Advance Regeneration in the Inland West: Considerations for Individual Tree and Forest Health

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ABSTRACT. Advance conifer regeneration readily survives release from overstory competition in the Inland West, but foresters are concerned about the ability of released trees to attain normal growth rates. There are also concerns about forest health issues associated with managing advance regeneration. The best pre-release predictors of post-release growth response are pre-release vigor and crown ratio at release. The fastest growing trees before release grow the fastest following release. A general recommendation is that at least a 0.50 crown ratio at release is necessary for good response to release. A 0.50 crown ratio means that trees will have the necessary photosynthetic capability to respond to changes in stand conditions. The best time to release advance regeneration is after budset in the fall but before budburst in the spring. Release during this time period means needles that develop the first summer after release will be adapted to full sunlight. A conceptual framework of physiological response to release is presented.

INTRODUCTION

Forests of the Inland West have recently been the focus of discussions on forest health. Tree mortality caused by insects and diseases has been at

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unacceptably high levels, and large stand-replacing wildfires have been common. Overly dense stands of trees contribute to problems with insects, diseases, and wildfires. These dense, multi-layered stands often are the result of regeneration and growth of shade-tolerant species. Managing this regeneration has associated advantages and disadvantages. Better management decisions can be made by knowing how advance regeneration responds to release.

Advance regeneration are seedlings and saplings that become established prior to partial or total removal (or death) of the overstory. They are usually shade-tolerant species that become established under mature trees, although shade-intolerant species can be present in canopy gaps of even-age stands, under shelterwood harvests, and in uneven-age silvicultural systems. When the overstory is removed, advance regeneration is released to conditions of more sunlight, nutrients, and moisture while having less interference from larger trees. Seedlings can be considered advance regeneration in shelterwood removals, harvests in selection systems, and thinnings from above because they are released from competition of larger trees.

Reproduction by advance growth is the only way some species become established on some sites. For example, on a harsh subalpine fir (*Abies lasiocarpa*) habitat type, lodgepole pine (*Pinus contorta*) provides the necessary shade and thermal cover for subalpine fir to become established.

The occurrence of advance regeneration in forest ecosystems of the Inland West has been documented in several studies. Seidel (1979), in a northeastern Oregon study, reported 11 percent of 642 stocked milacre plots contained at least one advance regeneration-size tree in cutover stands. Seidel and Head (1983), in eastern Oregon, reported 32 percent of 811 stocked milacre plots contained at least one advance tree. For cutover forests in central Idaho, northern Idaho, and western Montana, advance regeneration was present on 40 to 46 percent of 5,244 stocked 1/300-acre plots (Ferguson and Stage 1982; Carlson et al. 1982; Ferguson et al. 1986).

There are advantages and disadvantages of advance regeneration in the context of forest health. Leaving advance regeneration keeps more of the "pieces in place" in forest ecosystems. Advance regeneration can quickly provide hiding and thermal cover for wildlife. Soil disturbance can be minimized because site preparation is not needed to secure regeneration.

A disadvantage of advance regeneration for forest health is that succession is usually accelerated to shade-tolerant species, with associated insect and disease problems such as tussock moth (*Orgyia pseudotsugata*), western spruce budworm (*Choristoneura occidentalis*), and various root and stem diseases. Shade-tolerant species often have slower growth rates than shade-intolerant species; therefore, leaving advance regeneration can be a dysgenic practice. According to Zobel and Talbert (1984), "One of the most serious types of dysgenic selection is the harvesting of desired species from mixed stands, leaving only the undesired species." Leaving advance regeneration can also be a dysgenic practice if genetically inferior trees are left on the site to grow and reproduce.

Another disadvantage of releasing advance regeneration relates to decreased use of fire in forest ecosystems and the shortening of the regeneration period. One beneficial process of fire is that it raises soil pH for a few years, allowing many species of trees, shrubs, forbs, and grasses to become established. Without fire, and with continued site occupancy by most conifers, soil pH gradually decreases. If conifers occupy a site for hundreds of years, the resulting low soil pH can cause forest health problems such as aluminum toxicity and nutrient imbalances (Binkley 1987).

The same effect of lowering soil pH over time can happen if the usual successional period for shrubs, forbs, and grasses is eliminated or shortened following a regeneration harvest. Advance regeneration can lead to rapid site occupancy, thus eliminating the number, size, and duration of shrubs, forbs, and grasses. The higher proportion of time that the site is occupied by conifers would lead to lower soil pH. A study by Nelson (in preparation) in northern Idaho shows the beneficial role of shrubs in raising soil pH. Rainfall having a pH of 5.2 decreased to 4.8 after being intercepted by the conifer canopy, but was raised to 5.1 after being intercepted by shrubs.

