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Climatic Distribution of Blister Rusts on Pinyon and White Pines in the USA

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SUMMARY: Surveys of the pinyon pine blister rust were made on pine May 1992, 1993, and 1994, and on *Ribes in* August of 1993. There was a zone without *Ribes* at the lowest (driest level) then a zone with *Ribes*, but no rust. Above this zone various percentages of the pines were infected. The percentage of infected trees was found to be highest in a belt from 6300 to 6700 feet elevation on three Great Basin Mountain Ranges. Above 6700 feet there was less rust although there were abundant *Ribes* and numerous pines with good growth. The rust distribution seems to depend on spore transport as well as temperature and moisture distribution. The greatest concentration of infected trees seems to occur at the backflow recharge area of slope drainage winds where spores are carried in on night breezes and the areas are cool and wet enough to favor rust infections.

INTRODUCTION

My latest studies on pinyon rust are based on the background of white pine blister rust studies made from 1948 through 1968 in the North Central States of the USA. The hosts studied are *Pinus monophylia* and *Pinus strobus*.

"Singleleaf pinyon *(Pinus monophylla),* also called pinyon, nut pine, one-leaf pine, and pinon (Spanish), is a slow-growing, low, spreading tree that grows on dry, low mountain slopes of the Great Basin. It dominates extensive areas in the dry mountain ranges of Nevada, southern and eastern California, and western Utah. Some stands are in Baja California, northwestern Arizona, and southeastern Idaho. Single-leaf pinyon grows under more xeric conditions than any other pine in the United States. Its climate is similar to that of pinyon *(Pinus edulis),* but during the growing season, relative humidity and precipitation are even lower and potential evapotranspiration is greater."(1).

Singleleaf pinyon pine has been spreading across the Great Basin since the last ice age and has spread across the northern two-thirds of Nevada in the last 10,000 years (2).

"Eastern white pine *(Pinus strobus),* also called northern white pine is found across southern Canada from Newfoundland, Anticosti Island, and Gaspe peninsula of Quebec; west to central and western Ontario and extreme southeastern Manitoba; south to southeastern Minnesota and northeastern Iowa; east to northern Illinois, Ohio, Pennsylvania, and New Jersey; and south mostly in the Appalachian Mountains to northern Georgia and northwestern South Carolina. It is also found in western Kentucky, western Tennessee, and Delaware. A variety grows in the mountains of southern Mexico and Guatemala. The climate over the range of white pine is cool and humid. The distribution of white pine coincides reasonably with that part of eastern North America where the July temperature averages between 18 and 23 C (65 and 74 F)." (5).

In 1993 and 1994 Dr. Van Arsdel re-surveyed some of his 1948 to 1968 blister rust studies on eastern white pine. More detailed surveys are planned in the North Central States, but so far these surveys indicate that the climatic zones of rust distribution are about the same as they were in 1948-68. There has been an increase in the amount of blister rust on the Coulee Experimental forest in 1993 compared to the 1950's and 1960's; however this was probably due to an increase in the amount of planted white pine rather than to climatic cooling.

The life cycles of *Cronartium ribicola and Cronartium occidentale* are identical except for the pine host. Uredinial spread occurs between *Ribes* plants, telia are formed on the *Ribes* leaves and the basidiospores produced on the basidia on the telia carry the rust to the pines. The basidiospores are released at night and to survive they must be carried to the pine and infections started before daytime drying (Fig. 1). Abundant moisture and dew is required for basidiospore production and for pine infection. This late night transport time is a time of stable laminar gravity

