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The distribution of white pine blister rust in the Sacramento Mountains of New Mexico

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Summary

White pine blister rust, *Cronartium ribicola* was discovered by F.G. Hawksworth in 1990 on southwestern white pine, *Pinus strobiformis*, in the Sacramento Mountains near Cloudcroft, NM. Informal surveys that year by pathologists of the Southwestern Region and the Rocky Mountain Station showed that the rust had already spread throughout the Sacramento Mountains. The rust distribution within the Sacramento Mountains reported here was determined from three plot series established by Conklin (1990 to 1997) with 41to 52 trees in each plot, by Van Arsdel and Popp (1996 to 1998) with 8 to 37 trees in each plot, and by all four authors in 1998. Various site features including elevation, aspect, and *Ribes* species and abundance were noted for each plot. Trees have been observed from one to three times to determine the presence and location of rust cankers and the appearance of new infections. Data from each plots series indicated that the rust in the Sacramento Mountains was increasing and was influenced by *Ribes* distribution, elevation, and topography. Rust incidence was greater where *Ribes pinetorum* was abundant, where the rust had been present longer, and at higher elevations. Of the six species of *Ribes* reported in the area Sacramento Mountains, only *R. pinetorum* and *R. cereum* were common and widespread. Wherever the incidence of blister rust on pine was high, *R. pinetorum* bushes were present, and rust incidence was greatest near these bushes. The presence of *R. cereum* had little effect on the distribution of the rust on pines. At lower elevations, *R. pinetorum* was found on north slopes and in some canyon bottoms; it was widespread above 2740 m (9,000 ft.). Below 2590 m (8,500 ft) there was a local topographic effect upon the rust distribution, and infection of pines was greatest at the base of the slope. At higher elevations, for example above 2740 m (9,000 ft.), rust was widespread and local topographic effects were not evident.

Key words: *Cronartium ribicola, Pinus strobiformis, Ribes*

1 Introduction

The introduction of white pine blister rust (*Cronartium ribicola* Fisch.) in the Sacramento and White Mountains of New Mexico has provided an opportunity to study the introduction and distribution of the rust into a relatively small and discrete area where the effects of a variety of climatic and environmental factors could be studied in detail (Geils 1993). Surveys immediately after Hawksworth's discovery in 1990 showed that the rust was already widespread throughout the mountains (Hawksworth, 1990).

The importance of southwestern white pine, *Pinus strobiformis* Engelm. has been understated in the literature. There are about 202 000 ha (500 000 acres) of forests in the Sacramento Mountains, the adjoining White mountains, and the nearby Capitan Mountains that contain southwestern white pine (Conklin 1994). In roughly half of this area it is a significant stand component. Here, the species grows with a range in elevation from about 2130 m (7 000 ft.) to over 3050 m (10 000 ft.). This population seems to be the largest in the southwestern USA. Smaller populations occur in nearly all the higher ranges of mountains in New Mexico and Arizona. It has a wide range of occurrences in Mexico. The general form of the tree is much more like that of the western white pine (*Pinus monticola* Dougl. ex D. Don), than limber pine (*P. flexilis* E. James) with which it has been taxonomically confused. Compared to limber pine, southwestern white pine has a larger, straighter form, much longer and thinner cones with thinner recurved scales, longer needles, and a lack of stomata on the outer surfaces of the leaf bundles that makes the tree look greener (Andresen and Steinhoff 1971, Little *et al*. 1980). There are populations of intermediate forms on isolated mountains between the ranges shown on map number 8 in Critchfield and Little (1966). These intermediate forms are generally shown as one pine or the other. Both species do occur in the Sangre de Cristo Mountains, which are shown as having overlapping ranges on that map.

There were six species of *Ribes* present in this region, and a seventh has been reported. *Ribes pinetorum* Greene (orange gooseberry) was common in the mixed conifer forest above 2440 m. It typically became more abundant with increasing elevation, and was generally widespread above 2740 m. Below 2440 m it was found on north slopes and in canyon bottoms. *Ribes cereum* Dougl. (wax currant) was more widespread than *R. pinetorum*. It was much more common at lower elevations than *R. pinetorum*, but it was also found at higher elevations. It was generally found on warmer sites than *R. pinetorum*, but it was also found on cooler sites. *Ribes mescalerium* Cor. (Apache currant), *R. inerme* Rydb. (white stem gooseberry), and *R. wolfii* Rothr. (black currant) were much less common than the above species. *Ribes aureum* Pursh. (golden currant) was found in stream bottoms below the elevations of the pines. *Ribes montigenum* McClatchie has been reported in these mountains, but we have not found it in the field or in the local herbaria. It may be present at higher elevations on Sierra Blanca, the highest peak in the White Mountains.

