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White Pines, Blister Rust, and Management in the Southwest

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Cover: Mature southwestern white pine and infected sapling (inset); Lincoln National Forest.

White Pines, Blister Rust, and Management in the Southwest

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Executive Summary

White pines in New Mexico and Arizona are threatened by the invasive disease white pine blister rust, *Cronartium ribicola*. Blister rust is already causing severe damage to a large population of southwestern white pine in the Sacramento Mountains of southern New Mexico. Recent detection in northern and western New Mexico suggests that a major expansion of the disease is likely over the next several years. Although little can be done to control blister rust in most forest situations, managers can address this long-term threat in a responsive and prudent manner.

White pines, which include southwestern white, limber, and bristlecone pine, are found in most forested ranges of the Southwest. They most often occur as minor components in mixed conifer forests; several thousand acres are classified as white pine cover type. White pines have value for biodiversity, wildlife, aesthetics, and commercial timber. Although all North American white pine are highly susceptible to blister rust, there is evidence that low levels of genetic resistance occur in many populations. Resistance has already been found in several trees in the Sacramento Mountains, and seed from additional parent trees is being tested.

Blister rust can be expected to impact white pines throughout most of the Southwest in coming decades. Nonetheless, some sites are more prone to blister rust than others. Even where conditions are especially favorable for blister rust, some trees may be resistant, providing a seed source for natural selection and eventual recovery of a population. However, near to complete extirpation of white pines may occur in some areas. On low hazard sites, infection rates and mortality are expected to be relatively low. These sites serve as important genetic refugia for white pines.

Maintaining and promoting genetic diversity among white pines should be a key management objective, and a statement to this effect should be included in Forest Plans. We suggest that white pines be given a high species preference in silvicultural prescriptions. This simple, cost-effective strategy, by encouraging a diverse gene pool, would help insure the long-term survival of these unique trees. Eventually, seed from large numbers of known resistant trees could become the basis for a planting program to supplement natural populations.

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Introduction

Since the initial discovery of white pine blister rust (*Cronartium ribicola*) in southern New Mexico (Hawksworth 1990), we've been attempting to increase awareness of the vulnerability—and value—of the native white pines in the Southwest. The impact of blister rust on North American white pines has been a focus of attention since its introduction from Europe in the early 1900s. Recent range expansions of the pathogen and damage to high-elevation species (especially whitebark pine) have led to renewed interest at the National level (Samman and others 2003). This report quantifies the white pine resource of New Mexico and Arizona, summarizes the current status of blister rust, and provides recommendations to managers. We discuss ongoing efforts—including work with genetic resistance—to address this destructive disease.

The White Pine Resource

The Southwest is home to three species of white pine: southwestern white (*Pinus strobiformis*), limber (*P. flexilis*), and Rocky Mountain bristlecone (*P. aristata*). *P. strobiformis* and *P. flexilis* appear to intergrade throughout much of northern and central New Mexico and northern Arizona. The taxonomic and nomenclatural status of southwestern white pine has fluctuated over time (Andresen and Steinhoff 1971; Kral 1993), as have distribution maps for it and limber pine.

