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Red Alder: A State of Knowledge

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Robert L. Deal
and Constance A. Harrington
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ABSTRACT

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In March 23-25, 2005, an international symposium on red alder was held at the University of Washington Center for Urban Horticulture in Seattle, WA. The symposium was entitled "Red alder: A State of Knowledge" and brought together regional experts to critically examine the economic, ecological and social values of red alder. The primary goal of the symposium was to discuss new advances in the understanding of red alder biology and silviculture, changing market and non-market values, and the current regulatory climate for management of alder. This proceedings includes 14 papers based on oral presentations given at the symposium. These papers highlight some of the key findings from the history, ecology, biology, silviculture and economics sessions presented at the red alder symposium.

KEYWORDS: Red alder, *Alnus rubra*, history, biology and ecology, mixed-species stands, silviculture, pruning, plantation establishment, economics, inventory, supply.

PREFACE

During March 23-25, 2005, an international symposium on red alder was held at the University of Washington Center for Urban Horticulture in Seattle, WA. The symposium was entitled "Red alder: A State of Knowledge" and was presented by the University of Washington College of Forest Resources Rural Technology Initiative and Stand Management Cooperative and Washington State University Extension. The primary goal of the symposium was to discuss new advances in the understanding of red alder biology and silviculture, changing market and non-market values, and the current regulatory climate for management of alder. This symposium brought together regional experts to critically examine the economic, ecological and social values of red alder. More than 180 people attended the meeting.

The primary members of the Symposium Scientific Committee included David Briggs (Chair) University of Washington; Glenn Ahrens, Oregon State University Extension; Norm Andersen, Washington State Department of Natural Resources; Andy Bluhm, Hardwood Silviculture Cooperative; Robert Deal, Pacific Northwest Research Station; Del Fisher, Washington Hardwoods Commission; Don Hanley, Washington State University Extension; Bari Hermann, Weyerhaeuser Company; David Hibbs, Hardwood Silviculture Cooperative, Oregon State University; Pete Holmberg, Washington State Department of Natural Resources; Paul Kriegel, Goodyear Nelson Hardwood Company; Larry Mason, University of Washington Rural Technology Initiative; George McFadden, Washington State Department of Natural Resources; Joe Monks, Weyerhaeuser NW Hardwoods; Megan O'Shea, University of Washington; and Dave Sweitzer, Western Hardwoods Association.

Red Alder: A State of Knowledge was sponsored by several companies, agencies, and universities in the region. Sponsors included: British Columbia Ministry of Forests, Carlwood Lumber; Cascade Forestry; College of Forest Resources, Olympic Natural Resource Center, Rural Technology Initiative, and Stand Management Cooperative, University of Washington; Goodyear Nelson/Mount Baker Products; Hardwood Silviculture Cooperative and Extension Service, Oregon State University; Northwest Hardwoods; USDA Forest Service, Pacific Northwest Research Station, Focused Science Delivery Program; Washington Alder LLC; Washington Department of Natural Resources; Washington Forest Protection Association; Washington Hardwoods Commission; Washington State University Extension; Western Forestry and Conservation Association; Western Hardwood Association; and Weyerhaeuser Company. Sponsors helped defray some of the costs of the meeting including funding attendance for several students.

This three-day symposium included a pre-conference field trip and two days of plenary and concurrent sessions on the history of alder, biology, ecology and silviculture of alder, and the economic and regulatory climate for alder. The field trip included a tour of the Washington Alder mill near Mt. Vernon, Washington and stops in the woods to visit a 14-year-old plantation planted at different densities (one of the installations of the Hardwood Silviculture Cooperative) and another stop to discuss the restrictions on management in riparian areas and how they differ in British Columbia, Washington, and Oregon. The 2-day indoor session included 44 formal presentations as well as poster sessions and several moderated discussion sessions. The oral presentations (including portions of the field trip) were videotaped and are available on line as streaming video presentations at: http://www.ruraltech.org/video/2005/alder_symposium/index.asp

Following the symposium, we invited the speakers to also submit a paper for publication; 14 authors responded. Although we were not able to include additional information from all the meeting presenters, the papers that are included capture many of the key findings from the history, ecology, biology, silviculture and economics sessions.

Red Alder: A State of Knowledge was a very successful conference with excellent interaction between researchers, practitioners, mill owners, students, consultants, planners, and extension agents. We thank all those involved in planning, presenting, or contributing in some way to the meeting. We hope that this printed proceedings will add to the overall value of the conference and that you will find this information to be useful and of interest.

This is a product of the Sustainable Wood Production Initiative from the Focused Science Delivery Program of the Pacific Northwest Research Station.

Robert L. Deal
Pacific Northwest Research Station

Constance A. Harrington
Pacific Northwest Research Station

— *Red Alder: A State of Knowledge* —

CONTENTS

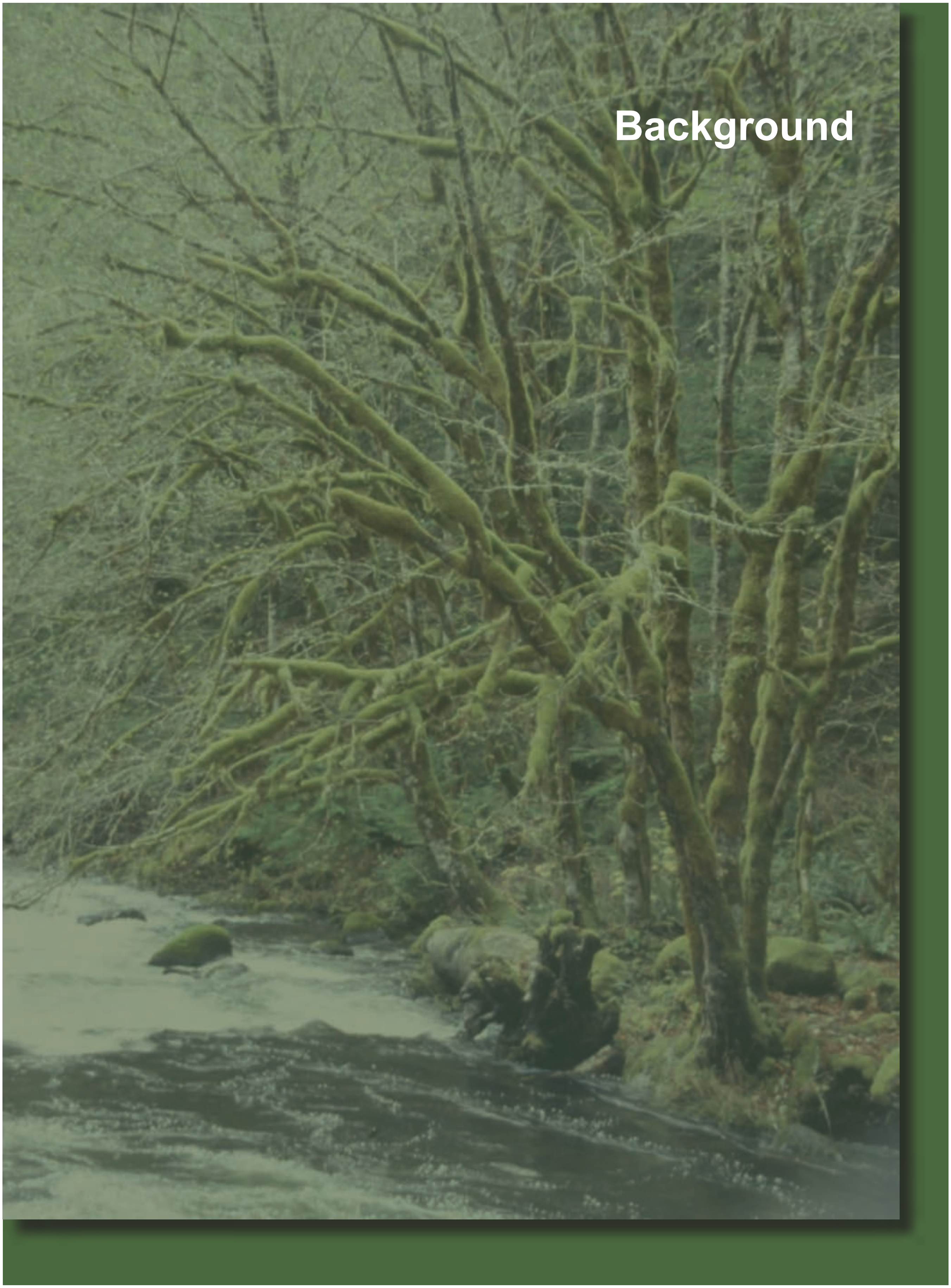
Background

Biology/Ecology

Management/Silviculture

Economics (Supply/Markets/Returns)

Background



— Red Alder: A State of Knowledge —

History of Research and Attitudes About the Biology and Management of Red Alder

Dean S. DeBell[1]