RESPONSE TO RELEASE

Response of advance regeneration to release has been reviewed by McCaughey and Ferguson (1988). This continuing collection of information has application to the general topic of keeping trees and forests healthy. The review pointed out some generalities about released trees.

Few trees die from the sudden exposure caused by overstory removal (when death was not caused by logging damage). For example, studies have found 2 percent mortality for red fir (*Abies magnifica*) in 8 years since release (Oliver 1986), 0.3 percent for grand fir (*Abies grandis*) and red fir in 5 years (Seidel 1977), and 7 percent for grand fir (Seidel 1980) in 5 years.

Tree size at release also is a factor in survival. Gordon (1973) found that released red fir and white fir (*Abies concolor*) that were less than 1 foot tall had a much higher probability of death from the sudden exposure of overstory removal. Tesch et al. (1990) reported the same trend for Douglas-fir

(*Pseudotsuga menziesii*). Because few trees die, a full array of responses to release is possible, from barely surviving to vigorous growth. Each tree has to be assessed individually to determine its probable response to release.

Diameter growth response usually occurs in the first or second year after release. This is followed in 2 to 5 years by increased growth in height. Height growth response is not evident until the second year after release for most conifers because terminal buds are pre-determined. Terminal bud expansion the first year after release does not reflect site conditions following harvest because terminal bud primordia were laid down the previous fall (Kozlowski 1964). Gordon (1973) felt that, after release, stems buttress rapidly as a response to counteract bending forces; therefore, initial diameter growth after release may not be an early indicator of response.

When diameter or height growth response is plotted over time, the result is a sigmoid response curve. Growth before release is suppressed, but has yearly fluctuations. Following release, trees respond with increased growth until they reach a post-release growth rate, which also has yearly fluctuations. Maranto (1993) has shown that Douglas-fir takes longer to reach a post-release growth rate on cold/wet sites than on warm/moist sites. This site effect may be true for other species as well (McCaughey and Schmidt 1982).

Some degree of physiological shock is typical for released regeneration, which results in a few years of slower growth immediately after release. Physiological shock is even common in thinnings (Harrington and Reukema 1983). The degree of physiological shock will, in large part, determine the number of years required to reach the post-release growth rate.

Studies suggest that released advance regeneration attains growth rates comparable to site potential for the species and site conditions. Oliver (1986) reported that 41 percent of released red fir reached or exceeded the expected periodic annual increment for the sites. Released western hemlock (*Tsuga heterophylla*) showed a slight growth lag, then grew like trees of a similar size that had not been suppressed (Oliver 1976).

PREDICTING RESPONSE TO RELEASE

Two primary tree characteristics can be used to predict the probable response to release: pre-release vigor and crown ratio at release. The best and easiest to measure indicator of pre-release vigor is 5-year height increment prior to release. Faster growing trees prior to release will grow faster following release (Ferguson and Adams 1980; Helms and Standiford 1985; Maranto 1993). Helms and Standiford (1985) also found the pattern of pre-release growth was important. Trees having constant or increasing growth for the 5-years prior to release responded better in height growth following release than did trees having a declining growth pattern. Another important benefit of measuring 5-year pre-release vigor is that it negates the need to quantify the amount of overstory competition the tree is receiving. This finding was documented for grand fir in northern Idaho (Ferguson and Adams 1980) and for Douglas-fir in central Idaho (Maranto 1993).

For some species it is difficult or impossible to measure the previous 5 years of growth accurately. In these cases, response to release should be better for the faster growing trees and can be quantified by measuring 1, 2, or 3 years of height growth prior to release, or by measuring diameter increment (Graham 1982; Carlson and Schmidt 1989).

The other useful tree characteristic for predicting response to release is crown ratio at release. Seidel (1980, 1985) found at least a 0.50 crown ratio was needed for true fir and mountain hemlock (*Tsuga mertensiana*) to respond well to release. Helms and Standiford (1985) found that released Douglas-fir regeneration with less than 0.45 crown ratio did not grow well following release. Oliver (1986) reported that red fir with at least a 0.40 crown ratio grew more rapidly after release. Thus, a minimum of 0.50 crown ratio should be adequate for releasing regeneration-size trees.

Other variables are useful in predicting response to release. Cool, moist sites are generally better for release because adequate moisture and/or shade are available to allow trees to respond well to overstory removal. Sites that are naturally cool and moist are northerly aspects and higher elevation habitat types. Sites can be silviculturally manipulated to remain cool by retaining partial overstories and leaving snags, cull trees, shrubs, and competing advance regeneration on the site for 2 to 5 years to provide shade while released regeneration adjusts to new site conditions.

On sites where moisture is limiting, seral species respond better to release than climax species. For example, Douglas-fir responds better to release on a grand fir habitat type than on a Douglas-fir habitat type (Maranto 1993) and grand fir responds better to release on western redcedar (*Thuja plicata*) and western hemlock habitat types where it is not the climax species (Ferguson and Adams 1980). When moisture is not limiting, climax species such as western redcedar and subalpine fir can respond well to release (Herring 1977; Graham 1982).

