SEASONAL FOLIAGE DISCOLORATION AND LOSS IN PACIFIC NORTHWEST EVERGREEN CONIFER TREES

Introduction

A hallmark of fall is leaf color change and drop, which is a phenomenon predominantly associated with deciduous broadleaf trees. However, some foliage on evergreen conifers also turns shades of yellow and orange in the fall and is subsequently shed. This is particularly noticeable on western redcedar (*Thuja plicata*), where splotches of bright orange are highly visible and can causes alarm for homeowners and small forest landowners because it is mistaken for a forest or tree health issue. It is actually a normal, annual function that does not mean something is wrong with the tree. This publication explores the different foliage retention strategies of trees, the phenomenon of seasonal foliage loss on evergreen conifers and how it differs from deciduous trees, and other seasonal color variations in Pacific Northwest (PNW) conifers that may look unhealthy but are generally harmless.

Background

Conifers vs. Broadleaf Trees

Trees are divided into two key types: conifers and broadleaf trees. Conifer means cone-bearing. Native Pacific Northwest (PNW) conifer trees are either in the pine (Pinaceae), yew (Taxaceae), or cypress (Cupressaceae) family. Trees in the pine and yew families have needle-like leaves and include trees like Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), lodgepole pine (*Pinus contorta*), and Pacific yew (*Taxus brevifolia*), while trees in the cypress family usually have awl- or scale-like leaves, such as Rocky Mountain juniper (*Juniperus scopulorum*) and western redcedar. Broadleaf trees have wider, flatter leaves. Native PNW broadleaf trees come from a variety of families and include trees like bigleaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and black cottonwood (*Populous trichocarpa*).

Evergreen trees have leaves year-round, whereas deciduous trees spend part of the year without leaves due to seasonally unfavorable growing conditions (Kikuzawa 1991). The term *conifer* is often used synonymously with the term *evergreen*, as most conifers keep their foliage year-round. Similarly, the term *broadleaf* is often synonymous with *deciduous*, as most broadleaf trees shed all their foliage in the fall. These characterizations do not always hold true, though. For instance, larches (*Larix* spp.) are deciduous conifers and Pacific madrone (*Arbutus menziesii*) is an evergreen broadleaf tree. Even "conifer" can seem like a misnomer sometimes, as yews and junipers have modified cones that are fleshy, berry-like structures. Other terms include *angiosperms* ("seeds in vessels"), describing broadleaf trees, since their seeds develop in an ovary (fruit), and *gymnosperms* ("naked seeds"), describing conifers, since their seeds do not develop in an ovary.

Leaf Habit

Leaf habit refers to whether a tree is evergreen or deciduous. There are trade-offs between evergreen and deciduous foliage. The resources a tree needs to construct foliage is roughly the same for the two foliage types per unit of mass (Villar et al. 2006; Villar and Merino 2001; Wright et al. 2004). Evergreen trees use their foliage for multiple years, but making the foliage durable enough to last multiple years comes at a cost of lower photosynthetic capacity (i.e., productivity) such that the tree needs multiple years to recoup the resource investment. Deciduous trees only use their leaves for one growing season, but the leaves are highly productive such that the tree only needs one growing season to recoup its resource investment (Givnish 2002; Kikuzawa 1995; Wright et al. 2004).

Both evergreen and deciduous strategies are effective in many environments, and both types of trees successfully grow together in many ecosystems (Kikuzawa and Lechowicz 2011; van Ommen Kloeke et al. 2012; Wright et al. 2004). Evergreen trees have lower productivity rates than deciduous trees, but they can be productive for more of the year, as they are able to

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photosynthesize later into the fall and earlier in the spring when deciduous trees are not leafed out (Givnish 2002; Stephenson 1990). Some evergreens can even photosynthesize during periods in the winter if air and soil temperatures are warm enough (Chabot and Hicks 1982; Sevanto et al. 2006; Schaberg 2000). This extended growing season can give evergreen trees an advantage on low-productivity sites, as the site limitations force deciduous trees to photosynthesize at lower rates than they otherwise could. With both the evergreen and deciduous trees photosynthesizing at relatively low rates (the evergreen trees inherently and the deciduous trees because of site limitations), the evergreen trees have the advantage because they can photosynthesize over a longer period. Evergreen trees also have lower soil nutrient needs, giving them a particular advantage on nutrient-poor sites (Aerts 1995; Stephenson 1990; Givnish 2002).