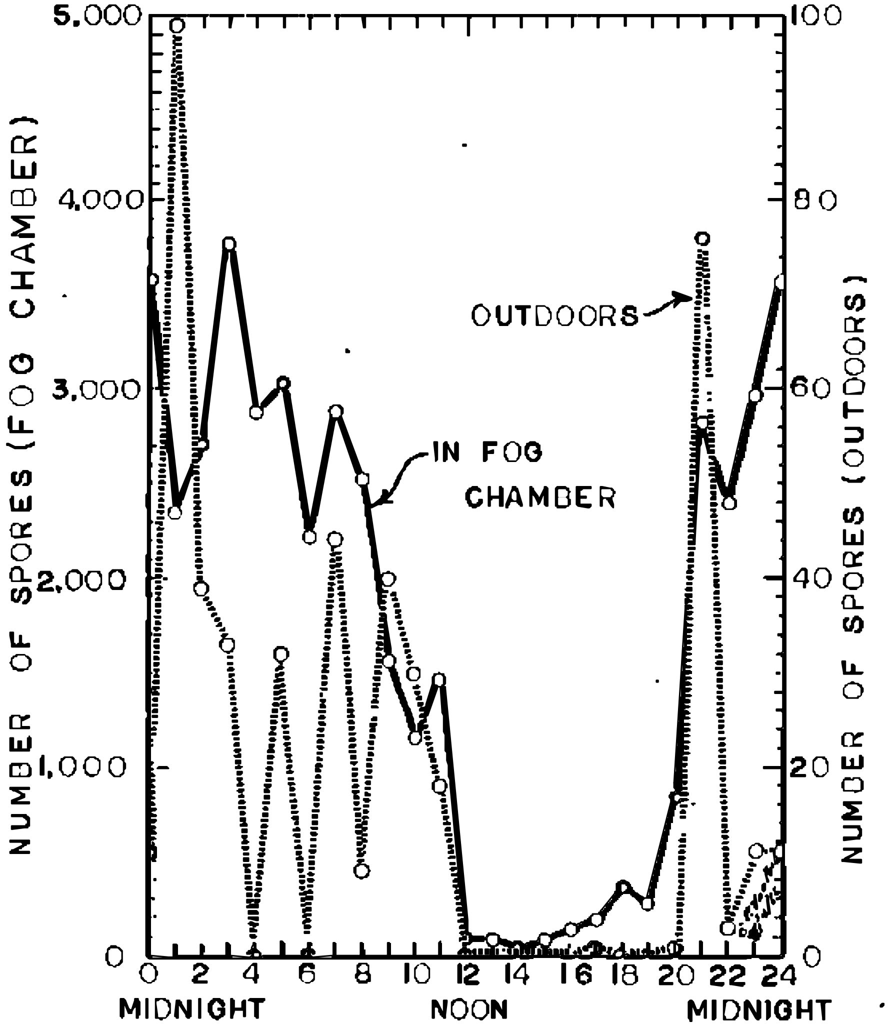

Fig. 1. A typical hourly release of blister rust basidiospores at 16 C in a fog chamber (solid line). Natural outdoor production data (broken line) are from a single-occasion release (8-9 October 1959). (3)

winds and their counter currents. Land to water air flows and their counter currents are also involved.

Abundant cool wet weather favors rust spread and warmer drier air limits or prevents its spread. In the North Central (Lake) States there is a gradient in the amount of rust spread to pines from cool wet north and high ground to the warmer drier south and lower lands. The rust spread gradient has been divided into four zones in the Lake States (Fig. 2). The northern zone (Zone 4) is characterized by long distance spread from *Ribes* to pines and infections high in the tree crowns. Telia are often produced on *Ribes* without uredinial spread occurring, and pine infection can occur in summer. Zone 3 is characterized by favorable infection conditions on all sites, but without the long distance spread. *Ribes eradication* is an effective control at short distances. Zone 2 has more rust on favored sites and requires less microclimatic enhancement of infection sites than in Zone 1. Rust is more abundant in a field where a forest stand on the south side shades the trees during the day. A large opening in the forest (more than 1:1 :D:H ratio) has more rust in its south part. Zone I has either no rust or rust confined to pines in especially limited cool moist sites such as in narrow valleys, at the bases of slopes, and in small forest openings (less that 1: I : D:H ratio). In Zone I heavy uredinial infection on *Ribes* defoliates the most abundant *Ribes can* before cool fall weather favors telial production. and the rust controls itself. Large *Ribes* free areas (usually sandy soils in the north) have no rust on pines except in Zone 4 where long distance spread occurs in certain areas (4).

