A Field Guide to Regeneration of Salal-Dominated Cedar-Hemlock (CH) Sites in the CWHvm1

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DISCLAIMER

The use of herbicide or fertilizer trade and manufacturer names in this publication does not constitute an official endorsement or approval of any product or service to the exclusion of others that may also be suitable.

TABLE OF CONTENTS

FIGURES

PLATES

BACKGROUND

Severe regeneration problems occur on cutovers of coastal old-growth cedar-hemlock (CH) forests in the CWHvm1. The problem appears as poor growth and chlorosis (yellowing) of regenerating western red cedar (Cw), western hemlock (Hw), amabilis fir (Ba) and Sitka spruce (Ss). These symptoms appear 5-8 years after clearcutting and slashburning, coincident with the expansion of the ericaceous shrub, salal, on the cutovers (Plate 1). This also coincides with the end of a period of high nutrient availability that follows harvesting on these sites. Some cutovers are nearly 50 years old and have still not achieved crown closure. The problem does not occur on adjacent cutovers that were formerly occupied by second-growth forests of hemlock and amabilis fir (HA), originating following a windstorm in 1906 (Plate 2). Mean annual volume increment on HA sites is 10-14 m^3/ha/y compared to 4-6 m^3/ha/y on CH sites. Lewis (1982) could not distinguish between the CH and HA forests on the basis of topography or mineral soil characteristics, and included them both in the S1 "salal-moss" ecosystem association. He further hypothesized that HA forests were a seral stage of CH forests, and that the superior regeneration and site growth conditions typical of HA sites might be achieved on CH sites through silvicultural treatments. In the biogeoclimatic ecosystem classification scheme (Green and Klinka, 1994), CH sites are classified as 01 "HwBa - blueberry" or 06 "HwBa - deer fern", with a modifier "s" that signifies the nutrient poor to very poor "salal phase" that occurs in subdued terrain on the west coast and north end of Vancouver Island.

Research has been conducted for a decade to determine the reasons for the poor nutrition of trees and the best silvicultural practices for alleviating the CH growth problem (summarized by Prescott and Weetman 1994). The low availability of nitrogen (N) and phosphorus (P) in CH cutovers originates in forest floors of the old-growth forests prior to clearcutting. Nutrient availability is low in all layers of the forest floor in CH forests. This is a result of three factors. First, cedar litter contains less N and more decay-resistant material than other species, and produces forest floors with low rates of N mineralization. Second, the forest floors in CH forests are wetter and have less soil fauna than in HA forests, leading to incomplete decomposition and mineralization of N. Third, the salal understorey in CH forests interferes with mineralization of N through the production of tannins. Processes involved in the development of low nutrient conditions on CH sites are demonstrated in Figure 1.

IDENTIFYING CH SITES

Prior to logging, CH sites are occupied by relatively open, uneven-aged old-growth stands of western red cedar and western hemlock. The Cw range up to 260 cm in diameter and 1000 years old; the Hw to 90 cm and 400 years. Many of the Cw trees have dead tops. Seedlings of both species are present in the understory, mostly growing on decaying wood. The other understory vegetation includes salal, herbs (mostly deer fern) and mosses (*Hylocomium splendens* and *Rhytidiadelphus loreus*). Skunk cabbage is present only in depressions. The soils are imperfectly to moderately-well drained Duric Humo-Ferric Podzols in coarse-to-medium textured materials. They have deep (>1m), permeable, reddish-brown mineral Bf horizons. They have mor humus, 10-25 cm deep, with nitrogen concentrations about 0.74 % and C:N ratios of 59. Rooting is primarily in the organic layer.

Following clearcutting, CH sites are quickly dominated by salal, with small amounts of fireweed and deer fern. Within 10 years after harvest, height growth slows to less than 10 cm/y in Hw and Ss, and about 30 cm/y in Cw. Foliage becomes yellow (chlorotic), and N concentrations in foliage are usually less than 1.0%, indicating a very severe N deficiency. Recently, some "transitional" sites of old HA forests with salal have been observed to become infested with salal after cutting. These sites are treated as CH sites, to prevent further reversion to CH conditions.