Abstract

Indigenous people of the coastal Northwest developed the earliest knowledge about red alder; next to western redcedar, they used the wood of alder more widely than any other tree species. Sea explorers from Russia and England were the first non-natives to observe and collect red alder specimens, but the first written descriptions of the species and its silvical traits were those in the published diaries of Lewis and Clark. Other pre-1900 references to red alder include journals and species descriptions by early botanists, and an 1882 book on "Forest Trees of California" by Kellogg that contained what may be the first mention of ecological amenities provided by alder, such as stream bank protection and trout habitat. Publications during the first two decades of the 20th century contained the diverse, contrasting opinions that remained through many decades: some foresters saw red alder as an undesirable species, to be removed and replaced with conifers as soon as practicable; others saw it as providing significant benefits to the forest; and some saw industrial possibilities in cabinetry and other uses. A comprehensive bulletin on utilization and management of red alder was published in 1926, but most of the silvicultural information then available was based on perceptive observations and measurements taken on temporary plots. In the 1930s, several long-term silvicultural projects were initiated by the Forest Service, and by the middle to late 1940's, interest and research in utilization and management of alder increased in other public organizations. The 1950s ushered in a long period of research and management interest in alder's soil-improving ability and growth rate, the competition it may create for conifers in plantations, and the use of herbicides to control or eliminate the species on conifer sites. In the 1960s, the long-term studies established earlier resulted in publications on several important topics: normal yield tables, growth and yield in pure and mixed stands, thinning, pruning, and soil improvement. Conversion of red alder stands to conifers increased, particularly on large industrial ownerships. Research on herbicides to control alder continued in the 1970s as new chemicals were developed. The expanding hardwood industry became concerned about future supplies, and began to question policies related to alder on public lands. National and international interest in short rotation culture of hardwoods (including bioenergy plantations) and use of nitrogen-fixing species as an alternative to chemical fertilizer stimulated further studies on red alder. Beginning in the 1980s, major changes in the status of alder began to occur in northwestern forestry. Oregon State University hired a hardwood silviculturist and formed a research cooperative focused on alder silviculture, industrial corporations began to establish alder plantations on high site quality forest land, the contributions of alder to wildlife habitat and riparian productivity were recognized, and prices for alder logs increased (and eventually equaled and at times surpassed) those paid for Douglas-fir. Today, red alder is acknowledged as a species with a significant role in the forest ecosystem and forest products economy and of the Pacific Northwest.

Keywords: *Alnus rubra*, early observations, management status, research history, red alder

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Introduction

Red alder (*Alnus rubra* Bong.) is an interesting and unusual species. Although lacking the impressive size of most trees in Pacific Northwestern forests, red alder now occupies a significant niche in the conifer-dominated ecosystem and wood products economy of the region. This was not always the case. During most of the past century, red alder was regarded as second rate, an undesirable, even threatening species. Even in those times, however, there were individuals and groups in forestry and other natural resource professions who saw value and possibilities in this hardwood species. Red alder is one of the first forest tree species to have had a symposium devoted exclusively to its biology. The first symposium held in 1967 at an annual meeting of the Northwest Scientific Association (Trappe et al. 1968) has been followed at 10- to 15-year intervals by three others. The second symposium dealt with utilization and management (Briggs et al. 1978), and the third with biology and management (Hibbs et al. 1994). The fourth symposium covered matters pertaining to markets and economics as well as biology, management and utilization, and many of the presentations are documented in this General Technical Report. A Hardwood Commission in Washington functions as an advocate and a Hardwood Silviculture Cooperative at Oregon State University is focused on alder research. Not a bad record for a tree regarded by many foresters as a third string species at best!

Organizers of this symposium asked me to provide a brief history of how the above situation developed, with particularly attention to research and attitudes concerning the biology and management of red alder. As I began to prepare this historical perspective, I identified more and more with a concern raised nearly two centuries ago by German forest scientist Heinrich Cotta (republished as Cotta 2000); that is, "the forester who practices much writes but little, and he who writes much practices but little." When tracing the history of alder over many decades, one is heavily dependent on published material. Unfortunately this written record represents only a small portion of both the experience and attitudes developing in any period, and the events and influences that shaped them. Despite such limitations, the history of red alder is an interesting one!

In the following pages, I shall relate first some information about the initial observations, collections and descriptions of red alder; then review some research reports and other literature that were published during the 20th century, particularly those items that reflected or influenced attitudes and management of the species; finally, I'll offer some thoughts about factors that contributed to the changing status of red alder in Pacific Northwestern forestry.

Early Observations, Collections, and Descriptions

The earliest knowledge about red alder obviously is that developed and passed on among the indigenous people that populated the Pacific Northwest. For many, many centuries, the wood of alder was, next to western redcedar (*Thuja plicata* Donn.), the most widely used of any tree species in Northwest Coast woodworking (Gunther 1973). Dishes, platters, spoons, cradles, and canoe bailers were made from alder. It was considered to be ideal firewood because it did not spark, and it was uniformly preferred for smoking salmon. Its value extended beyond the wood itself; the bark was used for dyes, and medicines were prepared from both bark and catkins (Turner et al. 1990).

The first observations and collections of red alder by non-native people appear to have been made in the mid- to late-1700s by Russian explorers in coastal Alaska. These collections were not described until the mid-1800s (Bongard 1833) and remained unknown to most of the western world until much later. In fact, it was not until the 1930s that red alder's scientific name was changed from *Alnus oregona* Nuttall to *Alnus rubra* Bongard to credit these earlier collections and descriptions.

Probably the next European to make an observation about red alder in the Pacific Northwest was Archibald Menzies, a botanist-naturalist with Captain George Vancouver's expedition. Menzies' personal diary refers to alder in several places, including a note about finding "American Aldar" at Discovery Bay on May 2, 1792 (Gorsline 1992).

The first written silvical (or ecological) observations appear to be those found in the original diaries (1804–1806) of Lewis and Clark (Thwaites 1905, reprinted 1959). Two hundred years ago (late October 1805), Lewis and Clark descended the Columbia River and near the mouth of Wind River observed a "timber resembling a beech in bark but different in its leaf which is smaller, and the tree smaller." This timber is believed to be red alder, and if so, the entry represents its first mention in their journal. The species was later referred to by Lewis and Clark as "black alder" or "beech." The smooth, beech-like bark of alder was no doubt the reason that both Lewis and Clark chose it to mark their presence at Cape Disappointment, the westernmost point of their journey (fig. 1). Lewis carved his name, and Clark later added not only his name but also the date and the line: "By Land from the U. States in 1804 and 1805." While at Fort Clatsop on the Oregon side of the river, Lewis and Clark observed that alder trees "grow separately from different roots and not in clusters or clumps as those of the Atlantic states." They also recorded phenological information—observing that alder "did not cast its foliage until about the first of December"; and they noted that "the black alder is in blume" on March 24, 1806, the day after they left Fort Clatsop for their return home.

Figure 1—The smooth, beech-like bark of red alder attracted personal inscriptions by both Lewis and Clark at Cape Disappointment.

Other early references to red alder in pre-1900 documents include the journals of James G. Swan (1852–1900) and David Douglas (1823–1827). Douglas collected alder near Cape Disappointment on April 8, 1825, and thought it might be *Alnus glutinosa* (European black alder) (Douglas 1959). In addition, original species descriptions of red alder (or Oregon alder) were prepared by H.G. Bongard (1833) and Thomas Nuttall (1842).

Kellogg (1882) wrote a particularly poetic account titled "The Great Red Alder" in his book, *Forest Trees of California*, and he may be the first writer to mention ecological amenities or values other than wood and plant products. His description of the species and its habitat included observations that trout seem to prefer those pools in which the mineral waters have been cooled and "toned" by alder's presence, and that their flesh there acquired an aldery-tinged color and quality (Kellogg 1882). He also indicated that the wood of red alder was highly esteemed as piles for foundations of bridges and other water structures because when kept constantly underwater, it is very durable. Such durability when immersed is probably the reason that another member of the *Alnus* genus was used along with oak and larch for piling in the marshes on which the city of Venice, Italy was built (Botkin, 1990).

Chronology of Research and Attitudes

The following chronology is intended to document briefly the evolution of knowledge and attitudes about red alder during the past century. To do so, a few items in each decade were selected to illustrate or reflect the status and development of information and thinking about red alder management during that period.

1900–1909

At the beginning of the last century, forestry in North America was in its infancy and was represented almost entirely by employees of the U.S. Forest Service.

In 1908, George Sudworth, a Forest Service dendrologist, included a description of red alder in his book, *Forest Trees of the Pacific Slope*. He recognized its "rapid growth" and referred to its "cherry-like, fine grain that was attractive when finished, and made the wood suitable for cabinet work" (Sudworth 1908).

