Lessons Learned on 50,000 acres of Plantation in Northern California[1]

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Abstract

Many lessons have been learned during reforestation of large wildfires and clearcuts in interior Northern California, a region of low rainfall and summer drought typical of a Mediterranean climate. Challenges appeared from time of establishment right up to commercial thinning. Establishment issues included procurement of improved seed, site preparation, soil mitigation, seedling performance, season of planting, and timing of vegetation management. Important decisions also had to be made with regard to mechanical vs. hand pre-commercial thinning (PCT), achieving a proper balance between reducing fire risk and compacting the soil, and prescribing spacing guidelines for thinning operations. On some sites damage from *Eucosma sonomana* (Kearfott) (western pine shoot borer) was a factor.

Introduction

From 1992 to 2004, Roseburg Resources Company in interior Northern California accumulated considerable experience while practicing intensive silviculture on company lands covering approximately 315,000 ac (128,000 ha) (*fig. 1*). Of the approximately 50,000 ac (20,000 ha) of plantation on these lands, two-thirds was replanted after wildfire. The remaining plantation acreage was the result of a shift in management emphasis over the last decade towards even-age management.

Northern California has a Mediterranean climate, with hot dry summers that present numerous silvicultural challenges. The climate also fosters a high fire frequency, with historical fire intervals of eight to twelve years (C. Skinner, USDA-FS Pacific Southwest Research Station, pers. comm.). The elevation of Roseburg Resources property ranges from 1,500 to 7,000 ft (500-2100m), rainfall ranges from 20 to 100 inches (50-250 cm) per year, and site class ranges from one to five, with the average being site 3 (Dunning, 1942). The vast majority of the ownership is Sierra Mixed Conifer, with smaller areas of Eastside pine, Ponderosa pine, Douglas-fir and White fir (Mayer and Laudenslayer, et al., 1988).

Reforestation practices on private land in Northern California have evolved over the last 25 years in response to experience gained on burned over areas. On Roseburg ground massive reforestation started with the Pondosa Burn in 1977. Other burns included the Day fire (1989), Fern fire (1990), and Finley Fire (1990). The lessons learned from these fires were aggressively applied to the Fountain Fire (FF) that started on August 20, 1992. This fire burned 64,000 ac (26,000 ha), 99 percent on private property, and included 41,000 acres on industrial ownership (Roseburg, Sierra

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[1]An abbreviated version of this paper was presented at the symposium on Ponderosa Pine: Issues, Trends and Management, October 18-21, 2004, Klamath Falls, Oregon
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Pacific and Fruit Growers Supply Co.). One percent of the industrial land base in California was consumed in the Fountain Fire, and 50,000 ac (20,000 ha) burned in two days with an intensity rarely seen before. On Roseburg property, the planting mix was 70 percent ponderosa pine (*Pinus ponderosa* P.& C. Lawson), 20 percent Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) and 10 percent White fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.). The rest of this paper will describe the many lessons learned from these reforestation efforts and subsequent silvicultural activities.

