Whitebark Pine Guidelines for Planting Prescriptions

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Abstract: This paper reviews general literature, research studies, field observations, and standard Forest Service survival surveys of high-elevation whitebark pine plantations and presents a set of guidelines for outplanting prescriptions. When planting whitebark pine, the recommendations are: 1) reduce overstory competition; 2) reduce understory vegetation, especially grasses and sedges; 3) avoid outplanting in swales or frost pocket areas; 4) provide shade protection; 5) plant where there is protection from heavy snow loading; and 6) provide adequate growing space.

Keywords: whitebark pine, *Pinus albicaulis*, reforestation, tree planting, pocket gophers, white pine blister rust, mountain pine beetle, cones, seeds, fire suppression

Introduction

Whitebark pine (*Pinus albicaulis*) is a keystone species in high elevation ecosystems across its range. It has a wide geographic distribution that includes the high mountains of western North America including the British Columbia coastal ranges, Cascade and Sierra Nevada ranges, and the Northern Rocky Mountains from Idaho and Montana to the edge of the Wyoming basin (figure 1). It is a hardy subalpine conifer occurring in elevations ranging from 5,000 to 11,000 ft (1,525 to 3,350 m), growing and surviving along ridge tops and other tough sites where no other tree species regenerate. Unfortunately, many of these fragile alpine ecosystems are losing whitebark pine as a functional community component. Throughout its range, whitebark pine has dramatically declined over the past 50 years due to the combined effects of insects, introduced diseases, and successional replacement.

Why Do We Care?

The integrity of the whitebark pine ecosystem affects watershed conditions including snow accumulation, snow melt, and quantity and timing of water flow; it contributes to rapid cover restoration after fire, blowdown, or avalanches; it is a major component of ecosystem diversity in the subalpine zone; it is a significant food source for the threatened grizzly bear, and is foraged on by black bear, birds, and other animals. Clark's nutcracker populations depend on whitebark pine as a food source and are the main seed disseminators. Whitebark pine enhances aesthetic views as recreationists admire the often distorted and windblown shaped krumholtz form of whitebark pine.

Without prompt action, we will lose this important component in cases where natural selection of blister rust resistant trees does not act fast enough. Outplanting whitebark pine is one management strategy that works with natural processes to keep or restore the presence of whitebark pine where seed supplies of whitebark pine are inadequate.

Decline of Whitebark Pine

White pine blister rust (*Cronartium ribicola*) has caused rapid mortality of whitebark pine over the last 30 to 50 years. Keane reported in 1993 that 42 percent of whitebark pine in western Montana have died in the previous 20 years, with 89 percent of the remaining trees being infected with white pine blister rust (Keane and Arno 1993). This has only multiplied in affects

Figure 1—Natural distribution range of whitebark pine in western North America. Diagram courtesy of Whitebark Pine Ecosystem Foundation Web site, reproduced from Arno and Hoff (1989).

since his study. In drier-colder conditions such as east of the Continental Divide, the rate of spread of blister rust has been slower and mortality is low. However, infection rates are increasing. Additionally, white pine blister rust kills the upper portion of the cone bearing trees before the tree succumbs to the disease, effectively ending seed production and the opportunity for regeneration.

Currently, Montana is experiencing an active mountain pine beetle (*Dendroctonus ponderosae*) epidemic. The impact to whitebark pine is the worst seen since the 1930s (Gibson 2005). Mountain pine beetle tends to preferentially attack large older trees, which are the major cone producers, again reducing the potential for seed production and subsequent regeneration. Unfortunately, in some areas, the few remaining whitebark that show blister rust resistance are being attacked by beetles, thus accelerating the loss of key mature cone-bearing trees.

Fire suppression over the past few decades has enabled other species, such as subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), to encroach into some high-elevation stands that were historically dominated by whitebark pine. This change in cover type and increased fuel loading, including ladder fuels, is creating higher fire-regime-condition-class situations typically not found in whitebark pine stands. Barrett (2004) found that whitebark pine stands typically fall in the Mixed Severity 3 Fire Regime with a 50- to 275-year mean fire interval, indicating highly variable fire patterns. These conditions of intense competition are also not conducive to producing good cone crops and successful natural regeneration. This is evidenced by the lack of young age classes in many areas of the Northern Rockies (Kendall and Keane 2001).