The primary silvicultural strategy on CH sites is to create a dense canopy as soon as possible, to shade out the salal and thereby reduce competition and improve nutrient availability. This is similar to the strategy adopted in the U.K. for growing Sitka spruce on sites dominated by heather, another ericaceous shrub. It is hoped that conifer growth will improve once the stands have closed canopies, but this has not yet been proven. This will be tested in the next few years as some of the treated plots in the research trials now have closed canopies. The results presented here are limited to strategies for hastening crown closure on CH sites. This goal can be achieved through a variety of silvicultural treatments. Following is an analysis of the relative success of these possible treatments for increasing regeneration success and productivity of conifers on CH sites. The field trials are discussed in more detail by Prescott (1996) and Prescott and Weetman (1994).

SILVICULTURAL SYSTEM

There has been little experience with systems other than clearcutting on CH sites. For conifers to regenerate within a reasonable time frame, salal must be controlled. Mechanical site preparation or burning are therefore necessary, which precludes most systems other than clearcutting. Clearcutting is also the most effective system for controlling dwarf mistletoe of hemlock.

HARVESTING

The preferred harvesting method on slopes less than 30% is hoe-forwarding. On steeper slopes, line systems such as grapple-yarding or skyline systems are used. Soil disturbance is not avoided because regeneration has generally been observed to be better on disturbed sites, but it must be kept within allowable limits.

SITE PREPARATION

Cedar-salal sites can be broadcast burned to reduce slash and salal cover, thereby creating suitable seedbed and plantable spots. In addition to temporarily disrupting the salal, burning also temporarily increases nutrient availability, leading to higher foliar nutrient concentrations and improved early growth rates of conifers. Intense burns will increase the amount of N lost, so low impact spring burns are recommended. Burning costs range from $350 /ha to $650 /ha, depending on the guarding costs for the site. Burning may not be feasible in small blocks with convoluted edges.

Scarification and cultivation have been shown to increase early growth of Hw and Cw on CH sites. Responses are even greater when scarification is combined with fertilization (Figure 2, Plate 3). The response to scarification appears to be largely due to the resulting disruption of salal, which reduces competition during the establishment of conifers. Cultivation or mixing of soil do not appear to increase nutrient availability on CH sites. Mounding may be successful on wetter sites such as "Cw-Ss-skunk cabbage" ecosystems and in the mid-coast. Mechanical site preparation can be used on sites that cannot be burned, such as those in the vicinity of riparian areas and wildlife corridors. Mechanical mulchers have caused unacceptable puddling; backhoes have been more successful on CH sites. Care must be taken with any equipment in wetter areas, to avoid interrupting water flow and creating unproductive wet depressions. The cost of mechanical site preparation on CH sites in 1996 is about $1 per planting spot.

REGENERATION

Cedar-hemlock sites should be planted as soon as possible after burning or site preparation so that conifer seedlings can take advantage of the nutrient flush and disruption of salal. Large planting stock (415B or 415D) and genetically improved stock will improve the competitive ability of conifers on CH sites. Survival rates for conifers planted on CH sites are over 90% for cedar and 85% for hemlock. Direct seeding has proven unsuccessful on burned sites, due to seed predation by rodents. Planting at fairly high densities (1400-1800) stems/ha will hasten crown closure, but broadcast burning may be necessary to create this many plantable spots. In a trial with Cw and Hw at 500, 1500 and 2500 stems/ha, growth of individual trees during the first 7 years was greatest at 1500 stems/ha. At 2500 stems/ha individual tree growth of both species was reduced. Stand volume of Hw was greatest at 2500 stems/ha, but Cw stand volume was greatest at 1500 stems/ha. Competition between trees is unlikely to be significant at this early stage of development. The reduced growth at higher densities is more likely related to the limited number of suitable microsites for seedlings on CH sites, which are characterized by uneven terrain and prevalent air pockets in humus.

Western red cedar is the preferred species on CH sites, because it will grow at acceptable rates without fertilization. However, mean annual increment of unfertilized cedar is low. Yellow cedar (Yc) may be planted on CH sites because it grows as well as Cw and has a higher market value. However, some mortality due to *Armillaria* infection has been observed in Yc plantations on HA sites, so 10-20% Yc is recommended. Western hemlock grows poorly on CH sites, but responds well to fertilization, so is a preferred species on sites for which fertilization is planned. Douglas-fir grows well on drier and warmer microsites, but poorly on others. Because the CH ecosystem is off-site for Douglas-fir, it often has poor form and low wood quality, although it can develop a dense canopy and large piece sizes. Sitka spruce and amabilis fir grow poorly on CH sites, unless they are fertilized. Fertilization of Ss increases its susceptibility to terminal weevil (*Pissodes strobi*). The incidence of weevil is low in hypermaritime areas, but there is some evidence that it is increasing, particularly on the west coast of Vancouver Island. Both Ss and Ba are better suited to sites richer than CH. Western white pine (Pw) grows well on CH sites, and outgrows other species on some sites. However the prevalence of blister rust limits the use of this species, unless a scheduled pruning regime is followed to reduce the incidence of rust. Lodgepole pine (Pl) is common on CH sites particularly in wetter locations, and may be useful as a nurse species for other conifers.