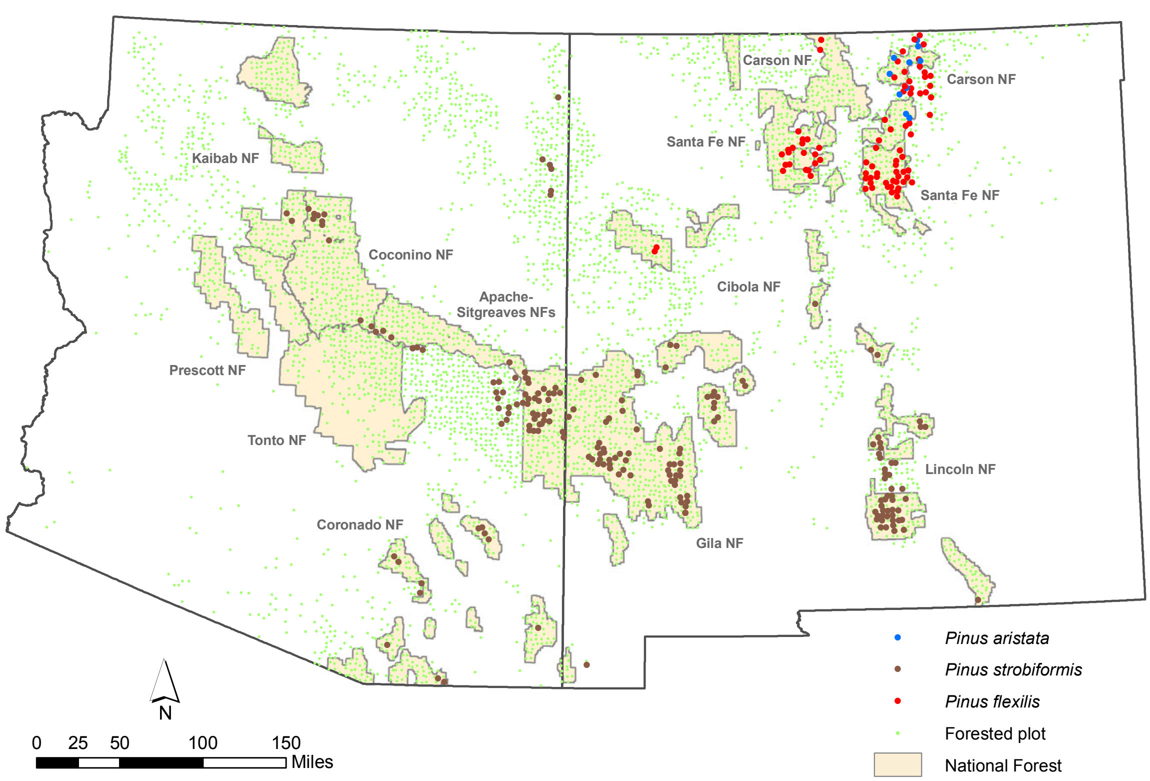

Figure 1. White pine distribution in the Southwest, based on 1999 FIA data (cycle 2).

In this report, we refer to southwestern white pine and limber pine collectively as **white pine**. The ecology and management options for both these taxa are similar. White pines are found in most of the forested ranges of the Southwest (Figure 1). There are more than 30 disjunct, genetically isolated populations in New Mexico and Arizona. They most often occur as minor components in mixed conifer forests, although at least 30,000 acres in the Region are classified as white pine cover type (O'Brien 2002, 2003). *P. strobiformis* alone occurs in at least 40 different plant associations or habitat types in Arizona and New Mexico (Stuever and Hayden 1997). White pines have value as biodiversity components, and for wildlife, aesthetics, and commercial timber (Burns and Honkala 1990). The large seeds are an important food source for several birds and mammals (Wall and Balda 1983; Benkman and others 1984).

Figure 2. Old-growth southwestern white pine, Mescalero-Apache Reservation, New Mexico.

Forest Inventory and Analysis (FIA) data indicate that there are roughly 75 million white pines in the Southwestern Region (O'Brien 2002, 2003; USDA Forest Service 2008; Figure 3). The largest populations are on the Santa Fe National Forest (NF) in northern New Mexico and the Lincoln and Gila NFs in southern New Mexico. The Santa Fe NF has two major, disjunct populations: Jemez Mountains (westside) and Sangre de Cristo Mountains (eastside). The Lincoln NF and adjoining Mescalero Apache Reservation—the initial and still primary blister rust outbreak area in the Southwest—have one of the largest contiguous populations and greatest densities of white pine. In Arizona, the largest populations are found on the San Francisco Peaks (Coconino NF) and in the White Mountains (Apache Sitgreaves NF and Fort Apache Reservation). Most known white pine populations in New Mexico and Arizona are represented on the FIA plot network (USDA Forest Service 2008; Figure 1).

