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UTILIZATION AND MANAGEMENT OF ALDER

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COVER PHOTO: A stand of red alder at Cascade Head Experimental Forest near Otis, Oregon. The trees are from 14 to 20 inches in diameter. *(U.S. Forest Service photo 325534)*

USDA Forest Service General Technical Report PNW-70

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UTILIZATION AND MANAGEMENT OF ALDER

Proceedings of a Symposium
sponsored by

University of Washington, College of Forest Resources,
Northwest Hardwood Association,
Pacific Northwest Forest and Range Experiment Station,
Forest Service, U.S. Department of Agriculture,
and
State of Washington Department of Natural Resources

held at
Ocean Shores, Washington
April 25-27, 1977

Compilers
David G. Briggs
Dean S. DeBell
William A. Atkinson

Published in 1978 by
Pacific Northwest Forest and Range Experiment Station
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Portland, Oregon

PREFACE

In the Pacific Northwest and British Columbia, red alder often grows on forest lands following natural or man-caused disturbances. Frequently ignored as a pest or weed, many alder stands have developed to the point where important utilization and management questions are being asked. It is recognized that alder is a fast growing species, and that its rapid early growth may hinder growth of conifers associated with it. It is also recognized that alder has the capability of improving soil fertility, and that it may help reduce root rot problems of conifers. These attributes pose new questions as to whether or not alder should be deliberately managed and, if so, how it should be managed and utilized.

To satisfy this need for information on utilization and management of alder, the University of Washington, College of Forest Resources, the Northwest Hardwood Association, the Pacific Northwest Forest and Range Experiment Station of the U.S. Forest Service, and the State of Washington Department of Natural Resources sponsored a 3-day conference at Ocean Shores, Washington, on April 25, 26, 27, 1977. Speakers from throughout the region covered all aspects of alder utilization and management, while speakers from eastern and southern hardwood areas provided broader perspectives on hardwoods in general. The conference examined questions such as whether alder should be considered a weed problem to be utilized and eliminated in favor of conifers, or whether it should have a long-term role in regional timber supplies.

Papers on all but three of the topics discussed at the Alder Conference are included in these proceedings. Abstracts prepared for the remaining three topics are also included. Thus, this document can serve as a comprehensive, state-of-the-art summary on utilization and management of red alder. It can also be used to assess information needs and determine priorities for future research.

Because hard data on red alder are very limited, the compilers wanted to capture the experience and observations of people working with the species. We also encouraged speculation regarding future supplies, markets, and management. To be consistent with such intent we have exercised very little technical censorship in compiling the proceedings. The authors are responsible for technical content and presentation of their respective papers.

ACKNOWLEDGMENTS

It would be impossible to express our appreciation to all the individuals and organizations that contributed to the success of this conference and the compilation of papers contained in this volume. There are several, however, who deserve special mention.

The initial concept for the conference began as a result of increasing inquiries for information on alder from foresters, researchers, and alder manufacturers. In the fall of 1976, a planning committee was established which refined the general conference concept into a well-defined program and recruited many of the speakers. The planning committee consisted of:

Dr. William Atkinson	College of Forest Resources University of Washington, Seattle
Mr. Sandy Bremner	Export Pacific Inc. Tacoma, WA
Mr. David Briggs	College of Forest Resources University of Washington, Seattle
Dr. Dean DeBell	Pacific Northwest Forest and Range Experiment Station Forestry Sciences Laboratory, Olympia, WA
Mr. Donald Hopkins	Department of Natural Resources State of Washington, Olympia
Prof. Reid Kenady	College of Forest Resources University of Washington, Seattle
Dr. Chadwick Oliver	College of Forest Resources University of Washington, Seattle
Mr. Thomas Prevette	Northwest Hardwoods, Inc. Arlington, WA
Dr. Bruce Rottink	Central Research Division Crown Zellerbach Corp. Camas, WA
Dr. Robert Strand	Central Research Division Crown Zellerbach Corp. Camas, WA
Dr. Jack Winjum	Centralia Forest Research Center Weyerhaeuser Company, WA

The efforts of this committee and the commitments of individual authors in devoting time and effort for this conference resulted in an excellent program. The moderators: Mr. Donald Hopkins, Washington Department of Natural Resources, Mr. Thomas Prevette of Northwest Hardwoods, Inc., and Dr. Robert Romancier of the Pacific Northwest Forest and Range Experiment Station did a most appreciated job of running the program and keeping to the time schedule.

Ms. Pat Davis of the College of Forest Resources was responsible for overall coordination and accommodations.

We wish to acknowledge the contribution of the Editing and Publication Group of the Pacific Northwest Forest and Range Experiment Station.

D. G. Briggs
D. S. DeBell
W. A. Atkinson

CONTENTS

INTRODUCTION

Page

Attitudes Toward Red Alder in the Douglas-fir Region
Robert F. Tarrant 1

Supply of Western Alder Stumpage, Its Quantity and Quality, 1976-1996 and Trends in Alder Stumpage and Product Markets
Gene R. Little 9

Properties of Red Alder (*Alnus rubra* Bong.) and Its Comparison to Other Hardwoods
L. Leney, A. Jackson, and H. D. Erickson 25

An Approach for Comparing the Relative Value of Alder With Other Species From Forest to End Product
David G. Briggs, James S. Bethel, and Gerard F. Schreuder 35

Alder Research Outside the Northwest: a Brief Overview
John C. Gordon and Richard B. Hall. 47

Hardwood Culture in the Eastern United States
R. L. Johnson 55

UTILIZATION

Harvesting of Red Alder
Edward T. Feddern 61

Alder Characteristics as They Affect Utilization
Toby Atterbury 71

Buyer's Perspective on Public Agency Timber Sale Procedures for Alder
Paul Barber, Marvin Noble, and Juel Sheldon 83

A Comparison of Lumber Grading Rules for Alder and Competing Species
Calvin G. Fye and David G. Briggs 85

Stabilizing Color and Drying Red Alder
Charles J. Kozlik 93

Alder--Should We Chip It or Saw It?
Rod L. Remington 103

Trends and Technologies in Southern Hardwood Sawmills
Fred J. Hill. 111

New Approaches to Producing Furniture Components from Hardwood Lumber
Sandy Mullin 123

Page

Alder: One of Tomorrow's Important Structural Raw Materials?
T. M. Maloney 125

Alder as a Wood for Veneer and Plywood
Harry McGuane 133

Red Alder as a Pulpwood Species
B. F. Hrutfiord 135

Red Alder as a Potential Source of Energy
Nicholas J. Smith 139

Developing New Alder Markets
R. D. Behm 157

The Potential for Integrated Utilization of Alder
David G. Briggs and James S. Bethel 163

MANAGEMENT

A Comparison of Red Alder, Douglas-fir, and Western Hemlock Productivities as Related to Site--A Panel Discussion
Gerald Hoyer, Walter Fergerson, Michael Newton, and David R. M. Scott 175

Regeneration of Red Alder
Reid M. Kenady 183

Natural Variation in Red Alder
Dean S. DeBell and Boyd C. Wilson 193

Biological Aspects of Red Alder Pertinent to Potential Breeding Programs
Reinhard F. Stettler 209

Herbicides in Alder Management and Control
Michael Newton 223

Short-Rotation Production of Red Alder: Some Options for Future Forest Management
Dean S. DeBell, Robert F. Strand, and Donald L. Reukema 231

Growth and Yield of Red Alder: Effects of Spacing and Thinning
J. Harry G. Smith 245

Insect Pests of Red Alder: Potential Problems
R. I. Gara and L. L. Jaeck 265

Red Alder Management and Diseases
Charles H. Driver 271

The Role of Red Alder in Reducing Losses From Laminated Root Rot
E. E. Nelson, E. M. Hansen, C. Y. Li, and J. M. Trappe 273

The Effects of Red Alder on Growth of Douglas-fir
Richard E. Miller and Marshall D. Murray 283

Page

Silvicultural Implications of the Reconstruction of Mixed Alder/Conifer Stands
George Stubblefield and Chadwick D. Oliver 307

Biological Components of Alder Yield Improvement
John C. Gordon 321

Comparative Mineral Cycling in Red Alder and Douglas-fir
Dale W. Cole, S. P. Gessel, and John Turner 327

The Value of Red Alder as a Source of Nitrogen in Douglas-fir/Alder Mixed Stands
William A. Atkinson and Willard I. Hamilton 337

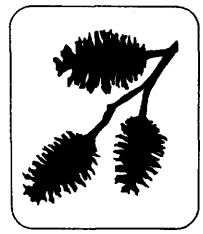
Techniques and Costs of Converting Hardwood Stands to Conifers
Robert M. Randall 353

Should Alder Be Replaced by Conifers?
Thomas R. Waggener 365

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ATTITUDES TOWARD RED ALDER IN THE DOUGLAS-FIR REGION



ROBERT F. TARRANT, Director
Pacific Northwest Forest and Range Experiment Station
USDA Forest Service
Portland, Oregon

ABSTRACT

A positive change in attitudes toward purposeful management of red alder is increasingly evident. Reasons for this change include critical problems of wood fiber supply and increasing costs of fertilizer materials. Several possibilities for exploiting red alder in forest management programs are discussed in light of its rapid early growth rate and ability to improve soil fertility. Additional research must be done, both in the physical and biological sciences if we are to capture the unique attributes of red alder in improved forest management systems. Red alder must be considered a tree of high potential value in a mature forest economy.

For the past 30 years, I have been particularly interested in the beneficial aspects of red alder, a fast-growing hardwood that inhabits streambanks and bottom lands in the Douglas-fir region. This species often invades forest sites following fire or old logging roads and other disturbed sites. My enthusiasm about this hardwood is not always shared by practicing foresters whose goal is to maximize timber production, and whose concern often is to keep alder from hindering the growth of Douglas-fir plantations. I would like to talk about how these two diverse viewpoints can come together and how the role of the forester in managing Douglas-fir must be based on a sound understanding of the ecosystems involved. If I can reminisce a bit about the development of my own attitude toward this most interesting hardwood, it may help set the framework for this conference.

My interest began with observations about the growth of alder and fir and the relationships of soils to tree growth. In 1948, I was making a soil reconnaissance in the Wind River Experimental Forest in southwest Washington, an area in the Yacolt Burn of 1927. It was a hot day and I had spent most of it working upslope and downslope through a nondescript, yellow-foliaged Douglas-fir plantation. Near the west boundary of the forest and about 4 miles from the nearest road, I came upon a shady plantation of red alder mixed with Douglas-fir in a 5- by 5-foot spacing.

Perhaps because the day was hot and the mixed forest was unusually cool, I stayed there longer than I might have otherwise. I spent several hours

wandering through the plantation and observing its unique characteristics. First, it was probably several degrees cooler than the surrounding Douglas-fir plantation. In addition, the foliage of the Douglas-fir in the mixed plantation was exceptionally dark green. The needles were more abundant and larger than those on trees in the Douglas-fir plantation. And the surface of the forest floor was entirely different.

When I returned to the office, I asked the pioneer Douglas-fir silviculturist, Leo Isaac, about the history of this plantation. He told me that after the fire--one of the region's worst--tree planting crews worked in the cold in March 1929 to reestablish the forest. He recalled that, during a lunchbreak around a warming fire, one of the planters said that if there had been a stand of alder on that ridge he'd have bet $5 the fire would have stopped right there. Intrigued by the ensuing argument, Isaac obtained some alder seed and arranged to have it grown in the Wind River Nursery.

By the time the alder seedlings were ready to plant, however, planted Douglas-fir seedlings were already growing at the planting site. As it turned out, the delay in planting the alder was serendipitous. First, planting the alder 4 years after the Douglas-fir enabled the slower growing fir to compete on an equal basis. Second, the alder seed had been collected at sea level, but the resulting seedlings were planted at an elevation of about 2,000 feet. As a result, frost killed the alder back to its root crowns each of the next two winters, again helping the Douglas-fir keep pace with the alder.

When I first saw the plantation in 1948, it was 19 years old in a remote part of the Experimental Forest where not many people had been; and aside from Leo Isaac's reminiscences, there was little record of detailed observation. Obviously, few people knew about the plantation, and fewer yet had any idea of the lessons it held for forest managers.

A preliminary study showed some striking differences between Douglas-fir trees in and outside the mixed plantation. Measurements indicated that the alder and fir trees were the same average diameter in the mixed stand, but that dominant Douglas-fir were larger in the mixed stand than in an adjacent pure fir plantation. In addition, the total volume of wood produced in the mixed plantation was more than twice that of the pure Douglas-fir plantation. Other apparent beneficial effects were also noted in the mixed plantation. For example, the form class was higher for fir grown with alder. Total nitrogen content was greater, both in the soil and in the foliage of Douglas-fir. Significant differences were also found in the number and composition of soil bacteria and fungi.

The initial study led to more detailed observations of the influence of red alder on soil properties. After wildfire, the presence of alder substantially increased organic matter and nitrogen in the upper soil horizons. Other researchers joined in pursuing various facets of the soil-improving characteristics of red alder until today we have amassed a

valuable body of information which suggests that this once despised "weed" tree could, in fact, become biologically and economically useful in the Douglas-fir region.

Having used the word "weed" in connection with red alder, I will eliminate it from further use in this context. A weed is a tree or shrub of low economic value that tends to grow freely and exclude or retard more valuable plants. There is no question that red alder grows rapidly, an attribute that leads to its early dominance over other trees. But the fact that alder grows fast and better on some sites than Douglas-fir is not necessarily a disadvantage. In some cases, if the alder is properly managed by foresters, it should be a distinct advantage.

I said earlier that foresters have not always had a positive outlook on red alder. That attitude is longstanding. In the West, conifers have always dominated the landscape. A hundred years ago, settlers making their way West passed through a thousand miles or more of gigantic conifers, the likes of which had not been known in the East. As these pioneers reached the Cascade Range, it must have been most impressive to travel through the shadow of a forest that towered as much as 200 feet above them. Small wonder then that the hardwoods -- bigleaf maple, white oak, madrone, and alder--made little or no impression.

The pioneers cleared the forest where they made their settlements and cut heavily into the stands of huge old-growth Douglas-fir, western hemlock, and Sitka spruce. The hardwoods were always handy to have around--for flooring, spools and spindles, charcoal, and firewood. But these uses were minor compared with the many structural uses of the more valuable conifers. Later, vast acreages of Douglas-fir were logged and left to regrow naturally. Although the conifers are prolific seeders and often regenerate naturally, it was red alder that came back first on many sites. But it was considered a detriment to establishment of Douglas-fir and other conifers. Little happened for many years to change those attitudes.

The fact that this major conference is being held to summarize what we know about alder, however, must indicate increasing recognition of both problems and potential benefits of red alder in intensive forest management. Further, there appears to be concern on the part of the developing hardwood industries that large-scale conversion programs will destroy future sources of raw materials. Both areas of concern appear to me to represent a positive change in attitude toward purposeful management of red alder.

I think there are several reasons for the changed attitude toward red alder. The first has to do with wood fiber supply. It has become increasingly evident that the supply of old-growth softwood timber is dwindling. Despite the fact that vigorous new young stands are replacing the old growth, evidence at hand indicates there may well be a waiting period while these new stands replace the old. Foresters are very conscious now of the need not only to better utilize the softwood resource but also to explore other potential sources of wood fiber.

How does the potential of red alder relate to our concern about softwood timber supply? When we attempt to stretch the wood fiber resource as far as possible, the rapid early growth of red alder becomes of major interest. On some sites, this rapidly growing tree can greatly outproduce Douglas-fir at ages up to about 30 years. These growth rates are for unmanaged, genetically unimproved stock. This attribute of red alder might be exploited not only for obvious uses such as pulp and other reconstituted fiber products but also as a means of capturing solar energy in the form of so-called energy plantations.

Another factor that has probably influenced attitudes toward red alder today is the high cost of fertilizers. Maintenance of soil fertility and soil stability is critical to continued, intensive production of wood fiber. A considerable amount of fertilization of forest stands has been carried out with urea, a product derived from natural gas. The short supply of natural gas and the rapid increase in fertilizer cost raise questions about availability of fertilizer in the future. The potential for using red alder or other nitrogen-fixing plants to complement or replace inorganic fertilizers is generally recognized.

In this connection, red alder as a source of nitrogen offers the availability of a natural alternative to a chemical one: in short, the attractive philosophy of organic gardening versus inorganic gardening.

There is an inherent feeling among many people I talk to that we should be able to utilize a commercial tree species that grows as fast as red alder rather than spend valuable forestry dollars to get rid of it. Yet, the fact remains that in our predominantly softwood timber economy, the value of red alder is today little appreciated.

The alder forest type currently occupies about 15 percent of the commercial forest land base in western Washington and western Oregon (3.5 million of 23.5 million acres). Although alder wood has many favorable qualities, current market conditions do not make it attractive to the landowner. Thus, conversion from alder to the original conifer type is proceeding rapidly on State, Federal, and industrial forest land.

The economic incentives for growing alder could be increased if existing markets could be improved or new products and markets developed. Markets for small-size logs are especially needed, because logs under 8-inch upper stem diameter generally represent more than half the stem volume. Such material returns little, if any, stumpage value to the landowner. There appears to be no united effort committed to an aggressive improvement of red alder markets. As a result, there are few incentives to harness the rapid wood-producing capacity of red alder.

No one can predict with any certainty future demands as to form of forest products. The rapidly increasing population and promise of technological advances seem to argue for greatly increased demand for reconstituted wood fiber products at the expense of solid wood timber products as we now know them.

Radical changes in concepts of forest management will be required in order to take advantage of the more attractive selling points for alder. Professional foresters must take a hard look at preconceived ideas that have developed in a region geared largely to harvesting the bounty of old-growth conifers.

Such innovative concepts are being advanced elsewhere. Pulpwood rotations of 10, 5, or even 2 years are being considered in the southeastern United States. There, sycamore planted at 4- by 4-foot spacing can yield more than 10 tons of green wood per acre annually. Harvesting, which may occur at intervals as short as 2 or 3 years, will be done mechanically. An estimated 350-400 tons of green wood could be harvested over a 30-year period (the usual rotation for pine pulpwood) by cutting and replanting sycamore at 5-year intervals. The growth potential of sycamore is much the same as that of red alder.

Several possibilities for exploiting red alder in an enlightened forest management program are immediately evident. The enhancement of the nitrogen capital of the forest ecosystem is of major consideration under highly intensified forest management. Just as farmers plant legumes to maintain soil nitrogen for agricultural productivity, so might silviculturists use red alder in a crop rotation system. Short rotations high in total cubic volume per acre would offer benefits of mechanical harvesting, short-term investments, reduction of labor costs, and restoring to productive use many thousands of acres such as those now lost to powerline rights-of-way.

Another possibility for using red alder to improve the forest environment is creating mixed plantations of alder and other tree species. Remember the initial illustration of the increased productivity that can be gained by planting Douglas-fir with alder. The Wind River study pointed out that total wood production could be doubled, at least at that site.

On moist sites, red alder grows naturally as a fairly permanent and dominant component of the vegetation. On such sites, red alder is probably the best adapted tree species. Productivity of wood fiber on these and other sites, however, might be increased substantially through admixture of another tree species such as black cottonwood. The mixture of *Alnus* and *Populus* is well documented in the literature as compatible and productive.

These are only a few examples of silvicultural systems that might be employed in a management situation radically different from the one now existing in the Pacific Northwest. We have little experience in red alder management, a factor that contributes strongly to our present lack of appreciation of the potential value of this species for producing wood fiber, maintaining and enhancing soil fertility, and providing other environmental benefits.

As a scientist and research administrator, I see a number of research needs that must be met if we are to bring about serious alder management efforts. These needs for new information fall quite logically into two major areas--one of which calls for research in the physical and social sciences and the other which demands silvicultural research.

A. In existing stands--

1. Develop new, economical equipment and methods for harvesting small material.
2. Improve utilization of red alder logs.
3. Develop new markets for red alder products.
4. Develop a better base of economic information to guide management decisions regarding conversion, retention, and interim management of red alder.

B. For future pure stands--

1. Develop effective use of red alder in short crop rotation schemes.
2. Relate patterns of total biomass, wood production, and soil nitrogen enhancement to stand age and density.

C. For future mixed stands--

1. Develop effective use of red alder in mixture with other hardwoods and/or conifers.
2. Determine the density of alder admixture needed to meet nitrogen requirements of mixed stands.
3. Define management regimes that will maximize usable volume and/or wood quality of mixed stands.
4. Determine effect of red alder on site quality aside from the addition of nitrogen (nutrient cycling, organic matter relations, etc.)
5. Determine whether mixed stands including alder are better able to resist disease, insect, and fire losses.

The information gained from this research will certainly have application to the 15 percent of our commercial forests currently classified as pure or mixed alder in western Washington and western Oregon. But it should also have far wider application, perhaps to the more than 60 percent of our commercial forest land that could be improved by the addition of nitrogen. And since alder supplies nitrogen in a number of ways, plantings of alder might be even more beneficial than chemical fertilization with nitrogen.

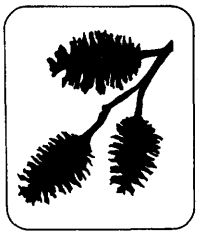
Those of us in forestry are often conservative in our outlook and are sometimes reluctant to consider new ways of doing things. So were the early-day farmers who fought to control unwanted vegetation such as clover and other aggressive nitrogen-fixing plants that occurred as weeds in their

fields. Scientists had to demonstrate the role of such plants in maintaining soil fertility and developed ways they could be managed and harvested for the benefit of man.

Now we have an opportunity to do the same thing with red alder. It is somewhat ironic that our efforts to improve Douglas-fir productivity in this region may be hampered by eliminating from the environment an organism that may have helped make these forests productive in the beginning. We already have a considerable amount of information on the beneficial effects of alder on the forest environment. The lessons from nature are clear, both from casual observation and from research. Efforts to improve our understanding of red alder should be increased. But I think we know enough now to begin using it in field trials, not only to produce more wood fiber but also to achieve a more productive balance of species and ecological interactions.

It is time to take a new look at red alder. I urge you to treat it as a valuable tree species. Let's consider alder, not as an aggressive weed, but as a tree with considerable potential in a more mature forest economy.

SUPPLY OF RED ALDER STUMPAGE, ITS QUANTITY AND QUALITY, AND TRENDS IN ALDER STUMPAGE PRICES AND PRODUCT MARKETS FOR THE STATE OF WASHINGTON



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Division of Technical Services
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ABSTRACT

There is a sufficient supply of alder for the foreseeable future. Most alder is in private ownership. There will be a tremendous surplus (four times the current harvest) during the 1980's and 1990's. The opportunities for price improvement don't look promising, so we do not see why anyone would intentionally grow alder. To create a favorable climate for the alder industry, attitudes about this species must change.

Introduction

The Washington Department of Natural Resources is involved in three activities related to alder.

1. The Private Forest Land Grading Program:

   All private and intermingled public forest lands in the State of Washington are being classified as to their forest productivity and operability. The program was initiated in 1974 and should be completed by December 1980. The survey correlates forest site to soils.

2. The Productivity Study - Phase II:

   The demonstration study will provide a forest inventory of western Washington from Landsat remotely sensed data. It is to be completed by June 30, 1977. This is an ongoing program. We fully expect it to continue with Phase II, which will continue our economic review, start the Landsat inventory demonstration project in eastern Washington, and test optimum use to which we can put satellite imagery on an operational basis. The program is funded by the Pacific Northwest Regional Commission and provides data on hardwood acreage by 20-year age class, by broad density classes, and for each of five major ownership groups.

3. Small Private Forest Landowner Attitude Survey:

   This survey is designed to give an insight into what small private forest landowners plan to do with their forest land. This infor-

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mation will be used to refine the existing Forest Productivity Study for Washington.

A Look at the Resource: Hardwoods in Perspective

Ten percent of the 18 million acres of commercial forest is hardwood (fig. 1). Two and one-half percent of the 1975 total harvest volume of the State of Washington was hardwood. Value of the hardwood inventory is less than one-half percent of the value of the total stumpage inventory, and the figures are going to get smaller. By 2040, we estimate that the acreage base will shrink to about 950,000 acres, or half of what it is now. From these data we conclude that the productivity per unit of conifer acreage is greater than the productivity per unit of alder acreage.

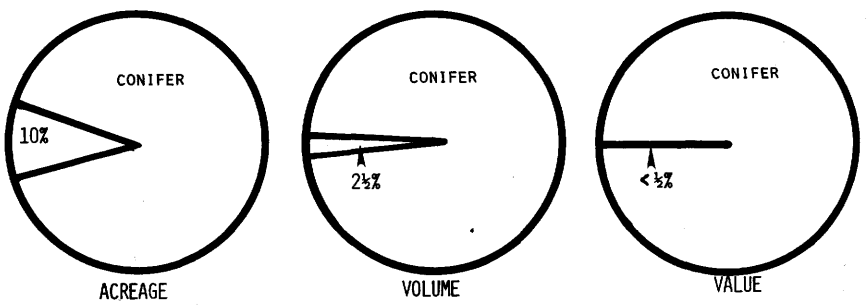


Figure 1.--Hardwoods in perspective.

A Look at the Resource: Where

A schematic of the western part of the State of Washington (fig. 2) shows where those 1.8 MM acres of hardwoods are located. The white area is that part of the State above 1,500-2,000 feet in elevation, where hardwood doesn't grow. The shaded area is the non-urban area (forested) under 2,000 feet in elevation where alder is most apt to grow. Part of this area is lined. The lined area is that part of the hardwood area that has been classified as urban. Much of the current alder base is in the urban area.

About half the inventory comes from the Puget Sound region where most of the urban area exists. The short term supply of alder is coming from the urban area and probably is the result of land conversion to other uses. This finding supports the belief that the alder base will be reduced.

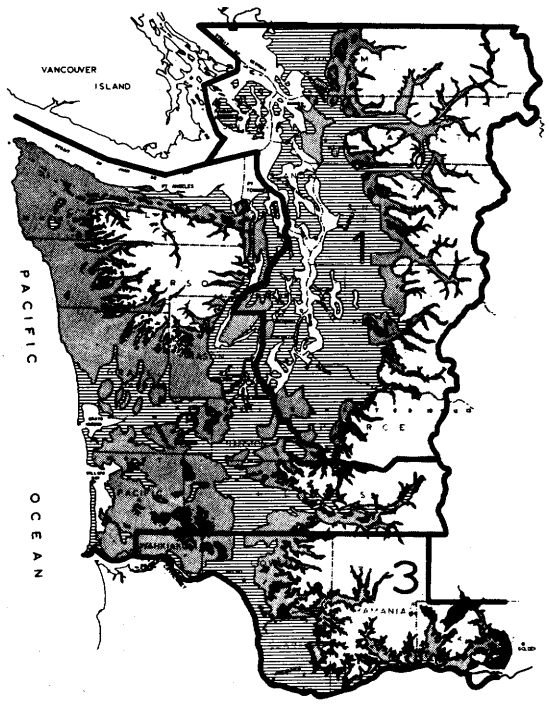


Figure 2.--A look at the resource: Where?

A Look at the Resource: Who

The 1.8 million acres of commercial hardwood is 82-percent private and 18-percent public owned (fig. 3). Consequently, hardwood supply, price, etc. are basically private issues.

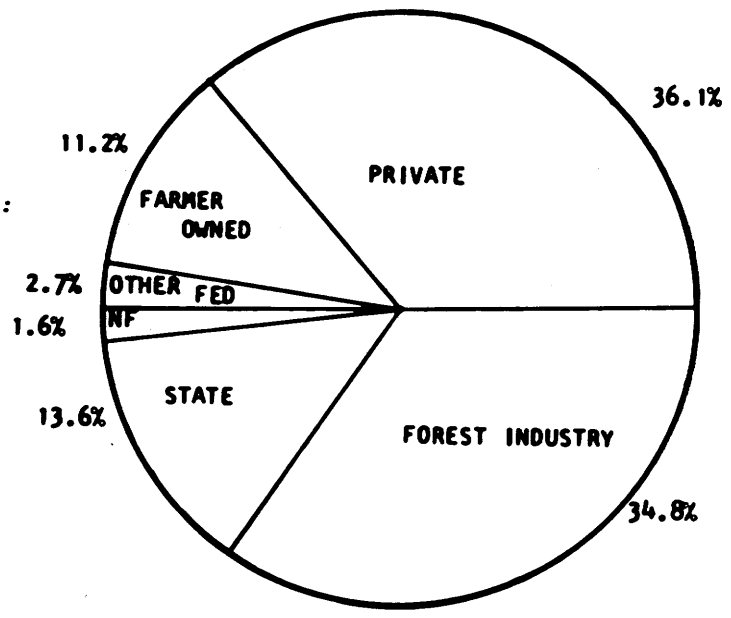
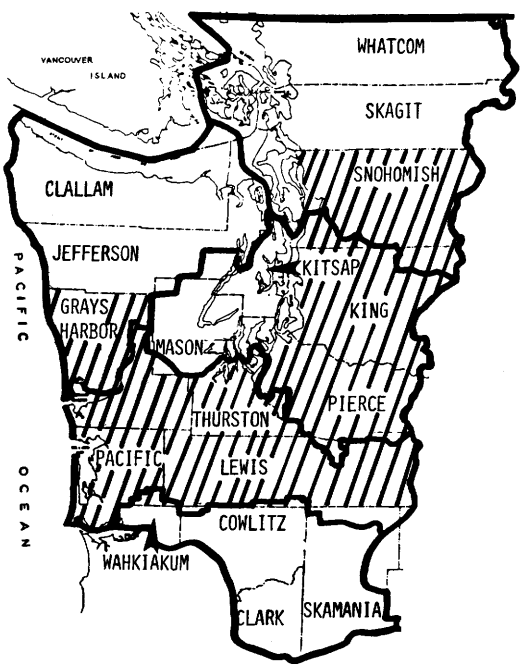


Figure 3.--A look at the resource: Who owns it (acres).

A Look at the Harvest: Where it Comes From

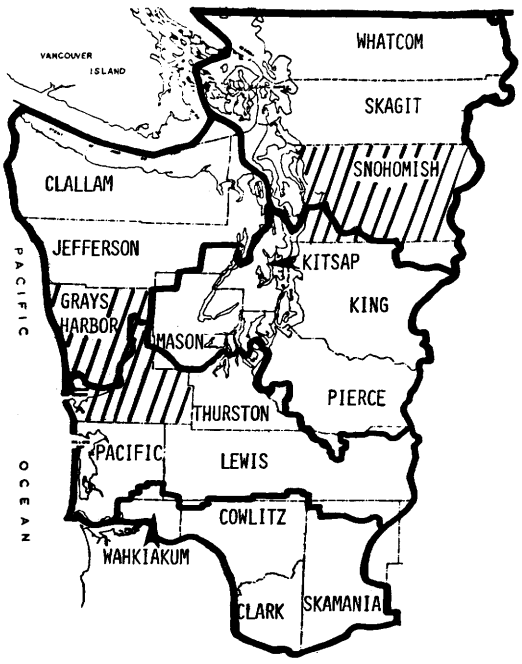
Figures 4 and 5 show those counties with production exceeding 20 MM board feet Scribner per year in 1973 and again in 1975. There was a good market in 1973 but 1975 was a very poor market year.

The information in figures 4 and 5 show that Snohomish and Grays Harbor Counties lead in harvest production and produce substantial quantities of alder volume in both good and poor markets. In addition, when we calculate sustainable harvest for each county independently, Snohomish County leads western Washington with Grays Harbor and Lewis Counties following. Snohomish, Lewis, and Grays Harbor Counties consistently rank one, two, and three in harvest and inventory volumes.



HARVEST VOLUME
OVER 20 MBF
1973

SOURCE: DNR TIMBER HARVEST REPORT 1973



HARVEST VOLUME
OVER 20 MBF
1975

SOURCE: DNR TIMBER HARVEST REPORT 1975

Figures 4 and 5.--A look at the harvest: Where it comes from.

A Look at the Harvest: Where it is Processed

Figure 6 shows both the location and size of sawmills. Smaller circles indicate those mills that produce from 0 to 40,000 feet of alder volume per daily shift. The larger circles show those mills producing from 40,000-79,000 board feet of alder per daily shift.

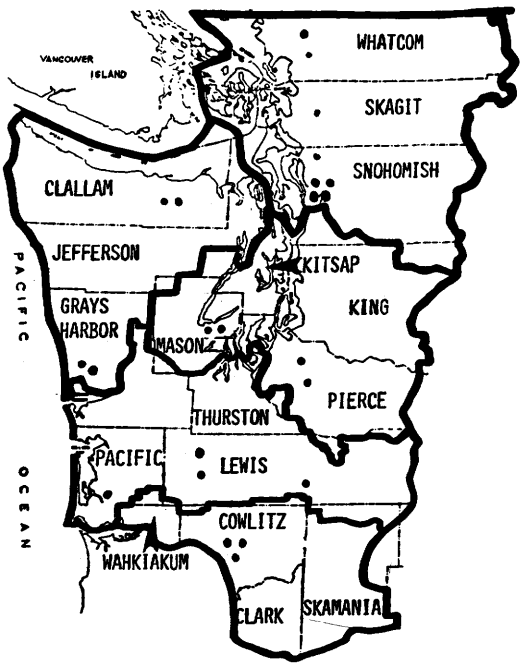


Figure 6.--A look at the harvest: Where it is processed.

The consumption of these mills is mostly sawlog grade volume and represents about 30 percent of the harvest potential of the areas that are logged. The remainder of the volume is, for the most part, unused pulp. The industry is composed of small, family operations. Because the mills are small, the industry is more mobile. Mill operation can be sporadic, consumption can change dramatically, and mill location has a greater tendency to change.

A Look at the Harvest: The Record

So little public harvest exists that data in figure 7 represent private harvest only. Industrial and small private ownership groups harvested in proportion to their ownership up until the mid-1960's. From the mid-1960's until present, the industrial forest ownership group harvested proportionately more alder from their acreage base. Apparently, the industrial forest ownership group can respond more effectively to the sporadic alder markets. We feel that the industrial forest ownership group may be converting land occupied by the alder resource to other uses.

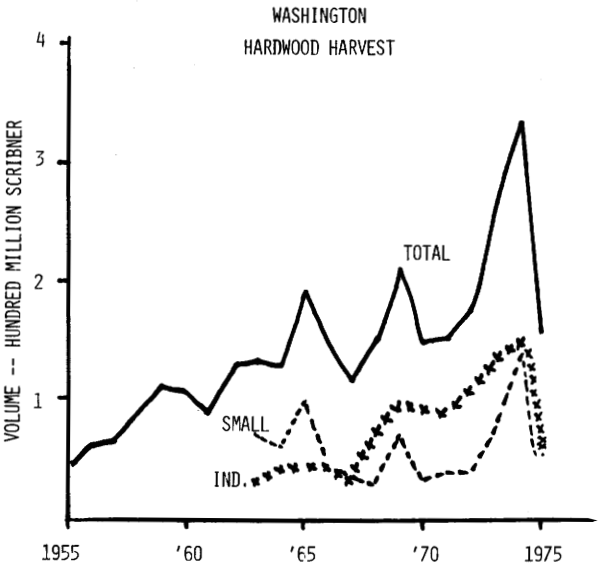


Figure 7.--A look at the harvest: The record.

A Closer Look at the Resource

A closer look at the distribution of acres by age class for the alder land base as it will exist in 1980 is necessary if we are to focus on that part of the alder inventory that will be available to us during the 1976 to 1996 period. Since alder stands are generally mature and ready for harvest at about 50 years of age, we should be interested in that part of the inventory that is now 30, 40 and 50 years of age. The inventory of the mid-1960's has been updated to 1980 (fig. 8). Twenty-one percent of the 1980 land base will be cut in the stands that would have reached 60 years of age. We harvest about 30,000 acres of alder per decade. The 60-year age class represents the approximate decadal harvest for 1970 to 1980. We can, therefore, assume that the 60-year age class has already been harvested. That leaves about 70 percent of the total land base in the 30-, 40-, and 50-year age class--a potential that far exceeds our current harvest.

There are very few acres of zero age, very little 10-year age class and very little, but slightly more, acres of the 20-year age class. Why? We might assume that, as alder stands decline in age, our ability to measure or identify them as alder inventory decreases. Or we may assume that the reduction in inventory as age classes become younger might be the result of a steady increase in conifer management here in the Northwest.

Can we assume, then, that, as conifer management increases and as the Forest Practices laws become more constraining, the alder inventory will decline? What will our alder inventory look like in 30 years?

DESCRIPTION

AGE	ACRES
10	?
20	9%
30	10%
40	43%
50	17%
60	21%

Figure 8.--A closer look at the resource.

A Closer Look: How Did Our Current Base Originate?

Let's take a look at where the inventory that we will be harvesting in the next 20 years came from. The history of our conifer harvest here in the State of Washington (fig. 9) indicates that, in 1929 and 1930, we harvested more acreage of conifer volume in this State than ever before in recorded history. The harvest from that point on went down rather gradually to the volume that we have today.

Heavy harvest volumes, no Forest Practices laws, and less intensive fire control with resulting large wildfires may have produced our current alder base. We have changed our pattern of harvest and land management. The reduction in our alder inventory land base seems to support the theory that improved management produces less alder base.

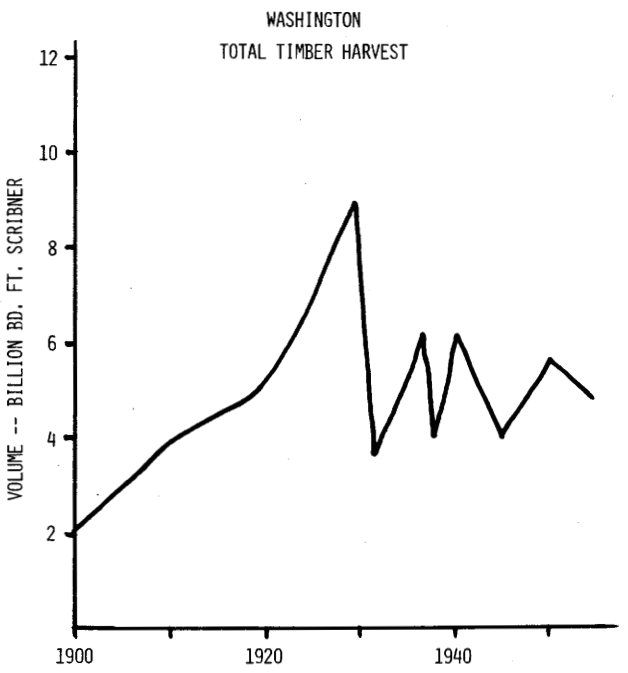


Figure 9.--A closer look: How did our current hardwood base originate?

A Closer Look: Volume

The assumption as to the source of the hardwood inventory is also supported by the three estimates of the inventory of hardwoods (fig. 10). This figure shows that in the 1920's, there was only one-third of a billion board feet of alder. By 1955, the estimate had increased to about 8½ billion board feet of alder; and by the mid-60's, the estimate had increased to about 12 billion feet--an enormous increase.

Let's take a closer look at the inventory for the 1960's. The upper part of the graph (between 7.1 billion and 12 billion board feet) consists of hardwood inventory mixed with conifers. If one were to consider only the stands that were classified as hardwood stands, we would have 7.1 billion board feet of hardwood, averaging 3,900 board feet per acre. If one were to look at only those acres of better stocked hardwoods containing 5,000 board feet per acre and greater, one would have an inventory of 3.6 billion feet on some 380,000 acres, with an average volume of 9,500 board feet per acre. Regardless of the inventory unit selected, one must recognize that there has been a 10- to 30-fold increase in volume in the last 40 to 45 years, depending on what one includes in the inventory.

The two arrows in the lower right-hand corner represent the following: If we were able to successfully manage all the existing alder intensively, this would require a reasonably stable inventory of 6 billion board feet. If, however, that same area were continued at its present level of management, we would need a reasonably stable inventory of about 4¼ billion board feet.

These data support our theories on how the alder inventory originated. We have ample inventory to continue at the current level of management, or even more intensively if we desire.

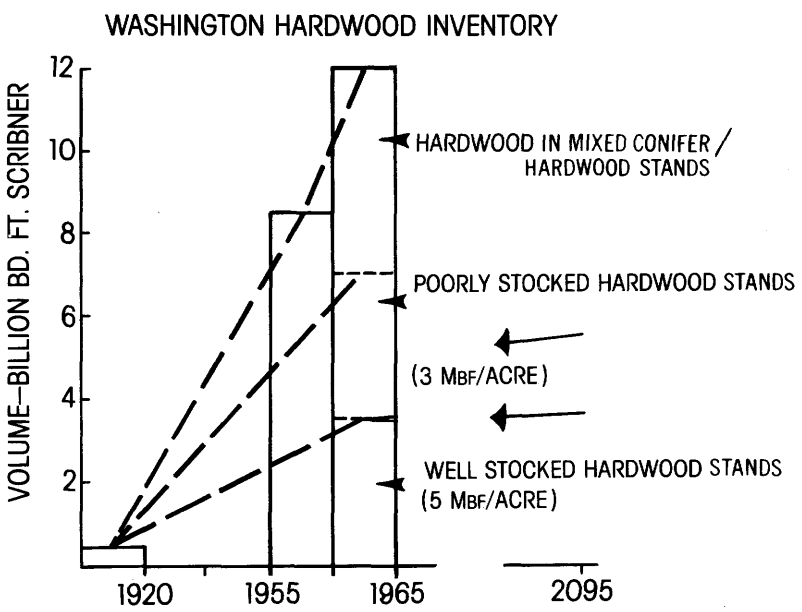


Figure 10.--A closer look: Volume.

A Closer Look: The Average Stand

Figure 11 gives us a closer look at what we consider to be the typical current hardwood stand. It is 40 years of age, exists on alder site index 90, and has an average d.b.h. of 10 inches. The cubic volumes in cubic feet (*CV*), Scribner volumes in board feet (*S*), and number of logs (*#L*) noted in the figure come from DNR Report 31[1] where we find that a high percentage of the stands that make up the inventory are pulp quality.

AN ACRE OF TYPICAL STAND
(80% NBA)

AGE	UNIT	PERCENT OF STAND ABOVE TOP DIB 8"+	10"+	TOTAL
	CV	43	3	2,100
30	S	67	6	5,800
	#L	31	4	340
	CV	54	23	3,100
40	S	74	34	9,900
	#L	38	13	450
	CV	67	31	4,000
50	S	84	44	14,300
	#L	47	17	570

Figure 11.--A closer look: The average stand.

The Harvest: An Overview

Big things are expected from Washington hardwood harvests. Since the mid-1950's, the annual harvest had been erratic, but on an upward trend (fig. 12). In 1975, something happened to that trend. To maintain the upward trend that developed from the fifties through the seventies, a most dramatic increase must occur from the 1975 level in the next few years. Our analyses project the potential harvest at somewhere between 700 and 800 million f.b.m. in the late 1980's. The harvest will then slowly taper off through 2045 to somewhere between 130 and 270 million f.b.m. per year and remain at that level for as long as we can calculate. This harvest potential was projected at two levels of management intensity: "Current," which assumes a pattern and level of management which is consistent with today's practices, and "Intensive '75," which assumes a very intensive level of management--the most intensive level of management practiced in 1975.

[1]Chambers, Charles J. 1974. Empirical yield tables for predominantly alder stands in western Washington. State of Washington, Dep. of Natural Resour. Rep. No. 31, Olympia.

We feel that it is going to take an enormous change in our current pattern of logging to use the potential that is available in the near future. If this potential is not used, we will not have much time to store it on the stump for future use as alder stands break up at older ages. Thus, there is some urgency to create consumption for the fiber that will be removed from alder sites converted to conifer production or to other competing land uses.

Is there anything that we see taking place now or in the near future that would cause us to believe that the excess in terms of two to four times our current annual harvest could be used economically and profitably?

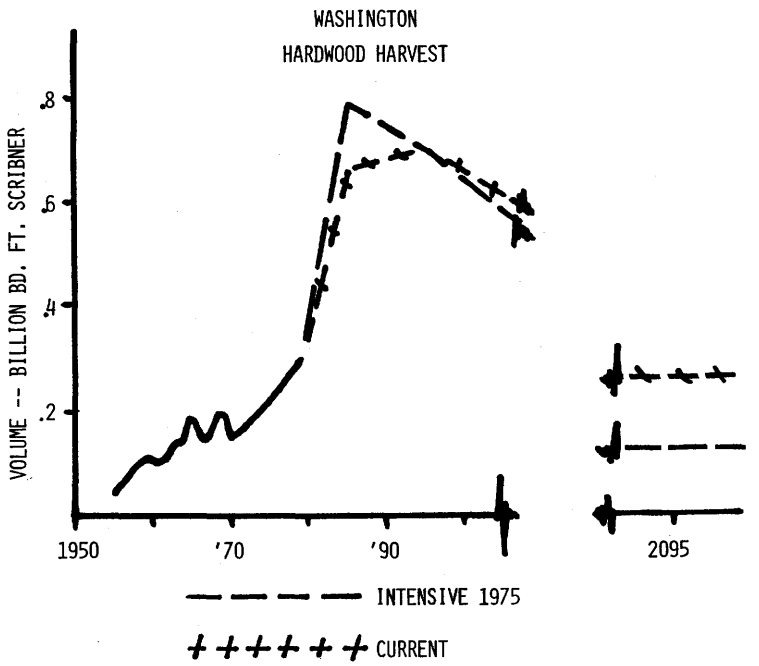


Figure 12.--The harvest: An overview.

The Hardwood Inventory and Its Potential—A Summary

The major portion of the alder inventory here in western Washington is privately owned. That ownership comprises a very small percentage of the total commercial forest land base in western Washington. Most of the inventory and the harvest comes from Snohomish, Lewis, and Grays Harbor Counties. The mill capacity is evenly distributed and consists mostly of small mills. There will be a huge increase in available inventory in the next 20 years, most of which will be lost if not logged during these two decades. Most of the existing inventory apparently was created in the thirties; and as Forest Practices laws and intensive management programs have increased, the acreage of hardwood base has decreased proportionately. The inventory of the sixties will shrink to about half its current size by the year 2000 and beyond, but this inventory will sustain considerably more annual harvest than we are now experiencing. The inventory consists of stands which contain small percentages (30 percent or less) of sawlogs and huge volumes of pulp material which is currently unused and left on the ground. It is going to take a huge change in our hardwood industry to use the volume available in the foreseeable future.

Markets and Price Trends

SAWLOG PRICES:[2] [3]

Price has increased (fig. 13) at the same rate as increased costs of labor and equipment used in logging. As the figure indicates, the trend line is up, but only keeps up with increased costs. Price, however, does not change with quality.

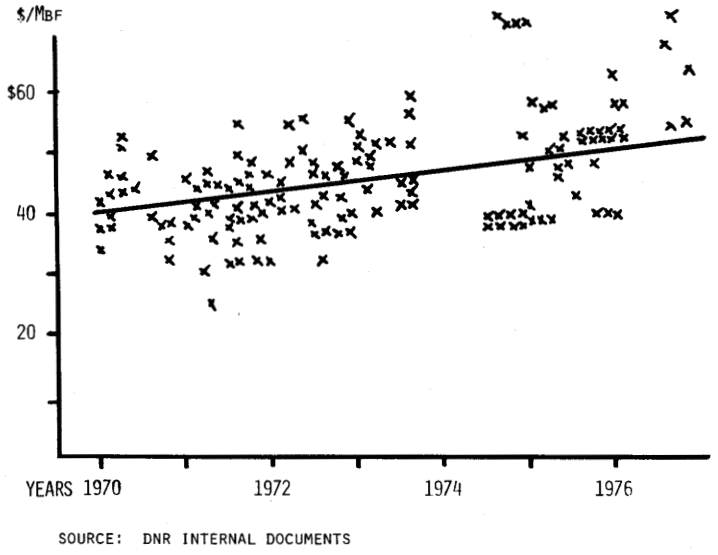


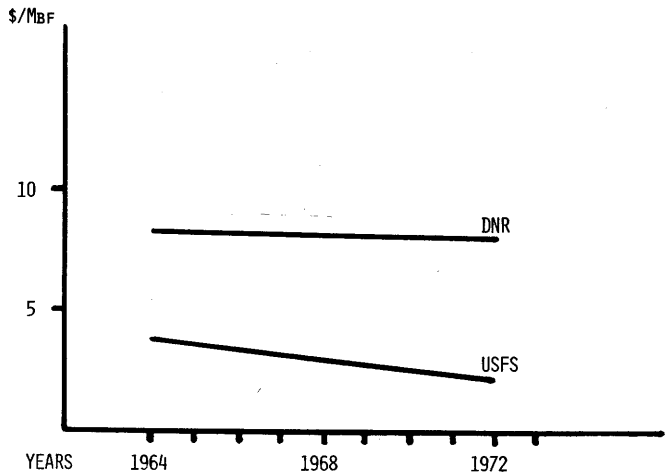
Figure 13.--Alder sawlog prices (#3 sawlogs, FOB MILL).

STUMPAGE PRICES:

If the data in figure 14 were plotted without inflation, the line would show a down trend: Price increase is not even keeping up with inflation. The cost of production, however, is rising faster than the price of logs at the mill. Thus, real stumpage prices are probably decreasing. In addition, these stumpage prices may be on the high side because of conversion benefits being built into stumpage and because enough conifer is included with each sale to offset the low alder stumpage.

[2]Prices include inflation.

[3]As reported to DNR by local mills.



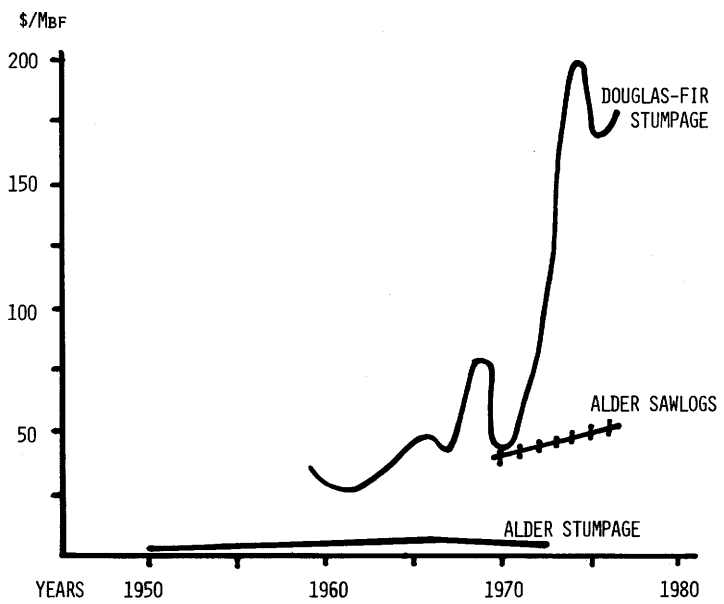
SOURCE: DNR, USFS

Figure 14.--Stumpage prices: Alder.

PRICES IN PERSPECTIVE

Figure 15 compares the hardwood stumpage prices with Douglas-fir stumpage prices over the same period of time. We'll illustrate the relative investment opportunities of alder stumpage as opposed to Douglas-fir stumpage. These figures for Douglas-fir come from Region 6 stumpage data. Department of Natural Resources stumpage for Douglas-fir is consistently higher. Incidentally, the difference between the price of sawlogs as plotted above and the price of hardwood stumpage probably represents the cost of production.

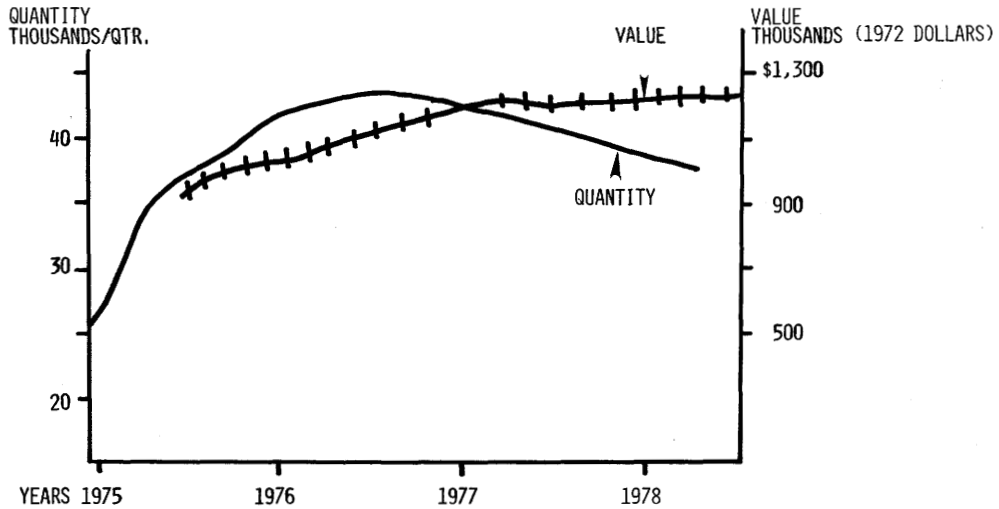
Figure 15.--Price trends.



SOURCE: DNR INTERNAL DOCUMENTS; ED HOLT, "PRODUCTION PRICES, EMPLOYMENT AND TRADE" USDA.

HOUSING MARKETS:

As population increases housing permits may increase as shown in figure 16 thru mid-1976. In the near future we expect a decline in permits, and leveling off in value.



SOURCE: WHARTON EFA, BOEING COMPUTER SERVICES, INC., FOURTH QUARTER, 1976

Figure 16.--Housing permits.

FURNITURE MARKETS:

Peak demand for furniture and cabinets (prime uses of alder) should follow housing starts simultaneously. Although an increasing trend has been projected for household furniture in figure 17, declining numbers in new household formations and housing starts would produce corresponding declines in furniture demand unless tastes and preferences turn to some new fad. Competition from producers of particle board, plastic, fiberglass and metal furniture will have an effect on projections.

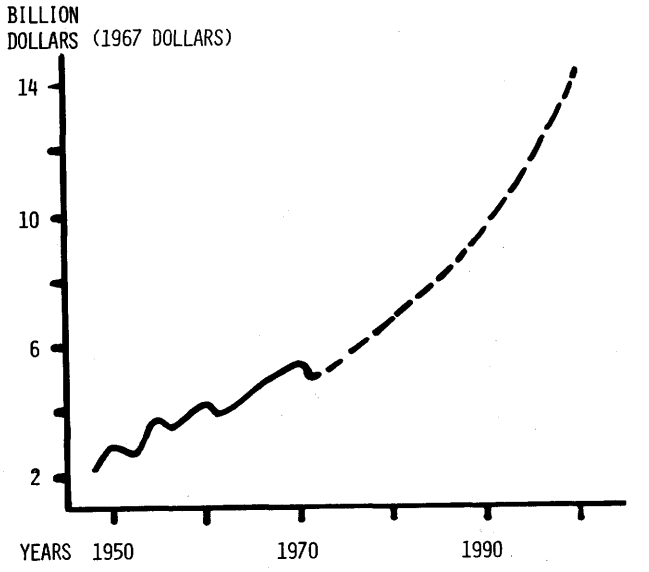


Figure 17.--Household furniture.

SOURCE: USDA, FOREST SERVICE, THE OUTLOOK FOR TIMBER IN THE UNITED STATES

Some Questions

IS THERE A SHORTAGE?

Some observers feel that there will be a shortage of sawlogs in the near future. This is not supported by biological information but may be based on some economic fact. No shortage exists, however, when the price for the product satisfies both the buyer and seller. As costs of production rise, cost of product must rise. Thus, shortages that arise will be economic rather than biological.

Alder will be a drag on the market. Forest managers and others may be figuring out how to get rid of it in the most cost-effective manner to make way for other land uses. This may distort the market and price.

THE FIREPLACE DILEMMA

This issue reared its ugly head in the marketplace and complicated the supply issue. In the larger cities, fireplace wood is currently selling for $35-$55 per cord delivered at the yard of the purchaser. This amounts to from $70-$110 per thousand for wood in fireplace lengths dumped at the homeowner's site. This could be heavy competition to mill owners in these areas who offer from $50-$75 per thousand for sawlogs or, at most, prices that correspond to fireplace wood. No telling what the energy shortage will do to this part of the marketplace.

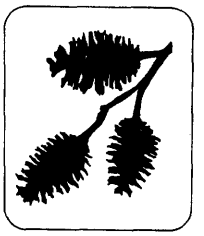
IMPACT OF CONVERTING HARDWOOD SITE TO CONIFERS

Hardwood interests really don't have to worry about alder supplies in the near future. As you recall, the worst management option presented provides assured potential of 1972 harvest levels (peak year) throughout the next 70 years. In addition, the latest DNR attitude survey of non-industrial private forest landowners reveals that only about 25 percent plan to eradicate hardwoods, and only when convenient.

WILL A CHANGE IN QUALITY OR QUANTITY CHANGE THE PRICE?

Price of stumpage is not keeping up with inflation. The huge volumes available will tend to depress prices even more and I suspect that there is little hope of changing the price structure to pay for quality differences in the near future.

PROPERTIES OF RED ALDER *(ALNUS RUBRA* BONG.) AND ITS COMPARISON TO OTHER HARDWOODS



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ABSTRACT

Red alder is compared with several common commercial hardwoods of the United States. The objective is to show that alder is suitable for many products for which other hardwoods of similar structure and specific gravity are used. One advantage of alder is its uniform color of both heartwood and sapwood. A limited test of alder specific gravity showed a range of 0.33 to 0.48 and no correlation with growth rate. Tension wood is shown not to be a problem in alder and not easy to detect. Growth stresses are believed to be more of a problem, causing the splitting of logs and warpage of lumber.

Introduction

Recent literature includes very limited information about research concerning the wood science and technology of red alder. Three general reports on alder include a brief summary of its wood properties (*9, 10, 13*).

Heartwood-Sapwood

There is no apparent heartwood in red alder. The center of the log cross section is no different in color from the wood on the outer part of the stem. Though there may be what is called physiological heartwood formed in the center of the larger stems, it cannot be distinguished by color dif-

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ference. This lack of heartwood-sapwood difference simplifies lumber grading and sorting by eliminating the need for separation of sapwood from heartwood as is necessary for wood such as walnut or sweetgum.

The center of the log may show discoloration due to incipient decay. Irregular discoloration due to stain fungi may also occur, especially in the outer zone. Alder is not decay resistant, and blue stains easily. Preventative measures need to be taken from the time the log is cut until the lumber has been dried.

Color

The color of alder changes between the time it is first cut and its final use, depending upon the conditions it is subjected to. When first sawed, the wood of alder is nearly white. It may turn pinkish white after some exposure to air and light. As the wood dries, the color either becomes an off-white to ivory or darkens to a reddish or yellow brown. The color and its darkness depends upon temperature and moisture conditions during drying (*1*, *5*). The control of this color change is important because it affects the marketing of alder. Many buyers want only a uniform honey brown. Kozlik (*6*) found that presteaming the lumber before drying had a distinct effect on the final color. The color is believed to be the result of changes in the polyphenolic extractives in the wood (*4*, *7*).

Wood Anatomy

Alder is classified, with respect to its wood anatomy, as a diffuse porous wood. As seen in figure 1, there is very little change in the wood structure from earlywood formed at the first of the growing season to the latewood formed at the last of the growth year where there is a slight, very narrow band of denser wood with few vessels and denser fibers. It is this narrow denser band that makes the growth ring distinguishable and shows as a subdued grain figure on the surface of a planed board.

The pores or vessels of alder are small and quite evenly distributed among the fibers. This gives the wood a uniform grain with a fine smooth texture. Because most of the rays of alder are narrow, they cannot be seen without magnification and so do not contribute to the figure as do oak or hard maple. Aggregate rays may occur. These wide composite ray structures can look somewhat like the large rays in oak (fig. 2). Aggregate rays, however, are sporadic in occurrence. They may be abundant in one piece of wood, sparse or entirely absent in others. The figure they cause is not consistent.

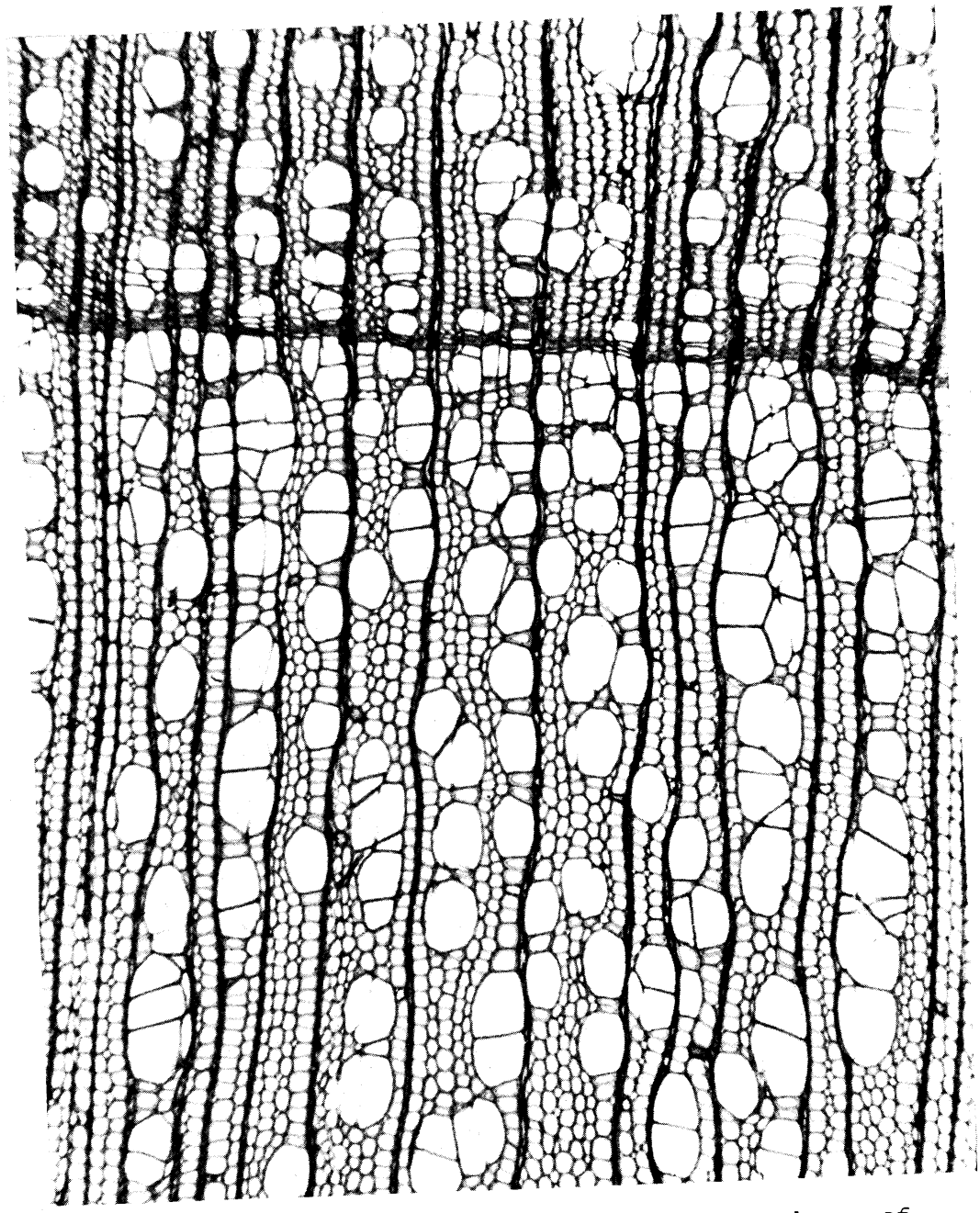


Figure 1.--Cross section of alder showing the change of structure at the ring boundary.

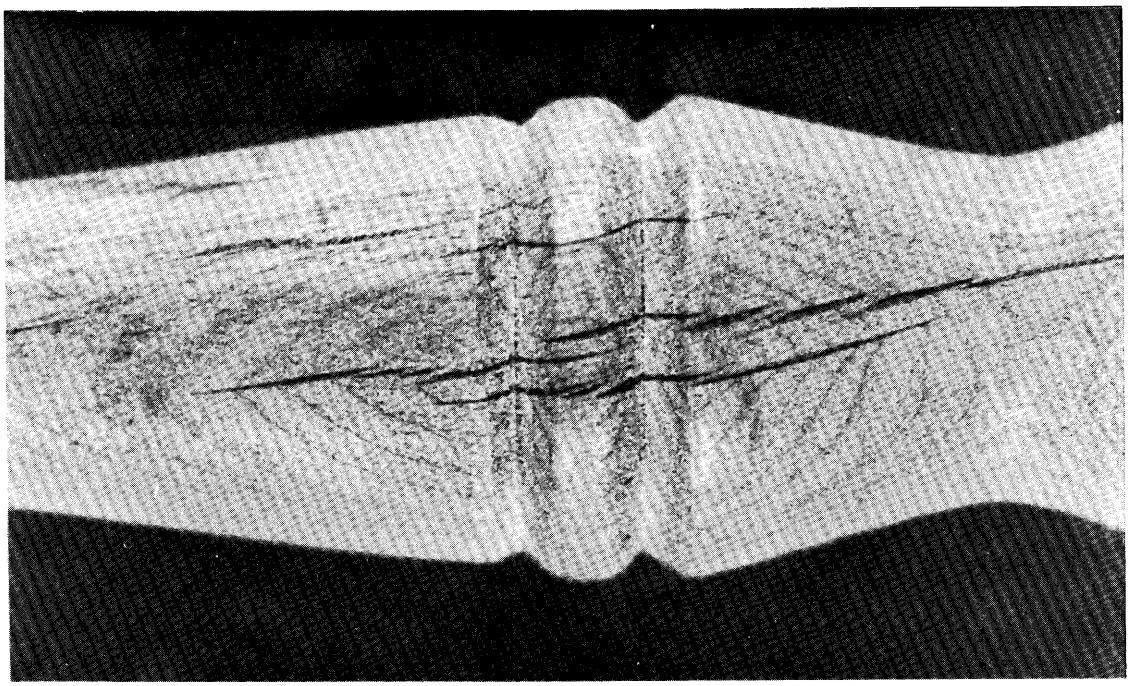


Figure 2.--Aggregate rays show on a turning of alder.

Ease of Working and Finishing

The fine, even texture and moderate density make alder easy to work with tools. It sands and polishes well to a very smooth surface. Since the vessels are small in diameter, there is not the show of vessel lines as in coarser textured woods such as walnut. The grain of alder does not show through a painted surface. It holds paints and coatings very well and takes stain readily (*3*). The subdued grain allows it to be finished in a variety of ways to suit designer taste.

Fiber Use

The fibers of alder average about 1.2 mm long (*2, 8*). The average lengths for the hardwood species range from 0.6 to 2.3 mm and for softwoods, 1 to 7 mm. Alder pulps well and is widely accepted both on the West Coast and in Japan. The chips, however, cannot be stored in piles for 6 months or more as there is considerable loss due to deterioration by micro-organisms. There is a loss of wood substance, and the burst and tear of the pulp is significantly reduced. Methods of treating the chips to retard deterioration in the chip pile have been tried with some success (*11*).

Physical Properties

Physical properties of alder can be shown best by comparing them to several commonly used hardwood species (table 1). For ease of comparison, the woods have been assigned an index class for each property to compare each to the other commercial woods of the United States as well as the woods in the table.

Table 1--*Comparison of selected physical properties of red alder and nine other commonly used woods*[1/]

Species	Specific gravity[2/]	Weight at 8% M.C. lb/ft[3]	Modulus of rupture[3/]	Impact bending	Tension perpendicular to grain	Compression perpendicular to grain	Hardness	Volumetric shrinkage[4/]
Cottonwood	31	20.9	2	2	2	1	1	3
Basswood	32	21.6	2	1	2	1	1	7
Alder	37	24.9	3	2	3	2	3	3
Yellow poplar	40	27.0	3	2	4	2	2	4
Maple, silver	44	29.7	2	2	4	3	3	3
Maple, bigleaf	44	29.7	4	3	4	3	4	2
Sweetgum[5/]	46	31.0	5	3	7	2	4	7
Walnut, black	51	34.4	6	3	6	4	5	4
Birch, yellow	55	37.1	7	6	9	3	7	8
Oak, red	56	37.7	6	4	7	4	7	5

[1/] Derived from data in the Wood Handbook (*12*).

[2/] Based on green volume.

[3/] The range of values for all the commercial woods of the United States is divided into 10 even index classes with 10 being the highest value.

[4/] The lowest figure is best with least shrinkage.

[5/] Marketed as redgum and sap-gum.

It is evident that alder is very close to yellow-poplar and silver maple in its physical properties. It is slightly superior to cottonwood and basswood, which are of lower specific gravity, and generally of lesser strength than those woods with higher specific gravity. Alder is better than most with respect to shrinkage. It has the important characteristic of "staying-in-place" by little shrinking and swelling with moisture changes.

Specific Gravity

As can be seen in table 1, specific gravity is a general indicator of certain properties. The first author recently made a limited test of specific gravity as related to growth rate. The end 6 inches were trimmed off boards in a load of lumber being prepared for drying in an experimental dry kiln. From these pieces, 55 specific gravity sample blocks were cut. The blocks were cut so they contained a fairly uniform width of growth rings. The average ring widths of the blocks ranged from 1 to 10 mm. Specific gravities of the blocks ranged from 0.33 to 0.48 with an average of 0.39. There was essentially no correlation between ring width and specific gravity. The linear correlation coefficient was -0.010. If further investigation substantiates this same lack of correlation between growth rate and specific gravity, the objective of maximizing growth rate can be followed without fear of reducing the specific gravity. Whether other properties are affected by variation of ring width will have to be tested. There appears to be a lack of such information in the literature.

Machining and Gluing

Table 2 shows how the machining properties of the woods compare. Alder has a comparatively good rating and should be able to be used interchangeably with most species now used to manufacture furniture or cabinets.

Table 2--*Comparison of machining properties*[1/]

Species	Planing	Shaping	Turning
Cottonwood	1	1	5
Basswood	7	2	4
Alder	6	3	10
Yellow-poplar	8	2	9
Maple, soft	3	4	7
Sweetgum	5	4	10
Walnut	6	5	10
Birch	7	8	8
Oak, red	10	4	10

[1/] Based upon data in the Wood Handbook (*12*). The range of all wood tested is divided in 10 index classes with 10 being the best.

Table 3 shows that alder glues well under a fairly wide range of gluing conditions with glues of a moderately wide range of properties.

Table 3--*Gluing properties*

Class I	Class II	Class III	Class IV
Glue easily for wide range of glue properties and gluing conditions	Glues well with less range of glue properties and gluing conditions	Glue satisfactory with best quality glues and well controlled gluing conditions	Require very close control of glues and gluing conditions
Cottonwood and yellow poplar	Alder, basswood, and sweetgum	Maple (soft), oak, and walnut	Birch and maple (hard)

To summarize these properties, the relatively low density and strength of alder should be taken into consideration in design. Dimensions may need to be increased to compensate when directly replacing a denser, stronger wood. The good machining quality, reaction to glue and finishing characteristics along with minimum shrinkage and swelling makes alder very suitable for use in furniture and cabinet work. In fact, it already has wide use in the furniture industry.

Tension Wood and Growth Stresses

Like a number of hardwoods, alder sometimes has reaction wood of the type referred to as tension wood. Extensive study of this type of wood was started at this College in 1957 by the last two authors of this paper. The usual tension wood characteristics could not be correlated with the uphill or downhill sides of the trees. Microscopic studies failed to demonstrate the general presence of tension wood. In fact, well-developed tension wood is rare in red alder, and the problems usually associated with the conversion of tension wood seldom are cause for concern in the alder industry.

These points are significant because the properties of tension wood are substantially different from normal wood. Tension wood is often difficult to detect. Sometimes it has a silky or dull lustrous appearance. Other times these features are not obvious. Staining techniques and microscopic examination are used to identify gelatinous fibers which are considered to be characteristic of tension wood. The gelatinous layer(s) of the secondary wall have highly organized cellulose molecules of higher than average molecular weight and are often less lignified than normal walls. All stages of development of gelatinous fibers are found in red alder, if it has tension wood.

The vessels are smaller and less frequent in tension wood. Tension wood of red alder has a higher density than normal wood (0.396 vs. 0.360), and the wood formed immediately before and after the tension wood is also more

dense (0.385). Tension wood shows greater longitudinal shrinkage (0.348 percent vs. 0.150 percent). This property is probably the most undesirable for tension wood in product use.

In hardwoods, tension wood often causes problems during manufacture of forest products by producing woolly surfaces when it is sawn, machined, or converted into veneer by peeling. This is especially common with cottonwood. Such surfaces sometimes produce poor glue bonds. Tension wood is more difficult to dry without degrade, and collapse is fairly common. Tension wood makes inferior pulp by the usual alkaline and acid sulfite methods but produces superior pulp by neutral sulfite and mechanical processes. The pulp yields are greater than for normal wood for the alkaline and neutral sulfite processes.

If tension wood is found in red alder, gelatinous fibers are found on all radii of the trees but are most likely found in the uphill radius of leaning trees or associated with areas of previous damage. Heavy concentrations of highly developed gelatinous fibers are rare.

Leaning red alder trees do develop eccentric growth. In our work on 40 leaning trees from eight locations, sampled at four heights (0, 8, 16, and 24 ft above ground), the greatest radius was usually on the downhill side, not the uphill side as normally expected. The uphill radius, however, was greater than the side radius. The degree of eccentricity could not be related to the degree of lean.

The manufacturing problems associated with harvesting and conversion of red alder are not generally due to tension wood, as it is of infrequent occurrence. Rather, the problems are more likely due to growth stresses. Although growth stresses are common in red alder, they have not been adequately studied. When the tree is felled, it will often "barber chair," a problem associated with growth stresses. During sawing, the logs will shift and may even jump out of the carriage dogs, or the logs and lumber will split open at the ends. This is typically caused by growth stresses. Microscopic compression wrinkles are found in the cell walls of such red alder and they strongly indicate growth stresses in the tree.

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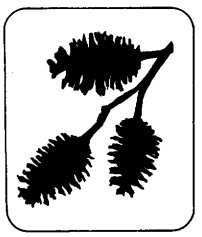
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AN APPROACH FOR COMPARING THE RELATIVE VALUE OF ALDER WITH OTHER SPECIES FROM FOREST TO END PRODUCT



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ABSTRACT

Comparing alder as a renewable species with other species depends on a thorough analysis of a variety of technical and economic data from the system for growing trees through their end use. All too frequently, detail and components of the system are overlooked in policy analysis because a consistent and comprehensive format of appropriate data is not available.

What is needed is a framework that incorporates diverse information on the technical, economic, labor, energy, and environmental aspects of production systems, captures those characteristics important to policy decisions, and thus facilitates the study of the role of alder as a source of materials in comparison to competing alternatives.

This paper explains the Reference Materials System (RMS) adapted by the National Academy of Sciences' Committee on Renewable Resources for Industrial Materials. RMS is suggested for use in examining the complex issues concerning alder management and utilization.

Introduction

During this conference, many aspects of alder utilization and forest management will be discussed; and comparisons with alternative species will

undoubtedly be made. Many of these comparisons will deal with questions of substitution (*6*, *7*). Should alder be replaced by conifers? Can alder displace traditional hardwoods in certain furniture markets? The answers to these questions depend on a thorough analysis of a variety of technical and economic data on the production system--from growing trees through their end use. What is needed is a framework that incorporates diverse information on the technical, economic, energy, and environmental aspects of the production systems, captures the characteristics that are important to policy decisions, and thus facilitates the study of the role of alder as a source of materials in comparison to competing alternatives (*6*).

The Reference Materials System

During the past 2 years, the National Academy of Sciences' Committee on Renewable Resources for Industrial Materials (CORRIM) adapted the concept of a reference material system (RMS), originally developed at the Brookhaven National Laboratory (*2*, *6*) for analysis of materials substitution problems. Specifically, the Committee examined the substitution of renewable for nonrenewable resources. For example, this study developed comparisons among wood, aluminum, and brick as materials for exterior siding.

The reference materials system (RMS) is a network representation of the flow of materials through all production and shipment steps or "activities" required to produce and convert a resource into a form that may be used for a specific purpose.

Figure 1 illustrates an RMS developed by CORRIM for a wood based exterior wall (*2*). At the left side are the resources considered, in this case the forest resource. Along the top are the activities required to transform the resource to the end uses, and along the right side are the end uses, in this case the exterior wall. The activities that may be considered are production or growing, harvesting or extraction, processing, transportation, primary fabrication, installation, erection, maintenance, and recycling. The transportation activity includes the aggregate of all transportation shipments through these various flow stages. A RMS representing the production of a specific product from a specific resource is obtained by tracing a path or trajectory from the raw materials through the activities to the end use. The information contained along this particular trajectory is mass flow in pounds and energy requirement in million BTU. Here the trajectories for converting other resources such as iron ore into nails have already been summarized to a single net figure. Depending on whether the RMS format is to be used as a framework for organizing technical data on labor, capital, raw material, or energy use, the numbers along the trajectory would portray man-hours, cost, value added, energy or material quantity flow. These or other measures of interest can be portrayed as aggregate quantities or as amounts per unit of raw material input or end product output.

In the CORRIM study, detailed trajectories were developed to portray physical material flow, labor man hours use, capital requirement, and process energy use. In the following discussion, a typical energy trajectory will

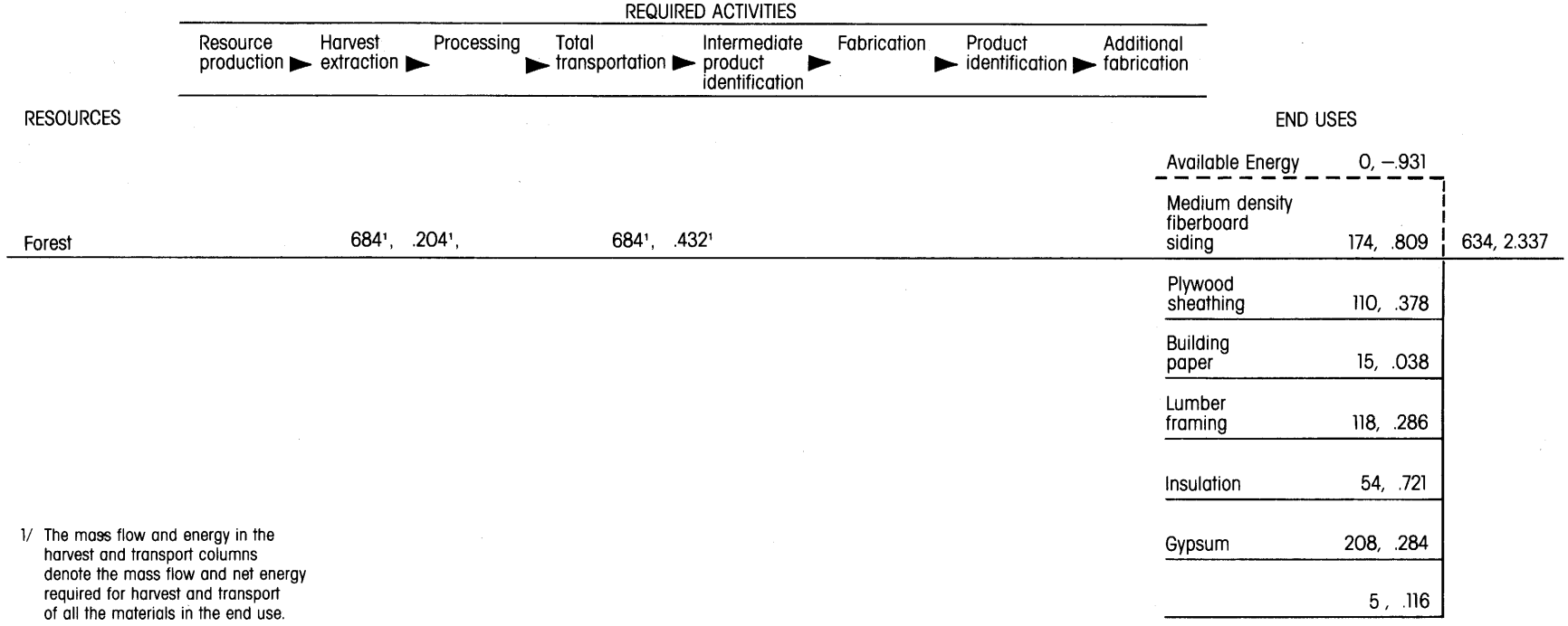


Figure 1.--RMS trajectory summarizing the mass flow (pounds) and process energy requirement (million BTU) for 100 ft^2 of wood based exterior siding.

be used as an example. Feedback or recycling can also be portrayed as shown by the available process energy from residues which can be used to offset the need for outside energy. Initially, trajectories may be developed at a very detailed subsystem level and then aggregated into an overview of the more general system. For instance, more detailed energy trajectories of the harvesting phase may be developed to derive the net energy usage in this activity.

Regardless of the level or kind of detail portrayed, the RMS can be used for analyzing policy alternatives as well as overview displays. For analytical purposes, the RMS is used in conjunction with perturbation analysis. Basically, this involves examining the specific end use in a utilization or substitution problem and defining all new processes and other changes along the affected trajectory. The flows and measures of interest along the trajectory are revised to reflect these changes and the consequences in terms of labor, energy, capital, material, or environmental measures are summarized.

The definition of the technical aspects of new processes must be done outside the RMS which simply captures those characteristics that are important to policy. All too frequently, such technical detail is overlooked in policy analysis because it is not available in a consistent and comprehensive format. A RMS example would be the comparison of wood, aluminum and brick exterior siding.

Table 1 presents data collected by CORRIM on the quantities of the material components and energy used per 100 square feet of construction of a wood-based exterior building wall (2,3). This table is the basis for the entries in figure 1. The energy aspects detailed for each component are fuel used in logging or extraction (col. 2), manufacturing energy (col's. 3 and 4), transportation fuel (col. 5), and energy produced from manufacturing residues (col. 7). The latter category represents production of energy as a by-product of making the exterior wall, whereas the former three categories represent energy consumption. Net energy required or "net energy drain" is the difference between the total energy consumed and the energy produced.

The information provided in table 1 was used to develop the RMS trajectory in figure 1. The ovendry weights of the fabricated components (col. 1 of table 1) have been converted from tons to pounds and are given as the first of each pair of numbers beside each component as listed under Product Identification in the RMS (figure 1). Thus 0.104-ovendry tons of gypsum (table 1) is equivalent to 208 pounds as shown in the RMS (figure 1). The sum of the weights of the components per 100 square feet of construction is 684 pounds. The manufacturing energy value for each fabricated component is the second of each pair of numbers in the RMS (figure 1). For example, the 110 pounds of plywood sheathing used required 0.008 million BTU of manufacturing electrical energy plus 0.370 million BTU of manufacturing heat for a total of 0.378 million BTU.

In the transportation activity, these 684 pounds of components required

Table 1--*Materials and energy use in construction of an exterior wall. (Exterior wall: medium-density fiberboard siding, plywood sheathing, 2x4 frame. Total net energy requirement per 100 square feet of construction[1/2/] is 2.541 million BTU)*

Fabricated component	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
	Weight ovendry	Logging fuel	Manufacture		Transport[3/] fuel	Gross total	Available mfg. residue energy	Net[2/] total
			Electric	Heat				
	Tons	------	-Million BTU thermal (oil equivalent)-					-------
Siding, 1/2 in. MDF @ 42 lb/ft^3	0.087	0.068	0.326	0.483	0.100	0.977	0.238	0.739
Sheathing 3/8 in. plywood	.055	.041	.008	.370	.114	.533	.203	.330
Building paper	.0075	.001	- - -	.038 - - -	.005	.044	0	.044
Framing, lumber	.059	.056	.046	.240	.116	.458	.490	.172
Insulation (2 in. bats)	.027	.017	- - -	.721 - - -	.025	.763	0	.763
Gypsum	.104	.015	- - -	.284 - - -	.068	.367	0	.367
Nails	.0025	.006	- - -	.116 - - -	.004	.126	0	.126
			.380	1.093				
			1.159					
Total	0.3420	0.204	2.632		0.432	3.268		2.541
Percent (of gross)		6.3	80.5		13.2	100.0		

[1/] Horizontal projection of roof structures.

[2/] Assumes energy from residuals can be internally used or exchanged in manufacturing phase only (not logging or transport).

[3/] Commodity factory to retail yard to house site.

an aggregate of 0.432 million BTU (sum column 5 of table 1). Similarly, logging or extraction to obtain raw materials to produce these 684 pounds of final components took 0.204 million BTU (col. 2 of table 1). In this case, manufacturing activities on raw materials produced residues that were converted to 0.931 million BTU (col. 7 of table 1) of available energy. This "gain" in energy is signified by the dashed back arrow indicating a return to the system. The net energy drain to produce these 684 pounds of components for 100 square feet of wall is obtained by summing the energy consumptions and subtracting energy production:

Million BTU	
0.204	Harvest, extraction
0.432	Transportation
0.809	Medium density fiberboard siding
0.378	Plywood sheathing
0.038	Building paper
0.286	Lumber framing
0.721	Insulation
0.284	Gypsum
0.116	Nails
3.268	Total consumption
-.931	Energy produced from manufacturing residues
2.337	Net

The apparent discrepancy between the net end use energy value shown in the RMS and the net energy value shown in table 1 can be resolved as follows. The figure in table 1 is based on the assumption that the energy from residues from these products can only be used internally or exchanged in the manufacturing phase only for this product and could not be channeled to other uses, which is unduly conservative. The RMS trajectory recognizes that this energy could be channeled to other uses. Trajectories for the alternative aluminum and brick exterior walls were similarly derived.

The RMS trajectories include harvesting, transportation, and manufacturing energy up to the construction site. Energy requirements do not include erection because, in general, the energy required for erection is relatively very low. The energy requirements for harvesting and transportation are aggregates for each end use, and pounds of material shown at these steps are total for all materials used in this process. The energy requirements for the manufacturing step under "Fabrication" is disaggregated, showing energy required for each material use. Also shown in the RMS diagram is the available energy or residual energy left from the manufacturing process.

From these RMS flows it became apparent that the wood-based construction requires less process energy than the other materials used for construction designs. Although not shown in figure 1, brick walls require 17.35 million BTU, aluminum siding 4.76 million BTU, as compared to 2.34 million BTU required by wood based construction. Thus the brick veneer walls require seven to eight times the process energy of comparable wood

construction and those incorporating aluminum about twice that of wood. It should be pointed out that this comparison examines only the processing energy to manufacture and produce the designs. There are other obvious factors to be considered such as maintenance, service life, and energy efficiency in use.

A RMS Example for Alder

To illustrate the application of RMS to alder, preliminary trajectories have been prepared for the physical flow and labor in producing alder from the forest stand to end use in furniture. In the flow trajectory, only the wood component is outlined. We have deliberately left out other ingredients such as glues, fastenings, finishes, etc.

The physical flow trajectory is shown in figure 2. It starts out with 100 cubic feet of alder raw material in the stand, and this includes bark, stump, tops, and cull material. Loss factors have been applied at each step to estimate the quantity of primary product, secondary product, if any, and residue at each process. These loss factors are based on national average data obtained from CORRIM (*3*), published reports (*1*, *4*, *5*) and estimates of average values obtained from a brief survey of alder manufacturers.