Tree age at release is not as important as the variables mentioned above for predicting response to release. When tree age at release is significant in regression equations that predict response to release, older trees respond less to release than younger trees. Successful response to release depends more on crown ratio, pre-release vigor, and site conditions than tree age.

PHYSIOLOGY OF RELEASE

A conceptual framework that explains the physiology of release is discussed below. Ideas for this section grew out of the work of Tucker and Emmingham (1977) in their study of western hemlock. Details from other published research are included to complete the story for conifers in the Inland West.

Crown Geometry

Advance regeneration is able to survive in the understory because of sunflecks that move across the forest floor (Emmingham and Waring 1973). When sunlight strikes the foliage, seedlings are able to begin photosynthesis quickly. Once the sunfleck passes, photosynthesis ceases.

Suppressed trees do not receive enough sunlight to support full crowns. Maximum photosynthesis is attained by capturing as much sunlight as possible when sunflecks shine on the foliage. Needles of advance conifers are most often displayed in single planes with little mutual shading of needles, as noted by Keller and Tregunna (1976) for western hemlock. This arrangement of foliage means that nearly every needle will be exposed to full sunlight after release.

Sun and Shade Needles

There are important morphological differences between needles that develop in the shade and those that develop in sunlight. These differences are important for trees responding to release. Shade needles have fewer, but larger, stomata than sun needles (Tucker and Emmingham 1977). After release, stomata in shade needles cannot completely close to control evapotranspiration, so needles abscise prematurely because of moisture stress (Keller and Tregunna 1976; Tucker and Emmingham 1977). There are more stomata on sun needles, and they are smaller. The smaller stomata close to control evapotranspiration.

Another difference between sun and shade needles is the amount of palisade mesophyll that protects the chlorophyll in the needle. Shade needles of western hemlock have a single row of palisade mesophyll while sun needles have a double row (Tucker and Emmingham 1977). Maranto (1993) found more palisade mesophyll on sun needles than on shade needles of Douglas-fir. The extra palisade mesophyll protects the chlorophyll that lies deeper within the needles. Without this extra protection, shade needles on released trees can die from sun scald.

Sun and shade needles can also differ in the amount of cuticular waxes on the outside of the needles. Maranto (1993) found that shade needles of Douglas-fir did not have as much wax as did sun needles. The additional wax reduces evapotranspiration.

Shade needles that are dropped prematurely or are killed by sun scald reduce the photosynthetic area (crown) that is available for the tree to adjust to release. Signs of physiological stress the first year after release are premature needle drop, sun scald, and smaller-than-normal current year needles. Current-year needles may be shorter in length because of moisture stress (Tucker and Emmingham 1977). Short current-year needles affect height growth the second year after release because photosynthates for terminal bud expansion come from 1-year old foliage (Kozlowski and Winget 1964).

Two important attributes of the development of sun needles are subject to silvicultural control. First, the protective double row of palisade mesophyll in needles is formed under shelterwoods (Tucker and Emmingham 1977). Thus, partial opening of the canopy should provide enough sunlight for the development of additional palisade mesophyll on needles that develop under the shelterwood.

The second attribute is that sun versus shade needles are not pre-determined when the bud is set in the fall (Tucker et al. 1987). Needles develop into sun or shade needles depending on the amount of sunlight received while they are expanding. Trees released after budset in the fall but before budburst in the spring would have current-year needles that are adapted to sunlight. Needles on trees that are released after budburst would have only shade needles.

In summary, released trees must make rapid adjustments to respond well to release. Keller and Tregunna (1976) noted tissue damage to western hemlock the first day after release. Released trees must be able to maintain a favorable water balance and not suffer extensive sun scald damage in order to retain enough crown to adjust to release. The degree of physiological shock determines whether the tree lives or dies, and the number of years surviving trees need to reach post-release growth.

The first summer following release is important because of physiological shock. A cool, moist summer would result in less physiological shock than a hot, dry summer. While we cannot know the weather the first summer after release, we can provide partial shade for released trees by removing the overstory in 2 or more cuttings, and by leaving snags, cull trees, shrubs, and other regeneration-size trees on the site for a few years. Releasing trees after buds are set in the fall but before budburst in the spring will mean that the current-year foliage will be sun needles.

There will be at least a 1-year delay in height growth response to release because most conifers in the Inland West have pre-determined buds. Height growth the first summer after release reflects conditions when the bud was developed the previous fall. Height growth the second year after release will reflect the new growing conditions for the tree and the degree of physiological shock that occurred the first year after release.