1910–1919

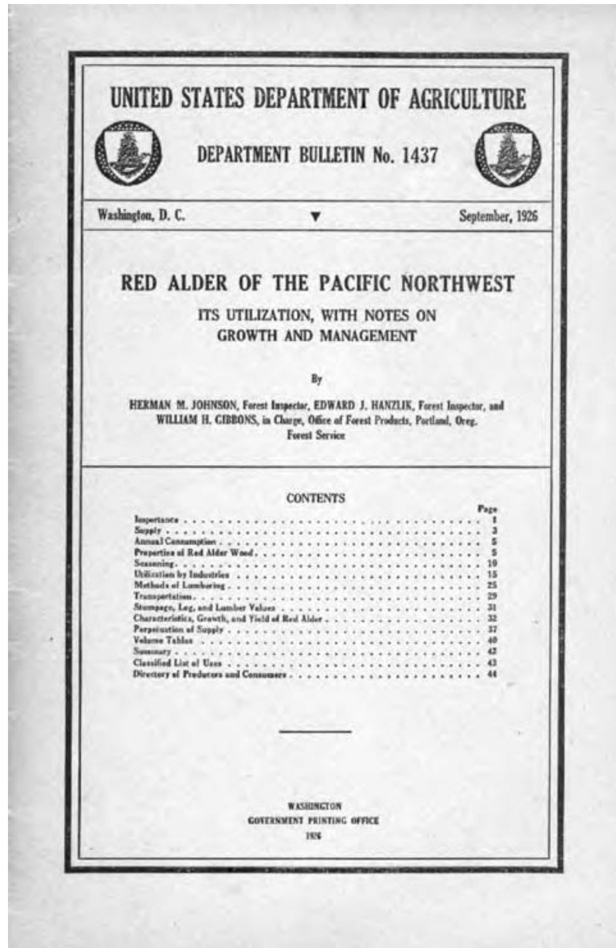
This second decade of the 20th century brought forth contrasting views about alder that persisted throughout most of the century. Two publications—both from USDA Forest Service—illustrate this contrast:

The first view—and the dominant one for many years—was published in 1912 in U.S. Department of Agriculture, Forest Service Silvical Leaflet 53–*Red Alder* (Graves 1912). Referring to six species of tree-size alder, the author, presumably Henry S. Graves, second chief of Forest Service and founding Dean of the Yale School of Forestry, writes "The most important of these is red alder, a medium-sized tree of the Pacific coast region. Although it has no particularly excellent qualities, and is not abundant enough to be very important commercially, it is one of the conspicuous broadleaf trees of its range, where there are but few broadleafs of any species." This paper contains some information about growth patterns, site suitability, and utilization—including a number of observations that seem to contradict the idea that the species had no excellent qualities. These appear to have had little impact on the author's opinion, however, as the leaflet concludes with the following comments on management: "Red alder is not a tree which merits the forester's especial care, although it is one of the most abundant broadleaf trees of western Washington and Oregon. .... The forester's chief aim should not be to encourage this species, but to find a means of profitably disposing of what already exists. Stands of alder, wherever practicable, should be utilized before decadence sets in, and in cutting them an effort should be made to convert the forest of alder into a forest of more desirable species."

That view contrasts sharply with a view presented 5 years later in a Journal of Forestry article written by Herman M. Johnson, a forest examiner for the Forest Service. It was titled, *Alnus oregona: its value as a forest type on the Siuslaw National Forest* (Johnson 1917). After reviewing some of the silvical characteristics, he argued that "the value of this species has not been given proper recognition," and described several useful purposes, including its value for fire protection and soil rehabilitation (both particularly significant on the Siuslaw National Forest as it had experienced extensive fires in the 1800s). Johnson concluded his paper as follows: "Although the Oregon alder has been commonly considered a weed tree and in many respects undesirable, this study has shown that it has been and is yet of great value to the Siuslaw National Forest." He then added: "it may be expected that in the near future it will develop an industry of considerable extent."

During this same period, Canadians were also beginning to examine the forests of British Columbia, and red alder receives brief mention. After describing some attractive growth and wood characteristics, the account ends with the statements: "The chief use, however, is as fuel, for which it is excellent. It is of local importance only and no estimate of the available supply has been secured." (Whitford et al. 1918).

About the same time, B. L. Grondal, a professor at the University of Washington College of Forestry, added his voice to those who saw a promising role for alder in the developing forestry economy of the Northwest. He wrote an article in the West Coast Lumberman titled *Seattle Shoe Factory Utilizes Red Alder* (Grondal 1918). Seasoned alder was used as sole material in shoes, and was "found by actual test to be superior to any other timber known."


UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1437

Washington, D. C. ▼ September, 1926

RED ALDER OF THE PACIFIC NORTHWEST

ITS UTILIZATION, WITH NOTES ON GROWTH AND MANAGEMENT

By

HERMAN M. JOHNSON, Forest Inspector, EDWARD J. HANZLIK, Forest Inspector, and WILLIAM H. GIBBONS, in Charge, Office of Forest Products, Portland, Oreg. Forest Service

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

Figure 2—First technical bulletin on utilization and management of red alder was issued by the U.S. Department of Agriculture in 1926.

Thus, early on in the development of forestry in the Northwest, the contrasting opinions that prevailed through many following decades were on the table: some saw red alder as an undesirable species, to be removed from the forest and replaced by conifers as soon as practicable; some saw it as providing significant ecological benefits to the forest; some recognized its superiority as a fuelwood; and some saw possibilities in cabinetry and actual use in a developing industry as sole material in a shoe factory!

1920–1929

Although there was not much research activity dealing with red alder in the twenties, the Forest Service published in 1926 the first comprehensive bulletin on its utilization, growth and management (fig. 2). The bulletin was co-authored by H.M. Johnson, who had foreseen the value of alder nearly a decade before on the Siuslaw National Forest, Edward Hanzlik, forest inspector, and W.H. Gibbons of the Office of Forest Products in Portland (Johnson et al. 1926). They addressed the species' importance in the first section of the bulletin stating "Red alder, although a wood of comparatively little importance outside of the region where it is found, is yet the leading hardwood of the Pacific Northwest…Its importance locally is due both to the intrinsic qualities of the wood and to the scant supply of other commercial hardwoods throughout its range." And after describing some of its wood characteristics, the authors wrote "The growth of the furniture industry and similar wood-using industries of the Pacific Northwest may indeed be said to depend in a large measure on the perpetuation of an adequate supply of alder." A section on *Characteristics, Growth and Yield* included the observation that alder is "exceptionally free from all sorts of diseases and injuries" up until the time of its maturity (about 50 years of age). They determined maximum size at about 120 feet in height and nearly 4 feet in diameter; and recognized that young alder trees grew "more rapidly even than Douglas-fir." Their yield data showed that stands as young as 30 to 40 years may average more than 90 feet tall, 12 inches plus in diameter, and contain more than 20,000 board feet per acre—this to a 6-inch top diameter and mininum breast-high diameter of 8 inches. Two-way volume tables were provided in both board feet and cubic feet. The management summary

Figure 3—Stand of red alder at Cascade Head Experimental Forest thinned and released from overstory conifers at age 10.

concluded: "The facts indicate that for many reasons red alder is a desirable tree to perpetuate as a forest type in the Pacific Northwest."

1930–1939

Most of the information available on red alder before 1930 was based on perceptive observations and measurements taken on temporary plots. In the 1930s, additional labor became available on the National Forests, including the Experimental Forests, in the form of the Civilian Conservation Corps (CCC). Several long-term silvicultural projects were initiated during this period, perhaps aided directly or indirectly by the CCC program.

In 1932, red alder was planted in a strip, 70-90 feet wide and about one mile long, in the Yacolt Burn on the Wind River Experimental Forest. This planting was intended to serve as a firebreak, but through a serious of serendipitous events, it provided a classic example of benefits possible in a mixed stand of red alder and Douglas-fir (these will be described later in this paper). About the same time, some direct seeding of red alder was done on the Olympic National Forest. During the 1935 to 1937 period, several long-term studies on growth and silviculture of red alder were established at Cascade Head Experimental Forest. These studies included plots that compared pure and mixed stands of red alder and conifers, and thinned and unthinned stands of alder (fig. 3). A test of pruning was also established.

In 1938, Thornton Munger wrote a paper for the Hardwood Record titled *Red Alder Long Considered but a Weed Tree, Now an Important Raw Material for West Coast Woodworkers* (Munger 1938). And the next year, T. J. Starker, of Oregon State's College of Forestry, published in the Journal of Forestry what may be the first paper related to genetic variation of the species (Starker 1939). In *A New Alder*, he described a genetic variant, the cutleaf or *pinnatisecta* variety of the species.

1940–1949

During the early 1940s, there was relatively little new research on the biology and management of red alder, probably due in part to the war effort. A study of sprouting of alder at Cascade Head indicated that coppicing was not a feasible regeneration method for red alder, at least not for trees of saw timber size (Worthington et al. 1962).

In the middle to late 1940s, however, interest in utilization and management of alder increased in several public organizations. There were projects on kiln-drying of hardwoods (Voorhies 1944) and other aspects of hardwood utilization at the Oregon State University Forest Products Laboratory (Robinson 1948).