In the southern most range of *Pinus strobus* the weather is warmer and rainfall is greater than in more northern parts of the range. There is a *Ribes* free zone where it is presumably too warm for *Ribes.* In the Dripping Springs Escarpment pine stands near Hopkinsville, Kentucky, Holly *(ilex opaca)* occupies the understory space where *Ribes*

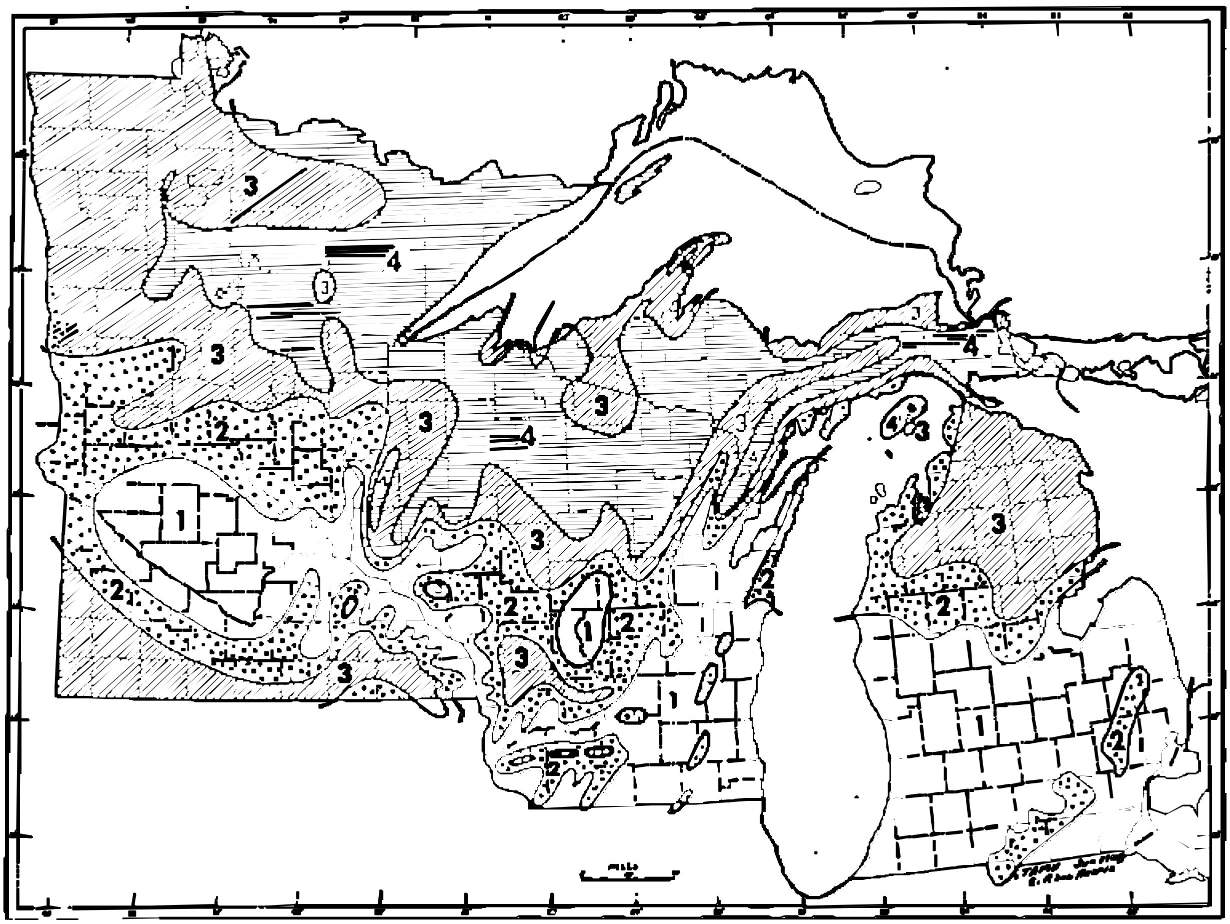

Fig. 2. Map showing differences in quantity of blister rust spread to white pine in the Lake States. Rust in tops of emergent pines carried from distant ribes are characteristic of Zone 4. The cooler the summer weather, the more favorable for disease spread. (4)

cynobati would be found further north. Blister rust is absent from this area. ,

MATERIALS AND METHODS

Pinyon rust presence was recorded on 1/100th to 1/10th acre (or larger if necessary to sample at least ten trees) field plots. The quantity of *Ribes* present were recorded and the presence of rust on the *Ribes'* leaves was noted. The number of trees present, the number of infected trees present and the total number of cankers were recorded. The percent of infected trees and the number of cankers per tree were calculated. Site factors influencing the climatic distribution of the rust were recorded. These included the degree of slope, aspect, position on the slope, elevations of the plot above sea level, and the type of vegetative cover. The data presented in this paper are based on the percentage of infected trees. Pinyon rust data were recorded in May 1992, 1993, and 1994 when aeciospore production was evident and in August 1993 when rust infection was noted on *Ribes*.

