BLISTER RUST CONTROL IN THE MANAGEMENT OF WESTERN WHITE PINE

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STATION PAPER Nº 3

JUNE 1940

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FOREWORD

Control of white pine blister rust is a major timber management problem in all white pine forests. In the extensive stands of western white pine it is a problem of particular concern because of host and climatic factors that favor rapid and serious disease invasion. Although timber management practices alone cannot be expected to control the disease, they can materially aid (or impede) this work through their influence on ribes establishment and development.

Effective, economical, and permanent suppression of the blister rust necessitates close integration of control measures with timber management, and a mutual understanding of problems, methods, and objectives so that full advantage may be taken of every natural aid to control. Timber growers must be blister-rust conscious and those responsible for disease control must be forest conscious. Each must be able to visualize the disease in its relation to the forest as well as to the tree - both in the stands of today and those of the future.

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INTRODUCTION

The forest industry of the western white pine region depends on the production of white pine as a major species on about 2,670,000 acres of commercial forest land. Continued production of this species and maintenance of the forest industry at anything approaching its present level is impossible unless the white pine blister rust is controlled. Existing merchantable timber can and probably will be harvested before serious losses occur but the young growth, which is the commercial future of this industry, is the great value at stake. The stakes are large - a major industry of the Inland Empire with sustained annual production estimated at 300 million board feet of lumber worth about $10,000,000, and several times as much in direct and indirect employment created by this valuable raw product.

Blister rust control is achieved through suppression of ribes, 2/ alternate hosts of the disease. This work is a tremendous undertaking, probably the most important and

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1/ Cooperative report by the Northern Rocky Mountain Forest and Range Experiment Station, Missoula, Montana, and the Office of Blister Rust Control, Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine, Spokane, Washington. Acknowledgement is made to a number of administrators and investigators who have contributed to and aided in the preparation of this paper, especially to H. E. Swanson, H. R. Offord, E. L. Joy, R. L. MacLeod, and C. R. Stillinger of the Bureau of Entomology and Plant Quarantine; Professor C. W. Waters of the State University of Montana; C. A. Wellner of the Northern Rocky Mountain Forest and Range Experiment Station.

2/ The generic name Ribes and the common name "ribes" are used in this manuscript to indicate both currants and gooseberries.

urgent job relating to the growth of timber in the western white pine region or any other five-needle forests in the nation. By the end of 1939, 1,817,400 acres had been given an initial working. This represents about 68 percent of the 2,670,000 acres of commercial forest land producing white pines worth protecting. Ribes have been satisfactorily and relatively permanently suppressed on about half this initially worked land. Before control is fully established on the remaining area, a second and in some cases a third working will be necessary, the number depending primarily on the original ribes abundance and whether site conditions have been causing these plants to decrease through shading and competition or to increase through sprouting and seed germination.

To secure satisfactory ribes suppression and control of blister rust on half of the gross area worked, 248,522 acres were given the second working and 22,205 acres the third. To gain this same objective for the entire 2,670,000 acres of white pine, there is the immediate need for completion of all first working followed by timely second and third workings where ribes eradication checks show this to be necessary to the establishment and maintenance of control. Unless these secondary workings can be made when and where needed the value of the initial work is gradually diminished and ultimately may be entirely lost.

Effective and economical control of the white pine blister rust necessitates on the part of all concerned a thorough working knowledge of the occurrence and growth of ribes in forest stands, the incidence and spread of blister rust on ribes and white pine, the influence of timber-management methods on ribes establishment and growth, and finally the disease endurance of forest stands. The purpose of this paper is to give essential information on these subjects as a guide to forest practices as they relate to the control of white pine blister rust.

THE ECOLOGY OF RIBES

OCCURRENCE OF RIBES

1. Species. Fifteen species of native ribes and four of cultivated are known to occur in the western white pine type. Eight of these, all native species, are of chief concern in the control program. Four of the eight are of major importance because of abundance and general distribution while the remaining four occur only occasionally in restricted localities. The few plants of the cultivated species are confined to homesteads or adjacent areas to which they have escaped.

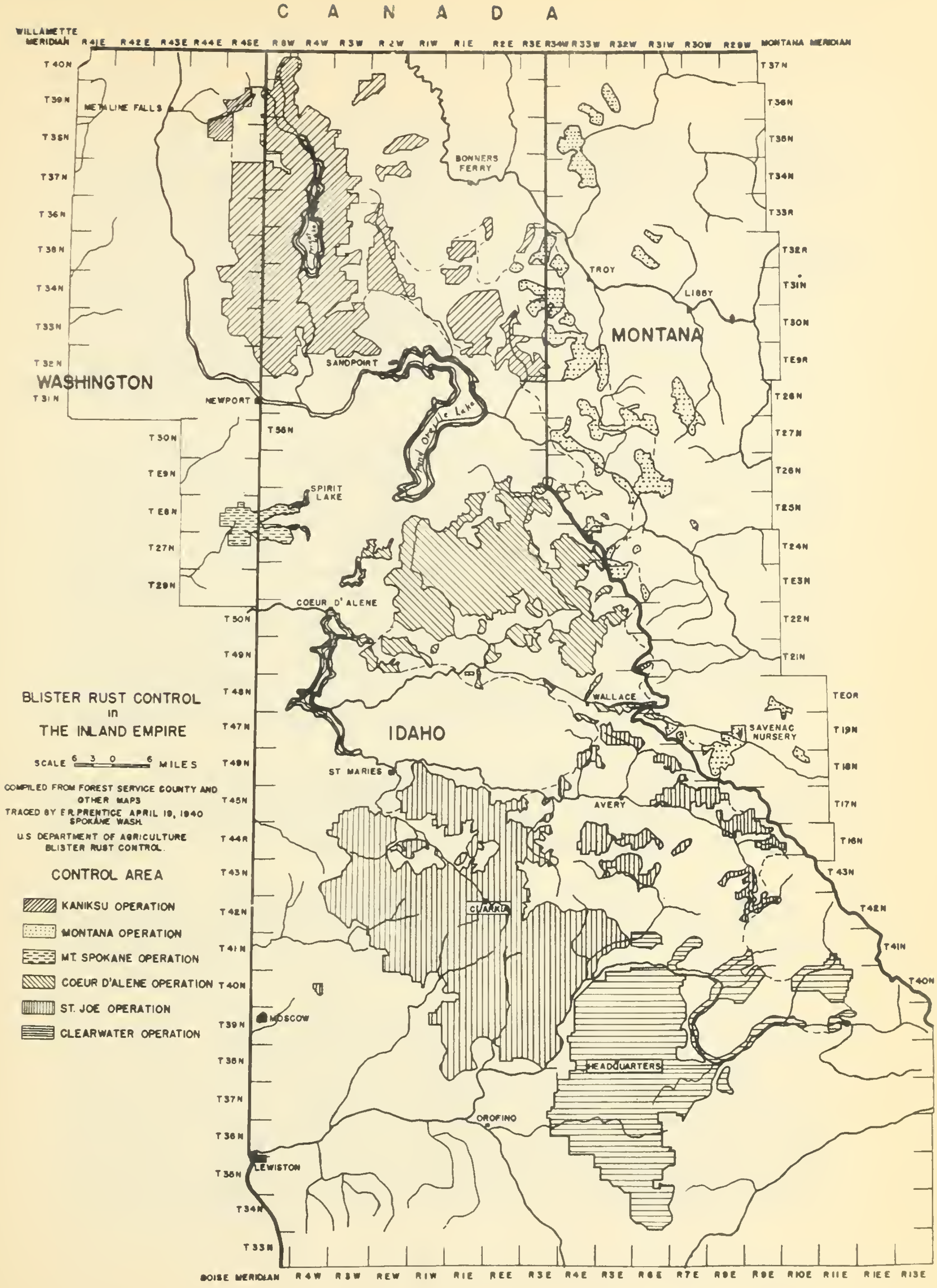


FIGURE I.— BLISTER RUST CONTROL AREAS IN THE INLAND EMPIRE.

The four major species, listed according to abundance as measured by the number removed during eradication are, Ribes viscosissimum Pursh (sticky currant), R. lacustre (Pers.) Poir (prickly currant), R. inerme (Rydb.) Coville and Britton (White stemmed gooseberry), and R. petiolare Dougl. (western or wild black currant). The four minor species are R. irriguum (Dougl.) Coville and Britton (inland black gooseberry), R. triste Pall (wild red currant), R. acerifolium Howell (maple leaf currant), and R. coloradense Coville (Colorado currant). The remaining seven species not listed rarely occur within the white pine region but are occasionally found in the border zones.