Evergreen trees also have advantages over deciduous trees when the warm season is also the dry season. In most temperate forests, including the eastern U.S., deciduous trees dominate because summers are wet. The combination of ample warmth and moisture allow deciduous trees to better utilize their seasonal high productivity potential. In the western U.S., where summers are droughty, deciduous trees are at a disadvantage because the time of the year when they are leafed out coincides with low availability of water and nutrients. In this region, the ability of evergreens to photosynthesize in the shoulder seasons of fall and spring when temperatures are above freezing and moisture is available is the key to their success. This is particularly true west of the Cascades where winters are mild, providing evergreens with a long growing season (Givnish 2002; Prentice et al. 1992; Stephenson 1990). PNW conifers, which are evergreen with the exception of larches, enjoy these advantages as well as the advantages of their conical crown shapes that are better able to capture sunlight in the overcast or low sun angle conditions that characterize PNW winters (Waring 1982; Waring and Franklin 1979).

Normal Foliage Loss in Evergreen Conifers

A Seasonal Phenomenon

Just like their deciduous counterparts, evergreen conifers shed foliage in the fall. However, they are only shedding their innermost foliage, which may be several years old. Over time, the photosynthetic productivity of foliage decreases due to shading from newer foliage, internal wear and tear, pathogen and insect damage, and dirt that accumulates on the surface. Abscission of older foliage occurs when either more resources are used by the tree to maintain it than the tree recoups via photosynthesis or the tree would obtain a net gain in productivity by transferring resources from the older needles to the newer, more productive needles (Kikuzawa and Lechowicz 2011). In other words, trees maximize profit in terms of gains from continued photosynthesis relative to the cost of leaf maintenance, and they maximize return on investment in how they allocate their existing assets. The "leaf economy" has been compared to the human economy, with trees acting similar to corporations (Villar et al. 2021).

The Curious Case of the Larches—Deciduous Conifers

The most extreme examples of seasonal foliage loss in conifers are the larches, which are deciduous conifers that drop all their needles in the fall. Two larch species are native to the Pacific Northwest: western larch (*Larix occidentalis*) and alpine larch (*Larix lyallii*). Larches inhabit sites at some of the highest elevations and most northern latitudes that trees can grow. These are areas characterized by particularly harsh winter conditions consisting of both low temperatures and low sunlight. The evergreen advantage does not work out nearly as well under these conditions, as there is less shoulder-season opportunity for photosynthesis and even higher energy requirements to construct foliage that can tolerate the more extreme conditions. The larch's strategy is to be deciduous, producing "cheap," disposable foliage that is highly productive during the growing season but has to be replaced annually (Figure 1). It is particularly advantageous to be a deciduous conifer in these environments, as the tall, narrow crown that is characteristic of conifers provides the best balance between light-collecting ability and resistance to damage from snow and ice accumulation at high elevations and latitudes, compared to the shorter, broader crowns of broadleaf trees (Gower and Richards 1990).

Figure 1. Larches are deciduous conifers, with all of their needles turning gold and dropping in the fall. Photo: K. Zobrist.

Pacific Madrone—An Evergreen Broadleaf Tree

Pacific madrone (*Arbutus menziesii*) (Figure 2) is one of only two evergreen broadleaf trees native to Washington, and by far the more common one. The other species is golden chinkapin (*Chrysolepis chrysophylla*), which is rare in Washington, only occurring in a couple of small, isolated populations (Zobrist 2014). Madrones keep their leaves for one and a quarter year, with the prior year's leaves falling in June after the new year's leaves are fully grown (Reeves 2007).

Figure 2. Pacific madrone is an evergreen broadleaf tree, keeping its leaves for one and a quarter year. Photo: K. Zobrist.

During abscission, foliage turns color and falls off the tree, similar to what happens to the foliage on deciduous trees. During this process, while the appearance of the tree may be somewhat alarming, it is part of normal conifer "housekeeping" and growth and will resolve itself with the changing of the seasons. The foliage that has turned orange or brown will be blown out of the tree with the fall winds. If the tree is otherwise healthy, it should look much better by the end of December.

This seasonal phenomenon tends to be highly visible in western redcedar because of the nature of its foliage; it has overlapping scales for foliage instead of individual needles. Thus, instead of small individual needles turning color, entire branchlets turn color. This is referred to as *flagging* (Figure 3). A closer inspection will reveal that the dead foliage is the oldest, innermost foliage (Figure 4).

Seasonal foliage loss can also be particularly noticeable in pines as well. Pines have longer needles than other conifers and a more open architecture that makes the branch interiors more visible (Figure 5). Pines also tend to have a relatively short foliage retention period, as long leaf length is associated with shorter leaf retention periods (Smith et al. 2019). In contrast, seasonal foliage loss is not very noticeable in conifers like Douglas-fir or western hemlock, as the small needles turning brown on the interior of the branches are not readily visible. The activity is revealed later in the season, though, when streets and roofs become carpeted with dead needles as they blow out of the trees with the fall winds (Figure 6).