Resurveys of the blister rust on white pines in the North Central States in 1993 and 1994 was based on new field plots. In 1993 more extensive observations were used in field reconnaissance because of heavy rains on rough terrain.

RESULTS

The distribution of pinyon rust *(Cronartium occidental)* on pinyon pines in the Great Basin of the U.S.A. indicates some similar factors favor the spread of this rust. Studies in northwest Utah and western Nevada indicate a lower zone on each mountain range without *Ribes* (In Utah a few occurred in stream valleys), then a zone above this with *Ribes* present, but no rust on pines and above this rust is present on pines to varying degrees.

In the zone where rust occurs, there was a great deal of

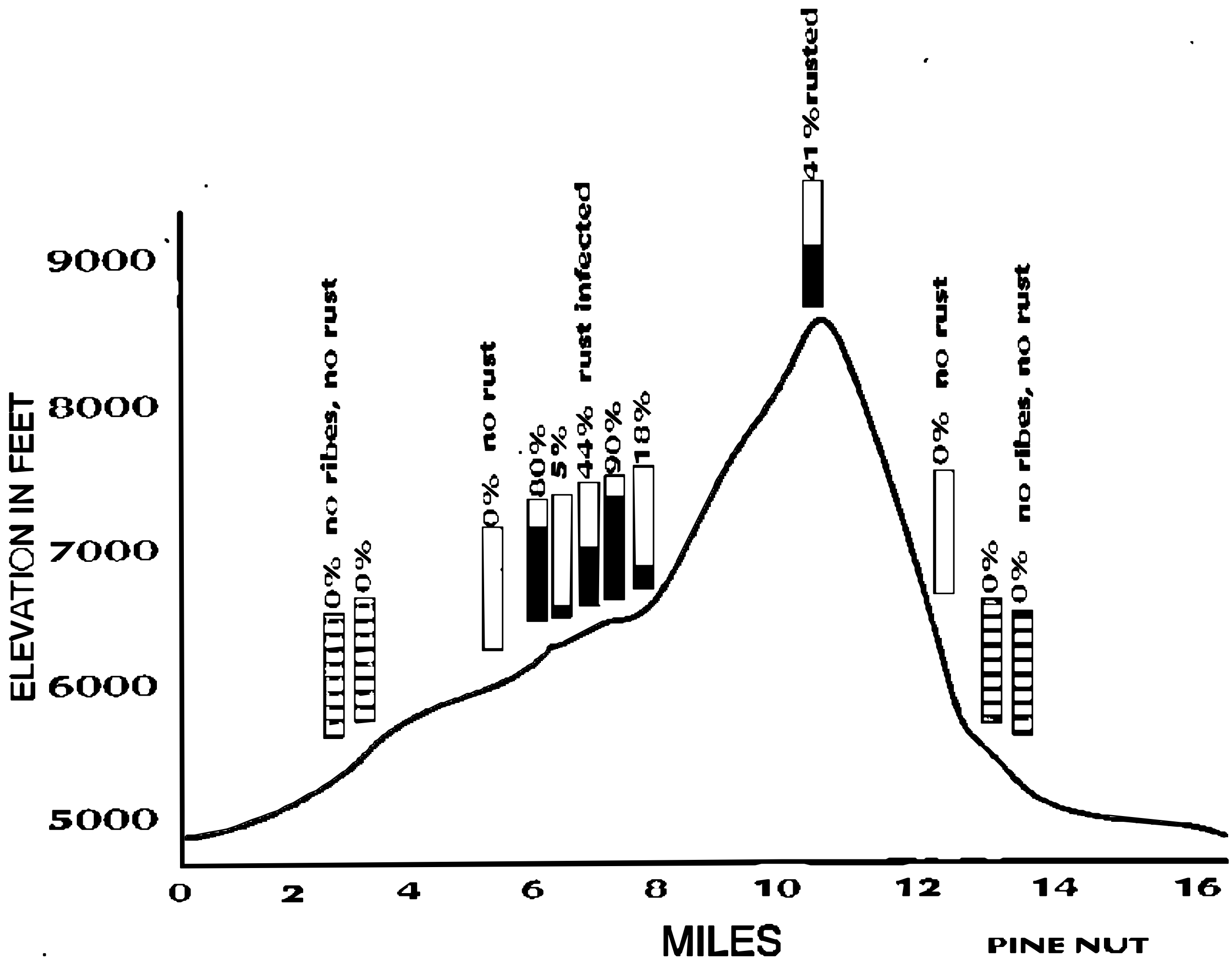

Fig. 3. Percentage of rust infection on pinyon pines on a west to east profile of the Pine Nut Range in western Nevada. Striped bars indicate plots with pines present, but without *Ribes*.

variation in the amount of rust as indicated by the percentage of infected trees. Figs. 3, 4 and 5 show the percentage of trees infected in three ranges of Nevada. *Ribes* are extremely abundant throughout the pine zone except where noted on Figs. 3 and 4.