The most abundant ribes, R. viscosissimum, accounts for 49 percent of the 393,267,000 bushes removed from the upland control area since the inception of the eradication program. It is generally distributed throughout the white pine type, inhabiting the well-drained forest slopes. Ribes lacustre is the second in number of bushes removed, accounting for 43 percent of the total. It is more widely distributed and cosmopolitan in its habits than the other species, occurring along streams as well as on uplands. Ribes inerme and R. petiolare make up about 6 percent of all bushes removed and are found almost entirely on moist sites such as stream bottom lands, swamps, and marshlands.

Except for R. irriguum, which usually inhabits the uplands, the minor species are found near streams or occasionally on very moist upland sites. Less than 1 percent of the total number of bushes removed have been of these minor species.

2. Ribes environmental types. Because of extreme differences in ribes species occurrence, forest land in the western white pine region is segregated into two broad classes, namely, upland and stream types.

The upland type, making up about 94 percent of the total control area, consists of forest slopes and benches that afford good drainage and aeration of the surface soils. This type is subdivided into ten recognized ribes eradication or timber types, the basis for division being the composition of the forest cover, the degree of stocking, and the age of the stand. The principal ribes in this type are R. viscosissimum and R. lacustre, with small amounts of R. irriguum in restricted localities.

Stream type includes the moist, poorly aerated alluvial land adjacent to streams, swamps, and marshes. While comprising only 6 percent of the total control area, this type is of great importance because of heavy concentrations of extremely hazardous ribes and the difficulty encountered in securing their permanent suppression. Stream-type ribes are dangerous because of their high susceptibility to the disease and their occurrence within a zone of high humidity which facilitates rust development. Also their persistence through sprouting and regeneration from seed prolongs the period during which the application of control measures is necessary for their complete elimination. The principal ribes in this type are *R. lacustre*, *R. inerme*, and *R. petiolare*, being named in the order of their abundance.

GROWTH AND DEVELOPMENT OF RIBES

Requirements

1. Soil. Ribes grow in soils differing widely in composition and pH value. Optimum growth of most species is attained on a medium loam derived from decomposed native rock, organic material, and wind deposits. Soils of the white pine region are of this type and predominantly acid which combine to favor the luxuriant development of ribes.

2. Temperature. Exposed sites where plant life is subjected to temperature extremes are unfavorable for ribes. Protection that will afford temperature moderation is conducive to their optimum development.

3. Moisture. The upland ribes flourish on sites that afford good drainage but retain some available surface moisture during the growing season. The stream-type ribes require very moist soils for optimum growth and development. The extreme here is *R. petiolare*, which can grow with its roots entirely submerged in running water.

4. Light. Upland ribes *R. viscosissimum* requires approximately 60 percent or more full sunlight for optimum growth and development, *R. lacustre* and *R. irriguum* require at least 40 percent. Once firmly established in the developing forest cover, however, these species will survive under light intensities as low as 25 percent. These upland species fruit sparingly to moderately under 50 percent of full sunlight.

Stream-type ribes are more tolerant than the upland species, requiring not more than 60 percent full sunlight for optimum development. Fruiting is greatly impaired, however, if they receive less than 40 percent full sunlight, although sparse to moderate production results when light intensities are as low as 30 percent. These ribes readily propagate asexually by layering. Such regeneration of R. lacustre has been observed in situations which excluded all but 10 percent of full sunlight.

Seed Production and Storage

Ribes usually are prolific annual seed producers on optimum sites. Production of large seed crops are often restrained, however, by climatic factors such as late spring frosts and early drought. Seeding commences the third and fourth year in the life of new ribes bushes, but does not develop to serious proportions until the fifth year or later. Heavy seeding continues from this age until the bushes are weakened by suppression from a developing forest cover or by overmaturity. The seed being wingless and comparatively heavy is disseminated mostly in the immediate vicinity of the parent plant. A small amount of seed is disseminated over longer distances by birds and rodents.

Ribes produce the bulk of their total seed yield in the early stages of forest succession. Most of this seed becomes stored next to the mineral soil. It has been found that approximately 81 to 90 percent of the ribes seed is stored in this lower humus zone on top of the mineral soil. The balance is divided with 8 to 16 percent in the upper humus and 1 to 2 percent in the duff. Most of the seed in the humus and duff eventually finds its way to the bottom of the organic mantle, either through a gradual sifting process or the slow disintegration of the duff and humus from below. This organic mantle becomes thicker with each year's new deposits and creates an insulated zone which prevents rapid and extreme changes in temperature and holds the moisture relatively constant. With these conditions prevailing, germination of the seed is prevented.

The insulating organic mantle is known to favor the longevity of ribes seed. Available evidence indicates that much of the ribes seed buried beneath the forest carpet remains viable for a period equal to or greater than the life of a white pine stand. Nothing else will satisfactorily explain the prompt and abundant appearance of ribes on newly logged areas hitherto apparently ribes-free. This indicates that a normal forest rotation of 120 to 130 years is insufficient to exhaust or destroy the store of ribes seed deposited during the first years of the establishment of the forest cover. The period over which stored ribes seed will remain viable presumably depends on how well it has been insulated. Evidence of this appears from the facts that stored ribes seed has been found to remain viable only for relatively short periods on poorly insulated, exposed sites, while the retention of viability for long periods is associated with sites of a northerly exposure and a thick organic mantle. It is known, however, that the amount of viable seed decreases as the age of the forest and the consequent storage period is increased.

Germination

Ribes seeds are not readily permeable to air and water so tend to remain dormant until environmental factors break the resistance of the hard seed coat. Laboratory tests have shown that such a breakdown of seed stored in the humus is largely facilitated by bacterial and fungal action, with weathering aiding the process.

Other tests have shown that ribes seed germinate more promptly when subjected to daily alternation of temperature than when kept at constant temperatures. This may provide the explanation for the long retention of viability of seed stored under good insulation conditions in the forest floor.

The immediate cause of abundant ribes seed germination in the forest is a disturbance or breaking up of the duff and humus covering. Such disturbances are of two classes, namely, fire and mechanical.

1. Fire. The action of fire is of major importance in stimulating ribes seed germination. This occurs through the removal of duff and humus and the opening of the forest canopy which create favorable germinating conditions, particularly with regard to the soil temperatures. The stimulating effect of heat on the dormancy of ribes seed is also an important factor. The proportion of the stored ribes seed that germinates following fire depends mainly on the severity of the burn. An intense fire consuming most of the organic mantle will, of course, destroy nearly all stored seed. Most fires, however, particularly single burns, do not consume all of this mantle and leave much more of the duff and humus covering than appears at first sight. This and the further fact that the bulk of the seed is in close proximity to the moist mineral soil

accounts for the abundance of ribes germination following these burns. The greatest germination occurs on forest areas swept by light fires that destroy most of the upper layers of the forest mantle but only very little of the ribes seed.

Between 70 and 90 percent of the total germination occurs the year following fire. Nearly all occurs within 3 years, which apparently exhausts most of the seed supply. Thousands of ribes per acre have been observed to appear within a year or two after the burning of an apparently ribes-free area. On other areas, however, very few appear which indicates that either the seed was destroyed in burning or it was not present before the fire.

2. Mechanical. The second type of disturbance which exposes stored seed and results in germination is mechanical. This comes from such activities as logging and road construction, which score, mix, and agitate the various forest floor layers. The amount of stored seed germinating from this depends on the extent or severity of the disturbance. Germination resulting from mechanical disturbance is usually much less than that caused by burning, because the latter removes the inhibiting duff and humus covering and more completely exposes the deposits of seed. A mechanical disturbance, of course, may thoroughly disturb the forest floor without leaving all of the stored ribes seed in position favorable for germination. Large numbers are again buried too deep for germination where they either continue in dormancy or lose viability. The peak of germination following a mechanical disturbance usually occurs in the second or third year. On cold and moist sites it is quite common for the peak to be delayed until in the third year or later.

Early Survival

As with coniferous seedlings, the bulk of ribes seedling mortality occurs during the first year following germination. The rate of mortality drops off sharply the second year and seedlings surviving more than three seasons are fairly well established. At least half of all ribes seedlings die during the first season. As would be expected, heaviest mortality occurs on exposed sites subject to high temperatures and deficient moisture. Of the thousands of seedlings that appear following broadcast burning, few will normally survive the first season unless the site is naturally protected from heat and drought under conditions such as may be found on some northerly slopes.