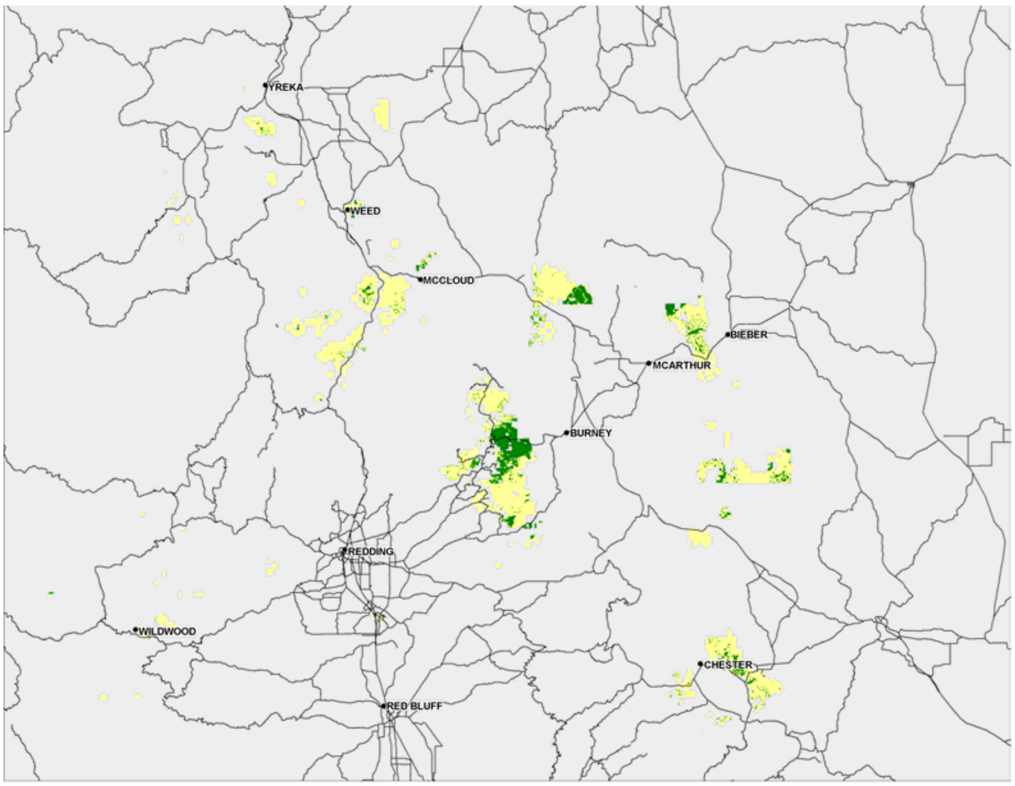


Figure 1—Vicinity map of Roseburg Resources ownership and plantations in Northern California.

Planning

The key to success of any reforestation project is proper planning. The temptation on large projects is to get started immediately with activities on the ground. However, the first step should be to break the project up into ecological units based on soils, aspect, elevation, vegetation type, access, slope, operability, and other attributes. Defining units of workable size can help focus efforts on achievable management objectives rather than on the overwhelming size of the undertaking. Knowledge of Geographic Information Systems (GIS) and spreadsheet software is invaluable for managing detailed information. Successful reforestation must be done in a series of steps and requires paying much attention to detail. Failing on any one of these steps often spells failure for the whole effort.

Units were prioritized on the basis of many factors relevant to maximizing success. The primary factor was the need for vegetation management. Competing vegetation from resprouting woody plants (mostly chinquapin) requires 2-3 years to grow sufficient crown volume to absorb enough chemical to completely kill the root system. Units with this type of competing vegetation were therefore deferred until the end of the reforestation effort. Areas where we could not use herbicides (along any perennial surface water) were planted immediately to take advantage of the site preparation from the fire. Beyond that the priorities were set by operational issues, such as timing of logging and a range of elevations to ensure as long a planting season as possible.

Planning does not take years; it can be done in a short period of time. Plans were completed in a matter of weeks on the Fountain Fire (FF). Logs were rolling into the mill by September 9, less than three weeks after the fire started and before the fire was even declared under control. It is important to take advantage of the site preparation created by the fire rather than see what competing vegetation re-occupies the site. Where woody vegetation was present before the fire, it will vigorously re-sprout after the fire. Use of herbicides within stream buffers was limited, so it was particularly important to take advantage of the site preparation achieved by the fire and to reforest without delay. Look for speculation stock in the nurseries that would be available to plant the following year.

Even though logging started immediately after the fire, rules set forth in the California Forest Practices Act (CFPA) provide a set of guidelines that ensure that environmental issues are not ignored. Stream buffers were established, archaeological surveys were completed, erosion mitigation measures were taken, and approximately 100 miles (160 km) of roads were improved with rock and drainage facilities. Although not required by the CFRA, Roseburg prepared Timber Harvest Plans (THP's) to ensure protection of the environment.

Seed Procurement and Inventory

Large landowners and governmental agencies normally maintain a seed inventory for small emergencies and unanticipated management needs. To meet the demand created by large fires, normal inventories are often inadequate. In this case, foresters must look on the open market for available seed from the correct seed zones and elevations. State agencies usually have seed available, as do private cone processors. A general rule of thumb is to move seed upon no further than 500 ft (150 m) up in elevation and 1000 ft (300 m) down, relative to the elevation of origin (J. Kitzmiller, retired from USDA-FS, pers. comm.). Likewise, seed should not be moved any further than the adjacent seed zone within the same series (climate). A standard inventory should be enough to reforest 10 percent of your land base, but probably more in areas of high fire risk. The more infrequent the cone crops, the larger should be the maintained reserve.

Superior seed programs can help reduce the amount of seed maintained in inventory. Seed orchards usually produce a more predictable and consistent source of seed. In addition to the reliability of seed production, improved seed generally has been developed to increase growth rates. On average, the first generation of improved seed is expected to increase growth by 10 to 15 percent, with an additional 10 percent from the second generation (J. Kitzmiller, retired from USDA-FS, pers. comm.). Improved seed is available for small landowners in California from the California Department of Forestry and Fire Protection. This state agency is a member of the North Sierra Tree Improvement Association (NSTIA), the most successful tree improvement cooperative on the west coast for ponderosa pine. The seed zones covered by the cooperative include 521, 522, 523, 524 and 525, on the west slope of the Sierra Nevada ranging from the Pit River in the north to the American River in the south.