The data for this RMS trajectory for alder are based on limited sampling. This is presented for the purpose of demonstrating the utility of this form of analysis in assessing substitution opportunities. For effective use of this type of analysis, it would be essential to obtain hard data for input to the system. In interpreting this trajectory, we must recognize that these figures represent estimates of average conditions over all types of products and processing facilities. The dashed vertical line signifies separation of manufacture commonly performed in the Northwest from manufacture commonly performed in other parts of the country.

If alder is destined to become an important continuing major component of northwest forests, then clearly a sound development is to increase the level of value added in the region in the processing of the resource. If alder is a transitory species that is not likely to be a significant part of the continuing resource, then substantial investments in processing facilities will not be attractive and the wood will continue to be wasted or moved in minimally processed form to other regions for conversion to finished product.

In the Northwest in the typical mature natural alder stand, we estimate that about 35.2 percent of the stand remains behind as forest residue in the form of tops, stumps, and cull material. About 34.5 percent of the stand volume is available as pulp logs and chips from manufacturing residue and another 16.4 percent is in the form of other residues such as bark, sawdust, and surfacing residue. Only 12.4 percent of the stand enters the furniture industry as surfaced dried lumber. These percents do not quite add up to 100 percent. The small difference is the volume loss from shrinkage during drying. It is assumed here that the rough green alder is dried to 9 percent

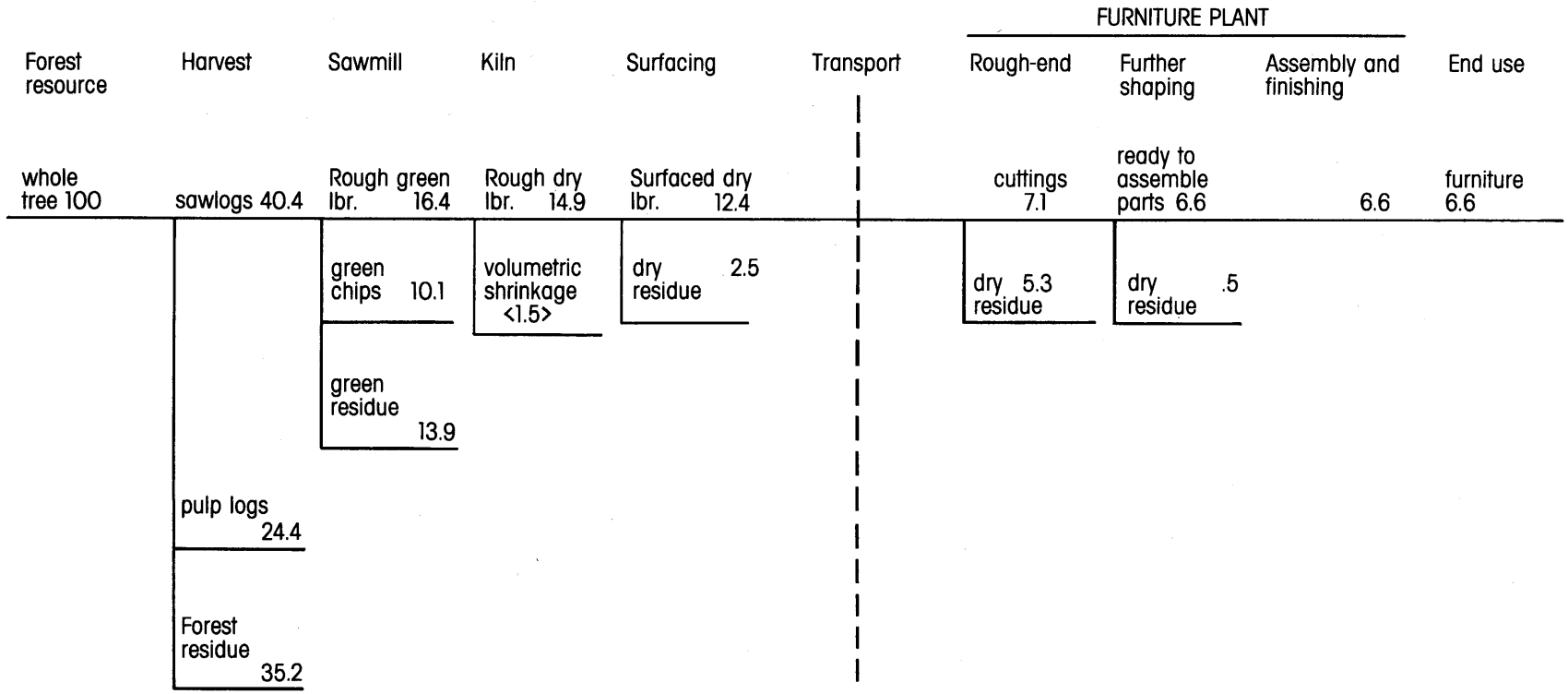


Figure 2.--RMS trajectory showing flow of alder from forest to furniture and use (numbers are cubic volumes).

moisture content. The recovery of dry surfaced lumber is approximately 31 percent of the log volume on a cubic volume basis.

Of the surfaced dry lumber received by furniture manufacturers, about 53 percent becomes furniture with the remainder developed as various forms of residue (sawdust, chips, particles). The conversion factors assumed for furniture manufacture are 57.5 percent yield in manufacture of cuttings from lumber and 92.5 percent yield in converting the cuttings into ready to assemble furniture parts. The loss in production of cuttings was estimated from the U.S. Forest Products Laboratory study on dimension yields from alder lumber (*4*) and from discussion with furniture manufacturers, who also suggested a yield range from a low of about 50 percent to about 65 percent, depending on the product line and mix of lumber grades used. The manufacturers contacted also suggested that about 90-95 percent of the cutting volume becomes finished parts after losses in turning, shaping, etc. In these cases, we have used the midpoint of these ranges. The trajectory points out that only 6.6 percent of the volume in the stand is likely to become furniture. It also indicates substantial opportunity for residue using industries.

A second trajectory (fig. 3) was prepared to illustrate the labor in producing furniture from alder. The values are man hours per cubic foot of material produced at each production activity. These figures were derived from CORRIM data (*3*) and from a brief survey of industry representatives. Again there is considerable variability in labor use depending on product line, degree of mechanization, etc.; and these numbers should be considered as only rough averages. They are useful however in showing the relative labor use among the various activities. A clearer picture of the labor use is gained when the labor man hours are multiplied by the corresponding quantity of material in figure 2. This information is summarized in table 2.

It is interesting to note the substantial contribution to employment which alder provides in regions outside the Pacific Northwest. These values may not be appreciated in the Northwest because they accrue very largely elsewhere. We strongly suspect that a value added trajectory (difference between gross receipts and factor costs) would be even more strongly biased toward activities in the conversion trajectory that are accomplished largely outside of the Northwest. One reason for this assumption is related to the input of other materials (glues, hardware, finishes) which greatly enhance the product value and the increasing cost of labor as the material moves from stump to finished furniture. At the same time, furniture producers in other regions may have a more difficult time utilizing alder manufacturing residues which could be readily absorbed in the Northwest. These factors combined together suggest a case for a vigorous attempt to attract more of the alder furniture industry into the Northwest if alder is viewed as an important continuing resource.

There are problems associated with the practice of shipping raw materials long distances to convert to consumer products. Integrated utilization may be difficult. A region which may be readily suited to the manu-

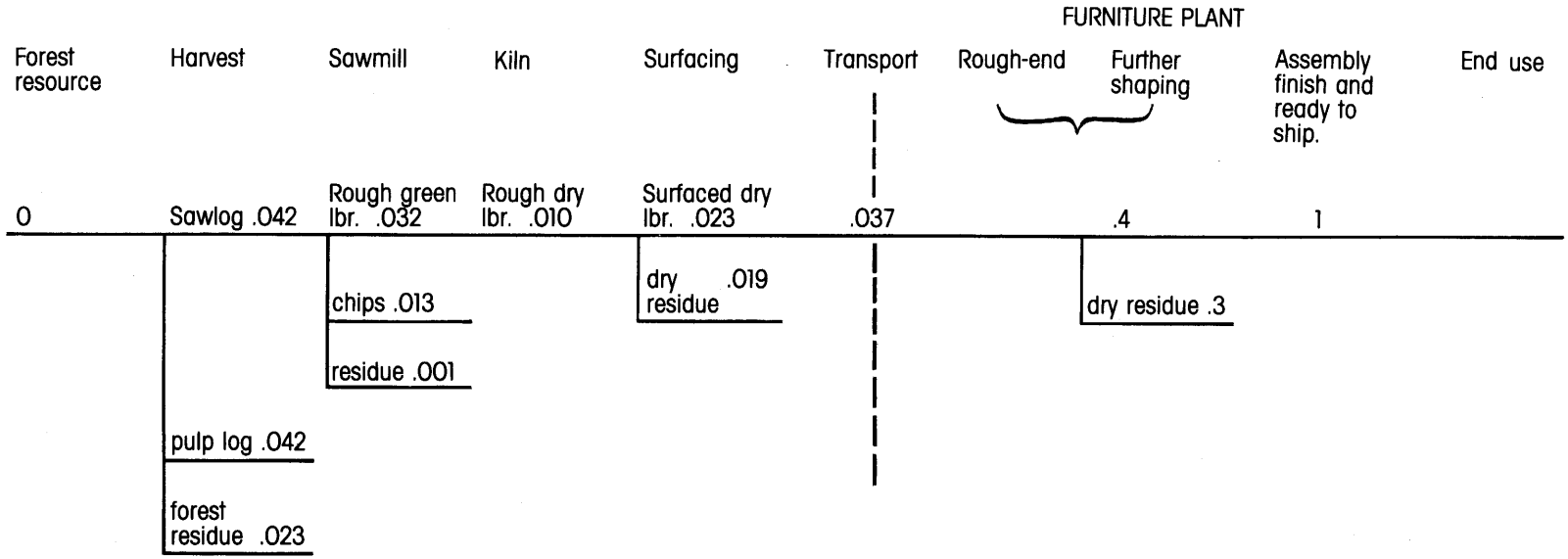


Figure 3.--RMS trajectory showing use of labor from forest to furniture and use (numbers are man hours per ft^3 at each stage).

Table 2--*Summary of labor man hours used in converting 100 cubic feet of alder stand into furniture*

Activity	Man hr/CF	CF	Total man hours	
Forest growing	0	100	0	0
Harvest sawlogs	.042	40.4	1.70	3.53
pulplogs	.042	24.4	1.02	
residue	.023	35.2	.81	
Sawmill R. G. Lumber	.032	16.4	.52	1.17
chips	.013	10.0	.13	
residue	.001	13.9	.01	
Kiln R. D. Lumber	.010	14.9	.15	
Surfacing S.D. Lumber	.025	12.4	.31	
residue	.019	2.5	.05	
Furniture parts for assembly	.4	6.6	2.64	10.98
residue	.3	5.8	1.74	
Assembly, finishing & ready for shipment	1.0	6.6	6.60	
Transport[1/]	.037	12.4 + 6.6	.70	.70
Total of man hours for all activities				16.38

[1/] Logging transportation labor is included in the harvest man hour data.

facture of the primary consumer product may be poorly adapted to the economically feasible conversion of residues. As wood markets improve to the point where whole tree utilization becomes an attractive prospect, there may be great advantages associated with the development of a diverse product conversion complex near the source of the raw material. For example, this could well argue for the growth of a substantial Northwest furniture industry based on alder as a raw material.

The alder utilization trajectory in figure 2 indicates that well over one half (57.4 percent) of the standing volume of stemwood is recovered in a variety of residue forms. At this time, relatively little of this residue is converted to useful consumer products. Growing demand for sources of wood fiber and increased attention to problems of providing viable substitutes for fossil fuels (*7*) suggest that opportunities for integrated utilization of the whole alder tree will be vastly improved in the near future and this could change the climate for the development of an integrated alder conversion system and make alder more attractive as a cultured species.

Finally, one can speculate about the changes in the trajectories if alder became a more deliberately managed species. The trajectories previously illustrated are based upon alder as it occurs in an essentially unmanaged condition. We would expect the following trends if alder production moved from the unmanaged to the managed state:

1. Man hours invested in forest growing would increase.

2. Forest residue would decrease and the fraction of usable roundwood would increase. Control of stocking and improvements in the trees grown as crop trees would increase the yield per tree and also result in fewer culls and small or stunted trees.

3. Perhaps deliberate management can significantly reduce the 35 to 50 years needed to grow merchantable sawlogs in unmanaged natural stands.

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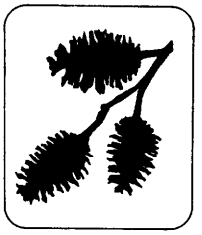
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ALDER RESEARCH OUTSIDE THE NORTHWEST: A BRIEF OVERVIEW [1]



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ABSTRACT

Over the past century Europeans have done much cultural and physiological research on Alnus glutinosa. *Black alder has also been studied and used extensively in Europe and the Eastern United States for land reclamation. Most physiological research on black alder has been related to its capability to fix nitrogen symbiotically, although some data on photosynthesis and translocation are available. Other European alder species that have received attention are* Alnus incana *and* Alnus cordata. *The Netherlands, Germany, Sweden, Finland, and Great Britain have alder genetics or tree improvement programs at one or more locations. Most of the cultural studies have had as their objective the increased use of black alder as an intercrop or rotation crop with conifers or poplars. In Great Britain there is renewed research interest in* Alnus rubra, *as a windbreak species for the protection of conifer plantations, and as an amenity tree.*

Introduction

We are fortunate in the Pacific Northwest to have a native, nonlegume nitrogen fixer that is fast growing and industrially useful, *Alnus rubra* (red alder). Some 13 genera of nonlegume woody angiosperms, encompassing 157 nodulated species, are now reported in the literature. Of these 13 genera, *Alnus* contains the largest number of species (32 out of 35)reported to bear nodules (*3*). Thus, a large reservoir of alder genetic variation is available for study and use, and perhaps more important, the possibility exists of great genetic variability in alder endophyte populations. Alders other than *Alnus rubra* in places other than the Pacific Northwest have received considerable research attention in the past and are receiving renewed emphasis.

[1]This is paper 1179 from the For. Res. Lab., Oregon State University, Corvallis, Oregon 97331.

The purpose of this paper is to give a brief overview of alder research in Western Europe and in North America outside the Pacific Northwest. European black alder, *Alnus glutinosa*, has received the most research attention in these areas. *Alnus incana* (grey alder) and *Alnus cordata* (Italian alder) have also been studied, but considerably less than *Alnus glutinosa*.

Ecology and Physiology

Black alder was the first nonlegume species upon which nodules were observed and reported (*17*), and its forestry potential was recognized early (*4*). Nitrogen fixation by black alder under field conditions was not confirmed until the 1950's (*2*). During that decade, the first broad treatment of the ecology of black alder was published in English (*8, 9*). Thus, intensive study of *Alnus glutinosa* is a recent phenomenon. Other European and Eastern North American alders have received even less attention. Study of black alder as a recent development is surprising because black alder has a vast range and plays an important role in many forest ecosystems. The natural range of *Alnus glutinosa* covers Europe except for the arctic and the Russian steppe (fig. 1). Its Eurasian distribution appears to be limited to areas receiving at least 50 cm of annual precipitation (*8*). Over much of its range, it occurs with *Alnus incana*, with which it is said to hybridize freely.

Black alder is commonly found on stream and lake margins and coastal lowlands, and McVean (*9*) reported that it "cannot regulate transpiration to any great extent by stomatal closure" and that "the alder is not adapted for the invasion of grassland, either directly or after a shrub phase. Neglected grass in which drainage has become interrupted and given rise to seasonal surface wetness is, however, ideal." Akkermans (*1*) recently studied nodulation and nitrogen fixation in fieldgrown *Alnus glutinosa* in the Netherlands. He observed that nodule weight in the field was consistently between 2 and 7 percent of the dry weight of the whole tree and estimated that the mean actual nitrogen-fixing activity in black alder groves probably doesn't exceed 130 kg nitrogen per hectare per year. No comparable figures are available for *Alnus incana* or *Alnus cordata*, but Akkermans' values for *glutinosa* are in rough agreement with those of Zavitkovski and Newton (*18*) for *Alnus rubra*. Mystery surrounds the alder nodule endophyte and its interaction with the host, but recent research (*13*) indicates that the endophyte varies greatly in infective capacity. Little is known about the alder endophyte's life in the soil, and an infective form has yet to be isolated in pure culture, although Lalonde et al. (*7*) have reported the isolation of a noninfective form. Good progress is being made toward understanding the way in which the *Alnus crispa* endophyte enters the host and the way it is nourished inside the nodule.[2] Perhaps the most important physiological studies from a forester's point of view are those relating

[2]M. Lalonde, Kettering Institute, Ohio.

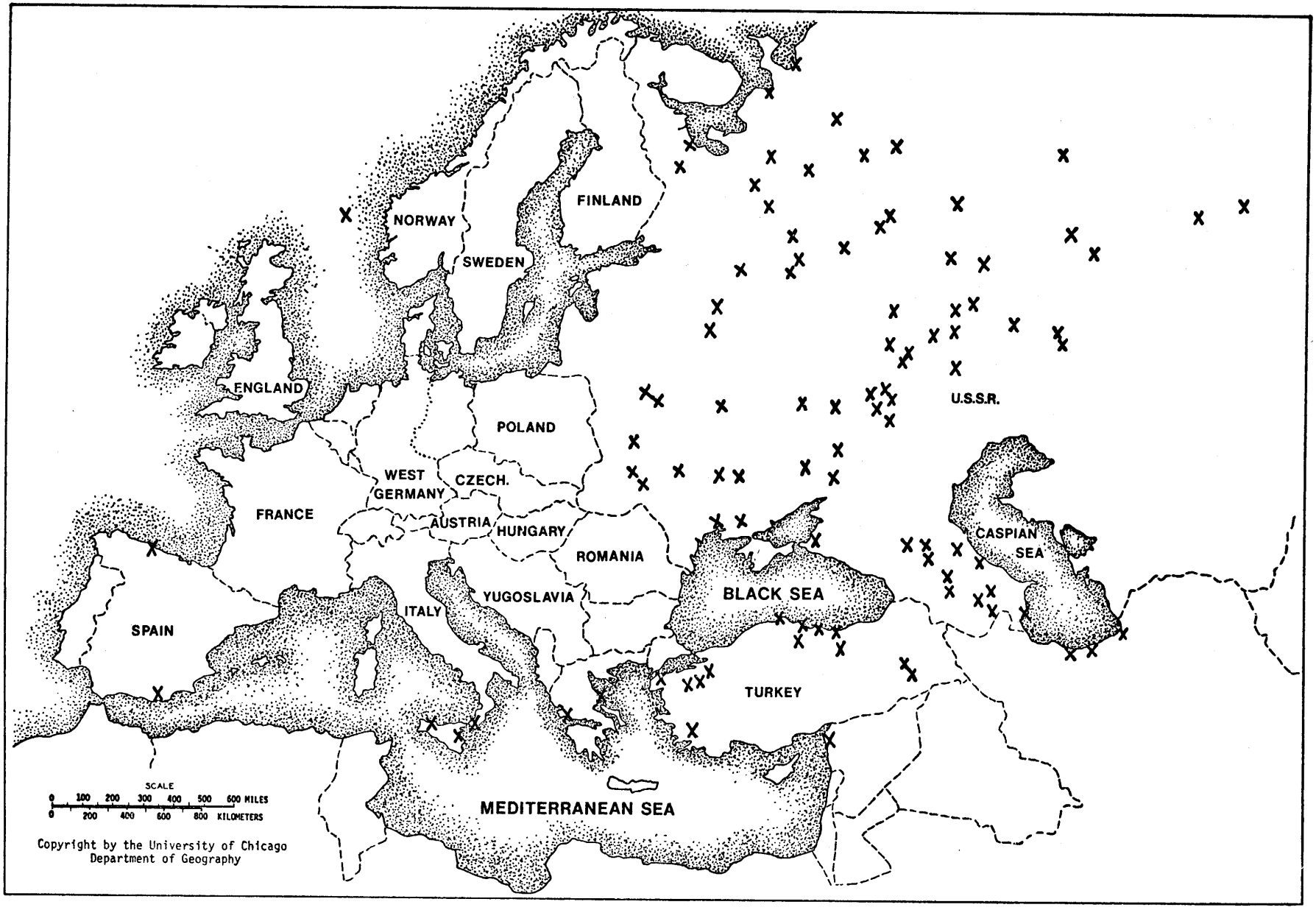


Figure 1.--Occurrence of Alnus glutinosa (*L.*) *Gaertn. is indicated by the symbol X.*

host tree properties to the effectiveness of nitrogen-fixing activity by the endophyte. The capacity of the host tree to supply photoassimilated carbon to the roots appears to be the principal limitation on fixation rate in nodules (*15, 16*). Recent studies in which the photosynthetic capacity of *Alnus glutinosa* was varied both genetically and environmentally showed that photosynthetic capability was positively correlated with nitrogen-fixing capacity (*6*).

Genetics and Silviculture

Basic genetic information about alders is scarce. The somatic chromosome number of *Alnus glutinosa* has been reported to be 28 or 56; other *Alnus* are reported as having 28, 42, or 56 chromosomes. Again, *Alnus glutinosa* has been the subject of most West European, as well as North American, practical tree-improvement work. Superior trees have been identified, and provenance and breeding work has begun in the Netherlands, Sweden, Finland, and West Germany. Weisgerber (*14*) reported that because of the increasing silvicultural importance of black alder in Germany, seed orchards are being established on the basis of progeny tests. In an initial comparison of progenies from free orchard pollination and controlled pollination, Weisgerber found that those resulting from controlled pollinations were usually superior to free-pollinated progenies.

In the United States, some tree-improvement work has been done on *Alnus glutinosa*. In 1963 the Forest Service established a provenance test of 15 *Alnus glutinosa* seed sources with material collected primarily from Germany. The test was put on a strip mine area in southeastern Ohio where soil pH ranged from 4 to 5. After 7 years of growth, the best trees averaged 20.4 feet in height and 2.7-inch d.b.h. Seed sources from southern Germany performed better than those from northern Germany, Belgium, Denmark, or Sweden (*5*).

The North Carolina Cooperative Hardwood Project has had an active program involving European alder for several years. Several companies are cooperating, but most of the work has been done in Alabama by Gordon White of Champion International.[3] Starting with seedling populations of unknown origin (Illinois Conservation Commission nursery production from Herbst Brothers seed), White now has some plantings 6 years old which have been producing seed for 3 years. He has selected 17 trees from these populations and used them as parents for 120 control-pollinated families which will be set out as a progeny test in 1977.

A new range-wide seed collection for *Alnus glutinosa* has been initiated by R. B. Hall at Iowa State University under the auspices of the NC99 Regional Tree Improvement Project. The objective of this work is to expand significantly the germ plasm base of *Alnus glutinosa* available for selection

[3]G. White, Champion International, and B. Zobel, North Carolina State, Raleigh, North Carolina, personal communication.

and breeding programs in the United States. Collections of seed were requested from more than 60 potential European cooperators. Response has been good. Material has already been received, and the collection should be completed in the fall of this year for outplanting in 1978 and 1979.

Most silvicultural research on alders has been directed toward their use as reclamation species or nurse crops, although there is recent interest in them as components of short-rotation fiber-production systems.

In 1965 the U.S. Forest Service established an intermixture study with *Juglans nigra* (black walnut) and *Alnus glutinosa* (unknown seed source) on a bottomland site in south central Illinois. After nine growing seasons, the alders averaged 35 to 40 feet tall and 5 to 6-inch d.b.h. Maximum size was 52 feet in height and 8.9-inch d.b.h. Unfortunately, at this rate of growth the alders overtopped the walnut (average height 23 feet) and suppressed their growth. Other conclusions of this study were: 1) On good sites under management, European alder can produce 3-1/2 tons of dry matter per acre per year. 2) Dimension stock suitable for furniture manufacture could be produced on short rotations. 3) The wood-quality characteristics of pulp from 9-year-old European alder was satisfactory for the manufacture of printing-grade paper (*11*).

Additional interplanting studies with black walnut and European alder have confirmed the problem of overtopping. Consideration is now being given to testing slower growing alder clones for suitability.[4]

In Finland, recent research has shown alder to be adapted to short-rotation culture (*12*), and Mikola (*10*) has described the use of alders in reforestation of bogs after removal of peat. In reforestation, pine interplanted with alder and fertilized with wood ash were 29 percent taller than pines planted alone with the same fertilizer treatment.

In Britain, there is renewed interest in *Alnus rubra* (there usually called Oregon alder) as a windbreak species for protecting conifer plantations, and as an amenity tree. Because it is deep rooting and deciduous, it is less susceptible to windthrow than Sitka spruce, the most commonly planted conifer. It is recommended particularly for poorer peat soils. On many sites in northern Britian, however, red alder is subject to an unexplained dieback usually occurring after 5-10 years of rapid growth.[5] This dieback is the principal factor limiting the use of red alder in British silviculture. Provenance trials and physiological research are now underway in an attempt to solve the problem.

[4]C. Bey, U.S. Forest Service, Carbondale, Ill., personal communication.

[5]R. Lines, Forestry Commission, Edinburg, Scotland, personal communication.

Conclusion

There is renewed interest in North America and Western Europe in alder research and silviculture. We in the Pacific Northwest can profit from alder research elsewhere. Better coordination among research efforts would speed realization of benefits to be derived from alder culture.

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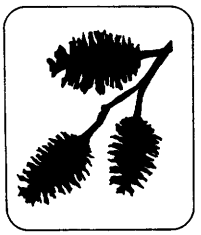
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HARDWOOD CULTURE IN THE EASTERN UNITED STATES



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ABSTRACT

Many hardwood plantations are being established in the East. Populus deltoides, Platanus occidentalis, Liquidambar styraciflua, *and* Juglans nigra *are the species that have been planted and studied most.*

Introduction

This paper describes hardwood management in the eastern United States where natural stands account for over 99 percent of the hardwood production. Today, however, between 100,000 and 150,000 acres are in plantations; and the acreage is increasing.

Research on planting of southern hardwoods has been conducted by the Forest Service, U.S. Department of Agriculture, at the Southern Hardwoods Laboratory at Stoneville, Mississippi, for over 30 years. Initial efforts began with cottonwood in the 1940's and were greatly accelerated with the advent of commercial plantations in the 1960's. The Forest Service has two other units working with intensive plantation culture of hardwoods in the East. One is at Carbondale, Illinois, where research is being conducted on black walnut (*Juglans nigra* L.), and the other is at Rhinelander, Wisconsin.

The Trend Toward Plantation Culture

Eastern hardwood forests contain many species and grow on a wide range of sites. The biological diversity among species represents a challenge to silviculturists whose primary tool in the natural forest is stand manipulation. Evenaged management has been applied to many natural stands during the past 25 years which led, in the 1960's, to clearcutting as the primary silvicultural system. During the past 5 years, more consideration has been given to unevenaged management, partly because of public reaction to clearcutting.

By creating, through cutting or deadening, conditions that are conducive to the establishment and growth of hardwoods, silviculturists have been able to favor selected species in many different hardwood timber types. For example, forest openings of 1 acre or more usually favor the development

growing space, and growth is below potential. First and even second thinnings can be mechanized by removing alternate rows, but later thinnings are selective.

Merchantable yields from cottonwood plantations have ranged between 3 and 3-1/2 cords per acre per year over 10 years (*6*). Early results with other species indicate that plantation trees grow significantly better than the same species in natural stands.

Recent Work

Sycamore, black walnut, sweetgum, and *Populus* spp. have received the most attention for planting in the East, but current work at Stoneville involves nine other hardwood species, including five oaks. Considerable progress has been made with cottonwood on site selection (*1*), plantation establishment and management (*7*), and insect and disease identification and control (*8*). The most recent work with cottonwood involves 8- to 10-foot tall planting stock to eliminate the need for straddle cultivation, to reduce cost of site preparation, and to establish trees above competing weeds and deer (*9*). Basic work is also being done in nutrient cycling to guide foresters on selection of rotation lengths and the need for species mixtures.

The concept of growing hardwoods at spacings as close as 4 by 6 feet in short rotations (4 to 6 years) followed by whole tree chipping and coppice regeneration is receiving attention. Predicted yields from sycamore grown under this system are high but so are costs (*4*). Initially, the short-rotation, close-spacing work done in the southeast at Athens, Georgia, was for fiber production (*5*). But during the last 2 years, such systems have been envisioned for fuel. At the Forest Service Laboratory in Rhinelander, Wisconsin, hybrid poplars are planted at very close spacings (to 9 by 9 inches), irrigated, and fertilized to achieve maximum yields of fiber in a short time (*3*).

Although planting acreages of eastern cottonwood and black walnut appear to have stablilized, other hardwoods are being more widely planted than in the past. The basic technology for planting most hardwoods is either available or soon will be; the future is in refinements and cost-cutting techniques. Although methods of establishment and management may vary by species and localities, plantations of eastern hardwood species most surely will increase as the demand for hardwood products increases.

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HARVESTING OF RED ALDER



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ABSTRACT

The harvesting and marketing of red alder from the Oregon coastal counties requires a company to address itself to several major concerns before entering a major program.

A few of these would be the availability of an efficient contracting force, manpower, harvesting equipment, labor and overhead costs, and the availability of a continuing market. Also, operating seasons in relationship with inventory control, lack of demand for all log grades, sizes and species, capabilities of sawmills to market residuals and adequate log storage facilities.

The management of red alder has given the tree farm manager many logging, marketing, land rehabilitation, and associated challenges. Many of these challenges or obstacles are interrelated and will be discussed accordingly.

My company, Publishers Paper Co., owns and operates 150,000 acres of primarily high site land on the northern coastal mountain range of western Oregon. Of these lands, about one-third of the area supports a combination of native brush types and various age-classes of red alder and bigleaf maple species. Scattered throughout all of these lands, in densities ranging from single trees to small seed blocks, are mixed conifer stands of Douglas-fir, western hemlock, Sitka spruce and western red cedar. Years ago, the original conifer species on most of these lands were either burned or harvested, without any regard for regeneration except for occasional seed trees and seed blocks. Historically, the creek bottoms and lower wet sites of the Coast Ranges had always supported red alder. As time progressed, red alder encroached onto the burned or logged over areas.

Several years ago, we were faced with the question of whether to manage for red alder or to convert these stands to conifer species. Various organizations have made economic analyses on the feasibility of immediate conversion of alder to conifer species, without regard to age or size of the stand. Some studies favor the retention of red alder to full maturity. Since this will be discussed further in the conference, I will only express the thinking of our Company.

We foresee the ever-increasing problem of guaranteeing a wood supply of conifer species for our own softwood sawmills and paper mills. Presently, we rely heavily on raw material from State, Federal, and private timber sales. Due to the every increasing pressures on governmental agencies to increase Roadless and Wilderness Areas, in effect reducing allowable timber cuts and the use of more sophisticated and expensive harvesting techniques because of environmental concerns, the Company felt that having our own lands, with fully-stocked stands of conifer species, will be a necessity 30 to 40 years in the future. This is not to say that we are free of any harvesting restrictions. Restrictions continue to mount on private lands. We felt that we must be less dependent on questionable outside sources for future raw material demands.

Therefore, we have an accelereated alder and brushland conversion program on understocked high site lands to achieve our objectives of fully stocked conifer stands on conifer sites within the next 7 to 10 years. This does not mean that we are trying to make red alder an extinct species. On the contrary, when red alder is growing on true alder sites, it is being managed for that species.

Over the past few years, we, as the landowner and timber purchaser, and our logging contractors have continually encountered recurring problems in harvesting and marketing hardwood logs. Ever-present equipment failures and machine and line fatigue occur regardless of the type of harvesting operation and situation. The major concerns in alder harvesting and marketing are the following:

A. a timely road construction program.
B. availability of an efficient contracting force.
C. manpower.
D. harvesting equipment.
E. rising labor and overhead costs.
F. availability of a continuing market.
G. operating seasons in relationship with inventory control.
H. lack of demand for all log grades, sizes, and species.
I. capabilities of sawmills to market residuals.
J. adequate log storage facilities.

The development of a road system in all of our ownership containing stands of red alder is a continuing process. We initiated an ambitious road construction program 2 to 3 years prior to our accelerated alder harvesting program. Since rock sources are plentiful on our ownership in the northern coastal counties, the rocking of all mainline and secondary roads is normally completed one season after subgrade construction. The reason for this is to give the subgrade an opportunity to settle and become firm before the placement of about 40-60 yards of crushed rock per 100-foot station. We are not so fortunate in the central coastal counties of Oregon. Suitable crushing rock is scarce and must be limited to the mainline roads. Logging from secondary roads is usually limited to the drier spring and summer months.

The availability of an efficient contracting force is most difficult, and we have tried numerous operators. Some operators have started in alder logging with a low investment in equipment because of the uncertainty of the venture. Alder logging is not a high volume operation. Loggers can cover only a limited amount of ground in a given day and therefore produce a smaller volume than if they were logging conifers of a similar age and size.

But in order to harvest alder on a large scale, we had to rely on our existing conifer contracting force as a nucleus to build upon. Most of our contractors were equipped to harvest high volumes per acre of mature conifer species, using expensive cable systems.

We tried to convince some of the high producing operators, that generated 10 to 12 loads of conifer sawlogs per day, to shift down to a salvage concept of producing only 4-6 loads of alder per day. This was not done overnight. It has taken several operators and several years to come up with a group of operators who think nothing but red alder salvage logging. Even though a contractor would get the same number of dollars per day that are necessary to cover his daily costs whether he was logging conifer or alder, the idea that alder logging was profitable had to be emphasized time and time again.

It takes a lot of convincing to change a production oriented logger to even think that there may be profit in a hardwood species logging operation. This has been one of the hardest hurdles.

We have not done away with the small operator with a low investment in equipment. He is an important part of the harvest program. Small isolated tracts with below average volumes per acre are best suited for the small operator.

Manpower

The search for manpower for alder harvest operations continues to plague the contractor. Good, experienced timber fallers willing to work in alder stands are very difficult to obtain. The ability of timber fallers to physically traverse steep side slopes that support an overstory of merchantable red alder wih an understory of dense vine maple, salmonberry, and thimbleberry is difficult to measure. Timber fallers take special precautions to provide escape routes away from the specific tree that is being felled. This additional step of slashing or cutting the dense brush is time consuming but extremely important. Also, red alder growing in moderate to steep slopes tend to lean out over the slope. This situation requires additional falling time.

A practice used on large red alder and bigleaf maple is the "boring technique" of falling. After a face cut is made in the downhill side of the tree, a horizontal cut behind the face cut is made through the center of the tree. A narrow block of holding wood is left between the boring and the

face cut for support. The remaining horizontal cut of the back strap releases the tree. This will afford the timber faller an opportunity to minimize "stump pull" and "barber chairing." Also, it is the safest way to fall large, heavy leaners.

The present day direct-drive chain saw also gives the timber faller quicker and greater cutting ability over the gear driven saw. This is primarily a safety advantage in cutting red alder and will also minimize "stump pull."

Red alder, with its characteristic unbalanced crown and outward lean on steep slopes, normally dictates that the tree be felled downhill rather than across the slope. Steepness of slope and density of brush dictate the bucking of the tree into logs. In most cases, it is cheaper to have the landing chaser do the bucking. However, landing size and number of log sorts dictate the feasibility of this method. Limbing is a minimal part of the falling and bucking operation. What small side branches exist on a tree are usually eliminated during the course of yarding.

Rigging crews have similar difficulties in traversing the brushy slopes. The layout of logging turns on cable settings in hardwoods proves to be more time consuming than on conifer settings. The openness of the alder canopy allows more sunlight to reach the forest floor. Thus, brush cover grows more abundantly in alder stands than under the tighter and darker conifer canopy. The density of underbrush and the ability of men to work in and through it must be reflected in ample cost allowances for yarding. Cost allowances for falling, bucking, and yarding cannot be measured solely on the volume per acre of a stand or average yarding distances of a setting.

Another aspect of alder harvesting is the morale factor of woods crews. Historically, being piece-count or loads-per-day oriented, the rigging crew and landing crew has to relate to accomplishment in another way. Most rigging crews will cover 1 to 2 acres per day. Since alder stands on our tree farm range between 2 to 15 thousand board feet per acre, it becomes quite apparent that they cannot base their accomplishment solely on log production. Similar crew sizes operating in fully stocked conifer settings will far exceed their production. A sense of accomplishment is arrived at by knowing that logging is the initial step in reestablishing conifer stands on conifer sites.

Equipment

Regardless of the species harvested, similar techniques of cable yarding and loading are being used. Conventional cable yarding techniques such as ground leading which has minimum available deflection to the partial or fully suspended skyline system, which utilizes deflection principles, are commonly used in alder harvesting. The loggers' ability to ascertain when to use a specific system will maximize their productivity and profit. Also, timely preventative maintenance on equipment will provide less lost time in the long run.

There is an increasing awareness, and rightfully so, that the need to protect soil values and water quality is of vital importance. A minimum of ground disturbance and log breakage is achieved when the skyline or slackline system is used. Higher equipment investments are, however, required to accomplish these objectives. One must note that whatever the system used, it must pay for itself or it becomes economically impractical. Also, skyline yarding systems, while protecting soil values, do minimal disturbance to slash and brush concentrations. This in turn increases expenditures in slash disposal and site preparation operations.

Furthermore, regardless of the cable system, the lack of suitable and ample stumps for guylining the yarder is common in alder salvage. This is also true for placing tail blocks and corner blocks along setting boundaries that are established in pure alder stands. Alder stumps, used for these purposes, lack the holding power that large conifer stumps afford.

Some form of cable systems are used on 75 percent of our tree farm operations. These systems vary in size, vintage and capabilities. Many low investment machines are homemade by ingenious operators. A typical example of this would be a 50-foot Porta-Spar mounted on a pre-1940 Walters 2-1/2-ton truck with a BU50 hoist powered by a Walkashaw gasoline engine. This is an extremely slow yarding machine with a line speed of about 500 feet per minute and poor braking capacity for tight lining capabilities. As time progressed some of our operators upgraded their investments in yarders to machines like the track mounted West Coast Tower. This machine has faster line speeds, longer yarding capabilities, and a skyline drum for skylining operations.

When possible, tractor and rubber tire skidders complement the cable operation. Utilizing both the tractor and cable yarding techniques on a common landing will reduce logging costs. In the past, tractor and rubber tire skidding machines were limited to the dry summer months. Since the advent of the wide flat track skidding machine such as the FMC, we have been able to expand the non-cable yarding skidding season to the point that necessary cable yarding has been reduced by 10 percent to the present 75 percent. The running surface of this machine applies very little pressure to the soil as opposed to the conventional rubber tire skidder. It allows skidding during non-rainy winter months where skidders and tractors would be prohibited because of no traction. We have found that it does no appreciable amount of soil compaction. This machine is capable of yarding over a layer of brush and slash debris, thus minimizing the need for tractor roads. This type of machine will climb slopes up to 40 percent, sometimes yarding scattered volumes that would have been too expensive to log with a cable system. It also has a higher pay load than the conventional rubber tire skidder.

The present hydraulic-type loading machine affords our contractors the ability to load trucks quickly and neatly. An average of 40 to 45 pieces of alder per load can be expected. Only through experience can an operator become proficient in the loading of frequently fast-tapering, irregular-shaped alder logs.

Besides the main functions of a harvest program, additional tasks must be concurrently performed to prepare the site for further rehabilitation and to guarantee soil stability and water quality. These secondary, but important, tasks include machine and hand fire trailing, snag cutting, slashing of unmerchantable stems, stream clearance, occasionally complete cull log yarding to the landing site or a partial pull-in of merchantable logs from the perimeter of the setting. These are mentioned as part of the harvesting process because they add significantly to the overall cost of producing the alder log.

Cost

What do these individual operations cost? Cost will be given as an overall average for each job. We have harvested alder from areas that contain single trees per acre to an upper limit of 20 thousand board feet per acre. In nearly all cases, these volumes include varying amounts of scattered conifer species. Our basis for computing compensation to the logger is a combination of what we feel he should produce on a particular operation with the equipment and investment he has available, the length of the average operating season necessary to amortize his investment, the additional tasks to be performed that do not aid in log production and the contractor's labor, equipment repairs, overhead charges, and profit and risk expenses. Keep in mind that in nearly all instances of a salvage program, red alder has more pieces of irregular form, small diameter, higher difficulty in felling, bucking and yarding, and lower volumes per acre than conifer stands of similar age, size and density. Therefore one will experience substantially higher logging costs.

The first phase of the harvest operation is felling and bucking. Average cutting costs in alder are from $10.00 to $15.00 per Mbf. Since an average truck load of alder scales out at 3,500 bd. ft., this cost represents between $35.00 to $52.50 per load. Converted to a weight basis--the cost is $0.67 to $1.00 per thousand pounds. The average cutter today is seeking between $90.00 to $100.00 per day. This pays his wages for 6 hours cutting, transportation to and from the job, and saw costs. A timber faller will average from 10 to 14 Mbf per day of felling and bucking.

Because of the complexity of yarding due to the numerous types of yarding techniques and numerous obstacles encountered (streams, buffer strips, long reaches, and required log suspension) costs vary greatly and can only be discussed as an average. The basic yarding crew is four men. This includes the yarder operator, chaser, and two rigging men. Labor costs for this work force, including overhead and transportation, amount to $400.00 per day.

Overhead charges for labor, which have risen sharply, add costs to the operation. Take, for example, State accident insurance rates for Oregon. From July, 1975 to July, 1977 these rates have gone from $22.22 per $100.00 of wages to $35.00 per $100.00 of wages, or an increase of 58 percent in 2 years. This cost alone has increased the harvest cost an additional $5.00/Mbf.

With labor costs and the high cost of yarding equipment that must be amortized and maintained, one can quickly see that a high volume of production is necessary in order to achieve an average cost of $28.00 to $32.00 per Mbf or $1.88 to $2.15 per thousand pounds for the yarding phase. It becomes necessary to utilize the cheaper tractor yarding technique whenever possible to maintain cost control because of the necessity of cable yarding most of the area.

Loading costs average between $12.00 and $16.00 per Mbf or $0.81 to $1.08 per thousand pounds.

Advanced decking of logs from low volume yarding areas without immediate loadout will make loading equipment available for the higher producing adjacent settings. When cull yarding or stream clearance tasks must be accomplished on the logging side where the loader was working, the operator can shift his loader to the predecked wood. This helps maintain an even flow of logs to the market and allows cost control of the loading phase.

The additional tasks that are concurrently performed during the harvest continue to increase in cost. Snag cutting, fire trailing, stream clearance, and cull log yarding are all done to varying degrees on any particular operation. An overall realistic average cost for these tasks increases log harvesting $8.00 to $12.00 per Mbf or $0.54 to $0.81 per thousand pounds.

A summary of all harvesting costs reflects a range of $58.00 to $75.00 per Mbf f.o.b. truck. Converted to a weight basis, this amounts to $3.90 to $5.04 per thousand pounds.

Present trucking rates demand about $27.00 per hour. Based on a 9-hour day, the average log truck is able to haul three loads of alder per day. This total cost of $240.00 per day hauling 10.5 Mbf converts to $22.85 per Mbf or $1.54 per thousand pounds.

To summarize, these costs represent a range that the large majority of salvage operations will fall within. These costs do not reflect the company's administrative costs, stumpage rates, or road construction costs. They do represent costs experienced not only from company land operations but also from government alder conversion timber sales. Therefore, the range of logging and trucking costs is between $80.00 to $100.00 per Mbf or $5.44 to $6.58 per thousand pounds. One can see that these costs, when added to stumpage and administrative costs, will frequently exceed log market values. Rising costs of labor and equipment make it paramount for the logging industry to find more efficient ways of harvesting alder. However, the alder industry must also recognize these rising costs and do their part in allowing higher log values at the market place.

Another main concern is the availability of a continuing hardwood market. Adequate communication between buyer and seller about forthcoming market declines will minimize the amounts of felled and bucked red alder logs. As everyone knows, cut alder will decay rapidly if left in the woods, especially if felled during the sap flow period.

An adequate well rocked road system will allow flexibility in the landowner's harvest program by lengthening the operating season on his lands.

In recent years, government agencies have increased the sale of red alder in their efforts to convert alder stands to conifer species. The relatively short operating season, normally from June to October on many alder timber sales, has a log saturation effect on the market. This has forced change of some logging programs to the "off" season in order to maintain an even flow of logs to the market place.

Another problem of a large scale alder harvesting and conversion program is that all sizes and grades of alder are produced. Since the sawmill desires the higher diameters of alder sawlogs, the landowner is left with the low grade and pulp type logs for which he must find a suitable outlet. We have been fortunate in disposing of the smaller logs to a local plug mill. But as we accelerated the alder harvest, it became apparent that this one outlet within the economical haul distance could not absorb the high anticipated volume of smaller logs. At about this same time, alder lumber demands increased. Local sawmills started second shifts, thus requiring more wood. We could generate the sawlog volume to help satisfy their needs but in so doing, generated proportionally more small logs. To high-grade an alder stand, leaving the low grade and pulp logs, would not only be poor utilization and waste dollars, but would increase a slash debris problem. We reached an agreement that all outlets would be treated equally. Each sawmill, plug plant, or veneer plant would take camp run logs, which included logs down to a 5- to 6-inch top. This wood was sold to them on a per ton basis. We try to merchandize wood down to a 30-board-foot log size. This program has provided a wood supply to all outlets and has allowed us to continue our program.

Furthermore, as the demands for red alder increased, so have available supplies. Some government agencies also require the removal of the lower grades and pulp logs on alder conversion timber sales. The general size for merchantability is that No. 4 grade or 6-in-diameter logs be removed down to a volume of 10 bd. ft. This low merchantability standard of 10 bd. ft. per piece means that a 6-in log 8 foot long must be harvested. This type of utilization, along with stumpage rates of $40.00 to $50.00 per Mbf on No. 3 grade logs, only compounds the overall harvesting problems. In most instances, these stumpage rates are established by the various governmental agencies using their standard appraisal systems. Due to the rising logging and trucking rates, which are not truly reflected in the appraisals, it becomes necessary to subsidize contractors in other ways in order to show a breakeven point on alder harvest.

The lack of industry demand for bigleaf maple adds concern. Many of our ownership blocks have an abundance of bigleaf maple growing in association with red alder. This must be logged along with red alder in order to allow an operation to be economically feasible.

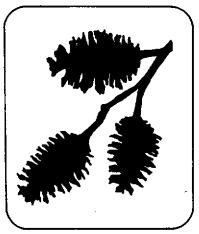
Capabilities of alder sawmills, plug mills, and veneer plants to market sawdust and chips have an effect on all sizes and grades of logs. Here

again, the buyer and seller must communicate in order to limit deliveries during times of soft residual markets.

The need of all manufacturing plants to provide ample storage facilities for logs is a continual problem. Buyers of alder must keep in mind that the producer cannot always deliver raw material as originally agreed. Due to weather and road condition changes, fluctuations in the softwood market, and timber sale restrictions, the supply of wood may lag behind a schedule or come faster than what the buyer wants. As alder sawmills take advantage of good markets by adding second shifts, they must recognize the need to expand yard facilities to handle adequate log supplies.

Finally, one of our concerns in the alder conversion program is public opinion. The private sector that lives, works, and recreates in and around harvesting activities must be informed as to reasons why certain management techniques are being used. Many times they will not agree with a specific practice, but it is our responsibility to communicate and express our view point. We are in an age that the public demands that we manage our resources wisely so that demands for the future will be met.

ALDER CHARACTERISTICS AS THEY AFFECT UTILIZATION



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ABSTRACT

The utilization of red alder in the Pacific Northwest is tied to its location, yield, tree size, and wood properties. Up to the present time, conifers have been utilized and managed because they are more profitable. When the older stands of large conifers are harvested, alder may become fully utilized on its own merits.

Alder (*Alnus rubra*) is the most important and the only significant hardwood in the Pacific Northwest. It ranges from central California to Alaska, with the best commercial stands being in the middle of the range (fig. 1).

Alder has been considered a weed and a problem by many forest land owners. This conference may mark a turning point in our attitude and management of this species--I hope so. Recent surveys of the Pacific Northwest have revealed increasing acreages and volumes of alder. In many cases this difference is due to better stand classification. Many previous surveys and forest inventories classified young alder as brush. Recognition may be an indication of better times ahead for alder.

Forest land managers in past years have tried many management techniques for alder lands which have included:

ignoring it,
destroying it by spraying, smashing, and "hack and squirt," and
harvesting, selling, and/or utilizing the logs, followed by attempts at conversion to conifers.

Usually these activities have cost the landowner or logger money. So we have a problem in utilization. Why? What characteristics of alder have created this problem?

Alder has several characteristics which have an effect on utilization:

location (a hardwood in a softwood economy),
prolific seeder, preferring good sites,
growth patterns and yields,
tree and log size, and
wood properties and grade.

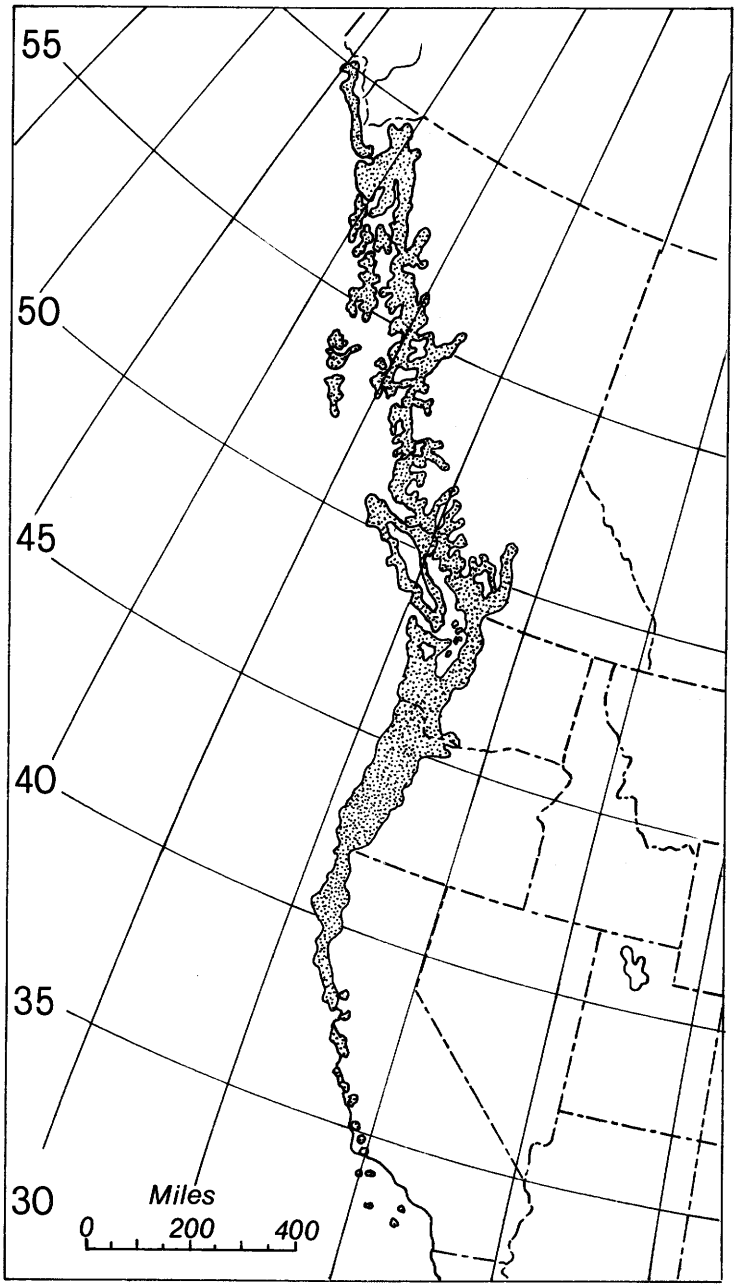


Figure 1.--Natural range of red alder (Alnus rubra).

A HARDWOOD IN A SOFTWOOD ECONOMY

Historically, the forest industry is geared for softwoods in the Pacific Northwest. The mills, logging equipment, land management techniques, and forestry education have been Douglas-fir oriented. Red alder finds itself in one of the largest conifer producing areas in the world.

The hardwood industry in the Northwest is small and struggling. Some pulp mills buy alder logs for chips. Alder sawmills are small and scattered about the region. Generally they are owned by private individuals with no land holdings. Alder logs are purchased from loggers or landowners, and often come from conifer clearcuts or farm lots. Products are sold to jobbers. Consequently, it is not uncommon for alder mills to open and close frequently, depending on log supply and orders for the products.

The demand for alder logs is far below the potential supply. This surplus in supply has created a rather low value for the logs. Comparisons of red alder characteristics in yields, grades and values with those of Douglas-fir and western hemlock are necessary in our current economic situation. All of the comparisons made in this paper are made from normal yield table data site index 140, site III, base 100. On base 50, this is slightly less than site index 90.

PROLIFIC SEEDER, PREFERRING BEST SITES

Alder is a prolific seeder, starting at young ages. Seed will carry for long distances. High site land that is clearcut and burned can and will seed in with alder if standing trees are within range. Many of the alder stands which exist today were started in the 1920's through 1940's from clearcutting and burning.

During this period, alder was not utilized except as fuelwood. Alder trees were either left, knocked down, or burned. Alder stands tend to be found in the damp, fertile creek bottoms, the best growing sites. These are also the most fire resistant sites. Consequently, alder seed sources are nearly always available. Thus, alder stands are very common in the higher site coastal and valley areas in the 30- to 50-year-age range. This will make up a rather large share of the wood supply in the next decade or two.

Industrial and private ownerships, which have contributed the lion's share of the forest products to date, also contain a high proportion of alder. Figure 2 illustrates the higher percentage of alder in private ownership. This is also the higher site land. Red alder only grows to elevations of 2,500 feet.

GROWTH AND YIELD

Alder is often referred to as a fast growing species. This is true in some respects and not true in others. Growth is a rather gross term, and must be specified to be meaningful. Height growth of young alder is very

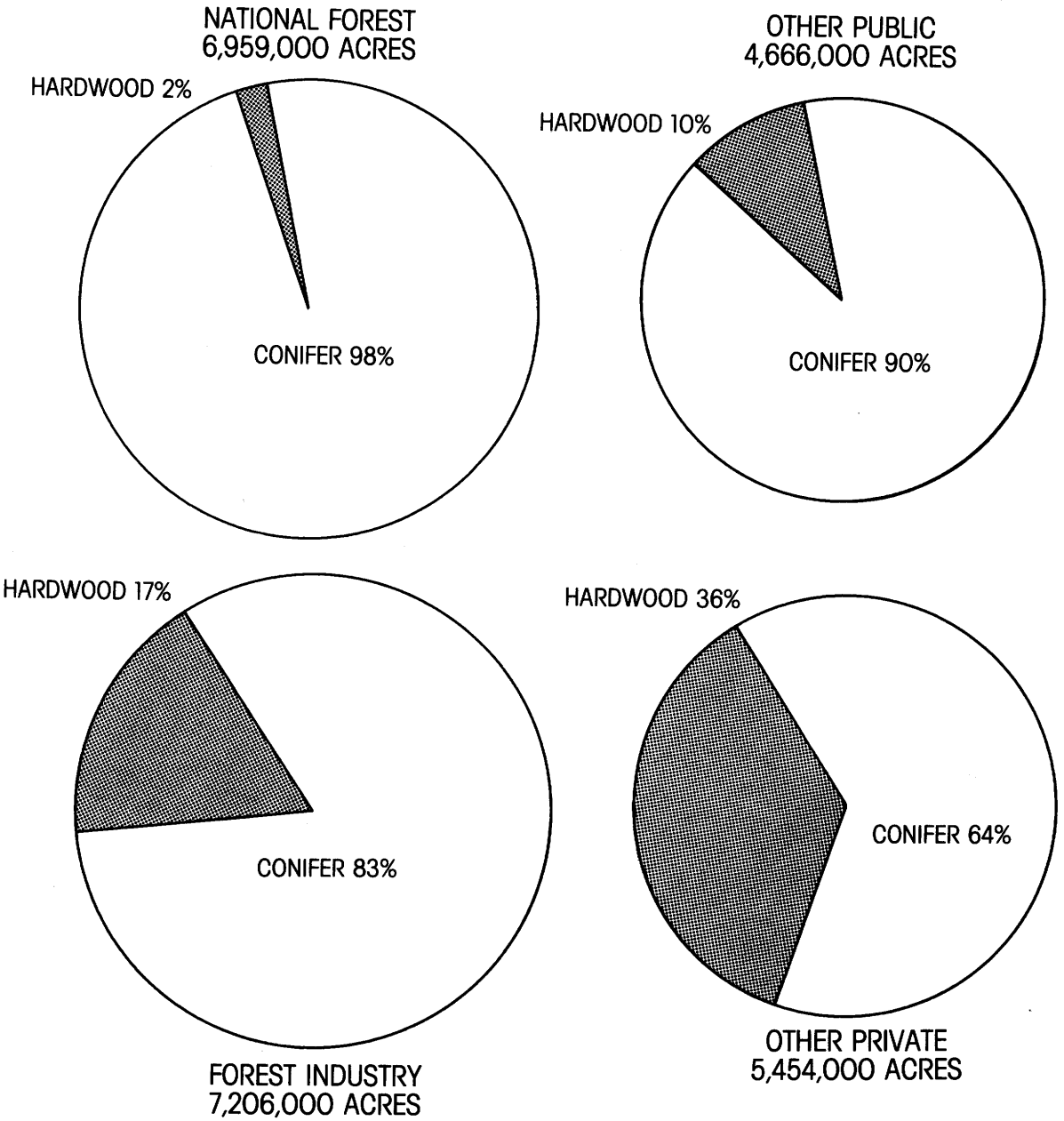


Figure 2.--Acreage distribution of alder and conifer by ownership category, Western Oregon and Western Washington.

rapid. Compared to the conifers (fig. 3) alder produces the tallest trees for the first 30 to 40 years. Many of you have probably observed alder growing 5 to 10 feet high on a new road cut in the first growing season. Plantations of Douglas-fir are often invaded by natural alder seeding which must be sprayed or it will quickly overtop the fir. Why, you may ask, do we spray the alder when it will outgrow the fir? The answer is volume. Figure 4 plots the gross cubic volume of the three species over a 60-year period. Alder does outproduce the conifers for the first 18 or 20 years; however, at age 60, a common rotation length, western hemlock volumes more than double those of alder. Short rotations may be an answer.

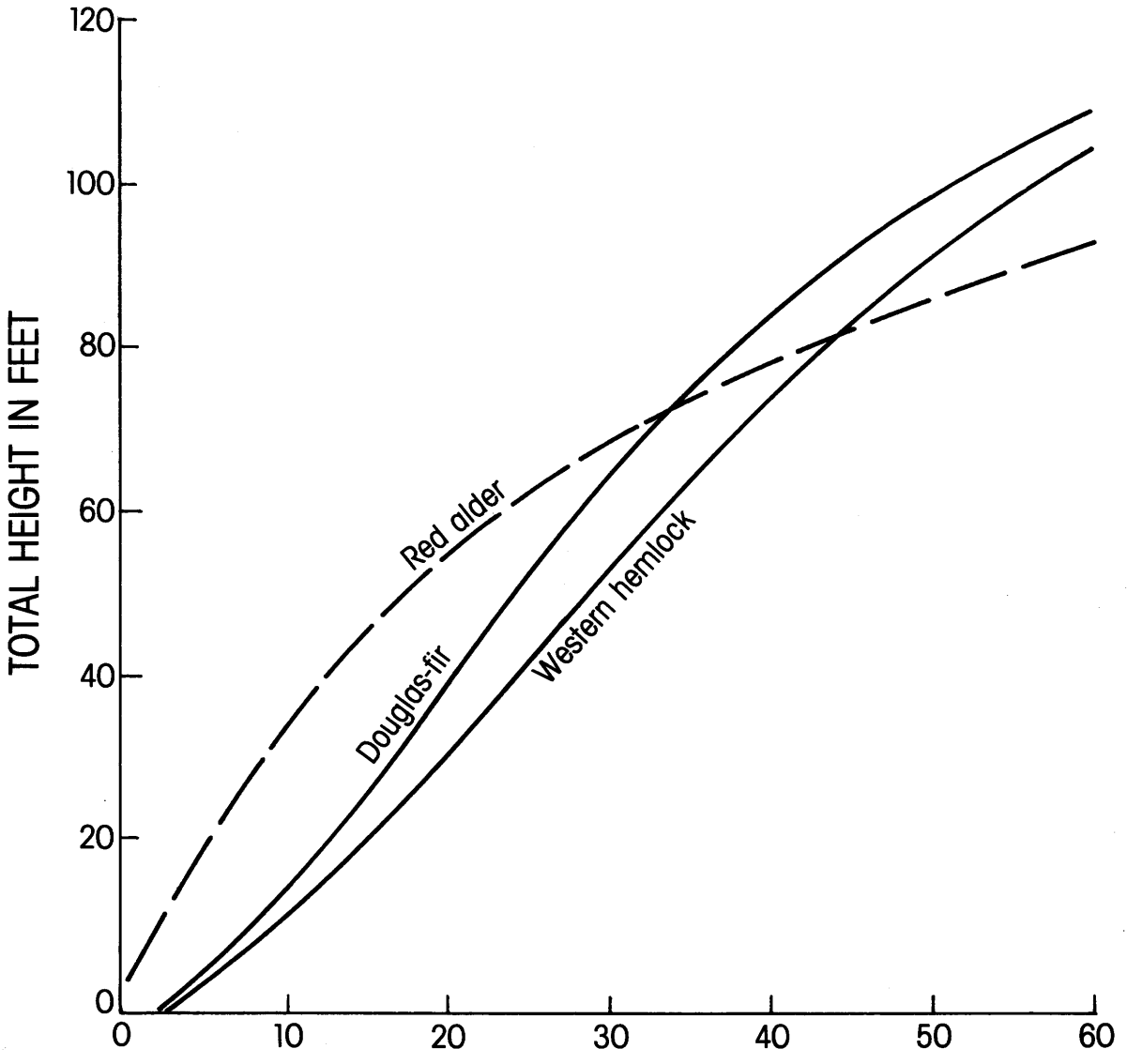


Figure 3.--Comparison of dominant and co-dominant height between Western hemlock, Douglas-fir, and red alder. Normal yield tables at site index 140.

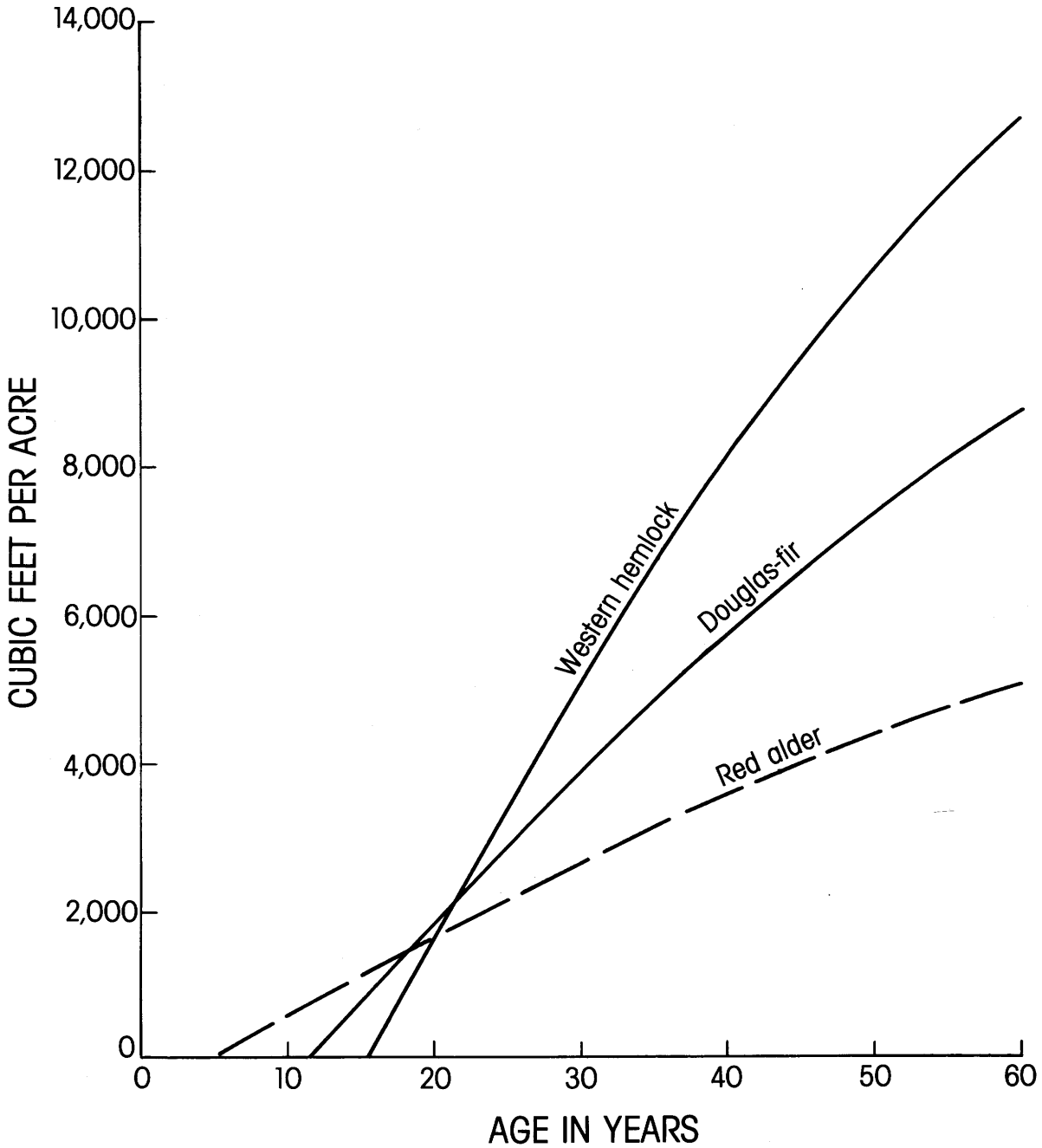


Figure 4.--Yield comparison of Western hemlock, Douglas-fir, and red alder. Normal yield tables at site index 140.

TREE AND LOG SIZE

Alder stands generally start with many thousands of trees per acre. Without management, which is the case for almost all alder stands, the trees compete for survival, resulting in slow diameter growth and high tree mortality. Consequently, the typical 40-year-old stand today has a small average diameter, usually about 10 inches. This results in a small tree and log size. Figure 5, however, shows that average tree volume for normal stands of alder is not much different than for conifers in the 60-year rotation. Red alder trees are actually larger than the conifers during the first 40 years.

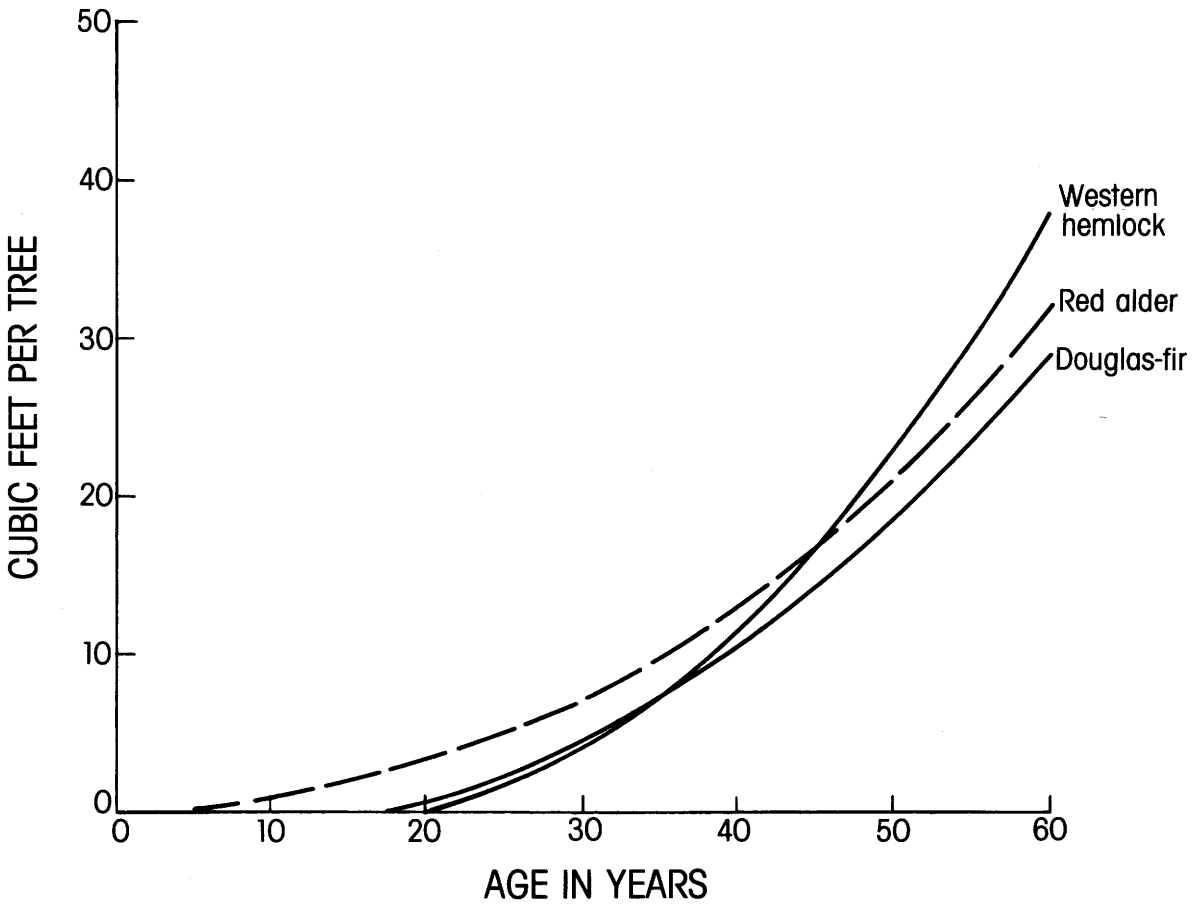


Figure 5.--Cubic feet per tree over age by species for normal yield table stands at site index 140.

The utilization of alder has not been complete partly due to size and age. Alder, being a short-lived species, rarely attains the age of 100 years. Conifers live much longer, allowing the individual trees to grow much larger. These older conifer stands still exist on many ownerships. Naturally, loggers will take the easiest, most valuable, and best trees first. Figure 6 illustrates that the cost of production increases as log size decreases. Conversely, value increases as log size increases. Our logging equipment is designed for the larger, more valuable conifer stands. Log handling and storage facilities are also designed for the larger wood. This, coupled with the fact that alder does not store well in cold decks for long periods, has kept most large landowners out of alder production.

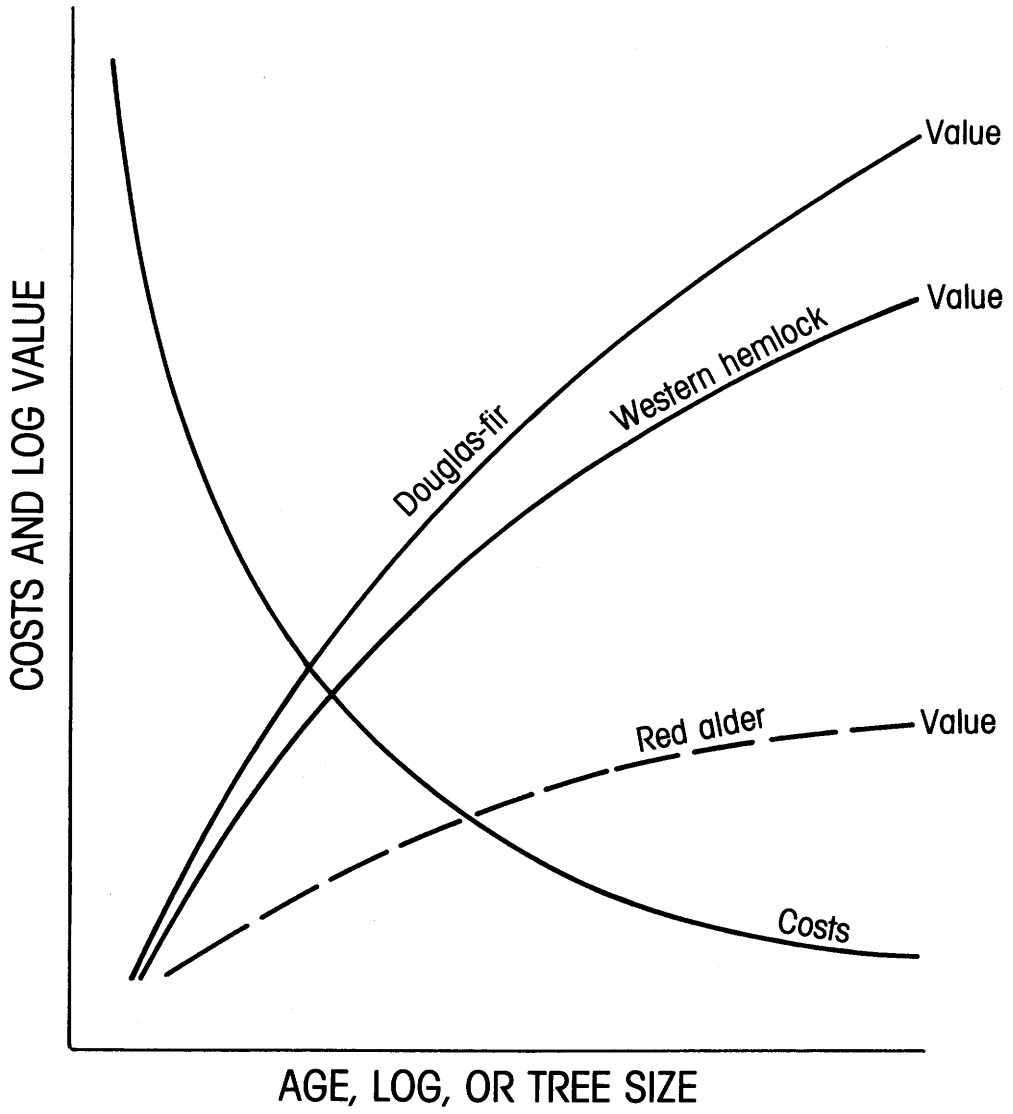


Figure 6.--Production costs vs. sales realization (price) over age, log, or tree size for Douglas-fir, Western hemlock, red alder.

High production cost and low unit values have made alder a poor performer in realization per acre. Figure 7 compares the three species in gross realization per acre on our site index 140 example. The conifer yield in dollars is two to three times that of alder.

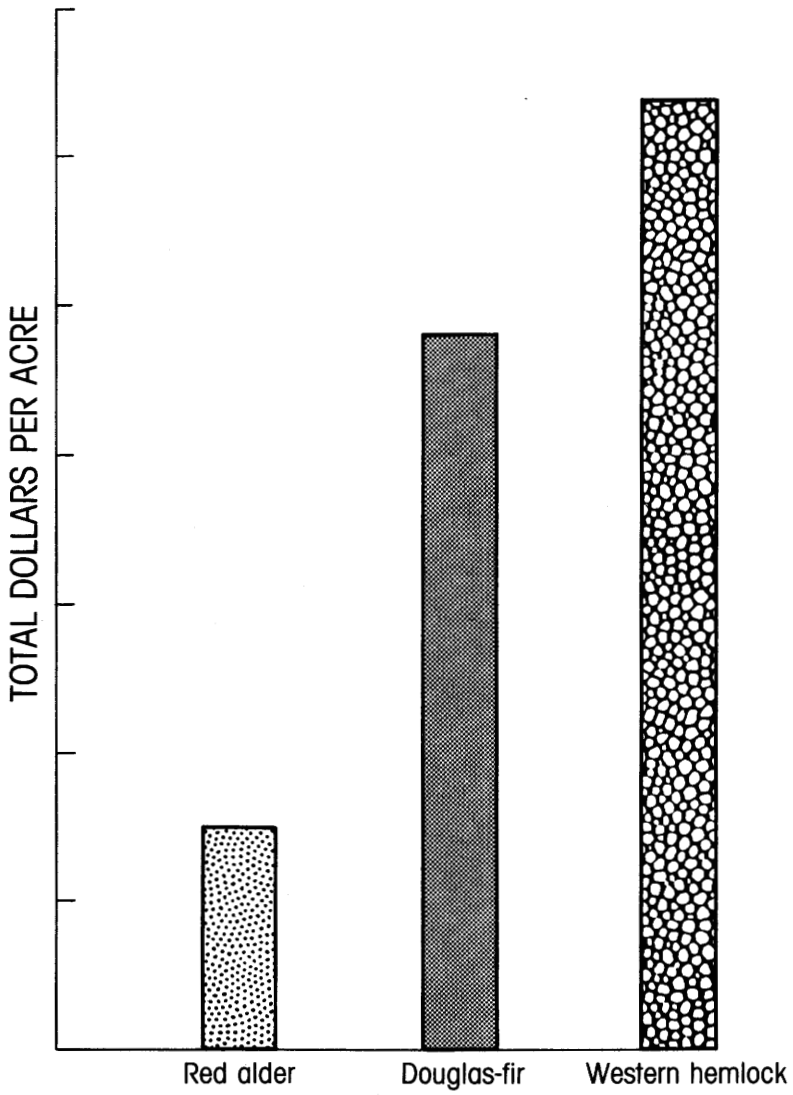


Figure 7.--Gross realization per acre by species for normal stands at age 60--site index 140.

WOOD PROPERTIES

Everyting I have discussed to this point has favored the conifers. Growth, yield, size, and value have created a favorable situation for the conifers.

Alder, of course, does not compete in the same marketplace as the conifers. To date, it has been used as pulpwood and as a substitute for other

hardwoods. Alder is being used in furniture, cabinets, novelties, trim, paneling, pallets, and plugs for paper rolls. The wood is easy to work, stains and paints nicely, and has a pleasing natural color of light yellowish brown when dry. It has a fine, uniform grain, and smooth texture. It has good nail and tack holding abilities with little tendency toward splitting. Green alder logs and lumber decay rapidly. The logs must be manufactured soon after cutting, and the lumber must be kiln dried. Alder has its own set of log grades, published by the Log Scaling and Grading Bureaus. These grades give the scaling diameters and the amount of high grade lumber that can be produced from a log.

Let's take a look at a typical red alder tree in a 40-year-old well-stocked stand. This tree has 12-in d.b.h. and is 80 feet tall. If we bucked two 32-ft logs we would net 18 ft^3, 13 in the first log and 5 in the second. This means 72 percent of the volume is in the butt log. This typical alder tree probably has no limbs or knots in the first 32-ft log. Even though alder trees are small and produce low volumes per acre compared with the conifers, they will produce a high percentage of clear wood. Conifers grown on a rotation of 40 to 60 years will produce little clear wood. Alder does. Will clear, knot-free boards and panels be worth anything in the future? I believe they will. This ability to produce clear wood plus nitrogen-fixing ability, in a future with an energy-short world, may make alder utilization a reality.

Conclusion

I sincerely hope this conference brings an awareness to our industry that this region has nearly 16 percent of the forest land base in alder which must be utilized and converted to useful products. Red alder in the Northwest is more abundant than the current demand. Log production has been geared for the larger, more valuable conifers. Utilizing alder stands has consequently been slow. The relatively low gross realization of alder compared to conifer may change as the age of the conifers is cut back to that of alder.

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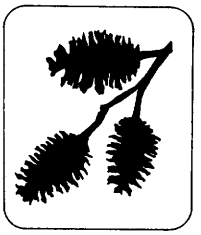
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BUYER'S PERSPECTIVE ON PUBLIC AGENCY TIMBER SALE PROCEDURES FOR ALDER



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ABSTRACT OF PANEL DISCUSSION

Experiences of the hardwood industry in buying alder from public land management agencies have not often been favorable. A wide variety of log selling procedures are found among the various agencies in the Pacific Northwest but there are common problems from the standpoint of the hardwood buyers. One such problem is related to the mix of species included in hardwood sales. A sizable volume of conifer timber is often included in the sale. This timber is difficult for the hardwood operator to market. The conifer component attracts bids from the conifer industry making it difficult for the hardwood industry to compete. Separated sales of hardwood and conifer would increase bidding by hardwood operators and improve utilization of hardwoods, which are often poorly utilized by conifer operators.

The second major concern about hardwood sales is the lack of accurate timber volume estimates. Operators have found that cruises on alder stumpage have cut out from 36-131 percent. This degree of uncertainty is a significant factor of concern for anyone attempting to bid on alder. Agency and hardwood industry personnel should work together to attain a higher degree of cruising accuracy.

Timber sale procedures and agency attitudes toward hardwoods vary tremendously. Agencies must recognize the unique features of hardwood stands as well as the needs of hardwood operators in order to develop procedures that are more conducive to active bidding by the hardwood industry.

A COMPARISON OF LUMBER GRADING RULES FOR ALDER AND COMPETING SPECIES



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ABSTRACT

This paper contains a comparison of lumber grading rules and practices for red alder and competing species in the hardwood lumber trade such as birch, yellow poplar, soft maple, and black cherry.

Introduction

Grading rules are the specifications used to define the quality of lumber. When logs are converted into lumber, they yield boards which vary in size and in the type and location of defects. Grading, in which lumber is segregated into use - oriented categories with an appropriate quality range, permits a user to buy the quality that best suits his purpose. The objective of grading rules is to classify and place on the market lumber of standard sizes, shapes, and qualities, irrespective of the varying conditions of manufacture and the kind and size of logs that produced it. For structural uses, strength is desirable; and hence the direction and width of the growth rings and the size, number, and location of knots are important. For doors, sash, furniture and similar items, boards that have clear or clean faces are desired.

The grade of a piece of lumber is based on the number, character, and location of features that may lower its strength, durability, or utility value. Among the common visual features are knots, checks, pitch pockets, shake, and stain. Some grades must be free or practically free of these features while other grades allow fairly numerous knots and other features within specified limits.

Hardwood lumber is graded according to three basic marketing categories; factory lumber, dimension stock, and finished market products. Hardwood factory lumber is similar to softwood factory and shop lumber in that it is graded on the basis of the percentage of the board area that will yield clear or sound cuttings of specified sizes. Grade is based on the quantity of usable wood in the piece rather than on the size, type, or location of defects. Hardwood lumber is usually graded from the poorest face in the rough green condition; that is, before kiln drying and surfacing.

Hardwood dimension stock is manufactured to the specific size and grade requirements of the end product. Both factory lumber and dimension stock are intended to serve industrial consumers. Finished market products are graded for unique end uses requiring little or no remanufacture (an example is hardwood flooring).

This paper concentrates on the grading of the hardwood factory lumber. Rules used in grading hardwood factory lumber are issued by the National Hardwood Lumber Association (*1*). Figure 1 summarizes the standard grades which are applied to most species. In practice, the first two grades, Firsts and Seconds, are combined into a single grade "firsts and seconds" (FAS). Figure 1 indicates that, in addition to the minimum percent yield requirement, the grading rules contain stipulations as to minimum board dimension, minimum cutting size, and the number of cuttings that can comprise the yield. For example, the highest grade of hardwood lumber is called "firsts" which requires that at least 91-2/3 percent of the board be in clear-face cuttings. Boards in this grade must be at least 6 inches wide and must be 8 to 16 feet long. As can be seen in figure 1, the actual FAS percent yield requirement varies according to the surface measure of the board and the number of cuttings that are allowed. The cuttings must also meet a minimum size requirement of 4 inches by 5 feet or 3 inches by 7 feet.

Information in figure 1 consists of basic grade descriptions. The reader should refer to the National Hardwood Lumber Association (NHLA) rule book (*1*) for more detail and for deviations associated with individual species. The grading rules for Pacific coast red alder summarized in figure 2 differ from the standard hardwood grades. These alder rules are described in detail on pages 45-46 of the rule book (*1*). For example, the highest alder grade is "Select and Better," which requires at least 83-1/3 percent yield in clear-face cuttings from boards at least 4 inches by 4 feet in size. This yield can be obtained in an unlimited number of cuttings, but the minimum cutting must be a least 4 inches by 3 feet or 3 inches by 6 feet.

Figure 1. — Standard hardwood cutting grades[1]

Grade and lengths allowed (feet)	Widths allowed	Surface measure of pieces	Amount of each piece that must work into clear-face cuttings	Maximum cuttings allowed	Minimum size of cuttings required
	In.	*Sq. ft.*	*Pct.*	*Number*	
Firsts:[2]					
8 to 16 (will admit 30 percent of 8- to 11-foot, ½ of which may be 8- and 9-foot.)	6+	4 to 9	91 ⅔	1	4 inches by 5 feet, or 3 inches by 7 feet
		10 to 14	91 ⅔	2	
		15+	91 ⅔	3	
Seconds:[2]					
8 to 16 (will admit 30 percent of 8- to 11-foot, ½ of which may be 8- and 9-foot).	6+	4 and 5	83 ⅓	1	Do.
		6 and 7	83 ⅓	1	
		6 and 7	91 ⅔	2	
		8 to 11	83 ⅓	2	
		8 to 11	91 ⅔	3	
		12 to 15	83 ½	3	
		12 to 15	91 ⅔	4	
		16+	83 ⅓	4	
Selects:					
6 to 16 (will admit 30 percent of 6- to 11-foot, ⅓ of which may be 6- and 7-foot).	4+	2 and 3	91⅔	1	Do.
		4+	(*3*)		
No. 1 Common:					
4 to 16 (will admit 10 percent of 4- to 7-foot, ½ of which may be 4- and 5-foot).	3+	1	100	0	4 inches by 2 feet, or 3 inches by 3 feet
		2	75	1	
		3 and 4	66 ⅔	1	
		3 and 4	75	2	
		5 to 7	66 ⅔	2	
		5 to 7	75	3	
		8 to 10	66 ⅔	3	
		11 to 13	66 ⅔	4	
		14+	66 ⅔	5	
No. 2 Common:					
4 to 16 (will admit 30 percent of 4- to 7-foot, ⅓ of which may be 4- and 5-foot).	3+	1	66 ⅔	1	3 inches by 2 feet
		2 and 3	50	1	
		2 and 3	66 ⅔	2	
		4 and 5	50	2	
		4 and 5	66 ⅔	3	
		6 and 7	50	3	
		6 and 7	66 ⅔	4	
		8 and 9	50	4	
		10 and 11	50	5	
		12 and 13	50	6	
		14+	50	7	
No. 3A Common:					
4 to 16 (will admit 50 percent of 4- to 7-foot, ½ of which may be 4- and 5-foot).	3+	1+	[4] 33 ⅓	(*5*)	Do.
No. 3B Common:					
4 to 16 (will admit 50 percent of 4- to 7-foot, ½ of which may be 4- and 5-foot).	3+	1+	[6] 25	(*5*)	1 ½ inches by 2 feet

Source: Wood handbook: Wood as an Engineering Material, USDA For. Serv., For. Prod. Lab. Agric. Handb. No. 72, rev. Aug. 1974.

[1] Inspection to be made on the poorer side of the piece, except in Selects.

[2] Firsts and Seconds are combined as 1 grade (FAS). The percentage of Firsts required in the combined grade varies from 20 to 40 percent, depending on the species.

[3] Same as Seconds with reverse side of board not below No. 1 Common or reverse side of cuttings sound.