At the end of the decade, William Lloyd (1949) of the U.S. Department of Agriculture, Soil Conservation Service established thinning plots in northwest Washington, and George Warrack (1949) began researching red alder for the provincial government in British Columbia. The same year, Morrison published in the *British Columbia Lumberman* what may be the first report on use of herbicides to control alder (fig. 4)—"Keeping roads alder free by the use of chemical sprays" (Morrison 1949). And Philip Haddock, then a young assistant professor at University of Washington, wrote a paper for the *Forestry Club Quarterly* with the interesting title *A Problem Child Reforms—New Perspectives in the Management of Red Alder* (Haddock 1949). He pointed out that continuity and stability of production was one of the main obstacles to any permanent alder industry. After recognizing the problems of alder competing with or preventing establishment of conifers on some lands, he suggested the need for more exact knowledge of alder as a soil builder before attempting large-scale removals of the species by chemical control methods or otherwise. The most surprising aspect of this paper was that Haddock went on to discuss some of the genetic improvement work occurring in Europe, and advocated applying such techniques to intensive management of red alder in the Pacific Northwest. (Note that this recommendation was made 56 years ago!)

Figure 4—Roadside spraying in the late 1940s and 1950s was an early use of herbicides to control red alder.

1950–1959

The early 1950s ushered in a long period of interest in the soil-improving characteristics of alder. Bob Tarrant (fig. 5) and others compared nutrient content of litter of several tree species (Tarrant et al. 1951). They found that red alder leaf litter had extremely high nitrogen content (40 percent higher than the next highest species); and they suggested that alder had possible value as a soil conditioner. Elsewhere, scientists began to examine the nitrogen-fixing capacity of several *Alnus* species, and the role of alders in soil development after the recession of glaciers (Bond 1954, Crocker and Major 1955, Lawrence 1958).

Figure 5—Robert Tarrant pioneered research on soil improvement by red alder in the 1950s and 1960s, and later served as Director of the Pacific Northwest Forest and Range Experiment Station.

In the mid-1950s, Bob Ruth began to evaluate performance of young conifer plantations in coastal Oregon (Ruth 1956, 1957). He found that alder and various brush (or shrub) species hindered conifer development. Although red alder had been considered as inferior to Douglas-fir and other conifers in some respects (size, use as structural material), this research indicated that alder could actually threaten conifer establishment and early growth. As a result, work progressed on use of chemicals to control this threat. Basal spraying with 2,4,5-T in oil was found to be an effective way to kill alder (Ruth and Berntsen 1956).

The first volume tables (Johnson 1955, Skinner 1959), site curves (Bishop et al. 1958), and some preliminary yield tables (Lloyd 1956) became available in the late 1950s.

At the National Convention of the Society of American Foresters (SAF) in 1958, Carl Berntsen presented a paper titled *A Look at Red Alder–Pure, and in Mixture with Conifers*. He examined the results after 20 years of silvicultural manipulations starting in a 10-year-old mixed stand of red alder and Douglas-fir (Berntsen 1958). One area remained as a control; conifers were completely removed from two areas to leave pure stands of alder, one of which was also thinned to 8 ft by 8 ft; all alder was removed from the fourth area to leave a pure conifer stand at 6 ft by 6 ft spacing. From age 10 to age 20, alder grew much more rapidly than the conifers. At stand age 30, however, the conifers were growing at 400 cubic ft per acre per year and the pure alder only 260 cubic ft per acre. Thinning the pure alder stand made little difference. Growth in the mixed stand was least. Implications of this study were that pure stands of either conifers or alder were superior to mixed stands, at least to age 30, and that alder thins itself rather effectively.

1960–1969

The 1960s were rich in production of information on several topics about alder. Studies established in the 1930s had matured, and interest in both managing and controlling or converting red alder had increased over time. A number of significant publications on silviculture and management resulted.

One of the most important was a collaborative effort among several landowners and agencies to gather data and produce normal yield tables for red alder. These tables were authored by Norman Worthington (fig. 6) and Floyd Johnson (PNW Station) with George Staebler (formerly with PNW Station but by then of Weyerhaeuser Company) and William Lloyd (Soil Conservation Service) and were published as a PNW Station Research Paper (Worthington et al. 1960). They provided—for the first time—a broad-based estimate of levels of production that might be expected from fully-stocked stands of alder over a wide range of sites and ages.

Berntsen published three significant papers on the alder silviculture studies that had been established decades earlier at Cascade Head Experimental Forest. One was a detailed examination (Berntsen 1961) of the study that he discussed at the national SAF meeting three years before (Berntsen 1958). A second paper (Berntsen 1962) evaluated 20-year growth of alder stands that had three different treatments: scattered overstory Douglas-fir occurred in two stands and was girdled; one of these two stands was also thinned; the third stand was initially pure alder and was not thinned. The latter grew much more rapidly than the other two and differences between those were minimal, suggesting again that red alder may be rather effective at self-thinning. The third paper (Berntsen 1961) dealt with pruning and carried

Figure 6—Norman Worthington of the Pacific Northwest Forest and Range Experiment Station's Olympia Research Center led efforts in the late 1950s and early 1960s to produce normal yield tables and a comprehensive bulletin on management of red alder.

two main messages: (1) branch stubs were grown over very rapidly, and although decay was present in every stub, it did not extend beyond the knots; and (2) gains in clear wood were offset by development of epicormic branches. The upshot was that pruning of red alder was regarded as a questionable practice for many years. In hindsight, it appears that this pruning test was conducted in stands that were released from overtopping conifers and further thinned at the same time (Rapraeger 1949); it therefore seems likely that these other stand-opening treatments contributed to epicormic branching at least as much as the pruning itself.

Worthington, Ruth, and Matson (1962) combined efforts to publish a comprehensive bulletin on management and utilization of red alder. This was an update of the earlier bulletin by Johnson, Hanzlik, and Gibbons (1926) some 36 years before, but with considerably more information on silviculture and management.

Scientific understanding of the effects of alder on physical, chemical, and microbial properties of the soil was also advanced in the sixties. Tarrant (1961) published a significant paper on a study conducted in the mixed stand of red alder and Douglas-fir at Wind River—the one created serendipitously by the intended firebreak mentioned earlier. Tarrant compared soil properties and Douglas-fir growth in the mixed planting with soil properties and tree growth in the adjacent pure stand of Douglas-fir; in the mixed stand, soil nitrogen and foliar N of the Douglas-fir and current growth of dominant Douglas-fir trees were greater than in the pure Douglas-fir stand. Such evidence and the striking visual demonstration (fig. 7) at this site stimulated interest by other scientists and managers in the possibilities that alder may offer in the region's forest economy and ecosystem. A detailed follow-up study by Tarrant and Miller (1963) showed that organic matter content was also increased, bulk density was lower in surface soil, and on average an additional 36 pounds of N per acre per year had accumulated beneath the mixed stand. These studies at Wind River led to studies of soil properties in the mixed and pure stands at Cascade Head Experimental Forest (Bollen et al. 1967, Franklin et al. 1968).

In other microbiology and pathology studies, red alder was shown to be non-susceptible to *Phellinus (*then *Poria) weirii* root rot (Wallis 1968). Survival of *Phellinus* in infected cubes of Douglas-fir wood buried in soil was poorer beneath stands containing alder than under pure Douglas-fir stands (Nelson 1968). Research was also conducted on rhizophere microflora and mycorrhizal associations of red alder (Neal et al. 1968a, 1968b) and interactions between alder and various root rot fungi (Li 1969).

In the mid-sixties, Tarrant presented a paper on forest soil improvement by growing red alder at the International Soil Congress (Tarrant 1964); Warrack published some results on thinning of red alder in British Columbia (Warrack 1964); and the Extension Service of Washington State University issued a circular on *Growing Red Alder for Profit* (Washington State University Extension Service 1964).

Figure 7—A strip of red alder planted as a firebreak in the 1930s resulted in more productive soil and taller Douglas-fir trees with darker green foliage than occurred in the surrounding Douglas-fir plantation.

The first symposium on alder was held in 1967 at the Northwest Scientific Association Annual Meeting, and was geared primarily to forest scientists. The proceedings (fig. 8), *Biology of Alder*, were published by the Pacific Northwest Forest and Range Experiment Station the next year (Trappe et al. 1968) and contained three papers on taxonomy, eight on ecology, ten on soils and microbiology, five on physiology, and two on growth and yield.

In 1969, Bernard Douglass and Ralph Peters, foresters with the State and Private branch of the Forest Service, installed the first field study of red alder genetics at Cascade Head Experimental Forest (fig. 9). This provenance trial consisted of seedling sources collected from 10 locations ranging from Port Orford, Oregon to Juneau, Alaska.