A sufficient seed inventory also must cover the full suite of species required for potential reforestation projects. Ponderosa pine seed stores for a long time (over 20 years) as does Douglas-fir, but white fir (and most other *Abies* species) does not store as long (10 years or less).

Seedlings and Nurseries

After large fire events, it is important to reserve space in preferred nurseries to assure an adequate supply of quality seedlings. Criteria for selection of nurseries include the type of seedling desired (bareroot vs. container stock), species, storage, growing climate, lifting season, and others.

An effective and clear line of communication with the nursery is vital. Each nursery has its specialty, and not every nursery is good at growing all species. A solid grasp of the physiology of each species is helpful for asking important questions and making sure the nursery is growing the correct tree for your needs. Knowing the growth cycle of each species is very important. Quiescence is an important physiological state to understand, and deals with the transition period between growth and dormancy. The nursery must apply specific cultural practices to ensure that the appropriate size and physiological state at the right time. Cultural activities will change depending on whether you plant in the fall or spring. It is important to visit the nurseries at least once each year, and to communicate regularly by phone to emphasize your need for a very specific type of seedling.

Many important conditions can be observed on your visits. Did you get the germination that you planned for? Is the facility organized? How is the irrigation working? Is water distributed evenly? How is the fertilizer being calibrated? Do the trees look as good as the nursery manager says they are? Are you really going to get the trees you ordered? If they look poor, then you may want to consider a visit during lifting and packing to make sure they are culling weak trees properly. Are your trees clearly identified? If not, how can you be sure that you are getting your trees? Showing up and calling shows that you care and will be monitoring the nursery's performance closely.

Another factor to consider when planning reforestation is the number of nurseries you order seedlings from. Even the best nurseries can have unexpected problems, so it is a good rule to have several nurseries growing your seedlings for any given project. That way, if one nursery has a problem then your whole program will not be affected.

Seedling Trends

The trend in interior California is toward a higher proportion of container stock. Some interesting facts emerge from studies in Douglas-fir and ponderosa pine[3]. Three years after planting, initial stock size had no effect on the seedling volume of ponderosa pine or Douglas-fir. However, stock size did affect survival, with larger sizes experiencing less mortality. Larger containers result in lower bed densities and, hence, yield shorter trees with large caliper and lower limbs. The lower limbs shade the stem and prevent sun scalding. The same results were obtained for white fir. The

[3] Fredrickson, unpublished data from Roseburg Resources field trials

best container sizes for ponderosa pine are stryro 5s or 8s; however; styro 8s and 10s worked best for Douglas-fir. If ungulate browsing is a potential problem, larger trees perform better (stryro 15s and 20s or plug-1 transplants). For surviving the summer drought, a relatively high root to shoot ratio (preferably 1:1, max.2:1) is essential, in contrast to the coastal region where taller stock is preferred.

The current trend in reforestation is to plant a mix of species. Conventional wisdom suggests that monocultures may invite insect problems, but even if they do occur the mix of species lowers the risk of total plantation loss. A big challenge in mixed species silviculture has been successful establishment of white fir with Douglas-fir. Planting the appropriate stock type is critical, and site preparation must be done to provide the specific types of microsites that Douglas-fir and white fir require. In the early stages of development these species are quite susceptible to sun scald and insufficient moisture. Providing dead shade and retaining soil organic matter to enhance water holding capacity are very important. The more organic matter that is retained during site preparation, the better is survival and growth. Organic matter retention includes minimizing the movement of organic matter across the unit. Maximizing organic matter retention, however, must be balanced against minimizing fire hazard.

Frost can be limiting to the success of high-elevation interior plantations. Fir planted on flats and low areas are susceptible to frost damage. The fir species are best planted on slopes (especially north aspect) with good air drainage.

Harvest Planning

Combining site preparation with logging activities can save a lot of money. In recent years our most effective tool has been a pre-harvest application of herbicide (mostly Chopper and Round Up, either separately or as a tank mix), preferably a year ahead of logging for maximum efficacy and greatest tolerance by conifer seedlings. We observed a 35 percent reduction in the need for release treatments as a result of pre-harvest applications[3]. Pre-harvest site-preparation provides more effective control of tenacious species like tanoak, snowbrush and other evergreen broadleaved shrubs and trees. Pre-harvest control is more effective in part because crowns and roots of undesirable species are not disturbed prior to logging and, allowing for better translocation and maximum efficacy of the herbicide. Pre-harvest site preparation also offers other benefits: lower labor costs, increased soil moisture retention, greater tolerance of planted conifers to treatment, and more options on choice of chemicals.