In summary, if the site is not to be fertilized, cedar (Cw and Yc) should be planted, since these species will grow at acceptable rates under the nutrient-poor conditions. If fertilization is planned, hemlock could also be planted, and growth of naturally regenerated Hw will also be enhanced. Repeated fertilization may be necessary to maintain adequate hemlock growth, which may result in Hw overtopping the planted Cw.

FERTILIZATION

Conifer growth on CH sites is limited by the extremely low availability of N, so fertilization is critical for improving productivity. Hw, Ba and Ss all respond well to N addition; Cw is less responsive (Figure 3, Plate 4). Greater responses are achieved when P is added in addition to N. The response period is 5-10 years. One application significantly advances the stand towards crown closure. The recommended rate of addition is 250 kg N/ha and 100 kg P/ha. The cost of fertilization with N and P in 1996 is $550-650 /ha. Fertilizer blends in which the N and P granules are the same size ensures even distribution of both nutrients across the cutblock. For this reason, forest grade urea with diammonium phosphate is the preferred blend. Sites should not be broadcast fertilized until the trees are large enough to capture a significant portion of the nutrients added, *i.e.* at least 5 years after planting.

Individual-tree fertilization at planting has been tested in two trials on CH sites. Spot application of granular NPK increased growth of newly planted Cw and Hw on CH sites. Hemlock response declined after five years, at which time broadcast fertilizer was applied. Responses have also been observed in Cw and Hw seedlings that received either 1 GromaxÒ teabag (24-4-7) or 2 WoodaceÒ briquettes (14-3-3) at time of planting. Additional trials are underway to compare broadcast fertilization at planting with spot application of granular fertilizer or teabags. Spot fertilization at planting may be particularly beneficial on sites which have not been burned, and may make it possible to use smaller seedlings. Some nurseries are experimenting with adding slow-release fertilizer to large diameter (415 or 615) plugs, which may provide an alternative to fertilization at planting.

Refertilization may be necessary after 5-10 years to maintain the growth response of conifers on CH sites. It is not known at this time if fertilization will be required after crown closure. Studies of the fate of fertilizer N have shown that less than 10% of the N applied is taken up by the trees. Most of the added N becomes immobilized in the soil and in the salal and is not available to trees after the first year, necessitating refertilization with N. In contrast, higher concentrations of P have been found in foliage and humus 10 years after fertilization with triple superphosphate at 100 kg P/ha. The sustained improvement in P availability after fertilization may negate the need for refertilization with P. When refertilization is being considered, concentrations of N and P in foliage should be measured and compared with levels considered to be adequate for each species: 1.45% N and 0.35% P in Hw, and 1.65% N and 0.16% P in Cw (Ballard and Carter 1986).

Trials with a variety of organic fertilizers have shown them to be effective for increasing conifer growth on CH cutovers. Responses to these fertilizers applied at a rate of 500 kg N /ha are generally similar in magnitude and duration to those achieved with chemical N+P fertilizer at 225 kg N/ha. The major drawback to using organic residues is the high application cost due low nutrient content per unit weight. Municipal sewage sludge and fish silage both increased height and diameter of cedar trees. Mixing with pulp sludge reduced the response to sewage sludge but increased the response to fish silage (Figure 4, Plate 5). Wood ash alone suppressed tree growth. Composted fish and wood waste and wheat straw both increased height increments and foliar nutrient concentrations of cedar during the first year after application. During the second year, height increments in the plots treated with straw increased even more, and foliar concentrations of N, P, K and S remained high. This suggests that there may be a long-term improvement in nutrient supply following addition of fresh residues such as straw.

Liming of CH sites does not increase tree growth or N availability. In a field trial, there were no visible effects five years later of lime addition at 2500 kg/ha. In a greenhouse bioassay, lime applied at a rate equivalent to 5000 kg/ha did not affect growth of seedlings of Cw, Hw or Ss.