[4] This grade also admits pieces that grade not below No. 2 Common on the good face and have the reverse face sound.

[5] Unlimited.

[6] The cuttings must be sound; clear face not required.

Figure 2. — Alder cutting grades[1]

Grade and lengths allowed (feet)	Widths allowed	Surface measure of pieces	Amount of each piece that must work into clear-face cuttings	Maximum cuttings allowed	Minimum size of cuttings required
	In.	*Sq. ft.*	*Percent*	*Number*	
Select and Better: 4+ (will admit 10 percent of 4 to 6 foot)	4+[2]	1+	83 1/3[3]	unlimited	4 inches by 3 feet, or 3 inches by 6 feet
No. 1 Shop: 4+ (will admit 10 percent of 4 to 6 foot)	4+[2]	1+	66 2/3[4]	do.	4 inches by 2 feet, or 3 inches by 3 feet
No. 2 Shop: 4+ (will admit 10 percent of 4 to 6 foot)	4+[2]	1+	50[4]	do.	3 inches by 2 feet
No. 3 Shop: 4+ (will admit 15 percent of 4 to 6 foot)	3	1+	33 1/3[5]	do.	do.

[1] Inspection to be made from the better side of the piece on rough or surfaced lumber, with pin knots considered to be no defect.
[2] Will admit 5% 3" wide.
[3] The reverse side of the cuttings must be sound or not below No. 1 Shop grade.
[4] The reverse side of the cuttings must be sound.
[5] The cuttings must be sound; clear face not required.

Differences in the Lumber Grade Structure of Alder and Competing Species

The principal types of lumber competing with red alder are from four east coast species, birch, yellow poplar, soft maple, and cherry, all of which are graded under the standard grades. The significant differences between the grade structures of Pacific coast red alder and these competing species lie in the following areas:

1. Dimension requirements of the Firsts and Seconds (FAS) standard grade vs. the Select and Better alder grade.

2. Determination of the grading face.

3. Limitation in the number of cuttings permitted to establish the required yield.

4. Dimensions of clear-face cuttings required in the Select and Better alder grade vs. the Selects and Firsts and Seconds (FAS) standard grades.

5. Alder is graded after kiln drying and surfacing.

EXPLANATIONS

Dimensional Requirements of the Firsts and Seconds (FAS) Standard Grade vs. the Select and Better Alder Grade

The Firsts and Seconds grade of the standard and hardwood rules has a minimum dimensional requirement of 6-inch width and 8-foot length. This is in contrast to the red alder Select and Better grade minimum dimensional requirement of 3-inch width and 4-foot length. Thus, for competing species, all pieces in a shipment of the grade of Firsts and Seconds must be at least of the minimum dimension; 6-inch width and 8-foot length. In contrast, a shipment of Select and Better grade alder could contain boards as small as 3-inch width by 4-feet long. In spite of these board dimension differences, however, the yield requirement for Select and Better alder and FAS are the same, i.e., 83-1/3 percent. Consequently, it should not be anticipated that, because of the smaller dimensions of Select and Better alder, any given volume would contain excessive volumes of short or narrow pieces.

Grading Procedure

It is the practice of the industry, when grading alder under the NHLA alder rules, to grade after kiln drying and surfacing both faces of alder lumber. The procedure allows for the removal of boards which should be downgraded due to defects incurred during drying and surfacing. This is a substantial advantage in contrast to other species which are graded in the rough green condition. Rough green grading cannot take degrade into account due to subsequent drying and surfacing operations.

Limitation in the Number of Cuttings Permitted to Establish the Required Yield

The number of cuttings permitted to obtain the required yield to establish the grade are limited in all competing species. In red alder the number of cuttings permitted to obtain the yield are unlimited. For example, in the standard grade of No. 1 Common, a piece containing 6 surface feet would be permitted two clear-face cuttings to obtain a yield of 66-2/3 percent, or one additional cutting if the total yield would be 75 percent or more. A maximum of three clear-face cuttings would be permitted to establish the grade of No. 1 Common. These cuttings must also meet the No. 1 Common minimum cutting size of 4 inches by 2 feet or 3 inches by 3 feet. In red alder No. 1 Shop grade, the number of cuttings to meet 66-2/3 percent yield are unlimited, providing they meet the minimum dimensional requirement of 4 inchs by 2 feet or 3 inches by 3 feet.

Dimensions of Clear-Face Cutting in Select and Better Red Alder and Selects and Firsts in the Standard Grades

Since red alder has a somewhat smaller lumber dimensional requirement, it is appropriate that the dimensions of the minimum size requirements for clear-face cuttings also be somewhat reduced. As shown in figure 3, the

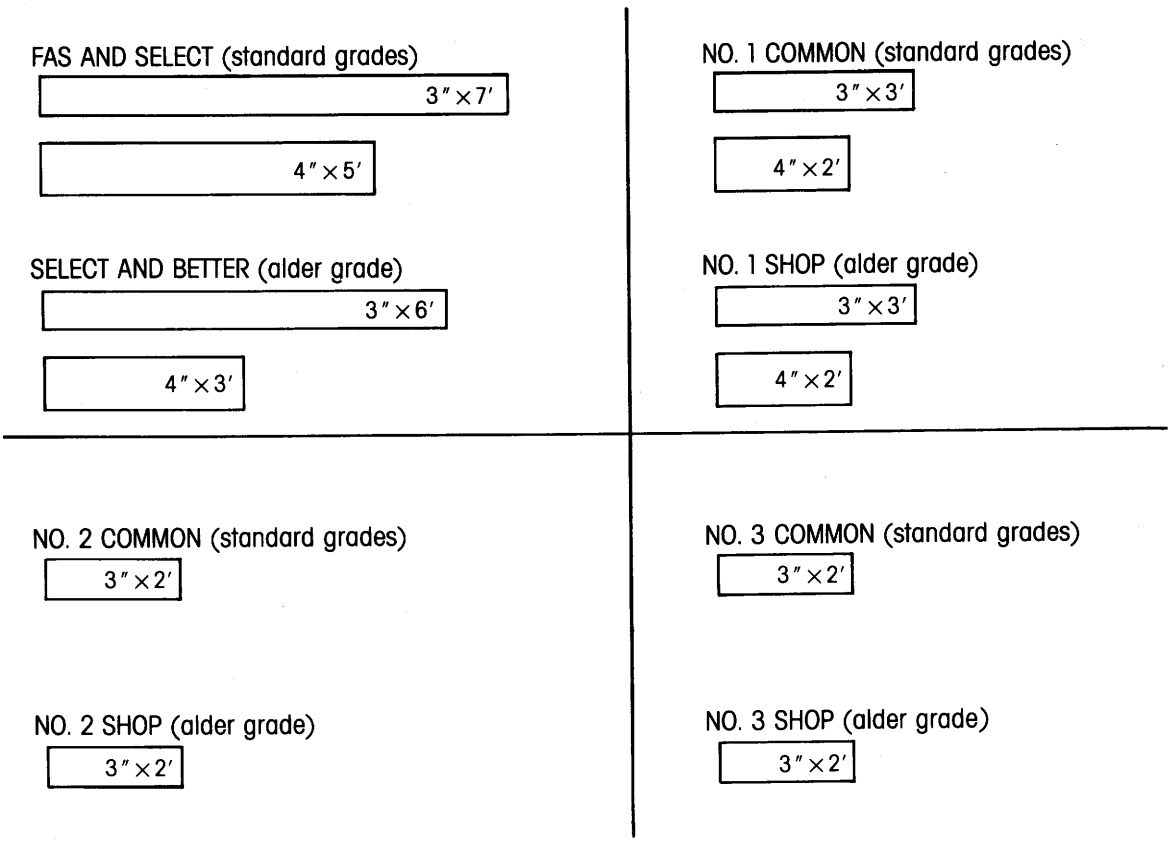


Figure 3.--Comparison of the minimum cutting size requirements of alder and standard hardwood lumber grades.

minimum clear-face cuttings for alder (which are 4 inches by 3 feet or 3 inches by 6 feet) are smaller than the cutting sizes required in the standard grades of Firsts and Seconds and Selects. Figure 3 also shows that there is no difference in the dimensional requirements of the cuttings in the standard Common grades and counterpart alder Shop grades.

Reference

(1) National Hardwood Lumber Association.
1978. Rules for the measurement and inspection of hardwood and cypress lumber. Chicago, Ill.

Appendix I

Introduction to the Fundamentals of Hardwood Inspection Procedures Relative to Grade Evaluation of Pacific Coast Red Alder

DEFINITIONS

A cutting unit is a piece 1 inch by 1 foot.

A cutting is a portion of a board or plank obtained by crosscutting or ripping, or by both. In the Common grades, a cutting shall be flat enough to surface two sides to standard surfaced thickness after it has been removed from the board.

A clear-face cutting is a cutting having one clear face (ordinary season checks are admitted) and the reverse side sound as defined in sound cutting. The clear face of the cutting shall be on the poor side of the board except when otherwise specified.

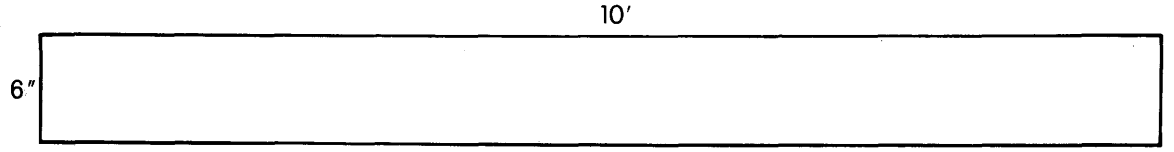
A sound cutting is a cutting free from rot, pith, shake, and wane. Texture is not considered. It will admit sound knots, bird pecks, stain, streaks or their equivalent, season checks not materially impairing the strength of a cutting, and pin, shot, and spot worm holes. Other holes 1/4 inch or larger are admitted but shall be limited as follows: One 1/4 inch in average diameter in each cutting of less than 12 units; two 1/4 inch or one 1/2 inch to each 12 units and on one side only of a cutting.

Wane indicates bark or lack of wood.

Pith is the small soft core occurring in the structural center of the log.

Stain in hardwoods is used to describe the initial evidences of decay.

CALCULATION OF NUMBER OF CUTTING UNITS,
SURFACE MEASURE AND GRADE DETERMINATION
OF A TYPICAL ALDER BOARD



1. To determine the number of cutting units, multiply width in inches by length in feet.

   6 inches by 10 feet = 60 cutting units

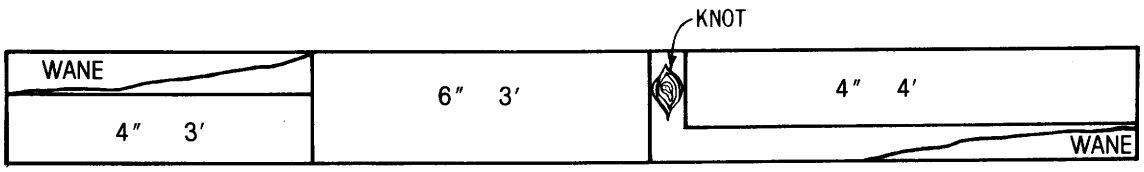
2. To find the surface measure, divide the number of cutting units by 12.

60/12 = 5 feet of surface measure

3. The grade is determined by the percentage of clear tree cuttings from the better face of the piece by the cutting unit method. Applying the required yield percentages of the alder grades to the number of cutting units in this board results in the minimum yield of cutting units required by each grade for this board.

Alder grade	Grade yield requirement	x	Cutting units in board	=	Required cutting units by grade for board
Select & Better	10/12 or 83-1/3 percent		60		50
No. 1 Shop	8/12 or 66-2/3 percent		60		40
No. 2 Shop	6/12 or 50 percent		60		30
No. 3 Shop	4/12 or 33-1/3 percent		60		20

4. Now, suppose the above board had defects and cuttings as shown below.



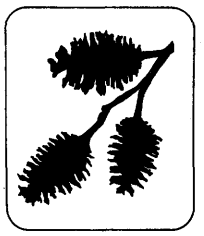
To determine the grade of the board, calculate the yield of the cuttings in cutting units and compare the total yield to the grade requirements determined in step 3. The cutting units in the three cuttings are

4 inches by 3 feet = 12 cutting units
6 inches by 3 feet = 18 cutting units
4 inches by 4 feet = 16 cutting units

These cuttings combine to yield 46 cutting units. This is insufficient to allow the board to make the Select and Better grade which requires at least 50 cutting units out of this board but the yield is sufficient to qualify the board in the No. 1 Shop grade.

On the basis of the sizes of the cuttings, the board would appear to qualify for the Select and Better grade. Figure 2 indicates that this grade requires cuttings to be at least 4" x 3' or 3" x 6'. The combined yield of these cuttings, however, is 46 cutting units which is less than the 50 cutting units determined to be the minimum required yield from this board, if it is to qualify as Select and Better. The board is therefore disqualified from Select and Better and is compared with the requirements of the next lower grade, No. 1 Shop. Since it meets the requirements of this grade, the board is graded No. 1 Shop.

STABILIZING COLOR AND DRYING RED ALDER



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ABSTRACT

A honey-brown color is established without difficulty in drying freshly sawed red alder lumber, but a reddish-tan to reddish-brown color requires dry-bulb temperatures above 185°F at 92-percent relative humidity or higher. A white or ivory color is obtained by steaming freshly sawed or partially air-dried lumber at 212°F and 100-percent relative humidity. The white color may be retained with air drying, but a honey-brown to reddish-brown color requires kiln drying immediately after setting the color. Kiln-drying practices depend on kiln capacity, boiler capacity, availability of logs, log storage, and customer specifications. Initial dry-bulb temperatures range from 150° to 190°F, and drying times for 4/4 lumber vary from 4 to 6 days. Equalizing for uniformity of final moisture content and conditioning to remove drying stresses for remanufacturing are important steps in drying for both producer and customer.

Introduction

Red alder lumber must be kiln dried to satisfy customer demands for grade, moisture content, and color. Alder lumber 5/4 or thinner is one of the easiest to dry in the United States; but thicker stock, such as 8/4 to 12/4, causes problems in kiln drying because of the time required--as much as 24 days. Moreover, the percent of degrade increases with thickness.

One difficulty is the setting of the uniform color, which is important to both producer and customer. Red alder varies in color from white to yellow to blood red immediately after the sawing of fresh logs. A study by Karchesy[1] reports that this staining phenomenon results from a novel diarylheptanoid xyloside, oregonin. Karchesy believes the chemical stain is caused by oxidation. The color of red alder lumber varies with site, time of sawing, log storage, and delay in kiln drying the lumber.

[1]Karchesy, J. J. 1974. Polyphenols of red alder, chemistry of the staining phenomenon. Ph.D. thesis, School of Forestry, Oregon State Univ., Corvallis. 103 p.

Many sources suggest kiln schedules for alder lumber up to 2 inches. Schedules of time-temperature rather than moisture content-temperature are more convenient for the producer but do not guarantee the desired moisture content (MC) and range. Final average MC will vary with seasons of the year, time of log storage, and individual kilns. I cannot, therefore, present a kiln schedule that will fit everyone's needs but can only suggest methods to improve drying practices, reduce kiln time, and set uniform color in the lumber.

After a study in 1962 at the Forest Research Laboratory, we suggested drying at 200°F dry-bulb temperature, then considered the maximum temperature, with corresponding steep wet-bulb depression. We also showed that a more severe schedule would not increase degrade. Mills with modern kilns have increased drying temperature, and a few mills are beginning the drying cycle with temperatures of 180° to 190°F. An accelerated schedule will reduce drying times for 4/4 and 5/4 lumber by 30 percent without additional degrade and will produce uniform color. Boiler capacity restricts many mills to initial temperatures of 170°F or lower; however, the drying rate may be increased by increasing the wet-bulb depression.

Stabilizing Color

The initial setting of drying conditions in the kiln establishes color and uniformity. Anderson and Frashour (*1*) investigated conditions required to set light brown and found that color varied with time, dry-bulb temperature, and relative humidity. Industrial practice has shown that honey tan may be obtained by using dry-bulb temperatures from 140° to 150°F, with 5°F wet-bulb depression for at least 12 hours. Commercial kiln drying at 180° to 190°F with 10°F wet-bulb depression for 18 hours will also produce honey-tan.

In cooperation with Paul Barber Hardwoods Company, I determined the effect of kiln conditions on setting colors, preventing sticker stain and mottling, and removing stain from discolored lumber (*4*). We tested steaming at temperatures 183° to 205°F and relative humidities of 92 percent and higher for 6 to 15 hours. The results are shown in table 1. Charges 2D, 2E, and 2F, steamed at 190°F at 92- to 96-percent relative humidity and immediately kiln dried, were uniformly reddish tan after 7 hours of steaming, reddish brown after 12 hours of steaming, and dark reddish brown after 15 hours of steaming. The dry-bulb temperature was maintained at 190°F to complete drying.

Dry-bulb temperature was increased to 197° and 201°F and relative humidity to 100 percent for charges 2G and 2H, but the color did not vary except when the time was increased. Apparently, time has the greatest influence in setting color at dry-bulb temperatures of 190° to 205°F and corresponding relative humidities of 92 percent and higher.

We steamed matched charges 2DD, 2EE, 2FF, and 2HH at the same kiln conditions as those for charges 2D, 2E, 2F, and 2H. After air drying 3 to

4 weeks, the lumber was kiln dried to determine whether the color was stabilized. Twenty percent or more boards were mottled from honey tan to reddish tan. Results clearly showed that color is not retained if the lumber is steamed and then air dried in order to reduce demand on the dry kilns. (Most mills, including softwood mills, increase their kiln production with accelerated kiln schedules or partial air drying.)

Steaming of freshly sawed lumber at 212° to 214°F and 100-percent relative humidity from 2 to 6 hours produced lumber of white to ivory color. (See table 1 for charges in series 1.) Tests showed that steaming at these conditions for 4 to 6 hours produced the most uniform color.

Table 1--*Steaming conditions and color stabilization for random-width, 8 foot long, unseasoned, 4/4 red alder lumber*

	Steaming				Color stabilization			
						Final color		
Charge[1/]	Dry-bulb temp	Relative humidity	Time	Kiln schedule[2/]	Mottled	Sapwood	Heartwood	Uniformity
	Deg F	Percent	Hours		Percent			
1AA	212	100	2	L	0	White	Ivory	Excellent
1BB	212	100	4	L	0	White	Ivory	Excellent
1C	212	100	4	L	8	White	Ivory	Excellent
1CC	212	100	4	L	0	White	Ivory	Excellent
1D	212	100	6	L	7	Ivory	Ivory	Excellent
1DD	212	100	6	L	0	Ivory	Ivory	Excellent
1E	212	100	4	L	0	White	Ivory	Excellent
1EE	212	100	4	L	7	White	Ivory	Excellent
2AA	183	96	6	L	31	Honey tan	Honey tan	Poor
2BB	183	96	9	L	26	Honey brown	Honey brown	Poor
2CC	183	96	12	L	45	Reddish tan	Reddish tan	Poor
2D	190	96	7	A	0	Reddish tan	Reddish tan	Excellent
2DD	190	96	7	L	44	Reddish tan	Reddish tan	Poor
2E	190	92	12	A	0	Reddish brown	Reddish brown	Good
2EE	190	92	12	A	20	Reddish tan	Reddish tan	Poor
2F	190	92	15	A	0	Dark red brown	Dark red brown	Good
2FF	190	92	15	L	21	Reddish tan	Reddish tan	Poor
2G	197	99	12	L	13	Tan	Red tan	Good
2H	201	100	15	A	0	Dark red brown	Dark red brown	Good
2HH	201	100	15	L	32	Reddish tan	Reddish tan	Poor
2II	205	100	6	L	36	Tan	Honey tan	Poor
3A	212	99	4	L	0	White	Ivory	Excellent
3B	212	100	8	L	14	White	Ivory	Good
3C	212	100	12	L	0	Ivory	Light tan	Excellent
3D	212	100	24	L	0	Ivory	Light tan	Excellent

[1/] Double letter suffix signifies charges that were steamed, air-dried for 4 to 6 weeks, and kiln-dried. Single letter suffix signifies charges that were kiln-dried immediately after steaming, except number three charges which were air-dried to 16- to 19-percent moisture content before steaming and kiln drying.

[2/] "L" signifies charges dried with initial dry-bulb temperature of 150°-155°F and finishing at 180°F. "A" signifies a constant dry-bulb temperature of 190°-200°F.

Steaming air dried lumber at 212°F and 100-percent relative humidity for 4 to 24 hours (series 3, table 1) eliminated sticker stain and did not produce enough mottling to cause degrade. The moisture content of the air-dried lumber averaged from 16 to 19 percent before kiln drying. Steaming from 4 to 8 hours produced white in the sapwood and ivory in the heartwood; steaming for 12 to 24 hours darkened the sapwood to ivory and the heartwood to light tan. In all instances, the boards lacked luster. White can be established successfully by steaming freshly sawed or partially air-dried lumber up to 2 inches thick, but stain caused by an organism will not be minimized.

Color stabilization at high temperatures and relative humidities has several disadvantages. Drying temperatures near 190°F and 85-percent relative humidity cause excessive shrinkage. This effect was verified by Espenas (*2*), who studied the effect of kiln conditions on the shrinkage of red alder, Douglas-fir, and western hemlock. Red alder was most affected of the three species when dried at kiln conditions for 12-percent equilibrium moisture content (EMC). Shrinkage at 215°F was more than double that of 90°F. Setting reddish tan or dark red brown in the lumber, therefore, caused a high percentage of thin boards or boards that had sticker markings after being surfaced from 4/4 to 15/16 inch. If boards were surfaced to 13/16 inch or less, color was uniform and sticker markings disappeared. Steaming at 212°F and 100-percent relative humidity for a white color did not cause excessive shrinkage when all charges were dried at initial 150°-155°F dry-bulb temperatures.

Another disadvantage of high-temperature steaming is that only a modern kiln can attain the temperatures and relative humidities required and, over a period of 2 years, will require more maintenance than kilns drying red alder lumber at usual temperatures.

Kiln Drying

Setting a honey-brown color in the lumber is the first step in the drying schedule. Initial dry-bulb temperatures of 150° or 180°F with corresponding wet-bulb depression of 5° or 10°F is sufficient to induce drying. I have determined no difference in degrade or loss of clear cutting units in drying at 150°, 180°, and 200°F (*3*).

After the color is set in 12 to 18 hours, the second drying cycle may be quite severe for 4/4 lumber. An EMC condition of 6 percent, compared to 9 or 12 percent, did not cause additional degrade or loss of clear cutting units. The amount of small end checks, the amount of checking in knot areas, and the general appearance of lumber dried at 200°F and 6-percent EMC were not favorable, however, when compared to results of a commercial schedule with an initial dry-bulb temperature of 150°F that ended in 5 days at 180°F. The change from conditions for high EMC in presteaming to conditions for 6-percent EMC (at 200°F) made kiln control difficult. When this sudden change was made, the heating system was on full demand, the vents remained wide open from 1 to 2 hours, and considerable heat was wasted.

Small end checks and checking in the knot areas were eliminated when conditions for 10- or 11-percent EMC were held for at least 12 hours before setting for 6-percent EMC. This reduced the amount of initial venting and saved heat.

The conventional dry kiln has ample air velocity to maintain an adequate drying rate. Kilns constructed 20 years ago have air velocities ranging from 400 to 450 feet per minute with proper baffling and loading. Perhaps the chief fault in drying is improper baffling or no baffling at all. Drying time is reduced about 30 percent if air velocity is increased from 150 to 600 feet per minute; the higher air flow generally assures more uniform drying throughout the charge. Frequency of fan reversal is dependent upon many variables, such as width of load, desired rate of moisture removal, and kiln construction; but uniformity of final MC is tied to the capability of air circulating in the kiln to remove moisture from wood surface regardless of its location. A low temperature schedule designed to dry 4/4 lumber in 6 or 7 days requires fan reversal about every 12 hours. An accelerated schedule lasting 4 days requires fan reversal every 6 hours.

When 4/4 lumber is kiln dried, the wet-bulb depression usually is increased 10°F every 24 hours with an accelerated schedule (190°F), and 5°F with a low temperature schedule (150°F). Drying times are approximately 4 days for an accelerated schedule and 5-1/2 days for a low-temperature schedule.

To present an optimum schedule for everyone's requirements is not possible. End or surface checking will occur in the first 24 to 48 hours for 4/4, 5/4, and 6/4 lumber on a low temperature schedule (150°F). For thicker stock, such as 10/4 or 12/4, the first 5 or 6 days are critical. After the initial period, the checks tend to close; but at fiber-saturation point, or about 28-percent MC, shrinkage becomes noticeable as warp. Cup and twist cause the largest loss of grade because of roller split during machining. When these occur, the schedule should be adjusted. Checking is caused by severe drying conditions or too rapid drying. Dry-bulb temperature need not be reduced, but the EMC conditions should be raised or the spread between wet- and dry-bulb temperatures decreased.

Procedures to reduce warp in lumber start in the sawmill with close tolerances for sawing, especially for thickness. Stickering and piling practices also will influence the amount of warp. Stickers should be placed every 2 feet and aligned well within the package and with stickers in packages above and below. Tiers of stickers should be supported by the bunks on the kiln trucks. The top three to five courses will have more warp than the others because no restraint is provided.

Most hardwood mills dry 4/4 to 6/4 lumber to an average MC of 6 to 8 percent. When the lumber is nearly dry, conditions for equalization are set to reduce final MC to the desired average within a predetermined range. Equalization is dependent on time, EMC conditions, MC before equalizing, and desired uniformity of final MC. Table 2 shows the effect of these variables on 4/4 lumber when equalized to a 7-percent average MC± 2 percent. Condi-

Table 2--*Results of various kiln conditions in equalizing and conditioning for 4/4 red alder lumber*

Charge	Initial moisture content[1/]	Equalizing					Conditioning			
		EMC	Kiln final moisture content				Time	Dry bulb temp.	EMC	Stress relief
			Time	High	Low	Avg.				
	- -Percent- -		Hr	- - -Percent- - -			Hr	°F	Percent	
6A	14.6	4	9	12.0	8.5	9.8	10	204	12	Good
6B	8.4	5	15	8.0	7.0	7.2	12	165	11	Excellent
6C	15.2	3	17	9.5	<6.0	7.1	7	200	10	Good
6D	8.0	4	9	9.0	7.0	7.6	11	190	11	Excellent
6E	10.0	4	19	9.0	7.0	7.3	11	190	11	Excellent
6F	<12.0	5	7	10.5	7.0	8.5	7	200	16	Excellent
6G	11.9	5	14	8.5	7.0	7.5	5	200	13	Good
6H	16.2	5	14	12.0	7.5	8.3	5	200	14	Fair
6I	>11.0	5	5	11.0	7.0	8.2	6	200	16	Good
6J	13.4	4	4	12.0	9.0	10.2	7	190	18	Excellent

[1/] Average before equalization.

tions for EMC of 3, 4, or 5 percent were tested to bring final moisture content down to a narrow range in a short time. For charge 6C, conditions for 3-percent EMC were effective in lowering boards with high MC to 9.5 percent. Some boards had less than 6-percent MC, which is probably undesirable for remanufacturing. Best results were obtained with conditions for 4- or 5-percent EMC.

Moisture content at the start of equalization influenced the range of final MC. For example, charges 6A and 6D were held at 4-percent EMC for 9 hours. Charge 6A ended with a range of final MC of 3.5 percentage points; and 6D, which began equalization with 8.0-percent MC, ended with a range of 2.0 percentage points (table 2).

Length of the equalization period also affected the range of final MC. In charges 6G and 6I, which had nearly the same initial MC, 14 hours of equalization reduced the range of final MC to 1.5 percentage points and 5 hours to 4.0 percentage points (table 2).

Study of results in table 2 shows that holding conditions for 4- or 5-percent EMC for 7 hours, with an additional hour for each percentage point of MC desired, will bring the range of final MC down to about 2 percentage points. When the wettest kiln sample registers 14 percent or more, however, this rule of thumb is doubtful. Also, equalizing 5/4 or 6/4 lumber will require additional time.

Another rule of thumb is to set conditions for EMC 3 percent less than the desired average MC when the wettest sample has 2 percent more than the desired average MC. Equalize until the wettest sample has less than 1 percent over the desired average MC. No two charges will dry the same, so kiln samples or hot moisture-meter readings taken in the kiln are needed to determine the MC before equalizing. One hot meter reading per 1,000 fbm should be taken until you are confident of the figures, then the sample size may be reduced.

The producer and customer usually agree on the final MC of the lumber but usually do not discuss removal of drying stresses or relief of casehardening in remanufacturing stock until the customer complains of distortion of his cut stock. Casehardening can be relieved only by conditioning in the kiln and is accomplished best with the highest dry-bulb temperature and EMC conditions that are controllable.

We held conditioning at dry-bulb temperatures between 190° and 200°F, except for charge 6B, which was held at 165°F in a commercial schedule (table 2). We rated relief of stresses with cut-prong samples similar to those shown in figure 1. The prong samples were rated visually as excellent (no casehardening present), good (slight casehardening), or fair (slight to severe casehardening).

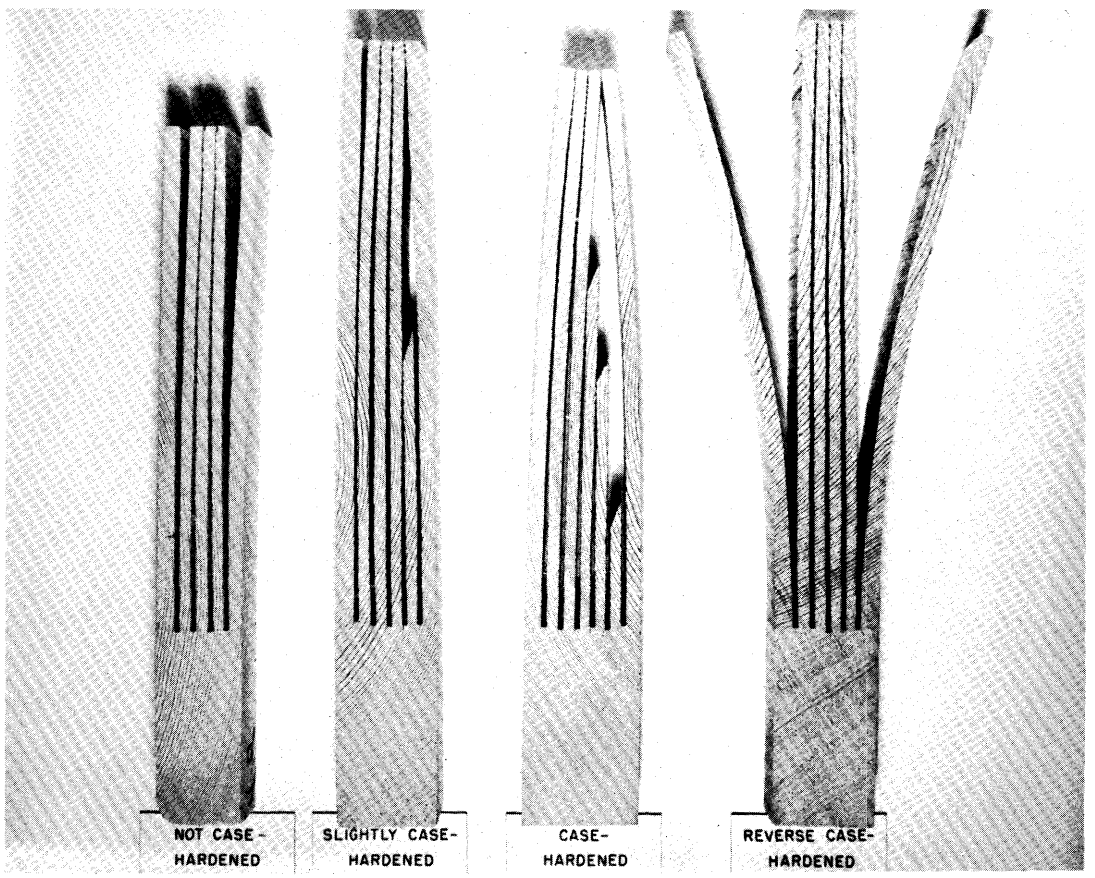


Figure 1.--Comparison of drying stress after conditioning.

Relief of casehardening stresses under conditions common to commercial practice required 11 hours at settings for 11-percent EMC, as in charges 6B, 6D, and 6E. If a commercial kiln could maintain conditions for 16- to 18-percent EMC, as in charges 6F and 6J, the time required for relieving stresses could be shortened to 7 hours. Time cannot be reduced much more, as shown by charges 6H and 6I, which did not demonstrate adequate stress relief.

The range of MC before conditioning is of major importance. Charges having a wide range in MC, such as 6H and 6I, required prolonged conditioning at high EMC conditions with only fair to good relief of casehardening. Therefore, range of MC before conditioning, time of conditioning, and EMC conditions are closely related. The thicker the lumber, the longer the conditioning period required. If you now require 12 hours to condition 4/4 lumber, 5/4 lumber will require about 16 hours, 6/4 lumber about 20 hours, and 8/4 lumber as much as 30 hours.

I have been deliberately evasive about wet- and dry-bulb settings and times for drying, equalizing, and conditioning. Each charge of lumber is different, as are kilns, operators, and customers' specifications. For problems with a new drying installation or with your present system, several State and Federal agencies offer assistance:

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Donald G. Arganbright
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University of Washington
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Western Forest Products Laboratory
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Vancouver, BC, Canada V6T 1X2

The drying process or any process in the mill will be as good as the quality-control program you have implemented. Think of quality-control not as a group of figures requiring statistical analysis but rather as a means of collecting information for improving your product.

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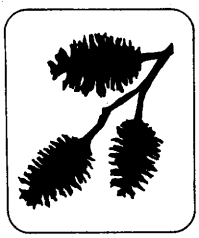
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ALDER–SHOULD WE CHIP IT OR SAW IT?



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ABSTRACT

It has been stated that the manufacture of red alder lumber is a small mill product; however, Northwest Hardwoods, Inc. has taken giant strides toward changing that image. Quality control and lumber sense are the key words that describe our operations goals. From expanded log consumption, constant machinery and process updating, to satisfied customers Northwest Hardwoods, Inc. has taken the Mom & Pop approach out of manufacturing alder.

Introduction

In years past, alder was a weed to be cleared from the land so that some form of softwood could be encouraged to develop. The potential for harvesting alder was not even considered. We have poisoned and spent thousands of dollars to remove this species from our land, and yet it continues to grow and flourish. As small sawmills began to spring up, many with only four or five employees including the working owner, some of the better sawlogs were brought in out of the woods. These mills were small and struggling to keep costs down, and there were many restrictions placed on the incoming log. The diameter needed to be of good sawlog size; and in many cases, the length had to be held short as unloading was often performed by the mill's only forklift. Chips weren't even thought of. It was all the mills could do to process enough logs to keep in business. All trim and edgings went into the fuel wood market - bark and all.

As in many instances, the hardwood chip was discovered by most sawmills through necessity. As the sawmills grew in lumber output, the firewood market stayed relatively constant and, in some areas, dwindled in favor of less troublesome fossil fuels. This left the mills with the alternative of finding new markets for residuals or closing down.

Debarking

In 1959, the first alder hardwood residual chipper went into operation at Centralia Hardwoods, and with it a Nicholson "coon hound" Rosser Head Debarker to remove the bark and provide a clean residual chip. The chips were mixed with sawdust and sold to a firm that was producing a corrugation medium.

The Rosser Head produced a block that was totally bark free but, in the process, removed vast amounts of wood and slivers. To improve the quality of debarking, a "32" Nicholson Ring Debarker® was installed in 1965. With the new debarker came the opportunity to consider more chipping as the new debarker's speed provided enough logs to keep the mill operating with time left over.

At this point, the decision was made to install a whole block chipper in the mill to upgrade the mill's saw block. This new chipper allowed us to experiment with the log mix coming into the mill. It was slow in todays standards, but at that time it placed us in the business of selling an increasing volume of clean whole log chips.

Today, with the availability of higher speed debarkers and increased interest in alder chips, we have elected to develop a modified merchandising line capable of handling a larger volume of woods run resources.

Today, we handle whole loads of logs with the use of heavy equipment allowing a quicker turn around for the trucks.

We deck each log with hydraulic loaders to facilitate more storage and insure a year-round operation. We have expanded our maximum inventory to the point that we are capable of storing 300 percent of what we stored 8 years ago and are using only 15 percent more land. This insures our sustained operation and allows those hauling to us the security of knowing we will be receiving logs year-round.

Merchandiser

In merchandising, there are two basic theories of operation: (1) Debarking the long log and bucking after debarking. It is felt that the quality of the log can better be evaluated with this method. (2) Our mills prefer bucking prior to debarking. We feel bucking ahead of the debarker allows us some advantages in removing the bark from the more crooked logs. Through our design, we are able to debark long straight chip logs without bucking or recover only a single saw block from an otherwise chip log.

As the log enters the merchandising line, we are faced with the first and most important decision: "Should we saw it or chip it?" To answer that question, each mill operator has to establish his own guidelines. He must recall all of his knowledge about his individual lumber market restraints, chip recovery values, and most important, his current resource, both volume available and cost. With this input, a graph can be developed so that the individual mill operator can evaluate his options. In graphing the options, we find the merchandiser operators can be given general instructions for the logs having diameters between 8 and 10 inches.

Probably the single most troublesome feature in any operation, softwood or hardwood, is the attitude and discipline that occurs in the woods.

In designing any merchandising line, there are a number of considerations--those that are of paramount importance concern the volumes of by-products that must be hauled away.

There are some weight considerations when dealing with alder. If you are going to saw all your logs, you would have to handle only 20-25 percent of the weight in the form of chips; if you were going to chip all logs, you would have to allow for 85-88 percent of the weight to be in the form of chips.

Once we have made the decision to saw rather than chip, we must again concern ourselves with alternatives based around the resource and the mill's marketing plan.

The Sawmill and Lumber Sense

At the headrig, we are presented with a block from the merchandiser that is free of bark and ready to be processed into alder lumber. The headrig area is slightly different in each mill. Some use the circle saw headrig, some the single-cut band mill, and in our case, the double-cut bandmill. Our goals are the same: to maximize flat grain lumber and orient the block to minimize undesirable defect structures such as spike knots. The output from our band mill has increased 20 percent during the past 2 years; however, our sawing time per saw line has not significantly changed. Our principle mechanical improvements have occurred in the carriage loading and block turning times. Aside from mechanical changes, we have spent a great deal of time and effort training our sawers to operate with "lumber sense"--the keys being quality and product control.

Every saw and saw system has its limits of performance. Each management team must determine where the trade off between recovery and output lies for their operation. Each philosophy has its merits and, for their operation, meets their marketing needs. The ultimate method of sawing for grade recovery would be total breakdown on the headrig - constantly turning the log and evaluating each board on its merits. The opposite extreme would occur if maximum volume was obtained by sending a whole log through a sash gang or possibly a quad band. We prefer to break down the block on two sides with the grade of the opening face as the control factor for the sawyers' decision. Once all the obvious #1 Shop and Better has been removed from the two opposite faces of the block, the resulting cant is sent to the circle gang where it is positioned to be fed through the saws, contingent on our historical recovery data, the market, and the judgment of the operator. This method does not maximize the grade recovery out of every block; however, we have developed our lumber markets contingent on our historical grade and volume recovery with this method. Throughout the operation, the key is on "lumber sense" and quality. Once missawn, a 4/4 board cannot be recovered and is lost forever. Our green lumber standards call for a maximum variation of 1/16 inch. We have fulltime quality control personnel along with our filers constantly monitoring the lumber for both thickness control and general product attitude. Should a deficiency be detected in our production,

we shut down or isolate the contributing unit until it can be repaired. In a production situation, it is difficult to establish an attitude of quality; but once established, it becomes as much a goal as production.

We have experimented with a variety of saw thicknesses, numbers of teeth, types of guides, methods of cooling, and saw change periods over the past years and, based on our green lumber quality standards, have elected to use thin plate carbide saws with air-water cooling.

Hardwood Softwood Yield

Compared to the softwood 1-inch board which, when dry and finished, sells at a net thickness of 3/4 inch, our alder 4/4 must dress out to a net thickness of 15/16 inch or 25 percent more wood. In comparing with a 2-inch softwood product which nets out at 1-1/2 inches, we must provide an additional 29 percent to net out at 1-15/16 inches.

Selling lumber random width as we do in the hardwood industry allows us to make the most pronounced recovery improvements anywhere in our mill at the board edger. When comparing the softwood products to the hardwood products, one finds that a board foot of softwood doesn't equal a board foot of hardwood. Let's look at an example: A softwood mill selling eight pieces of 2x6x10 will sell this lumber as 80 board feet; but when we check what the customer receives, we find that he received eight pieces 1-1/2" x 5-1/2" x 10', or a total of 55.04 board feet of actual wood. Our hardwood customer who settles for random width would, in this case, require us to provide a total of 44 inches width by 10 feet x 1-15/16 inches thick. We do not get any value from the shrinkage that occurred in the kilns, so the customer pays for 71 board feet and receives 71 board feet of actual wood. In summary, this says that we must, in order to meet the requirements of our customers, supply them with 32 percent more actual wood in order to develop the same volume sales as the softwood industry.

Board Edging

Bearing in mind that our recovery is contingent on the amount of actual wood we deliver to the customer, let's look at the board edger. Our board edgerman reviews and rips 40-43 percent of our total piece count coming out of the mill so, needless to say, we have spent many hours evaluating and training our edgerman. We have given him expensive laser lights to set his saws and require him to inspect and make necessary adjustments every 4 hours to insure his sawing is accurate and precise. Let's examine what could happen if the edgerman's saw on one side was sawing into the sound wood instead of coming out of the wane for a single shift. The average edger saw cuts a 1/4-inch kerf so we are only talking about 1/4 inch on one edge of 43 percent of all boards for one shift. For example:

.250" x 9.1' long = .1986 board feet
.1895 board feet x an average #2 shop price of $160/MBF = 3¢

Now you are saying that 3¢ isn't much but remember that this edger is reviewing 40-43 percent of your product so 3¢ by 4,730 pieces per shift equals $141.90 per shift. Extended on the basis of one shift for 12 months, all 4/4 thickness, shows a loss of $37,000. That's a little more significant! What has happened to that 1/4 inch? If you are lucky, it would make chips and yield an annual amount of about $7,000, but more likely it went into sawdust and you received at best $1,500-$2,000. With the difference, you could have placed a very expensive man on your payroll.

There is another aspect that makes the board edger in a hardwood mill more complex. Within the grading rules there are wane allowances. In some cases, an extra 1/2 inch of wane left on a certain portion of the board will lower it to the next grade and, from a dollar standpoint, the best of our recovery attempts is negated. Because of the complexity of the operator's job, especially within the wane allowances, he often over-edges the board to be safe. Each mill has to place the level of importance of the board edger job where they feel it best meets their needs.

Upon leaving the board edger, each board is reviewed once again by two men who can direct the board back to the edger if they feel additional edging is required.

Trimmer

Within our operation, the trimmer is used to equalize and end trim lumber prior to entering a mechanical sorting system.

The board passes through the trim saws and trips a length sensing limit switch then goes under a floating wheel and is sensed for thickness. These two sensings are sent through an electronic storage unit which times the boards and deposits them in the appropriate tray. On each tray there is enough accumulated lumber of the same thickness and length to make one package of green lumber. When the tray is full, it can be emptied individually, run across an automatic stacker, stickered, and collected into a bundle ready for the dry kilns. We selected this tray sorter and mechanical stacking system about 3-1/2 years ago in an attempt to reduce our mounting labor costs and improve the quality of stickering. To date, I am happy to say it has operated with a minimum of problems and we are handling 20 percent more lumber than when we had our green chain. In addition, this operation takes only three men in place of five to six men on the green chain.

An an added advantage, our Arlington Mill is using Simpson EKS stickers with excellent success.

Kiln Drying

In years past, we felt we had to air dry our lumber to reduce our drying costs and to improve our drying quality. Today, we feel more comfortable in getting the fresh lumber into the kilns and under a controlled

climate. All lumber is kiln dried prior to sale with the 4/4 dried to a moisture content of 6-8 percent and all other heavier thickness' dried to a 6-9 percent moisture content. Once we feel the lumber has had adequate residency, we open the kiln and check the lumber with a prong meter. If the meter indicates we are close, we cut ovendry samples from random areas within the kiln load and run them through a microwave oven to guarantee the kiln is at the correct moisture content. When drying material over 4/4 in thickness, additional prong tests will be cut to determine if the lumber is properly conditioned and ready for the customer. Only at this time will we empty the kiln into the storage ahead of the planer.

Abrasive Planned

In 1972, Northwest Hardwoods installed an abrasive planer at our Arlington plant and explored its potentials for our customers. The planer was a Kimwood batch feed, four-head 36-inch abrasive planer powered with a direct coupled 100 hp motor on each head. We operated the machine for 2 years modifying the dust handling system to provide fuel for our boiler and working with the abrasive belt manufacturers to improve the life of the belts. Upon evaluating our customers reaction to the abrasive planer, we found even better response than we had originally expected. In 1974, we installed another abrasive planer at Centralia. This was also a Kimwood, batch feed, four-head machine, but this time we installed a 50-inch machine with a 200-hp motors on the primary heads and 150-hp motors on the finish heads. Sound absorbing material was attached to the Centralia machine to lower the noise level to an acceptable limit.

More details on the qualities of abrasive planing could be mentioned, such as the fact that our finish is the same from the beginning of the run to the end of the day. If the finish is not satisfactory, or we want a smoother finish, we change the belts, an operation which takes about 1 to 3 minutes. There are no roller splits, knicks, snipped ends, or grain tear out around the knots or any other planing defects associated with many knife planers. If we get an equivalent to a knick in a knife planer, we get a blown belt, which, when changed in 1 to 3 minutes, eliminates the surface imperfection. The abrasive planer is so accurate that our quality control standards call for shut down of the machine if the thickness tolerance varies more than .005 inch. The inspectors, machine operators, and our quality control staff constantly check the thickness tolerance with dial calipers and insure that surface appearance is within standards.

Northwest Hardwoods is not prepared to disucss the costs involved; however, we can assure you that our per unit costs are consistent with the quality of our product, and we feel sure our product is second to none. Any high speed, highly accurate machine requires more than normal maintenance.

Inspection

Our inspectors are highly trained employees who have been with the company for years and have proven their ability to maintain a consistency of grading accuracy above 95 percent, which I feel very confident is more than comparable with the industry averages.

As mentioned previously, we have placed special emphasis on quality control and the "lumber sense" approach throughout our manufacturing facility.

Once packaged, all bundles take on similar appearance, irregardless of board thickness. The bundles are prepared in the same physical size units and tallied. Special emphasis is placed on tally because many units will manifest occasional short pieces, and we are very careful to deduct for the short pieces so that the customer receives 1 board foot for each board foot he purchases. We welcome and encourage all of our customers to secure one of our tally computer cards and check our tally accuracy.

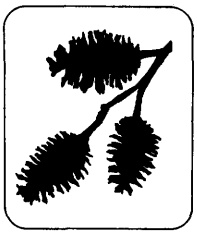
As one of the final quality control functions, random packages are selected from inventory, broken down, and a complete grade check and stick tally is performed. This is done to at least two bundles per day.

As proud as we are of our product, we never allow any lumber to leave our mills without being totally protected from moisture and dust by insuring all truckoads are fully tarped and all carloads are in sound cars.

Through all phases of our operation, we have placed special emphasis on quality and "lumber sense"--in merchandising the log, sawing the lumber, edging, handling the green lumber, drying to specific moisture contents, abrasive surfacing and the final step of dust and moisture protection while in transit.

I would like to leave you with the thought that alder, like all of Nature's creations, lends beauty to the Northwest and brings peace of mind to many of us.

TRENDS AND TECHNOLOGIES IN SOUTHERN HARDWOOD SAWMILLS



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ABSTRACT

This paper examines several hardwood sawmills ranging in capacity from 5 MM bd. ft. to 40 MM bd. ft. annually, and discusses the relative capital costs, operating costs, and characteristics of each facility. The paper further relates hardwood sawmill design to the characteristics of the hardwood sawtimber resource in the Eastern United States and explores the major industry concerns of (1) lack of growth in hardwood lumber production, (2) reduction in log size and quality, and (3) shifts in end-use markets. The uncertain supply of hardwood logs from small private ownership, the lack of market growth, and the variable earnings history of hardwood operations have discouraged most large corporate investment to date.

Introduction

Thank you for inviting me here today. I am delighted to have the opportunity to participate in your program. It's my first meeting with many of you, and I look forward to continuing these acquaintances in the future.

A little background might be in order for those of you unfamiliar with Union Camp. Our historic business, and still the core of the company, is the manufacture of bleached and unbleached grades of paper and paperboard. These are produced in four mills. About half of the mills' output is converted into bags, boxes, printing papers, and business papers in our own network of converting plants. The remainder is sold to other converters or merchants.

The 1.7 million acres of woodlands, which we own in six southeastern States, provide the raw materials for our mills. To maximize the return on our woodland assets, we have also entered other fields. The company is one of the largest pine lumber producers east of the Mississippi. Union Camp is also the largest manufacturer of wood-based chemicals in the forest products industry. Other activities related to our landholdings include commercial and residential land development, mining, and finally, we operate a chain of 48 building material and home improvement centers in the southeast.

Compatible with our need for raw material for bleached paper production and the desire to maximize returns on our woodland assets, Union Camp entered the hardwood lumber business last year. We now produce in excess of 24 MM bd. ft. It is my responsibility to evaluate and implement a major expansion of our hardwood lumber activities. It is my assignment today to share my knowledge of hardwood lumber manufacturing in the East. My comments will concentrate on five hardwood sawmill layouts ranging in single shift capacity from 5 to 40 MM bd. ft. annually. I will discuss the relative capital costs, operating costs, and general characteristics of each.

My basic objective is to stress the relationship between the characteristics of the hardwood sawtimber resource in the East and sawmill design. There are precious few innovations in hardwood manufacturing, but there are many changes in the resource acceptable for hardwood lumber. This Conference typifies the trend toward new species, smaller logs, lower grades, and shorter lumber.

Eastern Hardwood Resource

The sawtimber resource in the Eastern United States is comprised of about 12 species with oak predominating (table 1). In many areas of the South, oak, sweet gum, and yellow poplar account for about 75 percent of the sawtimber resource; but the many "miscellaneous" species and our lack of ability to control log flow by species present problems.

Table 1--*Volume of eastern hardwoods*

Species	Volume	Proportion
	Million cu. ft.	Percent
Select white and red oaks	32,613	16.5
Other oaks	38,796	19.6
Hickory	12,582	6.4
Hard maple	11,732	5.9
Ash, walnut, and black cherry	12,185	6.2
Sweetgum	10,527	5.3
Yellow-poplar	8,566	4.3
Yellow birch	3,249	1.6
Other	67,426	34.2
Total	197,676	100.0

This multitude of species creates problems in cruising and buying timber, scaling logs, log yard storage, and inventory management by species. We operate our pine mills with only a 2-day inventory but our hardwood mills require a 15-day supply for efficient operation.

U.S. Forest Service Forest Survey data indicates that hardwood growth exceeds removals by almost 2 to 1, but our sawtimber resource is getting smaller. Reduced log size results in a decrease in hardwood lumber grade yield. On our timberlands, one-third of the hardwood sawlog resource consists of logs below 12-inch d.i.b. Many hardwood sawmills in the South are for sale today because they cannot efficiently convert these smaller, lower quality logs.

Changes are occurring in the end uses of hardwood lumber (table 2). The furniture industry has traditionally been the major consumer of hardwood lumber. The pallet, container, and box market continues to increase, however, and is now our major consumer. Whether this has stimulated low grade lumber production or resulted from it, I cannot answer.

Table 2--*Sawn hardwoods--estimate of major end uses*

Item	Years		
	1971	1972	1973
	- - - - -	-Percent-	- - - - -
Furniture	34	33	29
Pallets	28	22	34
Containers and boxes	11	14	*
Crossties	11	14	13
Flooring	8	9	9
Laminated decking	3	4	8
Others	5	5	7
Total	100	100	100

*Included in pallets.

While consumption patterns are changing, total hardwood lumber production has not changed in 9 years. There is little reason to expect large production increases in the future in my opinion.

Estimated hardwood lumber production

Year	Million bd. ft.
1967	7,430
1968	7,188
1969	7,482
1970	7,138
1971	6,949
1972	6,770
1973*	7,008
1974*	6,904
1975*	5,506

*Subject to revision.
Source: Fingertip Facts and Figures, Natl. For. Prod. Assoc., Washington, D.C.

RESOURCE CONCLUSIONS

The changes in the acceptable hardwood sawtimber resource are setting the trends in sawmilling. The volume of hardwood timber is adequate, but diameter and quality are decreasing. Consumers are adapting to the changes in hardwood lumber size and quality but total consumption remains constant. The hardwood sawmill industry must adapt to these trends more rapidly in the 1980's than it has in the 1970's.

Production Alternatives

Let's turn our attention now to several hardwood lumber production alternatives. Presented in the next few pages are five sawmill layouts with varying debarking and breakdown equipment. If your background is in softwood lumber manufacturing, these mills will appear unsophisticated; but the eastern hardwood industry is less sophisticated than the pine industry.

MILL LAYOUT #1

The simplest sawmill considered has a capacity of 5-7 MM bd. ft. annually (fig. 1). It consists of a rosser head debarker, circle headrig, combination gang and board edger, and a two-saw trimmer. This mill can be constructed for about $800,000 excluding land costs, would develop sales of about $1.1 million and would have operating costs in excess of $700,000 annually. This mill does not have facilities for stacking, drying, or surfacing lumber. Ties, timbers, and pallet lumber would be the major products. The mill, representing the "modular mill" concept, is of the type Union Camp would use on 12-20-in hardwood logs of woodsrun quality.

MILL LAYOUT #2

The second layout represents a circle mill with an 8-in single-arbor gang edger, plus a board edger. The mill still utilizes a rosser head debarker, and a two-saw trimmer (fig. 2). This mill can be constructed for about $1.8 million, has an estimated production capacity of 10 MM feet per year. Operating costs would exceed $1.3 million on annual sales of $1.7 million. While the return-on-investment is lower for this larger facility, this mill design is more flexible than the previous mill. Separating the board and gang edger slightly increases capacity, reduces total mill downtime, but requires an additional employee. The increased flexibility to adjust product mix to market changes may offset a slight reduction in ROI. This design probably represents the most common hardwood sawmill in the South today.

MILL LAYOUT #3

This third layout represents a sawmill offered to us for acquisition. The mill is basically the same as Mill 2 with a gang edger. Mill 3, however, has two rosser head debarkers, a drop saw trimmer and a production capacity of 12 million board feet annually (fig. 3). The construction cost for this

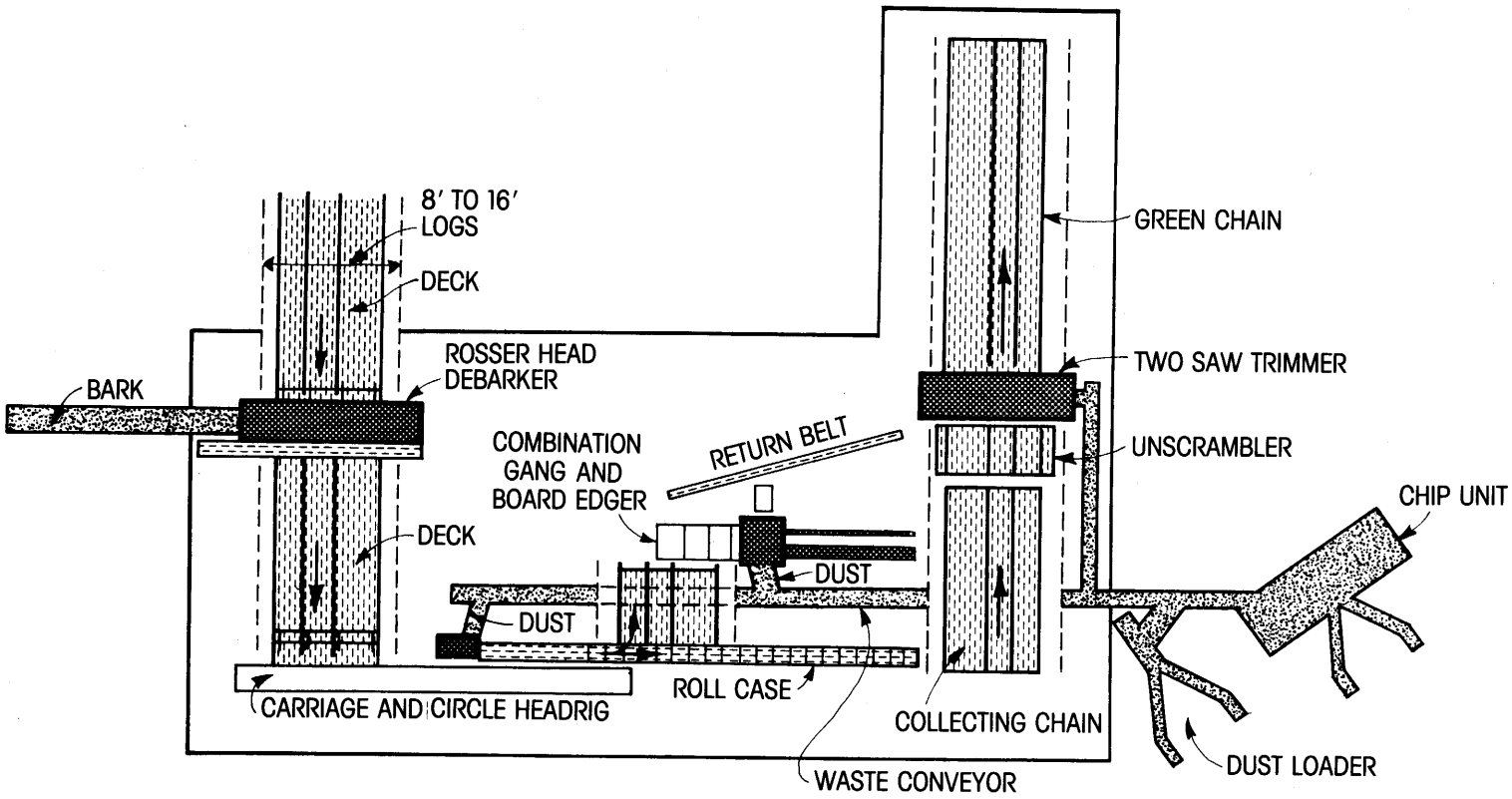


Figure 1.--Sawmill layout 1.

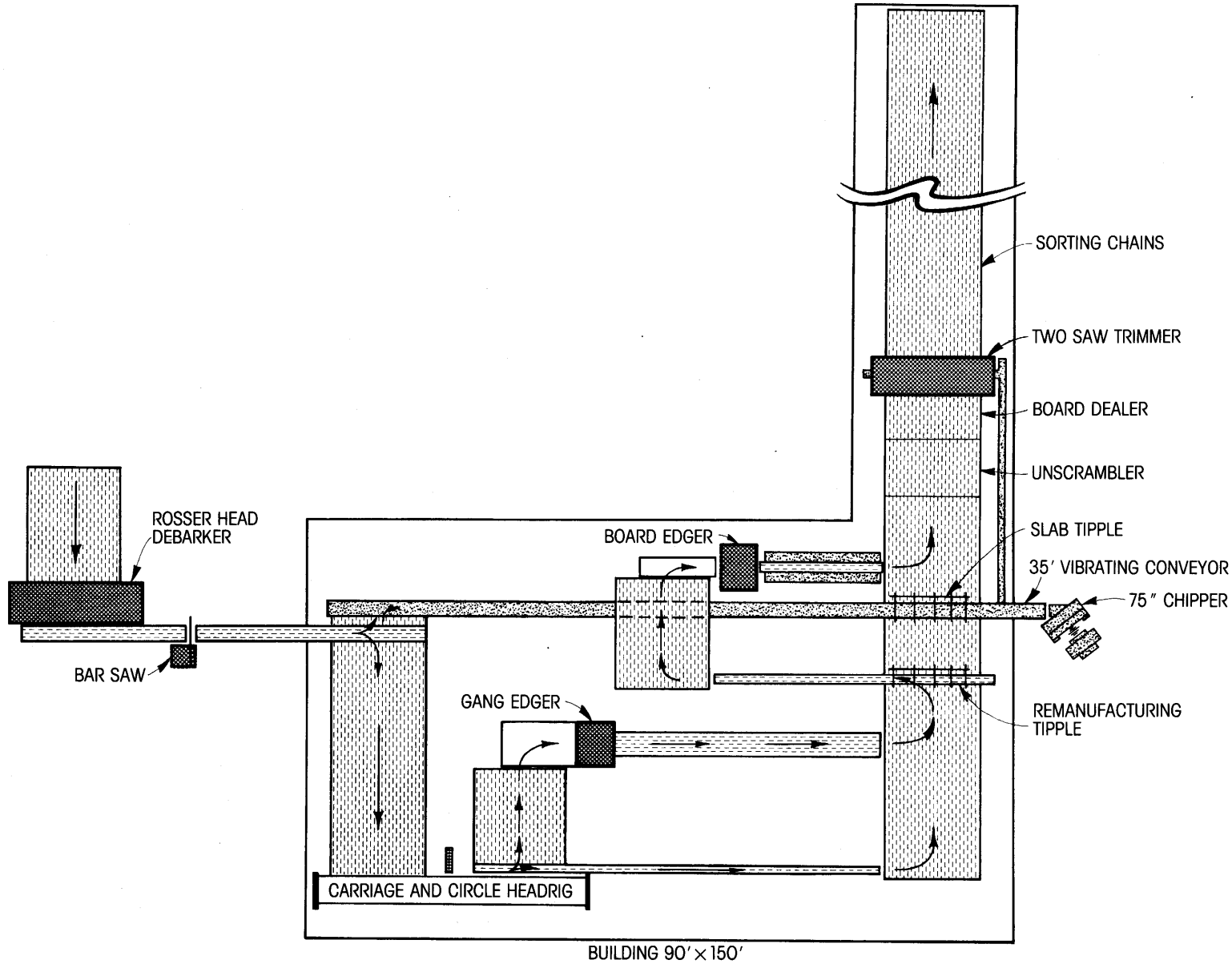


Figure 2.--Sawmill layout 2.

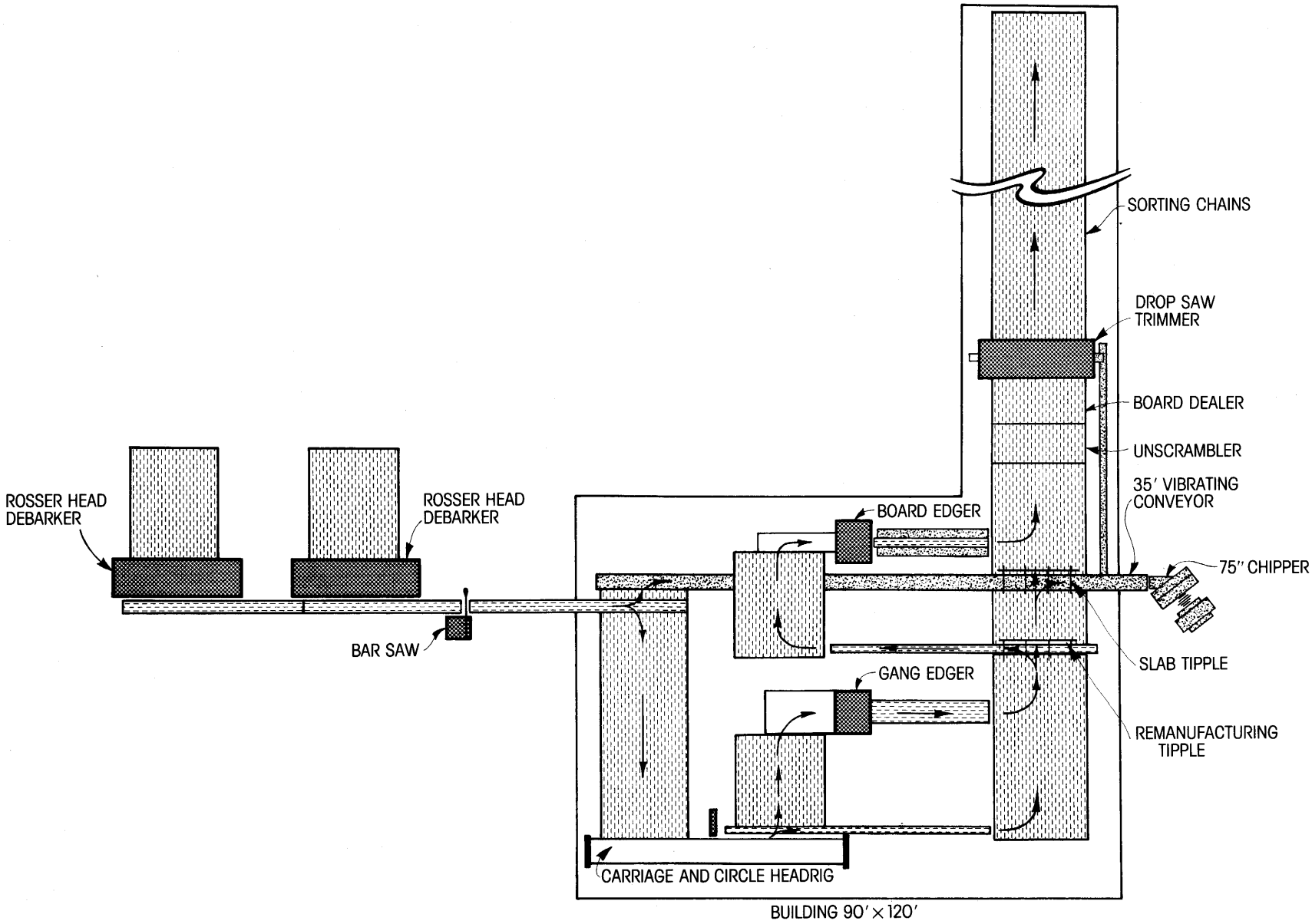


Figure 3.--Sawmill layout 3.

mill would exceed $1.7 million, would produce sales in excess of $2 million and operating expenses of $1.5 million.

This mill design provides an improved return-on-investment based on increased production at approximately the same capital costs as Mill 2. This mill does not require sophisticated maintenance, but it does require logs 10 in and larger.

MILL LAYOUT #4 - BAND MILL LAYOUT

This fourth mill layout is the first shown using a band headrig and line-bar resaw (fig. 4). It is difficult to justify a bandsaw filer for a small hardwood sawmill. This is also the first mill layout designed primarily for grade lumber production. We would use this equipment only for logs over 12 inches in diameter, and would anticipate average lumber value to increase $10/M bd. ft. compared to the previous circle mill with single-arbor gang edger.

Construction of this mill would cost about $1.8 million. Sales would be approximately $2 million for production of 11 million board feet annually. Operating costs of $1.4 million annually provide this mill with a competitive return-on-investment.

This mill layout is more common of the northern fine hardwood mills. It is a grade mill and, therefore, profitable only with a grade log resource. The equipment in this mill requires better maintenance than the previous layouts, but provides some of the best lumber available.

MILL LAYOUT #5 - CANTER MILL WITH CARRIAGE

This last sawmill layout represents a canter with a band headrig, line-bar resaw and circular gang edger (fig. 5). This mill is similar to our Franklin sawmill.

This layout utilizes a ring debarker for straight hardwood logs and a rosser head for poor quality logs, and combines breakdown of grade and low grade hardwood logs in large quantities. It is a sophisticated installation typically constructed only by large integrated companies in the East. It combines the ability to saw for grade and efficient utilization of small logs, but the log resource must be properly balanced to the design capacity of each.

The Canter mill is estimated to cost in excess of $3.9 million but has a production capacity of 40 million board feet annually. Operating costs would exceed $4.7 million on yearly sales of $7.1 million. The return-on-investment is competitive with the other four mill layouts discussed.

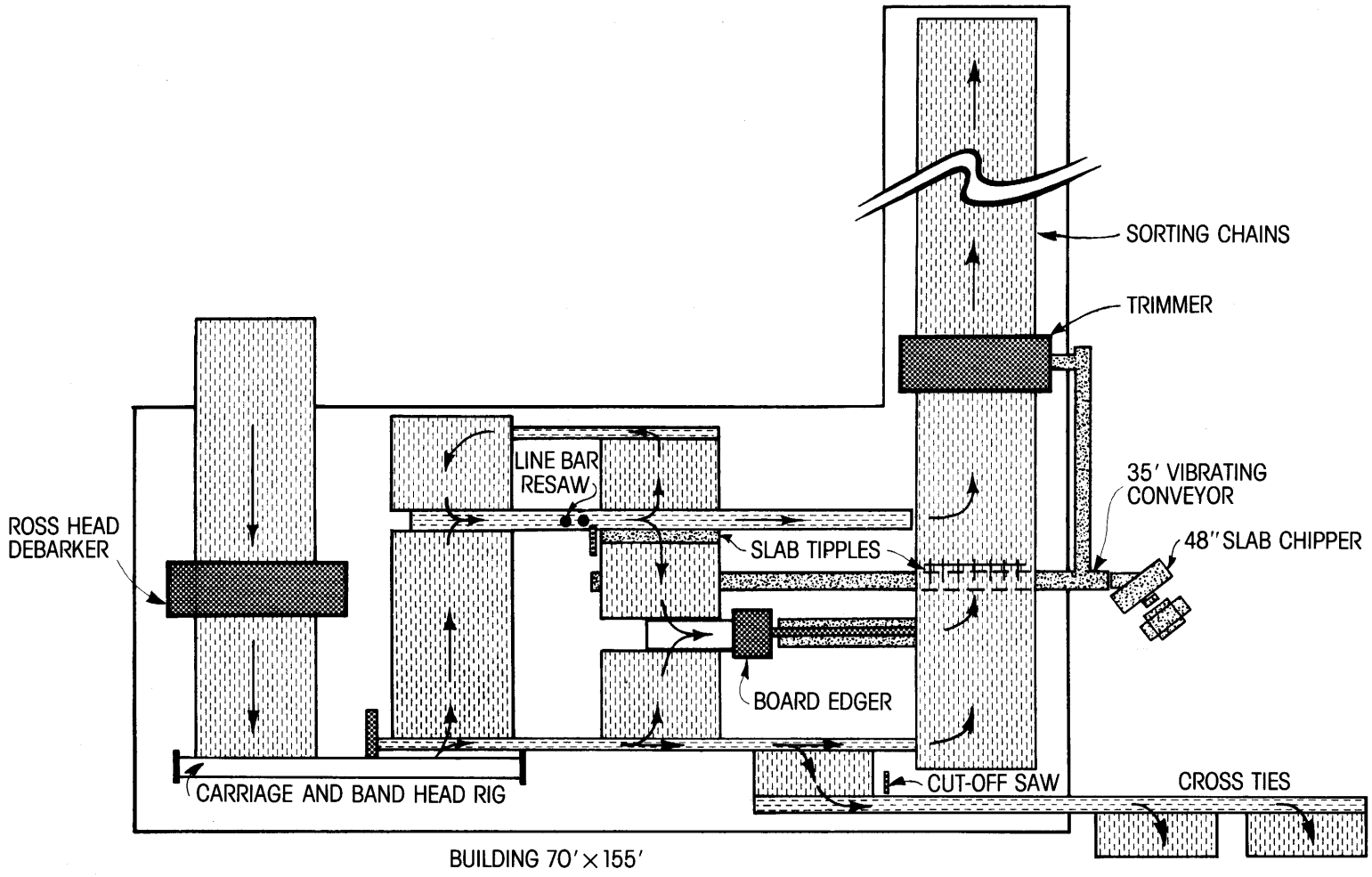


Figure 4.--Sawmill layout 4.

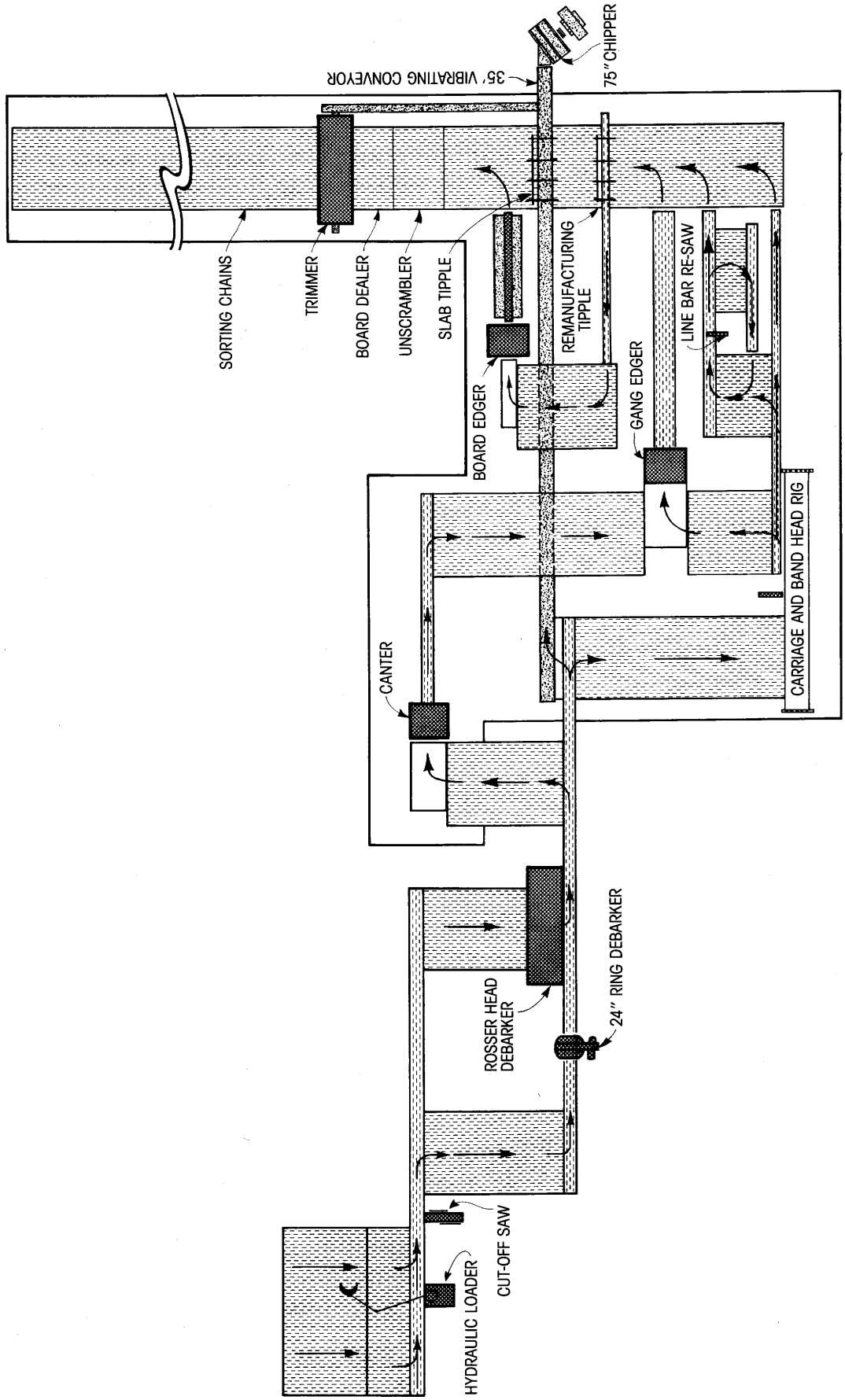


Figure 5.--Sawmill layout 5.

Basic Design Guidelines

It has been my experience that several basic principles of mill design should be continually reviewed.

1. Hardwood logs are not straight or predictable. A cut-off saw on the log deck is recommended even for log length mills.
2. Ring debarkers cannot handle all of the hardwood sawlog resource. A means of bypass is required for bad logs.
3. Double arbor gangs are designed to manufacture low grade cants into log grade lumber. The step-face from the double arbor often necessitates surfacing low grade lumber before sale to pallet manufacturers. The single-arbor edger serves well in many applications.
4. Production capacity is a function of mill design, but the mill design must first be a function of sawtimber characteristics.

Future of Hardwood Mills in the East

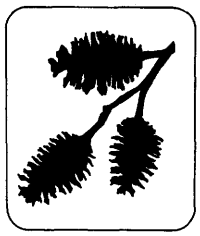
A year of trying to decide what Union Camp should do to better utilize its hardwood resource has not yielded any startling conclusions. I, however, hold the following points to be highly important.

1. The industry must adapt to the changing timber resource.
2. The industry will not grow substantially until rates-of-return justify higher capital investments.
3. Small independent hardwood sawmills will be replaced by large integrated firms attempting to better utilize timberland assets. Even so, the lack of market growth and the variable earnings history of hardwood operations will discourage many corporate investors.

Conclusion

I have appreciated the opportunity to present my opinions today. I would like to commend you for attending and participating in this Conference for it demonstrates your willingness to explore new alternatives for hardwood lumber. Changes are coming, and only those who are thoughtfully prepared will survive.

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NEW APPROACHES TO PRODUCING FURNITURE COMPONENTS FROM HARDWOOD LUMBER

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ABSTRACT

Furniture dimension parts are currently being manufactured from red alder on both the East and West Coasts. Species characteristics and the location of standing timber give alder certain competitive advantages. Dimension manufacturers, however, must continue to use every means to reduce the unit costs of processing. This paper described mini-computer systems presently being used in furniture dimension plants to reduce lumber waste.

ALDER: ONE OF TOMORROW'S IMPORTANT STRUCTURAL RAW MATERIALS?

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ABSTRACT

Alder is a lightweight, fast-growing species ideally suited for composition board and composite materials. Studies indicate that there will be a shortage of conventional raw material for plywood building materials in the Pacific Northwest. The composite panel made of veneer faces and a particleboard core offers a building panel that can possibly use alder for core. Plywood plants can maintain or increase their production rate using particleboard cores, thus avoiding problems associated with shortages of conventional veneer.

Demonstration alder flakeboards (a type of particleboard) showed excellent modulus of rupture, modulus of elasticity, and internal bond properties which exceeded those in competitive flake-type boards. Indications are that alder merits serious consideration as a raw material for structural panel materials (composition board and composites).

Introduction

Alder has long been used for a number of wood products. It has not, however, been an important structural product. In this paper I discuss the need for additional wood-based structural products, research and development programs underway for developing such new products, and the potential for alder as the raw material.

Until recently, a wealth of forest-based housing materials has been available to the people of the United States. Shortages in new housing materials are forecast for the future. Documentation backing the need for new housing materials can be found in: "Report of the President's Advisory Panel on Timber and the Environment" prepared by a 1973 select Presidential Advisory Committee (*1*), a 1973 Forest Service report "The Outlook for Timber in the United States" (*2*), and a study by the Committee on Renewable Resources for Industrial Materials, The CORRIM Report (*3, 4*). Housing is and will continue to be a critical national need relating to the general welfare of

people. It is, therefore, encumbant upon those involved in the forest products industry to provide the quantity and quality of materials for properly housing the people of the country.

Many programs are in operation to improve the growth of timber and to improve the utilization of the harvested forest. The best approach for immediate action is better utilization. With this approach forest and mill residues and smaller trees and previously unused hardwood forests could be better utilized. The impact is to be made in developing new wood materials from these raw materials.

Research and Development Programs

Researchers are thoroughly studying the problems and properties of a new family of manmade structural wood materials involving particleboard cores and solid wood facings and called Com-Ply®. Studs have been made using this concept, and they appear to be economically viable. This paper, however, will concentrate on the composite panel products in which alder can readily fit. This type of product can use approximately 90 percent of the whole tree rather than the approximate 1/3 now going into plywood type products. Tree species not now considered useful in the forest inventory, particularly as they relate to construction products, can be included.

Successful development and marketing of such products will provide much more additional building material for use and will also reduce the level of imports necessary to keep our expanding population, in terms of those establishing new households, adequately sheltered.

The research and development efforts have been underway for several years. This is particularly important to the Pacific Northwest as the size and quality of the timber available for the production of plywood diminishes. W. D. Page (*5*) in his background paper for the Third World Consultation on Wood-Based Panels described the reduction in the amount of "conventional" peeler logs available for plywood production. There is the further problem of our shrinking forestland base while population and economic growth continue upward. Thus, with the timber supply problem there is both an economic and a social problem involved in supplying housing to people; consequently, the research efforts now underway are directed where they will have the greatest immediate impact; namely, materials for housing.

Basic building materials such as lumber, plywood, and particleboard have been or are currently being produced from alder. Two particleboard plants operated in the State of Washington in the 1950's using alder--namely, the Columbia Hardboard plant in Everett and the Nu-Ply plant in South Bend. The composite products as described earlier appear to have a great potential when the use of alder is considered. In simple terms, these composite products consist of a particleboard core and veneer faces. At the present time a product of this nature is being produced by the Potlatch Corporation in Lewiston, ID. The particleboard core is made of flakes which are aligned in one direction. Aligning the flakes greatly increases the bending and

modulus of elasticity properties so that the particleboard is approaching the levels found in veneer. The final product is made similar to plywood with the aligned flake core running at right angles to the grain of the veneer faces. Thus, the product is very similar to plywood but at the same time core voids which can cause many problems are eliminated.

Within reason, the species is secondary; however, each one may have some attributes or negative factors which have to be considered. The main consideration is whether the job can be done in terms of performance. The building products are being considered as materials, and species is not the dominant factor governing properties. Instead, engineering characteristics in terms of performance are of most importance.

The composite product already manufactured by Potlatch is approved for use in the marketplace. It is actually performing as a type of plywood and is selling at plywood prices for sheathing applications. Potlatch has performed extensive research and development getting their product into the marketplace and has essentially opened the door for others so interested. The U.S. Forest Service, the American Plywood Association, and Washington State University are at the present time cooperating in a large study developing more information on this type of product. In particular the research is investigating two species; Douglas-fir and southern pine; particle geometry including shavings, ring-cut flakes, and drum-cut flakes; phenol formaldehyde, urea formaldehyde, and melamine-urea formaldehyde binders; and random and aligned particle orientation. This experiment is not a complete factorial experiment as most of the effort is concentrated in the Douglas-fir species and phenol formaldehyde resin area. This information, however, which is being developed by others, will be useful for those considering using alder as the core in the composite product. The additional work required to bring alder into use will be minimized because of all the information already generated.

It should be pointed out, however, that it may not be necessary to orient or align the particles in the core for increasing bending strength and stiffness as randomly formed materials are already extensively in use for structural applications in western Europe, Australia, New Zealand, and in Canada. Some of these products, particularly the waferboard from Canada, are already moving into the U.S. markets. More information on this type of product will also be developed in the composite board study. As will be seen later, alder lends itself well to this type of product and it may be a species for serious future consideration. It should be noted that over $1 million is now being committed to this initial research and development effort, none of which is coming directly from the alder industry.

Alder as a Flakeboard Raw Material

In this paper, building panels in the form of flakeboard (a particleboard) are emphasized, demonstrating the good qualities of alder for either the entire structural panel or the core of the composite products. The Northwest, as mentioned, will be wanting more panel raw material as the

quality of the harvested forests decreases. This is very important if the west coast industry is to maintain its position in the marketplace. The west coast has been blessed with much of the good raw material for products--such as Douglas-fir, ponderosa pine, larch, etc. But if the studies are correct, there will be a short-fall of this material, in its present form, over the next 20 years.

The Wood Technology Laboratory at Washington State University as well as other laboratories throughout the world have worked on many different raw materials for composite and composition board (particleboard/fiberboard) products. These include different types of grass, coffee bean hulls, coconut shells, reeds, palms, high-density hardwoods, and even fiberous material from municipal refuse. Quality wood material is highly preferred for making these types of products. Indeed alder fits many of the criteria for an excellent species for composite and composition board products. It is fast growing, lightweight, free from significant specific gravity differences between spring and summerwood, and easy to flake or otherwise reduce to particles. Flakes from alder have excellent particle dimensions for developing the properties necessary for good panel structural performance.

The crooked material can also be used because it is being reduced to flakes and, as mentioned previously, about 90 percent of the total wood can go into the product. Indeed, it may be possible to also include the bark without incurring significant damage to board properties particularly in the composite-type product.

It must be noted that the process for making a particleboard is a web of interrelating factors; however, all of these factors which include particle geometry, resin level, resin type, board specific gravity and thickness, moisture content of the mat when being pressed, and pressing conditions can be manipulated advantageously to produce the type of panel product desired. All of these factors are well beyond the scope of this paper, but they are noted to indicate that an extensive body of scientific and technical knowledge is already available for moving alder into these types of products and accompanying markets.

To demonstrate the potential for alder a number of flakeboard panels were made according to conventional manufacturing parameters. The following tabulation lists the basic manufacturing parameters.

Flake type:	drum-cut (hammermilled) ring-cut
Resin type:	phenolic
Resin level:	6 percent (oven-dry basis)
Wax level:	1 percent (oven-dry basis)
Board specific gravity levels:	0.64 and 0.72
Board size:	0.500 by 12 by 15 in

As can be seen two types of conventional flakes were made. Standard flakers were used for the flake preparation. The drum-cut flakes were nominally 0.015 in thick by 1.5 in long. Drum cutting flakes usually results

in a relatively wide flake which must be split into narrow widths for board production. This was accomplished by hammermilling the flakes without a screen mounted in the hammermill. The ring-cut flakes were nominally 0.015 in thick by 0.750 in long.

Some of these flakes were not dried immediately and this resulted in some oxidation. This is shown in the familiar orangish color of green alder that has been exposed to the air. Potential problems with gluing may result from this situation, and some boards were made with flakes that were dried immediately upon manufacture; some boards were made from oxidized flakes. It must, however, be immediately pointed out that this demonstration of board properties cannot be taken as a scientific study illustrating that there was either no problem with oxidation or vice versa. Drying of the flakes is normally accomplished immediately after cutting; this is a normal production step. The moisture content of dried flakes is nominally 4 percent.

After drying, the flakes were blended with the phenolic resin and wax in a conventional blender. The wax was included to inhibit the pick-up of water in the finished board. The blended flakes were then formed into mats and hot pressed according to a conventional schedule. The finished boards were evaluated for modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB). The modulus of rupture is a measure of the bending strength of the product. Modulus of elasticity is the property that controls the panel deflection. Deflection is the normal design parameter used with panel products. Internal bond information establishes how well the panel is glued together. The following tabulation presents information on the properties of the boards prepared for this demonstration. Figures 1-3 present this information in graphic form.