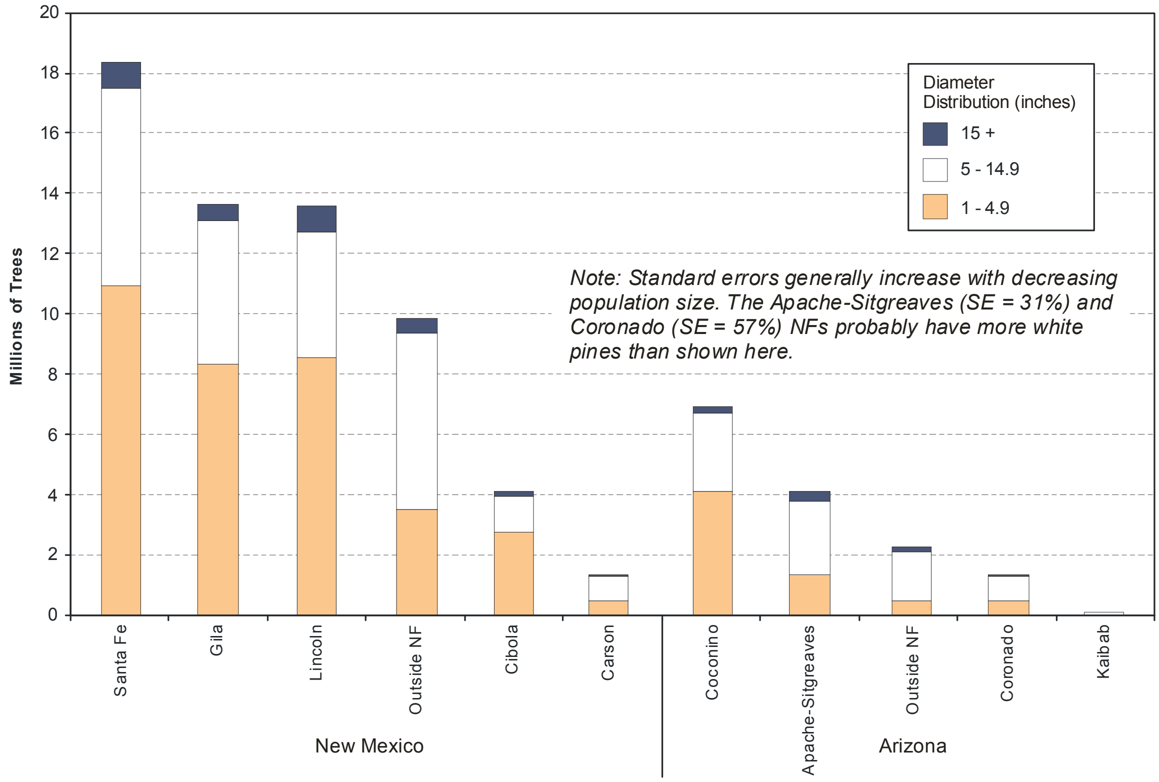

Figure 3. Numbers of white pines (*P. flexilis and P. strobiformis*) on National Forests in New Mexico and Arizona summarized from FIA data.

A sizable population of bristlecone pine is found in the Sangre de Cristo Mountains of northern New Mexico (Figure 1), the southern extension of a much larger population in Colorado. FIA data show about 5 million bristlecone pines in the Region (O'Brien 2003), all on the Carson NF and nearby private land [this population is known to extend south into the Santa Fe NF]. A small outlier of *P. aristata* is found on the San Francisco Peaks (Coconino NF) in northern Arizona; however, this population was apparently not sampled on FIA plots. Bristlecone pine undoubtedly plays an important ecological role where it occurs (Schoettle 2004), and is of keen interest to visitors of high-elevation forests.

Figure 4. Bristlecone pine, Valle Vidal Unit, Carson National Forest.

Current Known Distribution of Blister Rust (Figure 6)

By the time blister rust was detected on the Lincoln NF in 1990, it had already spread throughout most of the Sacramento and adjoining White Mountains of southern New Mexico (Hawksworth and Conklin 1990). The oldest infections found indicate that the disease had arrived in this area by the early 1970s. Plantings of infected white pine or perhaps *Ribes* (the primary alternate host) were initially suspected to be the source of the outbreak. However, it appears feasible (Frank and others 2008) and now seems likely that the pathogen arrived in this area via long-distance aerial transport of spores from California.

Infected trees were first found in the Capitan Mountains in 1994 and on Gallinas Peak (Cibola NF) in 1999. Spread to these locations was most likely a result of aerial transport from the Sacramento Mountains, based on proximity, prevailing winds, and age of infections in these new locations.

Figure 5. "Discovery Tree" – the first infected tree found in the Southwest, as it appeared in 1990. Flagging is from numerous 5-6 year-old infections. Located 2 miles NE of Cloudcroft, on the Lincoln National Forest.

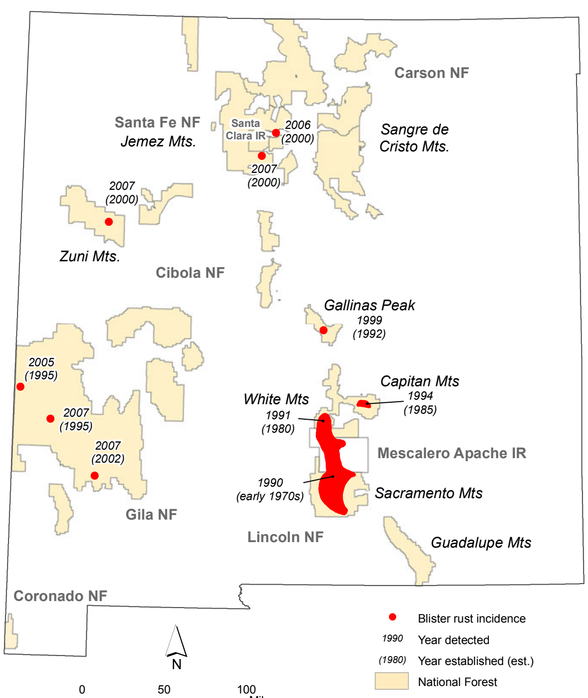

Figure 6. Known distribution of white pine blister rust in New Mexico.