Introduction of the rust into the Sacramento Mountains

There are two major hypotheses on the spread of white pine blister rust into the Sacramento Mountains. It is possible that the rust was introduced on planted white pine stock, but old infections indicate the rust was introduced into at least 3 sites in the early 1970s prior to the first recorded plantings made in 1977, indicating a natural spread. The rust is old and abundant in Bradford Canyon, Silver Springs Canyon, and Karr Canyon. The rust is definitely on 1975 wood and some is probably older. These sites are on the west flank of the mountains at approximately 2440 m in wind passes. The oldest heavy infections are remote from residential development, so the introduction of the rust from ornamental plantings at homes seems unlikely. The spread of rust into the mountains by planted infected *Ribes* plants is unlikely because of the low chances for spread from *Ribes* to pine. Wave years for conditions favoring pine infections are infrequent. The possibility of rust having been introduced at the former Cloudcroft Experimental Forest in the 1960s or 1970s on planted white pines needs to be investigated by checking for the presence of white pines that could have been planted there. Records form the forest do not indicated that there was any tree planting there.

Experience in tracing the annual introduction of peanut rust into Texas from the Dominican Republic and the West Indies at an 2440 m transport level from where the spores were brought down by frontal rains, suggests that natural introduction was most likely. In the case of the peanut rust, spores were trapped on slides in an airplane at 2440 m above ground, spores trapped in rain barrels preceded field infection by the proper 10–12 day intervals, and the spores from the rain traps were used to inoculate and infect peanuts (Van Arsdel and Harrison 1972; Van Arsdel 1973, 1974). The spread of white pine blister rust into Indiana further augments the conviction that this type of spread was likely. There, rust was found on *Ribes* in 1936, 1938, 1943, 1945, 1946, and 1947. There was no rust in the intervening years. The rust was on 1944 wood on two or three pine trees in 1947. The rust on *Ribes* was 483 to 644 km (300 to 400 miles) away from the rust on pines in Michigan and Wisconsin (Indiana white pine blister rust control annual report, 1949, E.P. Van Arsdel). Mielke (1943) provides a much better known reference on distribution of the rust. He documented the spread of the rust from pine to *Ribes* for more than 483 km in several directions. The documented transport from the coastal forest of British Columbia, Canada to the mountains of north central Idaho, USA would be comparable to the spread from California to the Sacramento Mountains. Mielke (1943) also cites references noting the high elevation spread of rust spores and pollen. The natural spread of the rust into the Sacramento Mountains was likely from the mountains of southern California where it was first found in the mid-1960s. The rust would probably have infected *Ribes* several times before pine infection occurred; such might be confirmed by examination of herbarium specimens. All of the older infection sites were at about 2440 m, the elevation at which clouds frequency flow into the mountains. There would be no need for rain to bring the spores down, because clouds flow right into the forests at this elevation and frequency bathe the trees in fog. It would take about 4.3 hours for the spores to travel the 1047 km (650 miles) from California in a 242 km (150 mph) jet stream wind. Both peanut rust urediospores and blister rust aeciospores are fairly large (25 µm long), thick walled, pigmented, daytime spores that can easily withstand a flight of that duration.

2 Materials and methods

Three series of sample plots have been established. The first series of sample plots established by Conklin 1990 to 1998 was rechecked for *Ribes* by Popp and Van Arsdel in 1998. The same trees on each plot have been checked every three years up to three times for the incidence of rust. These plots were located throughout the white pine range in the Sacramento and White mountains and include a wide range of site conditions. Each plot sampled 41 to 52 representative "crop trees" (trees of relatively good form and position selected without regard for rust infection). The sample on each plot included size classes from saplings to mature trees, selected over an indefinite area of one to three acres.

A second set of 16 plots were established by Van Arsdel and Popp in 1996 and 1997 and contained 8 to 37 trees each. The infection and environmental data were recorded in a slightly different form and *Ribes* data were included. All trees above 0.3 m high were recorded in plots of about 0.04 ha (0.1 acres), but some plots were larger or smaller to sample approximately 10 trees. These plot locations were designed to sample different microclimatic sites, and some were made in a transect across a portion of the Spud Patch drainage.