Ecological Environment

The practice of growing and outplanting whitebark pine is relatively new compared to traditional conifers, but it is gaining in importance, although at small scales. There is limited research on planting whitebark pine, but knowledge about the physiological and ecological characteristics of the species is increasing. With this knowledge, and the experiences from a few reforestation specialists from Montana and Idaho forests, we have outlined some guidelines for planting prescriptions. Particularly, we have considered the natural conditions of where whitebark pine grows, what conditions allow for good cone producing trees, where it naturally regenerates, and under what conditions seedlings establish.

The ecological niche for whitebark pine differs from other, more traditional, managed tree species where outplanting is common. It is adapted to a wide range of sites. On milder sites, however, it is out-competed by other species. It tends to have the competitive advantage on windswept ridgetops, shallow soils, and high elevation sites. It is typically a pioneer species. In the more mesic portions of it range, it is successional to shade tolerant species such as spruce or subalpine fir. In the drier portions, it maintains itself in a self perpetuating climax species. In the Northern Rockies, it is present on a variety of habitat types defined by Pfister and others (1977), although it is most common as a long-lived seral species on the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* and *Abies lasiocarpa/Luzula hitchcockii* types (Arno and Hoff 1989).

Whitebark pine appears to be relatively shade intolerant, with tolerance similar to western white pine (*Pinus monticola*) and interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and less shade tolerant than subalpine fir, spruce, and mountain hemlock (*Tsuga mertensiana*). It is more tolerant than lodgepole pine (*Pinus contorta*) and alpine larch (*Larix lyallii*) (Arno and Hoff 1989). Whitebark pine is most abundant on warm aspects and ridge tops having direct exposure to sun and wind. It is less abundant on sheltered north-facing slopes and in cirque basins where other more shade tolerant species dominate. Nevertheless, the tallest and best formed whitebark pines are often found in high basins or on gentle north-facing slopes. Although it is drought resistant, it is not frost resistant, at least during the growing season and for young establishing seedlings.

One of the earlier plantation trials for whitebark pine began in 1987 on Palmer Mountain on the Gallatin National Forest near Gardiner, Montana. One portion of the study evaluated outplanting survival based on physiographic location across the study site (figure 2). Trees were planted in rows starting in a swale, then up a 15 percent slope, over a