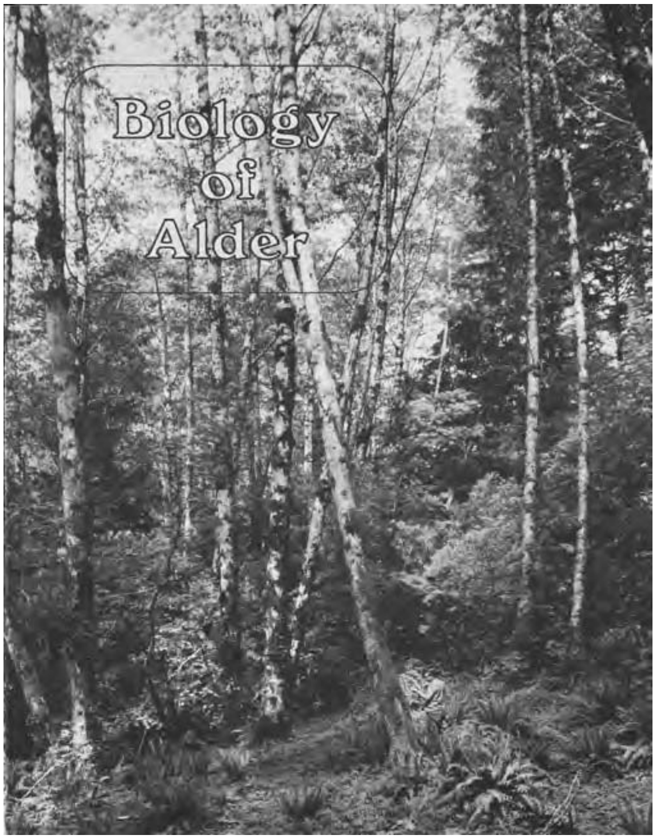


Figure 8—Proceedings of the first symposium on red alder were published in 1968 by the Pacific Northwest Forest and Range Experiment Station.

One might think the tide had turned during this decade regarding prevailing opinions about the usefulness for alder, but if it did, the change was minor. Forest managers were also looking more closely at stand conversion, and work on chemical release of plantations from alder and other brush was accelerating.

Staebler (1960) reported difficulties in killing red alder via a basal injection of 2,4,5-T. Many other studies were carried out using herbicides as basal sprays (Madison and Ruth 1962) or via injection or in frills to kill larger alder stems (Finnis 1964, Newton 1966). There was also work on application of foliar sprays to kill brush (one of the constituents being red alder) in conifer plantations (Hetherington 1964).

In 1969, James Yoho and other economists (1969a) published an economic analysis on converting red alder to Douglas-fir. They concluded that in most instances it was financially desirable convert red alder to Douglas-fir—and the sooner the better! They stated that forest managers were not rushing to respond to this profitable investment in conversion, and recognized that a large share of private owners do not respond at all—a good thing for the alder industry! Their paper stimulated a letter from the Chief Forester of Northwest Hardwoods, Inc. (Burns 1971) to the PNW Station Director. The letter began by suggesting that the paper was based upon "an inaccurate economic model, faulty data, and assumptions biased to give credence to the *one best species* myth peculiar to foresters in the Northwest." The letter then listed some reasons for such strong criticism, one of which was the assumption that "red alder stumpage rates would stay in the same ratio to Douglas-fir forever more!" The letter did, however, end on a conciliatory note; the chief forester offered to "cooperate in any way possible" in a new study to replace the "faulty" one.

Figure 9—A red alder provenance trial established in 1969 by State and Private Forestry at Cascade Head Experimental Forest was the first genetics field test and in 2005 is probably the oldest pure plantation of the species.

The same group of economists (Yoho et al. 1969b) also published a note at the same time that was probably somewhat better received by the alder industry. Although titled *Marketing of Red Alder Pulpwood and Saw Logs*, it was more than that. In it, the authors pointed out that quoted stumpage prices were not indicative of true market values because alder logs were usually a minor component of a timber sale and the concerns of buyers and sellers were usually centered on the conifer component. The economists foresaw a bright future for alder markets, however; the use of red alder in pulp mills was increasing at the time, and they thought the potential for market expansion and earnings in the lumber markets might be even greater.

1970–1979

The 1970s brought substantial increases in research on alder species throughout the northern temperate zone.

Studies on herbicides increased as many new chemical products were developed. Ron Stewart evaluated foliage sprays and budbreak sprays, and made recommendations for site preparation and release of conifer plantations from competition associated with red alder and other hardwood tree and shrub species (Stewart 1974a, 1974b). Further analyses were made on the matter of converting brush and hardwoods to conifers (Dimock et al. 1976).

The concept of short-rotation intensive culture of hardwoods, developed in the Southeast as "silage sycamore" in the mid-1960s (McAlpine et al. 1966), received some attention in the northwestern United States and Canada (Heilman et al. 1972, Smith and DeBell 1973). Red alder and black cottonwood were the species of choice (DeBell 1975, Harrington et al. 1979). When the oil crisis developed, an interest developed in using the concept for growing "energy plantations," and red alder (as well as poplars) figured prominently in early assessments (Evans 1974). The idea gained momentum and the U.S. Department of Energy was formed and initiated a long-term program of research on woody biomass production (Ranney et al. 1987); projects involving red alder (in addition to *Populus* and other hardwoods) were funded at several institutions in the Pacific Northwest (initially at University of Washington, Washington State University, and Seattle City Light, and later at the Pacific Northwest Research Station). The funds from this program fostered work on many aspects of red alder biology and silviculture.

Other work that had also started in the 1960s by soil microbiologists and forest pathologists at Corvallis led to the hypothesis that alder might serve as a biological control for laminated root rot of Douglas-fir (Trappe 1972). Several studies were undertaken in the 1970s to gather information on this possibility; these included additional exploratory studies and a long-term, large-scale test of effects of short rotations of alder or cottonwood on development of root rot in subsequent Douglas-fir crops on International Paper Company land in northwest Oregon (Nelson et al. 1978). Investigations of field survival of *Phellinus* in large Douglas-fir stumps did not confirm any special inhibitory effect of alder on the pathogen (e.g., Hansen 1979), but meaningful evaluation of the long-term empirical trial will not be possible for at least another decade. There is a general consensus, however, that on *Phellinus*-infested sites suitable for alder, a rotation of this non-host while the fungus exhausts its resources is a reasonable strategy for limiting losses from the root rot.

About this same time, the alder industry was expanding and became concerned about current and future log supplies. Public agencies began to be questioned about their policies related to alder management. There was a series of articles in the Portland *Oregonian* (Sorensen 1973a, 1973b). One investigated a so-called "mismanagement of the alder resource on the Siuslaw National Forest." The Corvallis *Gazette-Times* ran a feature on red alder that described the possible benefits derived from managing and utilizing red alder (Hall 1976). Washington Department of Natural Resources staff released several notes about alder management and the economics thereof during mid- to late-1970s (Prevette 1975, 1976; Koss and Scott 1977).

In 1977, a second symposium on alder was held; this one involved foresters and mill owners and managers as well as forest scientists and its focus was utilization and management of red alder. The proceedings, published by the Pacific Northwest Station (Briggs et al. 1978), contained many papers of practical as well as scientific interest. One of the papers (Miller and Murray 1978) examined growth and yield in the previously-mentioned stands of red alder and Douglas-fir at Wind River; at age 48, Douglas-fir in the mixed stand was taller by 16 ft and had a larger per acre volume despite having one-third fewer stems than in the pure Douglas-fir stand. Total volume of red alder and Douglas-fir in the mixed stand was about double that of the pure Douglas-fir stand. These substantial long-term growth benefits to Douglas-fir strengthened interest in the ecology and potential management of mixed species stands.

A great deal of interest developed during the decade in nitrogen fixation, stimulated in part by the high cost (in terms of money and energy) of nitrogen fertilizer. A workshop held at the Harvard Forest featured several papers on *Alnus*, two of which involved red alder in the Pacific Northwest—one a short-rotation intensive culture study of pure and mixed alder and cottonwood (DeBell and Radwan 1979), the other a conceptual paper on crop rotation of alder and Douglas-fir (Atkinson et al. 1979). Two years later, an international symposium on use of nitrogen fixation in management of temperate forests was held at Oregon State University (Gordon et al. 1979). Again, red alder and other *Alnus* species were prominent in the presentations.

1980 and Beyond

In the late 1970s and early 1980s, relative economic values began to change substantially—there were downturns in the forest products industry and values of Douglas-fir logs and stumpage declined for a time. During this same period, prices for red alder logs remained more or less stable. Gradually, prices for both Douglas-fir and alder increased. Trends were more erratic for Douglas-fir and there was a shift to smaller timber as public (primarily federal) timber sales declined. Red alder prices, however, increased steadily as both domestic and international (particularly Asian) markets expanded. In the past 5 years (i.e., since 2000), prices for alder sawlogs have commonly equaled or surpassed those for No. 2 and 3 Douglas-fir sawlogs.