By spraying competing vegetation prior to logging, the dead material often disintegrates during felling and yarding. Chipping and removing sub-merchantable material before or after logging can also eliminate brush. This chipping operation adds another opportunity to run over dead woody material and break it down. Another benefit of chipping is the removal of unmerchantable material and reduction in the need to pile, especially if the trees are whole-tree yarded to the landing, where tops can be chipped. Even though chipping can be costly, if the market for biomass chips is weak, the chipping often is cheaper than piling, and it leaves more forest floor organic matter distributed across the site. Sub-soiling may be helpful depending on soil characteristics.

The importance of proper planning is particularly evident when considering access. To mitigate possible adverse effects of roads water quality, fish, and wildlife, the temptation is to bloc roads off. Closed roads create significant logistical problems for subsequent silvicultural treatments (planting, spraying, thinning, burning, piling, etc.). Early coordination of the reforestation effort with the harvesting schedule can reduce long-term costs of silvicultural activities considerably, but this coordination of logging and reforestation activities is too often an after thought.

Mechanical Site Preparation

Many more tools are available now for mechanical site preparation than was the case just a few years ago. The brush rake is still a favorite and is used frequently in California on slopes up to 30 percent. Ponderosa pine responds well to this type of site preparation. With the trend toward more mixed species plantations and reducing cost, sub-soiling and planting or just planting through the slash is increasingly common. These practices increase the risk of severe wildfire from the higher fuel loadings, and increase the probability of animal damage due to the better habitat that down wood provides. In addition, the cost of planting, spraying and thinning increases.

Sub-soiling is often done in combination with tractor piling of logging slash. Due to previous logging and site preparation, compaction is often a problem, especially with clay soils (*fig. 2*). After clearcutting or stand-replacing fire, the opportunity exists to mitigate soil conditions. Subsoiling can also be used to mitigate soils conditions, including hydrophobic soil resulting from extremely hot wildfires. The lower soil strength after subsoiling usually results in cheaper planting costs and higher quality planting, since the planters do not tire as quickly. **Error!**

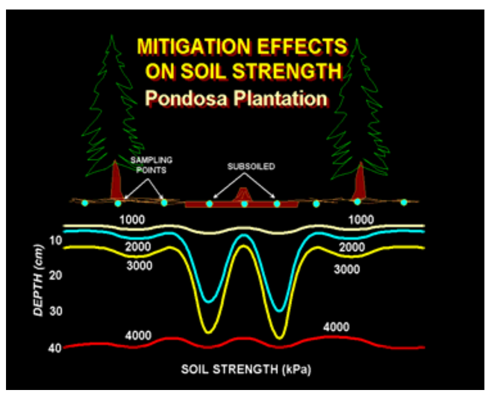


Figure 2—Soil compaction before and after mitigation in the Pondosa Burn.

The design of the shank on subsoiling equipment is important. The wings should be essentially flat, because the idea is to lift and fracture the soil, not to plow it. The shank should have a long leading tip, a sloped and tapered leading edge, and wings that feather behind the shank. Accumulation of roots and wood on the shank needs to be avoided because this accumulation acts as a plow. The operator needs to pay attention and lift the shank periodically. The target depth to sub-soil is a minimum of 18 in (46 cm) (R. Powers, UDSA-FS Pacific Southwest Research Station, pers. comm.). Due to the irregularities of the ground a target of 24 in (61 cm) is desirable, providing a range of treatment from 18 to 24 in (46 to 61 cm). Going deeper only slows the operation down and increases the cost.

The use of excavators for site preparation is becoming more common in California. Excavators are the preferred tool west of the Cascades in Oregon and Washington because they provide cleaner piles and increase organic matter retention (including large woody debris) across the site. However, the greater retention of organic matter again increases the risk of fire, and the more continuous fuel load increases the risk of escape from burning piles. An excavator with a 4-ft rake will increase the quality of planting and reduce the cost relative to an excavator with bucket and thumb.

The VH Mulcher mounts on an excavator or Timpco frame and works well for site preparation in slash or for making mounds. This tool was designed in Canada for shallow soils and high water tables. On such sites planting mounds are the preferred practices, contrary to accepted practices in dry Mediterranean climates. This tool works particularly well for making planting spots in slash, eliminating the need for piling. The VH Mulcher spins at a relatively high speed, so if the operator is not careful the mulcher can throw topsoil out of the hole, leaving only the C horizon to plant in. Depending on site conditions and management goals, several alternative microsites can be planted in the hole. The thumb on the head is used to move slash, and the bottom rotates to essentially drill a hole. By working the head back and forth you can prevent the removal of soil from the hole to some extent.