High mortality will also take place in seedlings growing under a fairly dense overwood, particularly on north and east slopes, because of low temperatures and light intensity. Optimum conditions for survival are found under the partial shade of a moderately open forest stand, one permitting approximately 50 percent of full sunlight to reach the ground. Heavily logged stands, particularly those which show considerable disturbance of the forest floor from fire and logging, are especially favorable sites for ribes germination and survival. The parallel between conditions favoring survival of coniferous and ribes seedlings is very close.

Growth in Forest Stands

The natural development and succession of ribes in forest stands are about as follows. Following fire or other major disturbance of the forest, large numbers of ribes seedlings usually appear. These originate principally from seed stored deep in the forest floor at some time in the distant past during the establishment of the forest cover just removed. Although there is a high mortality among the young plants, large numbers survive and flourish as part of the rather abundant shrubby vegetation normally developing with the coniferous reproduction in the western white pine type. Maturing quite rapidly, these bushes begin to produce seed when 3 to 4 years old. At the age of 5 years they commence abundant fruiting, which is continued until the coniferous stand begins to close. During this period there is an annual depositing of ribes seed in the forest floor that builds up a reserve seed supply.

With the closing of the coniferous stand, ribes with most of the other shrubby vegetation become suppressed and gradually succumb. During this period seed production falls off and finally ceases. Ribes viscosissimum, which is the first to go, begins to drop out when the stand is 15 to 25 years old, and by the time the stand is 40 to 50 years old it is found in appreciable numbers only in openings. Well-stocked stands of pole and mature timber are almost completely free of this species. New germination also practically ceases and the few seedlings which do appear fail to survive.

Being more tolerant and capable of asexual reproduction, R. lacustre is more persistent. Once this species is well established within the stand, a few bushes may survive throughout the forest cycle. The crown and roots of the original or parent bush may disappear but the plant is continued by one or more asexually propagated offspring. This situation, although requiring recognition in planning control, does not offer a serious problem since the remaining bushes are normally few in number and slow in growth with consequent limited disease-spreading potentialities.

Shade seems to be the major element limiting the growth of ribes since it restrains fruiting and normal foliage development. Soil moisture, another factor, is considered to be less important in the temperate white pine region.

In stand openings and in more or less permanent brush types adjacent to timber, ribes may continue to thrive indefinitely. The only common limiting factors are root competition and occasionally shading. The former occurs generally while the latter is apparent in the western white pine region only when ribes are associated with a dense cover of Ceanothus velutinus and Ceanothus sanguineus.

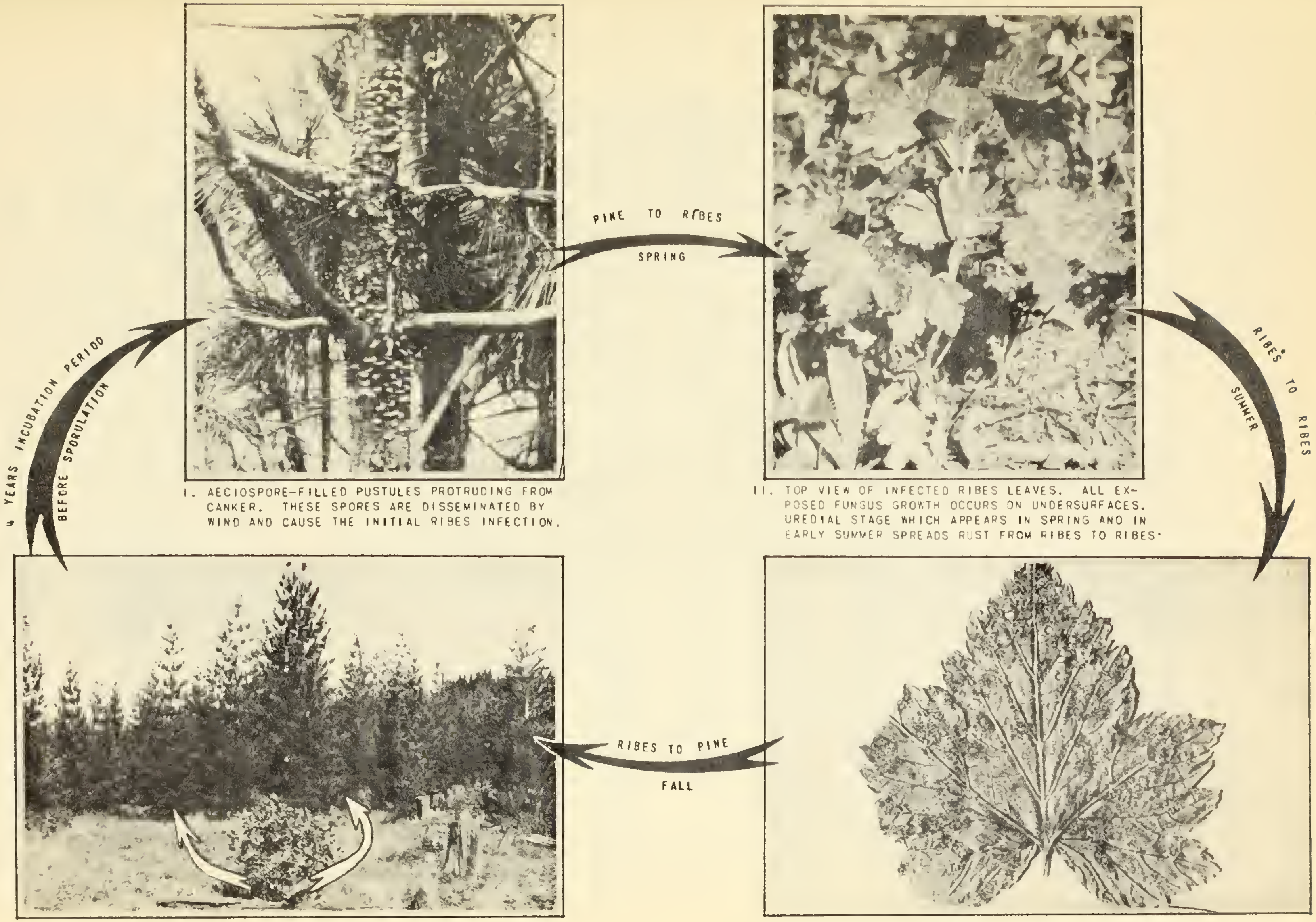
Many accessible brush areas in the region are being grazed annually by sheep. This keeps the areas sufficiently open to permit ribes to develop without much competition from the associated species of brush. On the other hand, the animals browse to some extent on the ribes foliage and terminal buds which tends to keep the bushes stunted. The extent to which grazing may hinder or help in the suppression of ribes is not definitely known at this time.

Ribes constitute an important part of the stream-type flora and in general maintain themselves indefinitely in equilibrium with other plant growth. Occasionally ribes are crowded out by heavy brush thickets or by the closing forest stand in the narrow stream zone. However, the ability of all stream-type ribes to propagate asexually and the availability of abundant moisture necessary for this process are conducive to the maintenance of the species in a flourishing condition. The fact that stream type is mainly outside the forest proper and thus relatively immune from the effects of fire and logging is also of importance. The combined effect of these factors complicates the permanent suppression of stream-type ribes, although in practice the suppression of these ribes has been notably successful, and only a limited come-back has been observed.

BLISTER RUST INFECTION OF RIBES AND PINE

INFECTION OF RIBES

Of the four major species of ribes in the Inland Empire, the western or wild black currant, Ribes petiolare, which grows in the stream type is the most susceptible to blister rust



I. AECIOSPORE-FILLED PUSTULES PROTRUDING FROM CANKER. THESE SPORES ARE DISSEMINATED BY WIND AND CAUSE THE INITIAL RIBES INFECTION.

II. TOP VIEW OF INFECTED RIBES LEAVES. ALL EXPOSED FUNGUS GROWTH OCCURS ON UNDERSURFACES. UREDIAL STAGE WHICH APPEARS IN SPRING AND IN EARLY SUMMER SPREADS RUST FROM RIBES TO RIBES.

IV. RIBES-PINE ASSOCIATION. SPORIDIOSPORES INFECT PINE THROUGH NEEDLES. GROWTH CONTINUES IN NEEDLE AND STEM FOR TWO YEARS BEFORE CANKER IS VISIBLE. THE PYCNIAL STAGE FOLLOWS WITHIN THREE MONTHS; THE AECIAL STAGE THE NEXT YEAR.