VEGETATION CONTROL

Several studies have demonstrated that a reduction in salal competition will increase growth of conifers on CH sites. Eradication of salal through manual removal followed by a single application of triclopyr ester (Release 4â) was effective at reducing salal cover for at least 9 years. Salal removal increased growth of Cw in particular, whereas Ss and Hw responded more to fertilization (Figure 5, Plate 6). However, the cost of manual salal removal is prohibitive ($5000/ha), and herbicides alone are not highly effective at controlling salal. Triclopyr ester is somewhat effective (Biring et al. 1996), especially foliar applications in the fall with a diesel carrier (D’Anjou 1990). However, conifers can also be killed when sprayed with triclopyr ester and diesel. Burning and mechanical treatments that temporarily disrupt salal appear to be the most viable means of vegetation control on CH sites.

There is some evidence that repeated fertilization with N alone, totaling more than 600 kg N/ha will cause a reduction in salal cover (Plate 7). Nearly total kill of salal has been observed in field trials on northern and southern Vancouver Island following heavy application of ammonium nitrate or urea. More research is needed on the effects of high N additions on conifer growth and drainage waters to determine if this may be a viable option for controlling salal and enhancing conifer growth on CH sites.

RECOMMENDATIONS FOR REGENERATING CH SITES:

- Clearcutting is the most viable silvicultural system because of the need for site preparation.
- Mechanical site preparation or slashburning are necessary to disrupt the salal prior to planting conifers.
- Sites should be promptly planted with large, genetically improved stock.
- Cw should be planted; Hw may also be planted if the site is to be fertilized.
- Fertilization with 250 kg N/ha and 100 kg P/ha will increase growth of conifers for 5-10 years. Individual tree fertilization at planting is also effective, but refertilization with N 5 years later will likely be required to reach crown closure.
- Organic materials such as fish silage, fish-wood compost, sewage sludge or fresh residues are effective fertilizers for CH sites.
- Manual removal of salal if effective but the cost is prohibitive; herbicides are not highly effective at controlling salal.
- A combination of salal removal and fertilization will yield greater responses than either treatment applied separately.

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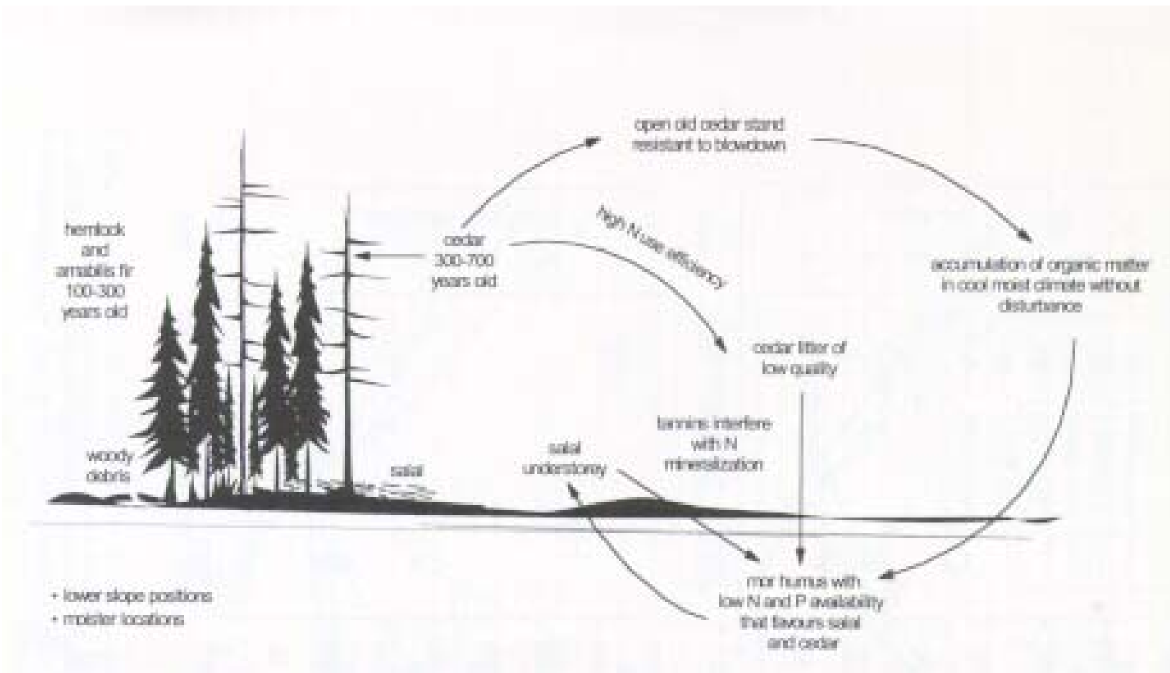

Figure 1. In the absence of a major disturbance, nitrogen in CH forests is continually immobilized in humus, leading to poor N supply in old-growth forests.