The Spyder is another tool that is relatively new, but is very effective for piling on steep slopes (*fig. 3*). This machine essentially walks on four legs, so is capable of working on slopes up to 100 percent. The Spyder has been used as an alternative to broadcast burning. In California, the maximum clearcut size allowed by the CFPA is 40 ac (16 ha), but the operational average is 15 to 20 ac (6 to 8 ha). Broadcast burning extremely expensive under these conditions. Increasing restrictions on burning due smoke management and air quality also limit opportunities for broadcast burning. Pile burning has a wider range of permissible conditions (larger burning window) than broadcast burning. A larger window is available for burning piles because they can be covered and burned later during wet conditions when risk of escape is low. The large amount of organic material left behind makes this escape risk a serious consideration.

Figure 3—Spyder is used to prepare sites for planting.

As mentioned earlier, chipping is a valuable tool that can be used to reduce the need for piling, but opportunities for chipping depend heavily on local demand for chips, the availability of an infrastructure to process and transport the chips, and a price that makes removable of this material economically feasible. The key factor determining economic viability is the number of dry tons removed per acre. For example, if 10 tons per ac (22 Mg per ha) must be removed, if the market will pay $40 per ton ($44 per Mg), and if hauling costs $45 per ton ($50 per Mg), then fuel reduction by chipping and removal will cost $50/acre ($132 per ha).

Masticators are another group of machines that mulch brush very well. One disadvantage is that they do nothing to disturb the root system, and another is that the machines are expensive. Without some follow up chemical treatment, sprouting shrubs and hardwoods will return within three to five years.

To summarize, the predominant trend in mechanical site preparation is to leave more organic material on site. This increased organic retention is a benefit to Douglas-fir and white fir survival, but it increases fire risk and drives up the cost of subsequent silvicultural treatments.

Broadcast Burning

The cost of broadcast burning is becoming prohibitive, except as a last resort, due to the increasingly small clearcut units in California. Burning is inherently risky and requires extensive training and experience to implement successfully. Increasingly strict smoke management guidelines designed to meet air quality standards also make it difficult to obtain permits and increases the costs.

Vegetation Management

Vegetation management is essential to the establishment of fully stocked plantations in northern California and many other regions. Without vegetation control, many plantations are doomed to failure (*fig. 4*). Chemical treatment is the safest and most effective means of ensuring reforestation success. Research in vegetation management has led to safer chemicals and lower application rates with the intent to minimize environmental impacts.

The objectives of vegetation management are: 1) to maximize site resources available to planted trees and thereby ensuring survival and enhancing growth, 2) to achieve the highest level of control with the least amount of chemical, 3) to obtain desired results while protecting and enhancing other resources and 4) to continually improve results through research and development.

Our vegetation management strategy has relied on well-planned initial site preparation. The current strategy involves pre-harvest chemical treatment, followed by logging, mechanical site preparation, and a residual herbicide to control the grass and forbs. The goal is to maintain a weed-free environment for the first two years to ensure successful establishment. Release treatments are scheduled as necessary to increase growth (*fig. 5*). Twenty five percent aboveground brush cover equates to root systems covering 100 percent of the area.

Figure 4—A demonstration area in the Pondosa Burn of northeastern California showing an established ponderosa pine plantation where competing vegetation was controlled and a brushfield resulting from no treatment.

One important key to success is application of the correct product on the target species, even if that means treating the same unit twice with two different chemicals. This approach will be cheaper in the long run because it is more difficult to kill the unaffected species after one or more growing seasons. Applications of the proper chemical will kill the undesirable species rather than simply brown them.. Growth regulators should not be mixed with a systemic chemical, e.g., Garlon and Roundup. The growth regulator destroys the cell structure in the plant before the systemic chemical gets translocated to the roots. Chemical application beyond the rates and volumes needed to kill the target species is a waste. Perhaps the most important factor is getting a good foreman and crew who will pay attention to the detail required to be successful.