In 1983, Bob Tarrant, Bernard Bormann, Bill Atkinson and I collaborated on a paper in the *Journal of Forestry* (Tarrant et al. 1983). We thought it timely to examine some options for managing red alder in the Douglas-fir region. We concluded that only small changes in then current costs, prices, and yields would make red alder management financially attractive. Crop rotation of alder and Douglas-fir and continuous rotations of sawlog alder appeared to be economically viable alternatives to continuous cropping of Douglas-fir.

A comprehensive bibliography of literature on red alder was issued by the Pacific Northwest Station (Heebner and Bergener 1983). It listed 661 documents, the vast majority with abstracts.

Throughout the eighties, the Department of Energy Short Rotation Woody Crops Program funded a great deal of research on biology and culture of red alder at the Pacific Northwest Station's Olympia Forestry Sciences Laboratory (fig. 10). Studies included tree nutrition and fertilization (DeBell et al. 1983, DeBell and Radwan 1984, Radwan et al. 1984, Radwan 1987, Radwan and DeBell 1994), initial spacing (DeBell and Giordano 1994, DeBell and Harrington 2002, Hurd and DeBell 2001), genetic variation (Ager 1987, Hook et al. 1987, 1991, Lester and DeBell 1989), stump sprouting (Harrington 1984, DeBell and Turpin 1989), seed germination (Radwan and DeBell 1981), vegetative propagation (Radwan et al. 1989), and seedling production (Radwan et al. 1992). Much of this work involved collaboration with other organizations, and it furthered the general state of scientific knowledge on the various topics.

Figure 10—A dense planting of red alder established as part of the U.S. Department of Energy's Short Rotation Woody Crops Program.

Findings from the research on stump sprouting indicated that red alder was not a good candidate for the coppice systems of management then advocated for energy plantations, but the basic understanding of factors affecting sprouting (Harrington 1984) led to development of effective guidelines for controlling alder by cutting in young conifer stands (DeBell and Turpin 1989). This approach was economically feasible and could be applied selectively within stands; it was also more socially acceptable than herbicide applications and became the routine practice for alder control on federal lands. The work of greatest immediate practical importance, however, provided methods to evaluate site quality for growing alder and was done by Connie Harrington (Harrington 1986). She and Bob Curtis also developed new height growth and site curves for red alder (Harrington and Curtis 1986); the index age used was 20 years total age (rather than 50 years as commonly used for most tree species) in recognition of the short rotations anticipated for the species.

In 1983, Oregon State University added a hardwood silviculturist to their faculty in the person of David Hibbs. A few years later, a research cooperative focused on alder silviculture was formed. This Hardwood Silviculture Cooperative (HSC) is led by Hibbs and involves cooperators from several industrial organizations, public agencies, and academic institutions. Decisions were made early on to concentrate on stand density management, and cooperators became involved in establishing plots in natural stands and also in establishing plantations at a range of densities (fig. 11). The HSC has installed 26 research plantations located from Coos Bay, Oregon to Vancouver, British Columbia, covering a wide range of site conditions. Each plantation contains blocks planted at four different spacings (100 to 1200 trees per acre), and each spacing block has several thinning and pruning treatments. Data from this endeavor will provide essential information for intensive management of red alder. Hibbs and his colleagues also studied some natural alder stands and existing plots to produce several publications on self-thinning guidelines, response to thinning, and stand development (Hibbs and Carlton 1989, Hibbs et al. 1989, 1995, Puettmann et al. 1992, 1993a). In addition, the cooperative published useful state-of-the-art publications on such matters as seed collection, handling and storage (Hibbs and Ager 1989), guidelines for regeneration (Ahrens et al. 1992), and stand density management (Puettmann et al. 1993b). More recent work of the cooperative is discussed in other papers contained in this volume.

In 1980, Weyerhaeuser Company acquired Northwest Hardwoods, Inc., a major producer of solid wood products from red alder. By the mid- to late-1980s, concerns about future log supply for these hardwood mills led to an interest in growing red alder on some of the company's land. Over the next decade, tens of thousands of acres of alder plantations were established on some of the highest site quality land for Douglas-fir in southwest Washington.

A third symposium on red alder was held in 1992 at Oregon State University on biology and management (Hibbs et al. 1994). The 1992 symposium brought together existing knowledge on many scientific and practical matters, and was attended by both scientists and managers. At that time, many shifts were developing in forestry and in the forest products economy throughout the Pacific Northwest.

Figure 11—A recently thinned stand density installation for red alder near Cascade Head on the Oregon coast.

In the years since, significant changes have occurred in land ownership (particularly industrial), mills, markets, and government and corporate policies. Issues related to riparian areas and various wildlife species have become more and more important and portend to be very influential in future alder management. On some sites, the influences are restrictive and may hamper harvest and subsequent investments in regeneration and management. In other situations, however, a recognition of the unique habitat provided for songbirds and other wildlife and beneficial effects on productivity and diversity of riparian sites may stimulate greater interest in managing red alder on some ownerships. These matters were addressed in the recent (fourth) symposium and are documented in other papers in this volume.

Figure 12—Red alder plantations have been established on industrial land having high productivity for Douglas-fir.

Concluding Thoughts

Over the past century, there has been a gradual but sustained effort to learn more about red alder and to develop an effective approach to its management and use. Much more so than we would expect for a species that early on was deemed undesirable and targeted for eradication. In recent years, a major turnabout in the status of alder in the forest management community and forest products industry has occurred (fig. 12).

I believe several factors have contributed significantly to this change:

1. Red alder possesses traits that are both valuable and uncommon. These include: rapid early growth, wood properties that are desirable and uniform, ability to fix nitrogen, and the provision of habitat features associated with hardwood trees in a region dominated by conifers.
2. Over the years, an adequate body of information to guide management was accumulated. This came about because several individual forest managers and scientists developed a personal interest in the species. These individuals carried out modest trials that were supported by their supervisors and employers, even though such work was a bit outside the main mission of their respective organizations. In the past two decades, research efforts on alder were accelerated through support from the Department of Energy's Short Rotation Woody Crops Program and formation of the Hardwood Silviculture Cooperative.
3. There has been a continual increase in value of red alder logs relative to logs of Douglas-fir and other conifer species.
4. The unique contribution of alder to the conifer-dominated forest ecosystem of the Pacific Northwest in terms of soil improvement, wildlife habitat and riparian productivity has been recognized and more fully appreciated.

Had it not been for the species' valuable intrinsic properties, the interest by—and encouragement and support of—individual foresters and scientists in its management, improvements in its relative economic value, and recognition of the other benefits it provides to the forest ecosystem, it seems unlikely that red alder would have achieved its present status in forest management and utilization.

The history of alder also provides us with a compelling example of the dynamic nature of forest resource management (including production forestry) and the extent to which attitudes and values can change—even within one rotation of a fast-growing timber species or within one professional career. This history challenges our natural tendency to think that certain components or processes in our forests are entirely good or entirely bad, or to focus on one way to manage them—whether choices and decisions involve tree species, silvicultural practices, or management policies.

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Literature Cited

Ager, A.A. 1987. Genetic variation in red alder in relation to climate and geography of the Pacific Northwest. Ph.D thesis. Seattle, WA: College of Forest Resources, University of Washington.

Ahrens, G.R.; Dobkowski, A.; Hibbs, D.E. 1992. Red alder: guidelines for successful regeneration. Special Publication 24. Corvallis, OR: Forest Research Laboratory, Oregon State University.

Atkinson, W.A.; Bormann, B.T.; DeBell, D.S. 1979. Crop rotation of Douglas-fir and red alder: a preliminary biological and economic assessment. Botanical Gazette 140(Suppl.): S102-S107.

Berntsen, C.M. 1958. A look at red alder--pure, and in mixture with conifers. In: Proceedings, Society of American Foresters National Convention, Salt Lake City, UT. Society of American Foresters Proceedings 1958: 157-158.

Berntsen, C.M. 1961a. Growth and development of red alder compared with conifers in 30-year-old stands. Res. Pap. 38. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 20 p.

Berntsen, C.M. 1961b. Pruning and epicormic branching in red alder. Journal of Forestry 59(9): 675-676.

Berntsen, C.M. 1962. A 20-year growth record for three stands of red alder. Res. Note 219. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 9 p.

Bishop, D.M.; Johnson, F.A.; Staebler, G.R. 1958. Site curves for red alder. Res. Note 162. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 7 p.

Bollen, W.B.; Chen, C.-S.; Lu, K.C.; Tarrant, R.F. 1967. Influence of red alder on fertility of a forest soil - microbial and chemical effects. Res. Bulle. 12. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 61 p.

Bond, G. 1954. Evidence for fixation of nitrogen by root nodules of alder under field conditions. New Phytology. 55 (2): 147-153.

Bongard, H.G. 1833. Observations sur la vegetation de l'ile de Sitcha. Akad. Sci. St. Petersb. Mem. Sci. Math. Phys. Nat. Ser. 6 II: 119-177.

Botkin, D.B. 1990. Discordant harmonies–a new ecology for the twenty-first century. New York: Oxford University Press. 241 p.

