its end is not triggered by the first warm days in spring. Budburst occurs when conditions are favorable for growth and there is little risk of the delicate new growth being damaged by frost. "When trees are bursting bud in April, the

daily temperatures are not necessarily a lot warmer than they might have been during a few days in January. Yet there is a mechanism that keeps the tree from bursting bud too soon. Trees have evolved this mechanism to keep them from growing at the wrong time of year," Harrington says.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

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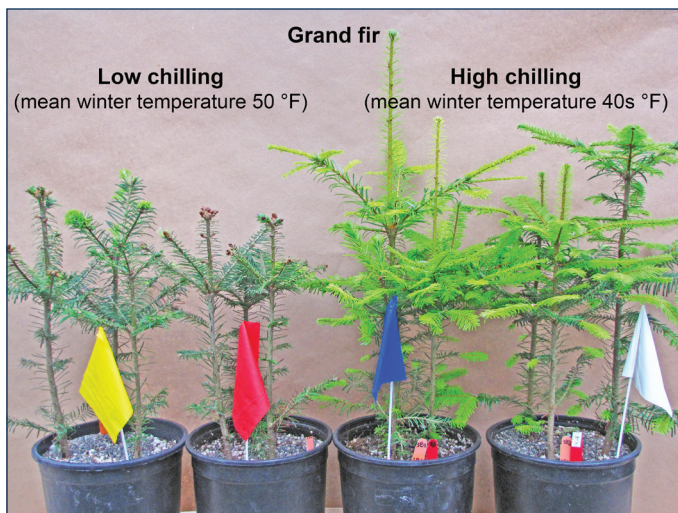
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Seedlings are moved from a heated greenhouse on the left to lath house with open sides on the right to expose them to different combinations of chilling and forcing temperatures.

Connie Harrington



Connie Harrington

Grand fir
Low chilling (mean winter temperature 50 °F) **High chilling** (mean winter temperature 40s °F)

True firs are quite sensitive to lack of chilling. Trees exposed to less chilling (yellow and red flagged pots) had less new growth for the year (bright green needles), whereas trees exposed to more chilling (blue and white flagged pots) had more new growth.

Climatologists predict the Pacific Northwest will experience warmer summer and winter temperatures in the future, which means the timing of budburst will be even more critical. Harrington explains, “As the climate becomes warmer, you want trees to burst bud a little earlier than they do now so that they can still take advantage of the good growing conditions before the summer dry period. But you don’t want them bursting bud so early that they could be damaged by frost.”

Most Pacific Northwest tree species require chilling temperatures to promote normal budburst. If trees have not spent enough hours during the fall and winter under chilling temperatures, the timing of spring budburst could be delayed. This could reduce growth because the trees may not have enough time to complete their normal period of height growth before the summer drought sets in. Not only could this potentially affect forest health, but also the diversity of tree species found across the landscape.

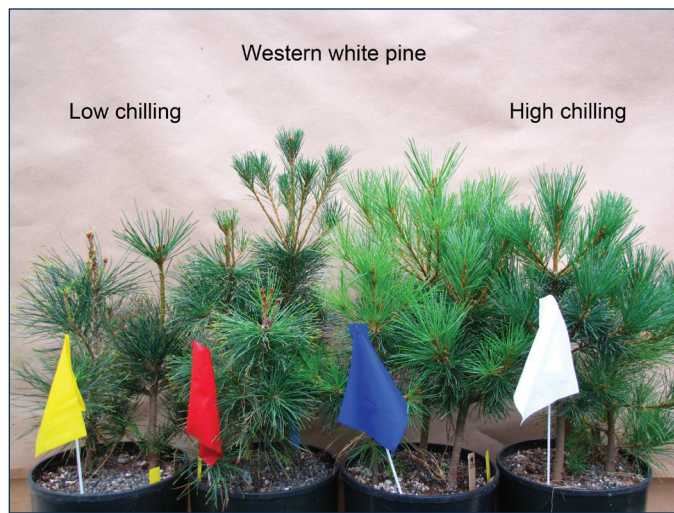
“Not all tree species are going to react the same way to a changing climate,” says Robyn Darbyshire, regional silviculturist for the Pacific Northwest Region of the Forest Service. “Many people have this idea that the tree species groupings we see today have always been together. Part of climate change education is understanding that these groupings will not shift together as a result of climate change. Each tree species will react in its own way to a warmer climate, as it is genetically programed to react.”