Pre-Harvest Site Preparation

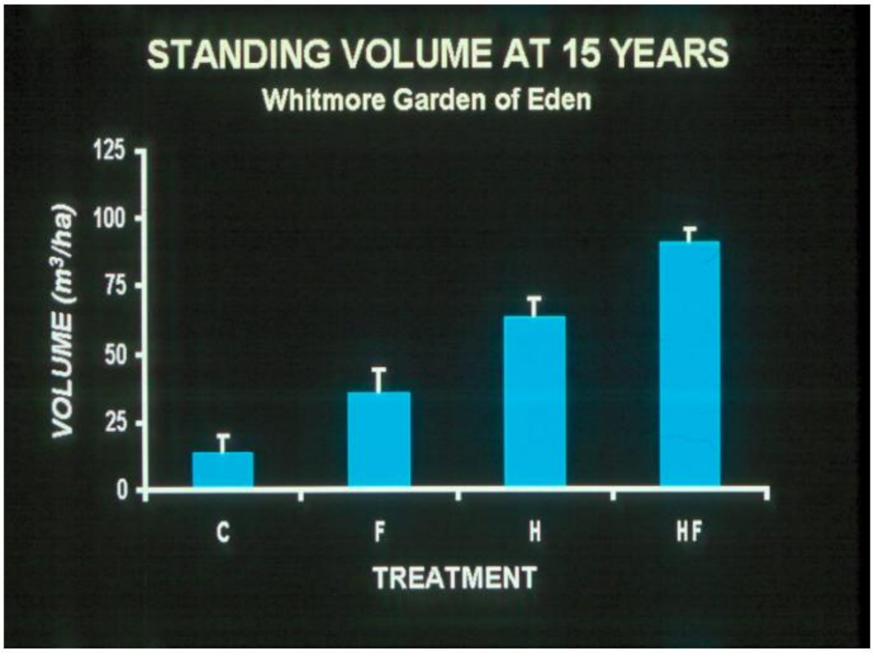
The goals of most pre-harvest herbicide applications include: 1) achieving long-term control without re-sprouting, 2) avoiding conifer damage, 3) minimizing application costs and 4) eliminating future entries.

So how do pre-harvest applications achieve these goals? Logging affects how the vegetation reacts to chemicals. Often after disturbance the plants go into shock and will not absorb chemical well. During logging the root to shoot ratio is increased by mechanical damage to the shoot; therefore, the remaining crown may not be able to absorb enough chemical to kill the root system. By treating before harvest, the root to shoot ratio is sufficiently low to ensure effective chemical control. In addition, plants are usually less able to resist chemical control when light, moisture and nutrients in the understory limit their sprouting vigor. Pre-harvest herbicide treatment is especially effective for schlerophyllous hardwood species that are hard to kill. Chopper (imazapyr) and high concentrations (5 to 10 percent) of glyphosate (especially with deciduous hardwoods) work well. Pre-harvest application also leads to greater success of fall planting due to increased soil moisture (*fig. 6*).

Application costs are lower before harvest, assuming that good access is available. The added benefit is reduced release costs after planting[4]. Lower rates of

[4] E. Fredrickson, unpublished data from Roseburg Resources field trials.

residual chemicals are required for herbaceous species than for both herbaceous and woody species. Also, options for chemicals to apply are much greater before harvest than after planting because conifer tolerance of the available chemicals varies.



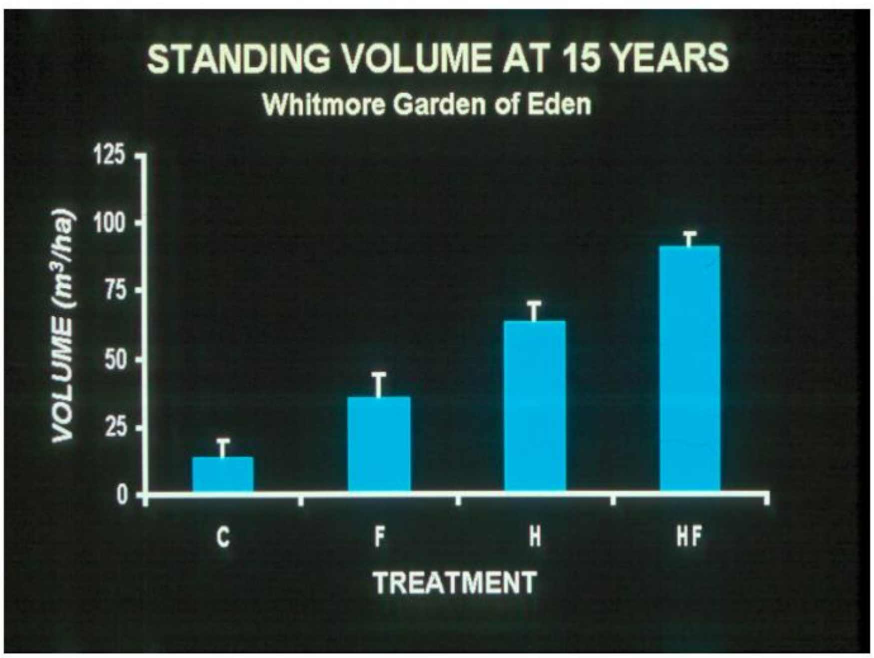


Figure 5—demonstrating the value of vegetation control, F=fertilization, H=herbicide, C=control. (Robert Powers, USDA Forest Service, Pacific Southwest Research Station, Albany, CA, unpublished results).