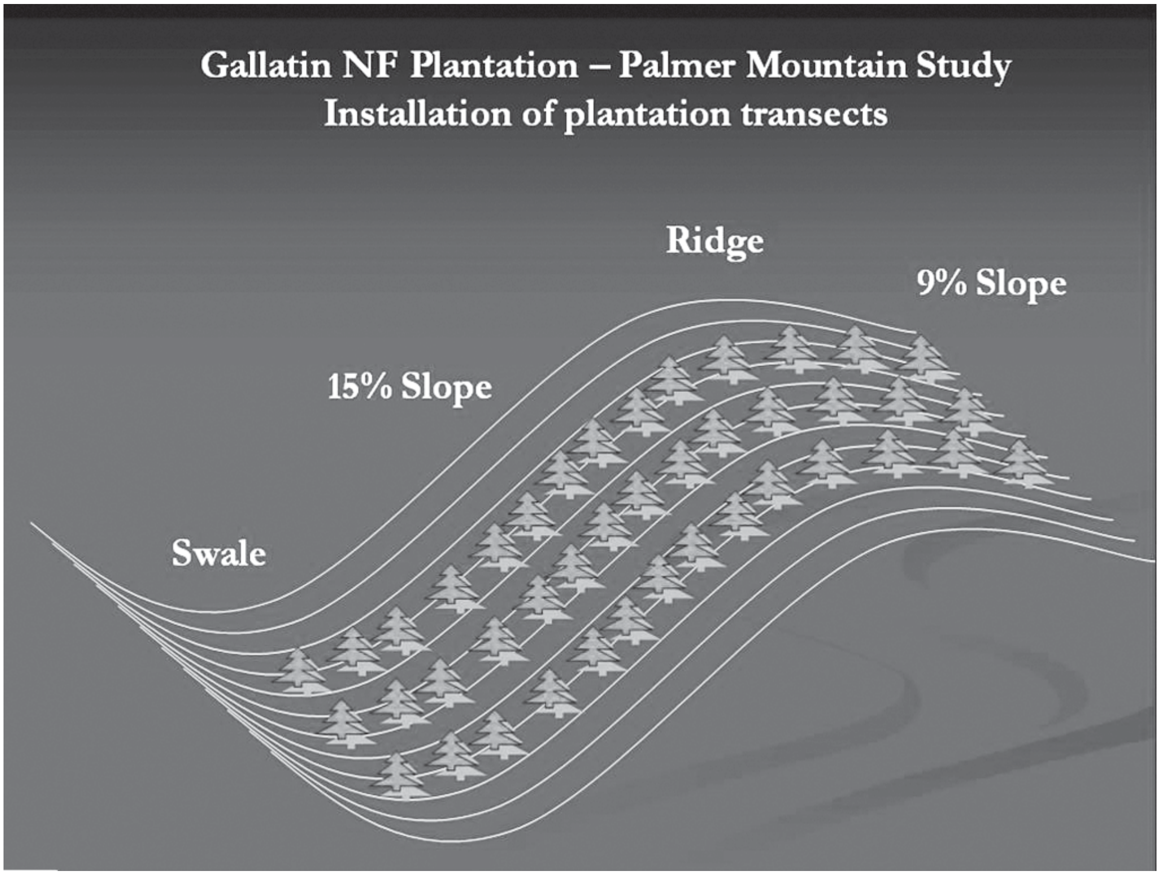

Figure 2—Schematic of whitebark pine seedlings planted across four physiographic locations on Palmer Mountain on the Gallatin National Forest near Gardiner, Montana.

ridge, and across a bench of less than 9 percent slope. While long-term results are not yet available, early results indicate the highest survival on drier ridges and gentle benches (McCaughey 2005) (table 1). Total survival decreased over the 11-year period, with the largest drop occurring in the first 5 years after outplanting. Eleven years following planting, survival was highest (47 and 39 percent) on the ridges and benches and lowest on the swales and steep slopes adjacent to the swale. Survival differences are probably due to the combined effects of other conditions based on topographic position. Gopher activity was visually higher in the swales and adjacent slopes where soils were deeper and grasses and forbs more abundant (McCaughey 1994a).

Table 1—Percentage survival of 11-year-old whitebark pine seedlings planted on four physiographic locations (swale, 15 percent slope, ridge, and 9 percent bench) on Palmer Mountain on the Gallatin National Forest in Montana.

	Physiographic location			
Year	**Swale**	**15% Slope**	**Ridge**	**9% Bench**
1987	100	100	100	100
1988	80	96	100	95
1989	58	86	100	86
1992	2	21	57	52
1993	2	20	47	44
1998	2	20	47	39

A second whitebark pine plantation study near Cooke City, Montana showed that from 1992 to 2001, survival on moist sites dropped from 100 to 50 percent. On dry sites, however, survival only dropped to 86 percent. Again, drier more severe sites with less vegetative competition and animal disturbance were better suited for whitebark pine survival. Long-term results of this study, along with results of a variety of other studies, tree row survival surveys, and field observations relating to site conditions, outplanting seasons, and tree spacing, will further aid silviculturists in refining prescriptions. Results and long-term survival are just beginning to become available for some research studies.

A regeneration study in western Montana showed that whitebark pine seedlings survive better when grown in association with grouse whortleberry *(Vaccinium scoparium)*. While vegetation competition is not favorable for whitebark pine survival, Perkins (2004) found that seedlings survived best when outplanted with grouse whortleberry or in bare ground. Poorest survival was in association with sedges typically found on moister sites. Seedlings planted in bare ground with no site amelioration survived at intermediate levels. Her study identified a positive correlation to growth when grouse whortleberry was present, better than even bare ground. While there may be positive effects caused by whortleberry reducing soil moisture evaporation and shade protection, its greater benefits may be by assisting seedlings via a mycorrhizal relationship or other below ground interactions. Further studies are necessary, but it appears that it is not by accident that whitebark pine and grouse whortleberry are commonly found together.