	Board Properties				
		MOR	MOE	IB	
Flake Type	Specific gravity	(psi)	(psi x 1000)	Specific gravity	(psi)
Drum-cut	0.65	4360	0.613	0.64	145
	0.72	4700	0.730	0.73	159
Ring-cut					
Non-oxidized	0.65	4160	0.601	0.65	140
	0.73	5460	0.807	0.72	178
Oxidized	0.65	3820	0.575	0.65	133
	0.63	4960	0.726	0.73	168

All of the properties found in these panels were judged as excellent for flakeboard. In comparison with commercial standard CS236-66 "Mat-Formed Wood Particleboard" (*6*), far exceed the minimum properties under consideration. These alder boards would be classified in this standard as 2B2. The minimum property requirements in this standard for 2B2 boards are as follows: modulus of rupture - 2500 psi, modulus of elasticity - 450,000 psi, and internal bond - 60 psi. A quick comparison shows all the alder board properties are far above the minimum property requirements. At the same time

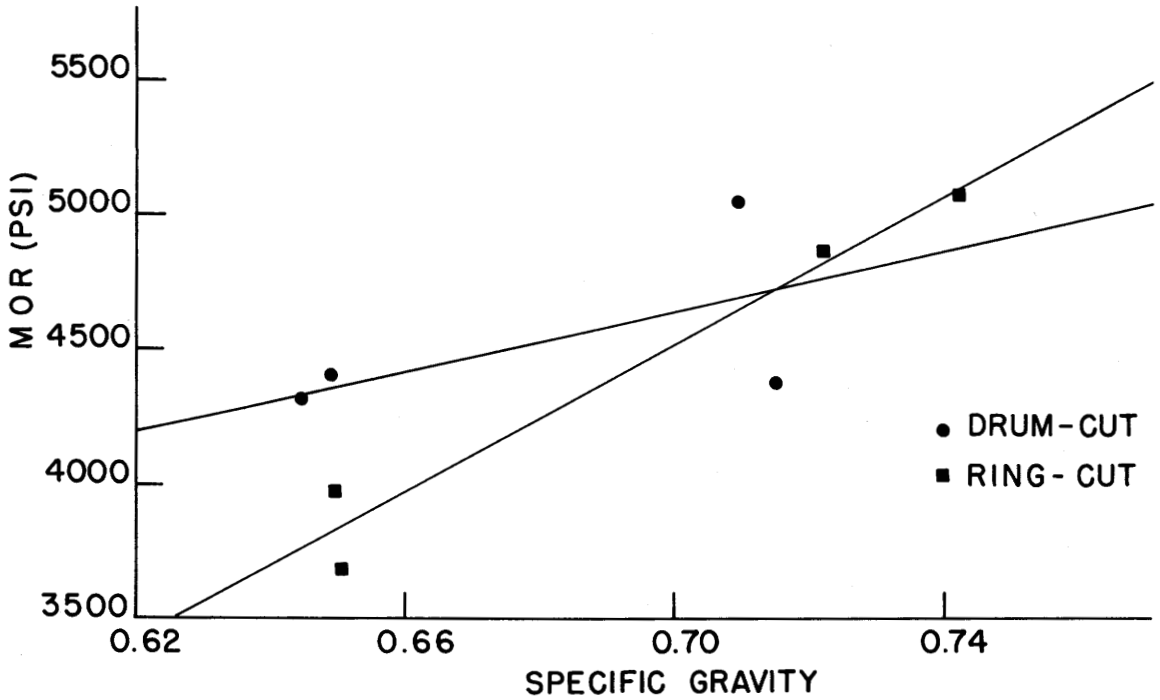


Figure 1.--Modulus of rupture vs. specific gravity for alder flakeboards.

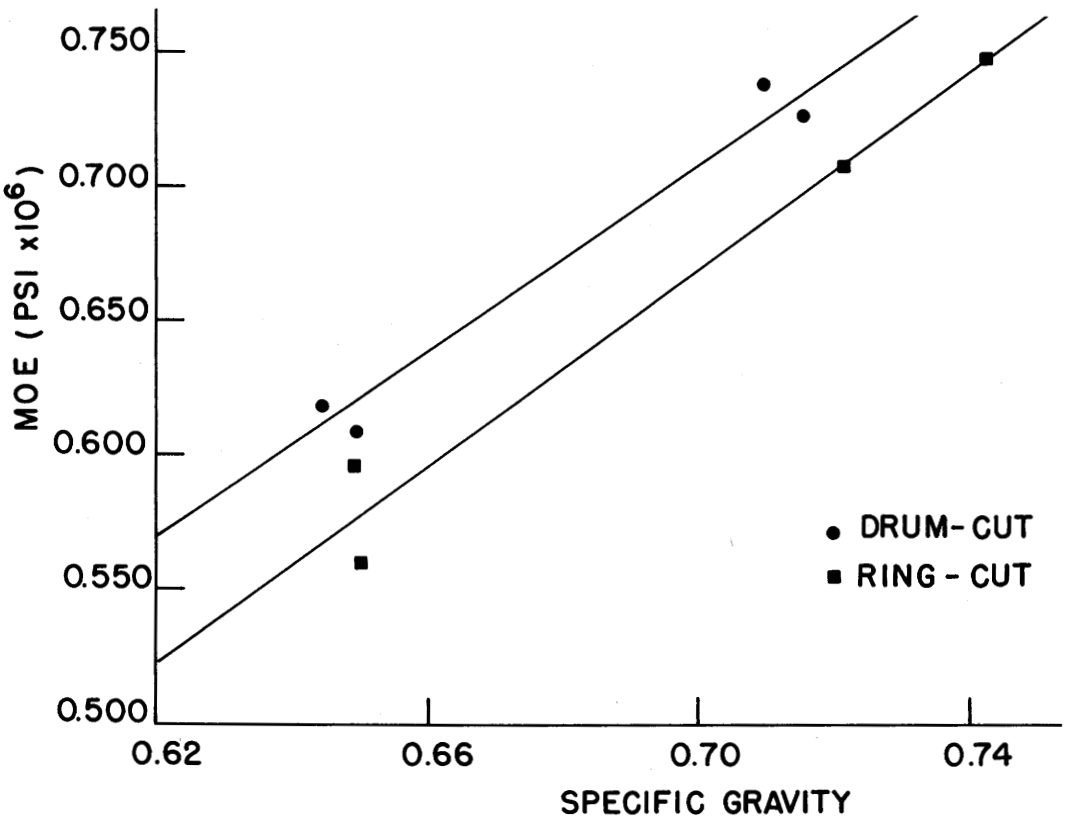


Figure 2.--Modulus of elasticity vs. specific gravity for alder flakeboards.

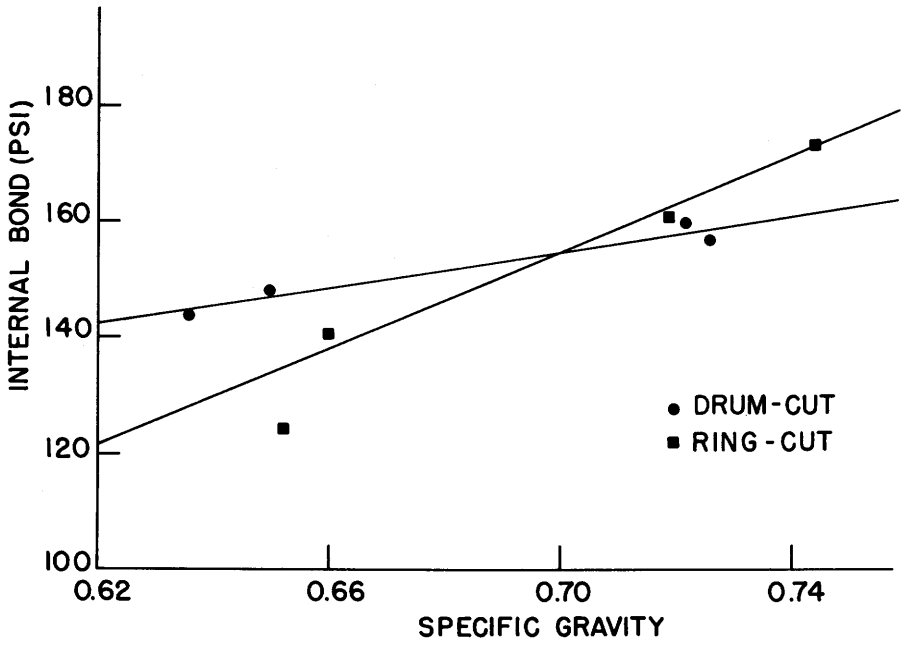


Figure 3.--Internal bond vs. specific gravity for alder flakeboards.

these properties, particularly in modulus of elasticity, are quite high even though the flakes are randomly oriented throughout the panel. A further improvement could be expected if the flakes were aligned so that the maximum bending and modulus of elasticity properties could be achieved. The properties as shown exceed those found in other flake-type products available in the marketplace for structural applications, most notably waferboard. The Canadian standard CSA Standard 0.188-1975 "Mat-Formed Wood Particleboard" (*7*) shows waferboard as having the following minimum properties: modulus of rupture - 2000 psi, modulus of elasticity - 400,000 psi, and internal bond - 40 psi.

It must be acknowledged that these standards are showing minimum properties, but field experience indicates that the demonstration alder boards have higher properties than normally found in other flakeboard-type products in the U.S. market at the present time. In fact, the properties are at such a level it would be probably possible to make lower density flakeboards than made for this presentation. This would result in the use of less wood and less resin and thus a lower cost for materials. It may be that there would be lower glue-line stresses in the composite products with the lower density alder board serving as the core between the veneer faces.

Other properties than those shown for the alder boards are needed in structural panels. Consequently, the minimum data presented here cannot be interpreted as showing alder to be acceptable for raw material in structural composition board or composite products. Based on experience and the data, however, alder has great potential for such materials. If large volumes are to be available, alder merits serious consideration, and research should be conducted using this species.

More research has to be done on the material, no matter what species is used; and, as mentioned, much of it is already in progress. Further information must be developed on the effect of the thickness density profile of

the particleboard core on composite products, the effect of density levels of the particleboard core, bonding problems due to oxidation of the wood in the case of species such as alder, durability, and the effect of particle type and size. Also needed is research on new and different binder systems. This will be important in the future as it will be impossible to make the glued type of products without new adhesive systems.

Conclusion

Alder appears to have a great possibility for use in both composition and composite-type products. It should be thoroughly appraised for consideration as a species of considerable value in future forests. The properties of flakeboards made for this presentation are excellent. The species is lightweight and easy to flake which is a great advantage. It may also be possible to use the wood and bark together particularly in the composite products. It is a fast growing species, especially through its first 20-30 years. Straight boles are not necessary for making the flakeboard products. It, therefore, should be carefully evaluated as a raw material for structural panel materials. Other advantages such as fixing nitrogen in the soil may also be of great importance in considering the use of alder as a structural raw material rather than other species which could be grown in its place, but this will have to be determined by those expert in this field.

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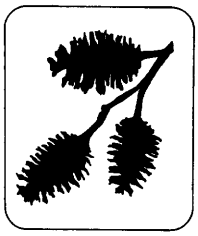
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ALDER AS A WOOD FOR VENEER AND PLYWOOD



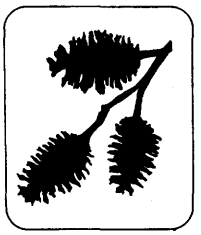
HARRY McGUANE, Owner
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Abstract

The oral presentation described the process of manufacturing alder veneer in a facility equipped with the only hardwood lathe in the West. The hardwood lathe is equipped with a fixed nose bar which is capable of achieving higher peeling pressures than conifer lathes equipped with a roller bar. The capability of achieving higher pressures is important in controlling the roughness, depth of checks, and thickness of the veneer. The end product is a dry veneer that is 1/24 inch in thickness. The majority of this veneer is used in the manufacture of quarter inch plywood wall panelling.

The market for alder veneer and its future are uncertain. Production of alder veneer has been low, and logs are frequently knotty so recovery of higher grades is difficult and costly. A large fraction is, therefore, a lower quality veneer which enters a very competitive market with surplus low quality veneers from other species. Style changes in the panelling industry and lack of familiarity with alder are other problems.

RED ALDER AS A PULPWOOD SPECIES



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ABSTRACT

In this paper I discuss the use of alder as a pulpwood species. Today most alder pulpwood is procured as roundwood. Debarking of small and frequently crooked logs and storage are indicated as problems. Chips are rarely stored more than a month as they color rapidly and strength and yield losses occur. Use of alder in a number of pulping processes is discussed. Alder is suggested as the best prospect for whole tree chipping in the Northwest.

Introduction

Red alder is a useful pulpwood species in the Northwest. It can be easily pulped by the kraft or sulfite processes or by several high yield processes. The chemical pulp produced has the properties of a good hardwood pulp - it is similar to the better known birch. The desirable properties are good formation and good printability and texture properties such as smoothness and softness. Alder pulp, in common with hardwood pulps in general, has lower strength properties than softwood pulp and is blended with softwood pulp in most uses.

Pulpwood Procurement

Most pulp mills obtain at least part of their supply of red alder from internal sources and supplement this with some outside purchases. About 90 percent is delivered as roundwood which is a preferred form especially if the wood is to be stored for a period of time. The wood should not be stored in contact with soil. Present prices offered for delivered pulpwood run between $24 and $29 per 4,800-lb unit on a bone-dry basis.

Debarking

Debarking is somewhat of a problem due to the small and frequently crooked logs and due to variation in ease of debarking. Debarking is easiest with straight, freshly harvested logs in the spring and summer; the bark is tighter after either summer or a storage period.

The bark content is not significant for use in high yield pulping for unbleached material such as corrugating media. Up to 2-1/2 percent bark can be tolerated in kraft pulping of alder since the bark cooks out in this process. Certain NSCM[1] processes require clean chips, such as Permochem, and chips for the sulfite processes should have no more than 1/2 percent bark, preferably about 1/4 percent. Ring barkers are frequently used and are only marginal for sulfite chips; a debarker using a cutterhead which produces a fairly clean log is the best choice.

Alder Bark Use

Most alder bark is sent to hog fuel, however, one mill at least powders the bark and markets this material as a fairly successful plywood resin extender. The hardwood bark is generally more acceptable in the Northwest than similar products produced from conifer bark.

Alder Chips and Chipping

A minor amount of alder chips is purchased by the pulp mills or obtained internally; the present market price varies from $29 to about $40 per bone-dry ton for clean chips, the variation is due to location and shipping costs presumably.

Alder chips are not at all suitable for storage and are rarely kept more than 1 month. The chips become more difficult to pulp (delignify), and alder chips generally lose strength and also tend to produce yellow specks which cannot be removed in sulfite pulping. The chips color rapidly on storage, and yield losses of 12 percent as well as major strength losses are reported in kraft pulping of alder chips stored 6 months (*1*).

Sulfite Pulping and Bleaching

Several companies carry out acid sulfite pulping of red alder. The cooks are done batchwise with a cycle time of about 6 hours, using an initial pH of about 2 and a maximum pulping temperature of perhaps 165°-170°C. The pulp is typically delignified to a K number of 13-14 and is obtained in a yield of about 45 percent. Sulfite alder pulp is always bleached and is easily brought up to high brightness, in the 88-91 GE range. A simple chlorination (C) and high consistency hypochlorite (H) sequence produces 88-89 brightness, CEH will give higher values. Dissolving grade pulps are also produced from alder, these are made by use of a heavy alkaline extraction stage and perhaps a final brightening stage, chlorine dioxide (D) or sodium peroxide (P).

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[1]See glossary at the end of the paper for definitions of standard abbreviations.

A point of no small significance today is the difference between softwood and hardwood spent sulfite liquor recovery. The evaporator condensate produced during concentration of the SSL contains about twice the BOD load from hardwood as from softwood. This is due mainly to acetic acid formed from the much greater acetyl content of hardwoods such as red alder.

Kraft Pulping and Bleaching

Alder is also easily pulped by the kraft process. About 20 percent of softwood chips are usually blended to produce a pulp that will run better on the machines. Pulps of K number 14 are produced in 49 percent yield in a typical manner.

Bleaching of alder kraft pulp is somewhat more difficult than sulfite pulp, however, with sequences such as CEHD or more commonly CEHED will produce pulps of 88-92 GE brightness. Some yield loss occurs with 90-92 percent yields across the bleach plant being typical--giving an overall yield of 44-45 percent.

The chip furnished for kraft pulping can contain more bark, perhaps up to 3 percent without any noticeable effect. Above this value dirt and specks become noticeable and additional alkali is required to reach the same K value.

High Yield Processes

The Permochem process is probably the highest quality high yield process using alder. Here a hardwood mix of about 90 percent alder is operated at an 85-86 percent yield, producing a pulp of 75 GE brightness that can be directly used (without bleaching) in tissue. This pulp is produced by a mild sodium sulfite cook followed by a refiner, similar to refiner groundwood.

Pulp Properties

The following tabulation summarizes typical handsheet properties.

	Kraft	Acid sulfite	Magnefite	Neutral magnefite
K number	13.8	13.7	13.3	20.3
Brightness	86	88	87	88
Burst[2]	117	66	81	92
Tear[2]	1.30	0.86	1.04	0.99
Tensile[2]	8,450	5,600	7,300	6,600

[2]CSF 300 ml

Pulp Uses

Bleached alder pulp is always blended with other pulps and, in addition to the uses already mentioned, is used in a variety of paper products. These uses are tissue, bond, envelope and book papers.

The Future

Red alder is the best prospect for whole tree chipping in the Northwest. Such chips have a bark content of up to about 15 percent, usually with only small amounts of twigs and foliage. This amount of bark can be handled in kraft pulping but has a noticeable effect. More alkali is required, the yield is decreased, and the BTU value of the black liquor is increased. These effects are not noticeable at bark contents below 3-4 percent and much can be done to lower the bark content. Chip debarking has met with some success and screening for fines removal also is successful.

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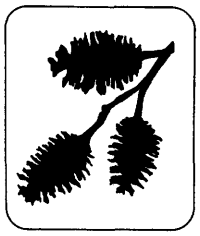
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Appendix I

GLOSSARY

BOD - biological oxygen demand.
BTU - British thermal units.
CEH - chlorination - extraction - hypochlorite bleaching sequence.
CEHD - chlorination - extraction - hypochlorite - chlorine dioxide bleaching sequence.
CEHED - chlorination - extraction - hypochlorite - extraction - chlorine dioxide bleaching sequence.
CSF - Canadian standard freeness.
GE brightness - standard brightness scale for pulps.
Kappa (K) number - measure of residual lignin.
NSCM - neutral sulfite semimechanical.
SSL - spent sulfite liquor.

RED ALDER AS A POTENTIAL SOURCE OF ENERGY[1]



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ABSTRACT

*The energy plantation is defined and set in the Pacific Northwest energy context. Analyses on naturally established 8- to 10-year-old red alder (*Alnus rubra *Bong.) at University of British Columbia are used to demonstrate above-ground yields and energy flows. Results show a current net community productivity of 28.5 oven dry metric tonnes/ha per yr (conversion efficiencies of 3-percent visible net radiation), and a mean annual productivity of 9.0 oven dry metric tonnes/ha per yr. Possible sources of fuel by bioconversion are discussed. Fluidized-bed, combined-cycle systems have good prospects for electrical generation. To satisfy British Columbia's (B.C.) 1981 energy needs, at least 1.2 x 10^7 ha of alder plantations will be needed (12 percent of B.C.). Use will probably continue as domestic fuelwood. A market for supplements to utilities based on coal, mill waste, and forest waste may develop. In the long-term, small energy plantations for local communities in B.C. are envisaged. The term biomass farm is used preferentially since it allows flexible appropriation of yields to a spectrum of potential uses.*

The Fundamentality of Energy

When Wordsworth was relaxing on the banks of the Wye, at the inception of the Industrial Revolution, it occurred to him there was

> "...a motion and a spirit that impells
> All thinking things, all objects of all thought
> And rolls through all things."[2]

This was the poetic realization of the centrality of energy in nature. Without apothesizing the Two Laws of Thermodynamics, Schumacher (*30*) has recognized that "...energy is to the physical world what consciousness is to the human world. If energy fails, everything fails." Man has mistakenly treated

[1]The research reported here was supported, in part, by the British Columbia Forest Service Productivity Committee grant PC 006 to Dr. J. H. G. Smith.

[2]William Wordsworth: Tintern Abbey.

finite fossil fuels as energy capital leading to the dissipation of primeval solar investments to produce a state of impending fossil fuel bankruptcy. The paradox of increasing energy demands and decreasing supplies as the world population moves with an exponential alacrity to 7 billion by 2000 A.D. (*23*) is disturbingly demonstrated in gas and oil price increases of about threefold in the past 4 years.[3] Last winter's brownouts in the United States convinced many of the reality of scarcity. Not only must we look to the palliatives of new technologies and the potentials of renewable fuels, but also to basic changes in life style. The recent Carter Administration energy package (*41*) and the British Columbia Energy Commission Report (*2*) have this implication at their core.

Presently, almost half the annual world wood harvest is utilized as domestic fuel (*13*). Even in the 1880's, most North American wood was cut for this purpose. By 1970 wood provided only 1 percent of U.S. energy requirements (*19*), and in 1969 only 2 percent of Canadian needs (*4*). An impending sense of entropy has caused foresters to investigate conceptual and technical panaceas couched in terms of the complete tree concept (*45*), sycamore silage (*22*), full forest utilization (*16b*), intensive, short rotation forestry (*35, 9*), the utilization of hog fuel and forest residues (*15*), as well as bark (*7*) for energy. An additional way to increase the gross ecological efficiency of energy flows from sun via forests to man may be by the yet embryonic energy plantation.

The Energy Plantation Concept

A model energy plantation would be composed of fast grown perennials (such as sugar cane and eucalypts) and/or annuals (such as sudan grass and water hyacinths) which would feed a centrally located conversion facility producing usable energy. The objective would be "the greatest amount of biomass possible per unit time and space, at the lowest possible cost, and with a minimum of energy expenditure" (*1*). Management would be agronomic in the extremist sense. In a visionary moment the Stanford Research Institute (*1*) has outlined the operation and design as follows: "Before planting, the fields would be cleared of weeds by application of a herbicide to eliminate competition for water and plant nutrients. Planting the biomass crop can be combined in one operation with application of fertilizer. At an appropriate interval after planting, a single dressing of fertilizer would be applied. The biomass crop would be harvested by means of a self-propelled combine which would chop the biomass to small pieces to facilitate drying. Aircraft would apply insecticides and fungicides when and where needed... Irrigation water would be applied at two-week intervals... The plantation would be operated seven days per week, 12 hours per day."

Such management of short rotation forests solely for energy yields was conceived only as recently as 1972 (*39*). At a time of petroleum scarcity, the idea offered a way to circumvent The Organization of Petroleum Exporting Countries domination of world economy. This nascent idea was included in a U.S. Government report in 1972 (*25*).

[3]Canadian oil prices: late 1973 - $4.20/bbl, 1977 - $10.60/bbl delivered to refinery gate. Canadian nat. gas prices: late 1973 - 31¢/Mft^2, 1977 - $1.0/Mft^3, wholesale prices delivered to utility. Data supplied by B.C. Energy Commission May 6, 1977.

Since that time, several detailed feasibility studies have been undertaken. It has been presented as a favorable energy option by Evans (*11*) in the Pacific Northwest by the Stanford Research Institute (*1*) and the Inter-Technological Corporation (*40, 39, 42*)--both for Southern U.S.A., and by J.P.R. Associates (*29*) for Vermont using existing resources. More critical are the findings of the Northwest Energy Policy Project team (*20*) for Washington, Oregon, and Idaho, Mitre Corporation, and Georgia-Pacific (*14*) for the U.S.A., and the Canadian Forest Service (*6, 28*) for Canada. Higher economic uses of biomass, inadequate yields, and the amount of land required are among the major problems.

Red Alder and Energy

Research into potential energy crops in the Pacific Northwest has now crystallized on red alder. Alder has many attributes which give it perfect fuel plantation qualifications: rapid seeding after land disturbance, maintenance of high densities, extreme light tolerance, full utilization of growing season, ability to coppice, improvement of soil fertility, and relative disease and pest resistance. In addition, work by Smith (*31, 32, 33*), De Bell (*8*), Smith and De Bell (*35*), and Zavitowski and Stevens (*45*) have demonstrated the high biomass attained in natural stands. This research indicated productivity between 26 and 30 oven-dry tonnes/ha per yr in young stands. Growth rate was thought to peak between 8-15 years. Verification of Smith and De Bell's work was, however, necessary since their data were based on small (2 m^2) plots and are thought to overestimate the upper limits of biomass (*34*). In addition, Zavitowski and Steven's research failed to recognize the effect of different stand densities within fully stocked conditions.

BIOMASS AND PRODUCTION OF RED ALDER AT THE UNIVERSITY OF BRITISH COLUMBIA

The Area and Methods

The University of British Columbia campus lies in the Coastal Douglas-fir wet subzone on podsolic soils developed over glacial debris. The alder stands sampled have developed naturally after total land clearing for road building and housing construction and were 8 to 10 years old. In order to determine the conditions controlling biomass production, eight 0.04 ha square or rectangular plots were established in July 1976 in fully stocked stands over a range of stem densities. Oven dry weight, biomass, and net production multiple regression equations were based on data derived from 10 sample trees from each plot, applied to the median tree on each 2-m^2 subplot and multiplied by the number of live trees per subplot to give the results in table 1. In addition, subsamples were taken through late summer and fall to determine the caloric content of red alder ecosystem components using bomb calorimetry. These data were tested by analysis of variance and Duncan's Multiple Range Test (table 2). Plots were also systematically sampled for lesser vegetation (table 3). A more detailed description can be found in Smith (*37*).

Mean Measurements

Table 1 ranks mean measurements, above ground biomass, and current productivity by number of live plus dead stems and site class. The number of live stems increases from 8,000 to 43,000 stems per hectare (s.p.h.) on good and medium sites but falls off markedly on the poorer site to 13,000 s.p.h. further reflecting lower site capacity. The number of dead stems increases with increasing stand competition from 5,000 to 17,000 s.p.h. Mean measurements display a diminution with increasing density in terms of crown width, root collar diameter, d.b.h., and height. The basal area is higher on the good sites (26 m^2/ha for plot 2) and lower on the poor site (10.76 m^2/ha for plot 8) although the pattern of variation between these extremes is not clear.

Biomass

Above ground biomass shows a mean value of 82 000 kg/ha giving a mean annual productivity of 9 000 kg/ha per yr. Smith's speculations (*31*) of a maximum of 60 000 kg/ha per yr are somewhat underscored, as are De Bell's estimates (*8*) of 20 000 kg/ha per yr in very dense 8- to 11-year-old alder. It is interesting, however, that the maximum subplot record of 376 000 kg/ha would indicate that over small areas 41 000 kg/ha per yr is achieved and may represent the management paradigm under these conditions. The most productive plot yielded 12 000 kg/ha per yr. To what extent intensive management can improve upon this remains speculative--I would suggest 15 000 kg/ha per yr as a conservative estimate. This compares with black poplar (*Populus trichocarpa* Torr. Gray) grown in the Pacific Northwest which may achieve 12 000 kg/ha per yr on 2- and 4-year cutting cycles (*9*). Because of a mix of collection, storage, and environmental reasons as well as other potential uses, leaves and reproductive organs should be excluded, thus decreasing biomass yields going to the fuel plant by 8 percent. The most dense stands have an unexpectedly high branch biomass. Although relative weight of branches per tree is smaller in dense plots (canopies are not yet discrete), much ingrowth is incurred giving greater absolute branch biomass.

Productivity

The current productivity between 8 to 10 years does not include a statement of loss to mortality or insect consumption over the growing season in order to define what Odum (*26*) called net community production. Growth in this age class may be entering the exponential phase with an average of 28 600 kg/ha per yr. Westlake (*43*) recorded maxima of 33 000 kg/ha per yr production in temperate perennial crops. These data confirm red alder's repute as a high yielding species. Current productivity is greatest in the more crowded stands, indicating that intense competition may delay the inflection point for production till a later age.

Ecological Data

Table 4 lists ecological data based on table 1. The biomass accumulation ratio is greatest in the more open (by total trees) stands (3.37 in the most open to 2.6 in the most dense), and also reflects decreasing productivity

Table 1--*Mean measurements, above ground biomass and net production for 8-10-year red alder ecosystems at University of British Columbia (averaged per 0.04 ha plot)*[1/]

Component Analyses	Plots ranked by density (live plus dead trees) and site									
	1	2	3	4	5	6	7	8	Average	Maximum[3/]
Mean measurements[2/]										
Number of live stems/ha	8,204	8,871	9,983	15,790	22,264	42,971	17,025	13,047	17,103	96,370
Number of dead stems/ha	5,239	3,435	9,142	11,737	16,729	16,729	6,079	1,169	7,169	46,950
Site class	G	G	G	M	M	M-P	P	P	M	--
Rcd (cm)	8.3	6.8	5.3	5.6	4.75	3.4	4.6	4.5	5.4	15.7
D.b.h. (cm)	6.0	5.5	4.4	4.6	3.5	2.6	3.6	3.4	4.2	12.2
CW (m)	3.2	2.0	2.1	1.9	1.6	1.1	1.4	1.6	1.9	4.9
Ht (m)	9.9	9.4	9.4	8.1	7.4	6.1	6.1	5.6	7.8	14.0
BA (m^2/ha)	25.6	26.0	17.8	23.5	19.01	20.48	20.2	10.76	19.6	76.5
Biomass (dry kg/ha)										
Total	96,922	92,517	67,631	112,027	82,883	106,883	58,372	39,640	82,128	366,639
Stem	62,347	57,124	42,817	73,016	42,902	54,528	32,134	21,926	48,349	229,894
Stem bark	10,028	9,603	7,291	12,381	9,290	13,070	6,990	4,892	9,193	34,718
Leaf	6,579	7,325	5,230	7,961	6,672	7,083	4,677	3,032	6,070	26,646
Branches	17,572	18,058	12,022	18,258	23,305	30,710	14,332	9,484	18,030	73,322
Reproductive organs	396	407	271	411	714	942	439	306	486	2,109
Current productivity (dry kg/ha per year)										
Total	28,737	28,015	20,029	32,315	35,952	40,831	25,125	17,802	28,601	117,420
Stem	14,531	12,793	9,301	15,803	18,701	19,347	13,863	10,134	14,309	57,464
Stem bark	1,505	1,442	1,095	1,860	1,393	1,960	1,049	733	1,380	5,214
Leaf	6,579	7,324	5,230	7,961	6,672	7,083	4,677	3,032	6,070	26,646
Branches	5,725	6,049	4,131	6,280	8,472	11,499	5,097	3,597	6,356	25,987
Reproductive organs	396	407	271	411	714	942	439	306	486	2,109

[1/] Rcd = root collar diameter; CW = crown width.

[2/] Site class G = over 27 m at 50 years; M = 18-27 m at 50 years; P = below 18 m at 50 years (based on Worthington et. al (*44*)).

[3/] Maximum for a single subplot (2 m^2).

Table 2--*Caloric values in 8-10 year red alder ecosystems--spatial and temporal flows (calories/gm, three replicates)*[1/]

1. SPATIAL

A. Overstory

July ($\bar{x}$ = 4636.1 ± 300.4)

Roots	Stem d.b.h.	Stem top	Stem base	Old cones	Catkins	Branches	Leaves	Bark base	Bark d.b.h.	Twigs	Strobiles	Bark top
4229	4399	4402	4406	4415	4534	4585	4752	4758	4787	4824	5068	5314

September ($\bar{x}$ = 4640.2 ± 226.3)

Strobiles	Stem d.b.h.	Roots	Branches	Bark d.b.h.	Leaves	Twigs	Catkins
4362	4438	4450	4537	4736	4748	4758	5065

November ($\bar{x}$ = 4712.8 ± 229.2)

Roots	Stem d.b.h.	Strobiles	Branches	Bark	Twigs	Leaves	Catkins
4382	4429	4547	4692	4833	4883	4898	5037

B. Understory

($\bar{x}$ = 4267.6 ± 269)

Ferns	Mosses	Herbs/Grasses	Rubus current	Rubus old	Conifer seedlings
3996	4080	4145	4209	4422	4755

C. Ground Layer

Humus	Litterfall
4517	4976

2. TEMPORAL (All three months)

($\bar{x}$ = 4668.8 ± 240)

Roots	Stem d.b.h.	Branches	Strobiles	Bark d.b.h.	Leaves	Twigs	Catkins
4354	4422	4605	4659	4785	4799	4831	4879

[1/] Line joins homogeneous subsets (Duncan's Multiple Range. α = 0.05).

Table 3--*Understory above ground biomass and net production for 8-10 year old red alder ecosystems*

Item	Plots ranked by (live plus dead trees) site								
	1	2	3	4	5	6	7	8	Average ± $S\bar{x}$
Biomass (dry kg/ha)	3 241	1 944	124	296	2 471	583	593	790	1 255±399
Percent of overstory biomass	3.0	2.0	0.1	0.3	3.0	0.5	1.0	2.0	1.5
Production (dry kg/ha per yr)	1 374	759	118	144	1 199	397	442	294	591±170
Percent of overstory production	5.0	3.0	0.5	0.4	3.0	0.1	0.1	2.0	2.0

of poorer quality sites. The leaf area index measures photosynthetic activity. Increasing leaf area means increased productivity potential. Greater leaf areas are associated with the denser stands and more productive sites (10.02 in plot 4 as against 3.81 in plot 8). Foliage assimilation efficiency expresses net production in terms of leaf weight and shows that, for a given site class, with increasing stand density, greater leaf production efficiencies are attained. One explanation may be greater noctural buildup of CO_2 in the dense stands giving them a photosynthetic premium over the more open conditions. The standing crop density index has been used by Kira and Shidei (*17*) to characterize the three dimensional arrangement of forests. It gives the apparent density of the standing crop. The denser stands occupy total space more effectively with an index of 1.74 in plot 6 as against an average of 1.06.

Table 3 shows above ground understory biomass and net production as 1.5 percent overstory biomass and 2 percent overstory production. The major reason for this small contribution is the intense shading. In the more open plots understory biomass and production is greater. Plot 5 has an unexplained high understory biomass for its density.

Table 2 gives the caloric value of ecosystem components. Results show that significant variation exists between parts of a tree and also over time. The last line in the table shows that over time (July, September, and November) a certain amount of fidelity exists between roots and stems, and then between bark, leaves and twigs, with branches forming a separate subgroup. Catkins and strobiles are, however, more variable over time as is shown by their ranking within each month.

Solar energy conversion efficiency for alder was derived from these data (see table 5). Above ground net primary productivity estimates for 8- to 10-year-old alder stands represent conversion efficiencies of 1.5 percent for net radiation and 3 percent for photosynthetically active radiation (PAR). Thus, alder appears to be one of the most efficient converters of sunlight in the Northern Hemisphere. Westlake's data (*43*) show that 3 percent PAR approaches the maximum attainable upper limit in temperate zones. If the average wood production over the life of the stands is, however, taken at 9 000 kg/ha per yr, conversion efficiencies are 0.5 percent net radiation and 1-percent photosynthetically active radiation.

Table 4--*Ecological data for 8-10 year red alder ecosystems at University of British Columbia*[1/]

Item	Plots ranked by (live plus dead trees) site								
	1	2	3	4	5	7	7	8	Average
B.A.R. (kg/kg)	3.37	3.30	3.38	3.47	2.30	2.60	2.30	2.23	2.75
L.A.I. (m^2/m^2)	8.28	9.22	6.59	10.02	8.40	8.92	5.88	3.81	7.64
F.A.E. (kg/kg)	4.37	3.82	3.83	4.06	5.30	5.76	5.37	5.87	4.90
S.C.D. (kg/m^3)	.98	.98	.72	1.39	1.11	1.74	.96	.71	1.06

[1/] B.A.R. = Above ground biomass accumulation ratio: (biomass/net production).
L.A.I. = Leaf area index: (leaf wt/m^2) x (surface area/kg or 12.59 m^2/kg for red alder).
F.A.E. = Foliage assimilation efficiency (net production/leaf weight).
S.C.D. = Standing crop density index: (standing biomass (kg/m^2)/average height standing crop (m)).

Table 5--*The solar energy conversion efficiencies of red alder at University of British Columbia between 8-10 years (Average of eight 0.04 ha plots)*

	Invested energy	Above ground NPP[1/] kg/ha	Caloric value of component K cal/kg	Energy budget K cal/ha	Percent distribution
A.	Stem wood	1.4×10^4	4.4×10^3	6.2×10^7	47
	Stem bark	1.4×10^3	4.8×10^3	6.6×10^6	05
	Branches	6.4×10^3	4.6×10^3	2.9×10^7	22
	Foliage	6.1×10^3	4.8×10^3	2.9×10^7	22
	Reproductive organs	$.5 \times 10^3$	4.7×10^3	2.3×10^6	02
	Understory	$.6 \times 10^3$	4.3×10^3	2.5×10^6	02
	Total	2.9×10^4		1.3×10^8	
B.	Incoming energy (Kcal/ha)				
	Net radiation (mean April-October 1974-1976)			8.9×10^9	
	Visible wave length (50 percent net radiation)			4.5×10^9	
C.	Efficiencies				
	Net radiation			1.5 percent	
	Visible wave length			3.0 percent	

[1/] NPP = net primary production.

Thus, although previous estimates have not been fully substantiated, red alder remains one of the most productive trees in the Pacific Northwest over short time horizons.

Methods for Converting Red Alder to Energy

Table 6 lists some of the techniques for deriving as much of the stored energy as possible for human use. Table 7 shows the weighted energy value of alder in comparison to other fuels. The biggest bane which militates against the use of wood fuels is the moisture content which engenders caloric downgrading, both in terms of increased unit weight and heat lost through evaporation. Unlike fossil fuels, wood is renewable, has low sulphur and nitrous oxide emissions, and particulate emissions can be controlled using current technology (*18*).

Table 6--*Some potential energy uses for red alder*

1. Carbonization (charcoal).
2. Direct thermal combustion (using steam turbines)
3. Biomass gasification/liquefaction:
   (a) Pyrolysis - low BTU gas (producer and wood gas)
   (b) Synthetic natural gas (methane)
      i. Direct - anaerobic digestion
      ii. Indirect - hydrogenation of lower energy gas
   (c) Distillation - by-products (methanol, acetone).
4. Combined cycle gasification using low energy gas.
5. Fluidized bed combustion/gasification.
6. Others, e.g., 'Muka' from foliage, slow burning wood stoves.

Table 7--*Approximate caloric value of red alder and other fuels*

Fuel	Comparative caloric value
Paraffin	10.4
Oil	9.8
Charcoal	7.1
Coal (bituminous)	6.9
Alder (oven dry)	4.6
Dung (air dry)	4.0
Alder (50 percent moisture, dry basis)	3.5

Carbonization of alder to charcoal has most relevance in developing economies (*10*) but also has potentials in specialized markets, e.g., barbecuing.

Direct thermal combustion to produce electricity has been scrutinized recently by consultants' analyses (*1, 29*). Comparative studies in Vermont (*29*) revealed wood-fired electric generating stations to be more costly than coal- or oil-fired stations. Total costs incurred in energy production inflated to 1977 prices are 3.8¢/kwh for wood, 3.1¢/kwh for coal, and 3.2¢/kwh for oil. This was mainly due to higher capital costs for steam boilers using wood. Presently, marketed wood-fired boilers are limited to 50 MW due to lack of demand thus limiting economies of scale (*18*). Also, high moisture content of wood reduces boiler efficiency to about 70 percent (*11*), and is much less than coal which is about 86 percent (*29*). Overall efficiencies for alder-fired 150 MW stations are calculated as 26 percent (table 8, Section A).

With the trend towards energy self-sufficiency in the forest products sector and with increased emphasis on coal and municipal refuse-based energy facilities, various technologies are being developed which set the fuel plantation in a more favorable position. One option is gasification and liquefaction by pyrolysis. Gasifier technology has been redundant since early developments in Germany because of the advent of natural gas (*3*). Water and wood are converted to CO and H_2 under high pressure and temperature in the absence of O_2 to yield low energy, clean burning gases of about 5 K cal/m^3.

Methane or sythetic natural gas may be produced directly by anaerobic digestion of wood or by hydrogenation of low energy gases. To get the correct 4:1 ratio of hydrogen to carbon, the conversion process requires 12 steps for wood yet only 4 steps for natural gas, thus making the process with wood three times as expensive (*11*).

Wood alcohols may be produced by dry distillation to yield methanol, and by acid hydrolysis to yield ethanol. Alcohols have great potentials as gasoline additives since they reduce pollutant emissions and allow higher compression ratios (*6*).

Combining gasification systems with conventional steam turbines under pressurized conditions gives improved efficiences which more than cancel out the high production cost of low energy gases. According to a recent report by British Columbia Hydro (*3*), two-thirds of the heat input to gas turbines may be rejected as waste heat. This heat may be utilized under a steam cycle to generate power at 20 percent efficiency. Even with such a poor steam cycle efficiency, the combined cycle net efficiency may exceed 40 percent. Prospects of 45 percent are envisioned using 1990 technology. Using this system, we can assume that wood will achieve similar efficiencies to coal due to more complete gasification.[4]

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[4]Dr. R. Woodley. Research Scientist. British Columbia Hydro and Power Authority Pers. Comm. May 4, 1977.

Table 8--*Energy efficiencies and land requirements for biomass fueled 150-MW generating plants*

A. Plant efficiencies using direct combustion

Station Heat Rate (SHR) = $\frac{\text{Net Heat Rate of Turbine (NHR)}}{(1 - \text{auxilliary power}) \times \text{bciler efficiency}}$

NHR = 2 080 K cal/kwh at 60 percent peak load

SHR = $\frac{2\ 080}{(1 - .09) \times .7}$ = 3 265 K cal/kwh

Plant Efficiency = $\frac{860 \text{ K cal}(1 \text{ kwh})}{3\ 265}$ = 26 percent

B. Energy production using direct combustion (11)

Weighted caloric value of alder (oven dry) = 4.6×10^6 K cal/tonne

@ 26 percent station efficiency = 1.2×10^6 K cal/tonne

@ 1.2×10^{-3} kwh = 1.4×10^3 kwh/tonne

1 MW yr = 8.76×10^6 kwh

1 MW needs 6.26×10^3 tonnes of alder/yr

At (say) 60 percent installed capacity 150 MW = 90 MW

90 MW needs 5.6×10^5 tonnes of alder/yr

C. Land requirements for direct combustion and combined cycle-based 150-MW fuel plantations

Yield (tonne/ha per yr) (excludes leaves)	- Area in hectares - Direct firing 26 percent efficiency	Advanced combined cycle (1990 technology) (23) 45 percent efficiency
1	5.6×10^5	3.2×10^5
8.5[1/]	6.6×10^4	3.8×10^4
22.5[2/]	2.5×10^4	1.4×10^4

D. No. stations and land required to meet B.C.'s total energy needs

1981 needs (2) = 2.1×10^{14} K cal = 2.9×10^4 MW

A 150-MW station contributes $\frac{2.8 \times 10^4}{90} \simeq 0.3$ percent or three hundred and ten 150-MW stations

Thus, land requirements are:

Yield (tonne/ha per yr)	Direct firing ha	Direct firing percent B.C.	Advanced combined cycle ha	Advanced combined cycle percent B.C.
8.5	2.0×10^7	21	1.2×10^7	12
22.5	7.8×10^6	8	4.3×10^6	4

[1/] 8.5 tonne/ha per yr = mean annual productivity of alder at University of British Columbia.

[2/] 22.5 tonne/ha per yr = net primary productivity between 8-10 years at University of British Columbia.

Generating power can be enhanced by replacing conventional spreader-stokers or dutch ovens with pressurized fluidized bed combustors (*1, 3, 29*). Fuel is dropped into a turbulent bed of non-combustible material such as sand--a hot gas is released which is cleansed and drives a gas turbine, the exhaust gas from which may be utilized in a steam cycle. Overall, the mix of fluidized bed combustors and combined cycles puts wood in an extremely favorable position. Variable fuel size tolerance is great, there being no need to pulverize. The Vermont study (*29*) has shown that in the use of this technique, wood is economically competitive with oil. Larger capital costs were offset by lower fuel costs and improved efficiencies. Costs were 2.61¢/kwh for biomass and 2.54¢/kwh for oil. Moreover, as oil, gas, and coal prices increase relative to wood, then biomass fueled combined cycle techniques can only appear more feasible.

Other alternatives include energy substitution with alder. Foliage utilization for cattle feed in the Union of Soviet Socialist Republics to produce muka (sic) (*16a*) is a current growth industry. One tonne of foliage used as animal feed might release one tonne of grain to increase world food stocks. Also, the market for slow wood-burning stoves has increased phenomenally (*6*). Presently the main use for alder in B.C. is thought to be as domestic fuel wood (*24*). Free use permits issued by the B.C. Forest Service have encouraged this since alder is not yet regarded as a commercial species, with stumpage at $2 per hundred ft^3.

Land Base Required

I have so far totally ignored the one factor which militates against red alder fuel plantations more than any other--that of land competition for other uses.

Table 8 takes the base case of a 150-MW generating station fired by wood using direct combustion. Part A shows that with a net heat rate of 2080 K cal/kwh the net plant efficiency is 26 percent. Part B shows that at 60 percent of installed capacity the station would require 560 000 tonnes of alder each year. Section C shows the land requirements based on three productivity levels under regimes of current and future technology. Section D computes the land required to meet B.C.'s total energy needs by 1981. We would need approximately three hundred and ten 150-MW stations. The land required for direct firing would amount to 21 percent of B.C.at 8.5 tonnes/ha per yr and 8 percent of B.C. at 22.5 tonnes/ha per yr. Even under the advanced combined cycle based on 1990 technology, the area needed would be 12 percent of B.C. at 8.5 tonnes/ha per yr and 4 percent of B.C. at 22.5 tonnes/ha per yr.

Although data are lacking for British Columbia, there are thought to exist over 300 million m^3 gross volume of red alder growing on more than 160 000 ha (*31*), much of this being poorly utilized (*24*). If this land were contiguous and brought into short rotation cycles, only four 150-MW stations could be supplied at 8.5 tonnes/ha per yr assuming future technologies. Clearly, it is folly to consider supplying all our needs from fuel plantations. Allocation of land to thermal forests raises serious doubts about

the highest and optimum use of land. First, alder is limited in its ecological range to below 800 m and requires at least 60 cm rain per year (*27*). In B.C. it is restricted to the Coastal Western Hemlock-Western Redcedar and Coastal Douglas-fir biogeoclimatic zones. Second, in the light of competition of land for timber, food, and grazing, alder will be relegated to second best sites where productive potentials will be maimed, long term sustained yield questionable, and mechanization frustrated by terrain. Moreover, the energy plantation concept is founded on the philosophy of economic growth. In a penetrating article entitled, "Not yet out of the woods" (*5*), Charles Calef levied the following strictures against the energy plantation. Like Schumacher (*30*), he saw the futility of societal preoccupation with growth; Calef argued that the energy plantation is based on this principle. It is reasoned that a more appropriate technology or biotechnology is needed which puts man within the thermodynamic carrying capacity of the land. Calef also questioned the environmental impact of energy plantations. In reply, it is doubtful--though still speculative--that red alder would be deleterious in this respect. If alder was grown from rootsprouts, then erosion would be minimized. Similarly, alder's inherent ability to fix nitrogen makes Calef's doubts redundant, especially if station ash is returned thus refurbishing potassium and phosphorous. By truncating the food-web from sun via alder to man, it will, however, be at the expense of flora and fauna. Thus, in the purist sense, the energy plantation could be esthetically and ecologically sterile because they would be very dense monocultures.

Conclusion

Traditionally, accepted precepts of energy abundance have lost their validity. The Carter Administration (*14*) and British Columbia Energy Commission (*2*) have both stressed the need for energy conservation. The time has come to transfer from finite to renewable and environmentally safe energy sources. During the interphase period, alder grown on marginal land could be used to supplement coal, hog waste, and forest residue-based electric generating stations for both industrial and consumer needs. In the long term, as coal and mill and forest wastes decrease, alder energy plantations will become more economic. But, it is unlikely that the economies of scale envisioned for eucalypts growing in southern United States (*1, 38*) will ever be achieved due to land scarcity. Satellite photographs show that fairly large areas of alder already exist on Vancouver Island. Small scale energy plantations or life support systems might be conceived growing around local communities, which when managed on 8- to 10-year cycles could theoretically provide the total influx of energy as well as animal and human feedstuffs, chemicals, and shelter. The term energy plantation, however, implies a market committment of biomass to energy. To avoid this inflexibility, it may be more reasonable to rename alder energy plantations as biomass farms. The goal would still be maximum biomass, but yields would be appropriated to the most economic and socially desirable end use, e.g., chips for pulp, particle board, domestic or station fuel, etc.

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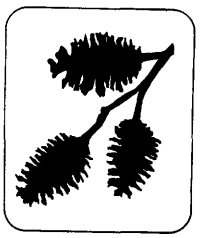
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DEVELOPING NEW ALDER MARKETS



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ABSTRACT

Attitude toward alder will play an important role in its future. Alder must be recognized as a species which produces a positive contribution to the local economy. The alder image can be improved by dropping the word "red" from its name and by promoting it as an alternate to other woods rather than a cheap substitute. The attitude of prospective buyers of alder will improve as the local industry improves delivery, quality control, and promotional efforts.

Two of the elements necessary for the successful marketing of northwest alder and bigleaf maple are indicated in the following two, seemingly unrelated points. These points represent attitude, rather than product performance or price. Without these attitudes, the 16 markets in which alder has its best expansion opportunities cannot be consistently sold.

There has to be a positive attitude about the value of the alder and its contribution to the local economy. State and Federal resource groups must look at the hardwood forests, not just as a cash stumpage value but as a source of community payroll which will be 300 or 400 percent in added value. The fact that hardwoods can be harvested three or four times before a softwood forest and can bring 6 to 9 times as much area payroll as softwood forests more than compensates for the lower stumpage yield.

An example of the results of a more positive attitude by government and civilian groups occurred a few weeks ago. While in the Seattle area, I heard a radio newscast which commented on the important value of northwest alder as a very desirable furniture wood. The phrasing was very similar to news releases which we had prepared when we were getting the State of Washington Department of Natural Resources to change the definition of alder from a "weed" species to a merchantable forest resource. The Oregon resource booklet still shows alder as an undesirable species, and this is one of the attitudes which we believe must be changed before our northwest woods take their proper place in the major markets.

At the same time, we should officially drop the term "red" from all discussions of alder. It is not red and in fact is the most uniform light tan wood available anywhere. To the manufacturer using wood, red is just as bad as waving a red banner in front of a bull.

A second change of attitude relates specifically to almost half of the producers of alder lumber. This is the responsibility for consistent quality and consistent delivery schedules. Too many opportunists remain who make wild promises and, when the market is good, mix in some marginal boards which disappoint buyers. It is like the bad apple in the barrel, an improper grade mix, and later delivery clouds the reputation of the entire wood industry.

One mid-west firm, using the term "knotty alder" for promotion, found in less than one year that it was outselling popular oak and pine suites. It took a strong selling job to get this firm to identify this hardwood, as most eastern manufacturers prefer to use "other selected hardwoods". The sales representative and mill sales manager prepared an elaborate presentation of reasons why alder would be a good sales point in the firm's promotion plans. The physical attributes were secondary to publicity articles written by editors of trade magazines. These articles were a result of close contact with editors. For example, firms who were using alder invited the editor to the plant for special conference on the firm's experience with alder. The articles proved to this furniture manufacturer that mention of western alder was a newsworthy subject, so he decided to use alder in his literature. The results have been highly successful. It is this selling in depth, beyond just supplying the material, that is most important in future use of our western hardwoods.

The current trend has been to the strong character woods such as oaks, pecan, and pine. If this midwest furniture company can make a huge success of a close grain alder group, outselling his oak and pine suites, it may be an indication of a trend away from strong grained woods to the more refined and subtle wood grains.

No wood species group, nor all wood industries combined, can set a trend in style. We can, however, accelerate a trend that is beginning and probably sustain it for a few years. It becomes important, therefore, to carefully evaluate all market trends and to keep close watch on wood tones. Alder is one of the most easily stained and finished woods on the market, and if we can catch an ascending color trend such as fruitwood, we have a better chance of building our market.

Keeping in constant contact with the furniture and cabinet industry is a basic part of my work with the wood industry. I carefully evaluate all major furniture markets, actually tabulating all exhibited case goods suites and table groups. In the past 40 years, we have evolved a chart of trends covering woods used, styles and color trends. We now can detect the start of a new direction or trend in consumer buying preferences. This information is important in establishing sales goals and promotion efforts. Furniture styles also influence the important kitchen, TV, and Hi-Fi cabinetmakers, though they usually follow these trends by 18 months to 2 years.

Since the western hardwood industry lacks a strong promotion program most of the effort should be concentrated in penetrating the midwest and east. California is already sold on alder as a product, though they still import large quantities of similar woods from Canada and the south. More

intensive work on the midwest and eastern furniture companies who use wood products will automatically influence other segments of the woodworking industry. Concentration on the use of character marked woods will be of special benefit since knots and swirls are a large part of the alder production grades. Alder has more than its share of sound knots that can be readily machined. Recent changes in style and species preferences for bedroom and dining room suites in the southern furniture market are shown in table 1. This chart is reproduced through the courtesy of the Fine Hardwoods/American Walnut Association. Table 2 is a comparison from the large regional markets in Chicago, Dallas, and San Francisco. Occasional tables groups, which often reflect consumer buying preferences sooner than case goods, have been tabulated by the staff of the Northwest Hardwoods Inc., and are reprinted with their permission.

The potential growth of the market for western alder and big-leaf maple has not been reached and could easily be doubled in 5 years with a carefully planned sales activity. It is truly remarkable that the volume sales has been sustained contrary to the overwhelming popularity of the strong character woods such as oak, ash, pecan, and pine.

The key to further penetration into the wood markets rests with those at this conference. It involves a more positive attitude of the importance of western hardwoods to the community payrolls, backed by more consistent quality control measures. A carelessness in grading has been a blight on our western industry for years, and recent "loose grading" has riled many fine firms who have long memories.

Selling must be in depth, involving design, finishing and production machine changes in the buyers plants. We need to cultivate a stronger distribution pattern to accommodate the hobby trade, the custom plants and the huge remodeling market. We should cultivate the high school shop instructors so their graduates will have more confidence in working with wood and with our northwest hardwoods. All of these activities need promotion by publicity and advertising to specific markets.

Table 1--*Furniture style and species changes: April 1976 to April 1977--southern furniture market survey--bedroom and dining room suites*

Item	April 1976		April 1977		Percent difference
	Number suites	Percent	Number suites	Percent	
Woods:					
Walnut	220	8.0	119	4.5	-3.5
Mahogany	52	1.9	50	1.9	0
Cherry	173	6.3	171	6.5	+.2
Maple	218	7.9	205	7.7	-.2
Oak	469	17.1	580	21.9	+4.8
Butternut	21	.8	--	--	--
Pecan	260	9.5	257	9.7	+.2
Birch	5	.2	--	--	--
Pine	286	10.4	308	11.6	+1.2
Olive-ash-burl	27	1.0	36	1.3	+.3
Ash	27	1.0	65	2.4	+1.4
Prima vera	53	1.8	44	1.7	-.1
Elm	13	.5	32	1.2	+.7
Prints & plastics	590	21.5	476	18.0	-3.5
Painted	270	9.8	216	8.1	-1.7
Other - solids[1/]	11	.4	21	.8	+.4
Other - veneers[1/]	42	1.5	65	2.5	+1.0
Glass - chrome-brass	11	.4	5	.2	-.2
Total	2,748	100	2,650	100	
Styles:					
Modern					
Contemp. Modern		25.8		29.0	
Commercial Modern		.1		0	
Total		25.9		29.0	+3.1
French					
Provincial		9.4		7.3	
Court		1.0		2.5	
Total		10.4		9.8	-.6
American		37.4		40.6	+3.2
Italian		13.7		9.0	-4.7
Spanish		7.8		5.0	-2.8
English		4.8		6.6	+1.8
Total		100		100	

[1/] Includes: avodire, acacia, bamboo, cane, mozambique, poplar, alder, ramin, teak, yew, chestnut, gum pao ferro, satinwood, rosewood, mappa burl and others not listed separately.

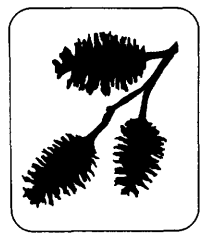
Source: Fine Hardwoods-American Walnut Association, 666 N. Lake Shore Dr., Chicago, Ill. 60611

Table 2--*Geographic preferences for wood tones and styles--occasional table survey at winter furniture markets*

Item	Chicago	Dallas	San Francisco
	599 table groups	790 table groups	793 table groups
		Percent	
Woods:			
Oak	14.3	19.1	24.2
Pine	8.0	11.7	9.5
Maple	5.2	8.0	3.0
Walnut	8.0	2.4	6.1
Pecan-hickory	6.0	8.0	5.8
Mahogany	5.3	5.3	3.1
Cherry	5.7	5.7	2.0
Alder	.7	1.2	2.4
Birch	.7	.6	1.1
Burls	8.1	5.4	8.6
Other woods	7.9	5.4	5.1
Bamboo-cane wicker	3.0	1.5	3.4
Plastic	3.2	3.9	1.8
Printed grain	10.0	11.3	11.4
Painted	3.3	2.7	3.0
Glass-marble metal	10.6	7.8	9.5
Total	100	100	100
Styles:			
Contemporary	50.9	59.5	64.7
Ranch	4.0	4.4	4.4
Oriental	5.9	1.9	4.0
Early American and Colonial	15.5	18.0	11.1
English	13.7	8.7	7.7
French	3.8	3.7	4.8
Spanish	3.3	2.3	1.2
Italian	2.8	1.5	2.1
Total	100	100	100

Source: Northwest Hardwoods, Inc., Portland, Oreg.

THE POTENTIAL FOR INTEGRATED UTILIZATION OF ALDER



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ABSTRACT

In attempting to evaluate utilization possibilities from forest stands, we are often confronted with an array of data that is either in the wrong units of measurement or has inappropriate utilization assumptions built in. Ecologists can often provide biomass data; but this is usually expressed in terms of total weights of crowns, stems, and roots with little regard to components useful to man. The foresters' tools are log rules, volume tables, and yield tables; but these are of limited value because they often incorporate fixed and somewhat arbitrary assumptions concerning product mix and manufacturing parameters.

What is needed is a method that views the stand in terms of its basic units, the trees, and on the basis of the sizes and shapes of trees can apply relevant manufacturing requirements to obtain estimates of product output. Such an approach is described and illustrated where an alder stand is being considered for conventional sawlogs and pulp, logs SHOLO and pulp, and a mixture of the two.

Introduction

Growing concern over the proliferation of natural alder stands following disturbances by logging or fire has led to increased interest in alder utilization, and consideration of whether it is more profitable to remove these alder stands so they can be replaced by conifers or to examine the conditions under which alder can be maintained as a renewable materials resource. Ecologists study the productivity of forest ecosystems in terms of organic production, but such studies typically concentrate on productivity in terms of total biomass expressed as weight per unit area, without much reference to the components that are used by man. Alder has been studied in this way (*9*) with relationships describing biomass per unit area and the distribution among root, stem, and crown components. Unfortunately, this kind of informa-

tion does not readily translate into estimates of products that are used by man. In fact, many different assortments of products can be obtained from this biomass, and the mix of products obtainable is often subject to change due to changes in utilization criteria which evolve from technological and market conditions.

Foresters have developed counterparts to the biomass studies in which attempts are made to predict the usable volume in the stand. Board-foot yield tables, volume tables, and log rules are among the devices commonly used to predict product output. Unfortunately, these rules and tables have built in assumptions about the utilization practices and standards of industry. For instance, the Scribner log rule ignores taper, and assumes 1-inch lumber thickness, and 1/4-inch sawkerf. Volume tables, in which an attempt is made to relate some easily measured tree dimensions (diameter, height, and form) to volume often compound these assumptions by attempting to estimate the volume in the tree convertible to a particular product, such as lumber or cordwood. In this case, assumptions are made about stump height, log length, minimum log diameter, minimum tree size, and the product to be made from the tree. In yield tables, stand volume per unit area is estimated according to age and other stand conditions; such tables also indicate the quantity of timber that can be expected for stands under the stated conditions. Yield tables are often based on a single product assumption and build in many of the previously stated assumptions.

The basic problem confronting someone evaluating the utilization of a stand is that each of these rules and tables is essentially a model of how those who prepared them expected the industry to behave. Perhaps, they were reasonably accurate for a while; but as technology and market conditions change they become increasingly obsolete tools for estimating what can be obtained from the forest. As an example, consider the problem of using an alder volume table giving Scribner volume above a 1-foot stump according to number of 8-foot logs to an 8-inch top diameter when in fact, your alder facility segregates out 8-foot veneer logs to a 16-inch diameter limit, processes 8-foot, 10-foot, and 12-foot sawlogs to a 12-inch limit through a thin kerf bandmill, and processes fiber material to a 4-inch limit. Also, how can one assess the impact of a change to processing sawlogs to a 10-inch limit? It is not an easy task to accurately make such predictions on the basis of tables which are based on a set of irrelevant or antiquated technological assumptions. The need for carefully characterizing the available raw material in terms of a conversion facility has often been emphasized (*6*). What is needed is a more flexible approach that views the whole tree as the basic unit and the forest as a collection of such units, and then allows any set of utilization parameters to be matched to the trees. Such an analytical system would improve our ability to address many of the difficult utilization questions.

The main problem of effectively using any stand is that of matching the biomass produced by the forest system to the available manufacturing and marketing system. At one extreme is the tropical hardwood forest, which in some cases may have more than 100 different species per hectare (2.5 acres).

Many of these species may be of no value to the available utilization infrastructure. If the only conversion facility available to such a tropical stand is a sawmill, then the utilization potential of the forest will be limited to that portion of the forest biomass that can be converted to the species, sizes, and grades of lumber that reasonably available markets will accept. In this case, the remainder of the forest is essentially worthless weed material as far as a particular mill is concerned even if knowledge of how to use some of the "weeds" by other processes is available.

The addition of new facilities such as veneer and pulp may increase the usable portion of the stand but may also remove some raw material from the sawmill. Changes in the market or development of uses for some of the weed species further complicates an analysis of how such a forest may be used. Even if the characteristics of a species permit its effective use, it may remain underutilized or may not be used at all if the cost of delivering it to the ultimate consumer is too great when compared with a competitive material.

In the Pacific Northwest, a similar situation has existed. Many years ago most species except Douglas-fir were weeds. Later, technologies and markets developed and hemlock and other conifers have assumed an important role in the forest economy. More recently, the hardwoods, particularly red alder, have begun the same evolutionary process. Fortunately, the weed component of Northwestern forests is quite low and most species have high value. With alder, however, the present utilization system is limited. Most of the alder roundwood harvest is produced as 8- and 10-foot high quality sawlogs for the manufacture of furniture lumber, or it is used for pulp. The combination of these two major uses may be such that many alder stands are operationally submarginal. The problem of improving the match between the alder stands and the conversion system may be treated in two ways.

1. If continuous use of alder on the same land is feasible, alder stands can be modified through more intensive management to produce a larger fraction of usable material per tree, per acre, and per unit of time.
2. Attempts can be made to modify the conversion and marketing system to allow for the better utilization of present natural stands.

Unfortunately, the former option requires much time while the latter requires much capital. In any specific situation, the solution chosen is likely to involve a mixture of the two options. All too frequently, discussions with respect to some mix of these options is taken on the basis of inadequate prior analysis and poor information. Testing the viability of alternatives through pilot commercial trials is generally too expensive. In this paper, an approach will be described that can be used to examine these questions. The approach was specifically developed to aid in answering hardwood utilization questions for tropical forests, but it is readily adaptable to other forest settings.

A Forest Utilization Analysis System

Figure 1 portrays the overall scheme. The forest stand and utilization criteria for the facilities are described and the models for harvesting, bucking, and primary manufacture (lumber, veneer, chips) segregate usable from unusable trees and products from residues. Along the production path, numbers of pieces and cubic volumes of trees, logs, and products in green condition are tallied.

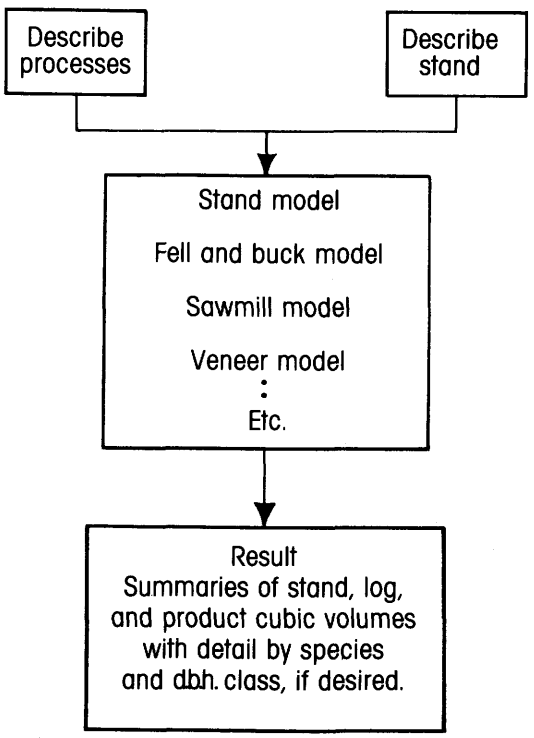


Figure 1.--Forest utilization analysis system.

This system is not unlike what one must go through in evaluating the value of a forest stand as a raw material base for a particular conversion facility. Based on some data on stand composition and structure, the volume is estimated on the basis of experience or an available volume table, and this is extrapolated to yield of products. Why, however, should a table using Scribner board feet (with 1/4-inch kerf and 1-inch lumber thickness) with 16-foot log lengths to an 8-inch top diameter be used to estimate lumber from a stand where the sawmill facility is a 1/8-inch kerf bandmill producing 8/4 stock from 8-foot and 10-foot logs to a 10-inch top diameter? In this new approach, the relevant facts about the specific facility are used. The utilization assumptions of log rules and volume tables are eliminated and replaced by the specifications of a specific mix of products or facilities. In a sense, this system is like the preparation of a local

volume table except that it can rather quickly produce new tables based on new stand conditions and/or manufacturing criteria.

The stand information consists of data commonly obtained by foresters. It includes age, site index, total height curves, merchantable height curves, taper curves, and a stand table describing the number of trees in each d.b.h. class. Based upon the information supplied, the dimensions and shape of a representative tree for each d.b.h. class can be constructed and its utilization potential examined. In mixed stands, some or all of this information may be repeated for each species. Presently, quality, in terms of rot, cull, and other forms of defect, is not included in the analysis. At a later time, we hope to incorporate information on this aspect.

The required utilization information depends on the facility and product mix to be examined. Specific modules are harvesting and bucking. They require designation of commercial species, diameter cutting limits, stump height, relative values of log types to be produced, desired log lengths, minimum log diameters and amount of bucking trim. On the basis of this information, the optimum bucking pattern of each tree is determined and the corresponding output of product from each log is estimated by models of veneer, sawmill, and chip processes. The veneer model requires a specification of chuck diameter and estimates the output of green veneer and residues from the lathe. The sawmill model is a simplified best opening face program for live sawing which requires definition of target lumber thickness, sawkerf thickness, and minimum board width. Manufacturing residues can be allocated for chip or fuel production.

The system can be used to examine problems such as the following:

1. the feasibility of a particular type of stand as a raw material source for a given facility.
2. the impact of a proposed facility change or a market change resulting in a modification of utilization criteria. The feasibility of a stand as a raw material supply source can, thus, be re-examined under the new conditions.
3. the impact of complimentary or competing facilities.

With traditional tools there would not be the time, information, or the flexibility to adequately examine the implications of such problems. With this approach, a small computer can perform these analyses in a relatively short time.

To summarize and integrate the results of these analyses, a reference material system (RMS), which is a network representation of the flow of materials from forest through the various production steps, is used. A pathway or trajectory is developed linking the resource components, processes, products, and residues. The quanitities of appropriate material predicted by the system are displayed along the trajectory. To this physical flow, data may be added containing information on labor, capital, process energy requirements, value added, or other pertinent information. A succession of RMS trajectories based on different utilization assumptions and stand conditions provides much insight when evaluating alternatives.

An Examination of Alder Utilization

To illustrate the application of the analysis to alder, an alder stand was used as a case study to test three possible facility configurations. The three configurations were a conventional sawmill producing furniture lumber, a SHOLO (short log) mill producing pallet decking lumber, and a combined complex producing both materials.

The SHOLO concept was developed in the eastern United States (*2, 4, 5*) as a new way of profitably converting low-grade hardwood trees and logs into products. It has also been suggested as a possibility for improving utilization of aspen in the Rockies (*8*). With this concept, each processing step after felling is aimed at specific end products. Long, low-grade logs are bucked into short logs which contain the desired end product, plus an allowance for end trim. Conventional lumber is not produced. In this way, gross defects are eliminated at the bucking station, and the effect of allowable defects is controlled by positioning the SHOLO log relative to the saw. This system can, therefore, utilize stems which are too small or too defective to produce a good conventional log but which still contain some decent material. In the example we will use the SHOLO concept for production of pallet deck lumber although the concept can also be used as a method for obtaining specific furniture parts from trees that otherwise could not be profitably processed.

The stand to be examined is based on data collected from 4.3 acres on the Pilchuck Tree Farm near Bryant, Washington.[1] These data were collected during a research program initiated by John Hauberg about 20 years ago. At that time the stand was approximately 40 years old and 90 feet tall. This translates into a site index of 100 on a 50-year basis (*1*). The average diameter was nearly 13 inches, and trees ranged from 5 inches to 25 inches. Alder constituted 118 stems per acre, and other species (Douglas-fir, bigleaf maple, western red cedar, western hemlock, and black cottonwood) accounted for another 62 stems per acre. Alder made up about two-thirds of the stems and about three-fourths of the basal area. Total height and height to live crown relationships were developed from data from stands in western Washington.[2] A published taper equation for alder will be used in this example (*3*). Table 1 summarizes stand information and presents the utilization criteria for the conventional and SHOLO systems. It is also assumed that the logging system also produces 8-foot pulplogs from the stand. Log values used are relative values, which are based on the assumption that a cubic foot of a conventional sawlog used for furniture is worth three times

[1]Stenzel, G., and D. P. Thomas. 1956. Studies in management and utilization of upland red alder. Coll. For. Res., Univ. of Washington, Seattle (unpublished).

[2]The authors express appreciation to Dr. Dean DeBell of the USDA Forest Service, Forestry Sciences Laboratory, Olympia, Wash. and Mr. Boyd Wilson, Forest Land Management Center, Washington Department of Natural Resources, Olympia, Wash., for providing data for the development of these relationships.

as much as a cubic foot of a pulplog and 1.5 times as much as a cubic foot of a SHOLO log. A cubic foot of a SHOLO log is assumed worth twice as much as a pulplog. In reviewing the results, the criteria and relative values must be kept in mind. The value of this method is that if results are desired for different values or criteria, they can be quickly produced.

Table 1--*Summary of stand data and utilization criteria for conventional and SHOLO systems*

A. Stand data

Stand table

D.b.h. inches	5	6	7	8	9	10	11	12	13	14
No. trees/A	0.2	2.1	5.6	4.2	7.9	14.7	12.3	12.1	10.3	11.4

D.b.h. inches	15	16	17	18	19	20	21	22	23	24	25
No. trees/A	10.0	8.3	5.3	7.5	1.8	1.6	0.7	0.7	0.5	0.2	0.4

Total height curve

$$\text{Total height} = .1096\ (\text{stand age})^{.3345}\ (\text{site index})^{1.0628}\ (\text{DBH})^{.2186}\ ;$$

where,

r^2 = .763, and
se = 8.3 feet = 10 percent of mean height.

Height to live crown curve

$$\text{Merchantable height} = .0020\ (\text{total height})^{1.7771}\ (\text{stand age})^{.5586}\ ;$$

where,

r^2 = .801, and
se = 14.1 feet = 33 percent of mean merchantable height.

B. Utilization data (Stump height = 1 foot)

Log criteria

	Type	Length (feet)	Trim	Relative value/CF	Minimum diameter (inch)
Conventional	SAW	8	0.5'	3	12
	SAW	10	0.5'	3	12
	PULP	8	--	1	4
SHOLO	SHOLO	40(inch)	0.5'	2	8
	PULP	8	--	1	4

Sawing criteria

Target lumber thickness 1 3/16 inch
Minimum board width 4 inch
Kerf 1/8 inch
All slabs, edgings, and trimmings to chips
All sawdust to fuel

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Results

Predictions for these three conversion alternatives are summarized in figure 2. At each point, the three numbers presented refer to (top to bottom) the conventional, SHOLO, and combined facility respectively.

The stand volume is estimated to be 4,559 cubic feet, including stump and top and excluding bark. In this example, only alder is being considered so there are no unusable or weed species comprising part of the volume. All of the alder is assumed to be felled in one operation. In some cases, with other species, cutting limits may be imposed and the usable and unusable trees would be segregated.

In the conventional system, 1,773 cubic feet of sawlogs, 1,606 cubic feet of pulplogs, and 1,180 cubic feet of forest residue (stumps and tops) are produced. The sawlogs yield 1,146 cubic feet of rough green lumber for furniture, and the sawmill produced 171 cubic feet of sawdust and 456 cubic feet of chipped slabs and edgings. If we consider both the sawmill chips and the pulplogs, about 2,062 cubic feet of material for pulping was produced from this stand.

When the stand is considered only for the SHOLO logs and pulp, 3,143 cubic feet of SHOLO logs and 241 cubic feet of pulplogs are produced. The SHOLO logs yield 1,887 cubic feet of pallet lumber, 327 cubic feet of sawdust, and 928 cubic feet of chips. The total material available for pulping is 1,169 cubic feet.

The bottom series of numbers along the trajectory indicate the results when the conventional and SHOLO systems are combined into an integrated system for processing this stand. Relatively little impact is made on the conventional lumber, but a substantial amount of volume that would otherwise be chipped for pulp can be salvaged for pallet material with the use of the SHOLO system.

This example illustrates the way in which the system can be used. Although not indicated along the trajectory, the anlaysis also provides piece counts indicating how many trees, logs, and pieces of lumber will be handled. Together, this volume and piece count information is very useful in understanding the interrelationships between products and the effects of changes in their relative values and in their processing factors. If, for instance, it was desired to determine the effect of changing the SHOLO minimum log criterion to 10 inches diameter, the analysis would be redone and a trajectory comparable to figure 2 would be developed.

The predicted stand volume of 4,559 cubic feet of alder per acre, where alder comprised 76 percent of the basal area stocking, compares favorably with the alder normal yield table (*7*) figure of 4,720 cubic feet per acre which is based on stands with at least 80 percent alder basal area.

As a final comparison, the alder predictions have been converted to a dry weight basis for comparison with published biomass data for alder stands

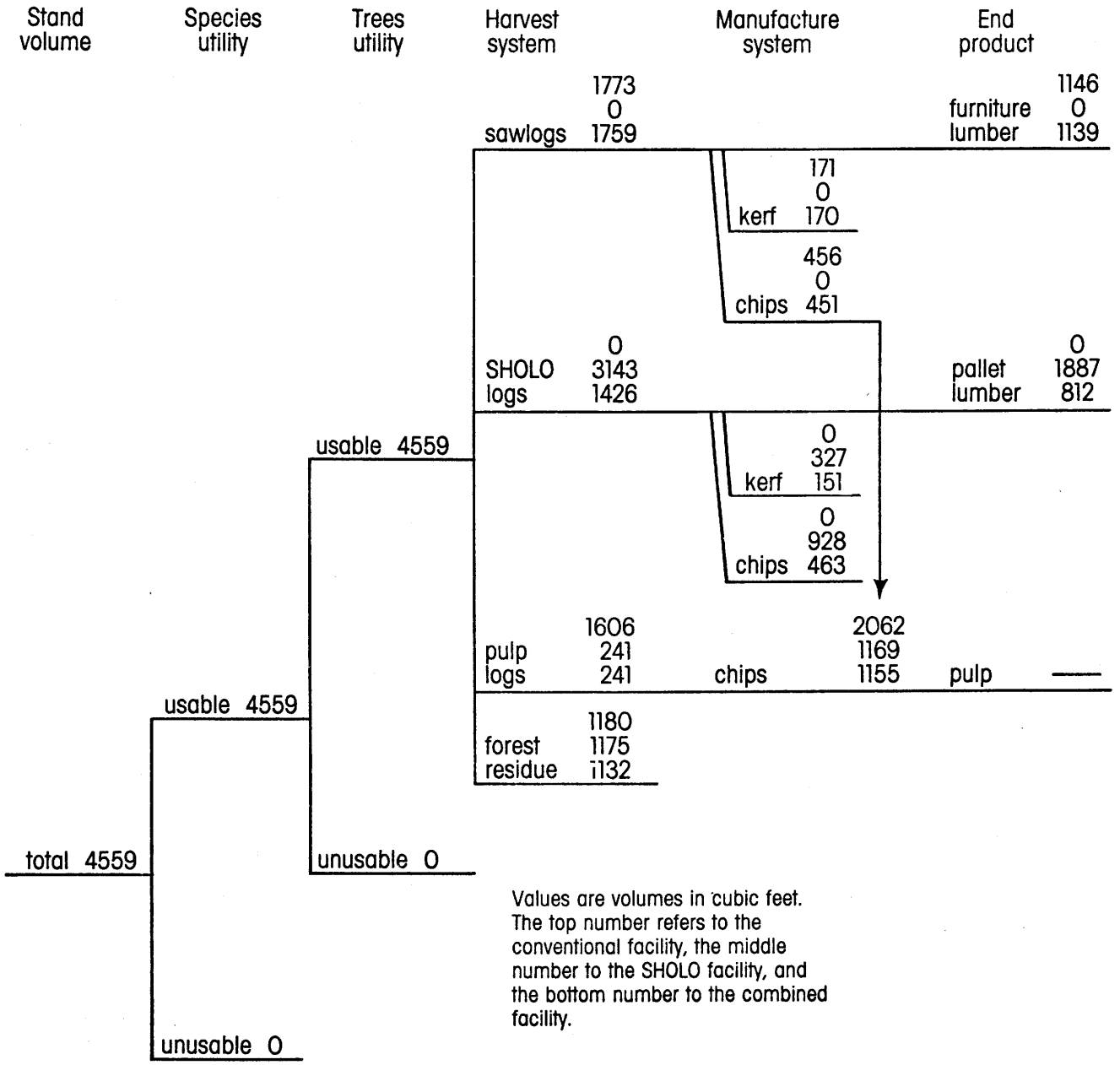


Figure 2.--RMS trajectory for three facility configurations.

(*9*). From the graphs in this study, the total alder biomass above ground for 40-year-old natural alder stands was estimated to be about 200 metric tons per hectare (89 short tons per acre). Roots are estimated to increase this by about 20 percent. Of the above ground biomass, if codominants are used as the typical tree, about 20 percent is estimated to be in the form of crown including foliage; bark was estimated as about 10 percent of stem weight. These estimates from the biomass study were used to develop the left bar diagram in figure 3 where weights are presented in short tons per acre. The model-predicted stem volume is in reasonable agreement with this biomass approach estimate of stem wood. The remaining three bar diagrams indicate how the three systems utilize this stand. The drop-off from stem to logs represents forest residue such as stumps and top material that is too small to use.

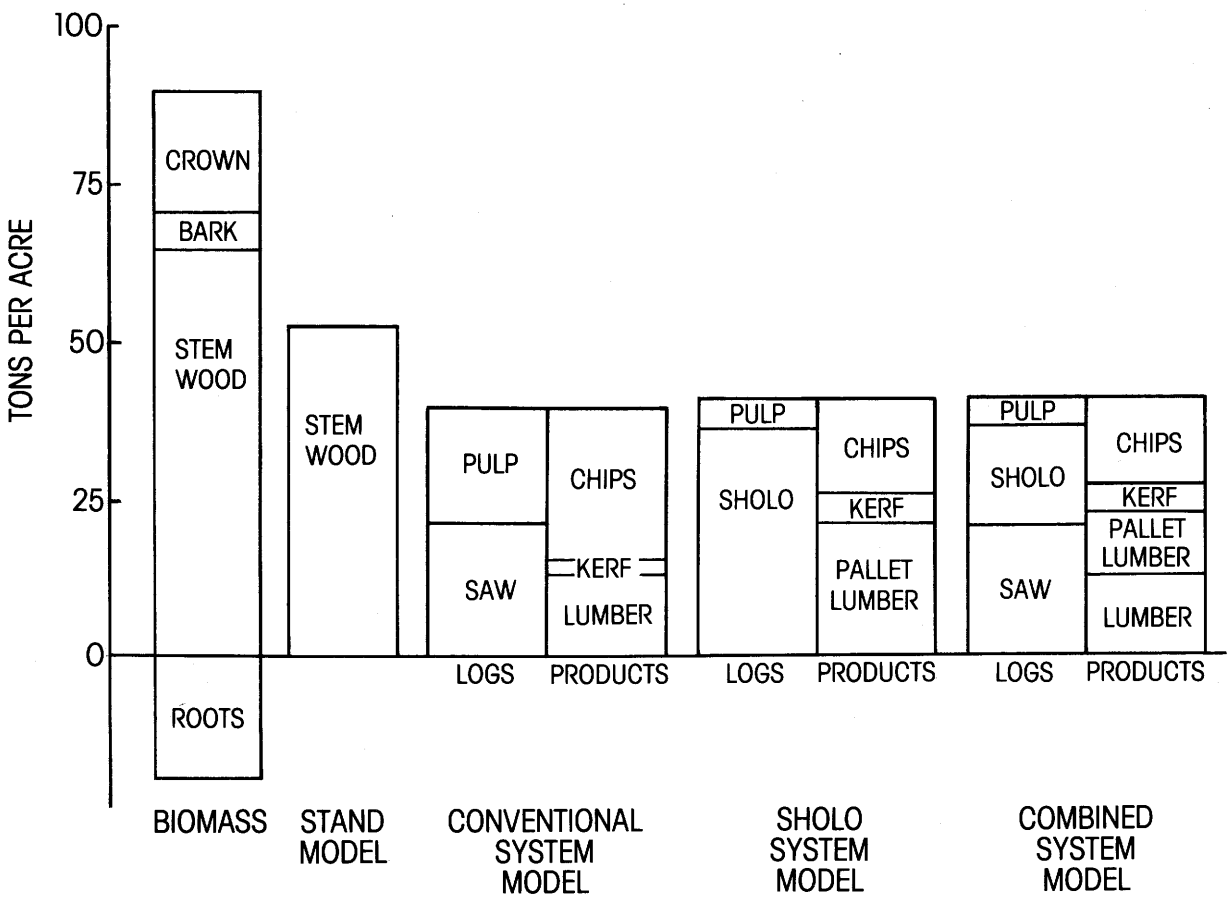


Figure 3.--Comparison of biomass with predicted utilization of a 40-year-old site index 100 alder stand.

The data suggest that the efficiency of natural alder stands is low when developing usable raw material for the primary lumber product. Conversely, one might say that the present system cannot efficiently make use of the material produced by the stand. There seems to be substantial room for improving the match between the utilization and forest production systems; working together, forest managers, researchers, and the alder industry can make improvements.

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A COMPARISON OF RED ALDER, DOUGLAS-FIR, AND WESTERN HEMLOCK PRODUCTIVITIES AS RELATED TO SITE– A PANEL DISCUSSION

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Introduction

A general hypothesis might state that all native tree species of an area are most productive on that particular site where the complex combination of climatic and adaphic factors is most nearly optimal. This is not to suggest that all species are equally productive or competitive in that specific environment. Moving from this optimum site along some gradient of environmental change (which by definition must be a worsening or decline), it is reasonable to assume that each individual species will decline differently in terms of productivity, simply because each is unique genetically and therefore ecologically.

This hypothesis might be modelled graphically as suggested in figure 1. Obviously a very large number of such over-simplified gradients might be

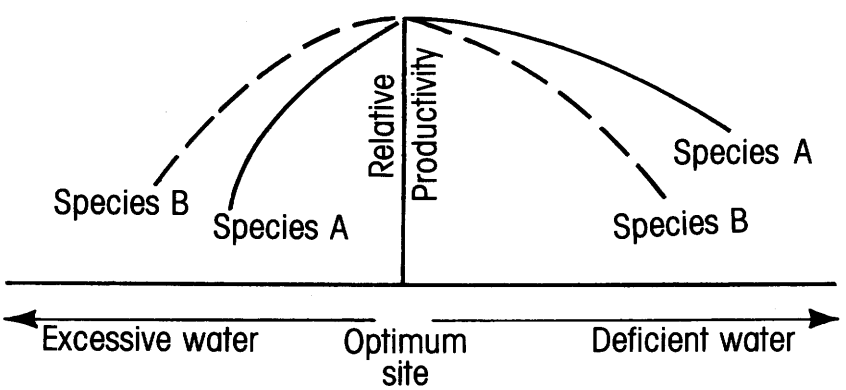


Figure 1.--Model of the response of two hypothetical tree species to available water gradients in the environment.

used, but two serve to illustrate the concept. It is also probably true that a single environmental factor cannot be altered without altering some other factor or factors and these may or may not be offsetting.

Conventional forestry wisdom in the Pacific Northwest has held that red alder behaves somewhat like species B in figure 1. Indeed there has even been some suggestion that alder was most productive, in an absolute sense, on sites that were too "wet" for best growth of conifers.

In the present discussion, the panelists examine existing evidence and introduce new data bearing on these points.

David R. M. Scott

Relative Site Index

Several comparisons of relative site index of red alder and Douglas-fir appear in the literature and are summarized in figure 2 together with previously unpublished information.

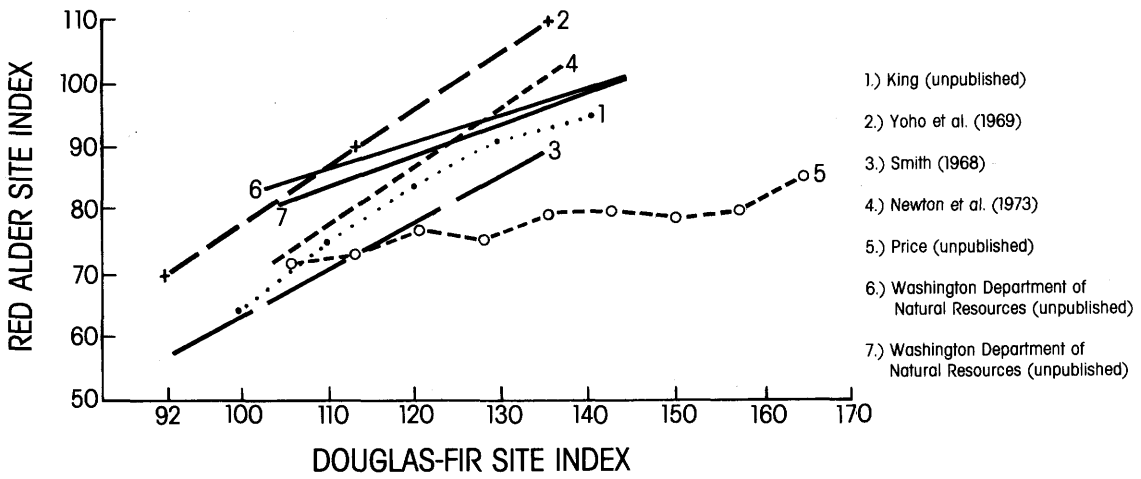


Figure 2.--Red alder and Douglas-fir site index relationships.

Relationship 2 was used by Yoho et al. (1969) for economic analysis and was reported as a "consensus of expert opinion."

Relationship 3 was developed from 403 sample plots in the Powell River area of southwestern British Columbia as reported by Smith (1968).