Keys pieces of advice are: 1) treat at least one year in advance of logging, 2) use esterified seed oils or seed oil silicone surfactant combinations to get good penetration (usually 5 to 10 percent depending on time of year, with more late in year), and 3) providing access is critical - *the most common challenge to pre-harvest site preparation is adequate planning with the logging department to ensure access in advance.*

Figure 6—Difference in available moisture three months after planting in units receiving competing vegetation control (left) vs. units receiving no control (right).

Fall Planting

Fall planting is difficult to manage historically gives unpredictable results. So why do we continue to pursue it? We found greatest success with fall planting above 5000 ft (1520 m), where snow limits access until after summer drought begins. Planting at high elevations can usually be done only at such a late date that little or no precipitation typically occurs after planting, and extreme temperatures can still occur before the trees develop root systems sufficient for survival.

So what does it take to be successful? Planting only after receiving early fall moisture (preferably 1 to 2 in (2.5 to 5 cm) in September) is critical, although we have seen that, in areas with pre-harvest treatment, a half-inch (1.2 cm) has been enough for successful reforestation. Choosing the proper sites and planting stock are important. Container stock works best due to its flexibility with respect to lifting and shipping on short notice. If weather prevents planting, then container stock stores well. Having stock that is hardened off enough to deal with the elements is important to deal with any hot weather in the fall. However, the trees should not be so hardened off that they are in dormancy and still capable of growing roots. The ideal is to plant at least three weeks before soil temperatures drop below 40˚F (4˚C), at which time root growth largely stops (above 5,000 ft (1520m) this usually occurs by November). When fall planting; a "hot plant" is essential; that is, the trees should be planted within 10 to 14 days of lifting so that they are ready to grow right out of the cooler. When storing trees, do not store below 40 degrees, otherwise the trees will be pushed into dormancy and will not grow roots after planting. If seedlings are kept longer than 10 days at 40˚F (4˚C) or more, there is an increased risk of fungal attack (*Botrytis* spp.).

Biodiversity

The use of herbicides often raises concerns about adverse impacts on biodiversity. DiTomaso et al. (1995) conducted a biodiversity study in three different fires, the Pondosa burn of 1977 (treated and planted between 1981 and 1988), the Tamarack fire of 1985, and the Fountain fire (FF) of 1992. The primary site preparation chemical was Velpar (active ingredient is hexanzinone). In the Pondosa burn and Tamarack fire, stands treated with herbicide showed greater species diversity than stands with no treatment; however, the trend over this chronosequence of three sites shows that with time the diversity will approach pre-burn species diversity in both treated and untreated stands (*fig. 7*). Untreated stands are rapidly dominated by a few species of brush, but treated units have greater diversity of grasses and forbs. The treatment effect is relatively short lived, so is consistent with the goal of setting back the competing vegetation only long enough for successful establishment and growth of seedlings.

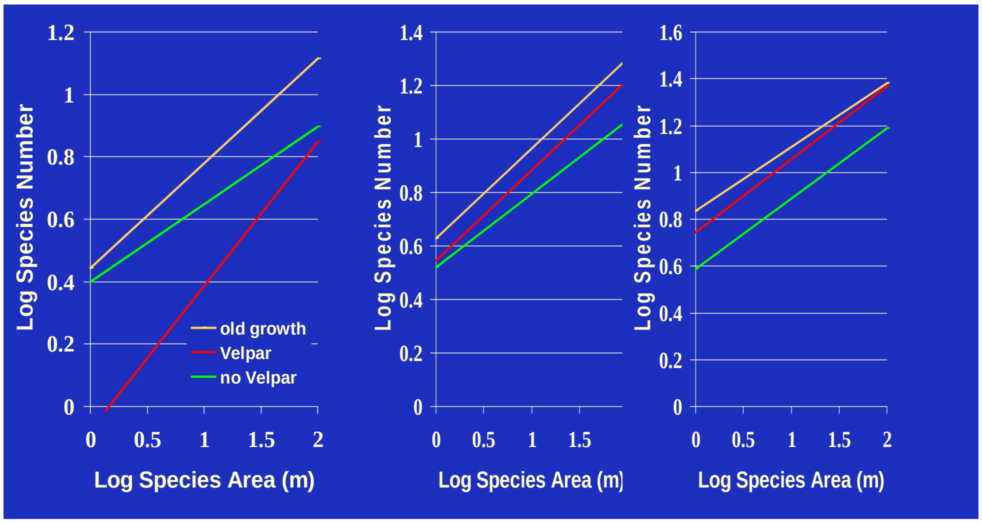


Figure 7—Plant species richness for three stand conditions (old growth, young plantation with Velpar treatment, young plantation with no Velpar treatment) and three stand ages (Fountain Fire (1992), Tamarack Fire (1985), and the Pondosa Burn (1977).