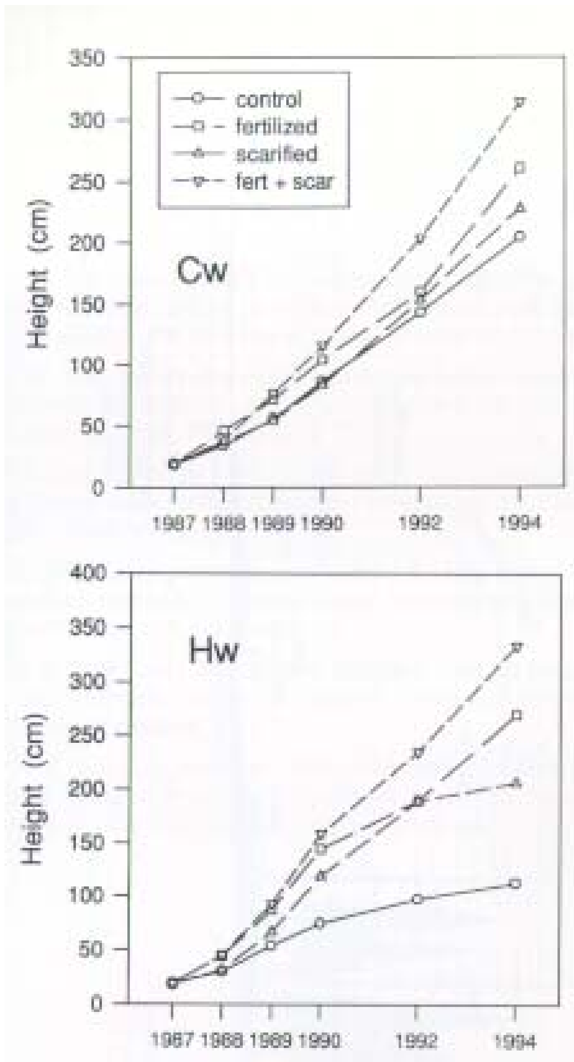

Figure 2. Scarification increases early growth rates of Cw and Hw on CH sites. Responses are even greater when scarification is combined with fertilization.

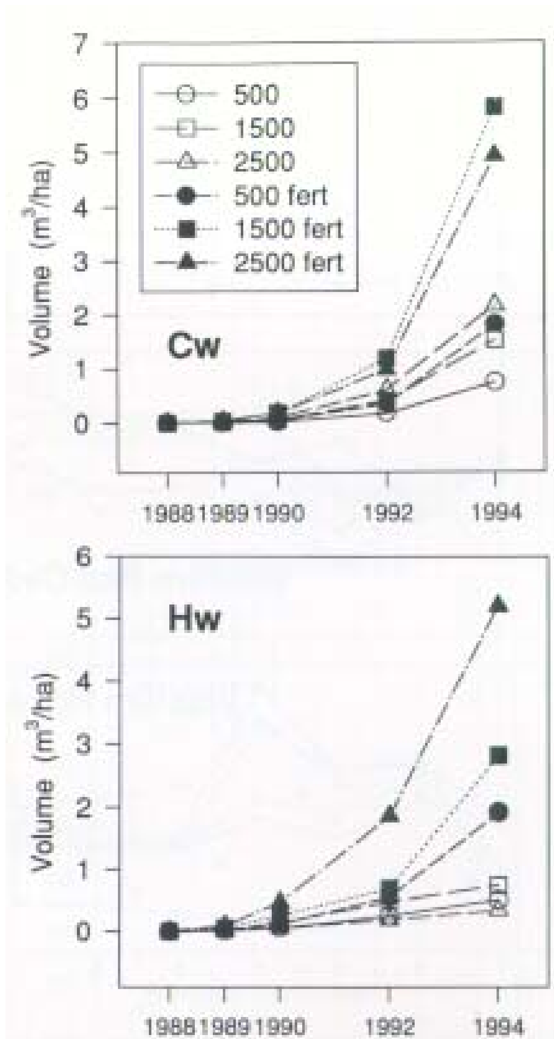

Figure 3. Individual tree fertilization at time of planting increases early growth of Cw and Hw on CH sites. At higher densities (2500 stems/ha) individual tree responses are lower due to lack of suitable planting spots, but stand volume is high. Trees were refertilized in 1993.