There was a heavy belt of rust from 6300 to 6700 feet elevation on the Pine Nut Mountain Range and the Wellington Hills Range. There was much less rust above and below this zone. There was surprisingly little rust on the mountain top despite the apparent relatively moist and cool conditions and abundant *Ribes*-, the pines grow well on top. The best explanation for this distribution is that the heavy rust zone is the recharge area from the back flow of the down valley wind pattern in the valley. This is the "late evening" flow shown in Fig. 6 (3).

Inversion caps with fog and smoke trapped under the inversion layer in the local flows of the type indicated in Figs. 6 and 7 have been noted on the west slopes of the Pine Nut Range and the Wellington Hills on still mornings in November of 1994. The tops of these "valley inversions pollution caps" were at the 6300 to 6700 foot elevations where the pine rust was most abundant.

DISCUSSION

More work is needed on temperature and moisture requirements for pine infection with pinyon blister rust and the nocturnal drainage winds must be checked, but the best explanation of this rust distribution appears to be a combination of spread from local *Ribes* plus a backflow spread that is much like the one found on the Bayfield County Lake Superior (Fig. 7) (3). A quotation of some of this backflow distribution explanation follows:

"Lake Breezes: We have stronger evidence that breezes

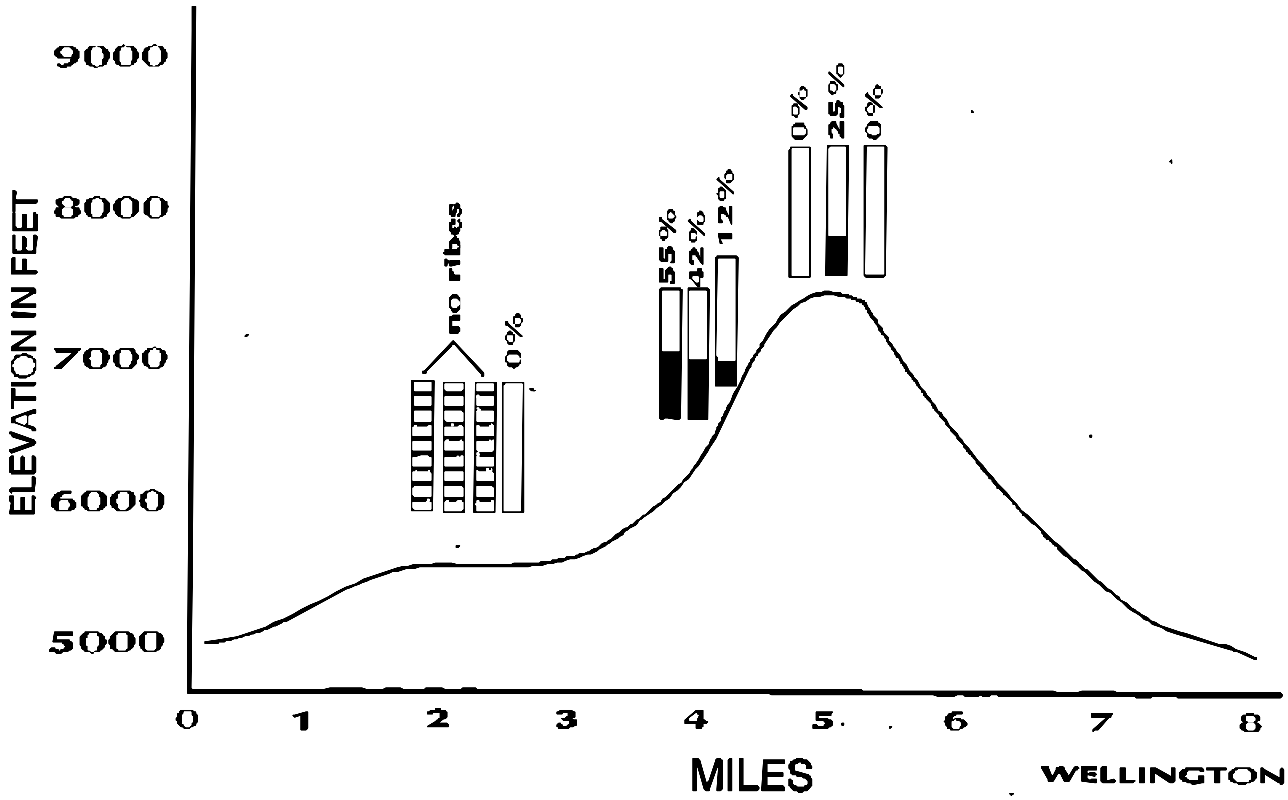

Fig. 4. Percentage of rust infection on pinyon pines on a west to east profile of the Wellington Hills in western Nevada. Striped bars indicate plots with pines present, but without *Ribes*.

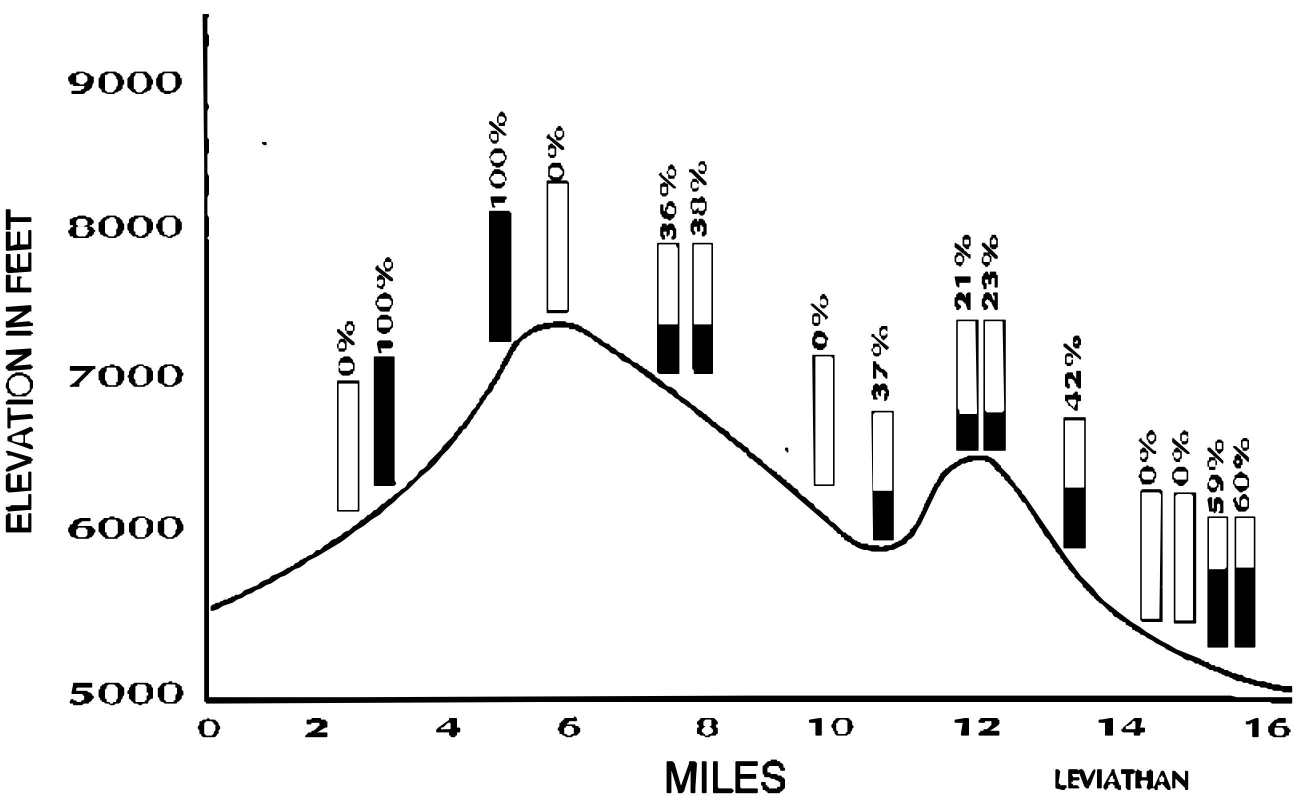

Fig. 5. Percentage of rust infection on pinyon pines on a west to east profile of the Leviathan section of the Carson Range in western Nevada and California.