Additional Observations

Although whitebark pine survives and can thrive at lower elevations and on more productive sites, it has lower survival due to greater impacts from competition and high gopher problems. It also does not tend to dominate and create wide crowned individuals due to competition and crowding from faster growing species. Cone crops on small crowned trees grown in dense stands are smaller than crops from open-grown trees (figure 3). The real niche for whitebark pine tends to be on shallow well-drained soils, steeper slopes, and windy exposures.

Whitebark pine appears to have stable horizontal resistance to blister rust, allowing management strategies to incorporate the resistance genes into outplanting programs (Hoff and others 2001). Keane and Arno (2001) describe a seven-step process that is important in whitebark pine restoration efforts, and managers need to add planting to this process as a critical reforestation tool. Management options include even- or uneven-aged silvicultural systems that provide light and localized site prep (Arno and Hoff 1989).

The best chance for success in restoring and maintaining whitebark pine is to outplant seedlings with blister rust resistance from a natural selection processes. Whitebark pine may have the highest susceptibility to blister rust of any of the 5-needle pines in North America; however, individual trees express notable resistance to blister rust (Hoff and others 1994). Cones should be collected from trees expressing resistance as a first but critical step towards improving rust resistance.

Growing the Whitebark Pine Seedling

Whitebark pine has been described by Farmer (1997) as one of the pines with a hard but permeable seed coat. Collecting viable whitebark pine seeds needed for production of nursery stock has been difficult because of seed consumers such as squirrels and the Clark's nutcracker. Cone production is very sporadic, with good cone crops occurring only every 3 to 5 years. Older open-grown trees with wide crowns produce the most cones and can be easily climbed when collecting cones (figure 3).

Seeds need adequate time in a conditioning environment to mature to the point that they will have adequate germination potential. Collect too soon and the seeds are not ripe; collect too late and rodents and birds will deplete the seed crop. McCaughey (1994b) recommends periodic collection of cones to determine maturity and then make final collections when embryo to total seed length ratios are above 0.65 and after endosperm to total seed length ratios reach 0.75 percent or above. Delay collecting if these conditions are not met, squirrel caching is minimal, and nutcrackers have not begun to collect seeds from the stand. If harvesting of cones and seeds by animals has begun but cones are not ripe, cone collection can begin but the manager must be aware that germination potential will not be optimal.

Nutcracker planted seeds are stratified by overwintering in cold environments where they are subjected to long periods of cold, moist conditions. These conditions help the seeds to overcome physical and physiological barriers to

Figure 3—Mature large crowned whitebark pine produce the most cones.

germination. Dry spring conditions reduce potential for seeds to imbibe water, resulting in seeds lying dormant for that year. Whitebark pine seeds can delay germination for up to 3 years after planting, germinating when spring moisture is adequate (McCaughey 1993). In certain wet years, germination can continue throughout the summer and into the fall (McCaughey and Tomback 2001)

Taking these lessons into the greenhouse, nursery experience shows that there is a variety of techniques to break various dormancy mechanisms. The simplest method is cold stratification for very long periods of time—over 4 months. Research shows that 45 to 60 days is the minimum needed. However, this procedure may not yield the highest germination rates (McCaughey and Tomback 2001). To increase germination reliability, the USDA Forest Service Coeur d'Alene Nursery has developed a multiple-step protocol for whitebark pine (Burr and others 2001). They use a warm and cold stratification, and then manually nick the seed coat of seeds that do not germinate on their own. They report that 90 percent of the seeds that will germinate do so in the first 2 weeks with this method. Seeds are geminated in a germinator and "germlings" are planted into containers. A recent development is an automatic seed scarifier (Gasvoda and others 2002), which mechanically nicks the seed without damaging the embryo. This promises to reduce labor costs and time in nursery operations.