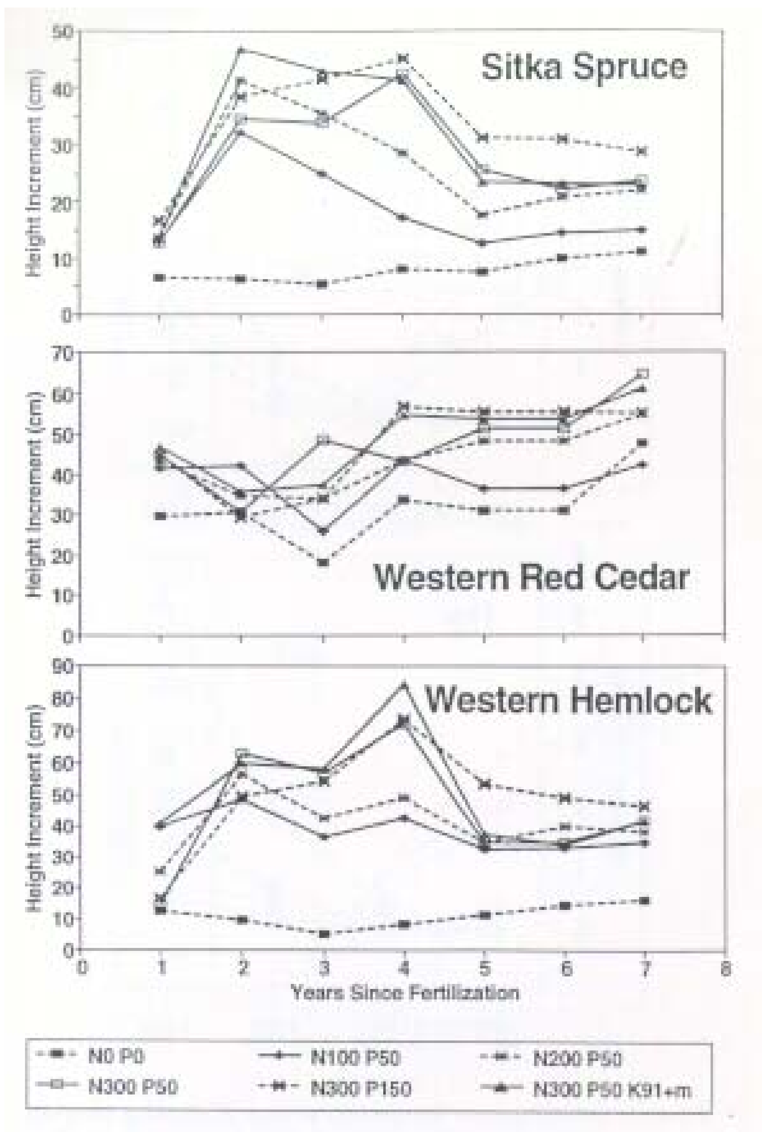

Figure 4. Fertilization with N and P greatly increases growth of Ss, Cw and Hw on CH sites. Responses last 5-10 years and significantly advance the stands towards crown closure.