In 2005, blister rust was found for the first time on the Gila NF, on a site about 3 miles from the Arizona border. The first sighting in northern New Mexico was in 2006, on the Santa Clara Pueblo. In 2007, infected trees were found on the Santa Fe NF (Jemez Mountains), at several more locations on the Gila NF, and in the Zuni Mountains (Cibola NF). The source(s) of these more distant outbreaks is uncertain, but could include additional long-distance spread from California.

Blister rust has not yet been detected in Arizona; conditions for initial establishment there appear less favorable than in New Mexico (Frank and others 2008). Blister rust has also not yet been found on bristlecone pine in this Region, but it has been reported on bristlecone in southern Colorado (Blodgett and Sullivan 2003).

Blister Rust Hazard

Some sites are more prone to blister rust (higher "hazard") than others. In general, cooler, moister sites are more favorable for rust establishment and development than warmer, drier sites. A preliminary hazard rating system, based on elevation, slope position, and habitat type, was developed for the Sacramento Mountains of southern New Mexico (Geils and others 1999). Intensive sampling in 5 study areas indicated that stands above 8000 ft., especially those in the white fir series, had more blister rust than lower elevation stands or those in the Douglas-fir series. Permanent plots scattered throughout the Sacramento and adjoining White Mountains further demonstrate that rust severity varies with habitat type and generally increases with elevation (Van Arsdel and others 1997; Conklin 2004). Moist canyon bottoms often provide conditions especially favorable for blister rust. Another indication of hazard is the presence and abundance of various *Ribes* species, which differ in susceptibility (Van Arsdel and Geils 2004).

The outbreak in the Sacramento Mountains, where blister rust has now been established for more than 35 years, has been described as of "savage intensity" (Kinloch 2003). Roughly 100,000 acres—most of the mesic mixed conifer forest in this area—already has severe blister rust infection, with frequent top-kill and mortality. A strong summer monsoon pattern, along with an abundance of highly susceptible *Ribes pinetorum*, help explain the severity of the outbreak in this area. However, a similar proportion of the host type in the Sacramento Mountains continues to have a relatively low rate of infection and much less damage from blister rust (Geils 2000; Conklin 2004).

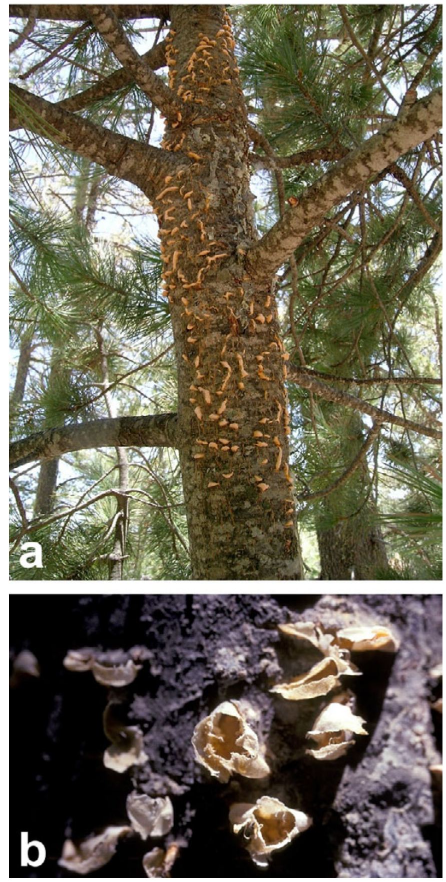

Figure 7. (a) Fruiting stem canker. Aecia (blisters) appear annually in the spring, typically beginning 3 to 5 years after initial infection. Aecia open in late spring (b), releasing windborne spores that can travel long distances.