As in the field, nursery-grown seedlings are slow-growing, which is typical of other high elevation species. Two growing season are required to produce plantable seedlings. Germination occurs throughout the first growing season. Secondary needles may develop the first season but they are most prevalent during the second growing season. Aggressive root development generally occurs. Recently emerged seedlings are vulnerable to a variety of damaging agents, including heat damage. Even with increased stem diameter, seedlings are easily damaged, and thus must be shaded during the warmest part of the growing season (McCaughey and Tomback 2001). Nursery growers observe that whitebark pine seedlings go into dormancy quite easily and early. Therefore, maintaining a long photoperiod will encourage a longer growing season.

Target seedlings are ready for outplanting in early July in Montana with bud set complete and root and caliper growth set to continue in the field. The soil moisture of the outplanting sites is generally good at this time due to late snow melt. Districts should plan for very short tree storage from the time of extraction to planting. If soil moisture is expected to be good in the fall, the nursery can continue the growing regime and extract seedlings just before fall outplanting. Root growth may occur but most will occur in spring. Our growers are using a large container, a Ray Leach Conetainer™ supercell (10 in^3 [164 cc]), to achieve the best seedlings.

Guidelines For Planting Prescriptions

Based on ecological and physiological information, planting trials, and experience in the Northern Rocky Mountains, we recommend the following guidelines be included in outplanting prescriptions:

1) Reduce overstory competition to increase light and day length to improve the effective growing season.

2) Reduce most understory vegetation, especially grasses and sedges, to reduce competition for available soil moisture. However, do not aggressively remove grouse whortleberry during site preparation. If grouse whortleberry is not present, then creating a planting site of bare ground is the best alternative.

3) Avoid outplanting in swales or frost pockets; consider the topographic position as well as the actual planting spot. Young whitebark pine seedlings do not appear to be frost hardy during the growing season. Ridge tops or exposed slopes are suitable.

4) Provide shade and protection for newly outplanted trees to improve water utilization and to reduce light intensity and stem heating. Planting by stumps or other stationary shade is important.

5) Plant where there is some protection from heavy snow loads and drifting snow. Stumps, rocks, and large logs are favorable microsites (figure 4).

6) Do not overcrowd outplanted trees to avoid long-term inter-tree competition. Open grown trees have the largest crowns and produce the most cones. Tree form is not as important because the purpose is to establish trees for long-term regeneration, cone production purposes, aesthetics, and a variety of other reasons that do not include timber production. Adjust spacing guides based on expected survival. At 50 percent survival, planting density should be 6.1 m by 6.1 m (20 ft by 20 ft), producing 247 live seedlings/ha (100/ac).

7) Plant when there is adequate soil moisture. Summer and fall outplanting have been successful, thereby avoiding the need for long expensive snow plows and delayed entry due to heavy spring snow loads.

8) Plant large, hardy seedlings with good root development (figure 5).

Conclusion

Planting whitebark pine is only a small part of the whitebark pine restoration strategy. Enhancing conditions for natural regeneration with prescribed fire or managed wildland fire are major actions that will make significant contributions to restoration. With proper attention to planting prescriptions and ensuring appropriate nursery culturing regimes, we can augment blister rust resistance and survival of outplanted trees where natural seed sources and natural regeneration are limited.

Genetics programs, which are testing for genetically improved seeds patterned after white pine and sugar pine blister rust resistance programs, will be a great aid in restoration. However, where opportunity exists to plant whitebark pine, we cannot afford to wait on the development of rust resistant tree stock.

Throughout much of its range, silviculturists are initiating the outplanting of whitebark pine as one small tool in their bag of management options. Planting prescriptions for whitebark pine are similar to those for other species on

Figure 4—Whitebark pine seedling outplanted in the shade of a stump to protect it from intense heat, help with conservation of water, and to act as a barrier to shifting snow and soil.

harsh sites, but whitebark pine fills a niche that we would typically avoid planting with other conifers. With continued monitoring in the field and with research studies, we can refine the prescriptions for survival, increase populations of rust resistant trees, and contribute to the population of regenerating whitebark pine. Working with our nursery partners in developing an efficient and affordable growing regimen that develops target seedlings is the key to outplanting success for whitebark pine.

Figure 5—Whitebark pine seedling grown in a large container plug showing a well developed root system that helps seedlings adapt to planting sites. Photo courtesy of the Targhee National Forest photo library.

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