III. TELIAL STAGE OF SUMMER AND FALL. EMANATING FROM THE UREDINIA, THIS HAIR-LIKE GROWTH IS THE SOURCE OF THE PINE INFECTING SPORIDIA.

FIGURE 2.— THE LIFE CYCLE OF WHITE PINE BLISTER RUST.

infection. The sticky currant, *R. viscosissimum,* normally found in the upland type, approaches the susceptibility of *R. petiolare* when growing under humid conditions. The white-stemmed gooseberry, *R. inerme,* and the prickly currant, *R. lacustre,* are much less susceptible than the other two species even when growing in situations favorable for the development of the rust.

Moisture is an important factor in the establishment and intensification of the rust. The higher humidity of the narrow belt along streams and the cooler sites of northerly exposures are particularly favorable for rust development. Thus, the initial spread of the disease into new territory usually takes place in the stream type or in favorable localities in the uplands.

The presence of *R. petiolare* along the stream is responsible for most of the centers of heavy infection on the St. Joe, Clearwater, and Cabinet National Forests. *R. inerme* and *R. lacustre* have not proved to be troublesome during the rust introduction period. Nevertheless they do constitute a significant factor in its spread after the disease begins to intensify around the first established centers. *R. inerme,* especially, has been responsible in a few instances for the development of new centers of infection on several forests.

The presence of numerous *R. viscosissimum* in the uplands under conditions favorable to blister rust development has accounted for a few introductory disease centers and many secondary locations. Unless these upland ribes are growing under conditions particularly favorable for rust development and greatly outnumber those near the stream, the amount of pine infection on the slope decreases as the distance from the stream increases.

After the rust has become established in a drainage it builds up rapidly in the upland types when large numbers of ribes are present, particularly *R. viscosissimum.* Where the ribes occur in small numbers, such as may be found after initial control work, there is little or no increase in the rust unless the area is adjacent to a heavy center of pine infection. In this situation practically every ribes, irrespective of species or size, presents a serious threat to the adjacent pine. Typical spread and rust damage in the two ribes types are shown in figure 3.

Under similar ecological conditions, the infection hazard to white pine is determined by the amount and distribution

DAMAGING INFECTION IN THE UPLANDS INTENSIFYING FROM AN INITIAL STREAM-TYPE RUST CENTER. EXCEPT FOR A FEW HEAVY RUST CENTERS AROUND LARGE PATCHES OF RIBES, THE UPLAND RUST SPREAD IS GENERALLY MORE GRADUAL AND MORE WIDELY DISTRIBUTED THAN THE STREAM TYPE.

HEAVY RUST DAMAGE ON PINE FROM STREAM-TYPE RIBES. UNLESS ALL STREAM-TYPE RIBES ARE PERMANENTLY SUPPRESSED, THEY WILL DEVELOP INITIAL CENTERS AND SERIOUS FOCI OF INFECTION ENDANGERING THE SURROUNDING UPLANDS.

FIGURE 3.— BLISTER RUST IN RELATION TO RIBES TYPES.

of ribes leaf surface on the area. Where the disease is generally distributed, a relatively few ribes seriously increase the amount of rust. On such areas a higher standard of efficiency must be attained in ribes eradication than on lightly infected or uninfected areas.

INFECTION ON PINE

In considering the development of infection on pine and the resulting damage, it is necessary to compare the unrestricted development of the disease on unworked areas with the restricted development following control work.

It has been noted, particularly in the early stages of rust spread, that most of the cankers on the young growth occur in the lower half of the crown. This results in a high rate of mortality for very young trees since their branches are short with needles carried close to the trunk. This permits most of the cankers to reach the main stem and results in the girdling of the tree. On very young trees the needles are usually retained directly on the bole and consequently may trunk cankers are introduced through needle infections on the main stem.

In young growth a large percentage of cankers occurring within 1 foot of the trunk are fatal, while this is true of a smaller percentage of those farther away.3/ 4/ The difference here is due largely to the suppression and normal death of branches before the cankers can grow into the bole. It may be readily seen, therefore, that in the early spread of the disease the potential damage decreases with the increase in size of the trees. That is, the taller and older the trees, the

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3/ In a study conducted by C. R. Stillinger of the Office of Blister Rust Control, the following information was obtained from young white pine reproduction. Of 2,097 selected tree cankers observed to reach the trunk, 99 percent grew 10 inches or less; of the same number 91 percent grew 6 inches or less.
4/ T. W. Childs and J. W. Kimmey of the Office of Forest Pathology observed in one example taken from all tree height classes of trees less than 50 feet in height that of 59 cankers within 1 foot of the trunk 93 percent were damaging; of 116 cankers within 1.1-2.0 feet 81 percent were damaging; of 85 cankers within 2.1-3.0 feet 44 percent were damaging; of 37 cankers within 3.1 - 4.0 feet 22 percent were damaging; and of 14 cankers within 4.1-5.0 feet 7 percent were considered damaging. "Studies on Probable Damage by Blister Rust in Some Representative Stands of Young Western White Pine," Journal of Agricultural Research, vol. 57, no. 8, table 2, page 563, October 15, 1938.

greater will be the distance of retained needles from the trunk on the lower portion of the crown, and consequently the fewer the chances of losses from infection.

This does not necessarily hold true if the ribes are left to cause intensification of the rust. With an increase in volume of sporidia there is a proportionate increase in cankers in various parts of the tree crown. More cankers will be found to occur in the upper parts of the crown in the older age classes of advanced reproduction and pole stands as the rust continues to increase from year to year. The possibility of tree loss in these older age classes is greatly increased from upper crown cankers occurring closer to the trunk or from so many branches being killed that serious defoliation and ultimate death results. These points relative to the probable damage of blister rust cankers in the various age classes are important with regard to management or cutting plans.

BLISTER RUST IN RELATION TO TIMBER MANAGEMENT

In relating blister rust control to timber management, the following fundamentals must be kept in mind:

1. Since the white pine blister rust is widely distributed throughout the western white pine region, the control problem is not one of keeping out the disease but of continuing to grow white pine in spite of the disease. It is both impracticable and unnecessary to keep the disease wholly out of any particular stand. It is important that rust damage be prevented from becoming localized and responsible for eliminating solid blocks of pine within the stand.

2. Little evidence can be marshalled to substantiate any claim that white pine is ecologically necessary for maintenance of an adequate forest cover in the region. The justification for blister rust control is economic. It is almost wholly a long-time investment in growing white pine on the basis that its value will be sufficient to make its protection a sound public investment. The economic and controlling objective is that expenditures be commensurate with expected benefit, and, further, that they produce the greatest possible return in white pine harvest yields per dollar spent on blister rust control.

3. Blister rust control is achieved primarily by suppression of ribes. Combating the disease by pruning or by

thinning infected pine stands can be considered only as possible aids to control. Basic strategy in ribes suppression is to exhaust the stored seed supply and eradicate existing ribes to prevent their spreading the disease and producing more seed. Eradication today of every living ribes bush in the region would by no means end the control problem because of the stored seed.

4. Blister rust cannot be controlled by timber-management practices alone, though cutting methods can materially aid or impede control primarily through their effects on ribes establishment and development. It is not likely that timber-management practices can be materially altered on account of blister rust control requirements. Rather, the problem is to harmonize control and management practices so as to take full advantage of every natural aid that is practicable, as indicated by available knowledge of ribes ecology and of the disease.

Timber-management and disease-control objectives are not in conflict. The objectives of both are best served by keeping the land fully occupied by growing timber. The more timber the less ribes.

CUTTINGS IN MATURE STANDS

Cuttings in mature stands are of especial significance in blister rust control as they usually create considerable forest disturbance, starting anew the regenerative cycle of both ribes and conifers. Cuttings may be grouped in two classes: Partial cuttings of varying degree and clear cutting.

Partial Cutting

There are various kinds and degrees of partial cuttings in mature stands each removing different proportions of the forest cover. Their importance in blister rust control consists more in their effect on ribes germination and development and on the establishment of white pine reproduction than in their relative influence on the probable future injury of blister rust to the mature trees on the residual stand. The influence of cutting methods on ribes depends on the degree to which the forest canopy is opened, extent of mechanical disturbance to the forest floor by logging, and the use of fire in slash disposal.

Light Cuttings

Light cuttings, leaving residual stands permitting between 20 and 30 percent of full sunlight to reach the ground,5/ will not permit the permanent development of any appreciable ribes populations. In well-stocked stands, up to about one-third of the total board-foot volume can usually be removed without increasing the intensity of light on the ground to more than 20 to 30 percent of full sunlight. Considerable ribes and coniferous germination will probably occur after cutting, especially in skid trails and around burned slash piles, but seedling growth will be slow and mortality high, and, taking into account the fact that partially cut stands always tend to expand their crowns to close the forest canopy, few seedlings of either ribes or coniferous species will long survive.