Relationship 4 is an adjustment of data given by Newton et al. (1973). It is based on 40 stands located from Tillamook to Oak Ridge, Oregon. Newton et al. (1973) used height-age trends of McArdle et al. (1961) as the basis for the Douglas-fir indices. These have been changed to conform to the Douglas-fir height trends of King (1966).

The remaining relationships in figure 2 are based on previously unpublished field data sets. Relationship 1 is from data collected in southwestern Washington.[1] Line 5 is developed from Douglas-fir and red alder trees from 151 inventory plots on the Siuslaw National Forest.[2] Lines 6 and 7 come from data collected in the Washington Department of Natural Resources' red alder studies. Line 6 comprises data collected specifically for a red alder/Douglas-fir site index comparison in which sample trees of both species were chosen close together in mixed stands and includes information from one similar plot of U.S. Forest Service origin.[3]

Relationship 7 is the compilation of site index samples taken from rather large (40 acres or more) "rehabilitation stands" in which both alder and fir were growing, mixed on a stem or small group basis. In each of 25 stands, 20 Douglas-fir and 20 red alder trees were systematically selected and measured for total height and breast height age. The sampling criteria conformed to the requirements of the red alder site index (Bishop et al. 1958) and King's (1966) site index system for Douglas-fir.

The correlation of red alder site index with Douglas-fir site index was virtually the same for both 6 and 7. One line with $r^2 = .47$ for 29 sample points would be adequate to illustrate the site index correlation on both sets.

The relationships shown in figure 2 are fairly consistent. All would fit within the 95 percent confidence limits of relationship 7, except 5 and the lower half of 3.

Gerald Hoyer

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Comparing Productivity

Another method of contrasting red alder productivity with that of conifers is presented in table 1. All site indices are on a 50-year basis.

Table 1--*Preliminary productivity ratings for Douglas-fir, western hemlock, and red alder (Grays Harbor, Pacific, and Wahkiakum Counties)*[1/]

Soil series	Douglas-fir (Number of plots)	Douglas-fir (Mean site index)	Western hemlock (Number of plots)	Western hemlock (Mean site index)	Red alder (Number of plots)	Red alder (Mean site index)
Group I--Well-Drained Upland Soils (400 to 1800 feet)						
Lytell	31	134	34	122	8	96
Elochoman	42	134	24	118	2	100
Zenker	19	132	16	121	8	97
Raught	8	131	5	118	2	102
Cathlamet	11	129	10	117	2	118
Germany	15	123	10	117	1	87
Wahkiakum	10	124	21	112	1	84
Squally	5	130	9	118	1	88
Bunker	8	128	27	105	1	77
Group II--Well-Drained High Elevation Soils (>1800 feet)						
Lates	3	108	16	92	1	75
Group III--Moderately Well-Drained Upland Soils (400 to 1800 feet)						
Swem	2	123	3	108	1	88
Willapa	2	125	19	115	1	68
Group IV--Well-Drained Bottomland Soils (<400 feet)						
Humptulips	0	--	0	--	1	105
Grehalem	1	137	0	--	2	104
Group V--Somewhat Poorly to Poorly Drained Bottomland (<400 feet)						
Aabab	0	--	0	--	2	89

[1/] Based on unpublished site index data and Soil Conservation Service maps on file at State of Washington Department of Natural Resources, Olympia, Washington.

Site index information for alder was developed from data collected on CFI (continuous forest inventory) plots in Grays Harbor, Wahkiakum, and Pacific Counties. Soil series determinations were obtained by "locating" these plots on soils maps prepared by the Soil Conservation Service and Department of Natural Resources. Site indices for Douglas-fir and western hemlock were based on estimates derived from preliminary soil-site relationships. All productivity information for each species was then averaged by soil series, and stratified into 5 soil groups based on elevation and soil drainage characteristics.

Certain trends became evident:

(a) Well-drained uplands are better alder producers than upland or bottomland soils with drainage restrictions. Well-drained bottomlands are also good alder sites.

(b) Among well-drained upland soils, those derived from sedimentary rocks are better alder sites than soils over igneous rocks.

(c) Site quality for alder appears to decrease as elevation increases. This may be a factor influencing the low site indices shown for the igneous soils since they were generally at higher elevations.

(d) Generally the higher the site for conifers, the higher the corresponding site index for alder.

(e) Soil maps can be a reliable base for predicting site indices provided modern soil maps are available and sufficient soil-site correlations have been made.

Walter Fergerson

Site Requirements

Site requirements of alder appear to be exacting principally at the time of establishment and after the third decade of development. Established alder grows rapidly over a wide range of sites during its first 20 years; the rate of growth during this period appears related largely to the duration of high moisture stress and moderately to temperature, with cool temperatures optimal. Growth is poor in a hot or continuously cool environment, such as a coastal environment, regardless of moisture regime.

Alder growth curves apparently do not harmonize well over a variety of sites. Height development is consistently rapid during the first 5 years in dense stands without grass cover. Heavy ground cover slows juvenile growth, especially in open-grown stands, and prevents establishment altogether when seeds are germinating.

After 5 years, favorable sites stimulate continued rapid height growth until 30 or more years of age. One 22-year-old stand has been observed with dominant trees from 88 to 92 feet tall and current increments of 2 to 2-1/2 feet per year. On poor sites, increments appear smaller in the second and later decades and, even though dominant, trees appear to be poorer competitors.

Alder growth after 40 years is difficult to study. Annual rings are often missing after age 30, and large numbers of missing rings after age 40 can compromise an effort to measure growth by stem analysis. The highest number observed was 79 rings; this was at the 60-foot level in a tree apparently 106 years old that showed 71 rings on one buttress at 4-1/2 feet.

Alder appears to require continuous dominance. There is little stratification among crown classes within a stand; mortality occurs soon after a tree drops to codominant status. Moreover, increase in the salmonberry understory after 20 to 25 years suggests that alder is unable to continue to dominate site resources.

Height growth appears necessary for crown spread, perhaps because of the ascending branching habit. For this reason, it is unlikely that diameter growth will be increased by thinning after about 15 years.

Alder is capable of providing nitrogen on nitrogen-deficient sites sufficient for its requirements, and more. Nutritional limitations are uncertain, but the need for abundant phosphorus and other macroelements is known to be prerequisite to nitrogen fixation. Cobalt, zinc, nickel, and iron are also required in nitrogen fixation; and deficiencies may account for observed nitrogen deficiencies.

The soil of alder sites should be aerated for good growth. Few sites on which alder grows well are better in the long run for hardwood than for softwood production. The peat-bog soils of the Oregon Coast Ranges that are poor conifer sites are seldom better than $SI_{50}/80$ for alder, and are usually poorer. It is likely, however, that alder is the only commerical species that can growth without root-rot problems on these sites without drainage. The presence of conifer stumps on a site indicates it is likely to grow a greater volume of softwood per acre per year than alder on rotation lengths over 25 years.

Michael Newton

Summary

What can be deduced from these presentations? Certainly there is no evidence to suggest that optimal sites for red alder are less than optimal sites for conifers. In both figure 2 and table 1, the optimal productivity of all species is found in similar environments. It should be pointed out that in figure 2 there is no direct evidence of the exact nature of the site variation. One might suggest, though, that decline in productivity is more likely to be related to excessive moisture rather than to moisture deficit because mixed stands of alder and conifers are more frequently observed on such sites. On dry sites, alder is rarely of sufficient importance to be noted mensurationally. This is borne out in table 1, where no excessively drained soils are listed and where only alder has been measured for productivity on poorly drained bottomland soils.

Further, in table 1 there is some evidence that within a general soil moisture regime class there may be more variation of alder site index than that of Douglas-fir or western hemlock. In figure 2 there is some indication of a greater relative variation of Douglas-fir than of alder.

All this suggests that alder may be somewhat less affected by excessive moisture than Douglas-fir (and perhaps hemlock) but may be somewhat more sensitive to other site factors, perhaps available nutrient levels, when moisture regime is constant. Just how such an observation relates to alder's nitrogen fixing ability is problematic.

The suggestion that estimates of alder growth or site index are often inflated due to genuinely missing rings should be regarded with some skepticism in the light of recent evidence that alder may indeed be younger than nearby conifers and that careful cross dating and ring determination techniques eliminate this factor as a source of significant error (De Bell et al. 1978).

There appear to be two circumstances where alder productivity may be superior to that of conifers. First on certain poorly drained sites where alder productivity is very low indeed but where conifers are even less productive and second on better quality sites, where management objectives, for some reason, have decreed rotations of about 20 years or less.

David R. M. Scott

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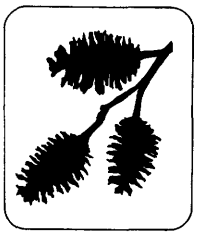
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REGENERATION OF RED ALDER



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ABSTRACT

*This paper brings together information regarding regeneration of red alder (*Alnus rubra *Bong.) from published and unpublished sources. Based on this evidence, red alder does not appear to be a difficult species to regenerate, either naturally or artifically. This should come as no surprise to Pacific Northwest foresters. Red alder reaches sexual maturity at around age 10 and produces large quantities of seed annually, with bumper crops about every 4 years. Natural regeneration occurs in open, disturbed areas where mineral soil is exposed. Seedlings may reach 3 feet in height the first year, and grow to 15 feet in 5 years. Alder seedlings have been successfully grown in both bare root and container nursery systems. Stratification of seed does not appear to be essential for reasonable levels of germination. Plantations of red alder have done well where reported. Coppicing of young alder is possible and offers an alternative fiber production system.*

Introduction

This paper discusses some of the phenological and silvical characteristics that apply to establishing stands of red alder (*Alnus rubra* Bong.), either naturally or by artificial methods. Information has been obtained from our own research, from the literature, and from unpublished work of practicing silviculturists and research scientists. For making this material available, the author is grateful to Dr. Dean DeBell, Pacific Northwest Forest and Range Experiment Station, USFS: Mr. Richard Reeter, Silva Seed Company; Mr. Frank Zelsnack, International Paper Company; Dr. George Edwards, British Columbia Forest Service; Mr. Dave Nelson and Mr. Robert Smith, Crown Zellerbach Wood Nursery; and Mr. Bernard Bormann, graduate student, University of Washington Department of Botany.

Seed Production and Dispersal

Red alder is the largest species in its genus and the dominant hardwood in the Pacific Northwest and southeast Alaska (*2*). At about age 10, individual trees begin to produce large quantities of seed, with optimum production occurring at about age 25. Peak production years occur on an approx-

imate 4-year cycle, with light or moderate crops occurring in the intervening years. Total crop failure is a rarity, although such a failure did occur following a severe freeze in November 1955.

Red alder is monoecious, with male and female strobiles occurring on the same tree. Deviations from this norm have recently been found and are reported by Stettler in these proceedings. Male strobiles (catkins) are conspicuous in late fall preceding flowering; and female strobiles, although less evident, are also present at this time. Flowering may occur from late February to early May, depending on latitude and climate. Cones (female strobiles) are 1/2 to 1 inch in length and contain 50-100 small, flattened, wingless, nut-like seeds (7). Ripening occurs in the period August through September, depending on location and climatic conditions. Seed dispersal begins shortly after conelet ripening and continues through fall and winter. The seeds are light in weight (666,000 per pound) (6) and are effectively dispersed by wind. Seeds of red alder, unlike Douglas-fir, have virtually no endosperm remaining in the mature seed and food reserves are stored in the cotyledons (fig. 1).

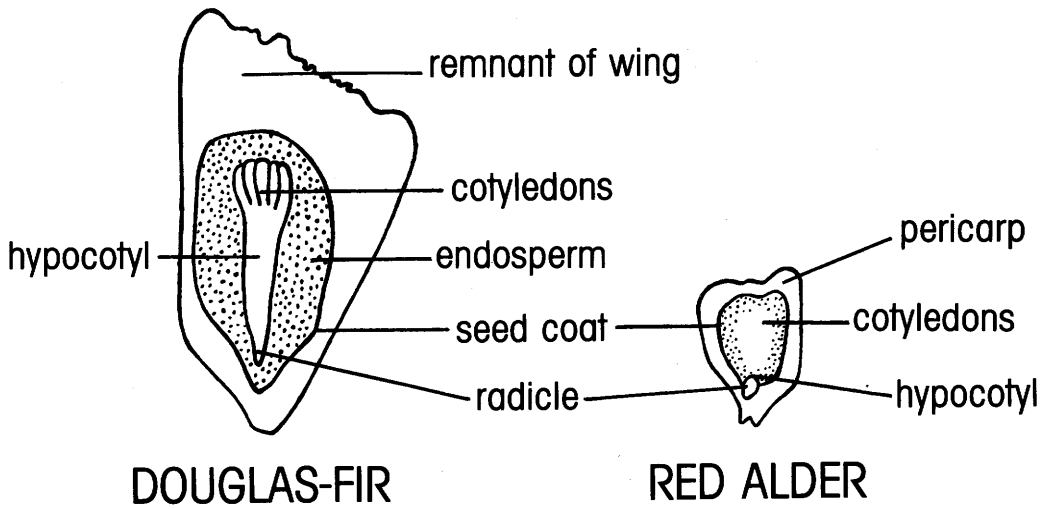


Figure 1.--Longitudinal section of Douglas-fir and red alder seed, illustrating absence of endosperm (female gametophyte) in seed of red alder (approximately 10X).

Cone Collection and Handling

Cones of red alder may be collected from standing or recently-felled trees when bracts start to separate on the earliest-developing strobiles. Collected cones may be opened by exposing to ambient air for several weeks or by kiln drying at 80°-100°F for a shorter time. In our work, we have found that cones may case-harden before collection, making it very difficult to extract seed from the cone.

Cones are considered collectable when sample cones cut longitudinally expose four filled seed per cut face. A 2-bushel sack of these cones will yield approximately 1-1/2 pounds of cleaned seed.[1] Cleaning by screening and blowing will produce above 95-percent filled seed.

Seed Stratification and Germination

Information regarding procedures for stratifying and germinating red alder seed is limited. Workers at the British Columbia Forest Service Nursery at Duncan, BC, tested seed collected in 1974.[2] Following moist-cold stratification, 67 percent of the seed germinated in 21 days under a regime of 8 hour 30°C light and 16 hour 20°C dark. Sixty percent of the unstratified seed germinated. After 1 year's storage at -19°C, 55 percent of the unstratified seed from the same seed lot germinated. Information provided by workers from other nurseries and seed companies suggests that, on the average, 50 percent of unstratified fresh red alder seed will germinate within 21 days.

At the University of Washington, several independent tests have been conducted on red alder seed. In one study, the effect of imbibition of water on the germination of red alder seed was investigated. It was found that seed stored at room temperature for 3 years reached a maximum germination percentage after soaking in water for 24 hours. Soaking for lesser and greater periods reduced germination (fig. 2).

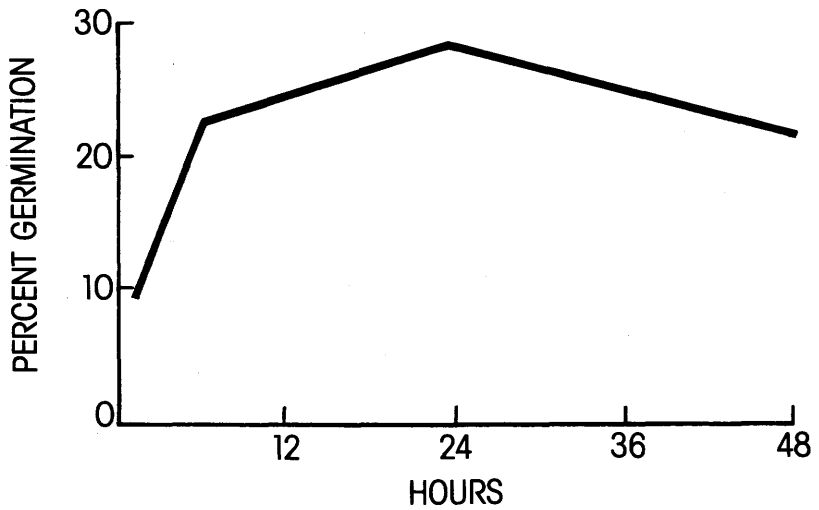


Figure 2.--The effect of soaking on the germination of red alder seed stored at room temperature for 3 years.

[1]Patillo, G., Silva Seed Company, Roy, Wash., personal communication.

[2]Hamilton, M., British Columbia Forest Service, Duncan Nursery, Duncan, BC, personal communication.

In a second study,[3] the effect of light intensity on seed soaked in H_2O for 24 hours was investigated. In this experiment, light intensity was controlled but not quantified by increasing the number of Whatcom No. 1 filter papers placed over petri dishes containing seed exposed to continuous artificial light. The results of this test (fig. 3) show that germination of red alder seed decreases with decreasing amounts of light.

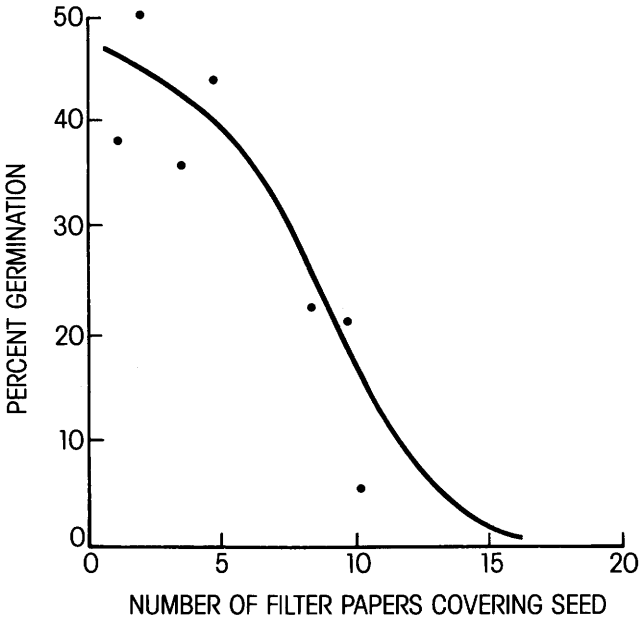


Figure 3.--The effect of light intensity on the germination of red alder seed. Intensity controlled by covering seed with filter paper.

Bormann also demonstrated that red alder seed has phytochrome-controlled seed germination; that is, red light induces germination while far-red light strongly inhibits germination (fig. 4). Under field conditions, the impact of this mechanism would be that seeds under thick vegetative cover or deeply buried in the soil (both far-red light conditions) would not germinate until the site was disturbed so that the seeds became exposed to some daylight which is dominated by red light.

Individual trees may be expected to produce seed with different capacities for germination, depending upon physiological condition, nutrition, maturity, pollination, or other causes. Figure 5 shows the percentage of germinated seed taken from three trees of equal age. The seed was soaked in water for 24 hours and stored at 35°F for 6 weeks prior to germination. Although the causes of the strikingly different germination rates are not known, the data may have implications to be considered when seed collections involve one or only a few parent trees.

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[3]Bormann, B. Unpublished data on file at Department of Botany, University of Washington, Seattle.

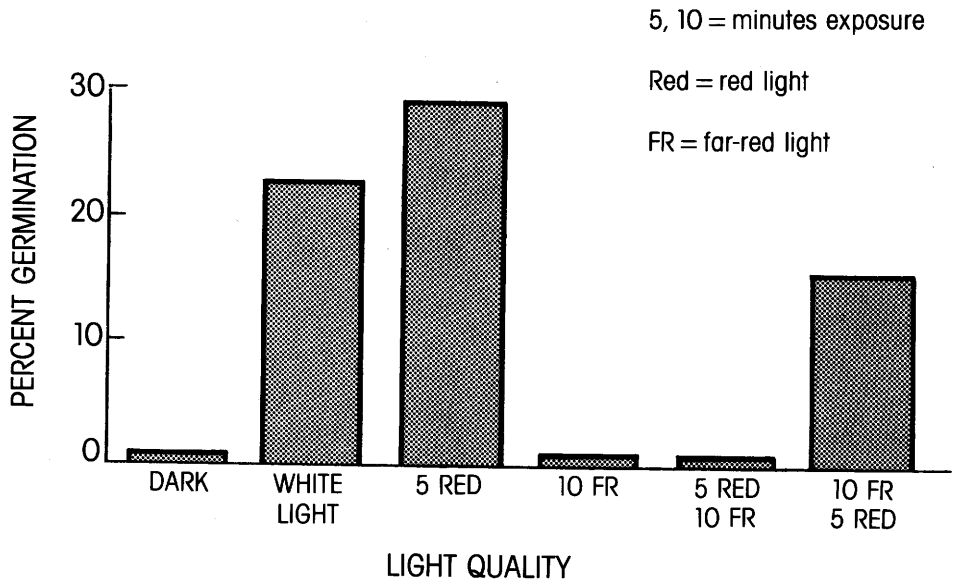


Figure 4.--The effect of light quality on the germination of imbibed red alder seeds.

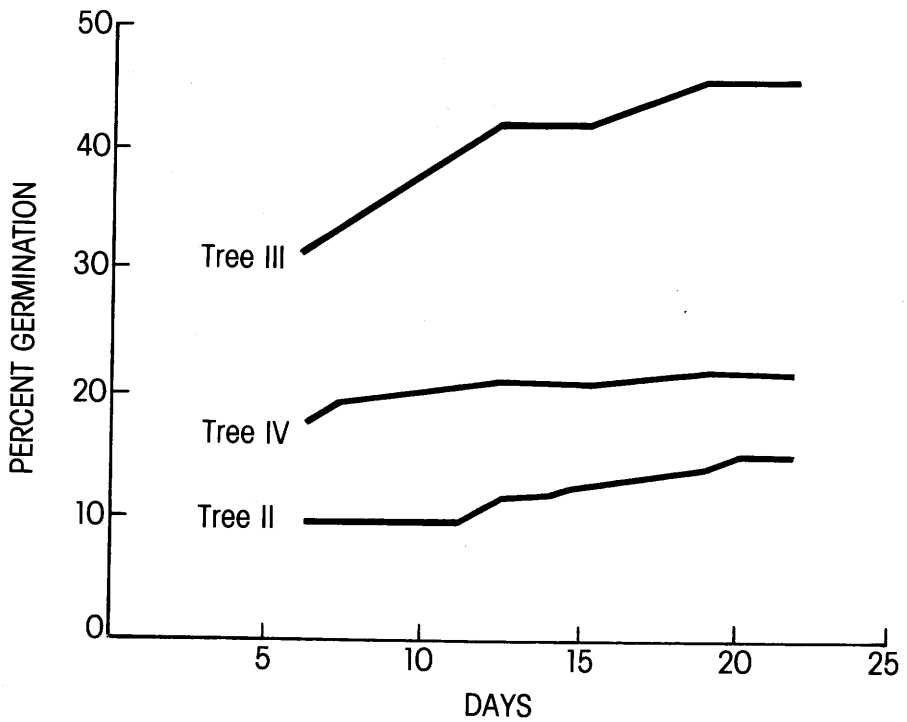


Figure 5.--Germination of red alder seed collected from three individual trees.

Under field conditions, red alder seed is commonly observed to germinate best on moist mineral soil exposed to full sunlight. Minore (*3*), working at Cascade Head Experimental Forest, also demonstrated that red alder germinates well on rotten wood (82 percent) and duff (80 percent).

Seedling Production Systems

The procedural options for growing red alder seedlings in nursery operations are perhaps narrower than for growing conifer seedlings because of the extremely rapid juvenile growth potential of red alder. Heights of 3 to 4 feet in the 1st year on good sites are not uncommon for alder. This amount of growth in nursery seedlings would undoubtedly require special handling if grown as bare root, transplant, or container stock.

Bare root red alder seedlings were grown in forest tree nurseries in the late 1940's, but operations were abandoned because of lack of interest. Recently, Crown Zellerbach and Silva Seed Company have grown red alder seedlings in containers. At the Crown Zellerbach Ed Wood Nursery,[4] seedlings were grown in CZ-Treetainers using a peat-vermiculite-perlite (1:1:1) growing media. Nutrients were withheld after mid-summer and moisture was cycled between field capacity and 5 bars stress. This regime resulted in 8- to 12-inch seedlings with good caliper and root systems after 6-7 months of growth. Silva Seed Company[5] has also grown red alder seedlings in containers and advises that seed must be sown late in the spring to avoid excessive height growth. Their seedlings reached a height of 2 feet and required top pruning.

Preliminary data from experiments conducted at the University of Washington indicate that red alder cuttings taken in February do not readily root. Similar reports from the British Columbia Forest Service concur with these findings.[6] Schmid (*4*), working with several hardwood species, found that dormant cuttings of grey alder (*Alnus incana*) were easy to root, provided that buds were retained and cuttings were treated with IBA (indolebutyric acid). Lepistö[7] reports that softwood cuttings taken from seedlings during a period of vigorous growth could be successfully rooted (70 to 95 percent) when cuttings were treated with 0.5-percent IAA (indoleacetic acid) in powder form and placed under intermittent mist. He further reports that scions from mature alder may be readily grafted to 1 to 2-year-old root stock using side veneer grafts near the root stock terminal.

Establishment Techniques

PLANTING

DeBell (*1*) reports average densities of 122,000 stems per acre at age 1-2 years and 14,000 stems per acre at age 8-11 years in the densest red

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[4]Smith, R., Crown Zellerbach Company, Ed Wood Nursery, Aurora, Oregon, personal communication.

[5]Reeter, R., Silva Seed Company, Roy, Wash., personal communication.

[6]Edwards, G., Canadian Forestry Service, Pacific Forest Research Centre, Victoria, BC, personal communication.

[7]Lepistö, M., The Foundation for Forest Tree Breeding, Helsinki, Finland, personal communication.

alder stands he was able to locate in the lower Columbia River Valley. Smith (5) also reports similar densities working in British Columbia. With these impressive numbers, the establishment of red alder does not appear to pose any major problem other than overstocking. Apparently, however, no one has seriously investigated either natural or artificial seeding of this species as a silvicultural technique and there may be undiscovered obstacles in the way of this approach. A moist seed bed, full sunlight, and warm temperatures are the principal requirements for germination of seed and establishment of seedlings in natural stands. Given these conditions, red alder should be one of the easiest forest tree species in the Pacific Northwest to establish by either direct seeding or natural seeding when a seed source is present.

Establishing stands of red alder by planting has not received much attention, and information is scanty. At the University of Washington Pack Demonstration Forest, we have had 90-percent first-year survival among wild alder seedlings lifted after flushing and immediately transplanted to an herbicide-treated sewage sludge area. Similar seedlings transplanted to a non-herbicided sludge area had a 20-percent survival after one growing season.

Zelsnack[8] reports that container-grown red alder seedlings planted by International Paper Company had a 1st-year survival of 75-80 percent. Small (Styroblock-2) container-grown seedlings had a poorer survival than did large (Styroblock-8) container grown seedlings.

DeBell[9] planted red alder seedlings grown in CZ-Treetainers at Lady Island. The stock had flushed at the time of planting and was damaged by frost after planting. Nevertheless, 1st-year survival was 97 percent. DeBell,[10] working with the U.S. Forest Service and International Paper Company, also conducted a study in Columbia County, Oregon, in which 72-88 percent of container grown red alder seedlings planted in plots of different spacings and slope positions survived the 1st year. Spacing had no apparent effect on survival; however, in all cases, survival of seedlings planted at the top of the slope was greater than in plots at the bottom of the slope (fig. 6). This was due, at least in part, to less competition from herbaceous species on the upper-slope positions.

COPPICING

Red alder may sprout from the stump or root collar after cutting and therefore has some potential for regeneration by the coppice method. In

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[8]Zelsnack, F. Unpublished data on file at International Paper Company, Longview, Wash.

[9]DeBell, D. Unpublished data on file at Forestry Sciences Laboratory, Olympia, Wash.

[10]DeBell, D. Unpublished data on file at Forestry Sciences Laboratory, Olympia, Wash.

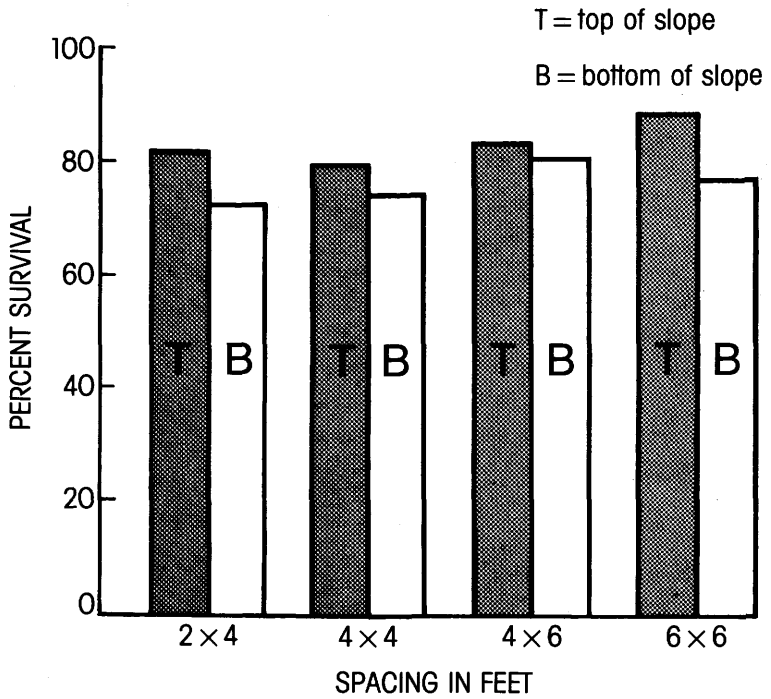


Figure 6.--Effect of spacing and slope position on survival of planted red alder seedlings.

1940, McComb,[11] working on good sites and in pure stands, cut 48 trees with breast height diameters ranging from 10 to 27 inches. The trees were cut during both dormant and growing seasons. By fall 1941, only 26 (54 percent) of the stumps had live sprouts. Of 20 stumps examined in 1945, only 1 had living sprouts and, in this case, root grafting was suspected because of the proximity of a living tree.

In April 1944, the U.S. Forest Service completed a release cutting in a dense young stand of red alder near Waldport, Oregon. At the time of cutting, stump diameters ranged from 3/4 to 6 inches at a height of approximately 4 inches. In 1947, Repraeger[12] examined 100 trees in the cut area to determine the amount of sprouting. At that time, stump diameters varied from 1 to 14 inches, with an average diameter of 4.3 inches. The 100 stumps had a total of 264 sprouts, of which 59 percent had originated from roots and 41 percent from stumps.

[11]McComb, F. Unpublished data on file at Forestry Sciences Laboratory, Olympia, Wash.

[12]Rapraeger, H. Unpublished data on file at Forestry Sciences Laboratory, Olympia, Wash.

In 1977, DeBell,[13] working at Lady Island, found that 95 percent of small, young alder (1- to 1-1/4-inch stump diameter) cut in the dormant season had living sprouts at the end of the 2d year following cutting.

From these studies, it is apparent that young alder will develop vigorous sprouts when cut either in the dormant season or early spring. Mature alder may sprout but much less vigorously than young alder, and the sprouts may be short-lived. Coppicing for at least one rotation may therefore be possible in young stands.

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(2) Fowells, H. A. (ed.)
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(3) Minore, D.
1972. Germination and early growth of coastal tree species on organic seed beds. USDA For. Serv. Res. Pap. PNW-135. 18 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

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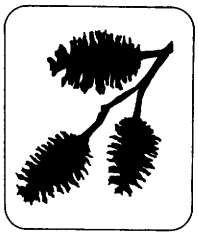
(5) Smith, J. Harry G.
1968. Growth and yield of red alder in British Columbia. p. 273-286. *In* Biology of Alder. J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. M. Hansen, eds. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

(6) U.S. Forest Service.
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[13]DeBell, D. Unpublished data on file at Forestry Sciences Laboratory, Olympia, Wash.

NATURAL VARIATION IN RED ALDER



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ABSTRACT

An 8-year-old provenance trial examined racial variation among 10 sources of red alder from Alaska, British Columbia, Washington, Oregon, and Idaho. The fastest growing sources are from northwestern Washington, but sources from British Columbia, southwestern Washington, and Oregon also grew well. The slowest growers were from Juneau, Alaska, and Sandpoint, Idaho--they also have the greatest frost resistance.

A study of phenotypic variation between and within eight stands was conducted in a small area west of Olympia, Washington. Although the stands were selected to cover the range in site conditions occurring in the area, only crown width index, branching characteristics, and bark thickness showed significant variation between stands. Variation from tree to tree within stands, however, was substantial for all traits.

The results of these studies suggest that individual tree selection will be a useful approach in alder improvement programs and that such programs can encompass rather large areas (or breeding zones).

Introduction

Information on natural variation in growth traits and wood quality is important for developing efficient tree improvement programs for forest species. Estimates of the genetic component of existing variation or heritabilities of selected traits are also needed. Such information is limited for red alder (*Alnus rubra* Bong.) because most forest managers and scientists have shown far more interest in killing the species than in

improving it. Nevertheless, two studies provide some data on racial, stand, and tree variation in red alder. One study is an 8-year-old provenance trial testing outplanting performance of seedling from a wide range of sources. The other study examines tree variability within and between stands in a relatively small portion of the species' range.

Geographic or Racial Variation

The natural range of red alder extends from southern California (latitude 34° N.) northward along the Pacific coast to Yakutat Bay, Alaska (latitude 60° N.). Though some stands have been found in northern Idaho, the species usually occurs within 100 miles of the Pacific Ocean and at elevations of less than 2,500 feet (Worthington et al. 1962). Some foresters have suggested that red alder attains its best development in northern Washington and southern British Columbia, but little or no data have been advanced to document those observations or to determine whether genetic or environmental factors are responsible.

In the fall of 1968, B. S. Douglass and R. K. Peter established a red alder provenance test with outplantings at the Cascade Head Experimental Forest near Lincoln City, Oregon, and in the Capitol Forest near Olympia, Washington. Severe frost damage in 1969 and 1970 decimated the Capitol Forest plantation. The Cascade Head plantation, however, is now growing vigorously and is in its ninth growing season. It has been evaluated six times and provides the basis for the following discussion of racial variation.[1]

DESCRIPTION OF THE PROVENANCE TRIAL

Sources of planting stock.--Natural seedlings, 12 to 30 inches in height, were collected from 10 locations during the winter of 1968-69, shipped to the Webster Nursery, Olympia, and stored at 35°F until they were sorted and planted. The locations are identified in figure 1; they include Juneau, Alaska, and Sandpoint, Idaho, in addition to eight well-spaced locations in Oregon, Washington, and the southern end of Vancouver Island, British Columbia. Latitude, elevation, and mean annual precipitation and temperature of the locations are listed in table 1.

Because all seedlings of some provenances were obtained from a very small area (e.g., less than 1 acre), they may represent a small portion of the gene pool at that general location. Moreover, the natural seedlings had already undergone some degree of natural selection and therefore are not a random sample of the gene pool at even a small locality. Thus, procedures used to sample the local populations would tend to reduce

[1] Unpublished plans, field data, and reports prepared from 1968 through 1976 by B. S. Douglass, R. K. Peter, and V. W. Clapp, USDA Forest Service, State and Private Forestry, Portland, Oregon.

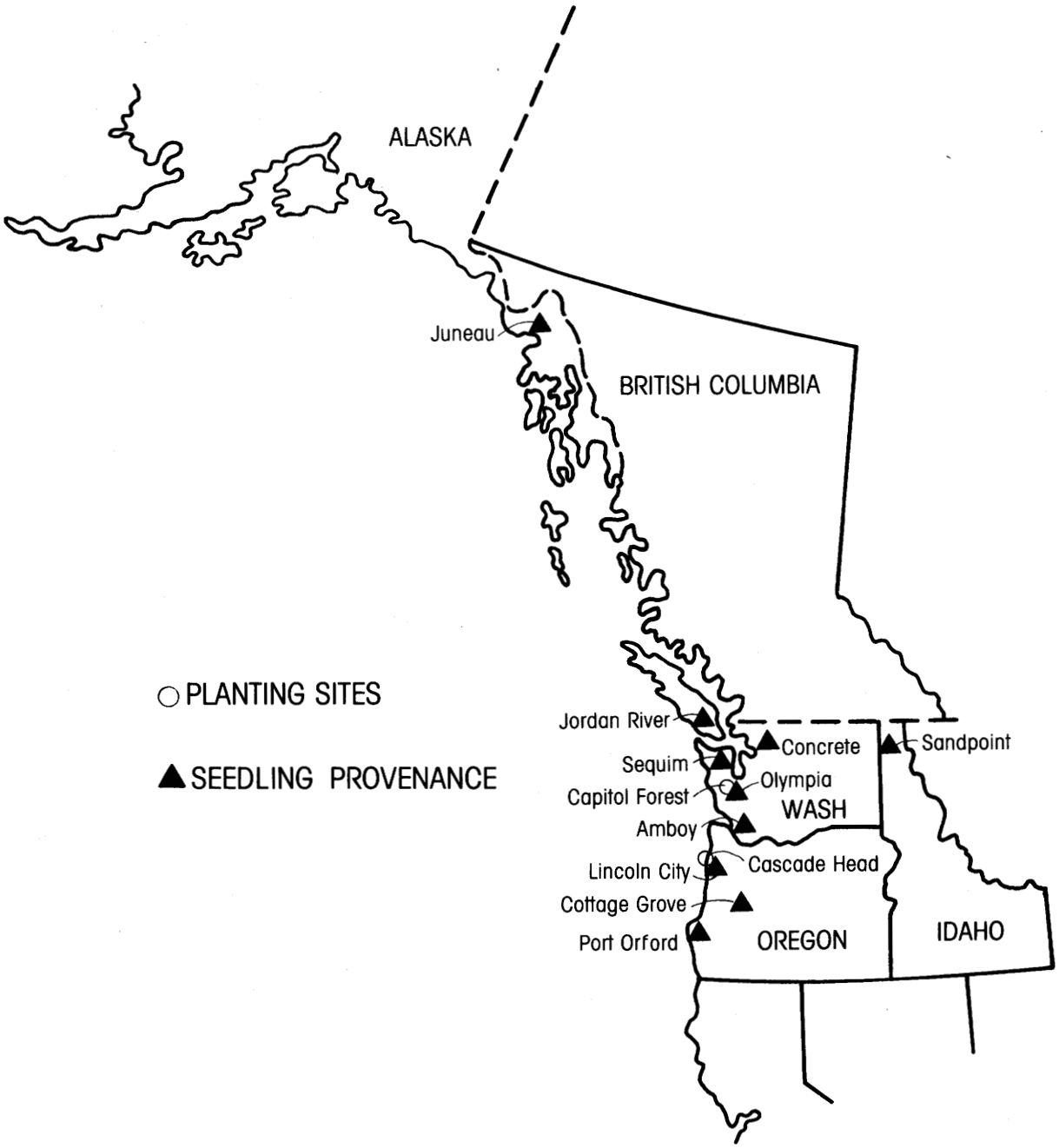


Figure 1.--Locations of sources tested in red alder provenance trial.

Table 1--*Location and features of native environment for red alder provenances tested at Cascade Head Experimental Forest in Oregon*

Location	Latitude	Elevation[1/]	Precipitation[2/]	Temperature[2/]
	°N	Feet	Inches	°F
Juneau, Alaska	57.0	150	90	43
Jordan River, British Columbia	48.5	300	74	48
Concrete, Washington	48.5	300	80	52
Sandpoint, Idaho	48.4	2,300	30	45
Sequim, Washington	48.1	200	15	49
Olympia, Washington	47.0	250	50	51
Amboy, Washington	45.9	500	70	51
Lincoln City, Oregon	45.0	300	90	51
Cottage Grove, Oregon	43.8	800	50	52
Port Orford, Oregon	42.7	900	70	53

[1/] Above sea level.

[2/] Estimated mean annual.

variability within a provenance and thereby exaggerate differences between provenances. These points should be considered when the data are evaluated.

The outplanting areas.--Ten acres, located at the head of a small creek on the Cascade Head Experimental Forest, were selected for one outplanting site. This area, near the town of Otis, is typical of alder sites in coastal Oregon. Elevation is 600 feet, precipitation (primarily rain) averages about 90 inches per year, and mean annual temperature is approximately 52°F. Soils are derived from sedimentary materials. Originally, the area supported a mature stand of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.), averaging nearly 100,000 board feet per acre. After logging, a central 100- by 400-foot area was cleared of all debris (except large stumps) to permit uniform spacing of the alder seedlings.

The Capitol Forest site was located on a portion of an abandoned State nursery about 15 miles southwest of Olympia. Elevation is 600 feet; estimated mean annual precipitation and temperature are 55 inches and 51°F. This area was thoroughly cultivated prior to planting.

Planting design and procedures.--The experimental design consisted of eight blocks (100- by 50-foot) in two strips perpendicular to the contour. Ten rows were located at 10-foot intervals in each block. Individual rows were randomly selected for planting with 10 trees of the same provenance, spaced 5 feet apart.

The trees were planted in March and April 1969. Prior to planting, roots of all seedlings were pruned to 8 inches in length; tops exceeding 24 inches were pruned to 18 inches.

Evaluation and measurement.--Early performance of seedlings was evaluated at both locations in July 1970, after nearly two growing seasons. Data were collected on survival, height, and general form. Multiple leaders and large suckers were removed because they probably resulted from top pruning and transplanting shock; thereafter, trees at the Cascade Head site developed naturally. Unfortunately, severe early frosts damaged the Capitol Forest planting in fall 1969 and fall 1970. After information on survival and frost damage were collected in 1971, this plantation was abandoned.

Evaluations were made at Cascade Head after the 1971, 1972, 1973, 1974, and 1976 growing seasons. Diameter measurements were initiated in 1976, 8 years after planting. In December 1976, the test area was thinned to 10- by 10-foot spacing, by removing every other tree in each row. Breast-high wood samples were collected from the cut trees for determination of specific gravity and bark thickness.

PROVENANCE PERFORMANCE

Survival.--Information on survival of planting stock is given in table 2. At Capitol Forest, the coastal Oregon sources (Lincoln City and Port Orford) and the Jordon River stock from southern Vancouver Island were hardest hit by the fall 1969 freeze. Seedlings from Juneau, Alaska, and Sandpoint, Idaho, however, were little affected. This is evident both in the initial survival percentages and in the number of seedlings frozen back to ground line. Many seedlings that resprouted after the 1969 freeze subsequently died; other seedlings were killed by the 1970 freeze. By fall 1971, losses were so great that subsequent evaluations of growth at this site would have minimal value.

Table 2--*Survival of red alder provenances at Capitol Forest and Cascade Head Experimental Forest outplanting sites*

Provenance	Capitol Forest		Cascade Head	
	Initial survival	Seedlings frozen back to ground	Initial survival	Subsequent survival[1/]
	- - - - - - - - Percent - - - - - - - -			
Juneau, Alaska	95	0	94	97
Jordan River, British Columbia	41	90	94	100
Concrete, Washington	80	70	84	99
Sandpoint, Idaho	90	10	79	97
Sequim, Washington	86	65	99	99
Olympia, Washington	93	60	95	97
Amboy, Washington	89	60	96	98
Lincoln City, Oregon	63	85	96	99
Cottage Grove, Oregon	79	75	91	98
Port Orford, Oregon	39	95	89	100

[1/] These values include surviving seedlings of both initial and followup plantings.

Survival after the first growing season at Cascade Head varied by provenance from 79 to 99 percent. Replacement plantings were made from holding beds if additional seedlings from the provenances were available. Subsequent survival of seedlings (living originals plus replacements) exceeded 97 percent. Therefore, initial survival differences were probably related to differences in handling and storage of the seedlings before outplanting rather than to genetic differences in adaptability to the Cascade Head site.

Height growth.--Average heights for trees at 2, 4, 6, and 8 years after planting are listed by provenance in table 3. Large differences in height were evident in the 2d year. Trees from provenances with the tallest trees (Concrete and Sequim) averaged 5.0 feet in height, whereas those from provenances with the shortest trees (Juneau and Port Orford) averaged only 3.1 feet, a difference of about 60 percent. In general, such differences have persisted through the eighth growing season (table 3 and fig. 2). Trees of the Concrete and Sequim provenances now average 30.3 and 29.4 feet, whereas trees from Juneau are only 14.4 feet in height. Because of inclusion of some Sitka alder (*Alnus sinuata* (Reg.) Rydb. seedlings (about one-fourth of the Juneau stock) that were not positively identified until September 1974, the poor performance of the Juneau stock in height growth as well as other traits is slightly exaggerated. After a slow start, the Port Orford source has recovered and is now ranked fourth tallest at 27.6 feet. Nevertheless, the difference in height between tallest and shortest sources has widened to more than 100 percent.

Table 3--*Average heights of red alder provenances after outplanting at Cascade Head*

Provenance[1/]	Years after outplanting			
	2	4	6	8[2/]
	- - - - - - - - - -Feet- - - - - - - - - -			
Concrete, Washington	5.0	15.2	21.5	30.3 a
Sequim, Washington	5.0	15.3	21.7	29.4 ab
Olympia, Washington	4.8	13.8	19.6	27.7 ab
Port Orford, Oregon	3.1	11.8	18.5	27.6 ab
Amboy, Washington	4.7	13.1	19.0	27.3 ab
Jordan River, British Columbia	4.5	14.0	19.9	26.7 ab
Lincoln City, Oregon	3.6	12.1	17.5	26.4 ab
Cottage Grove, Oregon	3.5	12.4	18.1	26.1 b
Sandpoint, Idaho	3.6	10.5	15.3	21.0 c
Juneau, Alaska	3.1	7.6	10.8	14.4 d

[1/] Ranked by height of red alder at age 8.

[2/] Means followed by the same letter are not statistically different at the 5-percent level of confidence as determined by Tukey's test (Steel and Torrie 1960).

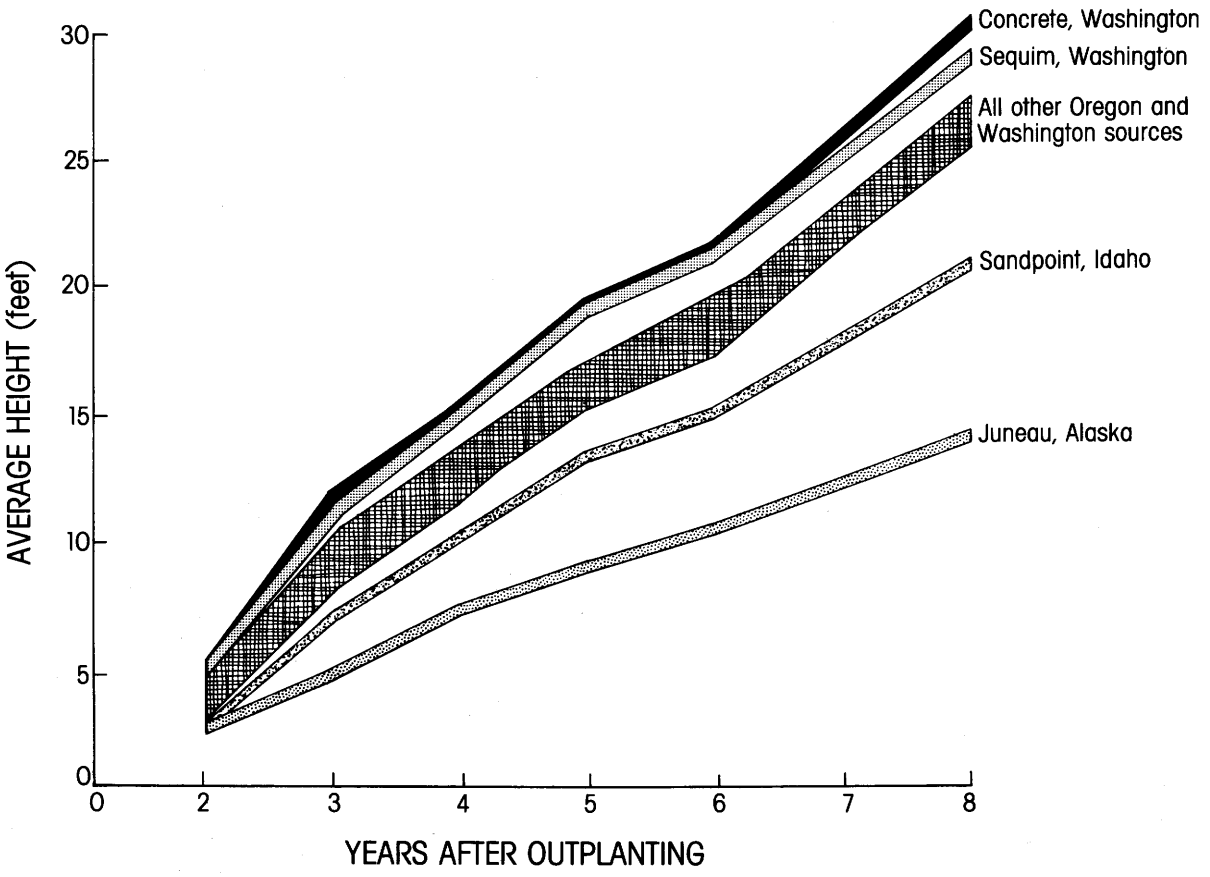


Figure 2.--Height growth patterns of red alder provenances at Cascade Head.

Based on 8-year height growth of red alder, the provenances can be split into two main groups: (1) the eight sources from Oregon, Washington, and southern British Columbia which are all growing well and are led by the Concrete and Sequim stock, and (2) the two outlying sources from Juneau and Sandpoint which are growing much more slowly.

Diameter growth.--Diameters measured after 8 years indicated provenance differences (fig. 3) similar to those discussed for height growth. The largest diameters (3.6 inches) were attained by trees from Concrete and Sequim, whereas Sandpoint and Juneau sources averaged only 2.1 and 1.5 inches. Diameters of some of the remaining sources, however, were not significantly less than those of the Concrete and Sequim trees.

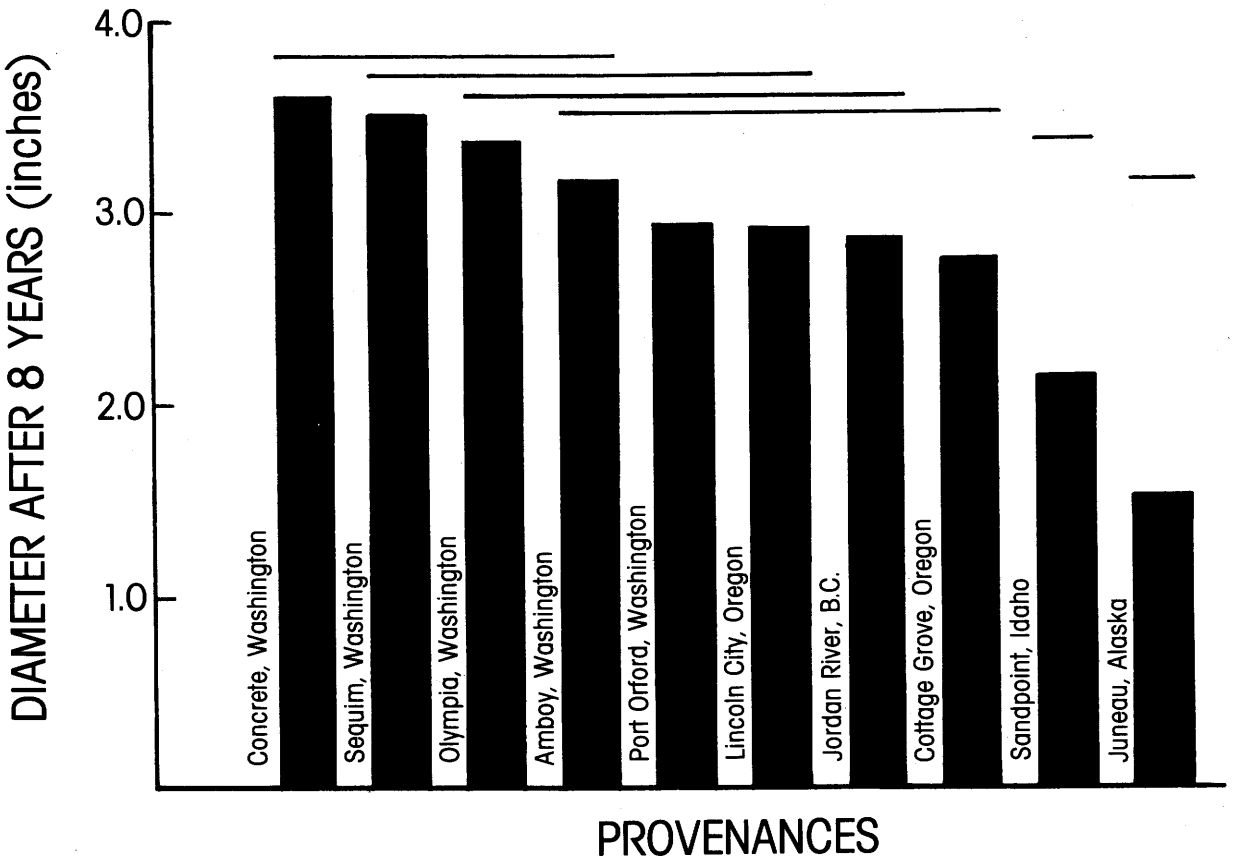


Figure 3.--Breast-high diameter of red alder provenances 8 years after outplanting at Cascade Head. Means joined by the same lines are not statistically significant.

Other traits.--Because factors other than growth rate may also be important in tree improvement programs, additional characteristics have been assessed at various times in the trial. Data on general stem form, frequency of multiple leaders, damage by a flat-headed twig girdler (*Agrilus burkei* Fisher), specific gravity, and bark thickness are given for each provenance in table 4.

Table 4--*Stem form and other characteristics of red alder provenances at Cascade Head*

Provenance[1]	General stem form[2]	Trees with Multiple leaders	Trees damaged by twig girdler	Breast-high	
				Specific gravity	Bark thickness[3]
	- - - - - Percent - - - - -			g/cm^3	Inches
Concrete, Washington	4.1	8	25	0.40	0.13 a
Sequim, Washington	4.6	14	30	.39	.15 ab
Olympia, Washington	4.0	13	10	.40	.14 ab
Port Orford, Oregon	2.8	28	10	.40	.14 ab
Amboy, Washington	3.5	23	19	.40	.16 ab
Jordan River, British Columbia	4.4	13	20	.41	.17 b
Lincoln City, Oregon	2.9	20	10	.39	.14 ab
Cottage Grove, Oregon	2.8	38	6	.40	.15 ab
Sandpoint, Idaho	2.3	39	10	.40	.17 b
Juneau, Alaska	1.3	50	2	.41	.14 ab

[1] Ranked by height of red alder at age 8.

[2] 5 = best; 1 = poorest.

[3] Adjusted by covariance analysis to common d.b.h. Means followed by the same letter are not statistically different at the 5-percent level of confidence as determined by Tukey's test (Steel and Torrie 1960).

The sources having the best form (e.g., straight stems and small limbs), as well as the lowest frequency of multiple leaders, were Sequim, Jordon River, Concrete, and Olympia. These provenances are also among those having the most rapid height and diameter growth.

The fastest growing sources were hit hardest by the twig girdler in a 1971 attack. Whether this damage incidence was due to genetic differences per se or to the greater amounts of succulent tissue associated with rapid growth is unknown. Fortunately, no twig girdler attacks occurred in subsequent years, and by the end of the 1974 growing season, the trees had essentially overcome the detrimental effects by overgrowing and strengthening the girdled portion or by forming a new leader below a girdler-caused break.

Compared with previously discussed traits, racial variation in wood density was minimal and differences were not significant. There was, however, considerable variation in wood density within each provenance. As might be surmised from the provenance averages in table 4, wood density was not related to growth rate. Racial differences in bark thickness were significant at the 10-percent level. Because differences were also related to tree size, values were adjusted by covariance analysis to a common breast-high diameter o.b. (outside bark). Following such adjustment, racial differences in bark thickness remained significant.

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Results from the study of racial variation are quite encouraging for alder improvement programs. Such implications will be discussed after we consider natural variation within a local area.

Phenotypic Variation Within a Local Area

Although the racial variation described previously has provided much useful information for alder improvement programs, foresters will also need data on the magnitude and patterns of variation in certain traits within a local area or breeding zone. It is within such an area that phenotypic selections can be made for the initial phases of breeding programs. Moreover, seedlings produced from seed collected in a local area can be planted with greater confidence in their adaptation to local sites. For these reasons, we initiated a study of natural variation of alder in an area west of Olympia.

DESCRIPTION OF LOCAL VARIATION STUDY

Boundaries of the local area are shown in figure 4. The Capitol Forest comprises most of the southern half of the unit, whereas the northern half includes land owned primarily by forest industry.

Eight stands were selected to cover the range in elevation, topography, soils, and rainfall occurring in the designated area (table 5). Average age of the stands varied from 20 to 73 years, and estimated site index ranged from 67 to 101 feet on a 50-year basis. Average breast-high diameter varied from 9.3 to 12.8 inches.

Table 5--*General characteristics of red alder stands sampled in local area near Olympia, Washington*

Stand location	Elevation above sea level	Soil parent material	Estimated annual precipitation	Stand characteristics[1/]			
				Age	Average d.b.h.	Height	Estimated site index[2/] (50-year basis)
	Feet		Inches	Years	Inches	- - -Feet- - -	
McKenny	300	alluvium-till	45	44	11.1	87	92
Porter	550	siltstone	55	35	11.1	87	101
Rock Candy	900	basalt	55	45	11.6	82	86
Wedekind	1800	alluvium-basalt	55	20	9.3	54	87
McCleary	300	mixed alluvium	60	73	12.0	87	76
Taylor Towne	400	till and local basalt	65	56	12.8	91	87
Schafer Park	325	mixed basalt and sediments	75	54	11.9	96	93
Stillwater	250	till and local basalt	80	59	10.7	72	67

[1/] Based on data collected from sample trees.

[2/] Based on: Norman P. Worthington, Floyd A. Johnson, George R. Staebler, and William J. Lloyd. 1960. Normal yield tables for red alder. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station Research Paper 36, 29 p. Portland, Oregon.

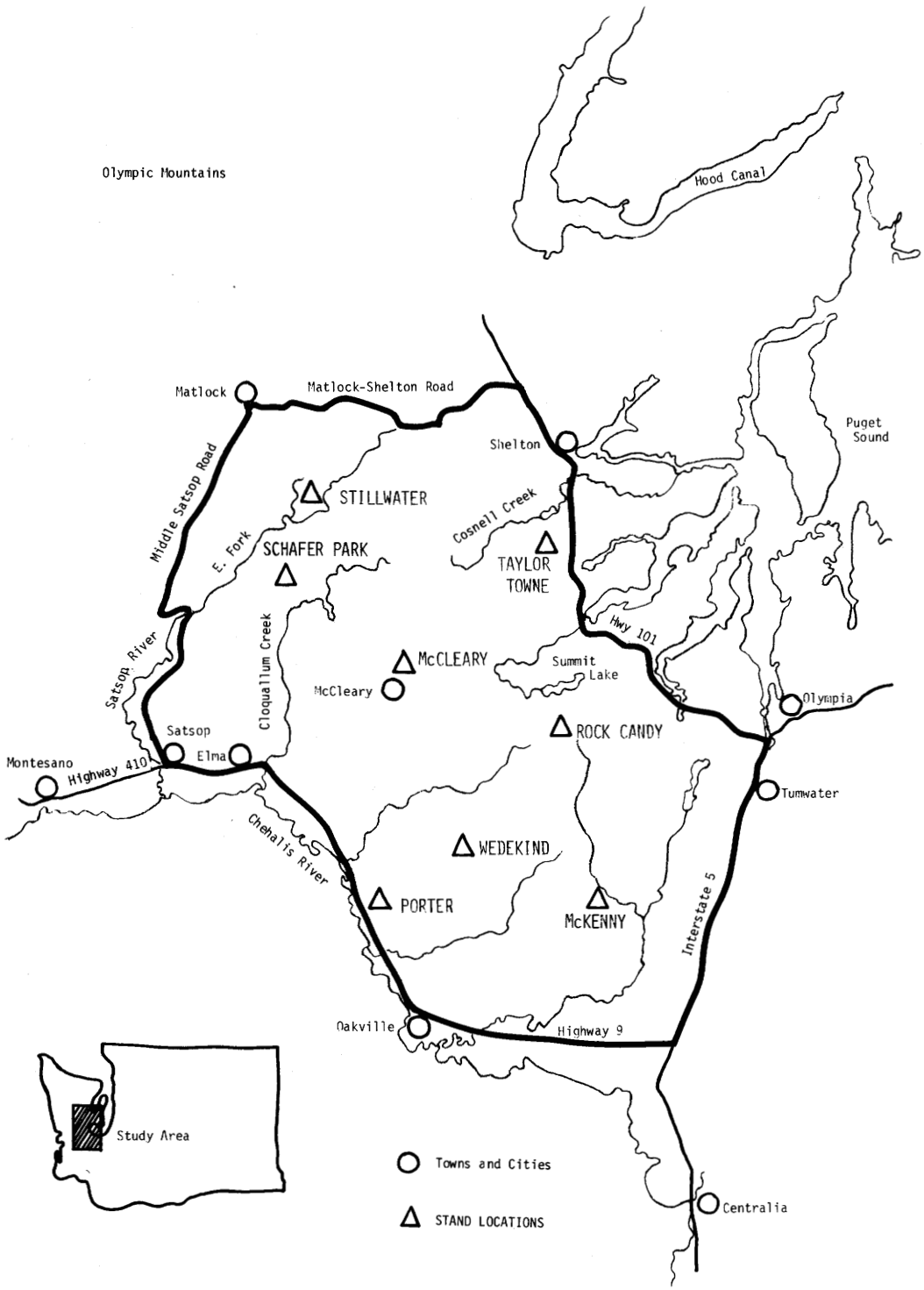


Figure 4.--Locations of stands sampled in study of phenotypic variation with local area.

Ten trees were chosen at random within each stand for assessing natural variation. After the general form of each tree was sketched and its lean and crown spread measured, the trees were felled to obtain measurements of height, upper-stem diameters, and branching characteristics. Seeds were collected for subsequent progeny trials. Also, stem cross-sections were cut at the stump for determining age and at breast height for measuring specific gravity and bark thickness.

Differences between stand means for most traits were tested by analysis of variance using a completely randomized design. Two observations of specific gravity and bark thickness were obtained for each tree, which permitted testing of the significance of differences between trees within a stand.

PHENOTYPIC VARIATION BETWEEN AND WITHIN STANDS

Trait evaluations for randomly selected trees in the eight stands are summarized in table 6. The mean, range in stand means, and range in individual tree values are listed for each trait. In addition, results of an analysis of variance of differences between stands and two expressions (standard deviation and coefficient of variation) of tree-to-tree variability within stands are given. The standard deviation is indicative of the dispersion of individuals around the mean. Expressed as a percentage of the stand mean (i.e., coefficient of variation), it is a measure of the relative variability of a given trait in different stands.

Table 6--*Summary of phenotypic variation between and within stands of a local area*

Trait	Unit of measure	Mean	Range in		Confidence level for differences between stands[1/]	Range in within stand variation	
			Stand means	Individual tree values		Standard deviation	Coefficient of variation
							Percent
Lean	Degrees	10	6 - 13	0 - 36	Nonsignificant	3 - 10	35 to 88
Stem form index	Percent	85	84 - 87	73 - 98	Nonsignificant	2 - 6	2 to 7
Crown width index	Feet÷inches	1.5	1.3 - 1.7	1.0 - 2.7	10 percent	.2 - .5	14 to 36
Clear bole index	Percent	54	22 - 63	11 - 82	Nonsignificant	7 - 15	12 to 32
Branch angle	Degrees	40	34 - 44	21 - 62	10 percent	6 - 12	15 to 27
Branch diameter index	Percent	38	28 - 47	13 - 74	1 percent	5 - 13	18 to 33
Wood density	Grams per cubic centimeter	.39	.38 - .40	.30 - .43	Nonsignificant	.01 - .02	3 to 5
Bark thickness[2/]	Inches	.13	.09 - .17	.12 - .49	1 percent	.03 - .07	15 to 21

[1/] All statements regarding significance of differences between stand means for specific traits are based on results of Tukey's test at the 5-percent level of confidence (Steel and Torrie 1960).

[2/] Values for the mean and range in stand means are adjusted by covarience analysis to a common tree size (radius outside bark). Other values have not been adjusted for differences in tree size.

Only crown width, branching characteristics, and bark thickness varied significantly between stands. Variation among trees within stands was substantial, however. The traits are discussed individually in the following paragraphs.

Lean.--Lean is thought to be an important trait because leaning trees tend to develop sweep which presents difficulties in handling and milling logs. Lean is probably also associated with reaction wood which further reduces lumber recovery. Magnitude of lean was measured by the angle of departure from vertical for a 6-foot stem section centered at breast height. Stand averages ranged from 6^{o} to 13^{o} but were not significantly different. The lean of individual random trees varied from 0^{o} to 36^{o} and averaged 10^{o}. The fact that lean was somewhat related to crown width:d.b.h. ratio ($r = 0.27$, $p < 0.05$) gives credence to the hypothesis that lean might be minimized by growing alder in well-stocked, uniformly spaced stands.

Stem form index.--Stem form index was calculated as the ratio (percent) of diameter (o.b.) at one-fourth height to diameter at breast height (o.b.). Differences between stand means were minimal, but individual tree values ranged from 73 to 98.

Crown width index.--Among trees of comparable sizes, narrow crowns may indicate efficient use of growing space. A crown width index was therefore computed by dividing crown width (feet) by diameter (inches). Stand means for this trait varied from 1.3 to 1.7 and differed significantly at the 10-percent level. Trees at McCleary differed from those at Stillwater with average indices of 1.7 and 1.3, respectively.[2] Other stands did not vary significantly from each other in this trait. The range in values from randomly chosen trees was 1.0 to 2.7.

Clear bole index.--Height to lowest live branch expressed as a percentage of total tree height can be taken as an index of clear bole length and of natural pruning under existing stand conditions. With the exception of the much younger, 20-year-old stand at Wedekind (22 percent), stand means for clear bole index varied little (53 to 63 percent). Substantial tree-to-tree variation existed within stands, however.

Branching characteristics.--Mean branch angle was determined by measuring the angle with a protractor and averaging the angles of three branches immediately above and immediately below the midpoint of the crown. Differences between some stands were significant at the 10-percent level. Trees at McKenny averaged 34^{o}, whereas those at Wedekind and McCleary averaged 44^{o}. Substantial tree-to-tree variation within stands also existed--mean angles ranged from 21^{o} to 62^{o}.

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[2] All statements in text regarding significance of differences between stand means for specific traits are based on results of Tukey's test at the 5-percent level of confidence (Steel and Torrie 1960).

A branch diameter index was determined by averaging diameters of the six branches and expressing the average as a percent of midcrown stem diameter. Stand differences were significant at the 1-percent level. The mean branch index for Wedekind (34) was significantly less than those for the Schafer Park (41), Rock Candy (43), and Stillwater (47) sites. McKenny and Taylor Towne, with average indices of 34, also differed significantly from Stillwater. Individual tree values on all sites ranged from 13 to 74. Thus, there appears to be a rather large amount of natural variation in branching patterns of alder.

Wood density.--Wood density was determined by measuring green volume and ovendry weight of rectangular samples (three-fourths inch wide by one-half inch thick) of wood produced during the first 25 years. The samples were opposite ends of a rectangular cross section cut from a breast-high disc. Although the minimal differences between stands in mean wood density were not significant, tree-to-tree variation within stands was highly significant. Wood density of individual trees ranged from 0.30 to 0.43 g/cm^3. Fortunately, the correlation between wood density and growth rate was not strongly negative ($r = -0.120$, $p < 0.10$).

Bark thickness.--Single bark thickness was measured at opposite ends of a rectangular cross-section cut from a breast-high disc sample. Differences in bark thickness between stands were highly significant ($p < 0.01$) after adjusting for tree size (radius outside bark) by covariance analysis. The variation in bark thickness among trees within a stand, however, was greater yet. At several locations, the bark of some trees was twice as thick as that of others. The economic implications of this trait may be two-edged: (1) thick bark may be advantageous if bark is used as an energy source at mills, or (2) pulp production could be limited by recovery furnace capacity if barky chips were used as the fiber source.

Implications

Substantial natural variation in red alder has been verified in the provenance trial and in an assessment of stand and tree characteristics within a local area. Such variation exists at several levels--geographic, stand, and from tree to tree within stands. The large amount of variation in economically important traits between individual trees within a stand is a good omen for selection approaches to genetic improvement of red alder.

Excellent performance of most provenances of red alder at Cascade Head suggests that it may be possible to move reproductive material to mild sites over rather long distances along the coast. Such inferences, however, drawn from a planting trial at one location, must be made with caution; and the frost damage sustained at Capitol Forest (an inland site) is indicative of problems that can arise. The Capitol Forest experience parallels an earlier report on frost damage to alder stock collected from an Olympia seed source at 50 feet above sea level and planted at an

elevation of 2,500 feet on the Wind River Experimental Forest near Carson, Washington (Tarrant 1961). Except for the poor performance of the Juneau and Sandpoint provenances (the geographic extremes of the species' range), reasons for relative performance of various sources at Cascade Head are not obvious. That two of the best sources, Concrete and Sequim, originated in areas of diverse rainfall (80 and 15 inches, respectively) illustrates this lack of obvious explanations. Although rapid growth is desirable for wood production, the slow-growing Sandpoint and Juneau sources may be useful for interplanting with Douglas-fir and other conifers. Their slow growth would not pose severe competition to conifers, and yet some soil-improving benefits (e.g., nitrogen accretion as determined by Tarrant and Miller (1963)) could be provided.

Fortunately, some desirable traits (e.g., rapid growth rate and stem form) appear to be expressed early and positively associated with each other. Although attack by twig girdlers was related to rapid growth, the damaging effects were overcome by the fast-growing trees. Moreover, lack of a strong negative correlation between wood density and growth in both studies suggests that foresters can select red alder trees for rapid growth without unduly sacrificing wood density and vice versa.

Of eight variables measured on 10 trees in each of eight stands in a local area of western Washington, only crown width index, branching traits, and bark thickness were significantly different between stands. This lack of significant variation between stands in most traits suggests that zones at least this large could be used in breeding programs. Moreover, this finding and other observations suggest that variation among trees within stands is far greater than variation between stands. Therefore, individual tree selection should be a useful tool in an alder genetics program.

Available information on magnitude and patterns of natural variation is most encouraging for red alder improvement programs. Though the portion of this variation in alder caused by genetic mechanisms is now unknown, work with other forest species indicates that many such traits are under genetic control (Campbell 1964, Dorman 1976). Fortunately, studies to provide some estimates for heritability of various traits in red alder are now underway on the Pacific coast. The biological aspects and alternatives to be considered in a genetic improvement program for alder are discussed by Stettler (1978).

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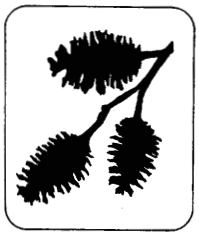
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BIOLOGICAL ASPECTS OF RED ALDER PERTINENT TO POTENTIAL BREEDING PROGRAMS



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ABSTRACT

After a brief introduction to general concepts of genetic improvement, I discuss selected biological factors of red alder (Alnus rubra) *affecting the feasibility and direction of potential breeding programs. These factors include the diversity of the genus, the species' life history, growth, reproductive biology, and nitrogen fixation. Because of its early sexual maturity, annual seed crops, and rapid juvenile growth, red alder promises to offer comparatively large genetic gains per unit of time and effort. Three alternative improvement programs with different emphases appear meritorious, i.e., (1) short-rotation fiber production, (2) normal-rotation log production, and (3) nitrogen production. Pending genetic improvement, information is needed on basic genetic parameters and on silvicultural techniques of intensive management.*

Introduction

The application of genetic principles to the improvement of forest trees is encompassing an ever-increasing number of species in the major forest regions of the world. What initially was tried on a small scale with a handful of commercially important conifers has become accepted as a general approach to raise forest productivity in quality and quantity, in a wide array of conifers and hardwoods.

Genetic improvement of a species is a form of regulating its variation toward a set of goals. Since this set is only a small subset of the criteria to be met under natural selection, the gain in desired variation is often tangible already in the first or second generation of controlled breeding. This gain, however, exacts a price. Part of the price is quite straightforward and comes in direct costs associated with improvement programs. Yet, even in this narrow framework, a cost/benefit assessment is rendered difficult by the arbitrary nature of economic models, the alternatives considered as comparisons, and the reference units of time adopted. Another part of the price is paid in even less tangible currency, such as decreased flexibility in organizational commitments, increased dependence

on specialized markets, regulatory constraints and their enforcement, the need for policy coordination among regions and countries, etc. But perhaps the least well understood price for genetic improvement is the biological one. The goals adopted in breeding are, by definition, anthropocentric; and they can be reached only with a concomitant change in gene frequencies, the ultimate impact of which may only be measurable generations hence.

We might, thus, view tree improvement as a form of domestication in which certain attributes and values of trees are enhanced at the expense of others, and in which a strategy is adopted for minimizing risks of maladaptation, and providing for potential changes in what is deemed desirable. For the planning of this process, the collective experience from agricultural plant domestication is a valuable, if insufficient, source of information. Trees after all, have unique life histories and occupy a unique position in our ecosystems. Species-specific research and region-specific monitoring will be the only way to set the course and judge the merits of long range tree improvement.

The global awakening of interest in the genetic manipulation of forest tree populations has also been witnessed in the coastal Pacific Northwest. As in other regions, early attention was given to studying seed-source variation in the most prominent species; in this case, Douglas-fir. Eventually, the emphasis was shifted to individual-tree selection and progeny testing; and by the mid-sixties, major commitments were made to operationally produce superior planting stock from selected parents in seed orchards. At that time, parallel, if less substantial, programs were initiated with western hemlock, Sitka spruce, and even noble fir. We may now ask: are conditions now favorable for such an undertaking with red alder? Or more specifically, what are the potential benefits we might derive from a purposeful breeding program of red alder?

There are many aspects that have a bearing on this question. In this paper, I will confine myself to a brief review of several biological factors that intrinsically affect the nature, direction, and success of potential breeding programs of red alder.

The Genus

DISTRIBUTION AND TAXONOMY

The genus *Alnus* is widely distributed, primarily in the temperate and cooler regions of the northern hemisphere, but also extending into the southern hemisphere along the Andes. Although hardly predisposed for rapid evolution, the genus contains a remarkable diversity of species, some, as *A. cordata*, having adapted to the Mediterranean climate, others, as *A. nepalensis*, to the harsh conditions of the Himalayas, some remaining shrubby, others growing into trees and successfully competing with the fastest growing conifers.

Murai, in his taxonomic studies of the genus *(24)*, recognized 29 different species, grouped into two subgenera with two and five sections each. More recently, Furlow *(10)*, based on a detailed study of the American taxa of *Alnus* using morphological, anatomical, palynological, and chemical data and involving both traditional and numerical taxonomic procedures, has proposed a different scheme. Perhaps the most important changes he has suggested are the recognition of three rather than two subgenera (i.e., *Alnus, Alnobetula,* and *Clethropsis*) and the conspecific[1] status of four American taxa with Eurasian species (i.e., *Alnus incana* subsp. *rugosa, A. incana* subsp. *tenuifolia, A. viridis* subsp. *crispa,* and *A. viridis* subsp. *sinuata*). Furthermore, Furlow has emphasized the need for a comprehensive taxonomic revision of the entire genus, based on unified taxonomic concepts and up-to-date information, to reduce the current confusion in the treatment of taxa and the concomitant proliferation of specific and intraspecific names.

Chromosome Numbers

Evolution of chromosome numbers has been quite conservative in the genus *(24)*. Virtually all species analyzed have a somatic complement of 2n = 28, with the exception of two Japanese alders (i.e., *A. Sieboldiana,* 2n = 56; and *A. firma,* 2n = 42). A somatic number of 2n = 14 was reported for *A. Inokumae* by Chiba *(6)*, leading to phylogenetic speculations *(25)*, and pointing to the presumably derived nature of the 2n = 28 number. Furthermore, in at least seven species with 28 chromosomes, occasional individuals have been found with either 2n = 42 or 56, suggesting spontaneous polyploidization.

HYBRIDIZATION

Natural hybrids are commonly found in alder wherever the geographic ranges of two taxa overlap *(10)*. This is particularly true when the two taxa are closely related, as in the case of *Alnus crispa* subsp. *crispa* and *A. incana* subsp. *sinuata* in Alaska, or in the *A. incana* subsp. *tenuifolia* - *rugosa* complex. Besides, many artificial hybrids have been produced in various parts of the world. A summary of reported interspecific hybrids compiled by Murai *(24)* lists a total of 26 different combinations, half of which are intrasectional, half intersectional. Several of these hybrids show good growth, among them the hybrid between *A. rubra* and the Eurasian *A. glutinosa (20)*.[2]

In an effort to elucidate crossability patterns within the genus, Hagman *(12, 13)* studied barriers in crosses between *A. incana and A. glutinosa*. He found interspecific incongruity[3] to be expressed by the retarded

[1]Conspecific = belonging to the same species.

[2]The cross *A. rubra* x *A. glutinosa* was also made by L. Karki in 1951 at the University of Washington in Seattle, and several hybrid specimens are still growing in the University of Washington Arboretum.

[3]Interspecific incongruity refers to the lack of functional affinity between two species as manifested in their inability to successfully hybridize. It is attributed to differences in many genes as a result of evolutionary divergence.

pollen-tube growth of foreign pollen in the style, a phenomenon also encountered in birches. Similar results were recently obtained by Millar (*23*) in experimental crosses between *A. rubra* and three other species of alder, i.e., *A. cordata*, *A. glutinosa*, and *A. sinuata* (or *A. viridis* subsp. *sinuata*, according to Furlow, (*10*)). Taking intraspecific crosses in red alder as a standard, she found pollen tubes of all interspecific crosses to be significantly slower, and more so with decreasing degree of relatedness (i.e., crosses with *A. sinuata* gave the lowest figures). She also found significant differences between reciprocal crosses, between conspecific individuals, and between years.

The Species

LIFE HISTORY

Red alder has typical characteristics of an early successional species. Its abundant and light seeds are easily dispersed; being short on nutrients, however, they need a favorable seed bed--typically, exposed mineral soil--to get established. The established seedlings enter a phase of phenomenal height growth associated with keen competition and sharp reduction of stem numbers per unit area due to mortality. Sexual maturity is reached as early as age 3-4 in individual trees, and 3-4 years later in the majority of dominant trees in a stand. Thereafter, seed crops are produced annually, with bumper crops every 3-5 years. Height growth begins to decline after 20-30 years, and maturity is reached at 60-90 years. Little, if any, advance regeneration by alder can be found under a mature canopy, it takes some opening, a minor disturbance, or the like, to get the next generation started.

Thus, as forest trees go, red alder is a good example of what population biologists describe as an "r-strategist." This term refers to one of two demographic parameters, r (for growth rate), and K (for population size) in the basic equation of the logistic growth curve of populations (*21*). As demographic trends are compared among different species, it seems that different life-history strategies have evolved that can be described in terms of r and K. Opportunistic species, or "r-strategists," seem to channel their energy in such a manner as to quickly discover a habitat, rapidly reproduce to use up the resources before competing species exploit the habitat, and disperse to new habitats as the existing one becomes inhospitable. By contrast, "K-strategists" are better capable of holding on to a habitat and extracting the energy produced by it. They seem to achieve this through longevity, competitive ability in suppressing other species while maintaining a population under limiting conditions, and successive replacement of dying members from a continuous but modest supply of propagules (*35*).

One may view these terms merely as a facelift for such familiar concepts as pioneer vs. climax forest, intolerant vs. tolerant species, colonizers vs. residents. Perhaps the significant change, however, are the following general recognitions. (1) Life histories are strategic programs of environmental tracking, embodied in the gene pool of a species, and subject to

natural selection. (2) While we may speak of a species' strategy, we should view it as a population phenomenon with a greater or lesser amount of inherent variation. It is this variation from which evolutionary changes in demographic parameters are derived. (3) Each life history is a composite of coadapted processes; a change in one results in correlated responses of others.

It is these "r" characteristics to which we can attribute the rapid expansion of red alder populations within the last century. It seems that the current abundance of alder has been virtually unprecedented in the post-glacial history of the Northwest, as judged by pollen-sediment studies (*14, 7*), and that it is due largely to the effective colonization of areas disturbed by man. We may visualize this process as a series of successive colonizing events following man's activities, each colonized area serving as the "launching pad" for the next one. With early seed production in alder, this process may well have involved five to six successive generations over the last 100 years, each of which being subject to intensive selection for "r" traits, and the resulting populations being particularly rich in these characteristics. We should keep this in mind when we consider establishing artificial selection programs for red alder, particularly with reference to the selection goals we choose and the gains we expect.

GROWTH

Little needs to be said about growth and yield of red alder since this aspect is well covered in these and previous proceedings (*32*). It may be merely emphasized that red alder, among Pacific Northwest trees, is second only to black cottonwood in juvenile height growth and that its growth and yield compare favorably with other alder species, although quantitative data are lacking to substantiate this point, particularly under Pacific Northwest conditions.

REPRODUCTIVE BIOLOGY

Reproduction by Seed

Red alder is commonly monoecious--male and female flowers being borne in separate but proximate aments. Deviations from this norm have been recently found by Millar (*23*) in several alder species in the form of pistillate aments carrying several functional anthers at their base. In 1977, the frequency of these bisexual aments ranged from 0.5 to 2 percent per tree for 10 sample trees in red alder, and was in the same range for fewer sample trees in *A. glutinosa* and *A. cordata*. Deviant aments were found in every tree sampled. By contrast, no deviations had been observed in the preceding year (*23*). Such year-to-year fluctuations in sex expression have been reported for other genera, also in dioecious species, and are being viewed today by evolutionary biologists as one of the adjustable variables in the adaptive strategy of plants (*1, 17*). In the case of monoecious alder, however, such a minor shift toward increased maleness should hardly make an impact on the prevailing mating system since, even under normal conditions, pollen is abundant, and self-pollination is facilitated by the proximity of male and female organs.

Are there barriers to selfing? Asynchronism between male and female flowering on the same individual seems to be operative in red alder only to to a minor degree if the small sample studied is indicative of the populations at large (*23*). Peak pollen shedding preceded peak female receptivity by no more than 2-4 days, with sufficient overlap of timing for selfing to occur.

Artificial selfing has been conducted in several alder species with variable success. Most of this work was done with *A. glutinosa* and *A. incana* and seemed to show various barriers at work, from reduced pollen-tube growth to lower seed set, to reduced viability and subsequent growth of seedlings (*18, 22, 8, 12*). On the other hand, Heitmüller (*16*) found these two species to be self-fertile; and more recently, Weisgerber (*33*) has reported breeding studies with *A. glutinosa* in which 7-year height growth of certain selfed progenies was equal to or better than that of outcrosses. In 1972 at the University of Washington, we initiated a comparative study of selfing and crossing in red alder involving both normal and mutant trees of the *pinnatisecta* variety (*31*). The percentages of filled seed ranged from 46-47 in normal x normal crosses, 11-14 in selfings of both normal and mutant trees, and 0.75-1.6 in isolated aments having received no pollen (i.e., apomictic seed)[4] (*15*). Germination of filled seeds was higher in selfs (71 percent) and in apomicts (54 percent) than in outcrosses (42 percent), but survival and growth of seedlings during the subsequent 3 years favored the outcrosses. Browsing and other damage by elk obscured some of these comparisons.

The occurrence of agamospermy in red alder, as demonstrated in our experiments, is in agreement with earlier observations of this phenomenon in other alder species (*36, 12*). So far, the evidence shows that alder is capable of producing seed in the absence of pollen. It is not known yet through which of the several embryogenic pathways these apomictic seeds have come about, except for *A. rugosa*, where adventitious embryony[5] seems to be involved (*11*, Chapt. 18). But it is important to realize that the presence of pollen need not preclude apomixis (in fact, in pseudogamy,[6] it is a necessary prerequisite) and that, therefore, the actual proportion of apomictic seeds may be higher than we suspect. In other words, some of the seeds from controlled selfings or outcrossings may actually be apomicts.

It is of more than academic interest to be able to discriminate among these alternative classes of seed since they harbor different amounts and

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[4]Apomictic seed formation, or agamospermy, is the development of seeds without fertilization.

[5]In adventitious embryony, the embryo originates from a diploid, somatic cell of the ovule.

[6]In pseudogamy, pollen apparently delivers the stimulus for seed formation, but not the gametes.

patterns of variation. The *pinnatisecta* material in our red alder offers a convenient marker for such an analysis, and experiments are planned to conduct it as soon as the F_1s between normal and *pinnatisecta* trees are sexually mature.

In summary, our limited information to date indicates that selfing and apomixis are operative in red alder, but how extensively and consistently, we do not know. The available data also suggest that the majority of seeds are most likely the result of outcrossing, a condition that is facilitated by the aggregation of red alder, its annual propensity for flowering, and its wind-borne pollen.

Vegetative Propagation

Red alder has the ability to produce sprouts, particularly after some injury to the stem. It is one of the reasons why we find occasional clusters or clumps of trees in natural stands. Under natural conditions, however, this cloning habit is only mild and seems less pronounced than that of paper birch (*Betula papyrifera*), let alone that of aspen (*Populus tremuloides*).

Artificial propagation can take advantage of this sprouting ability, which seems to be higher in young trees than in mature ones (*19*). Recent experiments have shown that coppicing of red alder can be successfully pursued on a short-rotation basis, with excellent sprouting after the second harvest.[7] Techniques for the propagation of *A. glutinosa* and *A. incana* by grafted scions and cuttings have been developed in Finland to the point where vegetative propagation offers a practical alternative to the rearing of plants from seed[8] (19). More than likely, these techniques can also be successfully applied in red alder.

NITROGEN FIXATION

The nitrogen-fixing ability of alder has received increasing attention ever since (1) it has been shown that nitrogen is a limiting factor for tree growth on many forest sites, and (2) the costs of industrial nitrogen production in the form of ammonia have soared due to the dwindling supply of fossil fuels. The latter fact has led to a global awakening of interest in all forms of biological nitrogen fixation; and judging by several symposia and reviews, a remarkable burst of research activity has taken place in this domain in recent years (*28, 26, 27, 5, 9*).

Many novel approaches to creating new or improved nitrogen-fixing biological systems have been proposed (*9*). At the same time, it has become apparent that in the systems studied, the biological machinery involved in

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[7]DeBell, D.S. Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Olympia, Wash. Personal communication.

[8]Lepistö, M. Personal communication. The Foundation of Forest Tree Breeding, Finland.

nitrogen fixation is highly complex and under the control of many genes in both host and symbiont. But, by comparison with the well-studied legume/*Rhizobium* system, the biology of nitrogen fixation in alder is still poorly understood. Several facts have emerged that have a bearing on genetic improvement of alder; they may be briefly enumerated:

1. All alder species are capable of acting as host for nitrogen-fixing endophytes (*4*).
2. Extensive surveys, involving thousands of trees of mainly *A. incana* and *A. glutinosa* in many countries, have shown all trees examined to be nodulated (*4*).
3. Rates of nitrogen fixation may be remarkably high (150-300 kg N/ha. yr.) compared to many other non-legume symbioses. In species such as *A. incana* and *A. viridis*, these rates exist under stringent conditions of high altitude or latitude (*30*).
4. The accumulated nitrogen contributes significantly to soil fertility and benefits growth of associated species such as *Picea*, *Pinus*, *Populus*, and *Pseudotsuga* (30).
5. Root biomass in *A. glutinosa* has been shown to be significantly different among provenances in a controlled study (*29*). A larger root volume provides more host substrate for nodulation.
6. Active nodules are metabolic "sinks" for photosynthetic products in the host plant (*34*). Rates of photosynthesis, respiration, and translocation, as well as the partitioning of photosynthates among alternative sinks, are host factors affecting the rate of nitrogen fixation.
7. The endophyte belongs to the symbiotic actinomycetes but has yet to be isolated and cultivated on artificial media (*2*). It, however, exists in a number of forms, each capable of symbiosis with a restricted number of host species (*3*).