To learn how different species will react to a changing climate, Harrington and Gould expanded upon one of their earlier studies, which focused primarily on Douglas-fir and the effects of chilling and forcing (warm-

ing temperatures) on the timing of its budburst. Although other researchers had observed that the timing of budburst is affected by the length of time a plant experiences chilling or forcing temperatures, Harrington and Gould’s study was the first to model the timing of budburst with temperature data in a way that allowed them to predict the timing of budburst over a large landscape. Their models included developing what they termed “possibility lines,” which graphically depict the tradeoffs between chilling and forcing temperatures on budburst.

“People who studied dormancy in the past were often trying to determine the optimum temperatures for chilling, so the temperature range which was most effective was pretty well known. But past trials often only studied the effects of chilling in the optimum range; they hadn’t really looked closely at what the shape of the relationship between chilling and forcing would look like across a wider range of temperatures,” Harrington explains.

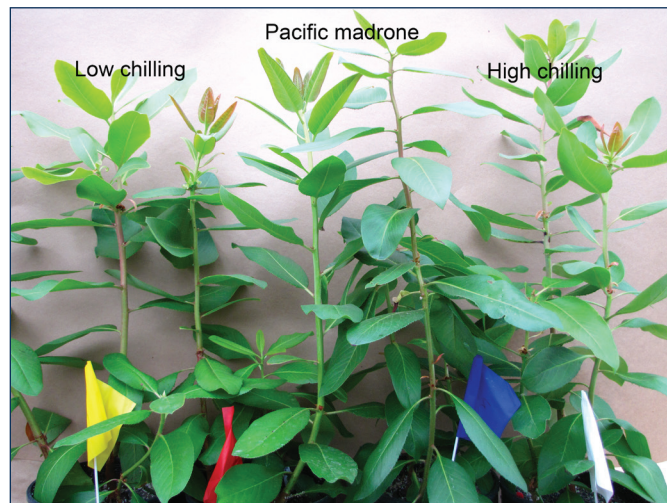
To see if the timing of budburst in other Northwest tree species would be affected by an increase or decrease in chilling and forcing temperatures, Harrington and Gould exposed 11 common tree species to several combinations of chilling and forcing tem-



Connie Harrington

Western white pine
Low chilling **High chilling**

Western pines are also quite sensitive to a lack of chilling. Note the reduced needle area on the new growth on the seedlings on the left in the yellow and red flagged pots. The plants with low chilling also are more likely to have multiple tops.



Connie Harrington

Pacific madrone
Low chilling **High chilling**

Madrone has a low chilling requirement. It burst bud normally and grew well in all treatments.

peratures. “In this study, we wanted to include as many major species as we could, such as western hemlock, western redcedar, western larch, and several species of pine and true firs. We also had the good fortune of including Pacific madrone because there was a researcher in Puyallup who was working on madrone and she had extra seedlings to contribute,” Harrington says. This study also examined the timing of budburst at the population level for some species to determine whether differences existed among populations.

The experiment spanned 3 years and was conducted in the greenhouse and outside beds at the PNW Forestry Sciences Laboratory in Olympia. Because of the logistics involved with monitoring a sample size of 800 seedlings or more and moving 1- to 3-foot-tall seedlings back and forth between chilling and forcing temperatures, Harrington and Gould

studied a few species each year. The following year, they replicated the treatments on another batch of seedlings to confirm the previous year's results.

For each species, a select number of seedlings were assigned to one of five treatments. These treatments ranged from a warm treatment in which seedlings spent the fall and winter in a heated greenhouse to a cold treatment where seedlings were outside all winter. Intermediate treatments had the seedlings moved back and forth between the warm and cold environments to experience a range of chilling and forcing temperatures. The trial started in October and each week on “moving days,” seedlings in pots flagged with a certain color were moved from the greenhouse to the outside or vice versa. Temperature data loggers

tracked the number of hours the seedlings experienced in each temperature. The scientists also monitored the seedlings throughout the summer, noting how the combination of chilling and forcing temperatures affected their subsequent growth and appearance.

Although most conifer species have discernable buds at the tips of their branches, which made assessing the timing of budburst easy, western redcedar was a bit more challenging. “Western redcedar doesn’t have a bud, and so for the cedars, we would actually make a mark on the stem using nail polish and measure from that mark,” Harrington says. “Once the length of the shoot was about a half inch greater than it was when we started measuring them in the fall, we concluded that the seedling had initiated height growth.”

Exposing seedlings solely to greenhouse temperatures, which prevented them from experiencing chilling temperatures, revealed that chilling affected the normal development of the seedlings in the spring—as well as the timing of budburst. Most of the pine and true fir seedlings that received very little chilling did not grow a full complement of needles, and often the side buds burst but not the terminal bud, which is responsible for height growth. As a result, they became more bush-like because growth would shift from what had been the main stem to one or more side branches. The scientists also noticed that if the terminal bud and many of the lateral buds did not burst bud quickly or normally, the seedling developed fewer new needles.