Figure 3. Fall flagging in western redcedar. Photo: K. Zobrist.

Figure 4. The foliage being shed is the oldest, innermost foliage. Photo: K. Zobrist.

Figure 5. Seasonal foliage loss is also readily visible in pines. Photo: K. Zobrist.

Figure 6. Douglas-fir needles accumulating on the ground in the fall. Photo: K. Zobrist.

Leaf Longevity

The length of time that a conifer will retain its foliage varies by species but usually ranges from one to ten years (Smith et al. 2019). In western Washington, average leaf retention has historically ranged from three to nine years for coastal Douglas-fir, four to seven years for western hemlock, two to five years for western redcedar, nine to eleven years for Sitka spruce (*Picea sitchensis*), and four to ten years for grand fir (*Abies grandis*) (Pease 1917).

Location, site condition, tree age, foliage position in the tree, and recent weather conditions can influence retention times. In a given species, foliage generated in more resource-limited environments will tend to be retained longer, as a longer payback period is needed for the tree to recoup the cost of its investment (Kikuzawa et al. 2013; Kikuzawa and Lechowicz 2011; van Ommen Kloeke et al. 2012). In other words, a tree growing on a colder, drier, or more nutrient-poor site will keep its foliage longer than a tree of the same species growing on a warmer, moister, or more nutrient-rich site. Foliage retention for a given species can even vary on the same site depending on canopy position, with trees growing in the shadier lower canopy keeping their foliage longer than trees growing in the upper canopy (Kikuzawa and Lechowicz 2011). For instance, Harlow et al. (2005) found that the average foliage retention time for western redcedar in northern Idaho is 6.8 years on upper canopy trees compared to 10.6 years on lower canopy trees.

Drought Impact on Seasonal Foliage Loss

Foliage that is produced in unfavorable conditions, such as a dry or nutrient-poor site or a low-light understory environment, will tend to last longer because it takes the tree longer to recoup its investment. In contrast, foliage that is produced under favorable conditions but suddenly subjected to unfavorable conditions may be shed prematurely (Kikuzawa and Lechowicz 2011). An excessive summer drought can accelerate seasonal foliage loss in evergreen conifers. The annual foliage loss process may begin earlier in the year, and there can also be an unusually high level of seasonal foliage loss that year. For example, a tree that may have normally shed only its seven-year-old foliage may shed its five-, six-, and seven-year-old foliage in an extreme drought year. The accelerated leaf shedding is a drought survival strategy, as less foliage means less overall water demand and water loss. Even though the leaves being shed may not have paid back the tree's investment cost, in a survival situation, it may be better for the tree to cut its losses, reallocate resources from the less-productive older foliage to the more-productive newer foliage, and shed the older foliage prematurely to reduce the tree's water demand (Dallstream and Piper 2021; Munné-Bosch and Alegre 2004; Stephenson et al. 2018).

Drought can also alter the timing of fall color change and leaf drop in deciduous species. The effect seems to differ by tree species, with drought accelerating color change and leaf drop in some species (e.g., Figure 7) but delaying it in others (Dallstream and Piper 2021; Xie et al. 2018). The interaction between drought and other stressors may also dictate how the

timing changes for these events. Xie et al. (2015) found that high drought stress delayed fall color change and leaf drop in New England deciduous trees, but a combination of moderate drought stress and high heat stress accelerated these events instead. Ultimately, changes to the timing of fall color change and leaf drop in deciduous trees in response to drought appear to be tied to multiple variables, including tree species, severity of drought, and the combination of drought with other stressors.

Accelerated seasonal foliage loss in either evergreen or deciduous trees under drought conditions is not necessarily cause for concern or an indication that the tree is dying. Rather, the tree is employing strategies to mitigate the impacts. It does indicate that the drought is causing stress, though, and continued or additional stress could cause more serious problems at some point.

Figure 7. Premature leaf senescence in quaking aspen (*Populus tremuloides*) in Snohomish County, WA, during a record summer drought. Photo: K. Zobrist.