Genetic Implications

OPPORTUNITIES FOR GENETIC IMPROVEMENT

Red alder harbors a vast amount of variation, as one would expect from a species with such an extensive latitudinal distribution. By inference and by analogy with other species covering a similar range, we can surmise that much of this variation is under genetic control. Results from a small provenance test, established by Douglass and Peter in 1968 with 10 seed sources, support this expectation (see DeBell and Wilson, these proceedings). Furthermore, a recent study has shown substantial phenotypic variation among trees within a stand (DeBell and Wilson, these proceedings). The amount as well as the pattern of this variation seems to be consistent with what we would expect from a species with extensive populations, even-aged stands, synchronous flowering, effective pollen and seed dispersal, and a breeding system that favors outcrossing.

Since the success of selective breeding depends on the amount of genetic variation available, we can say that red alder offers plenty of raw material for genetic improvement.

Additional variation may be made available from other alder species by way of hybridization. The most promising candidate for this purpose would be the closely-related *A. glutinosa*; other likely choices would include *A. rhombifolia* and *A. incana*. More distant crosses, although eventually feasible, are less likely to result in successful hybrids, due to disharmony of genomes. Barriers to gene transfer will be operative even among closely related species but may not be insurmountable.

DIRECTION OF POTENTIAL IMPROVEMENT PROGRAMS

Three avenues with different emphasis appear promising:

1. Short-rotation fiber production. Emphasis would be on rapid juvenile growth, desirable fiber properties, abundant sprouting after mechanized coppicing, and adequate nitrogen production to prevent rapid depletion of soil fertility. The most suitable stock for this purpose would probably be found among the younger stands in the most recently colonized areas after disturbance, representing the result of several past cycles of r-selection. The short rotation would permit the use of clonal mixes, combining intensive selection with vegetative propagation.

2. Normal-rotation log production. Emphasis would be on sustained volume growth, good stem form and branching characteristics, moderate seed production, and wood properties consistent with utilization needs. Recruitment of suitable stock would best be undertaken in currently mature alder stands presumably having experienced less r-selection pressure. Plus trees would be progeny tested and grafted into clonal seed orchards where seed would be produced for production plantations. An alternative option would be to conduct mass selection by leaving the best trees as seed sources for natural regeneration.

3. Nitrogen production. Emphasis would be on the role of alder as site improver, admixed to or alternating with conifers or black cottonwood. Desirable attributes would be all those associated with maximizing nitrogen production in a form most suitable for alder and/or companion species in either a short- or long-rotation time frame. Suitable stock may be found displaying good growth on poor sites and in climatically extreme conditions unfavorable for nitrogen fixation. Clonal testing and propagation would eventually be combined with selection of superior endophyte strains in an effort to produce synergistic pairs of host and symbiont.

EXPECTED GAINS

At this time, no heritability estimates are available on selected traits of red alder to permit specific predictions on the potential gains

to be realized from selective breeding. If we compare alder, however, with other Northwest species with active genetic improvement programs (e.g., Douglas-fir, hemlock, ponderosa pine, western white pine), we cannot help but be optimistic about its potential response to genetic manipulation. In fact, for several reasons, it may well be the species of the region most ideally suited for rapid genetic gains per unit of time and effort, because:

- it reaches sexual maturity unusually early;
- once mature, it produces annual seed crops;
- its rapid juvenile growth, combined with short-rotation management, permits an early assessment of qualitative and quantitative selection criteria;
- more than likely, it presents little problem for vegetative propagation.

For maximum genetic gains, selective breeding with progeny-tested parents will be prerequisite. Less spectacular gains can be expected from seed collection in superior stands.

Outlook

Red alder is the most abundant commercial hardwood in the Pacific Northwest. It has a number of features--rapid juvenile growth, multipurpose wood properties, nitrogen-fixing ability--that make it truly a regional asset. Its mature dimensions and quality compare favorably with those of other alder species here or elsewhere. Yet, it still exists in a wild state. Judging by the domestication success of mass selection in the European *A. glutinosa*, the potential gains from selectively breeding red alder are unusually high.

Whether genetic improvement programs are deemed feasible, and if so, at which level of commitment, will be largely decided by extrinsic factors associated with the economics of the forest industry. It is safe to say, though, as our region is gradually emerging from an exploitative forestry and as we are becoming more energy conscious, that the spectrum and diversity of forest-tree species encompassed in intensive management will be systematically broadened and will eventually include red alder.

In the meantime, the need for certain information can be anticipated. Two broad categories may be distinguished:

1. Basic biological information: e.g., the assessment of natural variation in growth, yield, quality, and wood properties and its partitioning into genetic and environmental components through provenance, progeny, and clonal tests. Special efforts should be directed at measuring genetic variation in the major variables affecting nitrogen production in both host and endophyte.
2. Information on silvicultural techniques of intensive management: This encompasses all aspects from the propagation and establishment

of planting stock to the harvesting of alder plantations under both short- and long-rotation schedules. Of equal importance is information on silvicultural treatment of natural stands toward increased quality and productivity.

In view of competing information needs on conifers, it is unlikely that a comprehensive research effort on alder will be made by any one agency at this time. Rather, we will see a scattering of individual studies reflecting different priorities and commitments. It may be useful, therefore, to consider organizational mechanisms that would serve to coordinate these individual efforts and ensure balanced progress.

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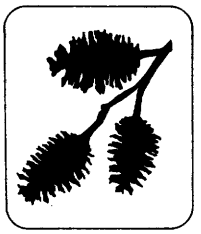
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HERBICIDES IN ALDER MANAGEMENT AND CONTROL[1]



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ABSTRACT

Herbicides can be used effectively to convert alder/shrub communities to conifers, to release conifers from such cover, and probably to prepare sites for alder production. To thin and cull young stands of alder, trichlopyr (not yet registered), 2,4-D amine, and cacodylic acid can be effectively injected into selected trees. In conifer management, alder and associated species can be controlled with (1) 2,4,5-T before bud burst (the best release tool), and (2) brushkiller (2,4-D + 2,4,5-T) in late summer (best for release from alder, hazel, thimbleberry, cherry, and ocean spray).

To convert brushfields, the initially expensive brown-and-burn procedure is most successful. In site preparation, phenoxys (2,4-D and 2,4,5-T) alone often require multiple treatments and often result in heavy animal use. Krenite ® , picloram/phenoxy mixtures, and glyphosate (registered in Oregon only in 1977) are satisfactory if treated stems larger than 3-in diameter are felled and large seedlings, preferably less palatable species, are used.

Introduction

Herbicides kill or control the growth of plants. An indirect and extremely useful result, however, is the release of site resources--resources that otherwise would be dominated by competing weed species--for the benefit of crop plants. We use herbicides as silvicultural tools to remove or create undesirable habitats for those plants that interfere with the trees we are trying to grow. Regardless of the species to be grown, we can apply the herbicide either before the desired species is established (site preparation) or after the crop trees are established (release) to promote their growth.

Herbicides have not been widely used to deliberately promote the growth

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and development of alder stands. Most of the concepts gleaned in conifer silviculture can, however, be adapted directly to alder culture. Obviously, the applications must be different although the same chemicals can be used; different species may be promoted or controlled simply by changing the application method or timing.

To elaborate on the use of herbicides in alder management, I must draw heavily on my own experience and synthesize that experience with extensive unpublished data. Also, I will extrapolate to alder some of the unpublished experiences of others working with cottonwood and yellow poplar.

Alder Site Preparation

In the Pacific Northwest, virtually no research has focused on chemical site preparation to establish alder in brushfields. My cooperative work with Publishers Paper Co. and Starker Forests has, however, provided data from conifer site preparation studies that should apply directly to alder. For these studies, several herbicides including glyphosate were applied during August and September of 1975 and September of 1976.

Glyphosate alone had properties that would help establish alder. That is: 1) Glyphosate left no residue in soil; 2) glyphosate controlled virtually all non-evergreen vegetation, including brush and herbs; and 3) glyphosate did not scarify the soil, thus preventing establishment of excessive alder stocking or weed vegetation. Establishment of alder requires control of herbaceous vegetation; and glyphosate controls deciduous brush totally and temporarily controls herbs. Site preparation with glyphosate would be appropriate only for plantations with poor seed bed conditions for natural regeneration.

Glyphosate is a strange compound. Plant responses to it are very different from the responses to phenoxys (that is, 2,4,-D and 2,4,5-T), and the differences show up in surprising ways. Glyphosate acts on root systems as well as tops, and root failure is extensive by the time tops develop symptoms. Basal cankers show up on some sensitive species before defoliation is complete. During the year or more a plant may take to die, it may produce considerable foliage, despite glyphosate activity being the result of foliage uptake. Many evergreen plants are almost totally resistant while dormant. To add to the paradox, understory vegetation is extremely sensitive, and three-fourths of a pound of glyphosate (one quart) per acre produces a nearly clean understory through a very dense canopy of 15-year-old alder. Strangely, broadcast application of the glyphosate before mid-August only slightly injured existing alder. Application of 3/4 to 1-1/2 pounds of glyphosate (active acid equivalent) per acre between early August and late September will completely kill salmonberry, bracken, hazel, ocean spray, vine maple, cascara, bitter cherry, and virtually all herbs. Earlier application will control herbs, but brush may recover. A comparison of times for effective and safe application of glyphosate and other herbicides (fig. 1) suggests that variation of the application date strongly affects the relative sensitivity of alder and conifers.

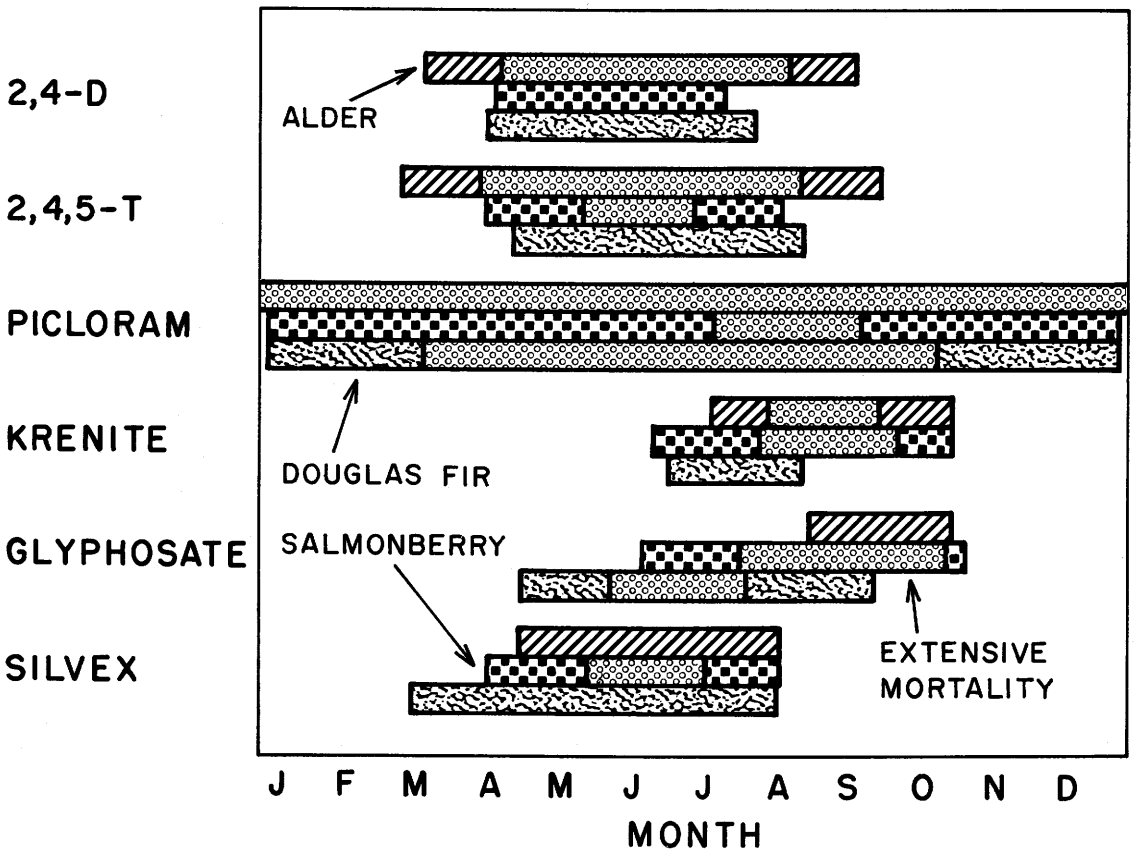


Figure 1.--Periods during which brush control herbicides injure alder, salmonberry, and Douglas-fir. Solid line indicates extensive mortality.

Thus, glyphosate apparently may be used selectively to clean alder growing in mixed stands or to clean understories in pure stands as an aid in harvesting and preparing for the next crop. It may also be used to control general vegetation and to prepare a site for the planting of alder or conifers.

Because glyphosate is extremely expensive now and its registration is pending, I will look at some alternative chemicals that may prove useful to establish alder. Data are largely limited to herb control trials. Two herbicides, simazine and dichlobenil, may help control herbs in plantations. Dichlobenil is registered for use in nurseries and with ornamental cultures of various hardwoods. Dichlobenil also can be used to control numerous herbs such as bentgrass that are commonly associated with alder in open coastal habitats. Simazine injures some hardwoods but not others. In Ontario, the Canadian Forestry Service has successfully used simazine in combinations with glyphosate for aspen regeneration. Simazine tends to remain in surface soil out of the reach of planted roots. Because of its adverse effects on new germinants, I do not recommend simazine for direct seeding.

Krenite® is now registered for use in forest site preparation. It injures alder through foliage, but leaves no soil residue. In general, Krenite® does not control herbs, and it is relatively ineffective on elderberry. It is most suitable where pure salmonberry impairs successful site preparation.

Alder Stand Improvement

Few natural stands of alder have ideal stocking or distribution of trees. Chemicals can be used to improve the manageability of such stands. Broadcast treatments are seldom safe, and established alder is sensitive to many brushkillers applied that way. For alder thinning and culling, however, selected trees can be injected with one of several herbicides that are highly effective yet safe for the residual stand. The well-tried 2,4-D amine, injected undiluted at the rate of 1 ml per inch of diameter, is very effective when applied between mid-June and September. Similarly, a mixture of Tordon 101® and 2,4-D amine at the same rate is effective from April to October; and Tordon 101® alone is effective any time. Trichlopyr, not yet registered for this purpose, is effective at full strength from September to November. In the spring, do not try to control adler with 2,4-D amine or with the organic arsenicals, MSMA (monosodium methanearsonate) and cacodylic acid. In the early summer, 2,4-D amine is most effective, while the arsenicals are most effective in October. Cacodylic acid is more effective than MSMA on alder, but MSMA is a better all-around herbicide for tree injection.

Of the effective chemicals, only cacodylic acid and 2,4-D amine are known to be nearly free of "backflash" damage to untreated trees due to herbicide translocation via root grafts. Picloram, one of the active materials in Tordon 101 ®, has a pronounced tendency to "backflash" and to remain active in soil for 6-12 months. This poses a problem in alder where the specific activity of picloram is extremely great. The residue from hardwood control appears to be a minor problem for the management of conifers.

Broadcast applications of glyphosate show promising signs of being able to control brush and other hardwoods mixed with alder. Application of three-fourths of a pound or less of active glyphosate (one quart) per acre

during August causes negligible injury to alder, but will severely injure nearly all other deciduous shrubs and cherry. Evergreen shrubs and hardwoods appear resistant.

Release of Conifers

Thus far, I've emphasized the use of chemicals to promote the growth of alder. When the virtues of alder are mixed blessings at best, we may be forced to use chemical silvicultural tools in order to capitalize on those assets. The observation that alder can fix up to 300 pounds of nitrogen per acre per year on nitrogen-deficient subsoils offers clear incentive for having alder and conifers co-exist on such sites. That ability to fix nitrogen, however, is combined with rapid juvenile growth that will suppress conifers established at the same time. Therefore alder must be grown so it can fix nitrogen, yet it must be controlled in time to protect the conifers, the beneficiaries of fixation. Release does just that.

Selective control of alder and associated species in coniferous plantations is quite simple and inexpensive. The phenoxy herbicides, 2,4-D and 2,4,5-T, have been used for this purpose for nearly 20 years with moderately good, if not outstanding, success. Selectivity with the phenoxys is strongly dependent on season, (fig. 1). Consequently, the spring dormant spray season, shortly prior to conifer bud burst, is the best time to control alder with minimum damage to conifers. Good selectivity is also achieved in early August. If the phenoxys are applied between the time shortly after bud burst and summer bud set, damage to conifers--sometimes severe--can occur; but trees usually recover in 1-3 years with no permanent injury.

The choice of herbicide depends on the season it will be used, the spectrum of species to be controlled, and its registration status. During the dormant season, 2,4,5-T is normally the most effective phenoxy when applied in a straight diesel fuel carrier. Addition of water substantially decreases the effectiveness of the mixture, whether as an invert emulsion or a normal emulsion; water sets up an absorption barrier at the bark surface that decreases the penetrability of the oil-based ester. Oil substitutes are neither available nor pending. Adding 2,4-D to the 2,4,5-T does not increase it effectiveness during the dormant season. In fact, the use of 2,4-D plus 2,4,5-T mixture has repeatedly proven less cost-effective than 2,4,5-T alone when applied to coastal brushfields during the spring dormant season. This is particularly true when vine maple and salmonberry are to be controlled.

Release sprays consisting of a mixture of 2,4-D and 2,4,5-T are more effective in August than during the spring dormant spray season. In August, application to each acre of 1 pound of each ingredient in water provided good control of alder, bitter cherry, hazel, ocean spray, and thimbleberry.

After the buds burst, spraying early foliage with a mixture of 2,4-D and 2,4,5-T in water provides some control, yet uses no oil. At least one public agency follows this procedure. Empirical evidence, however, shows that conifer injury is greater than with earlier treatments and that sprout-

ing species recover quite rapidly. Not everyone agrees with this analysis, but I believe that the earlier and later treatments are more selective than post-bud burst spraying which may require several repeat applications.

The most remarkable selectivity I have observed in my years of forestry herbicide research is manifested by glyphosate in brush-threatened conifer plantations. In conifer silviculture, aerial sprays of glyphosate (1-1/2 pounds or 1/2 gallon product per acre) that leave Douglas-fir and Sitka spruce nearly unscathed will control grasses, broadleaf herbs, bracken, blackberry, thimbleberry, salmonberry, hazel, vine maple, ocean spray, bitter cherry, alder, and possibly bigleaf maple. Glyphosate injury to conifers, when it does occur, does not seriously inhibit growth during the next season. In contrast, the injury to deciduous species other than alder apparently continues until the eventual death of the trees. Application of 3 pounds active glyphosate (1 gallon) per acre causes significant damage to Douglas-fir and moderate to severe injury to hemlock, but only minor damage to spruce; that same application kills virtually all ground cover (including sword fern) except salal. Thus glyphosate serves both as a release treatment (at 3/4-1 pound active or 1-1-1/3 quarts of products per acre) and as a site preparation treatment at somewhat higher rates.

Conifer Site Preparation

Site preparation entails more complete vegetation control than does release. Release only requires that established conifers be thrust above the competing canopy at a time of development when they can be expected to grow rapidly; in contrast, site preparation calls for intensive control of vegetation so that later release is unnecessary. When discussing long-term control of alder, we must consider the inevitable association of alder with salmonberry and other understory shrubs.

Krenite® has now been registered for use in reforestation areas for site preparation and release. Application of an aqueous solution (3-5 pounds of the active ingredient per acre) during September will simultaneously kill alder and salmonberry; unlike the phenoxys, Krenite® kills salmonberry roots. The same application also controls vine maple, hazel, ocean spray, bitter cherry, and perhaps other deciduous shrubs. However, control of all species decreases if application is earlier or later than September. Evergreen species are resistant; elderberry and thimbleberry are resistant to lower dosages. Because Krenite® can injure conifers, especially hemlock, it must be used with careful control of dosage for release.

Krenite® is an excellent site preparation treatment for use near waterways and scenic areas. It acts slowly, and quite specifically, on certain target species, especially salmonberry. A September application effects no obvious change in foliage until normal abscission. No brownout occurs; instead, by the next spring, the landscape looks like a gray haze of dead twigs with a green background of ground cover that survives with little injury. Krenite® is virtually nontoxic to fish and other wildlife, and the surviving ground cover tends to remain in good condition for big game and

other terrestrial fauna. Because Krenite® is a poor desiccant, the treated vegetation can not be burned readily.

The phenoxy herbicides alone simply do not do a good job of controlling any shrubs with an alder overstory; however, picloram plus 2,4-D or 2,4,5-T provides broad-spectrum brush control with some residual effectiveness. In our site preparation studies, we have recorded significant height increases on 5-year-old planted conifers after site preparation had included a mixture of picloram with the phenoxys. We attribute this to the residual effect of picloram on the sprouters and to the broader spectrum of species controlled with picloram. Without picloram, phenoxys inhibit many roots only slightly. The high productivity of the coastal soils, combined with resprouting abilities of several species, promotes the rapid recovery of mixed brush that is quite difficult to control with phenoxys. That situation considerably reduces opportunities for later release.

Standing dead alder will eventually fall and crush planted conifer seedlings. When Douglas-fir is planted, all alders more than 3 inches in diameter should be felled. Hemlock can tolerate slightly larger alder. The standing alder may be felled after planting the conifer, but only if alder has no leaves. Virtually no living residual alder is tolerable in a new plantation.

In preparation of an alder-dominated locale for reforestation with conifers, one must also consider how the nitrogen-fixing ability of the alder, and the consequently high fertility of the surrounding soil, have enhanced the wildlife habitat. When alder is removed by most chemicals, shelter and food supplies for wildlife remain abundant, and animal populations appear to equilibrate with the changed, and often improved, habitat. As the populations respond, mountain beaver, hares, and brush rabbits may severely damage the conifer regeneration. Animal populations probably will not increase if the ground cover, as well as the alder, is removed with a broad-spectrum herbicide such as glyphosate. Such a treatment almost certainly precipitates a temporary drop in the carrying capacity of the site. The decreased food supply, however, may cause the existing animal populations to feed on anything, including newly planted conifers during the first few months after application of the herbicide; late planting may be advisable. Although small mammals will be a less severe problem if the cover is burned, the cleared areas could be used as pastures and rearing areas by deer and elk. Thus, any site preparation operation relying on chemicals can result in serious animal damage problems. Consequently, the seedlings to be planted will be less vulnerable if they are not small or highly palatable. Our data indicate that Sitka spruce, hemlock, and grand fir are well-suited to such sites. If Douglas-fir is used, it should be the largest size available, preferably more than 24 inches in height.

Discussion of site preparation must include "brown-and-burn," a technique effectively used on coastal sites supporting mixed brush types. Burning compensates substantially for the specific control capacity lacking when conventional herbicides are used.

In brown-and-burn, the larger brush and hardwoods are slashed early in summer, then a systemic herbicide is applied to the brush. In late July or August, after the preliminary herbicide has translocated to the roots and suppressed growth of the vegetation, a desiccant such as dinoseb is applied to the remaining green vegetation. After the desiccant has dried the vegetation for 10-20 days, the entire area is burned.

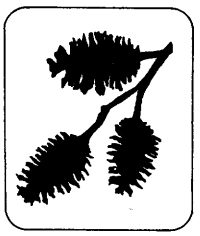
Brown-and-burn is a very expensive, but highly effective, procedure. It also is moderately hazardous during slashing, during application of dinoseb (a relatively toxic herbicide), and during burning. In addition, smoke control programs limit the opportunities for burning so that numerous desiccated areas resprout new vegetation before the area can be burned.

Brown-and-burn does have some advantages. By clearing the ground, this procedure not only reduces planting costs, but also substantially prevents much subsequent animal damage. Brown-and-burn reduces mountain beaver populations and temporarily eliminates rabbit and hare habitats. While minimizing costs per acre, large brown-and-burn projects also make much of an area temporarily undesirable for browsing by deer and elk.

Conclusions

Herbicides may be used to control or promote many types of vegetation. Careful regard for timing of application, dosage, and selection of chemical will determine what vegetation is killed. The degree of success in growing a desirable crop greatly depends on many other factors, especially choice of planting stock and animal damage. Careful attention to each step of the vegetation management process will insure maximum benefit per unit of cost, with minimum disturbance to the site.

SHORT-ROTATION PRODUCTION OF RED ALDER: SOME OPTIONS FOR FUTURE FOREST MANAGEMENT



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ABSTRACT

*Many options are available to foresters who may want to consider management of red alder (*Alnus rubra *Bong.). Four options are discussed in this paper -- a coppice system and three high forest systems: pulpwood log, saw-log and peeler, and pulpwood log and saw-log production. Coppice can be grown on 4- to 6-year rotations and pulpwood logs can be produced in 10 to 15 years on most sites. Estimated yields (per acre per year) of these options are about double those obtained in natural stands. Saw logs and peelers can probably be grown in 28 to 37 years, and yields are estimated to be about 40 percent higher than those listed in normal yield tables for well-stocked stands.*

Introduction

The intent of our paper is to examine some options available to foresters who want to consider management of red alder (*Alnus rubra* Bong.). Short rotations are essential for capturing the benefits of alder's rapid initial growth and the financial advantages associated with it; therefore, our paper will concentrate on short-rotation production systems. We will describe four of several possible management options. Each option will be

discussed in terms of products, rotation length, spacings, and suitable locations or sites. We will also provide estimates of yield and discuss some of the special problems and limitations associated with each option. We have not attempted to analyze the costs and benefits of the options, nor have we made comparisons with conifer culture.

General Overview of Short-Rotation Options

The four systems selected to illustrate options for production of wood and fiber include a coppice or sprout system and three conventional, high forest systems: (1) pulpwood log, (2) saw log and peeler, and (3) a combination of the pulpwood log and saw log option which involves thinning. Table 1 summarizes the major aspects of each system--primary products, average size of tree at harvest, plantation spacing, and rotation length. Each system will be considered in detail in separate sections.

Table 1-- *Summary of 4 options for short-rotation production of red alder*

System	Primary product	Average tree size at harvest		Spacing	Rotation length
		D.b.h.	Height		
		Inches	Feet	Feet	Years
Coppice	Barky chips	2	20 to 30	4 x 4	4 to 6
High forest	Pulpwood logs	6	45 to 47	9 x 9	10 to 14
High forest	Saw logs and peelers	14	81 to 95	17 x 17	30 to 38
High forest	Pulpwood logs and saw logs	6	40 to 43	8 x 16 to 16 x 16	9 to 12
		12	77 to 90		27 to 35

The Coppice System

The objective of the coppice system is growth of fiber for paper, other reconstituted fiber products, or energy. It consists of dense spacings of plants cut on short cycles, with regeneration by stump sprouting. The system was proposed for sycamore in 1966 by southern foresters (McAlpine et al. 1966). Soon thereafter, Smith (1968) suggested that such methods might be applicable for red alder in the Pacific Northwest. Subsequent evaluations by Schmidt and DeBell (1973) indicated that alder yields were favorable and satisfactory pulp could be produced.

YIELD ESTIMATES

We think the following specifications are reasonable for managing alder by the coppice system. Spacings of 4 by 4 to 6 by 6 feet would probably

be appropriate for cutting cycles of 4 to 6 years--at least data for cottonwood in the Northwest and sycamore in the Southeast point in this direction. Stands would be established initially with seedlings, but regeneration after harvest would be by stump sprouts for several cutting cycles. At harvest, the dominant sprouts would be 20 to 30 feet tall and 3 inches or less in diameter. Yield expressed in terms of mean annual increment might vary from 2 to 6 ovendry tons per acre or approximately 200 to 600 cubic feet per acre. Actually, one could probably expect about 4 ovendry tons under a good system of management.

This yield estimate is based on two studies conducted at Crown Zellerbach: (1) an evaluation of productivity in dense, young alder thickets, and (2) 2-year coppice yields from alder-cottonwood plantings spaced at 2 by 4 feet. Details on these studies and the yields obtained follow.

Natural thickets.--Information on stocking, dominant tree height, and mean annual production in alder thickets of various ages is given in table 2 (adapted from DeBell 1972). These data were collected from 28 small plots (6 by 6 feet) and averaged by age class. The plots were selected in thickets of extreme density and located in the lower Columbia River valley. Because the data represent a highly selective population, interpretations must be made with some caution. It appears that mean annual production can be very high in such thickets, especially at ages beyond 5 years. Production was highest for 7- to 12-year-old plots. This finding agrees with a report by Zavitkovski and Stevens (1972) that mean annual increment peaks between ages 10 and 15. Our data also suggest that mortality is high in dense, young alder thickets. Stocking in 1- to 2-year-old thickets averaged 122,000 stems per acre whereas 13- and 14-year-old stands had only 13,000 stems. Such loss of wood through mortality could be minimized under intensive, short-rotation management. Growth could be concentrated on fewer, larger stems, and maximum yields might be obtained at younger ages.

Table 2-- *Stocking and production in young alder thickets of various ages*[1/]

Age class	Stems per acre	Height of dominants	Estimated mean annual		Number of plots
			Dry matter production	Wood production	
Years		Feet	Tons per acre	Cubic feet per acre[2/]	
1-2	122,000	6.0	1.89	100	4
3-4	64,000	12.2	2.35	130	9
5-6	35,000	16.2	3.54	190	7
7-12	17,000	27.3	6.85	380	5
13-14	13,000	32.6	5.91	320	3

[1/] These data are based on averages of individual plots on sites of varying stocking and productivity within each age class; they may not indicate actual trends with time in 1 stand.

[2/] Assumptions: Wood (minus bark and foliage) ≈66 percent of total production. 1 cubic foot of ovendry wood ≈24 lb.

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Alder-cottonwood planting.--Pure and mixed plantings of red alder and black cottonwood (*Populus trichocarpa* Torr. & Gray) were established in March 1973 on an alluvial site near Crown Zellerbach's pulp and paper mill in Camas, Washington. These plantings had a dual purpose: (1) to compare coppice production of alder and cottonwood at 2- by 4-foot spacing and (2) to test effects of pulpmill sludge and of irrigation on growth of the two species.[1] The plantings have been harvested twice, after the 1974 and 1976 growing seasons. Although the 1974 harvest yields were relatively low (average about 1.5 ovendry tons per acre per year), stumps sprouted vigorously in spring 1975 and the growing space was rapidly occupied by several shoots per stump. The resulting coppice growth harvested in fall 1976 (table 3) averaged 60 percent higher than the earlier harvest, and some cottonwood treatments compared favorably with short-rotation yields of species in other regions (see, for example, Steinbeck 1973 or Ribe 1974). Irrigation led to improved yields from both species; sludge benefited growth of cottonwood but had the opposite effect on red alder, perhaps because of the high supplements of nitrogen fertilizer added with the sludge. Alder got off to a slower start than cottonwood, and yields averaged about 40 percent lower than those of cottonwood. This finding parallels observations that cottonwood almost invariably outgrows alder under natural conditions. When no sludge was applied, alder yields were equal to those of cottonwood. Presumably, if spacing was widened and rotation length extended to 4 or 5 years, 4 to 5 ovendry tons of alder per acre per year could be produced. Perhaps the most interesting sidelights of the 1976 harvest were the higher yields obtained in mixed plantings (4.2 ovendry tons per acre per year) compared with yields in pure plantings of the two species (2.5 ovendry tons per acre per year) (table 3). This may be indicative of gains that might be obtained with mixtures of alder and other species in other production systems.

Table 3-- *Effect of irrigation and pulpmill sludge on annual wood production from 2-year coppice*

Species	Irrigation	Sludge (tons per acre)		
		0	100	200
		Ovendry tons per acre per year		
Red alder	Yes	2.8	2.3	2.8
	No	2.5	2.4	1.9
Black cottonwood	Yes	2.8	4.3	6.1
	No	2.5	3.7	4.8
Mixed alder-cottonwood	No	4.2	--	--

[1]The sludge application included sufficient nitrogen fertilizer to bring the C:N ratio to 100:1.

SPECIAL CONSIDERATIONS

Concerns hindering immediate implementation of coppice management include efficient planting techniques, unknowns regarding sprouting capacity, harvest technology, and chip storage. Establishing large numbers of plants at dense spacings by conventional methods is costly, but perhaps costs would be acceptable if spacings were at least 4 by 4 feet with rotations of 4 to 6 years. Young alder stumps sprout vigorously, but sprouting of stumps of older saw-log size alder is not an effective means of reproduction (Worthington et al. 1962). Thus, there are unknowns regarding the number of times and the age to which alder stumps will sprout in a short-rotation coppice system. Harvesting still remains a source of concern, especially on wet, flood plain soils during the dormant season. Engineers believe the components for adequate systems are now available, but assemblage of a prototype harvester has yet to be accomplished. Degradation of chips during storage is also a potential problem; it may be resolved by immediate processing or by treatment if chips must be stored for several months.

The major obstacle to widespread use of the coppice system in the Pacific Northwest is the limited amount of suitable acreage. Production of total mill requirements by this system is probably precluded by limitations on land. A substantial increase (more than 10 percent) in fiber supply however, could be provided to some mills in the region. More important than fiber *per se* may be the use of densely spaced plantations for treatment of mill waste waters. Current environmental guidelines require zero discharge from mills by 1983. Whereas some companies are attempting to accomplish this by engineering advances within the mill, others are investigating the possibility of using intensively cultured plantations as a filter. With such a dual purpose, lease or purchase of highly productive agricultural land can probably be justified economically for coppice management--provided it is close to millsites.

High Forest Systems–General Considerations

High forest systems are management systems in which the crops originate from seedlings and the rotation is generally longer than that of coppice systems. High forest systems will probably play the greatest role in future production of alder in short rotations. Though planting and harvesting methods can be improved and tailored for alder production, existing techniques are usable and much more land is suitable for such management systems.

Given that rainfall is adequate for growth of alder, high forest systems may be applied to three types of land: (1) typical alder sites (stream bottoms, swales, and depressions in the uplands), (2) wet and/or deep soils now considered conifer sites, and (3) land where crop rotation is needed for correction of soil nutrient deficiencies or possible disease problems. Except in the last case where other considerations are involved, we believe that intensive, short-rotation management of alder should be considered only on lands having alder site indices of 90 feet or above at

50 years. According to an inventory by the State of Washington Department of Natural Resources, this includes about 70 percent of the land now growing alder in Washington. The two high forest systems which produce pulpwood logs (pulpwood log only and pulpwood log-saw log combinations) appear most applicable to lands having long, gentle slopes of 30 percent or less because small piece size will probably rule out cable yarding systems. There should be fewer topographic restrictions, however, for saw log-peeler production since tree size at harvest would lend itself to saw felling and cable yarding.

Our yield estimates for the high forest systems are based on several pieces of information.

1. Normal yield tables for red alder prepared by Worthington et al. (1960) provided data on relationships of average stand diameter, basal area, and spacing or number of trees.
2. Rotation length was also based on data in the normal yield tables, but with an adjustment for gain in years (reduced rotation length) because of early spacing. This adjustment was based on the assumption that the time required for a spaced stand to grow to a given diameter is equivalent to the time required for one-third of that number of largest stems in a normal stand to attain that size.[2]
3. Height was estimated from site index curves for alder (Worthington et al. 1960) for ages predicted as indicated above.
4. Tree volumes (cubic feet to a 4-inch top) were obtained from the double-entry volume tables for red alder compiled by Johnson (1955). Total stem volumes were computed from conversion ratios published by Brackett (1973). Estimates of total tree volumes were calculated from data on percent composition given in Smith and DeBell (1973).

Yield estimates obtained by the above steps were compared with data from the following sources:

a. 8-year performance of an alder plantation (DeBell and Wilson 1978),
b. response to thinning as reported by Warrack (1964) and Berntsen (1961a, 1962), and
c. Smith's (1972) summary of tree size and yields in juvenile alder stands.

Our derived estimates appeared compatible with the information available from these other sources. Though they are by necessity conjectural, we do believe our yield figures are a reasonable (and probably conservative) approximation of yields that might occur in managed alder stands.

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[2]This hypothesis was developed from experience in Douglas-fir plantations and spacing trials compared with natural stand development. Data are on file at Forestry Sciences Laboratory, Olympia, Washington.

Let us now examine these yield estimates and some special considerations for each of the three high forest sytems.

Pulpwood Log Production

YIELD ESTIMATES

To illustrate one of many possible options for producing pulpwood logs, we have selected a target stand having the following characteristics:

Stems per acre	540
Spacing	9 by 9 feet
D.b.h.	6 inches
Height	45 to 47 feet
Average tree volume (CVTS)[3]	5.6 to 5.9 ft^3
Total yield (CVTS)	3,000 to 3,200 ft^3

Although stands would appear nearly identical at harvest, rotation age and mean annual productivity would differ according to productivity of the site (table 4).

Table 4-- *Rotation age and mean annual increment for the pulpwood log option, by site index*

Site index	Rotation age	Mean annual increment		
		4-inch top	Total stem	Total tree
Feet	Years	Cubic feet per acre per year		
90	14	150	220	330
100	13	170	240	370
110	12	190	260	410
120	10	220	320	490

Stand age at harvest could range from 10 years on site 120 to 14 years on site 90. Corresponding mean annual increments (total stem inside bark) are 320 and 220 cubic feet per acre. Averaged over all sites, estimated yields are more than double the normal yields listed for red alder at the suggested rotation ages (Worthington et al. 1960). If suitable processing systems were available, whole-tree chipping could increase yields to about 400 cubic feet per acre per year on the best sites.

SPECIAL CONSIDERATIONS

Red alder plantations have been established successfully by planting container or bare-root stock after slash burning in at least two locations. These plantings have done remarkably well without followup control of vegetation, but initial growth was sometimes slower than anticipated. Limiting

[3] CVTS = cubic volume of total stem including stump and tip, inside bark.

mechanical site disturbance in order to minimize postlogging development of natural vegetation (including volunteer alder) may be desirable. Residual vegetation could be controlled by chemical means before planting, and on some sites control of vegetation after planting may be necessary. Suitable techniques for postplanting control by chemicals, however, remain to be developed.

Although estimated yields may not be as high as those potentially possible with the coppice system, there are fewer unknowns in this more conventional approach to fiber production. Existing methods for harvest (e.g., small feller-buncher-forwarding systems) could be used provided pulpwood log production is limited to gentle, unbroken topography. Modifications that minimize ground pressure, however, are needed to reduce costs and limit site damage on the wet soils suited to alder production. The problem of storage is of less concern with this system because logs can be stored for longer periods than chips, and water storage can be used if necessary. Moreover, current log and chip processing facilities can be used.

Saw-Log and Peeler Production

YIELD ESTIMATES

To illustrate possibilities for short-rotation culture of solid wood products, we have selected the following target stand:

Stems per acre	155
Spacing	17 by 17 feet
D.b.h.	14 inches
Height	81 to 95 feet
Average tree volume (CVTS)	35.5 to 41.5 ft^3
Total yield (CVTS)	5,500 to 6,400 ft^3

Trees would be initially planted at the wide spacing; no thinning would be involved in this option. Heights and volumes per tree at rotation age would vary with site productivity; the taller trees would occur on the most productive sites. Rotation age and mean annual productivity also would differ by site as shown in table 5.

Table 5-- *Rotation age and mean annual increment for the saw-log and peeler option, by site index*

Site index	Rotation age	Mean annual increment		
		4-inch top	Total stem	Total tree
Feet	Years	Cubic feet per acre per year		
90	38	140	140	200
100	34	160	170	240
110	32	180	190	260
120	30	200	210	300

Stand age at harvest could vary from 30 years on site 120 to 38 years on site 90, with corresponding mean annual increments (CVTS) of 210 and 140 cubic feet per acre. By normal yield table predictions, it would take 41 to 54 years (or 11 to 16 additional years) to grow trees of similar size in unmanaged stands. Or, viewed from another angle, estimated yields would be about 35 percent higher than normal yields at the suggested rotation ages for the target stand.

If tops and branches were chipped for reconstituted fiber products, total yield per acre per year would range from 200 to 300 cubic feet.

SPECIAL CONSIDERATIONS

Although it appears that saw log-veneer products could be produced in less than three-fourths the time it takes in unmanaged stands, there are some serious potential problems with this approach. Large tree size has been achieved by maintaining wide spacing throughout the rotation. Open-grown alder often develop numerous large branches. Pruning may therefore be required to obtain the quality of desired products; however, one pruning trial in red alder (Berntsen 1961b) resulted in rot pockets and epicormic branches.

The underutilized growing space at young stand ages may also lead to problems with competition from unwanted volunteer vegetation. This would require development of selective control methods. Existing harvest methods (including cable yarding systems) are suitable. There should be fewer topographic restrictions for this option than for any other short-rotation option for alder. Site preparation and control of competition, however, could place additional restrictions on land suitable for this option.

Pulpwood Log and Sawlog Production

YIELD ESTIMATES

Because of the potential problems associated with wide spacing, we decided to examine a system that would yield both pulpwood logs and saw logs. The system involves rectangular spacing (8 by 16 feet) of the initial stand with a row thinning for pulpwood at age 9 to 12. This would provide a square spacing (16 by 16 feet) of leave trees for subsequent growth to saw-log specifications. Characteristics of the target stand at thinning and final harvest dates are shown below:

Thinning (age 9 to 12)

Stems per acre	340
Spacing	8 by 16 feet
D.b.h.	6 inches
Height	40 to 43 feet
Average tree volume (CVTS)	5.0 to 5.4 ft^3
Volume removed (CVTS)	840 to 910 ft^3
Residual volume (CVTS)	840 to 910 ft^3

Final Harvest (age 27 to 35)

Stems per acre	170
Spacing	16 by 16 feet
D.b.h.	12 inches
Height	77 to 90 feet
Average tree volume (CVTS)	25.7 to 29.9 ft^3
Volume removed (CVTS)	4,400 to 5,100 ft^3
Total yield (CVTS) thinning + harvest	5,200 to 6,000 ft^3

Height at rotation age differs by site class. Length of rotation and mean annual production are listed for each site class in table 6.

Table 6-- *Rotation age, time of thinning, and mean annual increment for the pulpwood log and saw-log option, by site index*

Site index	Rotation age	Thinning	Mean annual increment[1/]		
			4-inch top	Total stem	Total tree
Feet	- - -Years- - -		Cubic feet per acre per year		
90	35	12	140	150	210
100	32	11	160	170	240
110	29	10	180	200	280
120	27	9	200	220	310

[1/] Thinning plus final harvest.

Total production by this system would be about 6 percent less than that of the saw-log and peeler option, and rotation age is estimated to be 3 years less. Gains of 40 percent over normal yields would occur. Again, utilization of tops and branches would increase total yield to 210 to 310 cubic feet per acre per year.

SPECIAL CONSIDERATIONS

The objectives of the 8- by 16-foot initial spacing with thinning are several. The denser spacing should result in fairly decent stem form and possibly in more rapid natural pruning. Thus, some of the problems anticipated with wider spacings may be lessened or avoided. In addition, early pulpwood production and thinning permits capture of site productivity normally lost with wide spacing and an earlier return on investment. Because of increased competition at young ages, expected rotations are 3 to 5 years longer than needed to produce trees of 12-inch d.b.h. with an initial stocking of 170 trees per acre.

Warrack (1964) indicated that epicormic branching occurred in a 37-year-old alder stand in British Columbia after thinning, but he does not mention the problem in his discussion of thinning a 21-year-old stand. Neither does Berntsen (1958, 1961a, 1962) mention epicormic branching of alder stands

thinned at 8 and 21 years of age. Perhaps epicormic branching is not a serious problem when young, vigorous stands are thinned as suggested in this option.

Site requirements are identical to those for the pulpwood log option. Plantations should be oriented to avoid cross-slope yarding which would likely scar and degrade some leave trees. The lean or sweep that is characteristic of alder in unmanaged, irregularly spaced stands may result from phototropic sensitivity of the species (Warrack 1956). If this is true, the geometric spacing of plantations may minimize this problem.

Site preparation needs would be similar to those mentioned for the pulpwood log option. Control of natural vegetation after planting, however, is more likely to be necessary because of the wider spacing.

A Wrap-Up

At present there is little interest in intentional management of red alder by most major forest product companies and public landowners. This lack of interest stems from the fact that merchantable volumes are lower and logging costs are higher in alder stands than in conifer stands. Moreover, past market values for alder logs have been lower and much more unstable than for conifer logs. Some of these factors can be affected by management and developments in harvesting technology. Market values will be affected by future changes in supply and demand for raw materials in fiber and solid wood products industries. If future changes increase the attractiveness of alder management, foresters have a wide range of options available. Of the four options presented in this paper, we suspect that the pulpwood log and the pulpwood log and saw-log options will receive more attention than the coppice and the saw-log and peeler options because potential problems are fewer and the need for new technology is less. In addition, these two high forest options afford greater flexibilities to foresters and mill managers in growing, harvesting, and utilizing the wood produced than does the coppice system. The period between initial cost outlay and first returns on investment is considerably shorter for the two pulpwood log options than for the saw-log and peeler option.

Experimental yields for the coppice system are high and in combination with waste disposal benefits, may lead to establishment of such plantations near mills. Estimated yields for the high forest options are substantially higher than those listed in the normal yield table for unmanaged stands at the suggested rotation ages (see table 7). The higher yields as well as the shorter time to harvest will enhance the profitability and therefore the attractiveness of alder management. Predicted yields of stands managed for solid wood products are about 40 percent greater than those of natural stands of the same age, whereas relative gains for stands managed only for pulpwood are greater yet. We suspect that these increased yields are somewhat conservative. They are based only on anticipated gains from proper spacing. Given other intensive cultural treatments such as site preparation, fertilization, and genetic improvement, even greater yields would likely occur.

Table 7--*Comparisons of short-rotation options and normal-yield table predictions in terms of yield at a given age and rotation age needed to attain a specified diameter*

Comparison[1/]	Yield (CVTS) at rotation age[2/]	Rotation age for specified diameter
	Cubic feet per acre	Years
Pulpwood log option	3,100	13
Normal yield table	1,100	22
Saw-log and peeler option	5,500	34
Normal yield table	4,100	47
Pulpwood log and saw-log option	5,500	32
Normal yield table	4,000	42

[1/] All data apply to site 100.

[2/] CVTS = cubic volume of total stem including stump and tip, inside bark. Normal yield table estimates were adjusted to total stem (inside bark) values based on conversion ratios presented in Brackett (1973).

In conclusion, it appears that intentional management of alder will result in much higher yields than occur naturally with this fast-growing species. If we consider alder's nitrogen-fixing ability, such yields increase the attractiveness of alternating a short rotation (e.g., 10 to 14 years) of alder with longer rotations of conifers, especially on the more nitrogen-deficient sites. As fiber and solid wood supplies become more costly to produce, alder seems destined to occupy a more prominent niche in the resource management picture of the Pacific Northwest.

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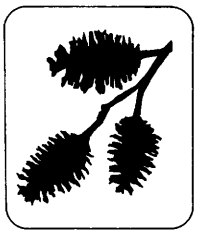
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GROWTH AND YIELD OF RED ALDER: EFFECTS OF SPACING AND THINNING



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ABSTRACT

In this paper I review information on the growth and yield of red alder. Recent point sample studies of 131 trees from Point Grey near Vancouver, British Columbia and 116 trees from the University of British Columbia Research Forest near Haney, B.C. are reported to show how trees and stands grow. Most attention is paid to the few studies which have demonstrated how growth of 20-year and older stands can be concentrated on fewer, higher quality stems.

Because very little is known about potential gains from spacing, planting, or precommercial thinning of red alder in the Pacific Northwest, I summarize data from current studies. Tree ring analyses of disks and cores are used to learn how surviving trees in old stands grew when young. I also discuss problems caused by multiple, missing, and locally absent rings. The critical period of stand establishment and heavy self-thinning is described using data from eight 0.1-acre plots in 8- to 10-year-old stands and from two 0.1-acre plots in 25-year-old stands. The basic units were 0.001-acre plots in which species and d.b.h. of all live and dead trees were recorded. Comparisons are made between several characteristics of mean trees on 0.001-acre plots and the biggest trees on 0.01 acres (top height trees). The 0.001-acre plots are regrouped into various plot sizes and configurations and stand densities measured by numbers of trees, d.b.h., and basal area to show what increases in d.b.h. and height might result from spacing and thinning. I summarize stand density indices and stocking as expressed by crown cover as well as discuss the roles of light-seeking and lean in self-thinning. I give examples of the numbers of years required to grow to breast height and patterns of growth in height and diameter by deciles above breast height and I compare recent annual height growth with growth of branches.

Premiums for size and quality for well-spaced stands are reviewed in comparison with gains in volume for very dense stands. I concluded that stand managers have many exciting options for improving growth and yield of red alder; but, in order to confirm conclusions drawn tentatively from examination of temporary plots, sustained studies of spacing and precommercial thinning are needed.

Introduction[1]

Results of early studies of growth, yield, and biomass have been reported fully (Smith 1968, 1972, 1974a, 1975; Smith and DeBell 1973, 1974) so there is no need to describe them here. My studies have documented the very large differences in growth of open, average, and dense stands for the south coast of British Columbia. Chambers (1974) reported empirical yields for predominantly alder stands in western Washington. Biomass, net primary productivity and energy flows have been summarized for our 8- to 10-year-old stands by N. Smith (1977).

This paper stresses some recent work on growth and yield, on stand formation by natural seeding, and on effects of various levels of stocking and density, following complete site preparation. It evaluates trends in numbers of trees per acre with increasing age and stand height in order to illustrate how total growth and yield can be shaped by various spacings. The few available data on spacing control and on thinning are summarized. Tree ring analyses and conventional stem analyses are used to determine how stand formation on well-prepared sites compares with that on less completely disturbed stands.

Methods

Because there were so many unanswered questions about effects of stocking and density on growth and yield and about the extent to which small plots can represent large plots (Smith 1975), main stress was placed last summer upon sampling of square milacre subplots on Point Grey near Vancouver, B.C. Within the 8- to 10-year age class, four 1/10-acre plots were established in fully stocked but open stands for comparison with adjacent dense stands on similar sites. One open and one dense 1/10-acre plot were established in the 25-year age class. Each milacre plot was studied as a unit and then combined with its neighbors in order to show the effects of eight sample sizes and configurations on estimates of yield. The areas sampled were naturally seeded following clearing for roads or housing projects. Site quality is medium, 35 feet at age 10 (Smith 1972). Most soils are sandy loams or loamy sands and well drained. Precipitation averages 45 inches annually. Stem analyses and tree-ring analyses were made to document height growth patterns to age 10 and to compare stand formation on intensively prepared land with that of older trees growing on less disturbed sites created by logging.

Bole shape and crown development are stressed. Numbers and basal area of live and recently dead trees are used to show effects of stand density on average and maximum yields. The effects of age can be seen by comparison

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of 9- and 25-year-old stands. Results are displayed in tables which can be used to answer or illustrate many important questions about growth and yield and effects of spacing and thinning of red alder. Data from the young stand plots can be compared with the characteristics of trees measured during point sampling on Point Grey and near Haney. Only the center trees were measured fully on Point Grey. Near Haney all trees in the point sample were measured (Smith 1974b).

CHARACTERISTICS OF INDIVIDUAL TREES

Most studies of growth and yield have reported volumes per acre with some supporting data on d.b.h., height, basal area, and numbers of trees per acre but paid little attention to bole shape and crown development. Therefore, the data in table 1 may be of particular interest because they record diameters outside bark at root collar, 4.5, and 9 feet. In addition, there are data on height to dead and live crowns, total height, crown width, and various ratios to show variation in lower bole shape and crown development.

Table 1 records data for trees in each of the 131 point samples made in 1976 in red alder stands on Point Grey, on and near the University of British Columbia campus. These can be compared with 116 red alders sampled during point sampling in 1973 (Smith 1974b) on the University of British Columbia Research Forest near Haney. The averages and data on variation indicate the range of tree characteristics that can be expected up to 45 years at Haney and to 80 years on Point Grey. Stand densities as expressed by basal area per acre are similar, 145 square feet. Stocking as expressed by crown cover averages 75 percent for both areas. There are 24 point samples from 8- to 10-year-old stands on Point Grey among the data in table 1. Crowns which average 30 feet in length are about twice as deep as they are wide. For both areas, the ratios of crown widths in feet to d.b.h. in inches are surprisingly high, about 2.3 and like, the ratio of height to crown width, (H/CW) seem to indicate open growth. On the other hand ratios of d.b.h. to height indicate rather crowded stands. Lower boles of both groups have rapid taper.

Degree of lean was measured as an indicator of the extent to which many trees have grown toward light in canopy openings created by natural thinning. Lean averaged 6 degrees, and ranged from 0 to 30 degrees for the Point Grey samples. Trees without lean should survive better and produce more valuable wood and therefore be favored during spacing control

Table 2 compares mean trees in milacre plots for 8- to 10- and 25-year-old stands on Point Grey. Data are given on angle of lean in degrees. The milacre data are summarized to show the d.b.h. of the maximum tree on each quadrat. In addition, the quadrats are summarized by numbers of live and dead trees and amounts of live and dead basal area. The ratios of maximum to mean d.b.h. and of dead to live basal area on each milacre are shown.

The data on averages and variation in tables 1 and 2 describe what we found and may also help planning of similar studies in other areas.

Table 1--*Comparison of point sampled red alder from Point Grey and University of British Columbia Research Forest near Haney*

Variable[1/]	Point Grey (N=131)					Haney (N=116)				
	Average	S.D.	Min.	Max.	C.V.	Average	S.D.	Min.	Max.	C.V.
D.b.h.(D)	6.99	3.85	1.0	20.8	55.1	8.92	2.96	3.1	16.8	32.1
R.C.D.	8.68	4.82	1.2	25.0	55.3	10.4	3.34	3.6	19.2	32.2
9.F.D.	6.52	3.51	0.8	19.0	53.8	8.5	2.76	3.	16.1	33.4
Percent C.C.	74.2	12.5	50.0	95.0	16.8	75.1	19.3	30.	90.	25.7
C.W.	15.0	7.17	3.0	43.0	47.7	18.7	7.46	10.	35.	25.5
H.L.C.	35.4	13.3	6.0	63.0	37.6	21.8	8.79	6.	50.	40.4
H.	63.8	22.4	14.0	112.0	35.1	55.0	14.0	20.	98.	25.4
B.A.	146.3	49.2	40.	300.	33.7	144.8	37.2	60.	300.	25.7
L.C.L.	28.4	15.0	3.0	88.0	52.8	33.3	12.3	2.	73.0	36.8
L.C.L./H.	.439	.127	.083	.87	29.0	.598	.143	.1	.842	23.9
C.W./D.	2.37	.762	.779	5.0	32.1	2.21	.52	1.07	3.85	23.6
H./C.W.	4.61	1.44	1.88	12.3	31.3	3.04	.822	1.33	6.53	27.0
9.F.D./D.	.936	.066	.80	1.53	7.10	.955	.025	.863	1.00	2.66
D./R.C.D.	.81	.076	.538	.964	9.32	.861	.076	.544	.988	8.84
H./D.	10.3	2.89	4.62	20.9	27.9	6.5	1.6	.294	12.6	24.6
D./H.	.104	.029	.048	.217	27.8	.163	.042	.08	.34	25.7

[1/] Standard deviations (S.D.), minimum (min.), maximum (max.), coefficients of variation (C.V.), root collar (R.C.D.), 9-foot diameters (9.F.D.) in inches; crown cover (C.C.) in percent; crown width (C.W.), height to live crown (H.L.C.), total height (H.), and live crown length (L.C.L.) in feet; basal area (B.A.) per acre in square feet; and various crown and boles development ratios. Prisms with a basal area factor of 20 were used. On Point Grey only the center trees were measured fully; near Haney, all trees in the point sample were measured (Smith 1974a).

286-657 O - 79 - 17

Table 2--*Comparison of mean trees on milacre plots of red alder from 8- to 10- and 25-year-old stands on Point Grey*[1/]

Variable[2/]	8-10 year plots (N=782)					25-year plots (N=93)				
	Average	S.D.	Min.	Max.	C.V.	Average	S.D.	Min.	Max.	C.V.
R.C.D.	2.17	.88	.70	6.20	40.6	8.31	2.26	3.90	14.3	27.2
D.b.h.	1.69	.69	.30	4.80	40.9	6.93	1.76	3.10	11.3	25.5
9.F.D.	1.53	.68	.10	4.40	44.0	6.57	1.72	2.80	11.2	26.2
H.D.C.	4.8	3.8	0	26.0	80.4	22.0	12.7	0	50.0	58.0
H.L.C.	13.3	6.5	1.0	36.0	48.9	40.2	13.0	10.0	66.0	32.3
C.W.	6.2	2.7	2.0	16.0	43.4	13.0	5.8	4.0	30.0	44.8
H.	26.0	7.5	8.0	46.0	28.7	63.3	10.7	8.0	76.0	16.9
Lean	7.3	7.1	0	45.0	97.6	3.8	4.6	0	20.0	122.
Max. D.b.h.	2.43	.80	.50	7.10	33.1	7.00	1.71	3.1	11.3	24.5
Dead N.t.	2.95	3.15	0	19.0	107.	.118	.357	0	2.0	301.
Dead B.A.	.006	.009	0	.101	144.	.009	.030	0	.177	348.
Live N.t.	7.08	5.43	1.0	33.0	76.7	1.16	.398	1.0	3.0	34.3
Live B.A.	.084	.048	.003	.321	57.2	.313	.169	.052	.917	54.2
Max. D./D.	1.54	.532	.94	5.25	34.5	1.02	.079	1.0	1.52	7.7
D.B.A./L.B.A.	.11	.315	0	6.94	285.	.041	.151	0	1.05	370.

[1/] Variables as in table 1 plus height to dead crown in feet (H.D.C.), amount of lean in degrees, and for each milacre plot maximum d.b.h., number of dead trees, dead basal area, number of live trees, and live basal area in square feet. The ratios are for maximum d.b.h. to mean d.b.h. and for dead basal area to live basal area.

[2/] Standard deviations (S.D.), minimum (min.), maximum (max.), coefficients of variation (C.V.), root collar (R.C.D.), 9-foot diameters (9.F.D.) in inches; crown cover (C.C.) in percent; crown width (C.W.), height to live crown (H.L.C.), total height (H.), and live crown length (L.C.L.) in feet; basal area (B.A.) per acre in square feet; and various crown and boles development ratios. Prisms with a basal area factor of 20 were used. On Point Grey only the center trees were measured fully; near Haney, all trees in the point sample were measured (Smith 1974a).

INFLUENCE OF STAND DENSITY ON MEAN TREE CHARACTERISTICS AND MAXIMUM D.B.H.

Table 3 records the milacres from 8- to 10- and 25-year-old stands in order of increasing stand density expressed as numbers of trees per milacre. This is the best way to employ single examination plots to infer what might have happened as a result of early control of stand density. As numbers of trees per acre increase from 1,000 to 25,000 and space per tree drops from 6.6 to about 1.4 feet, the size of mean trees decreases as shown. Mean tree sizes of 2.4- inch d.b.h. and 33.5-foot height drop to 1.0-inch d.b.h. and 20-foot height. Crown widths and lengths, and thus capacity for further growth, are much greater in the least dense plots. The numbers of dead trees increase with stand density but still average about two in the milacres now supporting only one tree. Live basal area per acre increases from 36 square feet for 1,000 trees per acre to about 100 square feet per acre for stands having 5,000 or more trees per acre. At this age, 5,000 trees are needed to occupy each acre fully, in terms of basal area per acre.

On the 25-year milacres reported in table 3, the self-thinning process has been carried to the point when no milacre supports more than three living trees. Basal areas per acre on those milacres which still have trees are very high, 278 for 1,000 and 518 square feet for 2,000 trees per acre. The ratio of dead to live basal area decreases rapidly with increasing stand density.

Table 4 records some influences of plot size on mean trees per milacre and shows what thinning to favor trees with the largest d.b.h. could do to increase stand size. Because four plots were square, .004-, .009-, .016-, and .025-acre, it was not possible to use all milacres. The largest trees on each milacre were compared to determine their average size and associated mean tree characteristics as plot size was increased. If these stands were entered now and thinned to favor trees with the largest d.b.h., d.b.h. of residual trees could be increased by 1.37 inches from 2.43 to 3.80 inches as trees per acre were decreased from 1,000 to 40, in 8- to 10-year-old trees. In the 25-year class the maximum d.b.h. could be increased by 2.51 inches from 7.00 to 9.51 inches. On the stocked quadrats, live basal area per acre increased from 84 to 139 square feet in the 8- to 10-year class and from 313 to 529 square feet in the 25-year age class.

One aspect of major interest is the very rapid accumulation of basal area per acre in the 8- to 10-year-old stands. These stands average 98 square feet per acre which compares very well with 152 at age 25 and 187 at age 75. There also are very real possibilities for increasing yield if managers could learn how to control stocking and density in order to achieve the best values that have been observed on small plots.

INFLUENCE OF STAND DENSITY ON HEIGHT

The small increases in height of mean trees associated with the largest trees on plot sizes up to .025 acres (40 trees per acre) in table 4, suggest that these largest trees are large because of factors in addition to site.

Table 3--*Influence of number of trees per milacre on characteristics of mean trees*[1/] *per milacre for 8- to 10- and 25-year-old stands*

Age class (years)	Number of plots	Root collar	D.b.h.	9-foot diameter	Height to dead crown	Height to live crown	Crown width	Height	Lean	Max. d.b.h.	$\frac{D_{max.}}{D_{aver.}}$	Basal area $\frac{Dead}{Live}$	Dead		Live	
													Number of trees	Basal area	Basal area	Number of trees
		(in.)	(in.)	(in.)	(ft.)	(ft.)	(ft.)	(ft.)	(degrees)	(in.)				(sq. ft.)	(sq. ft.)	
8-10	43	3.04	2.37	2.21	5.1	18.5	9.4	33.5	9.4	2.37	1.00	0.525	1.93	.0117	.0359	1
	76	2.78	2.16	1.97	5.2	15.0	8.3	30.0	7.5	2.71	1.32	.155	1.60	.0070	.0662	2
	95	2.56	1.98	1.81	4.8	15.0	7.5	29.4	8.2	2.56	1.34	.136	2.07	.0074	.0696	3
	95	2.33	1.84	1.68	5.2	14.3	6.7	27.6	7.0	2.64	1.55	.094	2.00	.0064	.0837	4
	93	2.29	1.83	1.66	4.3	13.6	6.9	27.6	7.7	2.72	1.57	.077	2.64	.0071	.1022	5
	59	2.11	1.63	1.48	5.1	12.8	6.0	25.0	5.5	2.41	1.59	.097	2.99	.0065	.0813	6
	59	1.98	1.55	1.40	4.9	12.7	5.8	23.8	6.1	2.38	1.60	.048	2.29	.0048	.0851	7
	45	1.92	1.47	1.28	4.5	11.4	5.5	23.8	7.4	2.36	1.66	.073	3.00	.0067	.0920	8
	38	1.91	1.49	1.33	4.7	12.1	4.9	23.4	6.3	2.44	1.71	.048	2.63	.0048	.0975	9
	24	1.78	1.36	1.20	5.2	11.1	4.7	22.9	8.0	2.19	1.94	.062	3.08	.0058	.0960	10
	17	1.72	1.27	1.12	4.6	9.6	4.0	21.0	5.9	2.15	1.73	.045	2.47	.0036	.0904	11
	22	1.80	1.39	1.24	5.8	12.2	4.8	22.3	5.3	2.23	1.67	.052	3.77	.0053	.1015	12
	15	1.76	1.35	1.23	6.1	12.1	4.5	23.2	8.0	2.23	1.66	.037	3.40	.0041	.1123	13
	18	1.68	1.26	1.11	3.3	9.4	4.2	23.1	4.7	2.06	1.68	.044	4.67	.0046	.1147	14
	16	1.41	1.09	.97	4.0	9.7	3.8	20.9	10.3	1.93	1.83	.058	6.81	.0054	.0926	15
	18	1.36	1.06	.92	3.7	10.5	3.4	19.6	8.9	1.90	1.81	.060	6.33	.0049	.0912	16
	5	1.32	1.00	.86	5.4	11.2	4.0	19.4	6.0	1.66	1.71	.048	6.40	.0033	.0788	17
	4	1.42	1.10	.98	3.9	12.0	4.3	21.2	7.5	1.88	1.71	.061	5.75	.0036	.1006	19
	9	1.28	.99	.86	2.4	10.3	3.6	20.1	8.9	1.97	2.09	.068	10.00	.0075	.1009	20
	7	1.26	1.00	.90	4.1	11.0	3.6	19.7	7.9	1.73	1.74	.032	6.71	.0027	.0840	21
	6	1.38	1.10	.97	3.3	12.0	3.7	20.8	6.7	1.92	1.83	.062	8.00	.0078	.1118	25
25	79	8.32	6.93	6.56	21.9	40.5	12.9	62.8	3.2	6.93	1.00	.047	.13	.0099	.2783	1
	13	8.48	7.13	6.82	22.2	38.2	13.6	67.3	7.2	7.54	1.08	.008	.08	.0024	.5175	2

[1/] In addition to the variables recorded in table 2, number of milacres (number of plots) for each stand density (live number of trees) class are given. Multiplying N.t. by 1,000 gives trees per acre to show the effects of increasing stand density on mean tree characteristics.

Table 4--*Influence of plot size on mean trees from plots with largest d.b.h. in 8- to 10- and 25-year-old stands*[1/]

Trees/acre	1,000	500	250	200	111.1	100	62.5	40
Plot size, acre	.001	.002	.004	.005	.009	.010	.016	.025
Milacres	782	400	191	160	64	80	34	31
Variable:[2/]	Averages for 8- to 10-year-old trees							
R.C.D.	2.17	2.32	2.42	2.47	2.63	2.45	2.45	2.56
D.b.h.	1.69	1.82	1.89	1.95	2.05	1.95	1.96	2.04
9 F.D.	1.53	1.65	1.72	1.78	1.87	1.76	1.78	1.87
H.D.C.	4.8	4.77	4.69	4.87	5.48	5.17	4.47	5.40
H.L.C.	13.3	13.7	14.1	14.4	14.5	14.6	13.5	15.1
C.W.	6.2	6.4	6.7	6.7	7.2	6.8	7.1	6.9
H.	26.0	27.0	27.4	27.5	27.9	27.3	27.2	27.6
Lean	7.3	6.7	6.4	6.6	6.0	6.7	7.6	7.1
Max. D.	2.43	2.77	3.12	3.21	3.48	3.50	3.75	3.80
Dead N.t.	2.95	2.70	2.69	2.51	2.67	2.33	2.35	2.71
Dead B.A.	.006	.0056	.0053	.0055	.0056	.0057	.0056	.0065
Live N.t.	7.08	7.19	7.47	7.09	6.89	7.00	6.53	6.71
Live B.A.	.084	.0993	.1141	.1183	.1250	.1315	.1341	.1390
Max. D./D.	1.54	1.67	1.83	1.83	1.98	2.00	2.07	2.13
D.N.T./L.N.T.	.417	.499	.471	.455	.526	.459	.402	.596
D.B.A./L.B.A.	.110	.067	.047	.045	.044	.042	.039	.046
Milacres	93	78	48	38	18	20	8	8
Variable:[2/]	Averages for 25-year-old trees							
R.C.D.	8.31	8.47	9.35	9.57	10.62	10.6	11.40	11.71
D.b.h.	6.93	7.08	7.80	7.93	8.73	8.71	9.24	9.51
9 F.D.	6.57	6.71	7.40	7.51	8.37	8.28	8.85	9.06
H.D.C.	22.0	22.1	24.1	21.7	23.2	24.7	21.6	16.8
H.L.C.	40.2	40.7	45.0	43.5	46.9	46.0	47.4	43.9
C.W.	13.0	13.3	15.0	15.4	15.8	17.2	14.9	17.0
H.	63.3	63.6	66.5	64.2	69.6	66.7	71.6	70.1
Lean	3.8	3.8	3.8	3.5	4.6	2.9	6.3	1.9
Max. D.	7.00	7.17	7.90	8.02	8.86	8.71	9.54	9.51
Dead N.t.	.12	.13	.17	.21	.17	.05	.13	0
Dead B.A.	.009	.0097	.0012	.0147	.0127	.0028	.0022	0
Live N.t.	1.16	1.18	1.21	1.18	1.28	1.20	1.38	1.13
Live B.A.	.313	.329	.397	.407	.503	.483	.598	.529
Max. D./D.	1.02	1.02	1.02	1.02	1.02	1.00	1.05	1.00
D.N.T./L.N.T.	.103	.122	.156	.197	.167	.050	.125	0
D.B.A./L.B.A.	.041	.044	.045	.053	.030	.011	.003	0

[1/] The influence of thinning to leave the tree of largest d.b.h. for various plot sizes and associated numbers of trees per acre can be seen by comparing average d.b.h. with maximum d.b.h. for each age class.

[2/] Root collar (R.C.D.), breast-high (D.b.h.) 9-foot diameters (9 F.D.) and maximum diameter (Max. D.) in inches; crown width (C.W.), height to live crown (H.L.C.), total height (H.), and live crown length (L.C.L.) in feet; basal area (B.A.) per acre in square feet; and various crown and boles development ratios. Live or Dead N.t. refers to number of trees. Prisms with a basal area factor of 20 were used. On Point Grey only the center trees were measured fully; near Haney, all trees in the point sample were measured (Smith 1974a).

Although their larger size may be due to minor effects of age and microsite, it is likely that some genetic advantages also exist.

The decrease of maximum d.b.h. with increasing stand density (table 3) shows that not even greatly increased opportunities for genetic and microsite selection can overcome the increased competition within very dense stands.

STAND FORMATION AND RECENT GROWTH

In order to determine how the stands grew initially in the eight plots established in 8- to 10-year-old stands, stem analyses were made of the biggest tree on 0.01-acre plots. Table 5 records data for these top height trees. Their 1976 d.b.h. and height are shown, plus average annual height growth to breast height and for the years 1973 to 1976. Average and maximum numbers of trees and basal area per acre are shown for each plot. Mean annual increments of total cubic feet volumes per acre in all trees averaged 104 (52-172) in 8- to 10-year-old stands and 162 in 25-year-old stands. In general, the densest plots support the shortest mean trees, but there must also be a site quality effect on height growth. Most trees which are slow to reach breast height will be associated later with below average height growth.

Table 6 records the average annual growth for 1973-76 for two branches cut from the widest part of the crowns of top height trees. In 1973, branch growth averaged 2.58 feet which was 78 percent of height growth. In 1976 branch growth averaged 0.99 feet which was only 54 percent of height growth. These data on slowing of branch growth and presence of few branches older than 4 years, confirm observations that because of their intolerance, lower branches do not persist long in dense alder stands.

Table 7 records actual rather than extrapolated data (Smith 1972) on average heights at ages 1 to 8 and estimates for 9 and 10 for the biggest trees on 0.01 acre plots. At age 10, heights of dominant and codominant trees should average 47 feet on good, 35 on medium, and 23 feet on poor sites (Smith 1972, table 18). Therefore, it can be seen that our plots bracket the medium site class and provide new information on the shape of height curves to age 10.

TREE-RING ANALYSES OF DISKS AND CORES

Red alder is a diffuse-porous species with poorly defined rings. If great care is taken during ring counts, it is possible to estimate annual growth from cores and disks; but there will be considerable uncertainty. In most years, radial growth stops with the formation of a dense band of fibers 0.03 to 0.30 mm wide. In some years such a band of fibers is formed on a few trees, but then followed by another much smaller ring of apparent earlywood and another band of latewood at the end of the growing season. Some years when crowns have been damaged, no ring will be formed at breast height, and occasionally there will be locally absent rings at breast height.

Table 5--*D.b.h., height, and height growth of average top height trees on eight plots of 8- to 10-year-old trees, and numbers of trees and basal area per acre for average and maximum milacre plots*

Plot	1976		Average annual height growth, feet[1/]					Number of trees per acre		Basal area per acre	
	D.b.h.	Height	To breast height	1973	1974	1975	1976	Average	Maximum	Average	Maximum
1	4.17	37.8	5.00	3.98	4.35	3.91	2.33	2,557	7,000	81	268
2	2.47	22.1	2.37	2.93	2.75	1.93	1.53	4,755	12,000	44	117
3	3.75	37.5	4.09	4.18	4.99	3.36	1.77	3,456	9,000	66	177
4	2.30	26.9	2.81	3.26	3.52	2.46	1.76	17,149	37,000	82	164
5	3.15	27.1	3.46	2.93	2.48	1.54	0.90	8,380	19,000	79	192
6	4.45	36.7	4.50	2.86	3.01	2.31	1.43	3,705	13,000	104	321
9	3.56	31.4	3.75	3.00	3.25	2.41	2.11	7,041	16,000	81	201
10	3.80	33.0	4.50	3.20	3.10	1.97	2.80	6,383	19,000	93	229

[1/] Averages for all top trees (heights of trees of largest d.b.h. on 0.01 acres) on each plot. The 1976 data were collected in late June or early July, values for other years are based upon stem analyses.

Table 6--*Recent growth of the widest branches of top height trees*

Plot	1973		1974		1975		1976	
	Branch number 1	2	1	2	1	2	1	2
	Average annual branch growth, feet							
1	3.50	3.70	4.43	3.05	3.93	3.57	1.83	1.87
2	2.81	2.67	2.56	2.49	3.23	2.99	.65	.54
3	2.54	2.40	2.96	3.19	3.27	2.75	1.00	1.01
4	2.47	2.56	2.55	2.45	2.00	1.91	.74	.94
5	1.98	1.99	2.25	1.78	1.72	1.77	.51	.47
6	2.31	2.52	2.08	2.31	1.94	1.85	.59	.79
9	2.25	2.58	2.34	2.44	1.91	1.85	1.26	1.32
10	2.47	2.60	2.03	2.33	1.93	1.70	1.20	1.13

Table 7--*Height growth of the biggest trees on 0.01-acre plots in 8- to 10-year-old stands*

Growth	Age class (year)									
	1	2	3	4	5	6	7	8	9	10
	- - - - -Average heights of 10 top height trees (feet)- - - - -									
Slow	3.0	6.0	10.0	13.7	16.0	19.0	21.0	24.5	26.0	28.3
Average	2.3	6.0	10.6	15.5	19.7	23.7	27.3	29.2	32.0	34.3
Fast	2.0	6.0	11.5	19.0	24.5	27.0	31.5	35.0	38.5	42.0

Special care must be taken to measure typical rings and to date stand origin (Smith 1974a).

Table 8 records average growth of the top height trees by plots for the first 8 or 9 years from pith. These data based upon careful measurements of disks show the buildup of growth from around 0.1 inch in the 1st year to peak at around 0.3 or 0.4 in the 5th or 6th year with a decrease to 0.1 or 0.2 inches by the 8th or 9th year. Probably the recent decrease in radial growth is associated with the high density of these plots, which was illustrated in table 5. With wider spacing, the high growth rate could be sustained much longer.

Table 9 is based upon measurements of cores made by a Swedish tree ring measuring instrument (Addo-X). Two cores were extracted at breast height from each of the 131 Point Grey samples in table 1. Widths of earlywood and latewood were measured and processed by conventional methods (Smith, Cown, and Parker 1976). In addition, specific gravity of each core was determined and a subsample of 10 cores processed by x-ray densitometry (Parker, Smith, and Johnson 1977). Measurements of the first cores taken from each tree were subsequently reanalyzed for the four areas in table 9 to illustrate the widths of latewood, earlywood, and rings as well as percentage latewood. Areas 1 and 4 support latewood about twice as thick as that found on areas 2 and 3, perhaps because more water is available late in the season. All areas have very low percentages of latewood, and there is very little difference in specific gravity between latewood and earlywood components of rings. In order to compare the average levels and patterns of table 9 with those in table 8, it is convenient to remember that 4 mm equals .157 inches and 6 mm equals .236 inches. Then it can be seen that table 9 does not appear to have equivalents for the first two rings from pith that were measured for table 8. Because not all cores hit the pith, table 9 probably overestimates widths of the first few rings from pith. Apart from this, there is little in table 9 to suggest that the mean trees in the point samples are much different in juvenile growth from the top height trees from which the disks were taken in very dense plots. Thus, we have indirect evidence of rather similar patterns of stand development in young and old stands. Unpublished measurements of recent annual growth when compared with the data recorded in table 9 shows that in 25-year-old stands percentage latewood doubles and ring width halves. Even when ring widths drop to average 1.5 mm in 75-year-old stands, percentage latewood seldom exceeds 8.

Table 8--*Radial growth at 0 and 4.5 feet for top height trees on 8- to 10-year-old plots*

Plot	Section[1/]	Age (year)	Ring from pith									Number of disks
			1	2	3	4	5	6	7	8	9	
			Radial growth (in)									
All	R.C.	9.16	0.09	0.15	0.28	0.22	0.30	0.31	0.26	0.21	0.19	73
	B.H.	7.89	.09	.13	.25	.20	.27	.27	.25	.19	.15	73
1	R.C.	8.70	.05	.12	.33	.34	.40	.46	.42	.36	.15	10
	B.H.	7.80	.05	.12	.30	.30	.38	.39	.38	.14	--	10
2	R.C.	8.70	.16	.12	.28	.31	.30	.26	.15	.05	.06	10
	B.H.	6.80	.10	.13	.28	.27	.24	.18	.06	--	--	10
3	R.C.	9.00	.10	.22	.36	.23	.33	.35	.30	.22	.14	10
	B.H.	7.90	.09	.18	.27	.21	.29	.31	.27	.16	--	10
4	R.C.	8.60	.08	.13	.20	.12	.23	.20	.17	.13	.07	10
	B.H.	7.00	.08	.12	.20	.12	.22	.19	.15	.10	--	10
5	R.C.	9.20	.06	.12	.22	.17	.30	.31	.26	.20	.17	10
	B.H.	7.90	.06	.10	.19	.16	.25	.29	.23	.15	--	10
6	R.C.	10.00	.10	.15	.29	.20	.28	.32	.29	.32	.37	10
	B.H.	9.00	.09	.15	.25	.19	.25	.30	.29	.29	.21	10
9	R.C.	9.70	.13	.15	.27	.19	.29	.27	.23	.20	.24	10
	B.H.	8.50	.14	.14	.26	.18	.27	.25	.20	.16	.10	10
10	R.C.	10.00	.19	.21	.27	.18	.26	.27	.17	.21	.24	3
	B.H.	9.00	.15	.16	.23	.17	.24	.22	.20	.23	.11	3

[1/] Disks were cut at root collar (R.C.) and breast height (B.H.).

Table 9--*Widths of latewood (L) (.01 mm), earlywood (E), rings (R) and percentage latewood (% L/R) for the first 10 rings from pith for four areas on Point Grey*

Area	Number of trees	Variable	Rings from pith at breast height									
			1	2	3	4	5	6	7	8	9	10
1	34	L	14	16	17	15	15	14	13	16	15	15
		E	627	604	546	478	432	426	342	375	424	385
		R	641	620	563	492	447	440	356	391	438	400
		L/R	2.5	4.2	3.4	3.8	4.4	3.7	5.8	5.2	4.7	5.3
2	16	L	7	9	8	9	7	8	7	8	9	10
		E	749	688	742	629	615	554	431	492	429	362
		R	755	697	750	638	622	562	438	500	438	372
		L/R	1.2	3.0	1.5	1.9	1.5	1.4	2.4	1.9	3.3	3.4
3	33	L	6	6	7	7	6	8	6	7	7	6
		E	559	545	559	518	585	554	454	537	454	435
		R	565	552	566	526	591	562	460	544	461	442
		L/R	1.6	3.3	3.3	3.5	2.9	2.1	2.3	1.7	2.6	2.6
4	11	L	17	17	14	18	14	13	16	11	14	12
		E	729	729	802	569	610	550	474	468	453	476
		R	746	746	816	586	624	563	489	479	466	488
		L/R	2.6	3.5	2.1	3.9	2.8	3.0	3.8	5.1	3.4	4.5

VARIABLE DENSITY ESTIMATES OF YIELD

Table 10 illustrates the effect of stand density expressed in terms of relative basal area upon average d.b.h. and numbers of trees per acre. These data were obtained by point sampling during the 1966 inventory of Crown Zellerbach's Tree Farm License No. 2. Following calculation of average basal area per acre in trees 3.1-inch d.b.h. and larger, point samples were classified to illustrate the effects of five stand density classes. The classes were 1-50 percent for open, 51-80 for sparse, 81-120 for average, 121-150 for dense, and more than 150 percent of average basal area per acre for very dense stands. As can be seen best for the 35-year age class in each site class in table 10, the low basal areas of open stands may result from stocking with few, usually large trees. High basal areas come from survival of many, usually small trees. The relatively few large trees of open stands of red alder probably are the result of incomplete stocking that allowed trees to grow at open growth rates (Smith 1972, 1974a). The very dense stands probably represent full occupation of the site with crowded trees that will suffer heavy mortality as self-thinning reduces their numbers in the immediate future.

If there are good premiums for size, the timber manager should aim for average or dense stands at age 35. If the objective is to maximize yield at harvest and size is not important, the timber manager should grow stands which become very dense at the desired harvest size (Smith 1976, 1977).

The average yields expected by the B.C. Forest Service for good, medium, and poor site classes are shown for 7.1-inch and larger trees in table 11. It appears as if mixture of conifers with alder leads to increased yield. The Crown Zellerbach data from table 10 do not represent the same site classes because the top two are roughly equivalent to the B.C. Forest Service good site, but yields of 70- and 90-year age classes exceed those indicated by the B.C. Forest Service volume-over-age curves.

SELF-THINNING

The natural role of self-thinning is obvious to anyone who has observed the growth of alder seedlings as I did this spring. I started out with 346 million seedlings per acre at 1-inch height and these decreased to 25 million seedlings per acre at 6 inches. The inevitable decrease of numbers of trees with increased height or d.b.h. is subject to much variation, which I can illustrate for our 875 milacres in 9- and 25-year-old stands. The logarithm of number of trees per milacre can be estimated from the logarithm of mean d.b.h. to account for 47.2 percent of the variation with an error of estimate of .276. Using only the 151 plots with 12 or more live trees at age 8-10 or 2 to 3 live trees at age 25 leads to a statistically superior equation with R^2 0.823 and standard error of estimate of .119. Unfortunately, the intercepts and regression coefficients are nearly identical to those for the full sample so the statistical gain is illusory. Use of height with mean d.b.h. did not improve the equations. For the 131 point samples summarized in table 1, the logarithm of average d.b.h. accounted for 68.0 percent of the variation in logarithm of number of trees per acre. Estimation with the logarithm of height accounted for 49.3 percent of the

Table 10--*Average d.b.h. (D) and numbers of trees per acre (Nt) by stand density classes*[1/] *for pure and mixed red alder, 3.1 inches + d.b.h*

Age class	Stand density classes													
	All		Open stands		Sparse		Average		Dense		Very dense		All	All
	D.b.h.	Number of trees	D.b.h.	Number of trees	D.b.h.	Number of trees	D.b.h.	Number of trees	D.b.h.	Number of trees	D.b.h.	Number of trees	Basal area	Number of point samples
	Site class 2 (170 at 100) (135 feet at 50 years)													
25	10.2	389	7.8	251	13.8	155	11.2	292	--	--	10.3	692	220	6
35	12.0	277	18.8	38	11.9	199	11.7	276	12.0	311	10.0	654	178	44
45	11.9	323	--	--	9.6	326	12.6	3.09	12.4	375	--	--	232	13
55	13.8	272	--	--	14.3	186	13.4	266	13.9	368	--	--	251	11
65	15.3	182	19.0	42	--	--	15.0	182	13.8	254	--	--	189	11
														(85)
	Site class 3 (140 at 100) (95 feet at 50 years)													
15	6.8	489	--	--	4.5	670	8.3	310	6.3	578	--	--	97	5
25	9.6	386	--	--	10.3	227	9.0	405	9.8	655	9.1	591	153	25
35	10.7	312	12.1	107	11.2	193	10.2	352	11.7	319	9.7	587	166	80
45	12.1	299	13.8	88	12.1	175	13.2	224	10.2	487	10.7	712	190	31
55	13.8	304	18.3	88	16.7	121	12.6	347	13.1	399	--	--	246	25
65	13.0	231	10.0	147	14.5	138	12.8	234	11.7	352	14.0	297	179	24
85	18.3	138	19.3	59	18.5	86	17.9	150	--	--	18.2	244	248	5
														(195)
	Site class 4 (110 at 100) (75 feet at 50 years)													
25	9.8	255	8.0	143	8.9	163	15.4	108	8.2	431	--	--	116	5
35	9.4	302	8.7	146	8.8	255	10.4	243	8.8	447	9.6	466	131	21
45	9.0	535	--	--	--	--	8.8	548	10.6	459	9.9	602	220	7
55	12.5	281	18.0	45	10.2	215	15.5	137	12.7	308	--	--	196	11
65	10.2	392	--	--	--	--	10.2	392	--	--	--	--	220	2
														(46)

[1/] Open (O) stands have 1-50 percent, sparse (S) have 51-80 percent, average (A) 81-120, dense (D) 121-150, and very dense (VD) 151+ percent of the average basal area per acre in square feet tabulated on the righthand side of the table along with number of point samples.

Table 11--*Some average yields by site and age class*

Site class	Age class	Alder plus conifer[1]		Alder plus deciduous[1]		Alder plus conifers or hardwoods[2]
		Number of plots	Cubic foot volume 7.1 in+	Number of plots	Cubic foot volume 7.1 in+	Cubic foot volume 3.1 in+
1	30	2	5,829	5	3,773	6,204
	50	2	5,037	5	4,440	7,125
	70	2	6,134	1	5,455	9,946
		6		11		
2	10			3	950	
	30	14	4,334	25	3,126	3,825
	50	13	4,963	26	4,242	5,638
	70	6	4,618	7	3,382	8,539
	90	9	6,290	5	4,117	11,752
		42		66		
3	10	2	720	9	2,188	2,944
	30	12	3,039	15	2,046	4,336
	50	4	3,932	3	4,531	6,551
	70	2	2,998	3	3,145	--
	90	1	6,609	--	--	--
		21		30		

[1] B.C. Forest Service estimates for the south coast of B.C. for total cubic foot volume (Vcu) between a 1-foot stump and a 4-inch top d.i.b., less decay only, in trees 7.1 inches and larger in d.b.h., for good, medium, and poor sites.

[2] Crown Zellerbach averages for the data reported in table 10.

variation. Although the natural role of self-thinning will be difficult to define precisely from observations of temporary sample plots, it is feasible to extrapolate using either d.b.h. or height to estimate numbers of trees per acre. With further study, more useful stand density indices (Reineke 1933) probably could be developed; but best results will come from analyses of spacing trials (Smith 1976).