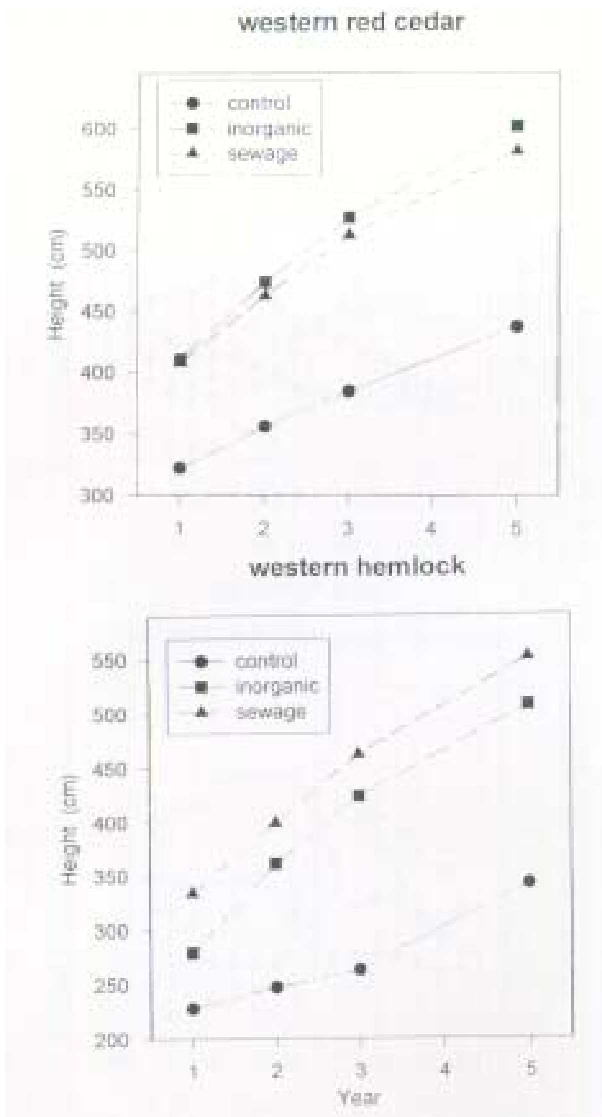

Figure 5. Height growth of Cw and Hw on CH sites treated with sewage sludge is similar to those fertilized with N and P.

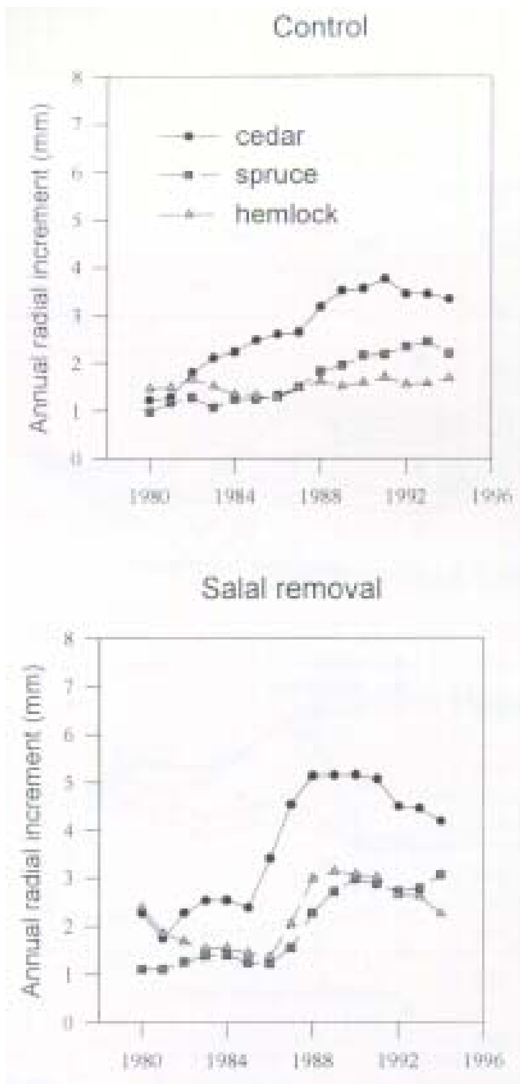

Figure 6. Removal of salal (manually followed by herbicide) is particularly effective at imporving growth of Cw; Ss and Hw respond more to N+P fertilization. Acombination of both treatments is most effective for all species.