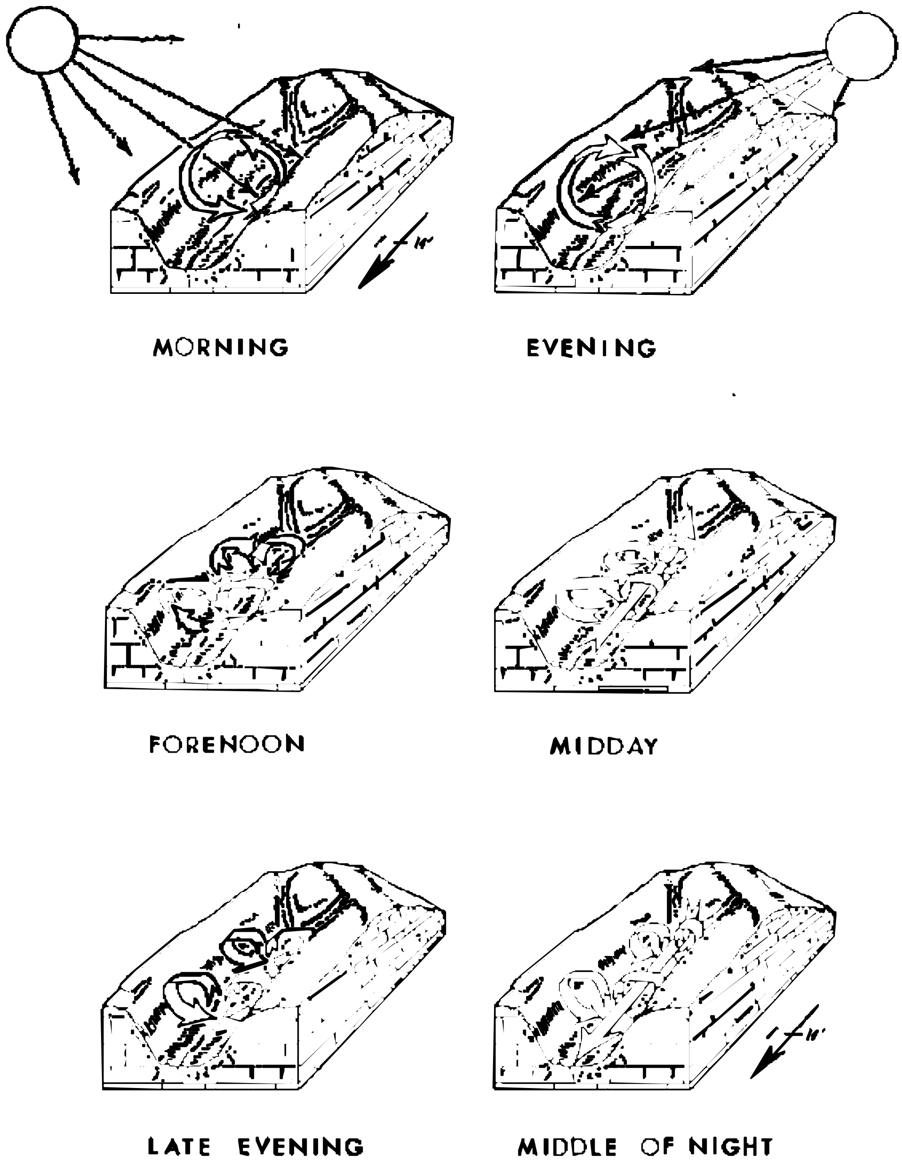

Fig. 6. Some night and day slope winds. (3)