Other Nonserious Seasonal Foliage Discoloration and Loss in Evergreen Conifers

Winter Bronzing

Another seasonal foliage discoloration that occurs in the winter is bronzing on western redcedar, especially on seedlings (Figure 8). Plants produce pigments as protective chemicals. For instance, some plants will produce anthocyanins in response to a variety of different environmental stressors, causing leaves to turn red (Chalker-Scott 2016). In the case of western redcedar in the winter, the tree produces a purple carotenoid pigment called rhodoxanthin in response to a combination of sun exposure and low temperatures. The tree's ability to photosynthesize decreases with decreasing temperatures. In bright sunlight, the foliage is then exposed to more light than it can utilize for photosynthesis, so the tree produces rhodoxanthin to protect the foliage from damage due to the excess light energy beyond that which it can use at the lower rate of photosynthesis. This winter sunscreen gives the sun-exposed foliage a bronze color, while shaded foliage remains green (Han et al. 2004; Solovchenko and Neverov 2017; Weger et al. 1993). This does not result in foliage loss; it is simply a seasonal color change. The bronze foliage will green up again in the spring, as this process reverses when temperatures warm up again.

Winter Desiccation

Winter desiccation, also called parch blight, can cause needle discoloration and loss in the Cascade foothills of western Washington and Oregon when unseasonably warm, dry winds funnel through the mountain passes from east of the Cascades in the winter. The warm, dry wind takes more moisture out of the foliage than the tree can replenish because the ground is frozen, killing the needles. The dead needles may stay green while conditions are still cool and wet, but when the weather turns warmer in the spring, they turn red and begin to shed. The damage typically occurs on the east sides of exposed trees, especially Douglas-firs. The sudden red appearance of damaged areas can be striking in the spring (Figure 9).

A similar phenomenon can occur as a result of rapid temperature fluctuations, such as unseasonably warm daytime temperatures combined with cold nighttime temperatures. This can occur across a narrowly defined elevation band in the mountains due to a temperature inversion. This is called red belt, because the exposed sides of the trees in that elevation band turn red, causing a red stripe across the hillside. Winter desiccation is not usually a serious issue because it does not usually harm the buds. The tree greens up again when the new year's foliage emerges from the intact buds later in the spring and the damaged old needles are shed. The needle loss can cause stress to the tree, though, so it may be desirable to monitor affected trees for signs of stress as the year progresses (Allen et al. 1996; Campbell 1999; Scharpf 1993).

When to Be Concerned

Normal seasonal foliage loss in evergreen conifers follows a recognizable pattern of shedding the oldest, innermost foliage on the tree in the fall while leaving several years' worth of newer foliage intact. There are some insects and disease agents that also tend to affect a tree's oldest foliage, but these agents usually leave evidence of their presence, such as speckling or chewing. For example, Swiss needle cast, a disease of Douglas-fir that can cause all but the current year's needles to turn yellow and fall off, has fruiting bodies that show up as tiny black dots on the undersides of the needles, giving them a sooty appearance (Figure 10). Needle loss happens during the spring and summer as opposed to fall (Goheen and Willhite 2006; Mulvey et al. 2013). Another example is sawflies, which are insects whose larvae feed on older needles of some conifers. They leave telltale partially eaten needles that turn red (Figure 11), and the insects themselves may be present and visible (Goheen and Willhite 2006). These are problems that may have a more serious impact on the tree, and property owners may wish to seek professional advice regarding treatment or control.

Different patterns of foliage loss or decline may also be signs of more serious problems. A dead top (Figure 12) could indicate severe drought stress. Uniform thinning and yellowing of the crown (Figure 13) may indicate root disease. Damage and loss to only the current year's foliage could be caused by a variety of pests, pathogens, or environmental conditions (Allen et al. 1996; Goheen and Willhite 2006). In extreme cases where all the foliage suddenly turns yellow, brown, or red (and it is not a deciduous conifer like a larch), the tree has died (Figure 14).

If there is concern about the condition of a tree, it is beneficial to monitor it for at least a full year (or even several years) to get a better sense of whether there is a sustained pattern of decline or just natural seasonal fluctuations. Conifers tend to look the healthiest in late spring and early summer. It is also helpful to observe various species of trees throughout all seasons over multiple years to get a sense of the trees' natural seasonal rhythms. Having a calibrated understanding of what the normal baseline conditions are for trees allows for better detection of conditions that may be abnormal.

Figure 8. Winter bronzing on a western redcedar seedling. Photo: K. Zobrist.