3 Results

The data from the first series of 12 plots, the Conklin plots, showed that there was generally an increase in the amount of rust with the amount of *R. pinetorum* nearby (Table 1 and Table 2), the elevation (Figure 1), and the length of time the rust had been present in the vicinity. The Silver Springs plot had the most rust because of its elevation, the relatively long time since the first infection (older than 1980), and the presence of *R. pinetorum* (Table 1 and Table 2). Much *R. pinetorum* occurred just outside the boundaries of this plot. Wills Canyon, the plot with the highest elevation, had the elevation and *Ribes pinetorum* presence, but had not had a long enough time since infection to insure a high level of rust infection. It had the greatest rate of increase in the amount of rust. The amount of *R. pinetorum* had been increasing in this plot in the aftermath of logging that occurred less than two years before the plot was established. In the 12 plots, the amount of *R. pinetorum* generally, but not always, increased with elevation (Figure 2). The amount of rust could also increase with elevation, but, as in the case of the James Ridge plot, when *R. pinetorum* was not present, then the rust was not abundant (Table 1 and Table 2). The size of the 16 plots in the Van Arsdel/Popp series was not big enough to draw major conclusions, but there was more rust at the higher elevations, and less when *Ribes pinetorum* was absent or rare on the plot.

Random sampling of white pines within six study areas (= airsheds; a mountain canyon whose nocturnal drainage winds make a more or less closed system) is in progress. To date, 1168 trees over 1.4 m (4.5 ft.) tall and 391 trees less than 1.4 in have been sampled on 96 plots. Rust was found on 32% of the taller trees and 8% of the seedlings. Preliminary analysis suggests that elevation, habitat type (series), and slope position are predictors of rust incidence and severity in the Sacramento Mountains. Stands above 2440 m typically harbored more rust than lower elevation stands. Conversely, on a given slope, rust incidence was generally highest near the bottom and lowest near the top (Table 3). At similar elevations, white fir (*Abies concolor* (Gordon & Glend.) Lindl. ex Hildebr.) and blue spruce (*Picea pungens* Engelm.) habitat types usually had more rust than Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) habitat types (Table 3).

Throughout these mountains, *R. pinetorum* was a major contributor to the spread of rust to nearby pines. *Ribes cereum* was rarely infected by *C. ribicola* and it did not seem to be important in the spread of rust to nearby pines. The high coverage of the leaves by another rust fungus, *Coleosporium ribicola* Arth. (= *C. jonesii* (Peck) Arth.) could possibly be limiting the amount of blister rust that can infect *R. cereum*, but this does not seem to account for the absence of blister rust in all areas. *Ribes inerme* was occasionally found infected with a little blister rust in some of the stream bottom patches, but this was rare. Blister rust has not been found on *R. aureum* along the stream banks below the elevation of the pines.

4 Discussion

The introduction of white pine blister rust into the Sacramento Mountains is an opportunity, a challenge, and a disaster. An opportunity because it gives a unique chance to study the development of an epidemic and hazard class zones for blister rust. A challenge because we need to learn to control and manage this situation. A disaster because a great many wonderful southwestern white pine trees are dying and more will die as more trees become infected.

The hazard classes are beginning to show that there are *Ribes*-free areas, especially at the lower elevations where many pines will survive by escaping the rust. There is a low elevation zone that has pine but no *Ribes pinetorum.* Above that there is a fairly low elevation zone where there are susceptible *Ribes* but little rust infection on the pine because it is not a favorable climate for rust infection. The next higher zone is one in which the rust is found where there are *Ribes* and locally favorable microclimates to benefit the disease. The next higher zone is one in which the rust is found within about 305 m (1 000 ft.) of susceptible *Ribes* plants. Lastly there is a zone so climatically favorable to the rust that the rust can spread long distances. In this climatically high hazard zone at high elevations there are *Ribes* free zones and zones with only *R. cereum* nearby that have only low percentages of trees infected. In such areas an important number of trees can survive. However, there are vast areas where climatic conditions and the populations of *R. pinetorum* are very favorable to spread of the rust, and many trees will die. Disease management practices can be developed using well known control principles augmented by new knowledge we can gain to reduce these losses to manageable levels in many areas.

Control of the rust (or management) would require site selection and pruning. The pruning is complicated by the local rust infection habit of infecting high-up in the trees, unlike in other regions where most of the rust is close to the ground. This is probably due to the transported moisture in the clouds being the main source of moisture permitting infection rather than rainfall being evaporated from the soil as it is in the Great Lakes region. The selection and breeding of resistant trees should be a long-term goal in control of the rust. There appear to be resistant individuals present in the infected areas in these mountains. However, multiple sources should be obtained in genetic resistance breeding programs.