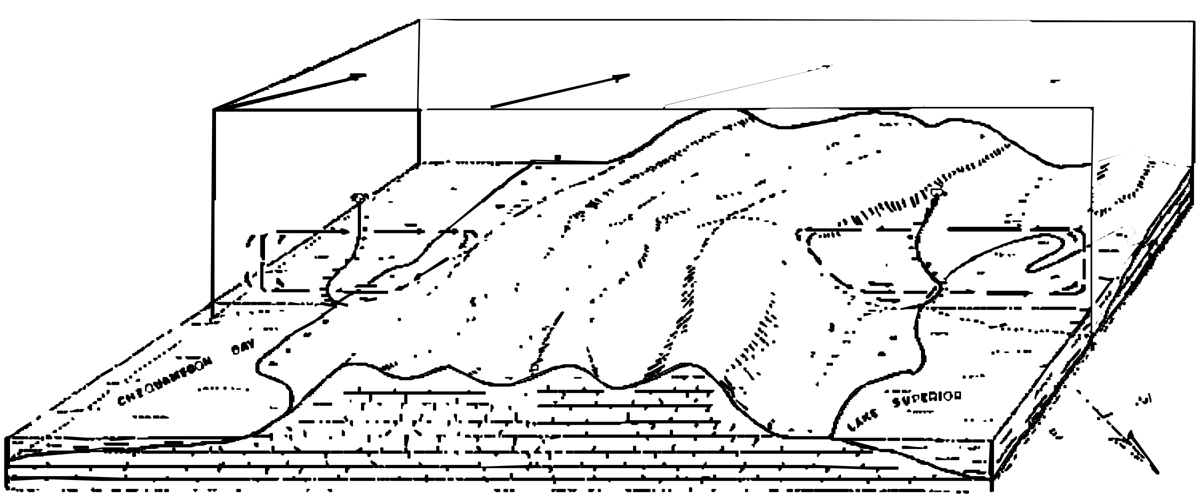

Fig. 7. Observed air circulations around the Bayfield Peninsula (Washburn to Cornucopia Profile) of Wisconsin. (3)

that develop near Great Lakes shorelines carry blister rust fungous spores. These breezes develop as a result of the difference between the air temperature over land and water....

"As the land gets cold at night, adjacent cool air moves in a low flow out over the warmer lake. Spores released on *Ribes* bushes less than 5 miles from the lake are usually carried out over the water by this breeze; thus pines behind the bushes but near the lakes are seldom infected. Above this cold flow a reverse flow carries the warmer lake air back over the land. Local warm spots above the lake area, such a those over swamps, forests, and small lakes, loft some spores to this backflow level. They ride the backflow to a strip 5-10 miles from the lake, where they are carried down by a downdraft. These spores infect pines high in the crowns as much as 5 miles from the nearest currant bushes.

"While we have not traced the spores all the way along this path, we have watched the lake breeze and countercurrents carry smoke and balloons along the way. We know the spores have 5 hours to move (before light kills them), so they can go 10 miles in the 2-mph breeze. This movement just fits the pattern of rust infections that have occurred on the pines in the past 20 years.

"Tethered balloons, balloons with streamers, and slow-climbing, electrically lighted free balloons were used in a study to determine the flow of wind on two sides of the Bayfield Country Peninsula in Wisconsin (Fig. 10). In this case, the offshore night breeze to the lake from the land was reinforced and accelerated by a down slope wind leading to the lake. Pines near the lake in the outflow areas had little rust. The wind speed out onto the lake was about 10 mph and the backflow above, which was much deeper and at a lower speed, flowed at an elevation of 450 ft. At the impact or downdraft area on each side of this peninsula is an area where white pine trees are almost entirely absent, al- though they are found all over the rest of the peninsula, both above and below this backflow area. The rust was so severe in this particular area that it killed all the white pine in the past 30 years. In this same backflow area there are serious infections of jack pine rust on the extensive jack pine plantations found on this peninsula. Within large, circular areas of several acres' extent, all the trees have been killed by rust." (3).

Unlike the situation in the Lake States, nocturnal drainage winds in Nevada mountain ranges flow into basins with little water. Heat sinks of rock, dense soils, or the sunny sides of trees may form the heat sources that cause the air to rise to the backflow in this case. Some basidiospores then would first ride to lower elevations in drain- age winds, then rise back to the backflow just under the temperature inversion layer and flow through the pinyons in the middle elevations. Additional research is needed to confirm this hypothesis.

In the Raft River Range north of Great Salt Lake there is also abundant rust at about 6500 feet elevation with much less below; however, detailed distribution surveys have not been made.

In summary, the amount of pinyon rust on pines was recorded on survey plots. The percentage of infected trees was shown on graphs of locations and elevation. It seems to be influenced by temperature and moisture distributions, and there seems to be a major influence of nocturnal drain- age winds and their backflows on rust distribution in parts of the (3reat Basin of the Western United States. This dis- tribution was especially evident on the Pine Nut Range and the Wellington Hills near Minden, Nevada.

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