EARLY CONTROL OF SPACING

Apart from the Cascade Head Provenance trial in which red alder from 10 localities were planted as 1-foot-tall seedlings at 5- x 10-foot spacings and thinned to 10 x 10 feet in 1976 (Clapp 1977), I have no data on control of spacing by planting. In 1975 Northwest Hardwoods planted 100 acres of red alder as 18- to 24-inch tall seedlings at 300 trees per acre near Port Angeles. In 1977 Walters is establishing two Nelder spacing trials for red alder on the University of British Columbia Research Forest. Similar studies should be established throughout the Northwest.

The only data I can find on early thinning of a young stand to create regular spacings were provided by Northwest Hardwoods in 1973. In April 1962 on the Pilchuck Tree Farm a 7-year-old alder stand was thinned to provide three 0.1-acre plots at 8-, 12-, and 16-foot spacings. When remeasured after 12 growing seasons in 1973 at age 19, a control plot was established. Early control of spacing had effectively redistributed growth. In comparison

with the unthinned natural stand which supported 660 trees and 114 square feet of basal area in 5.4-inch average d.b.h. stems, the 8 x 8 plot had 590 trees, 108 square feet, and 5.9-inch average d.b.h.; the 12 x 12 plot had 300 trees, 77 square feet, and 7.2-inch average d.b.h.; and the 16 x 16 plot had 180 trees, 43 square feet, and 8.1-inch average d.b.h. The increase of d.b.h. by 2.7 inches in 12 years was associated with a reduction of 71 square feet in basal area per acre. At this time the best spacing appears to be 12 x 12 but this could be increased if growth of the widely spaced trees continues to improve. With alder pulpwood selling at only $20.00 per cord at the mill, conversion of trees to more valuable products by spacing control and thinning can be very important, financially.

Near Northwest Bay on the east side of Vancouver Island, poor results followed an operational spacing at age 16, when the stand contained 1,266 trees per acre averaging 4.35 inches in d.b.h. and 42 feet in height, to 500 per acre. The thinning had no influence on d.b.h. or height by age 23 when both control and thinned areas supported trees 6.6 inches in d.b.h. and 57.5 feet tall (Smith 1974a). Four years later the situation had not improved. In one 0.05-acre plot in the control, the 14 biggest trees averaged 6.8 inches in d.b.h., and were larger than the 14 trees in the spaced plot which averaged only 6.3 inches. The 33 trees in the control plot averaged 4.6 inches in d.b.h. Affleck[2] concluded:

> Spacing does not release growth, but in fact, reduces eventual merchantable volume. Twenty-eight percent of the spaced trees developed heavy epicormic branching, while there was no evidence of epicormic branching in the control stand. There was no evidence of better growth form in the spaced stand compared to the control stand. Two trees were wind thrown in the spaced stand, while no trees were wind thrown in the control stand. The site itself is a good alder site.

EFFECTS OF THINNING

A major objective of thinning is the redistribution of gross volume growth onto the best trees in a stand. Results of thinning studies available to 1973 (Smith 1974a) showed that timing of thinning was very important and response uncertain. Warrack (1964) reported that thinning could increase average d.b.h. by about 4 inches but reduced the absolute yield greatly. Such an increase in size could have great importance in situations where the standard of utilization is rough. It might convert a loss of $125.26 per M fbm for 10-inch d.b.h. trees to a breakeven of $0.94 for 12-inch trees or to a modest profit of $16.58 per M fbm for 14-inch trees (Tessier and Smith 1961).

---

[2] Peter Affleck, MacMillan Bloedel Industries, Northwest Bay, B.C.

Conclusions

My analyses of these data should be refined and enhanced by simulation methods, but these could not substitute fully for field trials. Long-term research is needed to determine the extent to which stands can be shaped toward desired goals by planting and by early control of spacing. The data presented for various stand densities have illustrated substantial potentials for thinning to improve tree size. It is possible that planting or very early control of spacing in natural stands could increase both harvest size and yields by concentrating growth on the best trees for 20 to 30 years.

If a maximum of biomass or of full tree volumes is desired, a uniform distribution of closely spaced seedlings should be developed for harvest at age 10 to 15 years before excessive self-thinning reduces mean annual yields.

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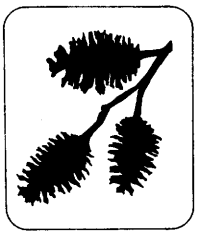
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INSECT PESTS OF RED ALDER: POTENTIAL PROBLEMS



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ABSTRACT

Although insect problems of red alder receive little attention at present, concern about insect damage will increase with increasing value and management of the species. Tent caterpillars and sawflies appear to offer the most serious threats to intensive management; defoliation by these insects could lead to drastic reductions in growth of heavily infested stands. Chrysomelid beetles, such as the alder flea beetle, can also be destructive as both larval and adult stages defoliate alder. Bark beetle populations are normally low and damage is limited; however, increased harvest, if accompanied by large amounts of logging slash, could result in population build-up and subsequent attack and mortality of trees in residual stands. Ambrosia beetles attack down logs and can degrade lumber unless removal and utilization proceeds promptly after felling.

Introduction

As the value of red alder (*Alnus rubra* Bong.) increases, the level of pest damage tolerated decreases. Undoubtedly the time will come when red alder's present insect complex will assume greater importance and effective control practices will be in demand.

In recent times, *A. rubra* is gradually shifting from an undesirable species to one of increasing utility; and studies on silvical characteristics have begun (*20, 21*); however, there is little current research on insect pests, especially on the potential impact of pest problems. Available entomological information is in the form of short pest descriptions (*4, 6, 7, 8, 10*), reports of outbreaks (*3, 5*), and as initial studies into the biology and control of potentially important pests (*2, 13, 14, 15, 16, 18*). This paper will highlight some of the available literature and stress potentially serious problems.

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Tent Caterpillars

There are two important lepidopteran defoliators of red alder, the forest tent caterpillar (FTC), *Malacosoma disstria* Hbn., and the western tent caterpillar (WTC), *M. californicum* (Packard). The FTC could become the most destructive pest threat to the intensive management of western hardwoods. The insect is common on a multitude of hardwood species throughout most of continental North America; severe and widespread outbreaks are common (*1*). In British Columbia, a 1948 to 1954 outbreak spread from numerous dispersed foci into a general infestation that covered thousands of acres (*5*). Outbreaks in Eastern North America have occurred every 6-16 years (*9*); Condrashoff (*5*) reports that population fluctuations are extreme.

Defoliation by the FTC and subsequent height and diameter reductions of aspen and birch are will documented. Growth losses as high as 86 percent during a time of especially severe defoliation have been noted, although tree mortality is negligible (*11*).

It is suggested that applied control of FTC outbreaks can be effected through use of a nuclear-polyhedral virus (*12, 16*). Oliver (*14*) found that aerial applications of Bidrin® at 0.25 lb/acre and phosphamidon at 1.0 lb/acre was an effective FTC control in Louisiana.

Red alder also is a highly preferred host for *M. californicum*, and 8-year outbreak cycles have been suggested in the Pacific Northwest (*18*). Worthington et al. (*21*) found that WTC outbreaks reduce tree growth over a 2-year period; tree mortality, however, is rare.

The WTC has a number of natural control agents. In British Columbia, a combination of parasites, nuclear-polyhedrosis and other viruses, pathogenic fungi, bacteria, and microsporidia have been effective to the point that WTC is not considered to be a serious pest in that province (*13*).

Bacillus thuringiensis Berliner, a crystalliferous spore-forming bacterium, has shown promise as an effective pathogen in field tests (*13*). Third instars were highly susceptible to thuricide 90TS foliar sprays. In addition to inducing larvae mortality immediately, the bacterial agent had sufficient residual life to prevent *M. californicum* reinfestation for up to a year.

Wellington (*18*) noted that a tachinid fly parasite, *Tachinomyia similis* (Williston), was especially effective in laying its eggs on the larvae of WTC during prolonged hot weather.

Alder Flea Beetle

The alder flea beetle, *Altica ambiens* (Lec.), belongs to a large family of leaf eating beetles, the Chrysomelidae. These insects can be especially destructive as both larval and adult stages defoliate alder. Other than

its general life cycle (*19, 10*), little is known about *A. ambiens*. Oviposition begins in the spring on partially rolled leaves, the emerging larvae and subsequent instars are voracious feeders. Leaves on saplings and pole-sized trees can be completely skeletonized in about a month. Shortly thereafter new adults emerge, and they feed on remaining leaves.

Pyrrhalta punctipennis (Mann.), another small chrysomelid, is also an active defoliator of red alder in the Pacific Northwest. Practically nothing is known about *P. punctipennis*; in fact, general texts omit the fact that it feeds on alder. Turnbull (*17*), however, has observed the damage caused by this beetle; he reports that red alders around Burnaby, BC, have been seriously damaged by *P. punctipennis*.

Sawflies

The red-backed sawfly, *Eriocampa ovata* L., introduced into North America from Europe (*3*), is a leaf skeletonizer of *Alnus*. This pest has seriously defoliated alder stands in eastern Canada and heavy damage recently has been reported in British Columbia (*3*). The insect has two generations per year in the Northwest and, under favorable environmental conditions, it is likely that outbreaks could develop, especially since *E. ovata* may have few biological control agents. Turnbull (*17*) considers that the red-backed sawfly may develop into the greatest insect pest of *A. rubra* in the Northwest. He also suggests that the sawfly is becoming more prevalent in response to the increased amount of available red alder.

The striped alder sawfly, *Hemichroa crocea* (Fourcroy), is another little-known defoliator of red alder. This insect also was introduced from Europe, and Craighead (*6*) mentions that red alder defoliations have been reported in British Columbia. *H. crocea* has two generations per year. It is conceivable that in combination with *E. ovata*, extensive sawfly damage could be expected.

Bark and Ambrosia Beetles

The alder bark beetle *Alniphagus aspericollis* (Lec.) breeds in the phloem of alder slash and young stressed trees. Its biology is well known (*7, 2*). As with most economically important bark beetles, *A. aspericollis* can become a threat to healthy red alder stands. The alder bark beetle population is normally low with colonization limited to scattered down logs and the occasional weakened tree. If the harvest of red alder were, however, to increase dramatically, with a great deal of logging slash left in the woods, bark beetles will find and attack this material. Shortly thereafter, the beetle population would increase (especially as they have two generations per year); and if the population were large enough, residual stands also could be attacked. Moreover, light *A. aspericollis* infestations result in isolated patch kills on the stems of attacked trees; these kills can provide an area for entrance of subsequent wood rotting fungi (*2*).

Down logs and slash are attacked heavily by three ambrosia beetle species, *Gnathotrichus almi* Blkm., *Trypodendron lineatum* (Olivier), and *Xyleborus saxeseni* (Ratzeburg). These beetles bore into the sapwood of logs and degrade the lumber by their entry holes, egg cradles, and accompanying stain. Prompt removal of logs from the forest, and subsequent utilization will prevent this type of damage.

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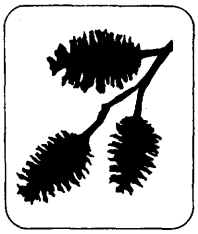
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RED ALDER MANAGEMENT AND DISEASES



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ABSTRACT

Relatively little is specifically known about diseases of red alder with respect to management. The status of reports in the literature concerning the subject is outlined. Research remains to be conducted on the part played by diseases of this species in respect to management.

Many workers have observed that alder stands start exhibiting symptoms of decadence about age 40 (*3*). It is not evident from literature that such decadence is induced entirely by disease. At this early stage in our knowledge, this doesn't prove anything. In fact, I tend to think that forest pathologists have had little more than a mycological interest in this subject.

From this point of view, Shaw (*1*) reports 167 species of fungi have been collected in the Northwest on this host species. On perusing the literature I have found the following infectious diseases known to occur on red alder:

1. one canker disease (wood exposed by a parting of the bark tissue),
2. one flower disease (catkin broom),
3. two leaf spot diseases,
4. two powdery mildew diseases, and
5. one white trunk rot disease.

At this stage of our knowledge the trunk rot disease induced by *Fomes igniarius* is of major concern. The impact of this disease is loss of utility of most wood within 8 feet of a fruiting body on the merchantable portion of the main stem.

So much for our known bases of disease information. In the future we should classify the remainder of the 167 fungi known to occur on this host species and prepare an evaluation with respect to the interest in intensively culturing red alder. As demonstrated for many forest tree species, the more we manage a species the more protection problems we can expect.

An initial area of interest should be to determine the course of top die-back in stands reaching 40 years of age. It is unusual that the most active part of a tree just stops functioning without some logical explanation other than old age.

Hypoxylon fuscum is well known to occur on many betulaceous species, one of which is red alder; it is known to induce a white-type rot in a relatively short period following infection. The infection period and site has been observed to be in close association with living or recently dead tissue of limbs and the main stem of this host. To my knowledge, however, this potential pathogen has not been demonstrated to be the cause of top die-back of red alder. More work needs to be done on this problem.

It is interesting to note that attempts to infect this host with the well known root pathogen *Poria weirii* has failed (*2*). Several other root decay fungi have, however, been reported on the host. The most interesting of which was *Fomes annosus* (*1*), the well known pathogen of conifer species.

In addition to living tree diseases, life of wood in use is also of interest. If concern is not given to this subject, potential markets may not be long lived after development. Red alder is recognized within the trade to be short lived when used in close association with moist soil. Such misuse should be avoided. Even better, specific recommendations should be made for deep penetration treatment with a proven wood preservative prior to installation in decay hazard environments.

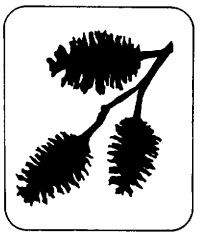
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THE ROLE OF RED ALDER IN REDUCING LOSSES FROM LAMINATED ROOT ROT



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ABSTRACT

*Red alder, in mixture with conifer or preceding stands of conifers, may be useful in reducing damage from laminated root rot (*Phellinus weirii*) on infested sites. This benefit could result from changes in soil nitrate, pH, fatty acids, phenolic compounds and microbial populations brought about by alder, as well as physical separation of susceptible root systems in mixed stands. Survey data tend to support this hypothesis. Disease incidence may be limited by reducing saprophytic survival of the pathogen or inhibiting its spread along conifer roots. Evidence for the former is greater than for the latter. Long-term experimental plots have been established to provide more definitive answers.*

Red alder is an unusual western forest tree species--not only as a hardwood with commercially valuable growth and form but, through a symbiotic relationship, it fixes atmospheric dinitrogen. Like other hardwoods, it is not damaged by *Phellinus* (*Poria*) *weirii*, cause of laminated root rot. It has also been hypothesized to function as a natural biological control of laminated root rot. In this paper, we critically evaluate present evidence regarding alder as a root rot control.

Importance of Laminated Root Rot

Laminated root rot is the most damaging disease of young-growth Douglas-fir in the Northwest. The annual loss is estimated at 32 million cubic feet in western Oregon and Washington (*2*). This includes the volume of trees killed by the fungus as well as the additional volume of timber that could have grown on root rot sites in the absence of the disease.

BIOLOGY OF THE PATHOGEN

Phellinus weirii is characterized by its slow spread, long survival time, and wide host range. These attributes lead to formation of slowly expanding infection pockets with long-dead trees in the center, a fringe of recently killed trees, and infected but still living trees around the perimeter. *Phellinus weirii* spreads along live roots from tree to tree increasing the radius of infection centers by about 1 foot a year (*17*). Spread is relentless but often erratic, governed by the pattern of susceptible root contacts beneath the stand. When live roots are not present, e.g. after harvest or a fire, the fungus can wait where it is for roots of the new generation to grow in contact with the old infected ones. The fungus remains viable in most infected stumps for 20 years and then slowly dies out (*6*). All western conifers are attacked, but pines and Cupressaceae tolerate the infection. Douglas-fir, the true firs, mountain hemlock, and in some situations western hemlock are very susceptible.

Laminated root rot is not evenly distributed through the Douglas-fir region; but where found, it often limits production of Douglas-fir. We suspect that intensive Douglas-fir management aggravates the problem. In natural forests, *P. weirii* must occur in a balanced state, slowly expanding around the perimeter of infection centers but dying out at its center in brush-filled openings as stands age. Root rotted trees often fall over, pulling much of the infective, rotted roots from the ground. A managed forest, on the other hand, is characterized by short generation times, stumps with infected roots left in the ground, and eradication or reduction of brush which might otherwise temporarily replace susceptible conifers.

CONTROL OPTIONS

No quick and easy control options are available to the forester. Fungicides don't reach the fungus below ground and fumigation is slow and costly. Physical removal of infected stumps greatly reduces residual inoculum but is feasible only on gentle slopes and with small stumps. The only real options for many managers are to accept the inevitable losses or to grow a less susceptible tree species. Of the *Phellinus*-tolerant conifers, only western red-cedar is suitable for most of the westside Douglas-fir region, and we don't know how to establish and manage this species. This brings us back to red alder.

The resistance of red alder to infection by *P. weirii* is possible due in part to its phenolic and lipid content. The combination of phenolic compounds found in roots of red alder inhibits *in vitro* growth of *P. weirii*

(*13, 19*). Linoleic acid, an unsaturated 18-carbon fatty acid isolated from alder, also inhibits *P. weirii* (*12*).

Effects of Red Alder on Soil

The dinitrogen fixation by nodules on alder roots leads to substantial nitrogen accretion in the soil. Most of the fixed nitrogen is transferred from the nodules to the host tree and is then cycled to the soil by rain throughfall, litterfall, and death of roots and nodules. The most striking net result over time is a buildup of NO_3^- ions in soil under alder as compared to conifers (*1*).

The higher NO_3^- levels under alder may be important in limiting activity of *P. weirii*. It cannot utilize NO_3^- as a nitrogen source for lack of the enzyme nitrate reductase (*10*), but many of its potential microbial competitors in the soil can. Fertilization with either NO_3^- or NH_4^+ has been shown to reduce survival of *P. weirii* in soil (*15*). Alder has the advantage over fertilization of adding nitrogen to the soil each year and maintaining relatively high levels after initial buildup.

A number of phenolic compounds and fatty acids have been shown to inhibit *P. weirii in vitro* (*9, 18, 19*). Alder roots and litter contain twice as high a concentration of phenolics as do those of Douglas-fir (*13*). Shrubs common to many red alder stands, such as *Rubus spectabilis* and *Sambucus racemosa*, also produce *P. weirii*-inhibiting phenolics (*7*). The soil under alder reflects this combined production in having far higher levels of phenolics than soil under Douglas-fir although these levels are not high enough to inhibit *P. weirii in vitro*.[1] Total fatty acids of soils under alder do not vary appreciably from those under Douglas-fir, but the kinds of fatty acids do differ markedly between the two kinds of stands (*8*). Most fatty acids are probably not found in quantities which inhibit *P. weirii*. For example, the absolute amount of linoleic acid in alder soil is 100 times lower than the amount necessary for inhibition *in vitro*. Inhibition in soil, however, where nutrients are less available to the fungus, probably occurs at concentrations below those effective *in vitro*.

Soil under alder is considerably more acid than under conifer stands on similar sites (*1, 16*). Growth of *P. weirii* is reduced in an acid medium (*11*). This difference in environment could have indirect effects on the activity of *P. weirii* as well since competing microorganisms would also be effected.

The net effects of increased organism inhibitors of *P. weirii* associated with alder soils are virtually impossible to separate from those of nitrogen, pH, and activity of microbial antagonists. The chemistry and biological activity of such compounds may be synergistic. The compounds themselves are subject to transformation by soil organisms. In any event,

[1]Li, C. Y. Unpublished data, Pacific Northwest Forest and Range Experiment Station.

the increased amounts of such inhibitors under alder will not likely benefit *P. weirii*.

The comparative soil microbiology of conifer and alder stands, has been studied only at the Cascade Head Experimental Forest on the central Oregon coast. As might be expected in view of their chemical differences, alder soils differ substantially in microbial populations and activities. Most notably, the alder soils contain higher populations than conifer soils of some organisms with strong potential for antagonism against *P. weirii*. *Trichoderma viride*, a demonstrated antagonist against *P. weirii*, was characteristic of the alder soil but rare under conifers (*21*). Alder and conifer soils differed in populations of several other microfungi, but their antagonism against *P. weirii* remains to be assessed.

Mechanisms for Disease Control

The hypothesis that alder somehow reduces incidence of *P. weirii* infection developed from scattered observations in the field. Laboratory findings have tended to support it. Red alder could reduce disease incidence in three ways: (1) by reducing survival of *P. weirii* in stumps and roots following logging, (2) by occupying the site in place of susceptible conifers until the pathogen has died out, or (3) by inhibiting spread of the fungus along living roots. The first two suggests control through crop rotation; the third through mixed stands.

REDUCING SURVIVAL OF PATHOGEN

Nelson (*14*) buried wood cubes colonized by *P. weirii* in soil under 40-year-old stands of alder, mixed alder and conifers, and conifers (mainly Douglas-fir) on the Cascade Head Experimental Forest. Three plots were located in each of the three stands and 18 cubes were buried on each plot to a depth of 9 inches with minimal soil disturbance. Three cubes were removed after 3 months and after 6 months to test for survival of the fungus. Six cubes were removed similarly after 12 and 18 months. *P. weirii* survived in some cubes buried in "conifer" soil through 18 months, in "mixed" soil only through 12 months, and in "alder" soil only through 6 months.

The results were encouraging but the design of the experiment was relatively insensitive for detecting differences. As a followup, Nelson (*16*) established 12 pairs of plots on the Cascade Head Experimental Forest. This time, 12 cubes containing viable *P. weirii* were buried on each plot of a pair in soil supporting pure alder or pure conifer stands. Cubes were buried 8 inches (20 cm) with minimal soil disturbance. After 12 months, soil samples were taken at the depth of the cubes and all cubes were then removed. Although the fungus survived somewhat better under conifer than alder stands, (24 vs 22 per cent) the difference was not significant at the 95-percent level of confidence. Soil samples showed a significantly higher level of NO_3 and lower pH under alder stands. Either of these factors could affect disease development without affecting survival of the fungus in stumps and decaying root systems.

Beginning in 1974, Hansen (*6*) excavated *P. weirii*-infested Douglas-fir stumps left 20, 30, and 50 years after logging. Initially, he looked at old stumps in young Douglas-fir stands and found that with age the fungus had died in many stumps. Where it hadn't, it was no longer viable at the extremities of roots.

Presently, infested Douglas-fir stumps in stands of young alder are being examined to determine if *P. weirii* remains infective there for a shorter time than in young Douglas-fir stands. A summary of data is shown in table 1.

Table 1--*Survival of* Phellinus weirii *in old stumps and roots on sites now occupied by Douglas-fir or red alder*

Stump age	Current stand	Stumps examined	Stumps with live *P. weirii*		Roots with live *P. weirii*	Average root diameter at limit of live *P. weirii*
Years		--Number--		Percent	Number	cm
20	fir	69	65	94	--	12.5
30	fir	65	38	58	87	18.9
50	fir	24	6	25	6	23.7
20	alder	45	33	73	102	11.0

In work completed, the fungus survived in 21 percent (94 vs 73 percent) fewer stumps under alder than it did under fir after 20 years. *P. weirii* remained viable, however, in somewhat smaller roots than it did in stands of Douglas-fir.

In British Columbia, Wallis (*20*) found viable *P. weirii* in old-growth stump roots as small as 4-cm diameter in 40-year-old mixed alder-Douglas-fir stands. But he also observed that in inoculum used to infect roots artificially, the fungus survived better in Douglas-fir stands than in mixed stands.

Alder seems to have some effect on *P. weirii* survival, but that effect is not dramatic and apparently requires a long time. How it happens, we have already hypothesized. How consistently it happens, what factors influence its effectiveness, and how long it takes, we have yet to learn.

INHIBITING SPREAD OF PATHOGEN

Let's look at the second possibility of alder reducing disease incidence. Microbiological and chemical changes in soil under alder have already been suggested. It is reasonable to expect them to inhibit develop-

ment of some organisms such as *P. weirii*. Even if alder-induced changes are not of the magnitude to significantly inhibit root disease, the physical presence of a non-host species acting as a spacer between host species should reduce spread dependent upon root to root contact.

What would happen if young mixed stands of alder and Douglas-fir reforested infested sites? Hansen (*5*) examined four such stands on the Siuslaw National Forest in the Oregon Coast Ranges. Systematically selected healthy and diseased Douglas-fir were sampled in stands ranging from 10 to 17 years old. In each case, it was determined whether or not an alder was present within 5 feet of the tree or within a distance equal to the height of the Douglas-fir being sampled.

Overall proximity to alder did not seem to affect chance of infection judging from either measure. Infections in young stands are initiated by contact with old, infested stump roots. The failure of alder in even-age mixture with Douglas-fir to prevent these initial infections is not surprising, considering the extreme infection hazard and short time for soil modification.

In 1972, Trappe and Wortendyke[2] examined Douglas-fir and adjacent mixed alder-Douglas-fir stands which met certain criteria:

1. *Phellinus weirii* was endemic in the area.
2. Stand age was between 30 and 100 years and was similar for each stand of a pair.
3. Conifers in the mixed stand were not dominated by the alder.
4. Sites for each stand of a pair were similar. Extensive scouting produced only six pairs of stands meeting these criteria, all in southwestern Washington.

Transects 8-ft (2.4-meters)-wide were run through each paired stand. The length of the transects ranged from 600 to 2,600 ft (183-792 meters) depending on the limits of the stand but were the same for each stand of a pair. All standing trees within each transect (1,300 in all) were examined for signs of *P. weirii* infection.

Data shown in table 2 were analyzed by Wilcoxon's signed rank test (*3*). This is a nonparametric test: it neither assumes a normal distribution of the measure variable nor uses quantified data. With only six paired stands the test indicated no significant difference in *P. weirii* incidence between pure Douglas-fir and mixed alder-Douglas-fir transects. If we assume equal variance and normal distribution (without evidence this is so) and use percentage of infection in a Student's t test, we find that the chance of a

[2]Unpublished Survey Data, Pacific Northwest Forest and Range Experiment Station.

greater percentage of conifers being infected in pure stands than in mixed is significant (P<5 percent). Even if the assumption were valid, the sample used was limited geographically. What occurs in southwestern Washington may not occur throughout the range of red alder.

Table 2--*Laminated root rot in pure conifer stands vs. alder-conifer mixtures*

Pair no.	Trees with infection		Phellinus centers	
	Pure conifers	Alder-conifer mixtures	Pure conifers	Alder-conifer mixtures
	- - -Percent- - -		- - -Number- - -	
1	9.3	2.3	6	2
2	2.6	3.1	2	2
3	5.3	1.7	4	1
4	1.4	0.0	1	0
5	12.5	0.0	6	0
6	1.4	0.0	1	0
Average	5.41	1.18	3.3	0.8

Wallis (*20*) inoculated roots of Douglas-fir in pure and mixed alder-Douglas-fir stands in British Columbia. In addition to reduced survival of *P. weirii* in the inoculum that he used in mixed stands, he achieved only one-third the percentage of successful infections in mixed stands than in pure Douglas-fir stands. In other instances, however, *P. weirii* infections of Douglas-fir roots in 40-year-old mixed stands did not appear to be inhibited.

Thus the case for alder reducing disease incidence by inhibiting infection and spread on conifer root systems is equivocal. Until more evidence is examined, mixed stands cannot be recommended as a solution to *P. weirii* problems.

Research Needs

Many questions remain about the role of alder in root rot control, but the over-riding need is to determine if it is effective under field conditions. Much could be learned from old root rot centers that regenerated to alder and have since been reconverted to fir. But apart from being nearly impossible to find, such existing situations lack the documented disease histories necessary for quantifying changes in disease incidence. Long-term experimental plantings on documented disease sites seem to be the only way to satisfactorily test alder's capabilities. Existing stands are being used to answer the more limited question "How long does *P. weirii* survive in old infected stumps on sites regenerated to alder?" This project will be completed in 1977.

A series of long-term experimental plantings have been established to test the effectiveness of alder alone and in mixtures with Douglas-fir or hemlock as a means of reducing subsequent root rot losses (table 3). Each test was established and replicated on carefully documented root rot centers. They represent a major, long-term commitment to test alder as a biological control agent.

In the meantime, forest managers must depend upon established guidelines based upon our present knowledge of laminated root rot (*4*, *20*).

Table 3--*Established, long-term plots evaluating alder as a control agent for laminated root rot*

Study	Duration	Location	Landowner	Other cooperators
Effect of alder-hemlock mixed stand on incidence of laminated root rot	1974-2014	Mapleton, Oregon	Mapleton R.D. Siuslaw N.F. USFS	Pacific Northwest Forest & Range Exp. Station
Effect of alder-Douglas-fir mixed stands on incidence of laminated root rot	1975-2035	Shelton, Washington	Port Blakely Mill Company	Pacific Northwest Forest & Range Exp. Stn., Oregon State University
Effect of crop rotation with alder or cottonwood in disease incidence in succeeding stands	1975-2035	Rainier, Oregon	International Paper Co.	Pacific Northwest For. & Range Exp. Stn., Oregon State Univ., Longview Fibre, Crown Zellerbach

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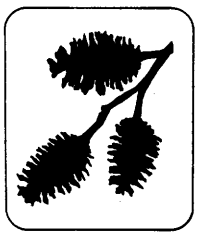
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THE EFFECTS OF RED ALDER ON GROWTH OF DOUGLAS-FIR



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ABSTRACT

We describe the long-term effects of off-site red alder that were interplanted in 1933 within a 4-year-old Douglas-fir plantation in southwestern Washington. Insufficient available nitrogen limits tree growth in this plantation. Red alder clearly increased height and diameter of the associated dominant Douglas-fir. Improved growth in diameter began when the Douglas-fir emerged through the alder canopy. This emergence occurred at about 30 years from seed at Wind River and in several even-aged, mixed stands that we also investigated. By age 48, Douglas-fir volume per acre in the mixed stand averaged about 3,100 cubic feet compared to 2,900 cubic feet in the pure stand. Red alder volume was about 2,500 cubic feet. Maintaining red alder in Douglas-fir stands can increase merchantable yields on nitrogen-deficient sites. Controlling stand density at an early age is necessary to maintain both Douglas-fir and alder in a dominant or codominant position. To provide adequate nitrogen and not seriously reduce Douglas-fir growing stock, about 20 to 40 uniformly distributed red alder per acre should be retained.

Introduction

Red alder, the most widely distributed commercial hardwood in the Pacific Northwest, supports nitrogen-fixing bacteria within nodules on its roots. Alder or other nitrogen-fixing plants can improve site productivity and growth of associated conifers by adding nitrogen and organic matter to the soil. For these reasons, Tarrant and Trappe (*12*) suggested using red alder in a soil-improving rotation or as an admixture with other tree species.

Red alder is well suited for short rotations because of its rapid juvenile growth and its ability to fix nitrogen at an early age; even 1-year-old alder have nodules and presumably nitrogen-fixing capacity. The rapid juvenile growth of red alder is, however, a concern of foresters who want to

maintain adequate stocking of Douglas-fir in mixed stands; red alder's juvenile height growth is more rapid than the initially slower growing conifers'. For example, 10-year-old alder seedlings are 30 to 40 feet tall on average and good sites in Oregon (7). Without chemical or mechanical control, equal-aged alder usually overtops associated Douglas-fir for about the first 25 years (*14, 2*). A large proportion of the Douglas-fir usually die during this period of suppression. Newton et al. (7) concluded from their survey of young stands in western Oregon that successful Douglas-fir regeneration required an age advantage of 4 to 9 years or spacing so that the Douglas-fir were 8 to 10 years old before alder encroachment.

In this paper, we shall describe the long-term positive and negative effects of red alder that were interplanted in a young Douglas-fir plantation on the Wind River Experimental Forest in southwestern Washington. We shall then briefly summarize our findings in mixed stands at three other locations. In contrast to the Wind River study area, the alder in these stands originated from natural seeding and were equal in age to the associated Douglas-fir. Because there were no pure Douglas-fir stands at these locations, we could not compare growth of this species mixed with alder to its growth when not mixed with alder. Having read this paper, you should recognize the potential benefits and requirements of managing mixed stands of these species.

Methods

STUDY AREAS

Wind River

Site description.--This Site IV study area is located near Carson, Washington at approximately 2,000 feet elevation. The Wind River study area, on the east edge of the 294,000-acre Yacolt Burn, was swept by wildfire in 1902 and 1927. Annual precipitation averages 96 inches with 26 percent falling during the April through October period (*8*). The soil, a moderately deep, well-drained gravelly loam derived from pyroclastic rocks, contains approximately 3,000 pounds of total nitrogen per acre to a 3-foot depth (*11*). This amount is about average for low productivity lands in western Washington Insufficient available nitrogen limits growth of Douglas-fir in the study area as demonstrated nearby in the same plantation. A single application of 140 pounds of nitrogen per acre when the Douglas-fir were 35 years old increased volume growth by approximately 70 percent (600 cubic feet per acre) during the next 11 years.[1]

Stand description.--The plantation was established after the Yacolt Fire of 1927. Two-year-old Douglas-fir from an unknown, off-site seed source were planted on an 8- by 8-foot spacing after the 1928 growing season. Four years later, 2-year-old red alder seedlings were interplanted on a 6-

[1]Unpublished data on file at the Forestry Sciences Laboratory, Olympia, Washington. See also (*6*).

by 6-foot spacing to create a 70-foot wide strip as a firebreak. These alder were also off-site, because the seed was collected at a 50-foot elevation near Olympia, Washington but the seedlings planted at a 1,900 to 2,100-foot elevation.

Early observers recorded that nearly all these off-site alder seedlings were severely frosted during the first fall and spring after planting, yet the native alders growing in the same locality were not frosted. The interplanted red alder would probably have competed more severely with the Douglas-fir if the alder seed had been collected at a similar or higher elevation as the planting site. Therefore, the results from the Wind River study may not be typical of natural Douglas-fir/red alder stands. We will respond to this concern later in this paper.

Despite off-site seed sources and delayed planting, however, the Wind River study area has advantages for determining the effects of red alder on growth of Douglas-fir. First, one can validly compare growth of fir with and without alder influence, because the Douglas-fir plantation was uniform in origin and spacing and the alder was restricted to one strip through the Douglas-fir plantation. In contrast, the so-called "pure" fir stand at our Cascade Head study area was created from a mixed stand by removing the alder after it had influenced the Douglas-fir for at least 8 years *(1)*. Second, insuffieient available nitrogen seriously limits growth of the Douglas-fir at the Wind River study area. Therefore, this species should respond to nitrogen additions by red alder.

Cascade Head, Delezenne, Skykomish

To check the general applicability of our findings at Wind River, we examined data from even-aged, mixed stands at three other locations in the Pacific Northwest.

Site characteristics.--Site index of the coastal Oregon stand at Cascade Head was somewhat higher than that at Wind River location (table 1). The Delezenne and Skykomish installations are both Site I based on trees with minimal influence of red alder.

Table 1--*Site characteristics of the even-aged stands*

Stand	Location (near)	Elevation	Annual precipitation	Soil	Site index (50-year)
		Feet	Inches		
Cascade Head	Lincoln City, OR	600	90	silty clay loam	120
Delezenne Creek	Elma, WA	200	70	silt loam	136
Skykomish River	Sultan, WA	400	50	silt loam	146

Stand description.--The Douglas-fir and red alder in these three areas originated from natural seeding with the exception of the Douglas-fir at Skykomish which were machine-planted. The oldest stand, at Delezenne Creek, was established after logging and burning; the other two succeeded abandoned pastures (table 2).

Table 2--*Stand descriptions of the even-aged stands*

Stand	Succession after	Total age at measurement	
		First	Last
		- - - -Years- - - -	
Cascade Head	pasturing	9	41
Delezenne Creek	logging and burning	30	53
Skykomish River	pasturing and logging	20	20

MEASUREMENTS

Wind River

Field.--When the Douglas-fir were 48 years from seed, we established four 0.2-acre plots in the pure stand and four matching plots in the mixed stand. These plots sampled a slope gradient from a level ridge to near a small creek. After measureing d.b.h. of all trees 1.6 inches and larger to the nearest 0.1 inch, we measured heights of 15 trees per plot of each species present. Randomization was constrained in that two-thirds of these trees exceeded the mean d.b.h. of the species on the plot and our height sample included the tree of largest d.b.h. for each plot and species. To determine breast-high age and past trends of diameter growth, we bored the eight largest trees of our height sample from each plot.

During plot installation, we noted that a large proportion of the trees in both the pure and mixed plantation had deformed boles. We assessed this past crown damage by estimating the height to the lowest point of bole deformity and classifying its effect on stem form and volume above this damage point.

Office.--We used standard procedures for summarizing data collected in the field. We computed 50-year site index for the six Douglas-fir that represented the upper 20 percent of the d.b.h. range on each plot (*4*). Cubic volumes of sample trees were based on general volume tables for Douglas-fir[2] and for red alder (*3*). The volume equation for each species and plot had the following format: Cubic volume, total stem = $a + bD + cD^2$, where D = diameter at breast height.

[2]James E. King and Kenneth J. Turnbull. Total tree cubic-foot volume table for Douglas-fir. Unpublished report. Copy on file at Forestry Research Center, Weyerhaeuser Company, Centralia, Washington.

Cascade Head, Delezenne, and Skykomish

We used data from seven mixed stands to compare with our Wind River data:

Stand	Plots	
	Quantity	Size
	(Number)	(Acres)
Cascade Head[3]	2	0.5
Delezenne Creek[4]	4	.2
Skyhomish River	1	.08

We computed site index (*4*), and examined trends in tree numbers by species, and height-diameter relations for these plots.

Results and Discussion

WIND RIVER

We shall first contrast the 48-year-old Douglas-fir in the mixed stand with the same seed source in the pure stand. We'll also show the tree size and volume attained by the alder in the mixed stand. In addition, we shall reconstruct past trends in number of trees and in height-diameter relations as indicators of past competition within the mixed stand. Finally, we'll compare the incidence and severity of past bole damage in both stands.

Current Stand

Dominant heights.--In the mixed stand at Wind River, red alder clearly increased height growth of associated dominant Douglas-fir. In four pairs of plots, heights of eight dominant Douglas-fir per plot averaged 14 to 27 percent taller in the mixed stand than those in the pure stand. Site index of these 48-year-old Douglas-fir stand was increased by 13 to 26 feet (table 3).

Site index of Douglas-fir in the pure stand was lowest at the top of the slope and gradually increased toward the creek (table 3). Site index in the mixed stand showed the same trends. The apparent gain in site index from the alder influence was least near the creek, presumably because soil nitrogen and moisture status were least improved by alder's additions of nitrogen and organic matter.

[3]Data provided by Richard E. Carkin, Forester, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, in January 1977.

[4]Data provided by James E. King, Department Manager, Resource Evaluation, Weyerhaeuser Western Forestry Research Center, Centralia, Washington, in February 1977.

Table 3--*Average dominant height and site index of 48-year-old Douglas-fir at Wind River*

Stand	Slope position of sample plot			
	Upper	Middle	Lower	Mean
	- - - - -Dominant height - feet- - - - - -			
Mixed	71	87	86	89	84
Pure	56	65	73	78	68
Difference	15	22	13	11	16
	- - -Site index, 50-year base - feet- - - -			
Mixed	92	106	111	110	105
Pure	69	80	92	97	84
Difference	23	26	19	13	21

Recall that red alder was planted in the mixed stand when the Douglas-fir were 6 years from seed. Height of dominant Douglas-fir in the mixed stand began exceeding that of dominants in the pure stand shortly after the red alder was introduced (fig. 1). The difference in average height of the 40 largest Douglas-fir per acre increased over time and was statistically significant ($P<0.01$) for ages 18 through 48 years.

Total stand volume.--Douglas-fir volume per acre in the mixed stand (fig. 2) averaged about 3,100 cubic feet compared to 2,900 cubic feet in the pure stand (fig. 3). This apparent 7-percent gain in cubic volume by age 48, however, was not statistically significant. Red alder volume averaged 2,500 cubic feet per acre. Therefore, the combined volume of both species was nearly twice the volume of the pure stand.

Tree numbers and volumes by diameter classes.--To compare stumpage values and logging costs in the mixed and pure stands, one needs to consider numbers and volumes of trees in specified diameter classes. We'll first compare Douglas-fir in the pure versus the mixed stand, then show size and number of red alder that were 4 years younger.

About one-half of the nearly 400 Douglas-fir per acre in the pure stand were in the 6-inch diameter class (table 4). This broad class included trees that were 5, 6, and 7 inches in diameter at breast height. Such trees could be merchantable in pulpwood under intensive utilization. In the 12-inch and larger classes, there were 22 trees per acre. These trees could be merchantable as sawtimber under current utilization standards.

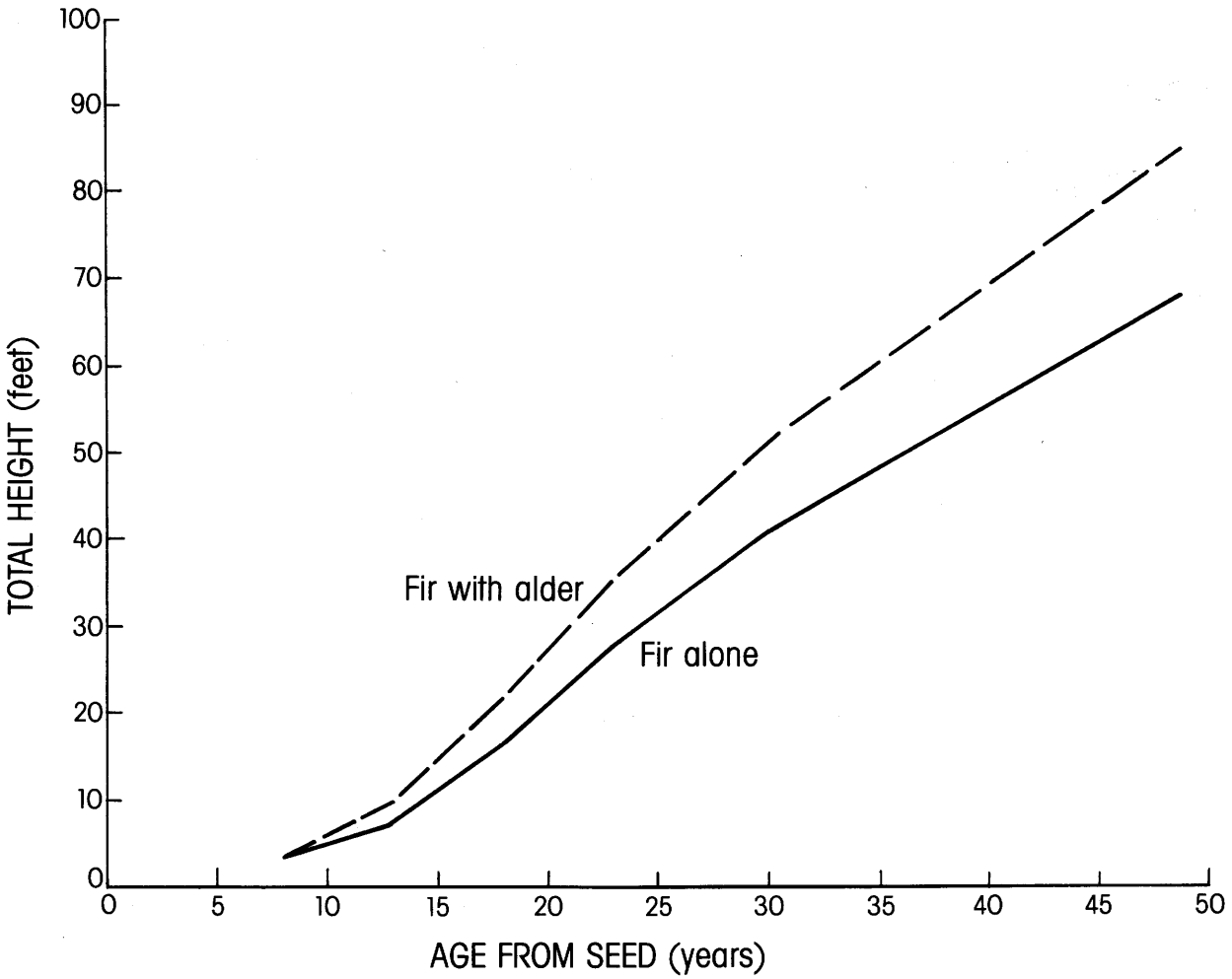


Figure 1.--Average height of dominant Douglas-fir in the pure and mixed stand at Wind River, data through 30 years adapted from Tarrant (10).



Figure 2.--A portion of the mixed plantation at Wind River. Note the 18-inch Douglas-fir to the left of center and the range pole beside it.



Figure 3.--A portion of the Douglas-fir plantation at Wind River. Note that the range pole in the center of the photo has 1-foot wide vertical bands.

Table 4--*Average distribution of tree numbers and volume by diameter class in 48-year-old stands at Wind River, per acre basis*

D.b.h. class (Inches)	Pure Douglas-fir	Mixed	
		Douglas-fir	Red alder
	- - - - - - -Number of stems- - - - - - -		
3	40	26	9
6	195	112	163
9	126	71	103
12	22	20	14
15	0	28	0
18	0	2	0
All	383	259	289
	- - -Cubic-foot volume, total stem- - - -		
3	49	30	27
6	943	451	1,010
9	1,414	835	1,216
12	490	474	285
15	0	1,141	0
18	0	179	0
All	2,896	3,110	2,538

In contrast, the mixed stand contained fewer, but larger, Douglas-fir. An average of 259 Douglas-fir remained or about two-thirds the number in the pure stand. Again, nearly one-half of these were in the 6-inch class. The most striking difference, however, was the presence of 50 Douglas-fir per acre in the 12-inch and larger diameter classes (table 4). Thirty of these could be called "superdominants"; they were present only in the mixed stand and were uniformly distributed. Sawtimber-sized Douglas-fir represented 58 percent of the total volume of Douglas-fir in the mixed stand compared to 17 percent in the pure stand (fig. 4).

Numbers and diameters of red alder.--The mixed stand averaged slightly more red alder trees than Douglas-fir. Again, the 6-inch diameter class was modal; it contained more than half the alder trees (table 4). An average of 14 alder trees per acre attained the 12-inch d.b.h. class, compared to 22 Douglas-fir in the pure stand. Recall that 50 Douglas-fir in the mixed stand also reached this 12-inch diameter class or larger. Despite greater stand density in the mixed stand, alder not only increased the diameter growth of associated Douglas-fir, but also attained sawtimber size.

Past Trends

Interplanting 1,200 alder seedlings per acre in a 4-year-old Douglas-fir plantation at Wind River increased competition. We estimated the effects of this competition by combining our recent data with earlier observations and published data (*10*).

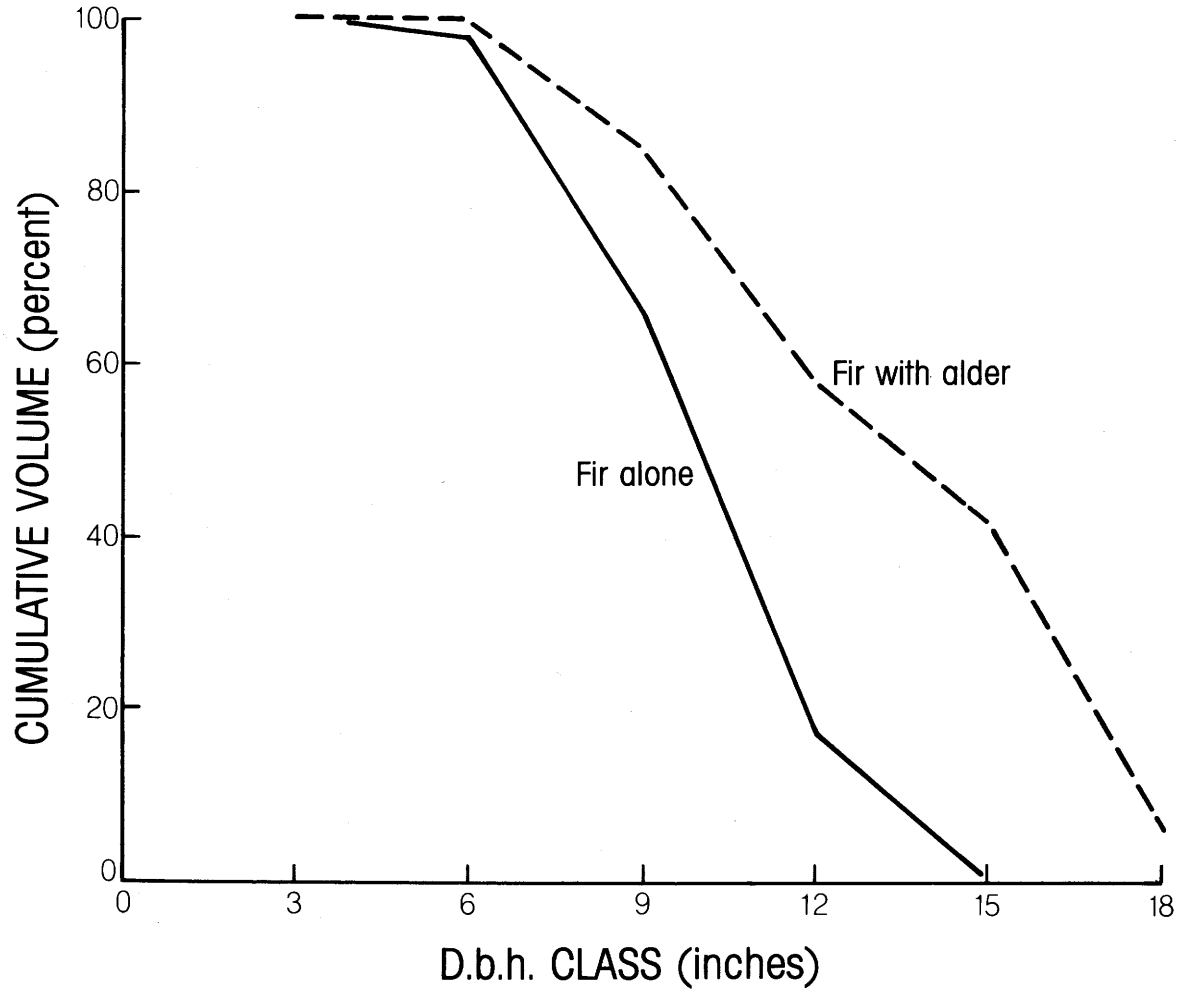


Figure 4.--Cumulative volume distribution by diameter class in 48-year-old Douglas-fir at Wind River.

Surviving trees.--Of the original 680 Douglas-fir planted per acre, an average of 383 or 56 percent survived in the pure stand compared to 258 or 38 percent in the mixed stand (fig. 5). This greater loss of Douglas-fir in the mixed stand could be anticipated since there were also about 1,210 alder seedlings planted per acre with no subsequent stocking control. The trends of surviving Douglas-fir are not parallel for the mixed and pure stands in either the 2- to 30-year period or the 31- to 48-year period. The mixed stand had greater losses of Douglas-fir in both periods and particularly in the 2- to 30-year period.

Red alder losses exceeded Douglas-fir losses in the mixed stand. Of the original 1,210 alder seedlings planted, only 24 percent survived competition and environmental stress compared to 38 percent of the Douglas-fir. Although the off-site alder were severely damaged by frost shortly

after planting, only about 10 percent of the alder seedlings were actually killed by frost. According to early records, sprouts arose from the root collars of most frost-damaged seedlings. Therefore, supression was the more likely cause of early mortality in the interplanted red alder.

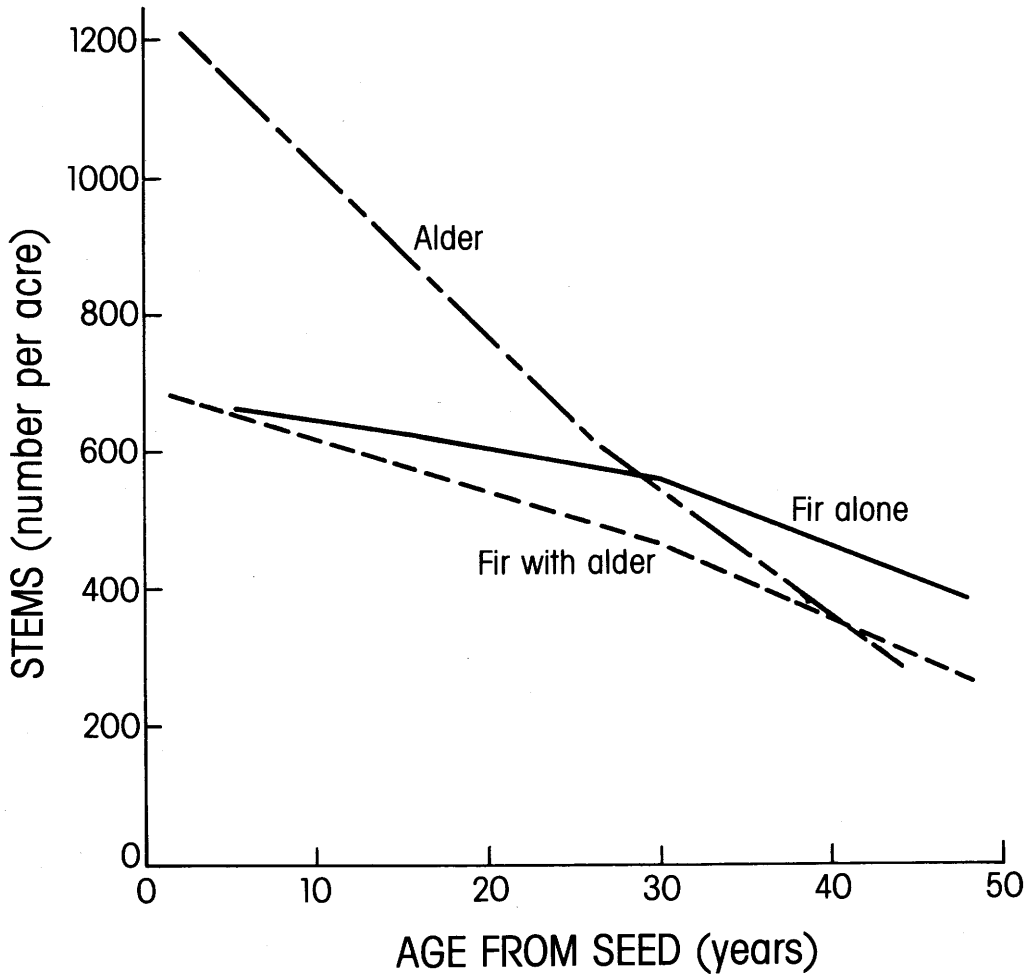


Figure 5.--Number of trees by species at Wind River.

Height-diameter relations.--We previously described the "superdominant" Douglas-fir in the mixed stand. These trees were taller and larger in diameter than Douglas-fir in the pure stand; they also towered above the alder canopy (fig. 6).

At 48 years of age, however, the crowns of about 70 percent of the Douglas-fir in the mixed stand were below the top level of the alder canopy. Therefore, we anticipate additional mortality of suppressed Douglas-fir in the future.

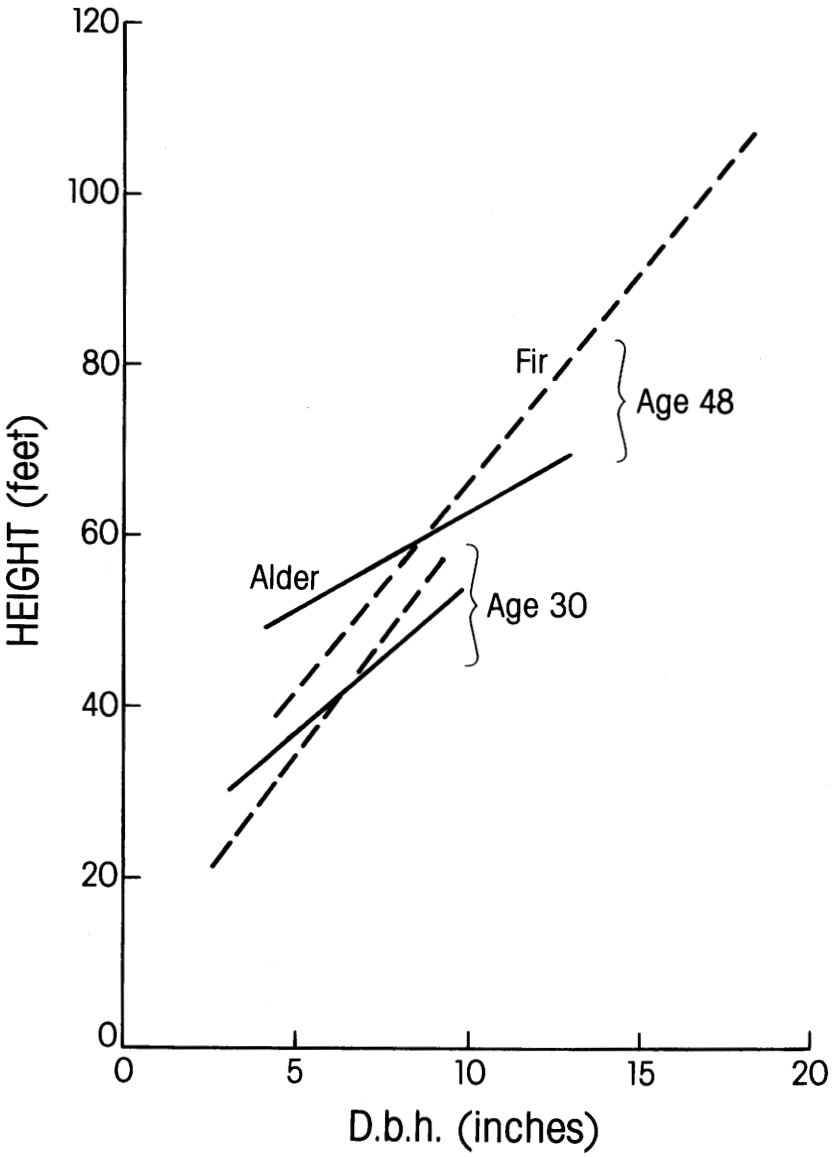


Figure 6.--Height-diameter relations at age 30 and 48 years in the mixed stand at Wind River.

Based on earlier measurements (*10*), we believe that the dominant Douglas-fir began emerging from the alder canopy when they were about 30 years old. At 30 years for the Douglas-fir and 26 years for the alder, dominant trees of both species were similar in height and diameter (fig. 6). Eighteen years later, however, the dominant alder averaged less than 70 feet tall, while the dominant Douglas-fir exceeded 100 feet in height and were strikingly larger in diameter.

Diameter growth of dominant Douglas-fir accelerated about the time they emerged from the alder canopy or when they were about 30 years old (fig. 7). Although the beneficial effects on height growth occurred by year 18 (fig. 1), the stimulating effects of red alder on diameter growth of Douglas-fir were minimal until tree mortality had reduced stand density and the fir began emerging from the dominating alder canopy.

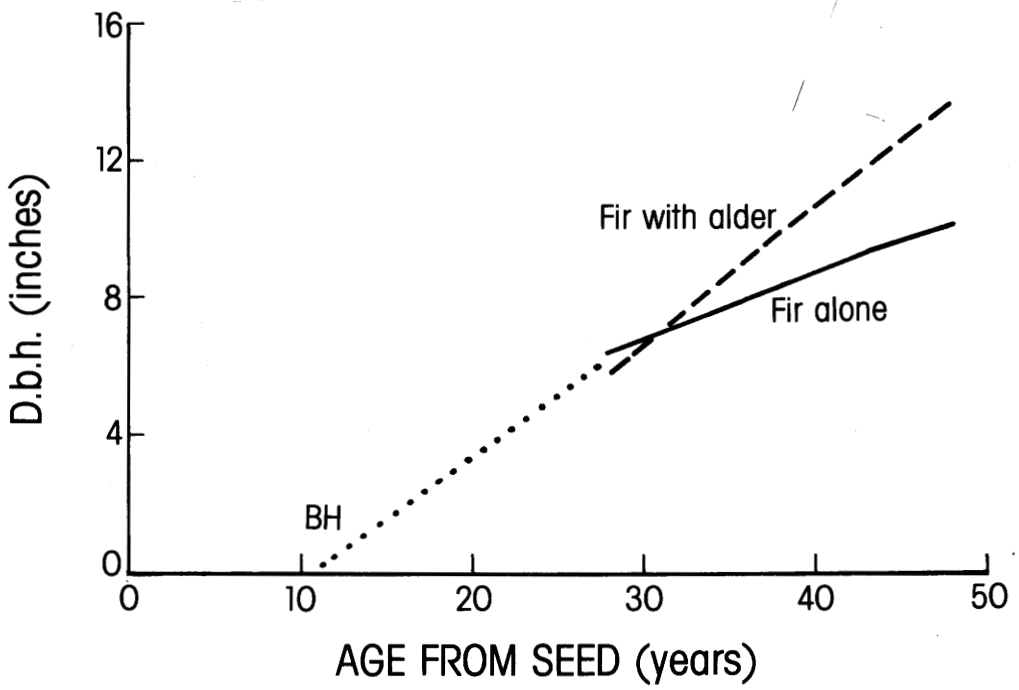


Figure 7.--Average d.b.h. of dominant Douglas-fir at Wind River.

Since these stands were left unmanaged, we can only assume that early thinning would have resulted in an earlier acceleration of diameter growth. Our findings at Wind River support earlier recommendations (*9, 13, 14*) of early and effective control of spacing to improve survival and growth of crop trees.

Bole deformity.--Nearly one-quarter of the Douglas-fir in the pure stand had bole deformity at one or more places. This past leader or top breakage was likely caused by winter damage that frequently occurs in the Wind River study area (*6*). Although the percentage of trees with bole deformity was more than twice as great in the mixed stand as in the pure, this deformity was not severe in most trees (table 5). Severe bole deformity was evident in 12 percent of the Douglas-fir in the pure stand and 10 percent in the mixed stand (table 5). We assumed that moderate and minimum deformity would have little effect on bole volume above the point of deformity; therefore, the reductions in bole volume will probably be nearly the same for both stands.

The incidence of damage in the mixed stand was about the same for Douglas-fir and red alder. The greater incidence of past top damage in the mixed stand is most likely due to the closer spacing of the trees.

Table 5--*Average percentage of trees at Wind River with bole deformity*

Severity of deformity	Volume above point of damage	Pure stand	Mixed stand	
		Douglas-fir	Douglas-fir	Red alder
Maximum	Negligible	12	10	3
Moderate	Reduced	5	32	38
Minimum	Near normal	7	16	20
All		24	58	61

Applicability of Results

The severe N deficiency of the Wind River site probably accentuates the benefits of alder's nitrogen-fixing capacity. Therefore, the positive effects of alder are likely to be greater here than in most sites managed for timber production. Moreover, this unique situation may not demonstrate the negative and competitive effects of alder under typical conditions. At Wind River the alder was an off-site seed source, was planted 4 years after the Douglas-fir on a 6- by 6-foot spacing, and was badly frosted soon after planting. In typical mixed stands, however, the alder is more site-adapted, is equal in age to the Douglas-fir, and may have greater initial numbers of stems.

CASCADE HEAD, DELEZENNE, AND SKYKOMISH

We investigated even-aged, mixed stands at three locations to check the general applicability of our findings at Wind River.

Surviving Trees

Initial and final stand composition.--Mixed stands of naturally regenerated Douglas-fir and red alder vary in the proportion of these species to other conifers, especially shade-tolerant hemlock, western redcedar, and Sitka spruce. High initial densities of even-aged red alder usually reduce survival of Douglas-fir, a species that is intermediate in shade tolerance. Our sample stands illustrate these general concepts (table 6). An adequate stocking of Douglas-fir in the final stand occurred only if the initial alder component was minimal or removed in an early liberation cut, e.g., Cascade Head and Skykomish (figs. 8 and 9).

Trends in stand composition.--Trends of species composition are well illustrated by the long-term records for four Delezenne plots located on uniform soil and topography (fig. 10). The number of Douglas-fir is closely correlated with number of red alder at stand age of both 30 and 53 years; the more red alder, the fewer Douglas-fir in the stand.

Table 6--*Changes in species composition in some even-aged mixed stands, per acre basis*

Area	Plot	Initial				Final			
		Age	Douglas-fir	Red alder	Both	Age	Douglas-fir	Red alder	Both
		Years	-Number-			Years	-Number-		
Cascade Head	11	9	436	1,010	1,446	42	54	290	344
	15	9	286	1,368	1,664	42	12	328	340
	17	9	454	(1/)	(1/)	42	188	0	188
Delezenne	1	30	305	40	345	53	175	35	210
	4	30	235	110	345	53	140	95	235
	3	30	125	210	335	53	60	120	180
	2	30	70	270	340	53	45	150	195
Skykomish	Mixed	2	960	444 2/	1,404	20	492	420	912
	Pure	2	896	205 2/	1,101	20	719	0	719

1/ An unknown number of red alder were felled and the conifers thinned.

2/ Red alder removed 4 years later.



Figure 8.--Twenty-year-old, mixed stand at Skykomish. Most Douglas-fir were overtopped by about 400 uniformly distributed red alder per acre. Note the range pole with 1-foot wide bands in the left-of-center foreground.

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Figure 9.--A nearby portion of the Skykomish plantation. Alder volunteers were cut when the stand was 4 to 7 years old.

The coefficients describing these linear relations between Douglas-fir and red alder have practical implications for silviculturists.

Stand age	a	b	r^2
30	347	-1.03	0.99
53	226	-1.21	.88

Each red alder tree replaced 1.03 Douglas-fir at age 30 and 1.21 at age 53; the coefficients were not significantly different (P>.05). If we assume that the same relation between numbers of alder and Douglas-fir was linear over the full range of species composition, the a-coefficients indicate that a pure stand of Douglas-fir at this location would have contained 347 stems per acre at 30 years and 226 at 53 years. Normal stands of this site index and age contain 355 and 290 stems per acre (5).

Age of Emergence

Some Douglas-fir survived despite heavy initial stocking of red alder in most of these even-aged stands (table 6). Douglas-fir probably attained a dominant crown position and crop tree status in the fortuitous absence of strong alder competition.

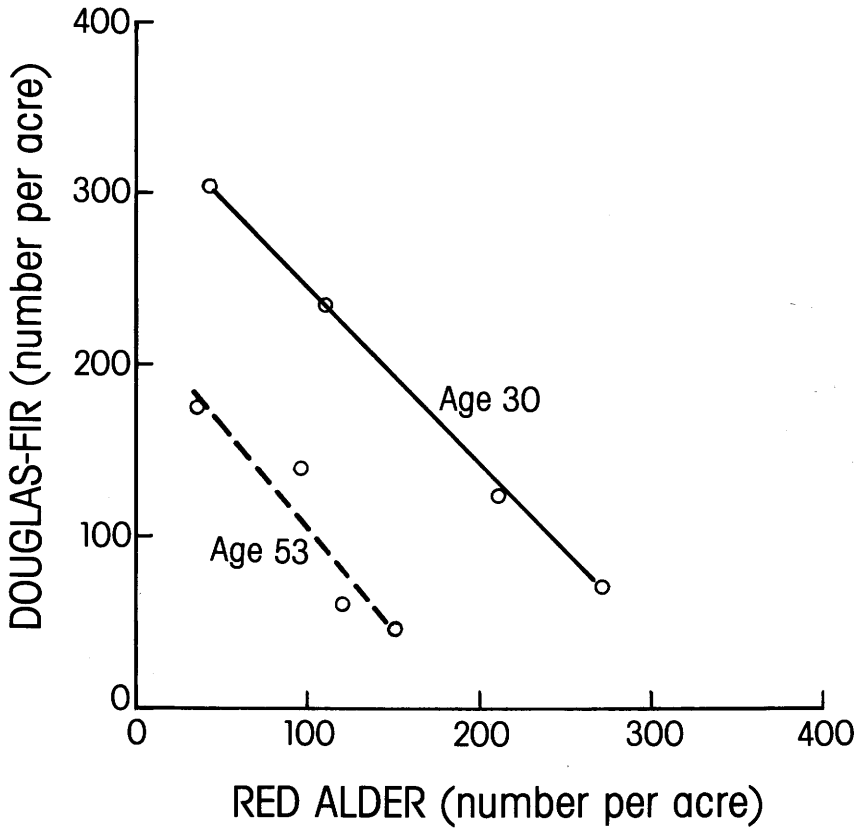


Figure 10.--Number of trees by species and age at Delezenne.

At the time Douglas-fir emerges through and above the alder canopy, its survival is usually assured. Recall that this emergence occurred at about 30 years in the two-aged Wind River plantation. The two natural, even-aged stands at Cascade Head and Delezenne represent typical conditions. Both show emergence and presence of "superdominants" at or before age 30 (figs. 11 and 12).

Height-diameter trends in these even-aged alder mixtures were similar to those in the Wind River plantation where the alder was 4 years younger than the Douglas-fir. The age of emergence in these even-aged stands was also similar to those reported earlier by Newton et al. (7). Based on early height growth trends of alder and Douglas-fir at numerous locations in western Oregon, they predicted that equal-aged Douglas-fir would attain dominance in mixed stands by 25 to 35 years on so-called "non-wet" sites and about 10 years later on wet sites where alder had a competitive advantage over Douglas-fir.

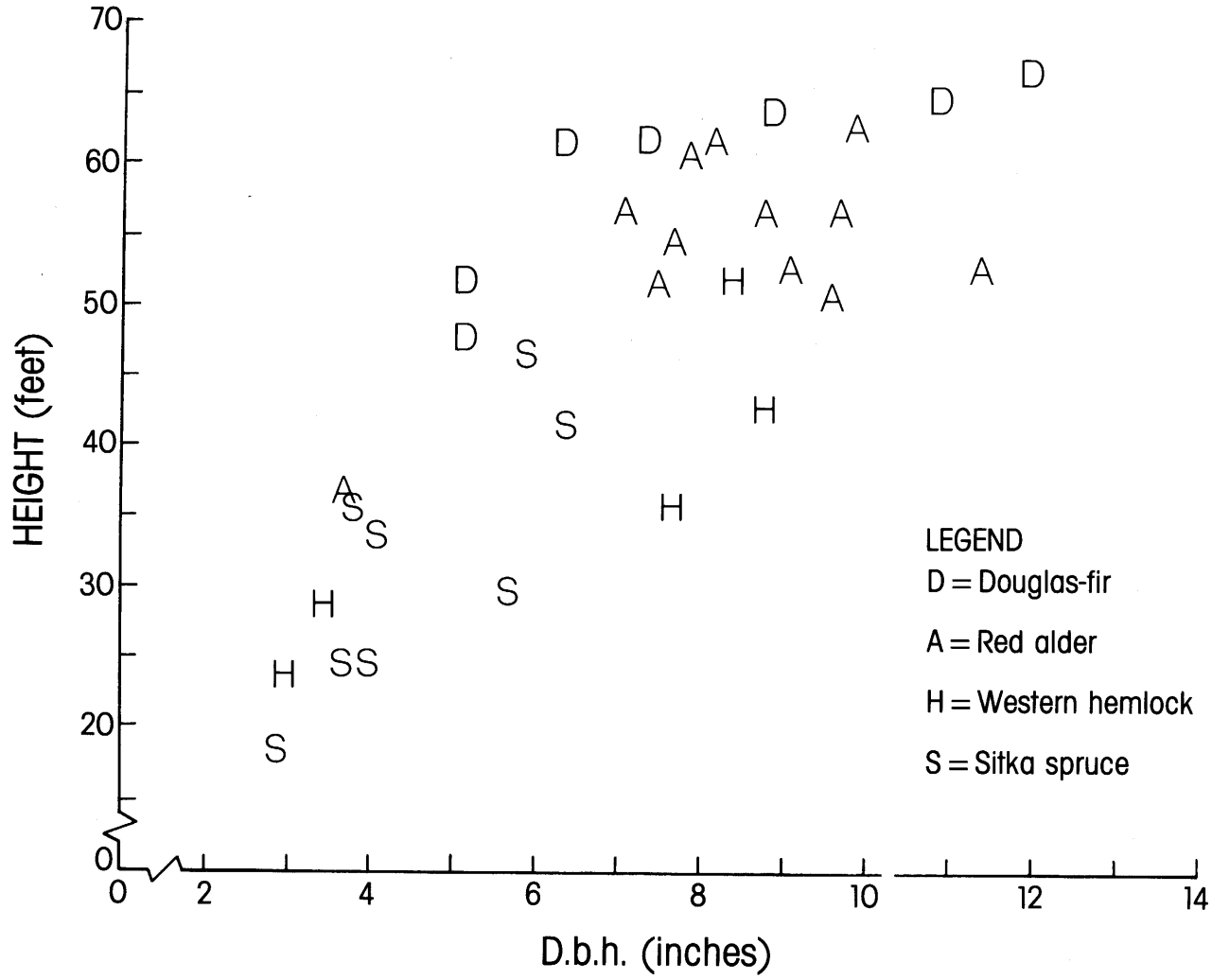


Figure 11.--Height and diameters of 30-year-old Douglas-fir and red alder in Plot 11 at Cascade Head.

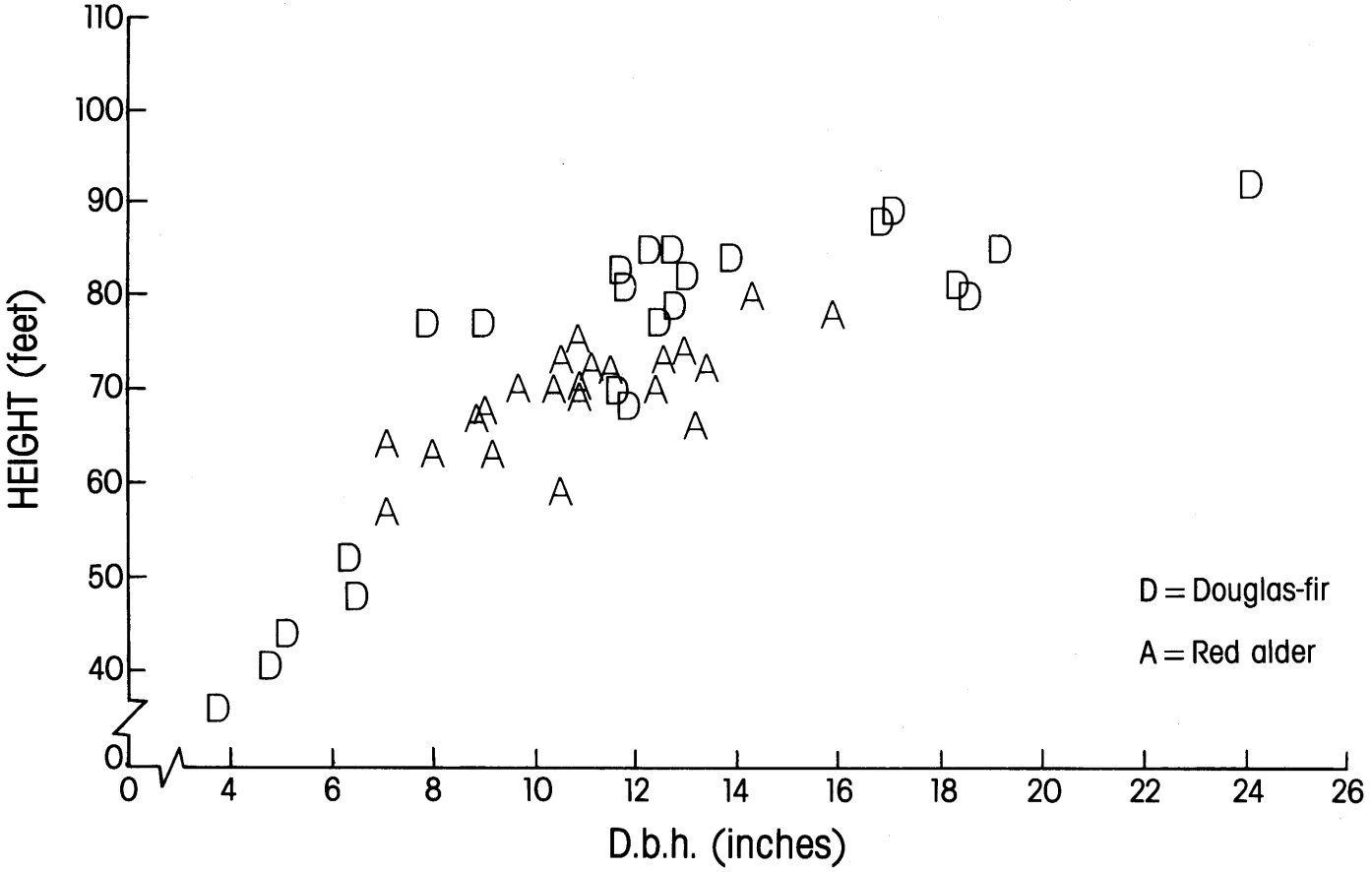


Figure 12.--Height and diameters of 30-year-old Douglas-fir and red alder in four plots at Delezenne.

MANAGEMENT IMPLICATIONS

To attain full stocking of Douglas-fir, foresters cannot rely on chance survival and emergence of Douglas-fir crop trees in mixtures with red alder. Full and uniform distribution of conifers will seldom be attained (fig. 13). Foresters recognize the competitive advantage of red alder over the more highly valued Douglas-fir and attempt to neutralize this by spraying mixed stands with herbicides. This treatment usually eliminates red alder as a potential crop tree and effective N-fixer. Paradoxically, however, foresters increasingly use nitrogen fertilizers to boost yields from Douglas-fir forests. To what extent could organic fertilization through N-fixing plants such as red alder substitute for inorganic fertilizers? What are the comparative costs and benefits? A key part of any analysis is determining the number of admixed red alder per acre necessary to maintain available nitrogen at optimal levels for growth of associated Douglas-fir.

These questions suggest we should compare two intensive management regimes for Douglas-fir. As tabulated below, our conventional regime controls volunteer red alder with a herbicide spray when the alder is about 5 years old. A subsequent precommercial thinning eliminates surviving alder and excess Douglas-fir. We assume that fertilizing with 200 pounds of N per acre at 10-year intervals will eliminate N as a growth-limiting factor. Commercial thinning starts at age 35 in both regimes.

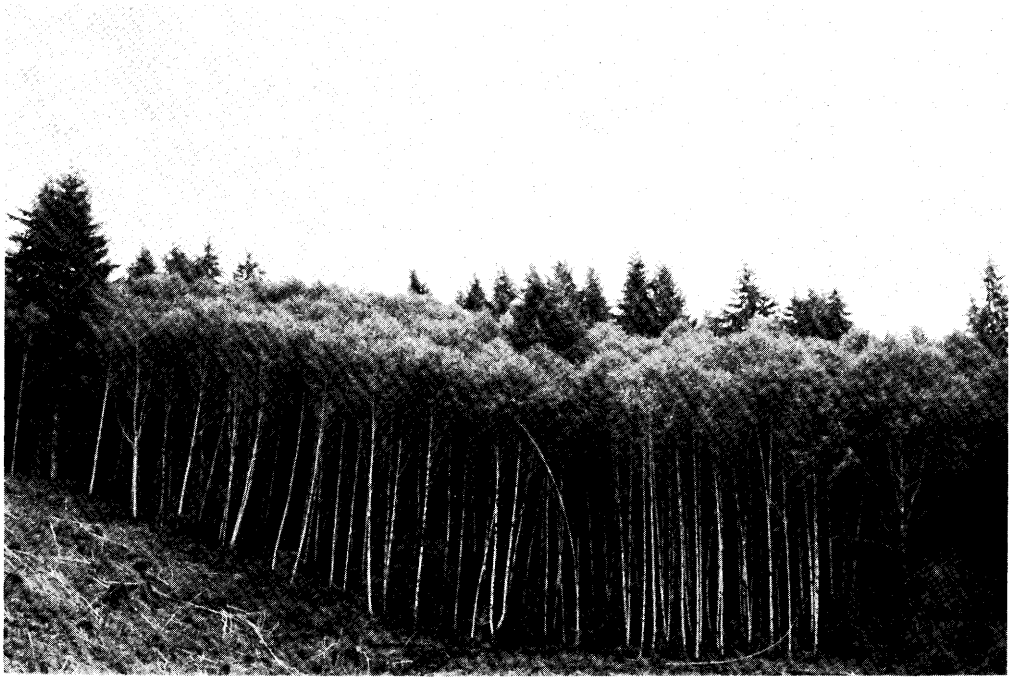


Figure 13.--A 50-year-old mixed stand near the Delezenne study area. Note the clumpy and non-uniform distribution of Douglas-fir.

Silvicultural activities in two management regimes for Douglas-fir plantations with red alder volunteers

	Regime	
Nominal age (Years)	Pure stand	Mixed stand
0	plant	plant
5	apply herbicide	stocking control
15	control stocking, fertilize	
20		stocking control
25	fertilize	
35	thin, fertilize	thin
45	thin, fertilize	thin

In our theoretical, mixed-stand management regime, early stocking control eliminates surplus trees of both species; all red alder that will not overtop Douglas-fir crop trees until a second precommercial thinning at age 20 are retained. The second thinning will leave a minimal number of uniformly spaced red alder in a dominant or codominant position to insure high rates of N fixation and to minimize bole sweep. Although these red alder will subsequently be harvested, their major purpose is to eliminate the need for fertilizers by maintaining or improving soil nitrogen and organic matter status for optimal growth of associated Douglas-fir.

The number of red alder to leave is critical to any economic comparison of the two regimes, because each red alder will replace at least one Douglas-fir that would probably provide a greater economic return. We recognize this species difference in future value at harvest as an "opportunity cost" of using red alder instead of commercial fertilizers. Clearly, the financial attractiveness of the mixed stand regime will increase if (1) the stumpage price of red alder improves relative to that of Douglas-fir and, (2) the cost of fertilization increases.

What is the minimum number of red alder crop trees to retain in the mixed stand for adequate N production? The fewer red alder retained, the lower will be this opportunity cost. At the N-deficient site at Wind River, we noted that Douglas-fir in the pure plantation that were within about 30 feet of the mixed stand were noticeably larger than those at farther distances. This suggests maintaining red alder in a mixed stand at a 60-foot spacing or 12 per acre. More than 12 will probably be necessary, because an individual red alder is not likely to be as influential as a group like we observed at Wind River. For improving nitrogen and organic matter status in Douglas-fir stands, we recommend 20 to 40 uniformly distributed, dominant red alder per acre. This number should not seriously reduce Douglas-fir growing stock.

Conclusions

1. Red alder increased height and diameter growth of associated, dominant Douglas-fir on a nitrogen-deficient site at Wind River.
2. The Douglas-fir, which were planted 4 years before the off-site alder, emerged through the alder canopy at 25 to 30 years from seed. Before this canopy separation, dominant Douglas-fir in the mixed stand were taller than those in the pure stand but had about the same diameter.
3. After emergence, dominant fir accelerated height and especially diameter growth. Within the next 20 years, some of the dominant fir in the mixed stand had attained 18-inch d.b.h compared to 13 inches for their counterparts in the pure stand. Moreover, 40 dominant Douglas-fir per acre averaged 20 percent taller than those in the pure stand.
4. Red alder increased sawtimber yields of associated Douglas-fir at Wind River. Moreover, some of the off-site alder trees reached sawtimber size. The total volume of the mixed plantation was nearly twice that of the pure Douglas-fir plantation.
5. The natural, even-aged stands at Cascade Head and Delezenne Creek represented typical conditions. Both showed emergence and presence of superdominant Douglas-fir at or before age 30.
6. An adequate stocking of Douglas-fir in the final stand occurred at our three locations with even-aged mixed stands only if the alder component was initially minimal or reduced to this by an early liberation cut.
7. Creating or maintaining red alder in Douglas-fir stands is a potential means for increasing merchantable yields from nitrogen-deficient sites.
8. The benefits of red alder or other N-fixing plants will probably be greatest on soils that are deficient in total or available nitrogen and low in organic matter and clay. Because nitrogen fertilizers have frequently increased growth of Douglas-fir over a wide range of sites in western Washington and Oregon, it is likely that N-fixing plants will also improve growth over a similar wide range of sites.
9. Controlling growing stock at an early age to keep Douglas-fir crop trees in a dominant or codominant position and to favor crop trees of both species will improve the benefits from mixed stands.
10. We recommend that 20 to 40 uniformly distributed red alder per acre be maintained in a dominant position to improve nitrogen and organic matter status in Douglas-fir stands.

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SILVICULTURAL IMPLICATIONS OF THE RECONSTRUCTION OF MIXED ALDER/CONIFER STANDS[1]

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ABSTRACT

Mixed alder/hemlock/redcedar/Douglas-fir stands which began growth after a 1927 logging fire were studied on till soils of the Marckworth Forest of the central Washington Cascades. The stand was always sparsely stocked. Essentially all stems had begun within 20 years of the disturbance. Red alders were the same age or up to 17 years younger than the associated conifers on the same plot, although the conifers were usually in a subordinate position. For analyses of site index, stocking, and growth rates, it cannot be assumed that the alders are the same age as the initiating disturbance. The alders varied widely in crown size and diameter but varied less in height. Basal area of individual alders was closely related to spacing. Closely spaced alders resulted in spindly stems of poor quality. Very recent alder stands generally begin with many more stems per acre than this stand did. Early thinning may be necessary to achieve adequate alder growth.

Introduction

Mixed stands of red alder (*Alnus rubra* Bong.) and conifers became widely established in western Washington, Oregon, and British Columbia after extensive logging and frequent fires in the early 1900's. Approximately 2.5 million acres of alder and mixed alder-conifer stands exist in the Northwest (Yoho et al. 1969), often on soils with the greatest potential for

[1]This study was supported in part by McIntire-Stennis Grants Nos. 61-9961 and 61-9964 to the College of Forest Resources, University of Washington. The study was done on lands managed by the Department of Natural Resources of the State of Washington.

conifer volume growth. Alder is commonly associated with western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western redcedar (*Thuja plicata* Donn.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). Many of these naturally seeded stands are of low value compared with pure conifer stands because of their relatively low volume and because unmanaged alders often have poor stem quality. Occasional natural alders of good stem quality and large diameter can be found. This study reconstructed the growth and competition patterns causing the development of alders of both good and poor quality. Two large alder/conifer stands approximately 50 years old were examined. Groups of alders and conifers with a range of sizes and stocking characteristics were selected. The trees in each group were simultaneously dissected, and the past growth patterns were reconstructed to determine the conditions leading to the observed variety of present stand structures. From these reconstructions of past growth patterns, silvicultural recommendations are made.

Study Area

The study was done on the Gordon D. Marckworth Experimental Forest in the foothills of the central Cascade Range of western Washington. In the 1920's, this land was owned and railroad logged by the Cherry Valley Logging Company. A large fire in about 1927 burned much of the cutover land and forest which now lies within its boundaries. Within a few years, the remaining timber was exhausted and the land claimed by the State for tax-delinquency. This land is now managed jointly by the Washington Department of Natural Resources (DNR) and the University of Washington.

The study was done mainly in Sections 35 and 20 (fig. 1). Elevation of the plots varied from 700 to 1,000 feet. The soils are mixtures of glacial till, residual materials, and ash. Site class for Douglas-fir is II- to III+.