The ribes leaf surface developed will be small and, since coniferous reproduction is of little silvicultural importance in such stands at this stage, possible damage is limited to the amount of infection the ribes can spread to the residual stand. This damage will seldom be appreciable. Also, very little ribes seed will be produced to augment future ribes populations. Since one important objective in ribes eradication is to prevent such seed production, this point is worthy of emphasis.

5/ In a study made by C. A. Wellner of the Northern Rocky Mountain Forest and Range Experiment Station, the following average relationships between light intensity and stand density were found to exist:

Light intensity (proportion of full sunlight reaching the ground)	Basal area per acre	
	In stands mainly grand fir, hemlock, and cedar	In stands mainly white pine, larch, and Douglas-fir
Percent	Square feet	Square feet
10	265	425
20	155	330
30	115	250
40	90	190
50	70	140

It is possible that a considerable number of suppressed ribes bushes could live under a mature stand without spreading enough disease to damage it appreciably before harvest. The danger here is that seed produced would lie dormant until the removal of the stand and then produce a crop of ribes capable of spreading blister rust to white pine reproduction with disastrous results.

Light cuttings made to harvest a portion of the merchantable stand, but not to obtain natural reproduction, will not, as a consequence of the above factors, add to present or future ribes suppression problems. On the contrary, they should be an aid in this work. Two or three partial cuttings, each causing some disturbance of the forest floor but not opening up the canopy sufficiently to permit permanent ribes establishment, should result in exhaustion of much of the supply of stored seed by inducing futile premature germination. There is also reason to believe that slightly higher soil temperatures resulting from a partial opening of the forest canopy may shorten the period of ribes seed viability. Once the seed supply is exhausted or no longer viable, subsequent major harvest cuts, no matter how heavy, will not bring in appreciable numbers of ribes seedlings.

Major Harvest Cuttings

Major harvest cuttings, those leaving residual stands permitting about 50 percent or more of full sunlight to reach the ground, open up the forest canopy sufficiently to allow good development of coniferous reproduction. This type of cutting often produces the worst blister rust hazard possible. An abundant and flourishing ribes population usually develops along with white pine reproduction which, because of small size, is very susceptible to rapid destruction by the rust.

Heavy cuttings create light and temperature conditions very favorable to ribes development, and the considerable mechanical disturbance and use of fire in slash disposal, normally going with the logging operation, stimulate germination of stored ribes seed. However, ribes eradication in cutover stands is complicated and made more expensive by the fact that not all stored seed is sufficiently stirred up or exposed to germinate at one time. The viable seed that remains will give rise to a new wave of ribes seedlings following each succeeding forest disturbance. To illustrate: A stand is logged mainly for white pine and a crop of ribes seedlings appear. A year or two later cedar poles and additional sawlogs are taken out, which stirs up the forest floor and results in another crop of seedlings. Then perhaps a few years later some larch, Douglas-fir, and a little grand fir become merchantable and are logged, giving rise to still more germination of stored ribes seed. These succeeding crops of ribes seedlings obviously necessitate several eradication workings if they are to be kept from infecting the pine reproduction.

It is unfortunate but true that at the present time timber-management requirements make this sort of harvest cutting the general rule. Among things that might be done to alleviate the ribes suppression difficulties somewhat are:

1. First, avoid secondary forest disturbances after the major disturbance just as much as possible. From a ribes eradication viewpoint it would be preferable either to cut everything that is to be cut all at once or to remove cedar poles or subsidiary products in advance of the major logging operation. The latter, however, is seldom practicable.

2. Correlate ribes eradication with logging plans. The peak of ribes germination on cutover areas usually comes the second year after logging. Because of the difficulty of finding young seedlings and the fact that many will die naturally, it is impracticable to attempt ribes eradication until these plants are two or, preferably, three or more years old. They must be pulled before they are five or six years old or seeding will take place. Consequently, ribes should ordinarily be eradicated between four and six years after logging. This timing of the control work with logging is extremely important. It is often a race to get the ribes out before they become infected and kill the white pine reproduction. Therefore, careful scheduling is necessary to keep down the cost of ribes eradication by waiting only until the ribes are large enough to be pulled effectively and not so long that the pine is lost and new ribes seed produced.

3. Do a clean job of slash disposal. Piling slash compactly in round piles, covering as little of the total ground surface as possible, and burning without spreading or "fingering out" from the slash piles, will produce minimum ribes germination. Ribes eradication in undisposed slash is the workman's nightmare, as the bushes are hard to reach and much slash must be handled.

Clearcuttings

Clearcuttings in western white pine are practiced:

(1) In overmature stands or burned over stands containing much dead, defective, and totally unmerchantable timber; and (2) in mature stands of mostly merchantable timber. In the first application all merchantable timber is logged, and the remainder of the stand, dead or alive, is clear cut and the area broadcast-burned and usually planted. It is a forest restoration measure, a means of reducing the fire hazard and putting commercially unproductive acres back to work. In the second, clear cuttings are usually employed in strips as a method of securing natural regeneration in conjunction with some seed source such as shelterwood strips or adjoining bodies of uncut timber. With both procedures the forest cover is completely removed and the area usually swept by fire.

Clear cuttings followed by broadcast burning create conditions generally favorable to ribes suppression for the following reasons:

1. Much ribes seed is destroyed in broadcast burning. The more intense the fire the better so far as ribes are concerned; on areas twice burned, nearly all seed is destroyed.

2. Seed not destroyed in burning (and on single burns probably less than half of the seed is burned) is released from its insulating duff cover and encouraged by higher soil temperatures to germinate promptly and completely. The peak in germination usually comes the first year after burning and is pretty well over in 2 or 3 years.

3. Except on protected and moist north and east slopes, ribes seedling mortality is high because of high temperatures and surface soil drought. On the more exposed sites few ribes will survive the initial season.

4. Eradication of surviving ribes is comparatively easy because the bushes are readily visible and travel through the area is not difficult.

Though ribes control is not a difficult problem on most broadcast-burned areas, some have been observed on which, because of an unusual combination of abundant stored seed, light burning, and favorable site conditions, a large and flourishing ribes population has become established. If these bushes become infected, white pine will have little chance of surviving the blister rust on such areas. Therefore, before scheduling planting of such areas it is important to investigate the exact ribes and disease situation. It may be advisable to delay planting until the ribes have been eradicated. On clear-cut areas naturally regenerated, white pine seedlings appearing

PARTIAL CUT WHICH REMOVED ONE-THIRD THE VOLUME OF A 65 YEAR OLD WESTERN WHITE PINE STAND WITH PRACTICALLY FULL FOREST CONDITIONS REMAINING. FEW IF ANY RIBES WILL SURVIVE UNDER SUCH CONDITIONS.

HEAVY PARTIAL CUT IN NEARLY PURE WHITE PINE STAND. ABUNDANT SEEDING FROM RESIDUAL TREES IS PRODUCING FULL STOCKING OF WHITE PINE. PROMPT AND THOROUGH REMOVAL OF THE NUMEROUS RIBES IS NECESSARY TO PREVENT RAPID LOSS OF PINE SEEDLINGS FROM BLISTER RUST.

CONDITIONS BEFORE SLASH DISPOSAL FOLLOWING PARTIAL CUTTING IN WHICH DEAD, DEFECTIVE AND NUMERCHANTABLE TIMBER IS LEFT STANDING. RIBES REGENERATION IS PROLONGED, WHITE PINE SEEDLING SURVIVAL IS POOR.

RESIDUAL STAND, AFTER HEAVY PARTIAL CUT OR FIRE KILL, HAS BEEN SLASHED AND CONTROL-BURNED TO DISPOSE OF UNDESIRABLE TREES AND FIRE HAZARD. RIBES REGENERATION IS PROMPT, NUMBERS DEPEND ON INTENSITY OF BURN. AREA IS REHABILITATED BY PLANTING.

FIGURE 4.— BLISTER RUST CONTROL IN RELATION TO HARVEST CUTTING METHODS.

in the first few years may be killed by the disease before the ribes can be eradicated. Not much can be done about such situations except to suppress the ribes as soon as practicable and accept a partial loss in the white pine seedling stand in the meantime. If there is a natural seed source new pine seedlings may replace those lost after the ribes have been removed. In any event if the initial crop of ribes following burning is eradicated before they produce seed there will be little future ribes trouble whether the area is subsequently disturbed or not, because of exhaustion of the seed supply.