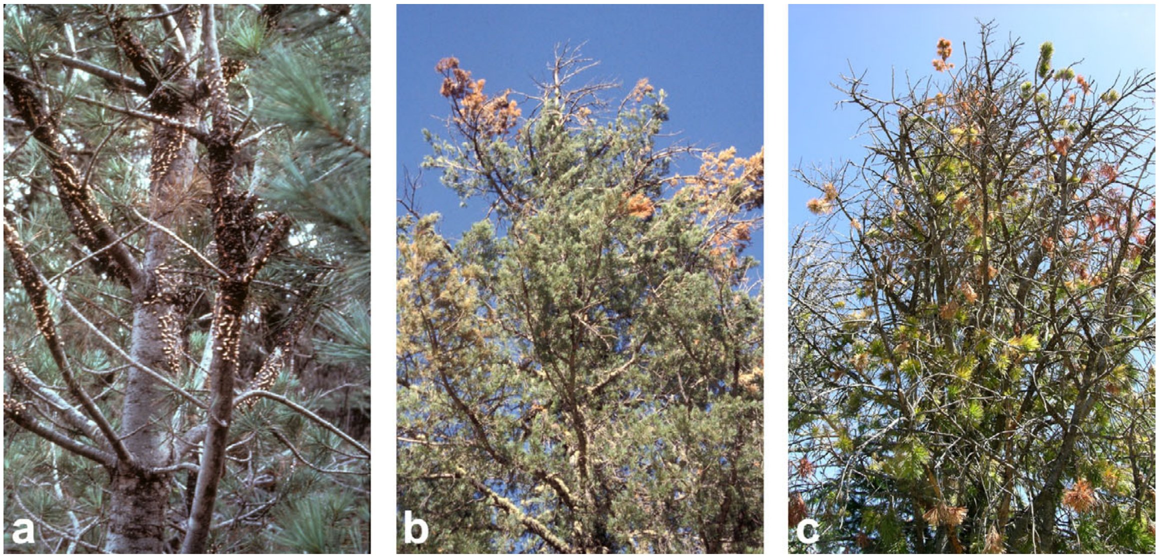

Figure 8. (a) This sapling has many separate infections, each 5−6 years old, the result of a major "wave" of infection around 1985. Lincoln National Forest. (b) and (c) Blister rust damage. Both these trees have been infected for about 20 years. Damage like this is now common on mesic sites throughout the Sacramento Mountains.

Recent detection of blister rust in northern and western New Mexico suggests that a major expansion is likely over the next several years. Eventually, the disease is expected to affect white pines throughout most of the Region. On high hazard sites, very high rates of infection and mortality can be expected, with the *potential* for near to complete elimination of white pines. However, on low hazard sites, damage should be much more limited. We think that a significant proportion of host type in the Southwest has a relatively low rust hazard.

Blister Rust Resistance

Genetic resistance has been the primary focus of blister rust research and management since the 1960s. This followed several decades of *Ribes* control work, which was largely discontinued due to rising costs and relative ineffectiveness, at least in western forests (Benedict 1981). There is strong evidence that genetic (heritable) resistance to blister rust occurs, at low frequencies, in many North American white pine populations. Several resistance traits that function in the needles, twigs, and stem of white pines have been identified, and are thought to involve one to many genes at several different loci (see Bingham 1983; Hoff and McDonald 1980; Kinloch and others 1970).

Figure 9. Orange gooseberry, *Ribes pinetorum*. This species is highly susceptible to blister rust and is common in many mountain ranges of New Mexico and Arizona.

Blister rust resistance is a complex subject, and our understanding of its genetic basis remains limited (see McDonald and others 2004; Vogler 2007). Some types of resistance are only partial, and have been termed "slow rusting" (Kinloch and Davis 1990) or "tolerance," while other(s) confer immunity. Various factors, poorly understood, may regulate the expression of resistance. Inherited resistance should not be confused with what is termed "escape," in which susceptible trees remain rust-free due to site factors (see discussion of site hazard above) or chance.

Research and operational programs to study, develop, and outplant resistant western white pine (*P. monticola*) and sugar pine (*P. lambertiana*), both valuable commercial species, have been underway for more than 50 years (McDonald and others 2004; Sniezko 2006). **Natural selection**, based on existing resistance within native populations, has also received attention (Hoff and others 1976; Hoff and others 1994; Krebill and Hoff 1995).

As management options, artificial selection (i.e. outplanting resistant stock) and natural selection can be complementary strategies in efforts to maintain viable populations of white pines. Natural selection can—and should—be facilitated through appropriate silviculture, a topic discussed later in this report. Seed from known resistant parent trees could eventually become the basis for a planting program to supplement natural populations.

Resistance Testing of *P. strobiformis*

We began a small-scale effort to locate and test potentially resistant trees in the Sacramento Mountains in 1994. That year, 75 resistant candidates of seed-bearing age were identified and tagged in Bradford Canyon, near Cloudcroft. These trees were growing in stands with severe rust infection, but appeared to be rust-free. Additional candidates have been selected in this area since 1994.