Briggs, D.G.; DeBell, D.S.; Atkinson, W.A. (compilers). 1978. Utilization and management of alder. PNW-GTR-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 379 p.

Burns, J.A. 1971. Unpublished letter to P.A. Briegleb, PNW Station Director, on Station Paper PNW-88, "The Economics of Converting Red Alder to Douglas-fir".

Cotta, H. 2000. Cotta's Preface. (Reprinted from Forestry Quarterly, Volume 1, 1902-1903; originally written at Tharandt, Germany, December 21, 1816) Forest History Today, Fall 2000: 27-28.

Crocker, R.L.; Major, J. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. Journal of Ecology 43: 427-448.

DeBell, D.S. 1975. Short-rotation culture of hardwoods in the Pacific Northwest. Iowa State Journal of Research 49(3): 345-352.

DeBell, D.S.; Radwan, M.A. 1979. Growth and nitrogen relations of coppiced black cottonwood and red alder in pure and mixed plantings. Botanical Gazette 140(Suppl.): S97-S101.

DeBell, D.S.; Radwan, M.A.; Kraft, J.M. 1983. Influence of red alder on chemical properties of a clay loam soil in western Washington. Res. Pap. PNW-RP-313. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 19 p.

DeBell, D.S.; Radwan, M.A. 1984. Foliar chemical concentrations in red alder stands of various ages. Plant and Soil 77: 391-394.

DeBell, D.S.; Turpin, T.C. 1989. Control of red alder by cutting. Res. Paper PNW-RP-414. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 10 p.

DeBell, D.S.; Giordano, P.A. 1994. Growth patterns of red alder. In: Hibbs, D.E.; DeBell, D.S.; Tarrant, R.F., eds. Biology and managment of red alder. Corvallis, OR: Oregon State University Press: 116-130.

DeBell, D.S.; Harrington, C.A. 2002. Density and rectangularity of planting influence 20-year growth and development of red alder. Canadian Journal of Forest Research 32: 1244-1253.

Dimock, E.J., II; Bell, E.; Randall, R.M. 1976. Converting brush and hardwood to conifers on high sites in western Washington and Oregon--progress, policy, success and costs. Res. Pap. PNW-213. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 16 p.

Douglas, D. 1959. Journal kept by David Douglas during his travels in North America, 1823-1827. New York: Antiquarian Press, Ltd.

Evans, R.S. 1974. Energy plantations: should we grow trees for power plant fuel? Inf. Rep. VP-X-129. Victoria, BC. Western Forest Products Laboratory. 15 p.

Finnis, J.M. 1964. Chemical frill treatment of alder. Research Progress Report. Western Weed Control Conference: 47.

Franklin, J.F.; Dyrness, C.T.; Moore, D.G.; Tarrant, R.F. 1968. Chemical soil properties under coastal Oregon stands of alders and conifers. In: Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M., eds. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 157-172.

Gordon, J.C.; Wheeler, C.T.; Perry, D.A. 1979. Symbiotic nitrogen fixation in the management of temperate forests. Corvallis, OR: Oregon State University Press.

Gorsline, J. 1992. Rainshadow–Archibald Menzies and the botanical exploration of the Olympic Peninsula. Port Townsend, WA: Jefferson County Historical Society. 63 p.

Graves, H.S. 1912. Red alder. Alnus oregona Nutt. Silvical Leaflet No. 53. Washington, DC. U.S. Department of Agriculture, Forest Service. 4 p.

Grondal, B.L. 1918. Seattle shoe factory utilizes red alder. West Coast Lumberman. May: 21, 32.

Gunther, E. 1973. Ethnobotany of western Washington–the knowledge and use of indigenous plants by native Americans. Seattle, WA University of Washington Press. 71 p.

Haddock, P.G. 1949. A problem child reforms - new perspectives in the management of red alder. Forest Club Quarterly 22(2): 9-15.

Hall, D.A. 1976. Trees of conflict. Corvallis, OR: Corvallis Gazette-Times August 4: 25-26.

Hansen, E.M. 1979. Survival of *Phellinus weirii* in Douglas-fir stumps after logging. Canadian Journal of Forest Research 9: 484-488.

Harrington, C.A.; DeBell, D.S.; Strand, R.F. 1979. An experiment in biomass production: results from three consecutive harvests of cottonwood and alder. In: Proceedings: Solar '79 Northwest. Seattle, WA: 363-366.

Harrington, C.A. 1984. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research 14(3): 357-361.

Harrington, C.A. 1986. A method of site quality evaluation for red alder. Gen. Tech. Rep. PNW-192. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Harrington, C.A.; Curtis, R.O. 1986. Height growth and site index curves for red alder. Res. Pap. PNW-358. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Heebner, C.F.; Bergener, M.J. (compilers) 1983. Red alder: a bibliography with abstracts. PNW-GTR-161. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 186 p.

Hetherington, J.C. 1964. Brush control in coastal British Columbia. Res. Note 38. Vancouver, BC: British Columbia Forest Service. 56 p.

Heilman, P.E.; Peabody, D.V., Jr.; DeBell, D.S.; Strand, R.F. 1972. A test of close-spaced, short-rotation culture of black cottonwood in the Pacific Northwest. Canadian Journal of Forest Research 1: 456-459.

Hibbs, D.E.; Ager, A.A. 1989. Red alder: guidelines for seed collection, handling, and storage. Special Publication 18. Corvallis, OR: Forest Research Laboratory, Oregon State University.

Hibbs, D.E.; Carlton, G.C. 1989. A comparison of diameter- and volume-based stocking guides for red alder. Western Journal of Applied Forestry 44(4): 113-115.

Hibbs, D.E.; Emmingham, W.H.; Bondi, M.C. 1989. Thinning red alder: effects of method and spacing. Forest Science 35: 16-29.

Hibbs, D.E.; Emmingham, W.H.; Bondi, M.C. 1995. Responses of red alder to thinning. Western Journal of Applied Forestry 10(1): 17-23.

Hibbs, D.E.; DeBell, D.S.; Tarrant, R.F., eds. 1994. The biology and management of red alder. Corvallis, OR: Oregon State University Press. 256 p.

Hook, D.D.; Murray, M.D.; DeBell, D.S.; Wilson, B.C. 1987. Variation in growth of red alder families in relation to shallow water table levels. Forest Science 33(1): 224-229.

Hook, D.D.; DeBell, D.S.; Ager, A.; Johnson, D. 1991. Dry weight partitioning among 36 open-pollinated red alder families. Biomass 21: 11-25.

Hurd, P.D.; DeBell, D.S. 2001. Growth and early stand development of intensively cultured red alder plantings. New Forests 21: 71-87.

Johnson, F.A. 1955. Volume tables for Pacific Northwest trees (a compilation). Agric. Handb. 92. U.S. Department of Agriculture. 112 p.

Johnson, H.M. 1917. Alnus oregona: its value as a forest type on the Siuslaw National Forest. Journal of Forestry 15(8): 981-987.

Johnson, H.M.; Hanzlik, E.J.; Gibbons, W.H. 1926. Red alder of the Pacific Northwest: its utilization, with notes on growth and management. Department Bulletin. No. 1437. Washington, DC: U.S. Department of Agriculture. 46 p.

Kellogg, A. 1882. Forest Trees of California. Sacramento, CA: State Mining Bureau. 148 p.

Koss, W.; Scott, B.D. 1977. Alder or conifer? Ask an economist? DNR Note No. 20. Olympia, WA: Department of Natural Resources, State of Washington. 2 p.

Lawrence, D.B. 1958. Glaciers and vegetation in southeastern Alaska. Ameri. Science 46: 89-122.

Lester, D.T., DeBell, D.S. 1989. Geographic variation in red alder. Res. Paper PNW-RP-409. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 8 p.

Li, C.Y. 1969. Biological influence of red alder on Poria weirii and other root rot pathogens. PhD thesis. Corvallis, OR: Oregon State University. 94 p.

Lloyd, W.J. 1949. Results of thinning a young alder stand. Pacific Reg. Tech. Note 8. Portland, OR: U.S. Department Agriculture, Soil Conservation Service. 2 p.

Lloyd, W.J. 1956. Red alder yield tables. Unpublished document. U.S. Department of Agriculture Soil Conservation Service, Seattle, WA.

Madison, R.W.; Ruth, R.H. 1962. Basal spraying of red alder. Weeds 10(4): 324-325.

McAlpine, R.G.; Brown, C.L.; Herrick, A.M.; Ruark, H.E. 1966. "Silage" sycamore. Forest Farmer 26 (1): 6-7, 16.

Miller, R.E.; Murray, M.D. 1978. The effects of red alder on growth of Douglas-fir. In: Briggs, D.G.; DeBell, D.S.; Atkinson, W.A., comps. Utilization and Management of Alder. Gen. Tech. Rep. PNW-GTR-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station: 283-306.

Morrison, V.L. 1949. Keeping roads alder free by the use of chemical sprays. British Columbia Lumberman 33(1): 108-110.