CUTTINGS IN IMMATURE STANDS

The objectives of cuttings and ribes suppression in young stands are in close harmony. Cuttings are made for the general purpose of producing fully stocked, fast growing stands of high quality at minimum expense, and hence with the least possible cutting and general forest disturbance. Ribes suppression is favored by retention of a full forest canopy and a minimum of ground disturbance. There is no real reason, consequently, why cuttings in young stands should add appreciably to the difficulties of ribes suppression. As will be brought out, practices undesirable from this standpoint are also undesirable silviculturally. Examples of intermediate cuttings are shown in figure 5.

Cleanings

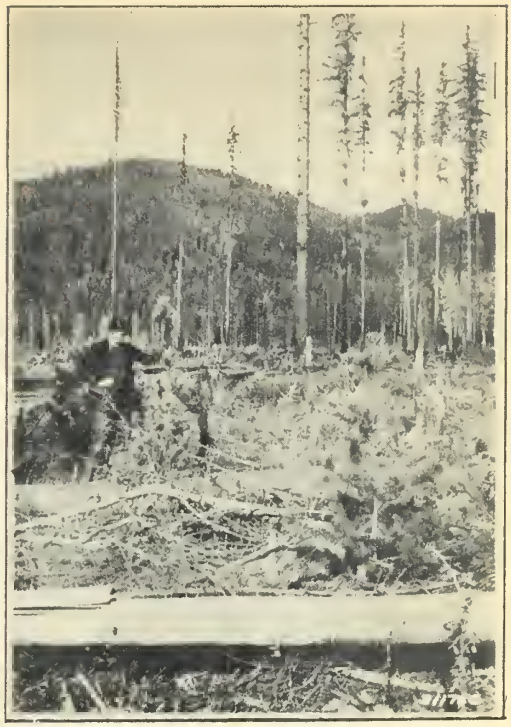
Cleanings are made in young stands between about 8 and 20 years of age to improve species composition and reduce excess stocking. They are the most economical and effective type of intermediate cuttings applicable in the western white pine type. It must be recognized that ribes naturally flourish in such stands and must be suppressed whether the area is cleaned or not.

From what is known of their effects, cleanings do not appreciably aid or impede ribes suppression. The ground disturbance caused by cutting is slight as slash does not need to be handled or burned.

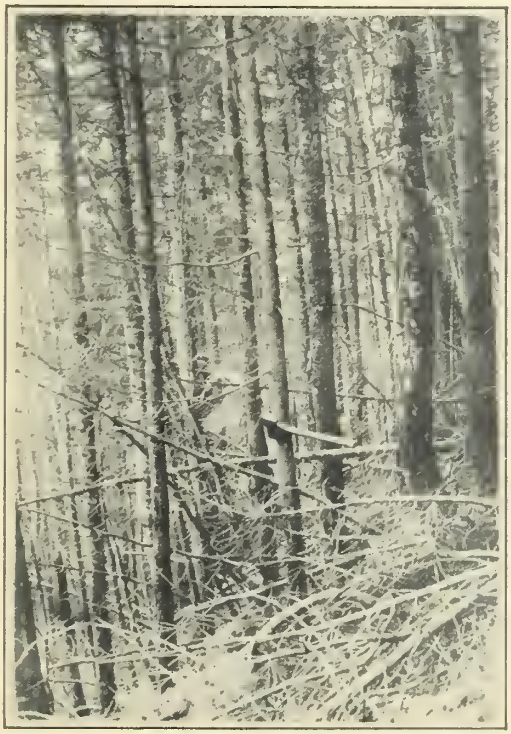
Improvement Cuttings and Thinnings

Improvement cuttings and thinnings are made in stands between 20 and about 60 years of age to improve species composition and increase rate and quality of growth. In practice, improvement cuttings and thinnings are combined under the general term of thinnings and are more or less indistinguishable on the ground.

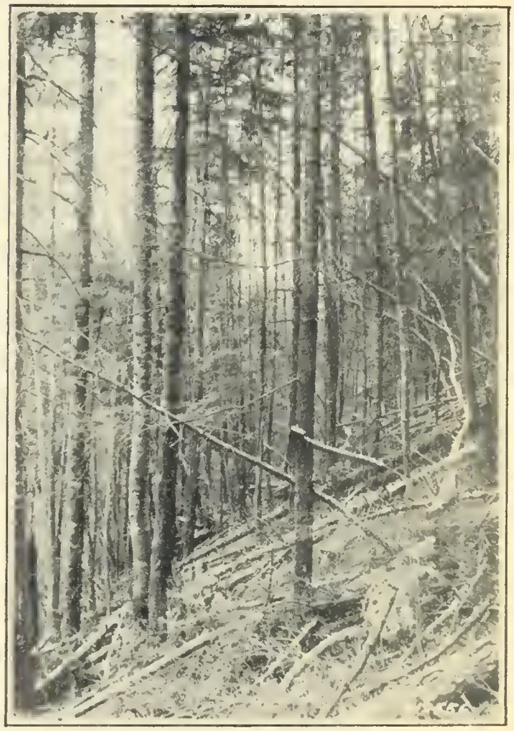
BEFORE WEEDING A DENSE REPRODUCTION STAND IN WHICH WHITE PINE IS LARGELY DOMINATED BY WESTERN LARCH. AS THE STAND CLOSES, CONDITIONS BECOME INCREASINGLY INHIBITORY TO DEVELOPMENT OF RIBES.



THE SAME STAND AFTER A WEEDING TO RELEASE THE PINE FROM DOMINATION. WEEDINGS SUCH AS THIS USUALLY DO NOT RESULT IN MUCH NEW RIBES GERMINATION, BUT THEY DO FAVOR INCREASED DEVELOPMENT OF THE RIBES PRESENT.



BEFORE THINNING A DENSE POLE STAND OF WHITE PINE LARGELY DOMINATED BY OTHER SPECIES ESPECIALLY GRAND FIR AND WESTERN HEMLOCK. HERE RIBES ARE GREATLY SUPPRESSED.



THE SAME STAND AFTER A CROWN THINNING TO RELEASE SELECTED CROP TREES. MOST OF THE SUPPRESSED AND INTERMEDIATE NONCOMPETING TREES ARE LEFT. THIS FORM OF THINNING HAS LITTLE EFFECT ON RIBES ESTABLISHMENT OR DEVELOPMENT.

FIGURE 5.—BLISTER RUST CONTROL IN RELATION TO INTERMEDIATE CUTTINGS.

Two general classes of these cuttings can be recognized as follows: (1) Thinning from below, often termed "low thinnings," where everything but trees selected as final crop tree possibilities are cut. The tangle of understory trees is all cleared away. (2) Crown thinning, or thinning from above, where crop tree possibilities are selected and cutting limited to their release, principally in the tree crowns, leaving non-competing overstory trees and most of the understory.

Low type of thinnings, especially the heavier grades, are the least desirable from a ribes suppression standpoint because they result in considerable opening of the forest cover, especially near the ground, and in mechanical disturbance of the forest floor. So much slash is created that some burning is usually necessary which further stimulates ribes development. Light thinnings may not create an appreciable ribes problem, but heavy thinnings definitely will. Low thinnings are seldom desirable silviculturally and are seldom applied because benefits usually are not commensurate with the cost.

Crown thinnings, which are more effective and economical silviculturally, do not seem to affect the ribes problem adversely. Cutting is held to a minimum and largely confined to overstory trees. The forest canopy, especially near the ground, is not greatly opened and little fire or mechanical disturbance to the ground cover results. Consequently, conditions favorable for ribes germination and development are not created.

DISEASE ENDURANCE OF FOREST STANDS

The relation of blister rust control to the management of western white pine is by no means limited to the effects of various cutting methods on ribes suppression. Of even greater importance is the endurance of forest stands to the disease. By endurance is meant whatever actual resistance forest stands may offer to ribes and the disease plus the extent to which they can suffer losses without permanent damage. The questions to answer are how much blister rust is likely to develop and how much loss can be tolerated in certain kinds of stands without materially reducing board-foot yields. The practical importance of these questions is indicated by the following points:

1. The suppression of ribes to the point needed for adequate control of the rust may require many years. Their

complete elimination from control areas is probably unnecessary and may be impracticable.

2. Some white pine areas of low-value productivity will not be given protection and consequently the disease will persist in the region.