Cone collections were made in 1997, 2001, and 2004, with seedlings grown and tested at the Institute of Forest Genetics (IFG), USDA FS, PSW Research Station in Placerville, CA. The 2004 collection also included seed from 7 trees in Wills Canyon, another heavily-infected area 20 miles south of Bradford Canyon. To date, progeny from 45 candidates have been tested in as many as three trials at IFG. Eight trees from the 2001 collections were also screened at the Dorena Genetic Resource Center in Cottage Grove, Oregon. Testing involves exposing young seedlings to spores cast from infected *Ribes* leaves, and observing reactions for several months, or up to five years, depending upon the resistance traits being studied.

Figure 10. Susceptible southwestern white pine seedling 4 months after artificial inoculation with *C. ribicola*. Orange droplets (spermatia) are the initial spore stage, preceding the blisters (aecia). Needle spots are also abundant.

Six of the parent trees from Bradford Canyon exhibit major gene resistance (MGR), based on a hypersensitive reaction (HR) in the needles (Kinloch and Dupper

2002; Vogler and Delfino-Mix 2008). Among the progeny of these six trees, about one-half were resistant and one-half were susceptible, indicating that the parents carry one copy of this major, dominant gene. Several of the other trees tested had one or more resistant seedlings, suggesting they were pollinated by resistant trees. Southwestern white is thus the 3rd white pine (after sugar pine and western white pine) in which MGR has been found. Ongoing, longer-term testing at Dorena appears to have shown additional resistance traits in southwestern white pine (Sniezko and others 2006).

In all likelihood, the white pines in New Mexico and Arizona have multiple resistance traits, similar to those reported in other white pines (see Bingham 1983; Kinloch and Davis 1996; Kegley and Sniezko 2004; Mahalovich 2006). Some of these traits confer only partial resistance, and to what extent these improve long-term survival remains uncertain. Similarly, although MGR and other single gene traits appear to confer complete immunity, these can (at least potentially) be overcome by new strains of the fungus. A better understanding of resistance will help scientists and managers better predict the long-term impact of blister rust and should lead to better management of white pines.

In 2008, seed was collected from 54 more white pines for study/screening at IFG and Dorena. These include additional resistant candidates from the Lincoln NF and phenotypically desirable (but not rust-challenged) trees from the Santa Fe and Cibola NFs.

Management Strategies

In general, management of white pines in the Southwest can, and necessarily will, be integrated with other resource needs and objectives. In a practical sense, little if anything can be done to control or stop the spread of blister rust in most forest situations. However, using the concepts of site hazard and resistance, discussed above, managers can address the blister rust threat in a responsive and prudent fashion.

Blister rust is already causing severe damage to white pines in the Sacramento Mountains, and will eventually impact populations in other parts of the Southwest. However, relatively little damage may occur on drier sites or other "low hazard" areas such as the Guadalupe and Santa Rita Mountains which lack susceptible *Ribes*. Where conditions are especially favorable for blister rust, some trees may be genetically resistant, providing a seed source for eventual recovery of the population. Maintaining and promoting genetic diversity among white pines should be a key management objective. A diverse gene pool may offer the best hope for the long-term survival of these unique trees.

Planting White Pines

Historically, white pines have been planted in only a few locations in the Southwest, mostly on the Lincoln NF. Several *P. strobiformis* plantations totaling about 2200 acres were established on the Lincoln between 1977 and 1990. Planting was discontinued following the detection of blister rust in 1990; all the older plantations were found to be severely damaged by the disease.

Availability of blister rust resistant planting stock may be desirable in this Region. However, for this to become a reality, a major effort in locating and testing additional candidate trees will be necessary. Region 5 has tested over 21,000 sugar pine; to date more than 1,700 parent trees with MGR have been identified. The rust resistant western white pine program is based on more than

3000 resistant or partially resistant parent trees, which Hoff and others (1994) consider a minimum number to assure genetic variation and durability of resistance. At the present time, seed from *known* resistant trees can be—and should be—collected and stored for gene conservation and future planting needs. Seed from additional *putatively* resistant trees (resistant candidates) should be collected and tested.

White pines could be planted on low hazard sites with relatively little risk of damage from blister rust, although a precise determination of site hazard is often difficult. Unfortunately, low hazard sites are usually relatively dry, making successful establishment less likely than on more mesic (and higher hazard) sites.

Any future plantings of white pine on mesic sites should include at least some resistant stock, with a combination or mix of resistance traits to help insure durability of resistance. In practice, this might involve using seed from several sources including known MGR trees, trees with partial resistance or "slow rusting" traits, and untested trees from heavily-infected sites that appear to be resistant ("phenotypic resistance"). From a scientific perspective, such plantings could provide ideal, long-term research opportunities, provided that seed sources are well-documented.