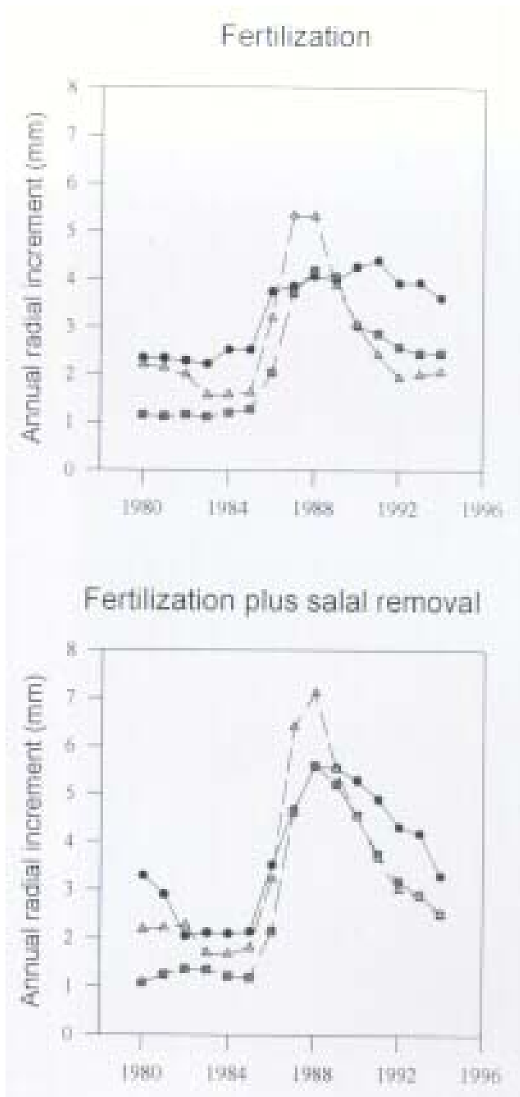

Figure 6 (cont'd)

Plate 1. Cedar-hemlock (CH) cutovers are characterized by dense salal cover and slow-growing conifers with chlorotic (yellow) foliage. These symptoms appear 5-8 years after clearcutting and result from low availability of nitrogen.

Plate 2. Adjacent hemlock-amabilis fir (HA) cutovers (left) have abundant regeneration and rapid growth of hemlock compared to CH sites (right).

Plate 3. Fertilization with 250 kg N/ha and 100 kg P/ha results in denser crowns, greener foliage and doubling or tripling of height growth. Hw, Cw, Ss and Ba are all responsive to fertilization of CH sites. Pictured is a plot of Hw on a CH site five years after N+P fertilization.

Plate 4. Organic fertilizers, including municipal sewage sludge, fish silage, fish-wood compost, and wheat straw improve growth of Cw, Hw and Ba on CH sites. A plot of Cw that received sewage sludge is on the left, an unfertilized plot is on the right.

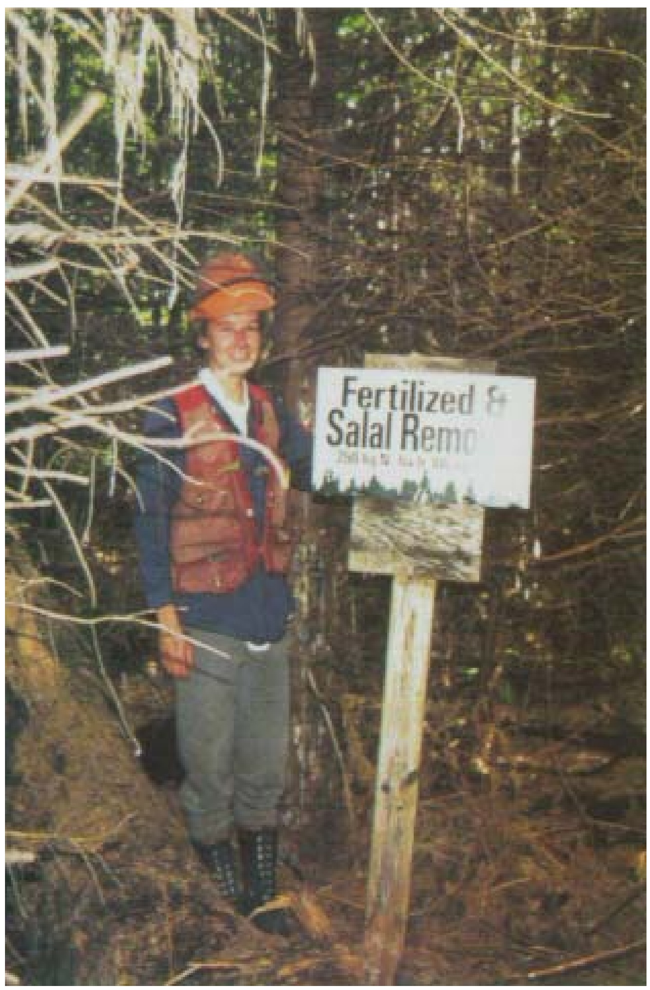

Plate 5. Crown closure is achieved in 10 years on CH sites from which salal is removed (manually followed by herbicide treatment), especially if the site is also fertilized. Pictured is an untreated plot (top) and a plot in which salal was manually removed and N+P fertilizer was applied nine years earlier (bottom).

Plate 6. Heavy or repeated fertilization with ammonium nitrate or urea kill salal. Pictured is an untreated plot (top) and a plot that received one application of urea at 1000 kg N/ha