BUDBURST NOW AND IN 2080

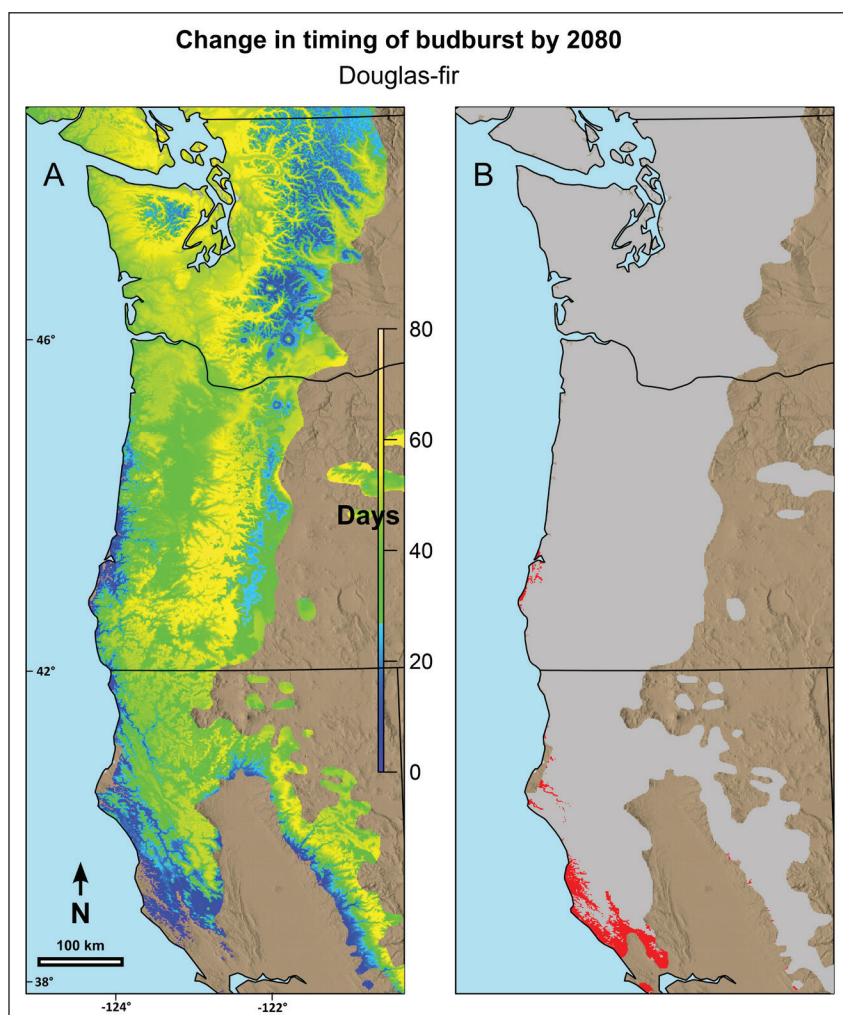
“The general public notices when the trees burst bud in the spring; people say things like ‘springs a spring, plants are bursting bud,’”

Harrington says. “Our work is taking those observations and developing a mathematical relationship—called a possibility line—that allows us to predict when budburst will hap-

pen from year to year and at different locations on the landscape and, when combined with climate projections developed by climatologists, when it will happen in the future.”

A possibility line is the combination of the chilling and forcing temperatures that are required for budburst. The area above the line represents the combination of temperatures where budburst is possible; the area below the line indicates where budburst is not possible. Each species has its own possibility line. For example, when western larch is exposed to many hours of chilling, it does not need as many hours of forcing temperatures for budburst to occur compared to other Pacific Northwest conifers. In contrast, when western hemlock experiences high levels of chilling, it requires more hours of forcing temperatures before budburst occurs. Madrone and redcedar were different than the other species studied because they did not require chilling for growth to begin and thus, they were capable of bursting bud under a wide range of forcing and chilling temperatures.