3. It is not essential that the disease be kept completely out of a stand but that losses from it be reduced at least to the level of natural losses and never allowed to be concentrated sufficiently to eliminate solid units of pine. On this basis allowable damage is that which does not cause a reduction of the normal yield or quality of white pine at time of harvest.

4. Anticipated damage must always be weighed against the cost of control, the over-all objective being to get the greatest possible benefit from the money expended.

The actual damage that the white pine blister rust will cause in forest stands depends mainly on (1) age of stand, (2) species composition and stand density, and (3) likelihood of initial infection and reinfection.

1. Age of stand. Other things being equal, young stands of less than sapling size are the most susceptible to the blister rust. This is because the branches are short and close to the ground, thus facilitating spread of the disease from the ribes usually present, and the needles are retained on or close to the bole, increasing the likelihood of trunk cankers both from bole-needle and nearby branch-needle infections. Because of the small size of the sapling boles, girdling and death will result in a relatively short time.

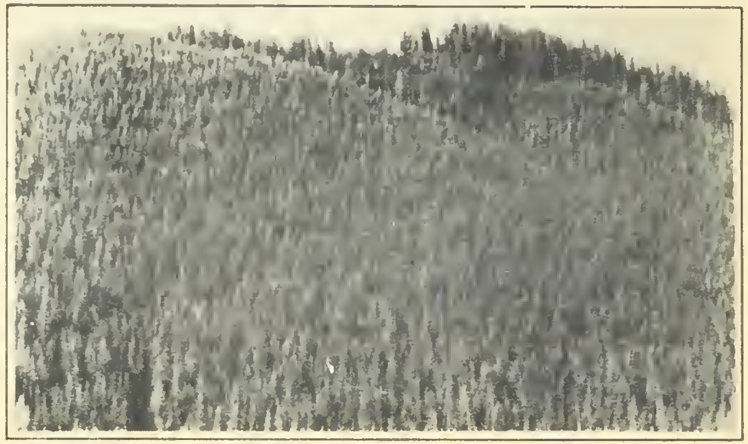
As the stands grow older, the crowns are farther from the ground and the foliage farther from the tree trunk. Also, natural pruning or the shedding of lower limbs commences. It follows then that as the stand grows older an increasing proportion of branch infections will die before reaching the bole. Many of those on living branches will at most kill only the branch ends.

2. Species composition and stand density. Probably the best index to the amount of disease loss that can be endured without permanent damage to the stand is its species composition and density. It must be remembered that until adequate control measures have been applied to all white pine stands, rust damage will be largely localized and be responsible for eliminating certain solid blocks of pine within the stand. After the application of such measures, however, and

KILLING CANKERS ON REPRODUCTION. THIS AGE CLASS IS EXTREMELY VULNERABLE TO BLISTER RUST BECAUSE OF ABUNDANT NEEDLES ON AND ADJACENT TO THE MAIN STEM.

POLE TREES DAMAGED BY RUST. TREES OF THIS AGE ARE LESS VULNERABLE THAN REPRODUCTION TO TRUNK CANKER KILLING DUE TO ABSENCE OF NEEDLES NEAR THE BOLE ON GREATER PART OF TREE. TOP AND BRANCH KILLING IS COMMON IN POLE STANDS.

REPRODUCTION, AGE 1-40 YEARS. THESE STANDS GENERALLY HAVE FIRST PROTECTION PRIORITY REQUIRING EARLY PERMANENT SUPPRESSION OF RIBES.



POLE STAND, AGE 41-80 YEARS. THESE STANDS GENERALLY HAVE SECOND PROTECTION PRIORITY REQUIRING ONLY ONE OR TWO WORKINGS AS RIBES ARE NATURALLY SUPPRESSED BY THE CLOSING FOREST COVER.

FIGURE 6. — BLISTER RUST IN RELATION TO STAND AGE.

only a scattering of ribes remains, damage can be expected to approach somewhat the natural mortality or normal weeding of the stand.

In well-stocked immature stands largely dominated by white pine, a considerable reduction in number of stems can occur with little real damage to the stand if this loss is not localized. At least half the basal area and up to nine-tenths of the total number of stems are commonly removed in thinning to the betterment of the stand. Considering this, one should thoroughly investigate the present status of blister rust in the stand to determine whether damage will be general and distributed throughout the stand or heavily localized. The first will not result in an appreciable economic loss unless the infection is extremely heavy, since mortality will be largely comparable to natural losses. On the other hand, localized damaging centers will result in serious reduction of final stand values. At the same time the very factors which caused so much infection will probably make the protection work much more difficult, which may mean that the remainder of the trees cannot be saved without excessive ribes eradication costs. Examples of stand density are shown in figure 7.

It is in stands where white pine is hard pressed by its associates to hold its own that blister rust losses become especially important. Here, when a white pine tree is killed, its growing space is occupied by trees of other and less valuable species, which rapidly decreases the proportion of white pine and thus the stand value. Neither the density of the stand nor its gross volume may be much affected by this shift from one species to another but stand values may be seriously reduced.

Because of this interaction between density and species composition it is impossible to define an over-all minimum stocking below which further reduction in number of white pine will cause an important reduction in final white pine volumes. Each stand must be considered separately. As stated, the effect of blister rust losses on white pine yields depends largely on whether pine is competing against pine or other species. Based on yield studies and empirical data, the following tabulation gives an indication of what might be considered minimum stocking to trees of all species at different stand ages in the western white pine type:

OPEN REPRODUCTION TREES UNDER 4 INCHES D.B.H. (DIAMETER AT BREAST HEIGHT) PREDOMINATE, SCATTERED OR IN INDIVIDUAL GROUPS. HERBACIOUS AND SHRUB GROWTH IS ABUNDANT. RIBES ARE MANY, FRUIT HEAVILY, REGENERATE SPARINGLY.

DENSE REPRODUCTION TREES UNDER 4 INCHES D.B.H. PREDOMINATE, UNIFORMLY DISTRIBUTED. HERBACIOUS GROWTH IS MODERATE. SHRUBS INCLUDING RIBES ARE LIGHT, SUPPRESSED, GENERALLY WITH LONG FEW-LEAVED STEMS AND WITH LITTLE OR NO FRUITING.

OPEN POLE TREES 4 TO 12 INCHES D.B.H. PREDOMINATE, SCATTERED OR IN INDIVIDUAL GROUPS. HERBACIOUS AND SHRUB GROWTH IS ABUNDANT AND REMAINS THROUGH LIFE OF STAND. RIBES ARE FEW TO MANY, FRUIT MODERATELY, REGENERATE SPARINGLY.

DENSE POLE TREES 4 TO 12 INCHES D.B.H. PREDOMINATE, UNIFORMLY DISTRIBUTED. TOLERANT HERBS AND A FEW SHRUBS REMAIN. RIBES ARE GREATLY SUPPRESSED WITH NO FRUITING AND NO SEEDLING SURVIVAL.

FIGURE 7.— BLISTER RUST CONTROL IN RELATION TO STAND DENSITY.

Age (Years)	Number of trees per acre of all species in dominant and codominant crown classes
20	750
40	450
60	300
80	200
100	160
120	140

In stands approaching this minimum stocking, any loss in white pine will materially reduce harvest yields.

3. Likelihood of infection. The complex of all factors, more or less outside the stand, that influence the incidence and spread of the disease determine to a great extent the likelihood of infection. The presence of ribes must first of all be considered as prima-facie evidence of the rust on all sites for no longer can white pine be safely grown to maturity in association with appreciable numbers of ribes. There are, however, a few known instances of forest stands which, due largely to their location, have not become seriously infected while others having approximately the same number of ribes present have been heavily damaged.

Geographical position and environmental associations of white pine stands are of particular importance. Stands in or near moist creek bottoms or on northerly slopes where temperate conditions prevail are more likely to become infected than those on drier and more exposed situations. Proximity to existing centers of infection is also a factor. Centers of heavy infection on the Clearwater and St. Joe Forests have largely developed in and spread out from moist creek bottoms where large concentrations of the highly susceptible Ribes petiolare were present. Centers of heavy infection on the Coeur d'Alene and Kaniksu Forests have developed primarily under favorable conditions in the uplands where large concentrations of R. viscosissimum were present.

The infection present in a stand at any one time is less significant than the possibility of repeated reinfection causing ultimate losses far exceeding natural mortality. For example, assume a center of heavy infection developed in a creek bottom and began to spread to an adjoining well-stocked 40-year-old stand 65 percent white pine. Assume further that 20 percent of the pine was thoroughly riddled by the rust from stream-type ribes. If these ribes were eradicated, stopping further reinfection, the stand as a whole would not be seriously damaged. However, if these ribes were not suppressed, the rust would eventually eliminate all pine within a limited distance. Furthermore, the scattered upland ribes surviving in the forest would become heavily infected and spread disease to the trees beyond the limit of stream-type ribes infection, thus generally affecting the entire stand.