Natural Selection and Silviculture

Natural regeneration will continue to be the predominant source of white pines. **Natural selection** for blister rust resistance in the western U.S. has been a topic of discussion for many years. Hoff and others (1976) describe a strategy of encouraging natural regeneration of known (or presumed) rust-resistant western white pine, a process they term "mass selection." Similarly, Hoff and others (1994) and Krebill and Hoff (1995) suggest that natural selection, augmented by cultural methods, may offer the best option for conservation of whitebark pine. Recently, Schoettle and Sniezko (2007) and Burns and others (2008) advocate proactive options to encourage natural regeneration of white pine in areas not yet impacted by blister rust, to improve the odds in natural selection following eventual disease establishment.

The idea of encouraging natural regeneration of white pine has merit, although it may be worth noting that most forest regeneration is unplanned. The simplest, most direct, and least costly strategy for facilitating natural selection is to favor white pines in harvest and thinning projects (whether or not a given project is labeled "regeneration cut"). Natural selection is clearly a "numbers game": having more white pines on a site improves the likelihood that at least some of them will be resistant to blister rust and have other desirable genetic traits. Favoring white pine helps ensure that it will continue to occupy the

Figure 11. Recently thinned stand in the Santa Fe watershed of northern New Mexico. White pines were favored for retention in this project area. Blister rust site hazard is low.

site through the current generation *and* provides a larger, more genetically diverse seed source for the next generation.

At the very least, white pines should not be discriminated against in project areas. White pines, where present, are usually minor stand components, so favoring them will not greatly affect other management objectives, including those intended for the wildland-urban interface (WUI). Conversely, without a favorable species preference, a minor stand component like white pine can easily be reduced proportionally within treatment areas and on the landscape, reducing its reproductive and genetic potential.

White pines have been favored in a several recent thinning projects in New Mexico. However, white pine has typically been ranked below both ponderosa pine and Douglas-fir in species preference, resulting in stands with a lower proportion of white pine than before treatment. In recent years, the justification has often been that white pine is less fire-resistant than these other species. This rationale seems narrow-focused and short-sighted: in fact, white pines are ecologically well-adapted to fire and have probably been affected negatively by more than a century of fire suppression/exclusion (Fins and others 2002; Samman and others 2003). Fire scars on surviving white pines have provided some of the best dendrochronological records of fire history in the Southwest. In contrast to the 75 million white pines in New Mexico and Arizona, there are approximately 1.5 billion ponderosa pines and 540 million Douglas fir (O'Brien 2002, 2003).

Figure 12. Fire scars are common on older white pines in the Southwest. White pines are ecologically well-adapted to fire.

Lessons from decades of western white pine management in the Pacific Northwest and northern Rockies are instructive. Since the arrival of blister rust in the 1920s, it is estimated that western white pine growing stock has been reduced by 90 to 95% (Fins and others 2002; Kinloch 2003). Although the disease itself certainly had a major impact, logging in the early and mid 1900s, followed by accelerated harvest of white pines and a decision to favor other species because of blister rust in the 1960s (Fins and others 2002; Schwandt and others 2006) clearly had a negative effect on these populations. Today, although resistance breeding and planting programs for western white pine have been active for more than 30 years, retention of wild trees (where they remain) is strongly recommended to help provide a broad genetic base and promote natural selection (Fins and others 2002). Similar recommendations have been made by geneticists throughout the western U.S. and Canada.

In practice, several options can be used in silvicultural prescriptions to favor white pines, depending on current species composition; for example:

1. retain *all* white pines of reasonably good form and vigor ("crop tree quality")
2. rank white pine first in species preference
3. rank white pine and ponderosa pine equal in species preference

Option 1 may be appropriate where white pines comprise less than 2 to 3 percent of the trees in a stand or treatment area. Options 2 and 3 would be appropriate where white pine is more abundant. Situations where white pine or both white and ponderosa pine can be favored over more shade-tolerant species are common. Each of these options, but especially option 1, can lend itself to irregular spacing or clumpy stand structure.

In stands already impacted by blister rust (primarily in the Sacramento Mountains, but increasingly elsewhere), every effort should be made to retain rust-free white pines when harvesting or thinning, since at least some of them are probably resistant. In heavily-infected stands, trees with relatively few, non-lethal cankers should also be retained, since these may carry traits for partial resistance. It is again worth noting that infected trees can have at least some resistant offspring if pollinated by resistant tree(s).

Selection pressure (natural screening) for resistance is highest where the disease is most severe, and natural selection ought to proceed most quickly on these sites (Krebill and Hoff 1995). At least in theory, each succeeding generation would have more resistance until a balance is achieved between host and pathogen. Of course, this scenario assumes that sufficient numbers of white pines, with sufficient natural resistance, are present. Extirpation of white pines may well occur on some high hazard sites. Planting rust-resistant trees *may* be the only option to maintain or restore white pines in some locations.