The transmission of rust by only one species of *Ribes* makes the Sacramento Mountains a better place than some others for control by alternate host eradication. Sampling of the rust where *R. pinetorum* is present and where it is not has already indicated that pines can be grown in the absence of this *Ribes* species. Local control by *Ribes* eradication has been shown to be effective in reducing the amount of rust infections on pines (Van Arsdel 1968). To paraphrase part of the paper: of Honey's and Putnam's 35 plots maintained from 1935 to 1932, 29 had eradication treatment. I found that during the four years before eradication (eradication years varied), 5174 cankers were initiated; during the four years after eradication, 103 cankers were initiated. This was 72.4 cankers per 100 trees before eradication compared to 1.4 cankers per 100 trees after eradication (Van Arsdel 1968). The eradication problem is less in *P. strobiformis* stands than in some other areas because only one species of *Ribes* is important in spreading the rust, and *R. pinetorum* has a limited range. The eradication of those bushes within the stand will greatly reduce the amount of rust infection, but important amounts of rust will come in from bushes in surrounding margins. The most effective control system for this region would probably involve *Ribes* eradication by airsheds. Studies of the drainage winds that move spores and the patterns of rust infection associated with them are needed to clarify the best ways to manage the rust. Pilot studies testing eradication procedures could be initiated before the results of the studies are in.

Ribes control may be a more viable option in the intensively managed forests of the Mescalero Apache Indian Reservation than on the Lincoln National Forest. White pine has been a preferred crop in many mixed species stands in the reservation because of dwarf mistletoe on the ponderosa pine P. *ponderosa* Dougl. ex P. Laws. & C. Laws.) and/or Douglas-fir. Most of the white pine in the reservation occurs at or below 2 440 m; overall, rust is less severe than in the higher elevation forests of the adjacent national forest. Moreover, compared to the Lincoln National Forest, there is relatively little *R. pinetorum* on reservation lands (*R. cereum* and/or *R. mescalerium* are much more common than *R. pinetorum* in most areas). It is conceivable that a relatively limited amount of *Ribes* control work could significantly reduce potential rust impact on the reservation. While stopping all infection is not a reasonable goal, management strategies can be developed to limit rust spread.

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Tables

Table 1. Amount of blister rust infection on 12 Conklin plots in order of elevation.

Elevation order	Field plot No.	Plot name	Elevation in feet	Date of oldest infection	Number of trees	Year sampled	Number infected	Cankers per 100 trees
1	8	Sixteen Springs	7200	1992	45	1995	0	0
						1998	4	9
2	9	Bonito Lake	7500	1990	48	1995	1	2
						1998	13	40
3	3	Poison Spring	7500	1989	52	1991	0	0
						1993	2	4
						1996	4	8
4	11	Lower Fence	7550	1989	49	1997	1	2
5	7	Monjeau	7800	1990	48	1995	0	0
						1998	2	4
6	5	Hoosier	7900	1985	41	1994	23	268
						1997	26	390
7	6	Long Canyon	8100	1989	46	1995	3	7
		Cansa Lookout				1998	12	35
8	12	Upper Fence	8100	1985	48	1997	25	354
9	4	James Ridge	8500	1985	45	1994	3	11
						1997	7	27
10	10	Little Apache	8700	1985	47	1995	34	434
						1998	34	515
11	1	Silver Springs	8700	1980	41	1991	39	1049
						1993	39	1220
						1996	39	1585
12	2	Wills Canyon	9300	1985	45	1991	3	7
						1993	6	49
						1996	26	256

Table 2. Amount of *Ribes* on 12 Conklin plots in order of elevation.

Elevation order	Field plot No.	Plot name	Elevation in feet	*Ribes cereum* FLS/acre	*Ribes pinetorum* FLS/acre
1	8	Sixteen Springs	7200	0	0
2	9	Bonito Lake	7500	310	0
3	3	Poison Spring	7500	85	55
4	11	Lower Fence	7550	2870	0
5	7	Monjeau	7800	0	0
6	5	Hoosier	7900	1350	75*
7	6	Long Canyon Cansa Lookout	8100	0	0
8	12	Upper Fence	8100	630	1200
9	4	James Ridge	8500	210	0
10	10	Little Apache	8700	1230	875
11	1	Silver Springs	8700	1100	10*
12	2	Wills Canyon	9300	550	1825

* About 10,000 FLS per acre of *R. pinetorum* found just outside the sampled area.

Table 3. Amount of rust on pines over 1.4 tall in Spud Patch study area by slope position and forest type series.