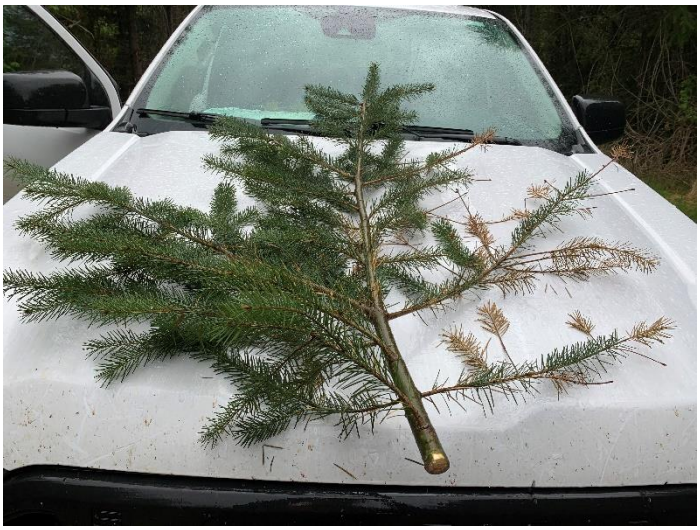

Figure 9. Douglas-fir in Snohomish County, WA, in spring 2021 after winter parch blight event, prior to spring bud break. Only the needles on the right side of the branch were affected as this was the side of the branch facing east, which was the wind direction. Photo: R. Brooks, WA DNR.

Figure 10. Black fruiting bodies of Swiss needle cast, which give the undersides of Douglas-fir needles a sooty appearance. Photo: K. Zobrist.

Figure 11. Sawfly damage to the older needles of a pine tree, leaving stubs and remnants of partially eaten needles. Photo: S. Katovich, Bugwood.org.

Figure 12. A tree with a dead top that is characteristic of a drought injury. Photo: K. Zobrist.

Figure 13. A uniformly thin and yellowing crown of a Douglas-fir suffering from root disease. Photo: K. Zobrist.

If property owners have concerns about the health of their trees, there are resources available. *Forestry Education and Assistance for Washington Forest and Woodland Property Owners* (Zobrist 2021) lists a variety of public and private sources of assistance for property owners and is free through WSU Extension. In general, a forestry professional is the best source of assistance for tree issues in a forested context, and an arborist is the best source of assistance for tree issues in a home landscape context. If there is an immediate safety concern with a tree that could cause serious injury or property damage, a hazard assessment should be done right away by a certified consulting arborist rather than waiting and monitoring. The PNW chapter of the International Society of Arboriculture (ISA) maintains a directory of certified consulting arborists on their website at https://pnwisa.org.

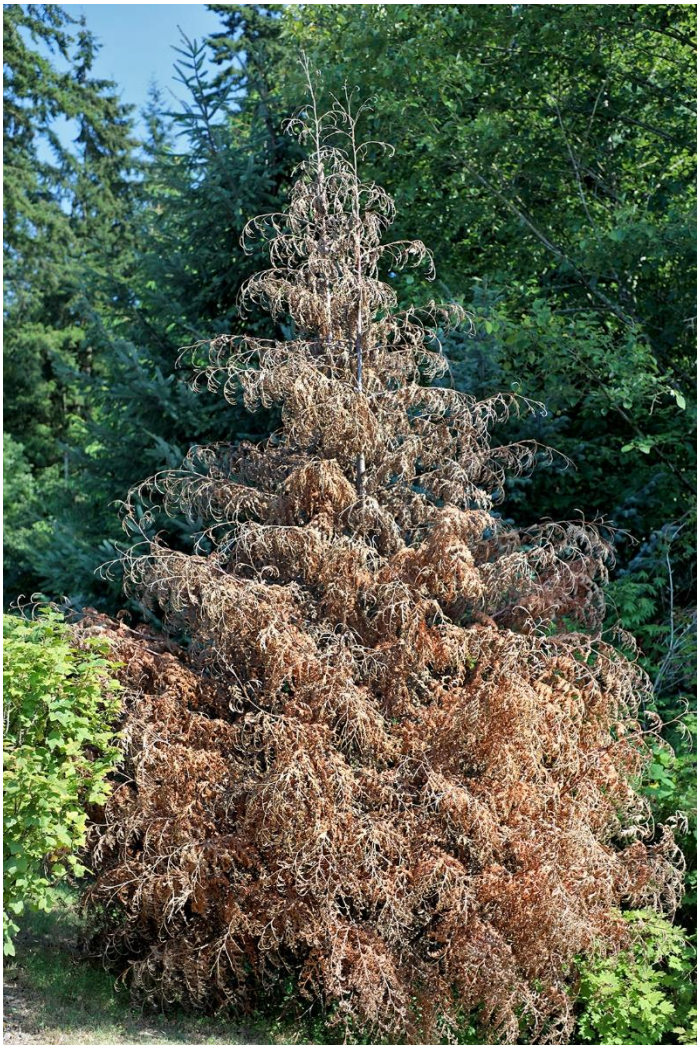

Figure 14. A western redcedar that died due to drought. Photo: K. Zobrist.

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