The presence of heavy concentrations of _R. viscosissimum_ in the uplands under conditions favorable to blister rust development will act as the same initial stimulus as stream-type ribes in developing heavy rust centers. As long as enough ribes remain in the upland forest to permit the disease to spread back and forth between pine and ribes, the rust will continue to intensify even though more slowly and secondary centers of infection may develop and cause serious economic loss. New ribes may spring up in these rust-caused openings and the space previously occupied by white pine will be taken over by the less valuable species. The exact extent to which the "back of the disease" can be broken depends on how rapidly these heavy rust centers can be controlled and adequate measures applied to the remainder of the stands to check further spread.

The interaction and relative importance of these three factors of age, species composition and stand density, and likelihood of infection, in relation to the disease endurance of white pine stands can be best understood and brought into focus by considering ribes suppressional problems and the probabilities of rust damage in particular types of stands.

1. Thrifty reproduction stand 8 to 15 years old, generally dominated by western white pine. Examples of this class are those which have regenerated naturally following logging and have undergone stand improvement for the purpose of releasing white pine plantations and stands originating naturally after cutting or fire which are not in need of release. Many such stands are developing on commercially valuable sites often as a result of heavy investment to prepare the site for planting or to remove a defective and worthless overstory that is seriously impeding development of the natural reproduction.

Protection of all such stands is highly important because they are very susceptible to disease invasion and ribes are usually present in large numbers. Furthermore, these areas will bear close watching for many years as new ribes seedlings may appear following any secondary disturbance. Many of these seedlings will come in on sites still favorable for their continued development since stands at this age cause little if any natural suppression of ribes. If the ribes become infected rapid elimination of the pine can occur often with the resultant loss of the investment in work already performed. A heavy loss of white pine stock on logged-over areas will be particularly serious if there is no assurance of a natural second crop either through stored seed or reseeding.

2. Thrifty, medium stocked reproduction stand 8 to 15 years old, including a relatively small proportion of white pine that is undergoing intense competition from other species. Examples of this class are the thousands of acres in the region which have been partially cut to remove white pine and western redcedar but in which a residual stand of defective and unmerchantable stock has been left. The problem of suppressing ribes here in complicated by uncertainty as to the future importance of white pine in the stand, since the greater proportion of the reproduction is likely to be of unmerchantable species. This will be of particular importance if white pine is competing with western hemlock and with grand fir. Protecting stands in which white pine will produce less than 8,000 board feet at maturity is considered uneconomic. Here a balancing of cost against expected benefit should be made before undertaking ribes suppression in such a stand. There are possibilities of making the investment more effective by accompanying ribes eradication with a cleaning operation to increase the proportion of white pine. If this is done it will not add to the ribes problem already present unless the "weeded" slash disposal is by burning. The status of new ribes seedlings germinating in this type of stand will be similar to that described in case 1, except that survival will be greatly hindered by the greater stand density.

3. Thrifty and well-stocked stand 15 to 30 years old with a high proportion of white pine. Though still very disease susceptible, such stands are beginning to suppress the ribes with a consequent lessening of the infection hazard. This is of great importance in controlling the rust after the ribes have been initially eradicated. New ribes seedlings occasionally appear on sites still in the open but the regeneration problem will not be serious providing the density of the stand is sufficient to form a gradually closing canopy. The number of white pine stems in such stands can be appreciably reduced without significant economic loss, providing this mortality is generally distributed, for at this age natural losses are normally heavy.

4. Medium to well-stocked stand 15 to 30 years old, including a high proportion of unmerchantable species which are inhibiting to various degrees the development of sparsely

populated white pine. There is a wide variation of stands falling into this general class, the entire group having originated as a result of partial cutting with a heavy residual unmerchantable stock remaining. If white pine is competing with western larch or lodgepole pine on these areas it will usually maintain itself in the stand. If competing with hemlock and grand fir, white pine will be hard pressed to maintain itself in the stand. The question of protecting these stands depends on the probable proportion of pine in the final stand and this point should be given careful consideration before undertaking ribes eradication.

5. Well-stocked pole stand 60 years old. The disease susceptibility of such a stand is relatively low and its general disease endurance high, especially if dominated by white pine. Few ribes can survive under such a stand, making it practically immune to serious loss unless there is a center of heavy infection within or nearby or heavy concentrations of ribes within infecting range. Few trunk cankers will occur in this age class but the increased proportion of branch infections normally found is often responsible for the killing of branches and tops. However, a large proportion of these cankers die before causing any serious loss.

Usually the few ribes present have reached an equilibrium and maintain themselves in scattered openings of the stand. New ribes seedlings occasionally germinate but rarely become established except along stream drainages throughout the stand. Ribes eradication in such stands is often necessary but is not unduly costly.

6. Medium to well-stocked pole stand 60 years old, with a relatively small proportion of white pine still in the dominant and codominant crown classes. The pine that has not reached these two crown classes should not be considered as final crop possibilities. Unless this pine can be brought through to maturity with a yield of between 8,000 to 10,000 board feet gross volume, the expense of ribes suppression would not be justified except for the purpose of protecting adjacent stands. The ribes populations in these stands can be considered as decreasing with no further seedling problems.

7. Mature stands 120 years or more old. In general, such stands, especially if well stocked, are not particularly likely to suffer greatly from blister rust damage. Trees of

this age have the greatest endurance to the disease of all classes. Serious damage might result, however, in the open type where large concentrations of upland ribes are still present or along streams where the foliage extends to the ground along the outer edge of the stand.

Ribes populations are often still abundant in the open type of mature white pine but usually entirely absent from well-stocked stands. Ribes seed in dense, mature stands has become so deeply buried beneath the thick forest carpet that no germination takes place except as a result of major forest disturbance such as logging or fire. As long as any forest type remains open there is always the possibility of some ribes seed germinating on sites favorable for their survival. If serious blister rust infection did occur in this age class it is probable that the crop could be harvested before occurrence of appreciable economic loss.

Many more cases could be cited for the western white pine type but the intent of this section is only to point out a line of reasoning and approach to the consideration of ribes suppression problems by listing a few generalized descriptive cases, There is a great need for more information on blister rust-timber management relationships. Everyone concerned with the problem should be on the alert to observe the incidence and development of the disease in various types of stands and the effect of ribes eradication operations in order to build up the background of specific information needed to cope with this problem most effectively and economically.

SUMMARY

1. The purpose of this manuscript is to acquaint all those concerned with the growing of western white pine with basic facts on the ecology of ribes and white pine which will aid in the coordination of all forestry activities toward the most effective and economical control of the white pine blister rust. It is important to utilize all possible natural aids in the suppression of ribes and to know when and how most effective and economic control measures can be applied.

2. It is important to know how the disease develops and spreads on both pine and ribes in order to apply effectively forest-management and ribes-eradication principles.

3. The type of cutting and slash disposal methods used in mature stands has a direct influence on the status of ribes populations and consequent rust damage. Good cutting practices are those which provide for adequate and

prompt restocking of white pine with a minimum number of ribes seedlings germinating and surviving.

4. Stand improvement in immature stands can be accomplished without creating ribes suppression problems. In conducting such work it is also important to take into consideration infection conditions and the possibilities of modifying cleaning or thinning methods to remove infected trees and lessen the rust hazard.

5. The disease endurance of forest stands is of prime importance in considering economic values, status of ribes, and probabilities of rust damage. The problems and needs of individual stands must be considered and control measures tailored to fit the specific need. Much depends on the ability of the man in charge on the ground to size up the particular situation and render the proper decision.

Any crop-producing areas that are selected for protection should have a minimum white pine productive possibility at rotation age of from 8,000 to 10,000 board feet per acre. Areas with less than this in sight should rarely be selected except for aesthetic and recreational value or where adequate control cannot be applied to adjacent valuable stands without work in low-value stands. It is important to think basically of blister rust control in terms of its effect on the board-foot production of western white pine and not in terms of the number of ribes per acre or the percentage of white pine trees with visible infection.

6. Timber growers must be more than ever blister-rust conscious and those responsible for disease control must be forest conscious. Both must be able to see the disease in its relation to the forest as well as to the tree if this valuable natural resource is to be grown and harvested in the Inland Empire.