To predict when budburst will occur under different climates, Gould and Harrington created models that projected budburst for the 11 tree species in 2080 based on their possibility lines. Sixty-five years isn’t that far off, given the lifespan of a tree, and the fact that some of the studied species are grown on harvest rotations of 40 to 80 years. What further complicates forest management is that the climate is not expected to change uniformly. Localized conditions may lead to greater or lesser change in certain areas. Species that can shift the timing of their budburst to stay in the sweet spot between frost and drought will have an advantage over species that cannot shift their timing. Warmer winters may cause a species’ range to constrict or expand

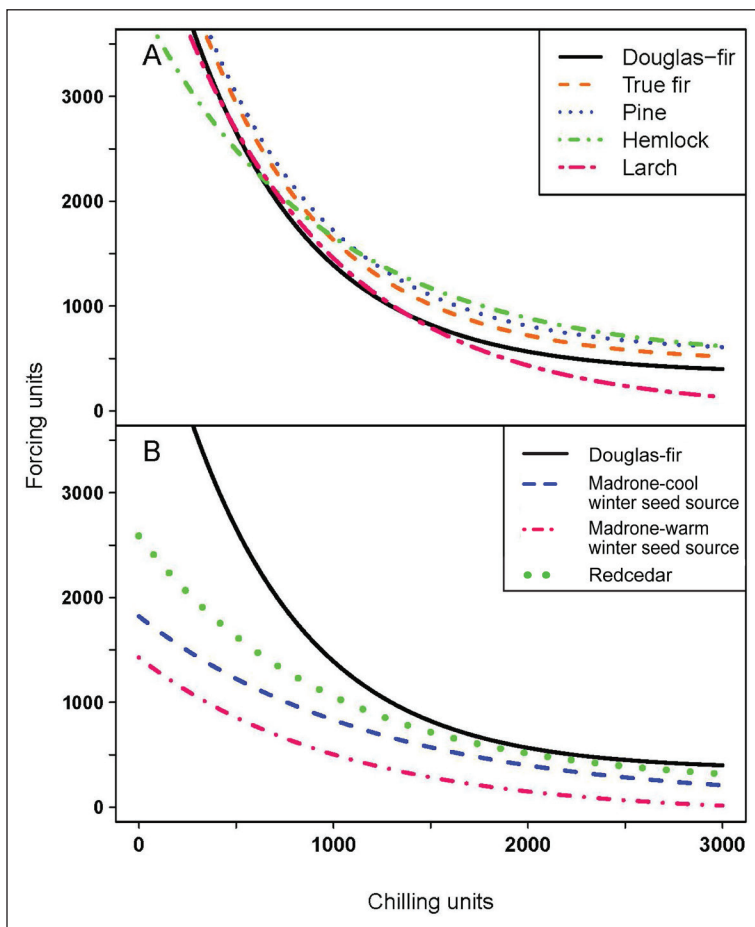


For Douglas-fir, trees in some areas are projected to burst bud more than 60 days earlier by 2080 (left panel) while trees in locations with warmer winter temperatures are projected to burst bud later than they do currently (red areas in right panel).

depending upon its chilling requirements for dormancy.

That's one reason why these modeling projections are valuable for land managers and silviculturists, like Robyn Darbyshire: "As we learn more about how the physiology of these species differ in respect to climate change, this might affect how we might tend those stands after they are established, such as doing more management to maintain one species on the landscape versus another."

Yet modeling a species' possibility line does not fully reveal when budburst will occur, because each population within a species has its own timing. This timing is a result of populations, through natural selection, being adapted to their local environmental condition. Harrington and Gould studied many populations of Douglas-fir, but only two to three populations of the other species. For silviculturists, having possibility lines for populations, will help them decide which seed source to use for reforestation. "There are differences amongst populations," Gould says.



By combining information on the chilling and forcing (warming) temperatures associated with budburst, scientists developed possibility lines for each tree species. Points on or above the line for a species indicate combinations of chilling and forcing where budburst is possible. Points that fall below the species' possibility line indicate combinations of chilling and forcing where budburst is not possible.



LAND MANAGEMENT IMPLICATIONS



- Many tree species may continue to experience sufficient chilling in their current ranges so range contractions are unlikely to occur by 2080. However, individual trees that experience fewer chilling hours may have reduced growth and poor form.
- Tree growth may be unchanged or enhanced in areas where the timing of budburst is predicted to occur early enough in spring for trees to complete their height growth prior to summer drought. Mid- to high-elevation areas will experience more chilling hours in the future, which may result in improved growth.
- Some species may exhibit poor growth and poor form where predicted climate change is expected to result in winter and fall temperatures too warm to provide effective chilling.
- Although each species has a general possibility line, populations within species may also have distinct possibility lines.

"With information about future climates and an understanding of the population's possibility line, you may choose a seed source that is

better adapted to future climate in terms of bursting bud at the right time."

"We must consider the distinctive characters and the general nature of plants from the point of view of their morphology, their behavior under external conditions, their mode of generation, and the whole course of their life."

—Theophrastus, Greek scientist considered the father of botany

FOR FURTHER READING

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