Slope position or type series	Number of trees	Number infected	Percent infected	Cankers per 100 trees
Lower slope	99	71	72	340
Mid slope	110	64	58	410
Upper slope	169	65	38	220
White fir/blue spruce type	165	108	65	490
Douglas-fir type	213	92	43	170

Figures

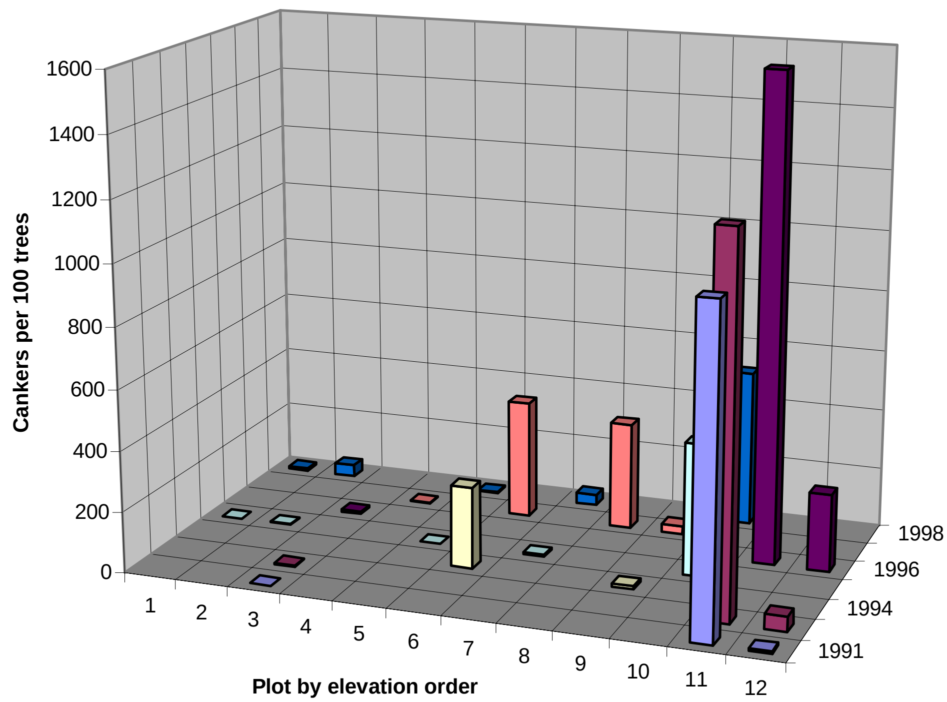

Figure 1. Amount of blister rust infection on 12 Conklin plots in order of elevation. See Table 1.

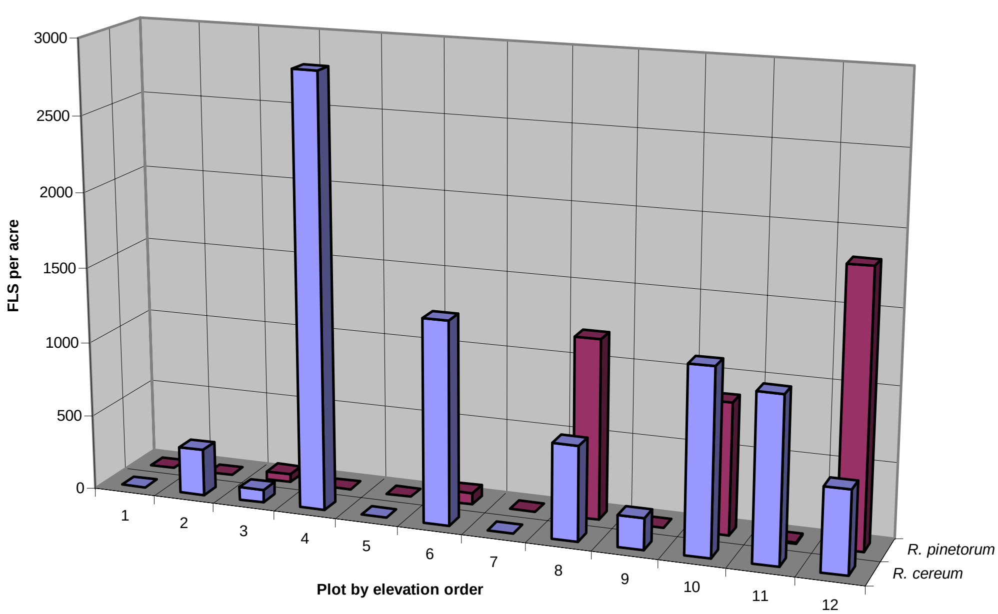

Figure 2. Amount of Ribes on 12 Conklin plots in order of elevation. See Table 2.