Munger, T.T. 1938. Red alder long considered but a weed tree, now an important raw material for west coast woodworkers. Hardwood Record: March.

Neal, J.L., Jr.; Lu, K.C.; Bollen, W.B.; Trappe, J.M. 1968. A comparison of rhizosphere microfloras associated with mycorrhizae of red alder and Douglas-fir. In: Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M., eds. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 57-71.

Neal, J.L., Jr.; Trappe, J.M.; Lu, K.C.; Bollen, W.B. 1968. Some ecotrophic mycorrhizae of Alnus rubra. In: Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M., eds. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 179-184.

Nelson, E.E. 1968. Survival of Poria weirii in conifer, alder, and mixed conifer-alder stands. Res. Note PNW-83. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 5 p.

Nelson, E.E.; Hansen, E.M.; Li, C.Y.; Trappe, J.M. 1978. The role of red alder in reducing losses from laminated root rot. In: Briggs, D.G.; DeBell, D.S.; Atkinson, W.A., comps. Utilization and management of alder. Gen. Tech. Rep. PNW-GTR-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station: 273-282.

Newton, M. 1966. New injection system for killing or curing trees. (Abstract). Meeting of the Weed Society of America 1966: 30-31.

Nuttall, T. 1842. The North American sylva; or, a description of the forest trees of the United States, Canada, and Nova Scotia, not described in the work of F. Andrew Michaux, and containing all the forest trees discovered in the Rocky Mountains, the territory of Oregon, down to the shores of the Pacific, and into the confines of California, as well as in various parts of the United States. Vol. 1: 41-46. Philadelphia, PA, D. Rice and A.N. Hart.

Prevette, T. 1975. Growing alder—how and how long. Forest Products Utilization and Marketing Bulletin. Department of Natural Resources, State of Washington July: 1, 3.

Prevette, T. 1976. Growing alder—a commercial species. Forest Products Utilization and Marketing Bulletin. Department of Natural Resources, State of Washington January: 1, 3-4.

Puettmann, K.J.; Hann, D.W.; Hibbs, D.E. 1992. Extending the size-density analysis to mixed species populations and investigation of underlying dynamics using red alder and Douglas-fir stands. Journal of Ecology 80: 448-459.

__1993a. Development and comparison of the size-density trajectories for red alder and Douglas-fir stands. Forest Science 39: 7-27.

Puettman, K.J.; DeBell, D.S.; Hibbs, D.E. 1993b. Density management guide for red alder. Research Contribution No. 2. Corvallis, OR: Forest Research Laboratory, Oregon State University. 6 p.

Radwan, M.A.; DeBell, D.S. 1981. Germination of red alder seed. Res. Note PNW-RN-370. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Radwan, M.A.; Harrington, C.A. Kraft, J.M. 1984. Litterfall and nutrient returns in red alder stands in western Washington. Plant and Soil 79: 343-351.

Radwan, M.A. 1987. Effects of fertilization on growth and foliar nutrients of red alder seedlings. Res. Pap. PNW-375. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Radwan, M.A.; Max, T.A.; Johnson, D.W. 1989. Softwood cuttings for propagation of red alder. New Forests 3: 21-30.

Radwan, M.A.; Tanaka, Y.; Dobkowski, A.; Fangan, W. 1992. Production and assessment of red alder planting stock. Res. Pap. PNW-450. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Radwan, M.A.; DeBell, D.S. 1994. Fertilization and nutrition of red alder. Chapter 15. In: Hibbs, D.E.; DeBell, D.S.; Tarrant, R.F., eds. Biology and managment of red alder. Corvallis, OR: Oregon State University Press: 216-228.

Ranney, J.W.; Wright, L.L.; Layton P.A. 1987. Hardwood energy crops: the technology of intensive culture. Journal of Forestry 85 (9): 17-28.

Rapraeger, H. A. 1949. Pruning and thinning of red alder. Unpublished office report dated December 6, 1949 and on file at Olympia Forestry Sciences Laboratory. 7 p., including tables.

Robinson, D.D. 1948. Utilization of Oregon hardwoods. Inf. Circ. 2. Corvallis, OR: Oregon Forest Products Laboratory. 22 p.

Ruth, R. 1956. Plantation survival and growth in two brush-treatment areas in coastal Oregon. Res. Pap. No. 17. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Ruth, R.H.; Berntsen, C.M. 1956. Chemical basal treatment to control red alder. Res. Note No. 128. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station 6 p.

Ruth, R.H. 1957. Ten-year history of an Oregon coastal plantation. Res. Pap. No. 21. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Skinner, E.C. 1959. Cubic volume tables for red alder and Sitka spruce. Res. Note No. 170. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Smith, J.H.G.; DeBell, D.S. 1973. Opportunities for short-rotation culture and complete utilization of seven Northwestern tree species. Forest Chronicle 49:31-34.

Sorensen, D.J. 1973. Alder mill operators angered by waste. Portland, OR: The Oregonian, May 2.

Sorensen, D.J. 1973. Alder shortage blamed on mismanagement. Portland, OR: The Oregonian, May 3.

Staebler, G.R. 1960. Basal injection of 2,4,5-T fails to kill red alder and bigleaf maple. Res. Note. Weyerhaeuser Company.

Starker, T.J. 1939. A new alder. Journal of Forestry 37(5): 415-417.

Stewart, R.E. 1974a. Foliage sprays for site preparation and release from six coastal brush species. Res. Pap. PNW-172. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 18 p.

Stewart, R.E. 1974b. Budbreak sprays for site preparation and release from six coastal brush species. Res. Pap. PNW-176. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 20 p.

Sudworth, G.B. 1908. Forest Trees of the Pacific Slope. Washington, DC: U.S. Department of Agriculture, Forest Service. Government Printing Office. 441 p.

Tarrant, R.F.; Isaac, L.A.; Chandler, R.F., Jr. 1951. Observations on litter fall and foliage nutrient content of some Pacific Northwest tree species. Journal of Forestry 49(12): 914-915.

Tarrant, R.F. 1961. Stand development and soil fertility in a Douglas-fir - red alder plantation. Forest Science 7(3): 238-246.

Tarrant, R.F.; Miller, R.E. 1963. Accumulation of organic matter and soil nitrogen beneath a plantation of red alder and Douglas-fir. Soil Science Society of America, Proceedings 27(2): 231-234.

Tarrant, R.F. 1964. Forest soil improvement through growing red alder (*Alnus rubra* Bong.) in Pacific Northwestern United States. Eighth International Congress Soil Science Transaction V: 1029-1043.

Tarrant, R.F.; Bormann, B.T.; DeBell, D.S.; Atkinson, W.A. 1983. Managing red alder in the Douglas-fir region: some possibilities. Journal of Forestry 81:787-792.

Thwaites, R.G. 1905 [reprinted 1959]. Original Journals of the Lewis and Clark Expedition. 8 volumes. Antiquarian Press, New York.

Trappe, J.M. 1972. Regulation of soil organisms by red alder: a potential biological system for control of Poria weirii. Berg, A.B. ed. Managing young forests in the Douglas-fir region, Vol. 3. Corvallis, OR: Oregon State University, School of Forestry: 35-51.

Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M. eds. 1968. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Turner, N.J.; Thompson, L.C.; Thompson, M.T.; York, A.Z. 1990. Thompson ethnobotany – knowledge and usage of plants by the Thompson Indians of British Columbia. Royal British Columbia Museum Memoir No. 3. 335p.

Voorhies, G. 1944. The essentials of kiln drying Oregon hardwood lumber. Res. Leaflet 2. Corvallis, OR: Oregon Forest Products Laboratory. 17 p.

Wallis, G. 1968. Resistance of Alnus rubra to infection by the root rot fungus Poria weirii. In: Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M. eds. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 195 p.

Warrack, G. 1949. Treatment of red alder in the coastal region of British Columbia. Res. Note 14. Victoria, BC: British Columbia Forest Service. 7 p.

Warrack, G.C. 1964. Thinning effects in red alder. Victoria, BC: British Columbia Forest Service, Victoria Research Division. 8 p.

Washington State University Extension Service. 1964. Growing red alder for profit. Pullman, WA: Washington State University. 6 p.

Whitford, H.N.; Craig, R.D. 1918. Forests of British Columbia. Committee on Forests, Ottawa, Canada: Commission of Conservation.

Worthington, N.P.; Johnson, F.A.; Staebler, G. R.; Lloyd W.J. 1960. Normal yield tables for red alder. Res. Pap. No. 36. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 p.

Worthington, N.P.; Ruth, R.H.; Matson, E.E. 1962. Red alder—its management and utilization. Misc. Publ. 881. Washington, DC: U.S. Department of Agriculture, Forest Service. 44 p.

Yoho, J.G.; Chappelle, D.E.; Schweitzer, D.L. 1969. The economics of converting red alder to Douglas-fir. PNW-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 31 p.

__1969. The marketing of red alder pulpwood and saw logs. Res. Note PNW-96. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 7 p.


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