LONG TERM CONSIDERATIONS

Increases in Shade-Tolerant Species

Shade-tolerant advance regeneration survives harvests in the Inland West and is able to respond well to release. There are other trends shifting species compositions towards shade-tolerant species. A second trend is past harvesting practices that removed the more valuable shade-intolerant species, while leaving shade-tolerant species to stock the site and regenerate in high numbers. This trend was recognized even in the 1920s in the northern Rocky Mountains (Koch 1923; Neff 1928), which led to recommendations for killing unmerchantable shade-tolerant overstory trees (Foiles 1950).

A third trend is control of wildfires. Human intervention has reduced the number and size of wildfires. Fire exclusion has allowed shade-tolerant species to regenerate and grow in the understory, whereas previously, low intensity ground fires periodically removed these trees.

A fourth trend is introduction of non-native pests such as white pine blister rust (*Cronartium ribicola*). Blister rust has drastically decreased the proportion of western white pine (*Pinus monticola*) in the Rocky Mountains (Bingham 1983), and is currently decimating whitebark pine (*Pinus albicaulis*) at higher elevations (Keane and Arno 1993). Both of these species are relatively intolerant of shade, and more shade-tolerant species are growing in their place.

A trend now beginning is ecosystem management. Under the Forest Service's new ecosystem management policy, clearcutting will be replaced, where possible, by partial cuts. Partial cutting will tend to favor shade-tolerant species over shade-intolerant species.

These long-term trends will shift species compositions to shade-tolerant species. This shift can be either good or bad, depending on the definition of forest health and land management objectives. What is clear is that land managers will have to counteract these trends if they wish to encourage shade-intolerant regeneration in forest ecosystems of the Inland West.

Insect and Disease Considerations

Insects and diseases are major factors to consider when releasing advance regeneration. Insect problems such as western spruce budworm and Douglas-fir tussock moth are associated with shifts in species composition to shade-tolerant species. If regeneration is defoliated prior to release, reduced crown area makes it that much more difficult for trees to respond well to release.

There are several decay fungi that can infect trees through logging injuries. Readers are referred to McCaughey and Ferguson (1988) for discussions of decay fungi that infect shade-tolerant conifers of the Inland West.

Dwarf mistletoe (*Arceuthobium* sp.) can infect advance regeneration before release, thus perpetuating mistletoe into the next generation of trees. The longer the exposure to dwarf mistletoe from overstory trees, the higher the probability of infection in the understory. Advance regeneration that is infected on the trunk often are topkilled (Scharpf 1982). Dwarf mistletoe reduces growth of advance regeneration and limits the ability of the tree to respond well to release.

The life cycle of Indian paint fungus (*Echinodontium tinctorium*) makes this heart rot an important concern when managing advance regeneration. Indian paint fungus infects true firs and hemlocks in the Inland West. Infection occurs on stubs of shade-killed branchlets of suppressed trees (Etheridge and Craig 1976; Filip et al. 1983). A minimum of 40 years of suppressed growth is necessary to produce suitable infection courts. After the stub heals over, the fungus becomes dormant for up to 50 years. Infections are reactivated by mechanical injury such as logging scars, broken tops, broken branches, frost cracks, or even insect attacks.

Thus, Indian paint fungus is present in suppressed trees but does not become a problem until many years after release. If decay-free trees are a management goal, true fir and hemlocks that have been suppressed for more than 40 years are poor choices because of the high probability of dormant Indian paint fungus. Filip et al. (1983) provide guidelines for managing advance grand and white fir regeneration for Indian paint fungus and other decay fungi.

CONCLUSIONS

The occurrence of advance regeneration is a normal part of secondary succession. There are advantages and disadvantages of releasing advance regeneration that must be weighed when deciding how to achieve desired future conditions in Inland West forests. The purpose of this paper was to present a summary of information for managing advance regeneration so that better decisions can be made.

If the decision is made to release advance regeneration, there are several key points to remember. Faster growing trees prior to release will grow better following release. At least a 0.50 crown ratio is recommended for good response to release, and it is important to minimize physiological shock that would cause premature needle loss or sun scald.

Releasing advance regeneration can be a dysgenic practice in two ways. The first is when genetically inferior trees are left on the site to grow and reproduce. Second is a change in species composition. Shade-tolerant species often do not grow as well as seral shade-intolerant species. This shift in species composition can dramatically decrease yields. While released trees may grow as well as subsequent trees of the same species and size, they may not grow as well as other species on the same site. Counteracting this is the uncertainty of establishing subsequent regeneration.

A trend in human management of Inland West forests has been a shift to shade-tolerant species. This trend will likely continue into the future under ecosystem management concepts because of more partial cuts. Forest managers need to be aware of these long-term trends so that positive steps can be taken to encourage establishment of adequate numbers of shade-intolerant species to maintain the desired proportion of species in Inland West forests.

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