Pre-Commercial Thinning

Most foresters generally leave too many trees after thinning (Webster, 1997), often necessitating a second precommercial thinning to avoid stand stagnation and excessive mortality. Evaluating stand density using Reineke's (1933) Stand Density Index (SDI=equivalent number of 10-in (25-cm) trees per ac), Oliver and Uzoh (1997) have shown that ponderosa pine stands rarely exceed an SDI of 365 (902 25-cm trees per ha). However, heightened risk of bark beetle mortality begins at an SDI of about 230 (568 per ha). Disturbance from snow breakage is confined almost exclusively to stand densities of more than 183 SDI (452 per ha). Ensuring that trees in the stand get to a commercial size (minimum mean diameter of 14 in (36 cm)) as they reach these SDIs requires pre-commercial thinning to approximately 140 trees per ac (346 tree per ha) or less (Table 1). The stand density bounds for a managed depend on the level of risk one is willing to accept under stressful conditions such as drought.

Table 1*. Stand density index (SDI) given by four different combinations of tree density (trees/ac) and quadratic mean diameter (QMD, in). SDIs are based on a slope of –1.77 for the maximum size density limit (Oliver and Powers 1978).*

Trees per ac (per ha)	**QMD, in (cm)**	**SDI (metric)**
140 (346)	**13 (33.0)**	**223 (551)**
140 **(346)**	14 (35.6)	254 (627)
140 **(346)**	15 (38.1)	287 (709
140 **(346)**	16 (40.6)	322 (795)
140 **(346)**	17 (43.2)	358 (884)

Pre-commercial thinning presents the problem of slash disposal to prevent excessive fuel loading and fire risk. Within the public agencies, reducing fuel risk is a high priority, so lopping or some type of fuel treatment is required after thinning. In forest industry, minimizing cost is a higher priority, so lopping is done only along roads to meet regulatory requirements. This type of fuel creates an elevated fuel hazard and after ignition supports longer flame lengths, making fire risk and potential severity higher for 5 to 10 years after the thinning.

Where co-generation plants exist, cutting and hauling the material to the plant can reduce other types of fuel. Marketing the biomass of small-diameter material in this way can offset the costs of thinning and reducing fuel loads.

Western Pine Shoot Borer

The western pine shoot borer (*Eucosma sonomana* Kearfott) is endemic to the interior West and attacks young ponderosa pine. The female attraction pheromone was identified in the 1970s. Many studies have explored the use of pheromone for tree protection. One application technology referred to as microencapsulated, or MEC, was tested aerially in 2002 and 2004 and worked very well (Gillette and others 2004). This product was developed by 3M and involves microscopic capsules mixed in water. Unfortunately, the company has decided to discontinue manufacturing the product. Applied Pheromone Technologies in Vancouver, Washington, has just registered a hand application product in California (Last Call AK). This product is a mating disruptant and an insecticide that together “attract and kill” (AK) the target species. Another aerial product consisting of tiny flakes and produced by Hercon is being tested in 2005.

Williams (1989) showed about a five percent increase in volume growth where the male pheromone was introduced as a disruptant. In that study a single application to a young stand yielded better results than multiple treatments to older stands. Recent observations (Webster and Gray, unpublished data) show a doubling of damage to the terminal shoot after pre-commercial thinning. Endemic populations of the western pine shoot borer within the Pondosa Burn of eastern Siskiyou County damaged 20 to 40 percent of the trees in 1996. After thinning, damage increased to 80 to 90 percent of the trees, and it took about five years for damage to return to endemic levels. If only a single pheromone treatment was feasible, these observations suggest that a treatment immediately after pre-commercial thinning may be the best strategy.

Conclusions

Three main conclusions are worth re-emphasizing:

- Planning is critical!!
- Attention to detail is essential!!
- Research is invaluable!!
    - Increases success
    - Reduces cost in the long term
    - Increases the potential for growth
    - Develops treatments friendlier to the environment

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