Low hazard sites, which appear to comprise a fairly large proportion of white pine habitat in the Southwest, serve as natural **genetic refugia** for white pine. Although many, perhaps most, of these sites will eventually get some blister rust, we expect that white pines can be managed there with relatively little impact. Retaining and perhaps increasing the white pine component on these sites seems especially important in regard to gene conservation, since blister rust will likely have a major impact elsewhere.

Thinning Pros and Cons

White pines are early to mid-successional (Jones 1974) and tend to be poor competitors in dense, mixed conifer stands. Thinning, by reducing competition, can increase the longevity and reproductive potential of white pines in many situations. Thinning can also reduce potential for stand replacement fire and susceptibility to bark beetles.

Unfortunately, thinning can increase the potential for blister rust damage on some sites (Schwandt and others 1994; Fins and others 2001). Increased sunlight reaching the forest floor tends to increase the abundance of *Ribes*, leading to increases in blister rust. Dense conditions limit not only *Ribes*, but also dispersal of rust spores through a stand.

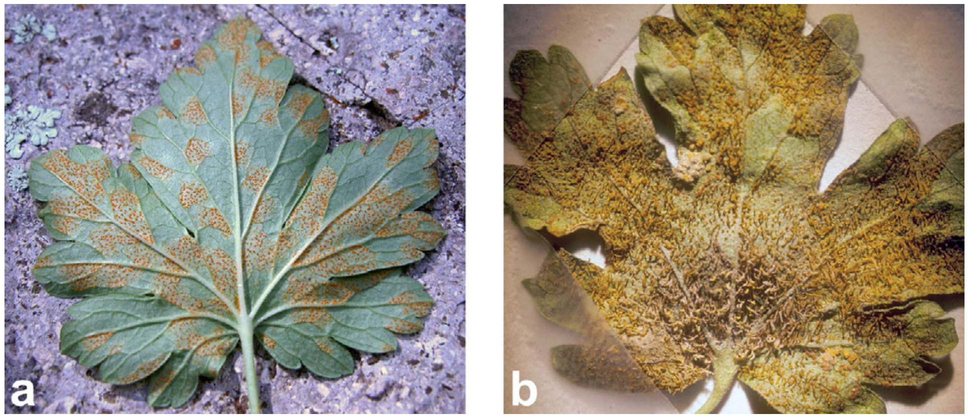

Figure 13 (a). Initial spore stage (uredinia) on *Ribes* leaf. These spores cause additional infections on *Ribes*, resulting in large inoculum loads in favorable years. (b) Later spore stage. Hair-like structures (telia) appear in late summer, producing spores that infect pines.

Similar trade-offs occur in regard to small (or large) openings created by silvicultural treatment: these may encourage regeneration of white pines, but can also increase *Ribes*. Overall, the potential benefits of thinning stands with white pines probably outweigh the negative effects in most areas. However, evaluation of potential rust hazard within specific project areas can help determine situations where thinning and other treatments might increase long-term damage from blister rust. It is worth mentioning that removing trees with blister rust infections usually has little effect on disease spread, since all new infections originate from spores produced on alternate hosts (usually *Ribes*).

Other Management Options

Pruning can be used to remove potentially damaging blister rust cankers, as well as reduce potential for new infections, on individual high-value trees, but is probably not justified in most forest situations. Pruning and other management options, including *Ribes* control and use of herbicides and fungicides, have been addressed in several reports from other Regions (e.g. Hagle and others 1989; Schnepf and Schwandt 2006; Burns and others 2008).

As with other invasive pests, **eradication** efforts might be considered following a *recent* introduction of blister rust, especially where the potential for rapid *re-infection* is low. For example, maintenance of a “rust-free zone” may be desirable on the San Francisco Peaks of northern Arizona. In practice, this would involve continual, periodic monitoring of the white pine population, and prompt removal or pruning of any infected tree(s) detected.

Management Strategies – Conclusion

Blister rust will increasingly impact white pines in the Southwest in the coming decades. Although direct control is impractical in most forest situations, a diverse gene pool among white pines should help insure the long-term survival of these unique trees. Favoring white pines in silvicultural treatments is a simple, cost-effective strategy that will not interfere with other resource objectives. Eventually, seed from large numbers of resistant trees could become the basis for a planting program to supplement natural populations. The desirability of maintaining and enhancing white pine populations should be addressed in revisions to National Forest plans.

Figure 14. Old-growth white pine in Zuni Mountains, New Mexico.

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