Procedures

Thirty-one circular sample plots of one-fiftieth acre each were established in red alder-Douglas-fir timber types as mapped by the DNR. After stocking, stem quality, and crown classes were examined for each species on all plots, six plots were singled out for more intensive study. These six plots covered the range of alder and conifer stocking encountered; diameters of the alders on these six plots ranged from 5 to 18 inches. First, the six intensive study plots were examined for minimum estimates of mortality by intensively searching the litter. Next, each area was mapped for location of live and dead stems. Crown areas were then projected onto the ground and mapped. All plot trees and those trees whose crowns overlapped crowns of the plot trees were felled. Sections were cut at: the base, 1.0 foot, 4.5 feet, 8.0 feet, and every 4.0 feet thereafter. All disks were brought to the lab and aged as described below. All trees were cut in the winter of 1976-1977.

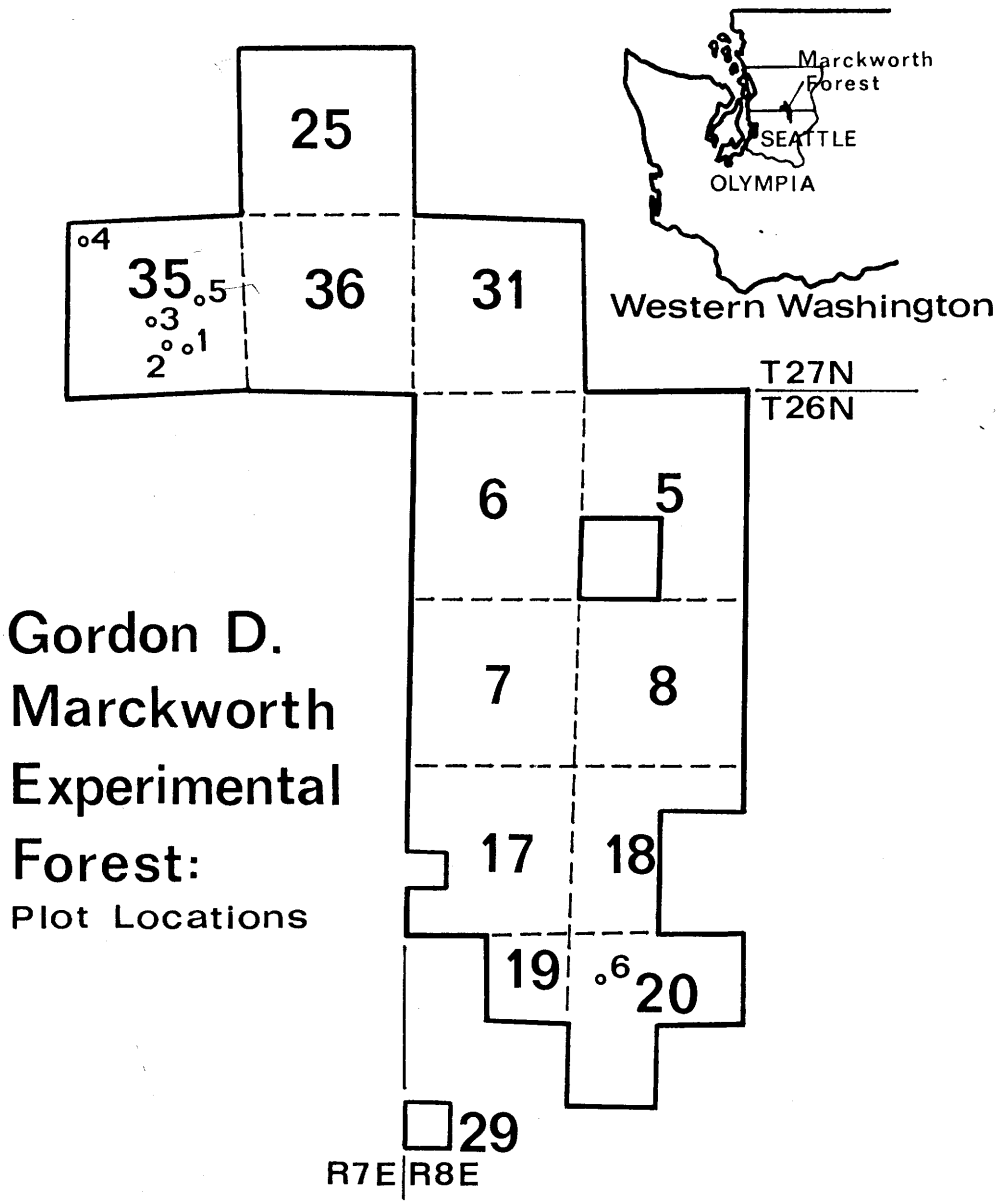


Figure 1.--Location of the six reconstructed plots on the Marckworth Forest and location of the Marckworth Forest in western Washington (inset).

It is known that trees when suppressed often do not produce an annual ring over the entire bole of the tree (Larson 1956, Bormann 1965)[2]; therefore, it was necessary to find a way to account for potentially nonexistent rings. It was possible to date disks by locating the annual ring produced following the freeze of November 1955. The rings produced during the 1956 growing season were generally much smaller, irregular, or had abnormal amounts of summerwood. On many of the alders a black line was found between the growth rings of the 1955 and 1956 years. When the 1956 ring was located, it was known that 20 years existed outside of it. The rings inside of this were generally large enough so that "missing rings" were unlikely; the exceptions were a few small hemlocks. It is also possible that disks younger than 21 years could have dropped rings which were unnoticed.

Results and Discussion

STOCKING

Table 1 shows the estimated number of living stems and total number of stems per acre by species, based on intensive searches of the litter for dead stems. All of the stands sampled appeared to be initially sparsely stocked and of natural regeneration. The initial stocking of conifers was only 346 stems per acre. On each acre, 59 Douglas-fir appeared to seed in initially; but of these, only 18 per acre remained after 50 years. At most, there were only 160 alders per acre; however, others which might have existed could already have rotted away.

Table 1--*Number of stems of each species living at 50 years, and estimate of total number of stems, living and dead, since stand initiation based on analyses of stumps and other evidences in six plots*

Species	Total dead + alive	Number alive at 50 years
	-Per acre-	
Douglas-fir	59	18
Red alder	160	114
Western hemlock	123	64
Western redcedar	164	105
Cherry	119	0
Maple, willow	27	9
Total	652	310

[2]Oliver, C. D. 1975. The development of northern red oak (*Quercus rubra* L.) in mixed species, even-aged stands in central New England. Ph.D. dissertation, Yale University School of Forestry and Environmental Studies, New Haven, Conn. Appendix 4B:178-180.

AGE DISTRIBUTION

Figure 2 shows the age distributions by species for the studied trees on and surrounding the six plots. The age pattern was not as anticipated. The alders were larger than most associated conifers. Rather than the alders being older than the conifers, however, they invaded after the conifers on five of the six plots. In fact, they were up to 17 years younger than the first invading conifers. The greatest difference in alder ages on a single plot was 5 years. The alder ranged in age on all six plots from 51 to 30 years with the mean age being 37.7 years. A similar pattern of wide range of alder ages has been found in several stands near Olympia (DeBell and Wilson 1978). Johnson et al. (1926) reported the ability of alders to invade sites which were not completely restocked with conifers.

Hemlock and cedar were generally as old as or older than alder. An exception was one hemlock on plot 1 (fig. 2) which had started upon a rotting stump. Including Douglas-fir, the conifers had a range of ages of 52 to 41 years, the average being 45.5 years. Douglas-fir were found living on or near only those plots in which they had started 10 years prior to the alder (this pattern has been found previously by Newton et al. 1968). Plots 1 and 2 each had standing dead Douglas-fir which appeared to have died from competition with the alder. This delay in the alder invasion may be important to the establishment of Douglas-fir in natural mixed stands. It is probable that no Douglas-fir would be found on the site if the alders had all invaded when the first conifers did.

Figure 3 shows height growth patterns of selected trees representing the species and canopy positions found in this study. In spite of the younger ages of the alders, they were found to overtop most of the other conifers (fig. 3). When in competition with western redcedars, the alders were mainly in dominating positions. A 10 to 12 year delay in the alder invasion was necessary for cedar to reach the upper canopy when grown with alder (unless the cedar were allowed sufficient spacing to gain the necessary height advantage before the alders closed in).

Hemlock did outgrow alder at times if the alder was delayed 8 to 10 years.

ALDER GROWTH PATTERNS

Figure 4 shows the height growth of the tallest alder on the six plots. (The dominant alder growths of plots 4 and 6 were averaged because their height growths and ages were very similar.) Growth of red alder appeared to vary between plots with height growth curves tending to steepen with increasing length of delay of alder invasion. Plot 5 was an exception. The alder here was shorter, perhaps because of less optimum soil conditions; other species on this plot were also shorter.

The heights reached by the dominant alder in most cases were similar and not related exclusively to age. Except for plot 5, it is assumed that there is no major influence of site on growth between these plots. The

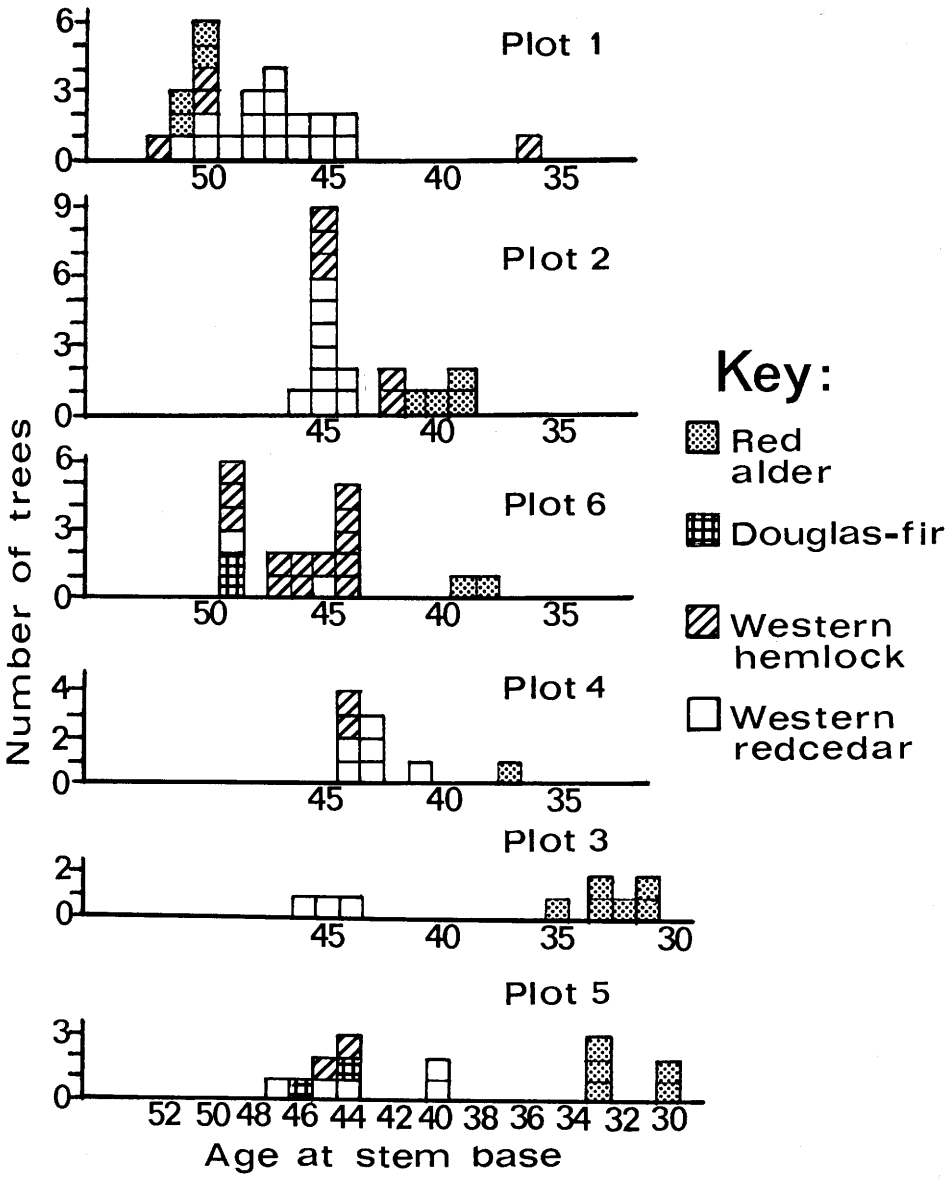


Figure 2.--Age distribution of stems by species for the studied trees on and surrounding the six plots. Plots are shown in order of delay of alder invasion.

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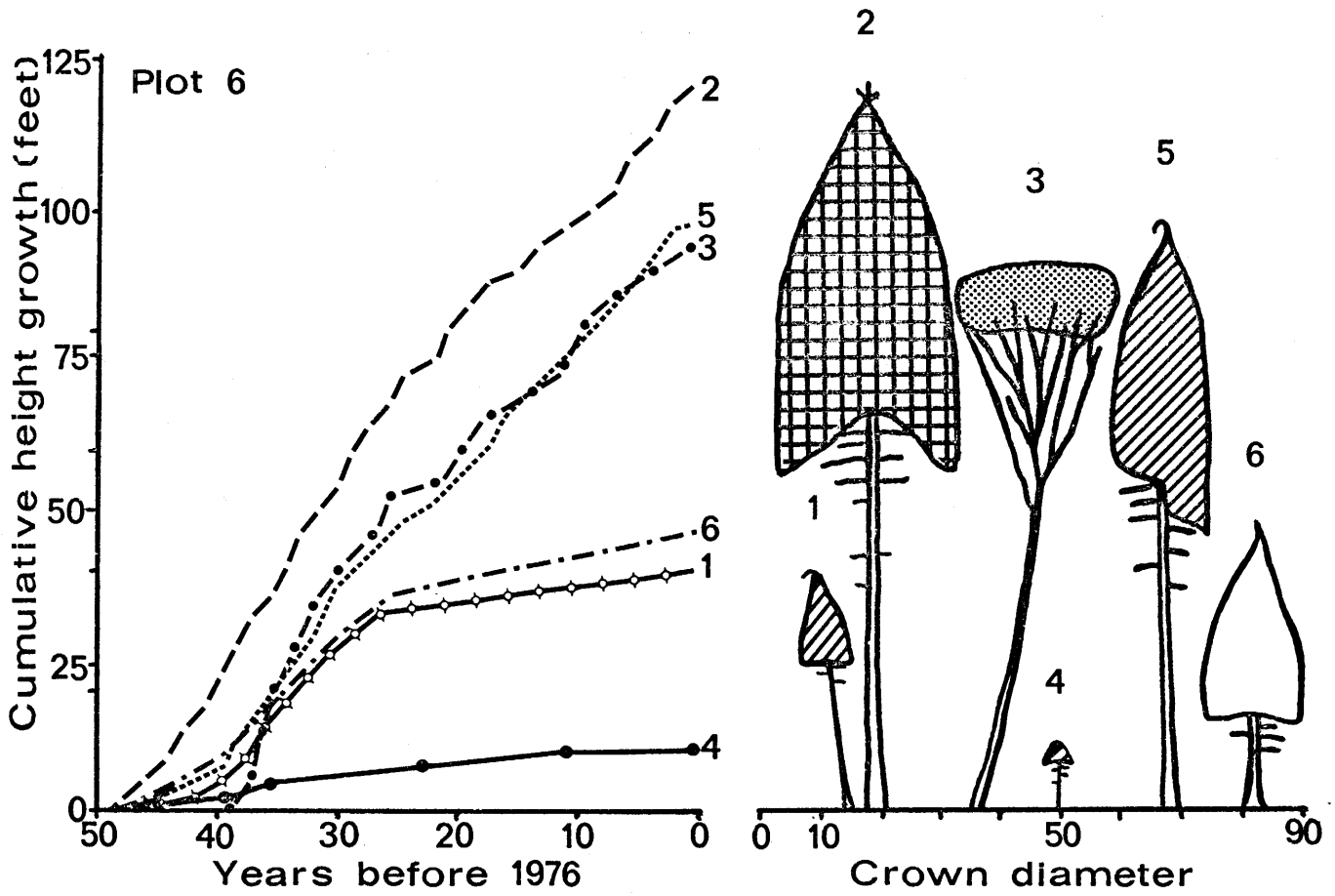


Figure 3.--Height growth patterns of selected red alder (dotted crown), Douglas-fir (gridded crown), western hemlocks (oblique-lined crowns), and western redcedar (blank crown), representing typical height growth patterns and canopy positions.

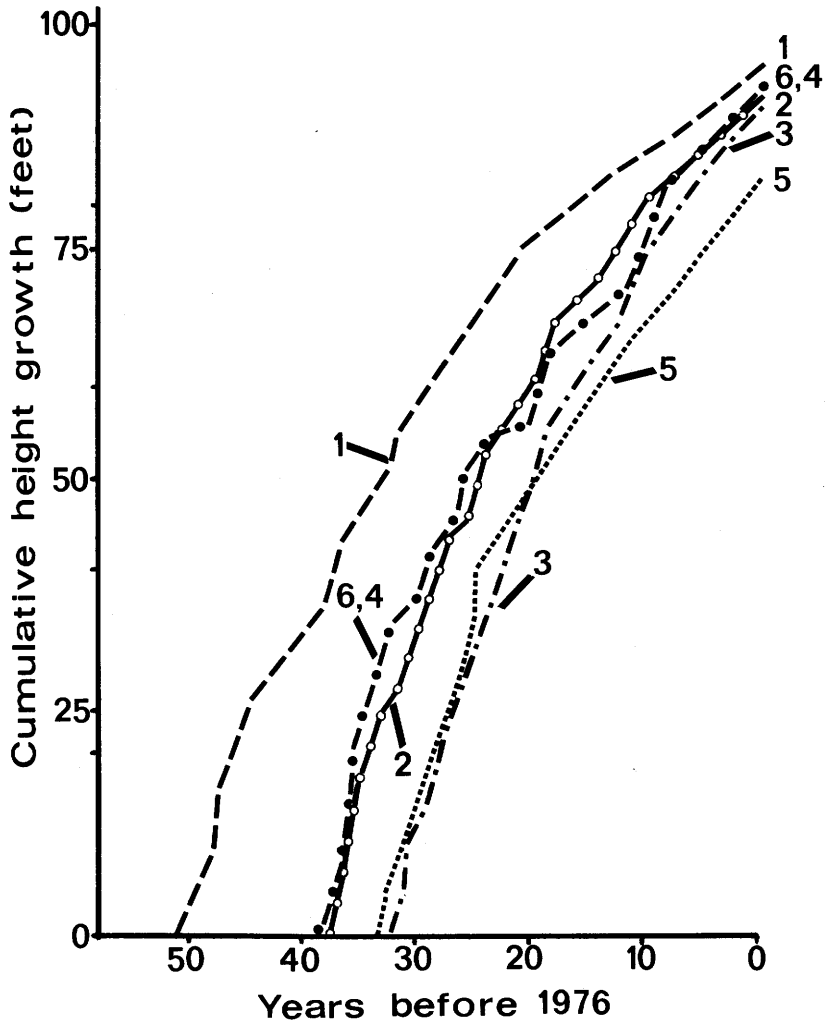


Figure 4.--Height growth pattern of the tallest alder on each plot studied. Height growths of the tallest alders on plots 4 and 6 were averaged because their patterns and times of initiation were very similar.

younger alder grew with more competition from the sides. Consequently, their height growth potential may have been concentrated more strongly into their terminals, rather than developing large lateral branches as well. Diameter growth, however, was reduced on the younger dominants. Figure 5 shows diameter growth patterns of the same five alder shown in figure 4. The restricted crown size of the younger alder may have resulted in more rapid height growth but decreased diameter growth.

The younger alder, about 30 to 35 years of age, typically had slender, twisted, and leaning stems, small crowns, and poor form. This does not mean, however, that alder cannot also be suppressed.

Within each plot, height growth patterns were similar while diameter

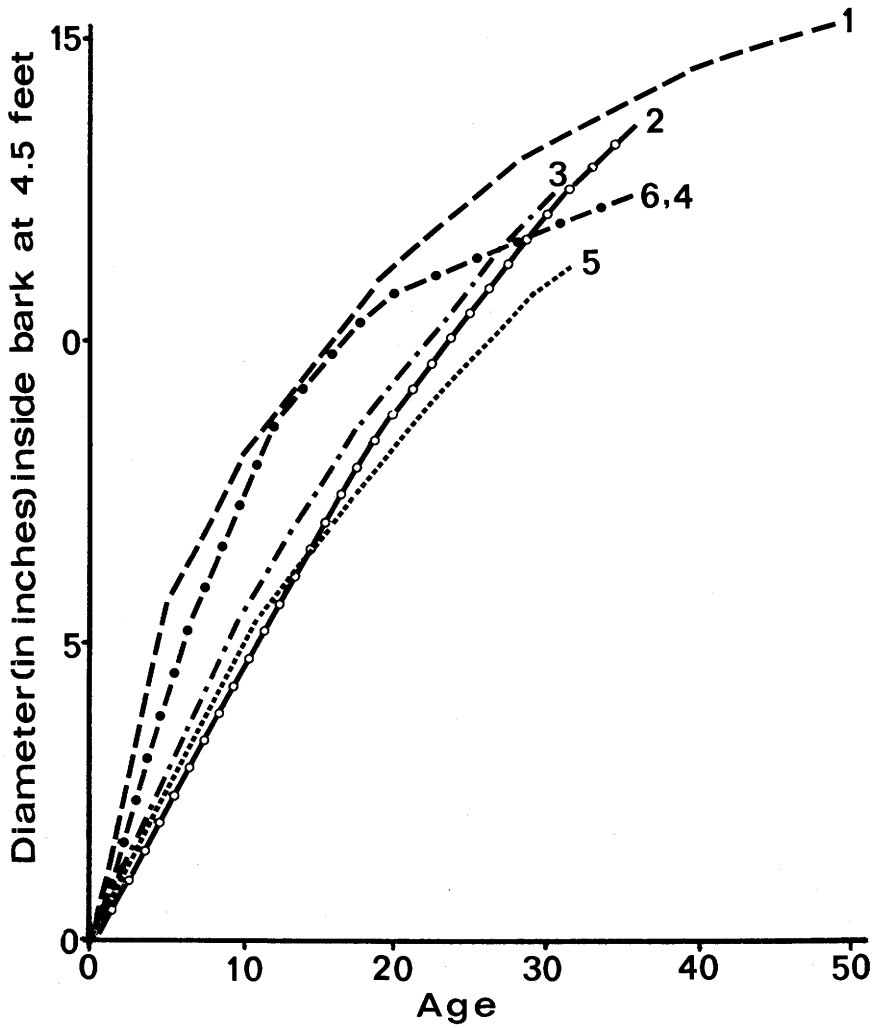
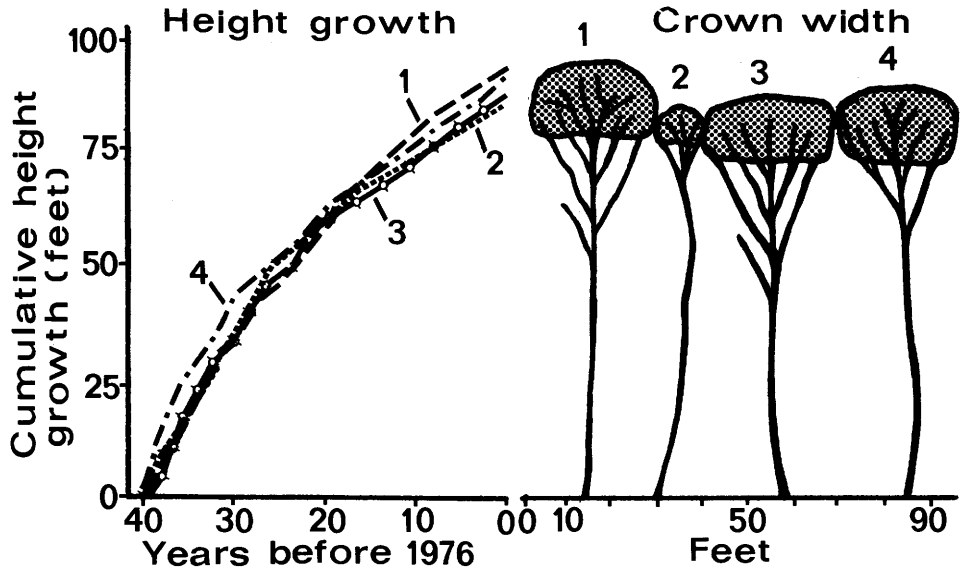
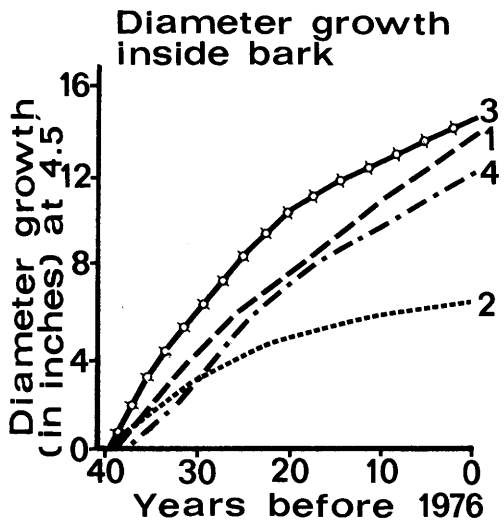


Figure 5.--Diameter growths (breast height, inside bark) of the alders shown in figure 4.

growths varied greatly. Figure 6 shows this for plot 2. There is a similarity in height which seemed relatively unaffected by the crown width. This striking similarity of height growth could lead to the stagnation observed in other studies (Haddock 1948, Warrack 1949).

Diameter growths, however, were directly related to crown sizes. Figure 7 shows the relation of crown surface area projections to basal areas of all the alder examined.





	Height	d.b.h. (in.)	Crown area (feet^2)
1	92'11"	14.9"	673
2	84'11"	7.2"	99.3
3	88' 9"	15.8"	727
4	91' 8"	12.5"	502

Figure 6.--Height and d.b.h. growth patterns and present canopy sizes of all four alders found within one plot. Height growths are very similar; however, crown sizes and diameter growths vary markedly.

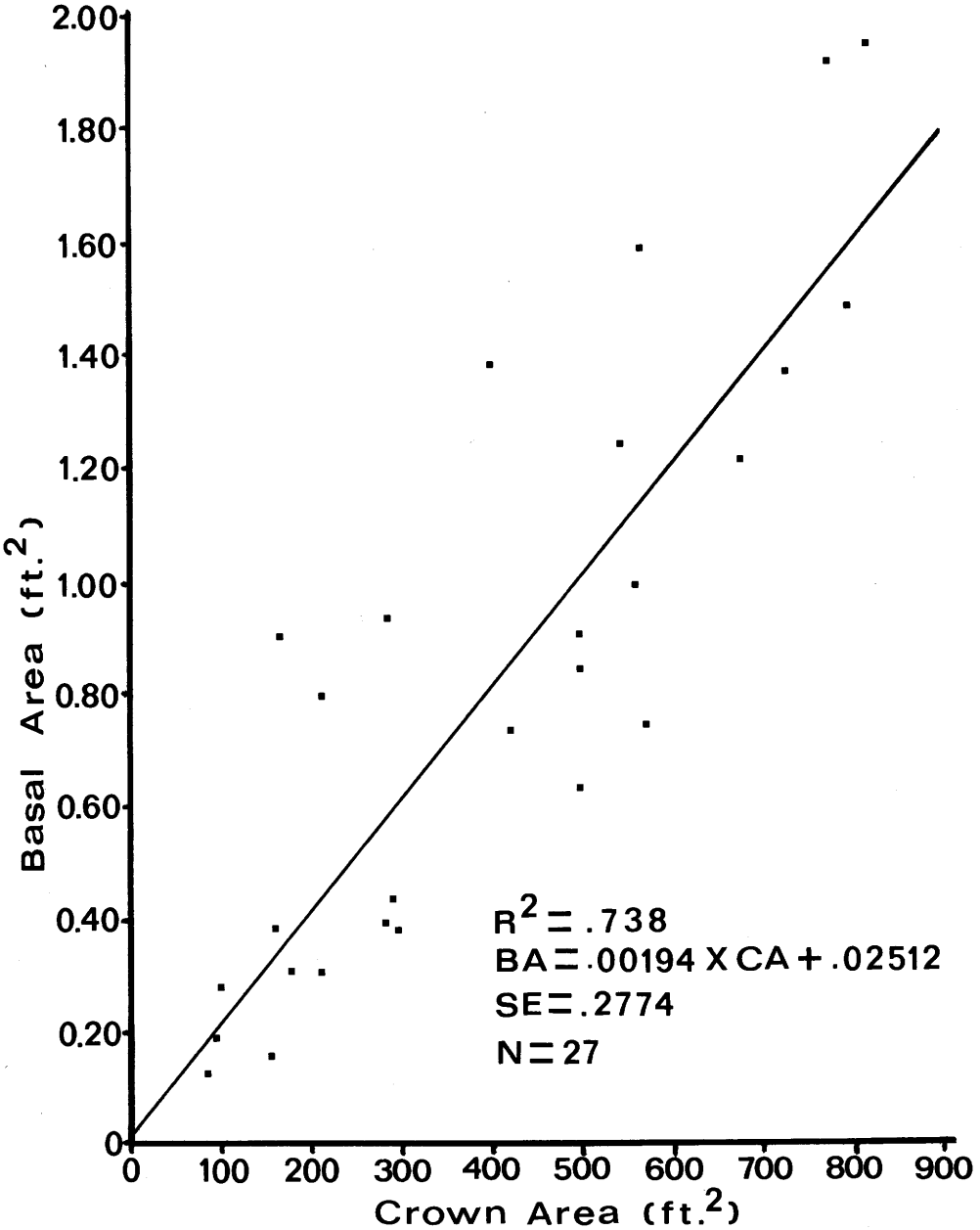


Figure 7.--Relation of individual tree basal area (BA) at breast height to surface area (CA) of the crown projection of the 27 red alders studied.

Silvicultural Opportunities

PURE STANDS

If it is desirable to establish conifers, alder should be eliminated until crown closure of the conifers or until they have a 10-year head start. Intensive use of herbicides is one possibility which presently has varied success. Another alternative may be dense planting of conifers with later precommercial thinnings. With only 350 stems per acre of conifers initially in this study area, the alder were able to invade over an extended period. The future pattern of alder invasion on these sites may be different since an alder seed source now seems readily available over these lands. The ability of alder to overtop conifers permanently, however, may disappear on poor sites.

If alder is acceptable as a crop tree, natural stands may not be acceptable. Natural stands can be of wide age ranges and have poor stocking. Other stands may be so dense that acceptable yields may not be possible without intermediate operations. Precommercial thinnings should be delayed until alder are 6 to 7 years old since new recruitment by seeding will then probably be shaded out. Sprouting may still be a problem. Alder can (if given the chance) produce stems of 10- to 15-inch diameters on rotations of 30 years or less.

Any estimate of site in these natural stands can be confounded by the differences in age and by the wide variation of observed growth patterns.

MIXED STANDS

Mixtures of alder, hemlock, and cedar may also be desirable. These stands can be grown by allowing all three species to enter at the same time; alder will grow above the other two species on good sites. Several silvicultural opportunities are possible.

Cedar grown beneath alder can reduce the brush normally associated with alder. This will reduce site preparation costs during subsequent rotations even if the cedar are not commercially harvested. Cedar could also reduce the limbiness and improve the quality of alder. In fact, discussion at this conference revealed that alder grown with conifers are preferred over alder grown in pure stands. Any cedar volume gained would be a bonus.

Instead of one harvest operation, it may be desirable to remove the alder overwood when the alder reaches a merchantable size. Hemlock and cedar, which it appears can be released from suppression (Oliver 1976), can then be encouraged as a second crop. Presently, this practice is being followed in parts of Europe with aspen (*Populus* sp.) overwoods and Norway spruce (*Picea abies* [L.] Karst.) being the tolerant understory conifer (IUFRO 1976).

It appears that cedar are better suited than hemlock or Douglas-fir in

a two-stage stand such as this. Douglas-fir cannot tolerate the shade. Hemlock did not appear capable of as much height or diameter growth as cedar when in the understory. Some of the hemlock which did grow into the overstory lacked sufficient diameter growth to support their spindly stems upon removal of the alder. Several of these had already bent over in the present stands because of lack of stem support.

In natural mixed stands, we observed that the occasional Douglas-fir which did dominate the alder often were becoming emergent wolf trees. To use these trees as a measure of site index could be misleading since growth can be increased by nitrogen additions from the alder (Tarrant 1961, Miller and Murray 1977). Also, growth is at times decreased since these exposed crowns become knocked out by winds, frosts, and other storms. One Douglas-fir, whose crown was 30 feet above the alders, had its top knocked out three times. Another, which was 15 to 20 feet above the alders, had lost its leader twice.

On accessible lands it may be possible to plant Douglas-fir in rows spaced about 12 feet apart. Alder could be encouraged between these rows and controlled by silage harvests until the firs are tall enough (about 12 feet) to survive any subsequent growth or invasion by alder. In this way, short-term returns could be gained with the silage harvest. Nitrogen would also be added to the site while the alder are being controlled.

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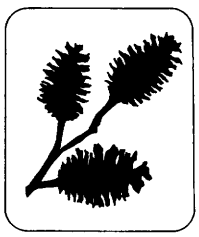
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BIOLOGICAL COMPONENTS OF ALDER YIELD IMPROVEMENT[1]



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ABSTRACT

Although alder has not been extensively used in intensive forestry, its potential is great. Two species, Alnus rubra *Bong. and* Alnus glutinosa *(L.) Gaertn., are particularly promising because of their growth habit, characteristics, and having been studied more than other alders. The concept of ideal plant type, or ideotype, is useful in determining the yield potential and the need for improvement in specific characteristics of crop plants.*

When alders are compared to an ideotype for maximum yield of fiber, they fit well--rapid juvenile growth, ease of vegetative propagation, crown shape, growing season utilization, nitrogen fixation, microbiological relations, genetic variation, and early flowering are all positive. Characteristics with poorer fit are water relations, unit-leaf-area rate of photosynthesis, fecundity, and wood properties. These, however, are susceptible to some genetic and cultural improvement. Recent studies have shown, for example, that photosynthetic capacity and the ability to fix atmospheric nitrogen are closely related but that considerable genetic variation exists in both characteristics.

Introduction

Although alders have not been extensively used in intensive forestry, their potential seems great. Their rapid juvenile growth and their ability to fix atmospheric nitrogen symbiotically recommend them as components of intensively cultured forests. In the Pacific Northwest, alder currently is an abundant, cheap, little-used resource. Elsewhere, however, alder culture is being seriously explored (7). If alder is to be exploited as a forest crop plant in the Pacific Northwest within the next 20 years, we should begin now to understand its growth and development and to estimate its potential for improvement. The purpose of this paper is to discuss alder (based on studies of *Alnus rubra* and *Alnus glutinosa*) as improvable plant material in relation to its potential role in intensive forestry.

[1]This is paper 1178. For. Res. Lab., Oregon State University, Corvallis.

Ideotype

Ideotype, or ideal plant type, is a concept useful in tree and crop improvement. To use the concept, one must design, *a priori*, ideal stand participants for an explicit production goal. There is not, of course, any unique ideal plant type, even of a single species. Rather, many ideotypes, dependent on production goals, can be designed for many purposes. For example, designs for ideal participants in stands grown for maximum yield of biomass would differ from those intended for maximum yield of wood fiber. Ideal stand participants for the production of larger diameter individuals to be used for veneer or sawlog production would differ markedly from either maximum biomass or wood fiber yield ideotypes. Ideotypes for alder intended for use as a nurse crop probably would differ from all these.

Here, I compare the properties of alder to a generalized ideotype for maximum yield of wood fiber (*2*). The major attributes of this ideotype, which assumes dense stands carried over short rotations, are:

(1) full utilization of the growing seasons by meristems from the time of stand establishment;

(2) laterally compact crown and root system, with high proportional investment of photosynthate in cambial activity, and minimum investment of photosynthate in reproduction processes and structures;

(3) high rate of photosynthate production;

(4) maximum production of dry mass per unit of environmental input (water, nutrients);

(5) easy vegetative propagation by cuttings and by sprouting after harvest;

(6) maximum genetic variation and early flowering, to allow rapid genetic improvement; and

(7) wood properties suitable for a wide range of fiber products.

Both *Alnus rubra* and *Alnus glutinosa* fit this general ideotype reasonably well. Both show rapid juvenile growth (*6, 8*). Biomass growth rates of young *A. rubra* stands exceed those published for any other North American woody species.[2] Both *A. glutinosa* and *A. rubra* stumps sprout readily after cutting when young, although *A. rubra* is said to lose this ability after about age 20 years.[3] *Alnus glutinosa* propagates readily from greenwood stem cuttings (*1*). Its use of the growing season is good also because it seemingly remains photosynthetically active well into the fall, as evidenced by retention of green leaves. Both *A. glutinosa* and *A. rubra* are wide ranging

[2]N. Smith, University of British Columbia, Vancouver, BC, personal communication.

[3]M. Newton, Oregon State University, Corvallis, Oregon, personal communication.

and should include great genetic variability. Alders are noted also for early flowering. Seed-to-seed is possible in 2 years. Perhaps the most interesting positive feature of the alders is their ability to fix atmospheric dinitrogen. This process is not without cost; considerable quantities of photosynthate are required to support the high energy demands of nodular nitrogenase activity. Alders, however, can apparently contribute high quantities of fixed nitrogen to the soil while sustaining rapid rates of growth (*9*).

Poorer fit to the ideotype exists for several characteristics. Alders are seemingly prodigal of water. McVean (*6*) states that stomatal control of transpiration is poor in *A. glutinosa*; *A. rubra* appears to be more mesic in its site requirements than *A. glutinosa*. Unit-leaf-area rates of photosynthesis are not high in *A. glutinosa (3)* nor in *A. rubra (5)*. Alders are usually prolific seed producers, and to the extent that this is not useful for reproduction or genetic improvement, it represents wastage of photosynthate from productive processes.

Overall, both red and black alder fit the generalized maximum fiber yield ideotype closely, and both are genetically variable enough so that less desirable characters could be improved. Improvement should be rapid once undertaken because of the alder's capability for vegetative propagation and for early flowering and seed set. One of the most intriguing aspects of potential alder improvement is the possibility of genetic variation in the endophyte organism that causes nodulation of alder roots. There may be optimum combinations of host and endophyte genotype that would result in more efficient nitrogen fixation.

Photosynthesis and N_2 Fixation

One of the best reasons for regarding alder as an important, improvable forest crop plant derives from the relation between photosynthetic capacity and dinitrogen fixation rate. For both soybeans *(4)* and alders (*3*), enhanced photosynthesis seems to lead to higher rates of dinitrogen fixation. If this is so, then attempts to increase dry mass yields by enhancing photosynthesis rates should have a double effect. First, enhanced photosynthesis should, of itself, increase rate of dry matter accumulation. Second, increased dinitrogen fixation should improve the nitrogen status of the plant. This, in turn, should increase the size and duration of the plant's leaf area, which would provide a further photosynthate increment. Studies with *A. glutinosa* clones show that large differences exist among clones in rates of photosynthesis and nitrogenase activity, and that the two are positively correlated ($r=0.86$) (table 1). If these findings are confirmed for larger plants, alders could be selected for accumulation of rapid dry mass and high rates of simultaneously dinitrogen fixation.

Table 1--*Rates of photosynthesis and acetylene reduction, nodule fresh weight, and total plant dry-weight means for each of 12* Alnus glutinosa *clones*[1/]

Clone (number)	Acetylene reduction (nmoles · h^{-1}) per plant	Acetylene reduction (nmoles · h^{-1}) per g nodules[2/]	Photosynthesis per plant (mg CO_2 · hr^{-1})	Nodule fresh weight (g)	Total plant dry weight (g)
5-50	335	386	12.80	0.98	5.29
3-25	266	473	10.90	0.55	4.30
3-23	188	533	8.80	0.40	3.79
1-23	179	332	9.30	0.54	4.28
2-50	157	161	11.80	1.02	4.89
2-58	151	275	8.80	0.52	4.10
3-13	142	352	2.90	0.26	2.11
6-15	133	228	6.80	0.58	3.25
6-12	127	232	7.60	0.57	3.21
5-37	123	171	0.86	0.67	3.05
4-40	38	276	6.60	0.14	2.81
3-21	25	92	6.50	0.15	2.79

[1/]Clone numbers are for identification only, with the first number designating the seedlot and the second, the individual plant from which the clone was propagated. Each tabular value is the mean of three observations.

[2/]Fresh weight.

Future Research

Perhaps the most important task for future research in the improvement of alder yield is to better understand the host-endophyte interactions. In particular, a search for optimum combinations of host and endophyte genotype should be launched. The gathering of endophyte from a wide range of habitats and its application to a known set of clonal alders would give a rapid indication of whether growth rate gains could be expected from larger trials. At the same time, a full range of alder genotypes should be collected, examined for fit to carefully constructed ideotypes, and used in breeding experiments to see whether a closer approach to ideotypes is possible. The silvicultural systems that gave rise to the ideotypes should be field tested with improved alders on a variety of sites representative of those where alder culture is contemplated. Of course, such a program is desirable only if we intend to use alder as a component of intensive silviculture in the Pacific Northwest at some future time. Many of its biological properties indicate that this would be a sensible thing to do.

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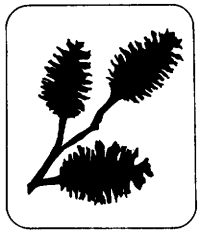
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COMPARATIVE MINERAL CYCLING IN RED ALDER AND DOUGLAS-FIR



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ABSTRACT

*A comparative study of mineral cycling between second-growth forests of red alder (*Alnus rubra*) and Douglas-fir (*Pseudotsuga menziesii*) was made at the Thompson research site within the Cedar River watershed, western Washington. Both sites have similar histories and are adjoining on glacial drift material. The rate of elemental cycling is far faster in alder than in Douglas-fir. The red alder ecosystem is accumulating 85 kg·ha^{-1}·yr^{-1} more nitrogen than the Douglas-fir, apparently through biological fixation. Greater percentages of the nutrients are stored within the trees and understory vegetation in the alder ecosystem, but these nutrients remain within the foliage and forest floor two to five times longer in Douglas-fir than in alder. Nutrient leaching losses are slightly higher within the alder ecosystem. This study helps clarify the role of red alder in second-growth forests and provides insight into the management of this type of ecosystem.*

Introduction

The biological merits of mixed softwood-hardwood forests emerged with the development of intensive forestry in Germany. Experience with pure strains of Norway spruce on sandy soils of northern Germany has led silviculturists to strongly recommend mixtures of hardwoods with conifers or hardwoods in place of conifers. As with many biological forestry problems, however, there is no simple solution because pure stands of beech can lead to podzolization. Obviously, the nature of the problem relative to pure or

mixed stands depends on the characteristics of the species and the nature of the forest environment, especially the soil.

These brief historical aspects are introduced to provide a setting for a discussion of the impact of red alder and Douglas-fir with respect to mineral cycling in northwest forests. The same concerns relative to pure stands frequently have been voiced in northwest forestry and red alder has been advocated as a species to provide a softwood-hardwood mix. Alder does have several merits for this purpose and most of these are already known to the audience making up this symposium. The principal advantage reported for red alder is its nitrogen-fixing ability and therefore the contribution of significant amounts of this element to our generally nitrogen-poor environments.

The higher nitrogen content of red alder litter not only provides for rapid buildup of soil nitrogen but also leads to a more rapid decomposition rate of organic material in the soil and forest floor. This change in the soil nutritional status and decomposition rates affects many additional properties of the soil system including the microbiological populations, release of minerals, and rates of leaching.

While it is true that both alder and Douglas-fir can occupy similar sites in the Pacific Northwest, many times as a mixed-species forest, they have little else in common. It is a purpose of this paper to assess some of the differences between the species, especially as they relate to the rate of cycling and accumulation of nutrient elements. Specifically, the following comparisons have been made:

1. Rate of elemental accumulation occurring within the major compartments of these ecosystems. From this comparison we will calculate the rate and location of nitrogen accumulation associated with an alder forest.
2. Rate of elemental transfer between major compartments within these two ecosystems, including rates of inputs and losses. This comparison provides us with an estimate of the relative capacity of these systems to conserve, store, and recycle nutrients.
3. Rate of elemental turnover in the foliage and forest floor compartments of these systems. From the comparisons we can estimate the length of time that nutrients remain within these two major ecosystem compartments.

It is our opinion that these results have a significant application to the management of forests in the Pacific Northwest.

The red alder and Douglas-fir stands compared in this article are situated on the Cedar River watershed in western Washington. These forests are adjoining each other on similar glacial drift materials. The study site is at approximately 230-m elevation, 64 km southeast of Seattle. Both stands have had similar histories. The entire area was harvested by clear-cutting nearly 50 years ago. Frequent fire passed through the site until

1928, when the Douglas-fir plantation was established. Alder naturally seeded itself to the Douglas-fir plantation boundaries, thus the forest is now composed of two nearly pure stands, one of alder, the other of Douglas-fir. It has been assumed that the differences currently found in the accumulation and cycling in these two adjacent ecosystems are caused by the vegetation and do not predate the establishment of these stands. From tree ring analysis and from the forestry inventory records of the City of Seattle Water Department, the Douglas-fir forest is now 47 years old. A ring analysis of the alder indicates a minimum age of 38 years.

Methods

Details of the field installation necessary for making the many measurements associated with these studies of mineral cycling have been described in earlier articles. The basic plot design, site description, and environmental monitoring systems are discussed by Cole and Gessel (*1*). The lysimeter system for collecting soil solutions is further detailed by Cole and Gessel (*2*).

Necessary chemical analyses were completed in laboratories at the College of Forest Resources at the University of Washington. Soil nitrogen was analyzed by the Kjeldahl procedure. Soil potassium and calcium were determined with an atomic adsorption spectrophotometer (Instrumentation Laboratories 353) following extraction with ammonium acetate. Organic samples such as foliage, wood, and forest floor were initially digested using a lithium sulfate modification of the Kjeldahl procedure (*5*). The nitrogen in these digestions was then determined with a Technicon Autoanalyzer (model II), and the potassium and calcium determined by atomic adsorption.

Results and Discussion

For the purposes of the comparison, three elements have been selected--nitrogen, potassium, and calcium. Nitrogen is the most critical element in the assessment in that it is in deficient supply within the Douglas-fir system and has been added to the alder system through a fixation process. Potassium and calcium were selected because of the relative mobility of these two elements. Potassium is not associated with structural materials of the plants and does not have to be mineralized to be released from organic substrates, thus it is highly mobile. Calcium, by contrast, accumulates in the older tissues, typically as a sulfate oxalate precipitate, and is therefore highly immobile within plant tissue. Theoretically, these two elements also behave differently within the soil solution because of differences in valence and ionic size.

It is evident through a comparison of nitrogen, potassium, and calcium accumulation and redistribution that alder and Douglas-fir have structured strikingly different ecosystems during this 38- to 48-year period. For example, in a 38-year period red alder has accumulated an additional 2 180

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kg/ha of nitrogen over that found for Douglas-fir (table 1). Although most of this accumulation can be found in the soil and forest floor, the total aboveground vegetation in the red alder ecosystem also contains large quantities of nitrogen (690 kg/ha)--an amount over twice that found in the associated vegetative component of the Douglas-fir ecosystem. A significant portion of this accumulation (100 kg/ha) is contained in the understory, which is largely a dense sword fern population.

We found no marked difference between red alder and Douglas-fir ecosystems in relation to total potassium and calcium accumulation by the vegetation (table 1). More of the total is contained in the subordinate vegetation of the red alder system (table 2), however, partly because of the greater density of subordinate species under red alder than under Douglas-fir, and also because of the high potassium (and, to a lesser extent, calcium) concentrations in the tissue of sword fern. The red alder ecosystem consistently contains a greater percentage of its elemental distribution above ground than that found for Douglas-fir (fig. 1).

Table 1--*Elemental distribution in red alder and Douglas-fir ecosystem (kg/ha)*

Element/ecosystem	Vegetation	Forest floor	Soil (exchange)	Soil (total)
Nitrogen				
Douglas-fir	330	180		3 270
Red alder	690	880		5 450
Potassium				
Douglas-fir	230	30	240	71 500
Red alder	230	90	140	77 200
Calcium				
Douglas-fir	340	140	740	98 800
Red alder	400	390	840	96 600

Table 2--*Distribution of elements within the vegetative components of red alder and Douglas-fir ecosystems (kg/ha)*

Element/canopies	Douglas-fir	Red alder
Nitrogen		
Overstory	320	590
Understory	10	100
Potassium		
Overstory	220	100
Understory	10	130
Calcium		
Overstory	330	300
Understory	10	100

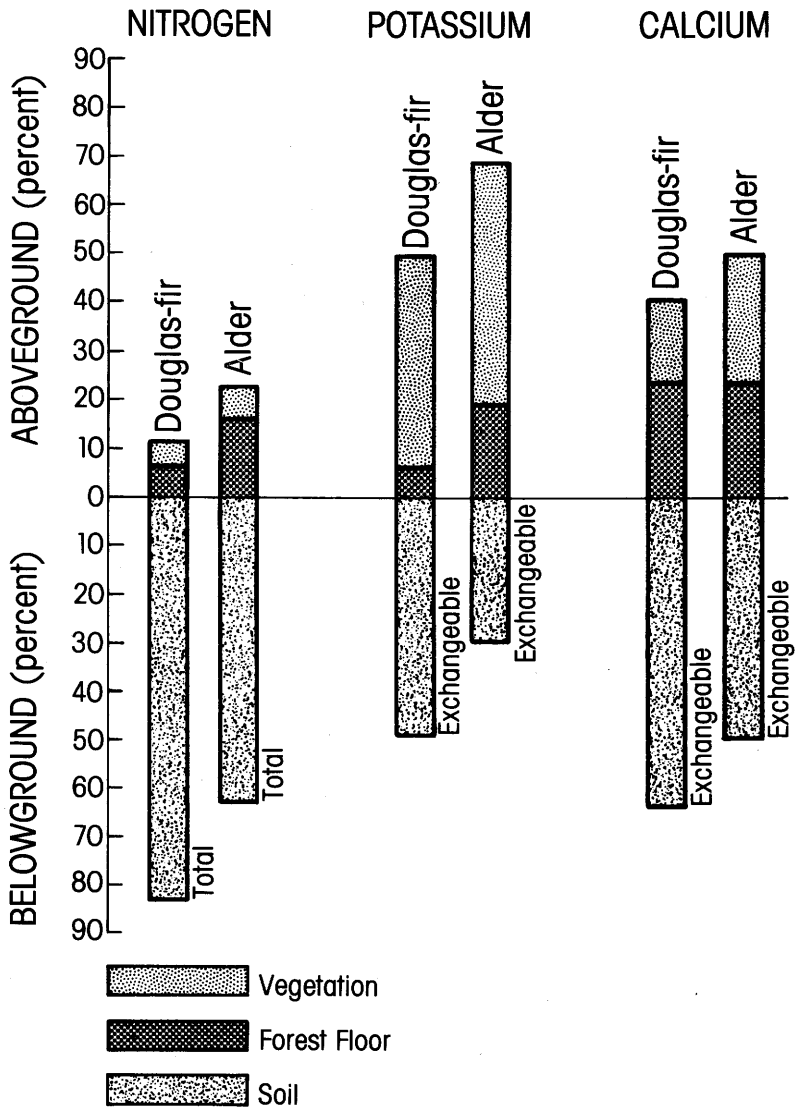


Figure 1.--Elemental distribution in red alder and Douglas-fir ecosystems.

Our data allow us to estimate the average annual rate of nitrogen accumulation[1] in red alder stands. During the approximate 38-year period of alder growth on this site an average annual nitrogen accumulation of 85.3 kg/ha has occurred. This annual increment of nitrogen is distributed within all the ecosystem components, with 57.4 kg in the soil, 18.4 kg in the forest floor, and 9.5 kg in the overstory and understory vegetation (table 3). This rate of nitrogen accumulation is not inconsistent with

[1]Nitrogen accumulation in the alder ecosystem is defined as the net difference in nitrogen content between the alder and Douglas-fir ecosystems.

other values reported in the literature. Tarrant and Miller (1963) calculated an average annual accumulation of 41 kg/ha over a 30-year period of alder occupancy relative to Douglas-fir occupancy of similar sites. Newton and co-workers (1968) have reported an extremely high value of annual accumulation of 321 kg/ha over a 15-year period of alder occupancy on sites near the Oregon coast.

Table 3--*Estimated nitrogen accumulation and average annual accumulation by 38-year-old red alder (kg/ha)*

Vertical Zone	Estimated N accumulation		Increase in red alder over Douglas-fir	Average annual accumulation
	Douglas-fir	Red alder		
Overstory	320	590	270	7.1
Understory	10	100	90	2.4
Forest floor	180	880	700	18.4
Soil	3 270	5 450	2 180	57.4
Total	3 780	7 020	3 240	85.3

Major differences in the pathways of elemental transfer in these ecosystems are also apparent (table 4). The annual elemental return by throughfall and litterfall is six to eight times greater in the case of alder than in Douglas-fir. The annual uptake is three to five times greater. By comparing uptake with return (throughfall, litterfall) we can obtain some insight into the amount of annual increase occurring in the program for these two species. The comparison clearly shows that the Douglas-fir system still has a net annual increase while alder has nearly reached a steady state between uptake and return. This fact implies that alder has reached maturity and is nearly at the end of its rotation age while Douglas-fir is still growing. These results are consistent with the respective ages of the two stands and from what we know to be their life expectancy.

Loss of nutrients by leaching appears to be slightly greater under the alder ecosystem (table 4). Lysimeter collections of soil solution beneath the rooting zone have demonstrated that some increase in the leaching of nitrogen was found, in all probability because a greater amount of soil nitrogen is converted to the nitrate form in the presence of alder. Nitrate-to-ammonium ratios are strikingly different in the nitrate concentration of soil samples collected under the 38-year-old alder stand and an adjacent alder stand only 10 years old (table 5). For example, the ammonium-to-nitrate ratios shift from 0.01 or 1:100 at the age of 10 to 0.29 or 1:3 at the age of 38 years. In contrast, the ratio did not change for the Douglas-fir sites, but remained at 1:50 for both the 10-year-old and 48-year-old sites.

The period of time that nutrients remain within the forest floor and foliage is called *residence time*. In the case of Douglas-fir, this time is

Table 4--*Annual nutrient transfers in red alder and Douglas-fir ecosystems (kg/ha)*

Element/process	Douglas-fir	Red alder
Nitrogen		
Precipitation	1.1	1.7
Throughfall	1.5	8.8
Litterfall	13.6	111.1
Uptake	39.0	130.0
Leaching loss	0.6	2.2
Potassium		
Precipitation	0.8	2.2
Throughfall	10.7	12.4
Litterfall	2.7	67.0
Uptake	29.0	98.0
Leaching loss	0.02	No data
Calcium		
Precipitation	2.8	2.2
Throughfall	3.5	10.0
Litterfall	11.1	83.0
Uptake	24.0	116.0
Leaching loss	4.5	5.6

Table 5--*Soil ammonium and nitrate*[1/] *in two age classes, for Douglas-fir and red alder ecosystems*

Ecosystem	NH_4^+ PPM	NO_3^- PPM	NO_3^-/NH_4^+
Alder (age 10)	7.5 ± 2.6	0.10 ± 0.06	0.01
Douglas-fir (age 10)	6.8 ± 4.1	0.12 ± 0.04	0.02
Alder (age 38)	20.6 ± 2.6	5.90 ± 2.30	0.29
Douglas-fir (age 48)	1.9 ± 0.6	0.05	0.02

[1/] Samples collected and analyzed June 1976.

about 4 years, and translocation of nitrogen from alder to young foliage occurs at senescence. With alder, the residence period reflects translocation of nitrogen from the leaf to the adjacent stem tissue before leaf fall (fig. 2). The residence time for nitrogen in the foliage of Douglas-fir is estimated to be 6.5 years while that for alder was only 1.1 years. Residence time in the forest floor showed a similar trend with the nitrogen remaining in the Douglas-fir site 10.2 years and 7.5 years in the alder site. The residence time of nutrients in the forest floor was always greater than the foliage except in the case of potassium at the Douglas-fir site. This was probably because potassium is not part of the organic structure and readily leaches once the organic material is dead.

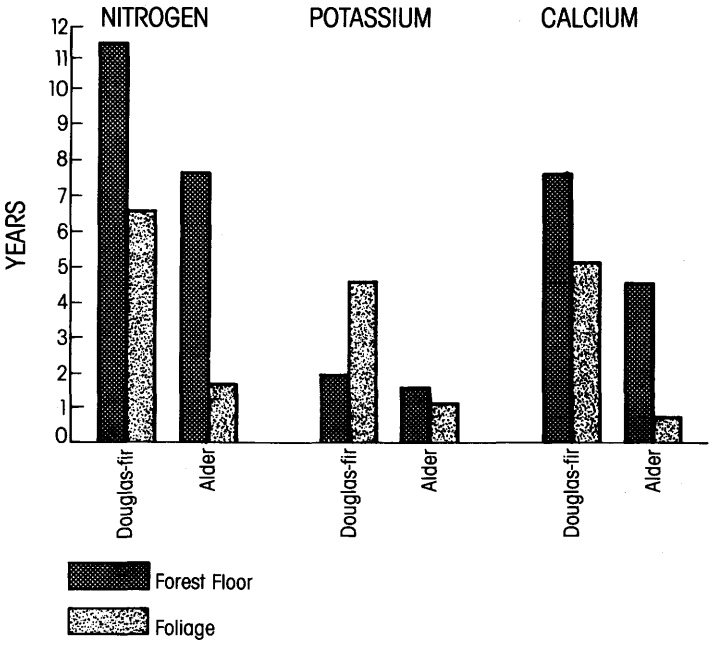


Figure 2.--Elemental residence time (yrs) in the foliage and forest floor of red alder and Douglas-fir ecosystems.

The tendency for the forest floor under red alder to decompose at a more rapid rate than under Douglas-fir can be seen in figure 2 and is further confirmed from the decomposition data presented in table 6. When a standard decomposition bag technique was used,[2] the forest floor organic matter residence time for alder was approximately one-third that of the Douglas-fir (table 6). This was caused more by the rapid rate at which the woody material under the alder decomposed than the rate at which the foliage itself was broken down.

Table 6--*Organic matter decomposition and forest floor residence times for red alder and Douglas-fir ecosystems*[1/]

Ecosystem	Annual weight loss		Forest floor turnover period
	Foliage	Woody material	
	- - - - -Percent- - - - -		Years
Douglas-fir	46.5	5.7	9.1
Alder	55.1	12.9	3.7

[1/] Data supplied by Robert L. Edmonds, College of Forest Resources, University of Washington.

[2] Personal communication, Robert L. Edmonds, College of Forest Resources, University of Washington.

Conclusions

From comparative study of these two ecosystems, we can draw the following conclusions:

1. Elemental cycling is faster in the alder than in the Douglas-fir ecosystem--three to five times faster for uptake and six to eight times faster for return to the forest floor.
2. The alder forest appears to be reaching a steady state (difference between uptake and return) at age 38 while the Douglas-fir forest is still accumulating nutrients at age 48.
3. The red alder ecosystem is accumulating annually 85 kg/ha more nitrogen than is the Douglas-fir ecosystem, apparently because of biological fixation. The greater part of this accumulation is taking place in the soil and forest floor.
4. A greater percentage of nutrient elements is stored above the soil in the alder ecosystem, which could have a potential implication regarding nutrient loss due to harvesting of the stands.
5. Nutrients remain in the foliage and forest floor two to five times longer in Douglas-fir than in alder.
6. Nutrient leaching in the soil under the alder stand appears to be slightly greater than under Douglas-fir because we believe the rate of nitrification is greater in the alder soil.

There is a significant difference between the two species with regard to their mineral cycling properties. We believe that the differences carry considerable weight with regard to how the systems should be managed and the potential desirability of growing them as a mixed forest.

Results from this study clearly show the soil-improving attributes of red alder, especially in relationship to nitrogen supply. This characteristic assumes greater importance in forest management in Douglas-fir forests because of the repeated demonstration of nitrogen deficiency over a wide range of environmental conditions. The possibility of managing forest lands for capture of the nitrogen input of red alder to improve growth rate and wood production of Douglas-fir must be seriously considered. An economic value for this input can be roughly estimated by attaching a per-pound value to the added amount of nitrogen accumulating in these ecosystems and relating it to the cost of applying a similar amount of nitrogen by other means as reported elsewhere in this symposium.

Acknowledgments

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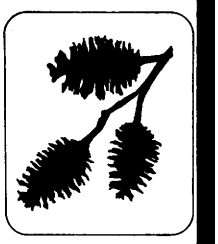
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THE VALUE OF RED ALDER AS A SOURCE OF NITROGEN IN DOUGLAS-FIR/ALDER MIXED STANDS



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ABSTRACT

Numerous studies of forest fertilization have demonstrated that Douglas-fir stands in the Pacific Northwest and British Columbia grow better when fertilized with nitrogen. Since the long-term outlook for fertilizer supply and cost is uncertain, foresters should be examining alternatives for maintaining and increasing forest productivity. Several nitrogen-supplying species of plants exist, of which red alder is the most interesting. Alder not only imparts significant amounts of nitrogen to the forest soil, but also is a tree of increasing value for wood products.

This paper examines the economic value of alder both as a source of nitrogen and for its wood value. Three approaches are taken:

(1) An economic analysis is made of existing research plot data on the Wind River Experimental Forest. Results are contrasted with the alternative of artificial fertilization.

(2) Investigations of the nitrogen supplying capability of red alder reveal that relatively few alders are needed in order to supply Douglas-fir with its nitrogen needs.

(3) A general model is proposed for evaluating alder's place in Douglas-fir forest management. Data requirements are identified.

Introduction

This paper discusses the current use of nitrogen fertilizer in Douglas-fir management, presents a brief analysis of future nitrogen fertilizer

supplies, considers possibilities for adding nitrogen through biological means, provides a financial analysis of Douglas-fir/red alder mixed stands, and, finally, conceptualizes a general model for evaluating red alder nitrogen input to a forest system.

CURRENT USE OF NITROGEN FERTILIZER

The artificial fertilization of Douglas-fir stands in the northwestern U.S. and British Columbia is one of the most intensive research areas in forestry (*1, 5*). Out of this effort has come one obvious conclusion: deficient nitrogen is the nutritional factor most limiting growth of Douglas-fir. Table 1 contains typical research results, and indicates that growth response to nitrogen is impressive.

As a result of impressive gains from nitrogen, along with large price increases for logs and trees, the silvicultural practice of fertilizing the forest has grown to be an extremely large business, covering many hundreds of thousands of acres. Annual cost of this activity will be close to $20 million by 1978. Barring a sharp rise in fertilizer cost, or a decline in wood value, operational forest fertilization of Douglas-fir can be expected to continue to increase at a fast rate.

Table 1--*Estimated mean response of 4-year gross total volume growth for Douglas-fir (percent above unfertilized control)*

Breast height age class (years)	Treatment (pounds of N per acre)	Site class			
		I	II	III	IV
		- - - - - - -Percent- - - - - -			
10	200	11	23	--	--
	400	12	26	44	--
20	200	6	14	24	41
	400	7	15	28	--
30	200	6	13	23	40
	400	7	15	26	45
40	200	6	13	24	41
	400	7	15	27	47
50	200	6	14	25	43
	400	7	16	28	--

Source: Regional Forest Nutrition Research Project, University of Washington.

NITROGEN FERTILIZER SUPPLY

The principal fertilizer used in forest fertilization is urea, which contains 46 percent nitrogen. Urea is a combination of ammonia and carbon dioxide. Ammonia is made by combining hydrogen from a natural gas such as methane with nitrogen from the air (fig. 1). Since nitrogen comprises 78 percent of the air, the supply of this element is, for all practical purposes, unlimited. Hydrogen is the key to urea manufacture. Nitrogen is

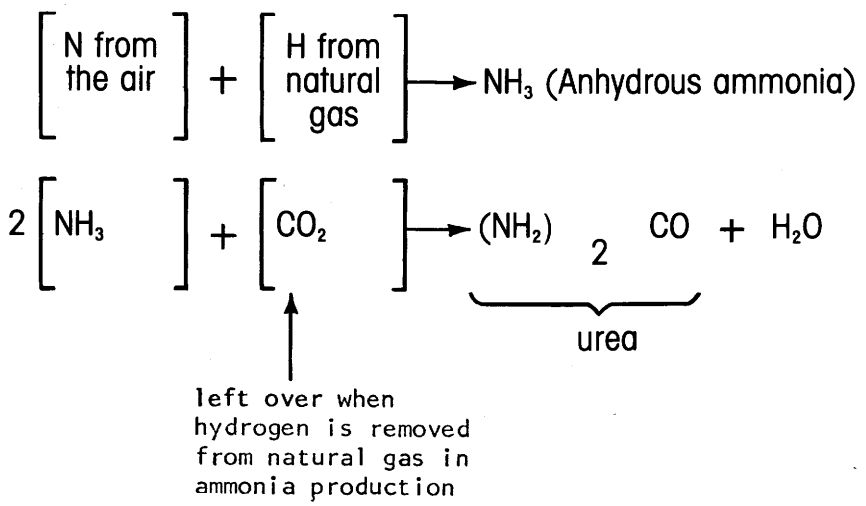


Figure 1.--Urea manufacturing process.

captured from the air in the process of making ammonia, but it requires 3 ft^3 of hydrogen to capture 1 ft^3 of nitrogen (*10*).

In addition to natural gas, hydrogen can be obtained from other petroleum derivatives, coal, wood chips, crop refuse, sewage sludge and, in fact, almost any combustible material. Natural gas, however, is the feedstock for almost all ammonia manufactured in North America; and it is being used up at an alarming rate. Proven reserves are declining steadily.

As we approach the end of the century, North America may turn to coal for its energy needs. In terms of availability, coal is the hydrocarbon with greatest potential for supplementing gas. Reserves of coal will last hundreds of years at current rates of use. At current levels of technology, however, the manufacture of nitrogen fertilizers based on coal will cost 50-75 percent more than today's gas-derived fertilizers (*10*).

At best, though, coal is an interim answer. A coal-based economy would use up coal reserves relatively quickly, so that supplies that now appear adequate for several hundred years might last considerably less.

It is also possible to use electricity to produce hydrogen, but this would require large amounts of electricity to decompose water into hydrogen and oxygen. The only foreseeable means of producing such amounts of electricity at affordable costs are fast breeder nuclear reactors and fusion processes.

Other possibilities also exist for supplying hydrogen in the future, but the fact must be faced that supplies of nitrogen fertilizer, being

directly linked to energy production, are certainly not assured in the future at prices resembling those we have today. Fertilizers will probably be available over the rotation of forests currently being planted, but the question is: "at what cost?" A truthful answer is that no one has any idea.

NATURAL FERTILIZATION

With the preceding background, it is clear that foresters and farmers should be exploring other avenues than synthetic chemical fertilization for maintaining and increasing productivity of their lands. Several possibilities exist. For example, legumes have the ability to supply their own nitrogen from the air and make it available to the crop. Another approach is through the use of blue-green algae, which can live on mineral elements, carbon dioxide,and solar energy, and from this produce ammonia. Both snowbrush and bitterbrush, two common forest plants, also fix nitrogen in root nodules (*13*).

Foresters in the Douglas-fir Region also have a naturally growing tree species that not only imparts nitrogen into the soil, but also grows rapidly and produces valuable wood. This species is red alder. It has long been known that red alder bears root nodules that develop into clusters of considerable size (*7*). Atmospheric nitrogen has been shown to be fixed in these nodules. Nitrogen so produced is translocated to other parts of the plant (*2*).

Litterfall beneath alder stands is an important contributor of nitrogen to the soil system. Red alder foliage has a much higher nitrogen content than does conifer foliage, and the amount of litterfall beneath alder stands greatly exceeds that of associated conifers (*6*).

Another major route of nitrogen from plant to soil is by direct excretion from living roots and nodules. It has been estimated that 60 percent of the soil nitrogen added in stands of red alder came from nodule excretions or free living micro-organisms (*15*).

Decomposition of dead roots and nodules is an obscure pathway for soil nitrogen enrichment by alder, and precipitation and fog-drip are additional means by which the nitrogen of alder trees is conveyed to the soil. Nitrogen contents of both stemflow and leaf-wash are higher beneath alder stands than conifer stands (*11*). Total annual contribution of available nitrogen to the soil by a fully stocked 38-year-old alder stand is in the neighborhood of 76 lbs per acre/yr (*3*). This represents a substantial contribution of nitrogen to the system.

FINANCIAL ANALYSIS OF RED ALDER AS A SOURCE OF NITROGEN

Very little empirical data are available on the fertilizer effect obtained by growing red alder as part of a predominantly Douglas-fir stand. Several researchers have reported on what is considered to be the only existing example of a valid comparison between the growth and development

of a pure Douglas-fir stand and a mixed Douglas-fir/red alder stand (*8, 11, 12*). These stands are adjacent to each other and are located on the Wind River Experimental Forest in southwestern Washington. Stand data are given in table 2.

Table 2--*Stand data - Wind River alder/Douglas-fir plots*[1/]

Species	Mixed stand	Pure stand
Douglas-fir seedlings planted (1928)	680/acre	680/acre
Red alder seedlings planted (1932)	1,210/acre	0
Douglas-fir volume in 1975 at age 47	27.00 CCF/acre	23.23 CCF/acre
Red alder volume in 1975 at age 43	19.41 CCF/acre	0
	46.41 CCF/acre	23.23 CCF/acre
Douglas-fir stems/acre in 1975[2/]	191	301
Red alder stems/acre in 1975[2/]	242	0
	433	301
Douglas-fir average tree size in 1975[2/]	14.1 ft^3	7.7 ft^3
Red alder average tree size in 1975[2/]	8.0 ft^3	0

[1/] Volumes are cubic volume to a 4-inch top.

[2/] 5.5-inch d.b.h. and larger.

Which stand would you rather have? The mixed species stand is undoubtedly the more valuable of the two, with a considerably higher volume and a larger tree size. These advantages, however, were obtained at the cost of planting 1,210 additional red alder trees per acre. Was this additional investment profitable? If the experiment were repeated, starting in 1977, would the mixed species stand still appear the better choice?

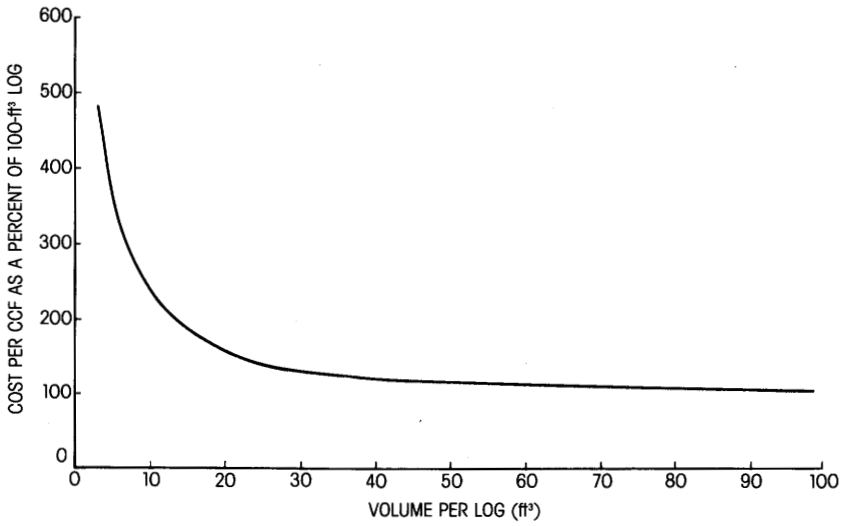
And, suppose we add a third alternative--fertilize the pure Douglas-fir stand at age 40. How does this approach compare in profitability to the other two alternatives? This latter alternative can be based on comparable data because, in fact, a fertilizer experiment was actually established in the pure Douglas-fir stand (*9*).

Hence, two questions will be examined:

1. If this experiment was repeated, starting in 1977, would the mixed species stand still appear to be the most profitable choice?
2. How do the mixed stand and pure stand alternatives compare in profitability with artificial fertilization of the pure stand?

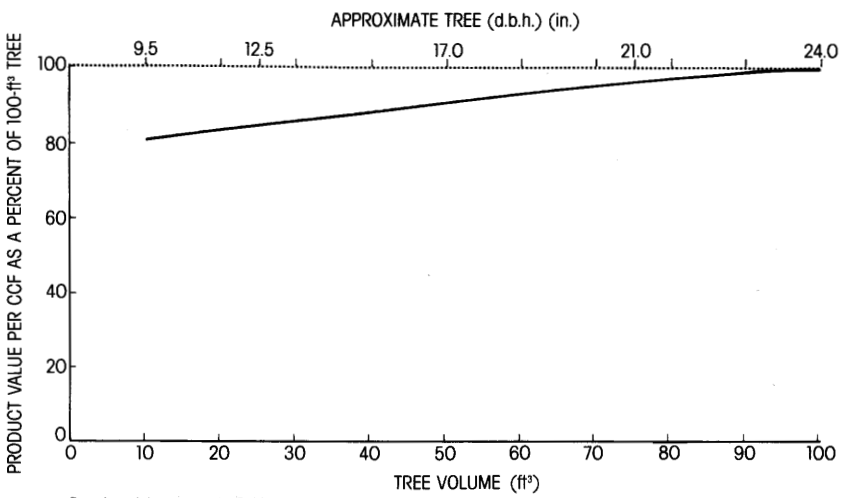
Before an attempt is made to value timber produced in this experiment, an assumption must be made regarding future stumpage prices. The best way

to do this is by examining the determinants of present stumpage price. Figure 2 illustrates the relationship between log size and harvest cost and indicates that small logs are much more expensive to handle than large logs. Not only are small logs and trees less valuable than large logs and trees because of harvest cost differences, but larger material also qualifies for higher and more valuable log grades and produces more lumber and less chip volume (fig. 3).



Source: T. C. Adams, "Production rates in commercial thinning of young-growth Douglas-fir," PNW-41, table 4.

Figure 2.--Effect of log size on logging cost using a 60-hp. wheel skidder (percent of 100 ft^3 logs).



Based on data reported by Dobie, Kasper and Wright, 1975, "Lumber and chip values from B.C. coast tree and log classes," B.C. Forest Products Lab.

Figure 3.--Effect of tree size on product value of Douglas-fir.

Estimates of average 1977 stumpage prices for Douglas-fir and red alder are given in figure 4. Red alder stumpage is generally of considerably lower value than Douglas-fir because of higher logging costs and lower merchantable yield per acre. An examination of 1976 log prices in Washington[1] revealed that once alder logs appear at a log yard they are worth almost as much as young-growth Douglas-fir. The problem is in the higher unit cost of moving alder out of the forest.

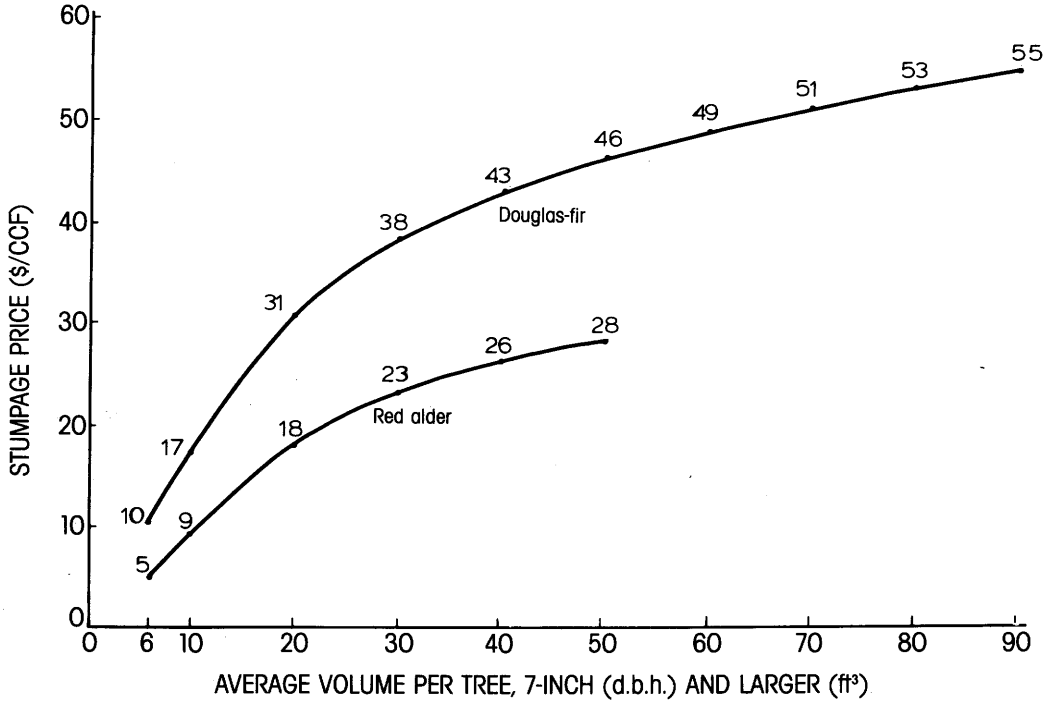


Figure 4.--Average stumpage prices by tree size for Douglas-fir and red alder (dollars per cunit).

Figure 4 is the starting point for future price estimates. It is assumed that the value relationship between tree sizes will remain unchanged over the next 47 years[2] and that all prices and costs, including fertilizer costs, will increase at an average "real" (i.e. inflation free) annual rate of 3 percent per year. Cost and value estimates, expressed in terms of 1977 dollars, are presented in table 3. The three alternatives are shown in schematic form in figure 5.

Present net worth analysis was used to compare the three alternatives, using a 6-percent "real" discount rate (table 4). The cost of interplanting such a high density of (1,210 trees per acre) of red alder trees causes the mixed-species stand to be a less profitable alternative than artificial

[1]Data from monthly log price reports of the Department of Natural Resources, State of Washington.

[2]An investment period of 47 years is used because the Wind River experiments were last measured at age 47.

Table 3--*Estimated costs and values, Wind River alder/Douglas-fir plots*

Species	Mixed stand	Pure stand, no fertilizer	Pure stand, with fertilizer
Douglas-fir volume[1/] - age 47	27.00 CCF/acre	23.23 CCF/acre	31.01 CCF/acre
Red alder volume - age 43	19.41 CCF/acre	0	0
Douglas-fir average tree size - age 47	14.1 ft^3	7.7 ft^3	10.3 ft^3
Red alder average tree size - age 43	8.0 ft^3	0	0
Estimated stumpage prices[2/] in 47 yrs:			
Douglas-fir	$94/CCF	$52/CCF	$72/CCF
Red alder	$28/CCF	0	0
Estimated stand value in 47 yrs:			
Douglas-fir	$2,538/acre	$1,208/acre	$2,230/acre
Red alder	543/acre	0	0
	$3,081/acre	$1,208/acre	$2,230/acre
Douglas-fir planting cost	$85/acre	$85/acre	$85/acre
Red alder planting cost in 4 yrs.	$140/acre	0	0
Fertilization cost in 40 yrs.	0	0	$235/acre

[1/] Volumes are to a 4-inch top.

[2/] Costs and values are in terms of 1977 dollars.

Table 4--*Present net worth of Wind River alder/Douglas-fir plots (assuming the study was repeated, starting in 1977)*

6 percent discount rate	
Mixed stand, (present net worth)	≈ $ +3/acre
Pure stand, no fertilizer, (present net worth)	≈ $ -7/acre
Pure stand, with fertilizer, (present net worth)	≈ $ +36/acre

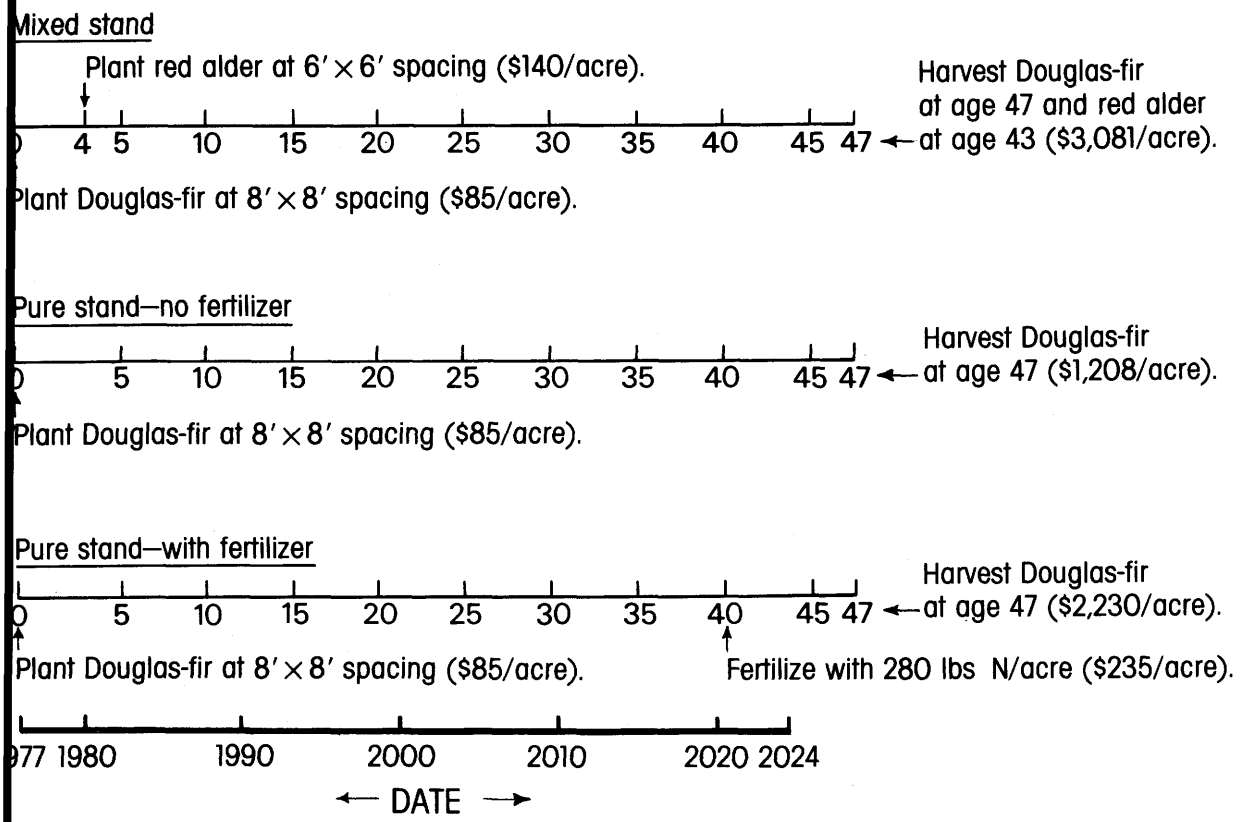
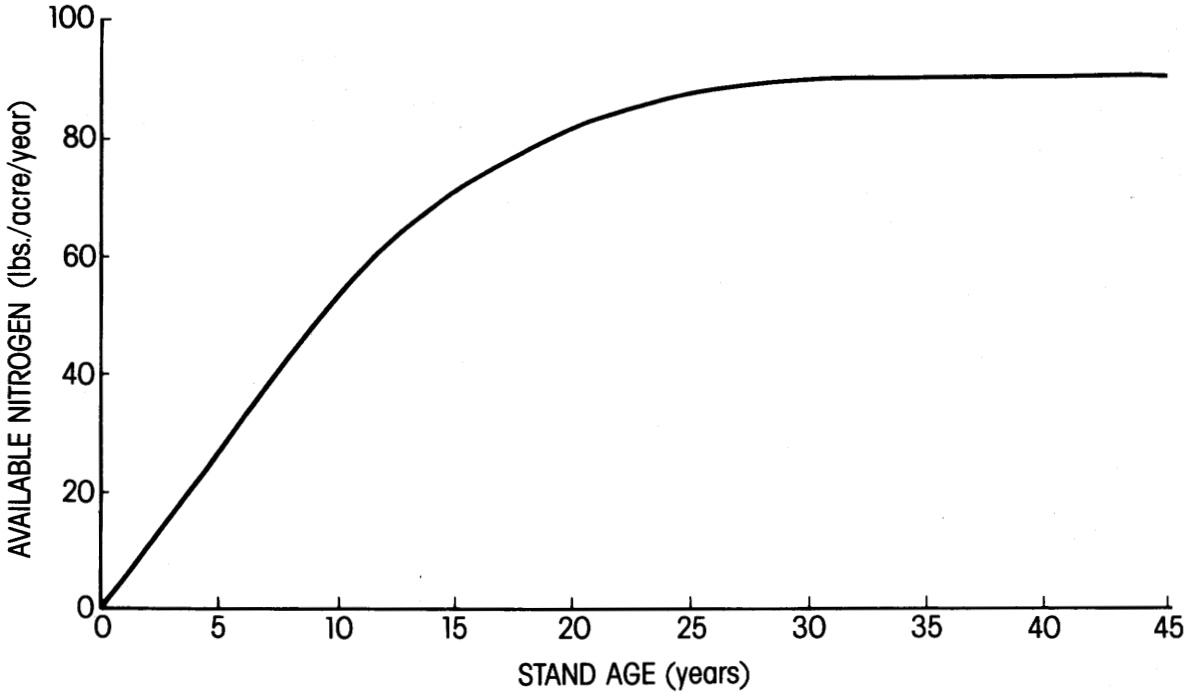


Figure 5.--Three alternatives for Wind River plantations (values and costs in terms of constant 1977 dollars).

fertilizer. This conclusion, however, assumes that nitrogen fertilizer costs increase at the same rate as Douglas-fir stumpage prices (i.e. 3 percent per year). Additional analysis revealed that if, in fact, nitrogen fertilizer costs increase at an annual rate of 5.4 percent (2.4 percent above the rate of increase for stumpage prices), red alder/Douglas-fir mixtures become financially attractive, even with this high planting density. Since estimates of long-term cost increases for nitrogen fertilizers are pure speculation, it seems prudent for foresters to thoroughly investigate the growth of red alder/Douglas-fir mixed plantations - or alternate rotations. Such information will be invaluable in the future.

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Based on: Cole, Gessel, and Turner 1978

Figure 6.--Estimated red alder available nitrogen input per year (pounds/acre per year)(3).

ALDER STOCKING REQUIREMENTS FOR NITROGEN INPUT

The Wind River studies raise an important question: is it necessary to have such a high density of alder to provide adequate nitrogen for Douglas-fir? Perhaps 1,210 alder trees per acre are too many. In order to shed light on this question, we start with an investigation of the nitrogen supplying capability of red alder stands. Figure 6 depicts estimates of available nitrogen[3] produced annually by a fully stocked alder stand at various ages (based on Cole, Gessel and Turner, 1978). Nitrogen inputs by an individual alder tree are estimated by dividing total stand input per acre by the number of trees found in a fully stocked acre (*14*). Results of this computation are presented in figure 7.

[3]Available nitrogen is that portion of total soil nitrogen that can be readily absorbed by tree roots.

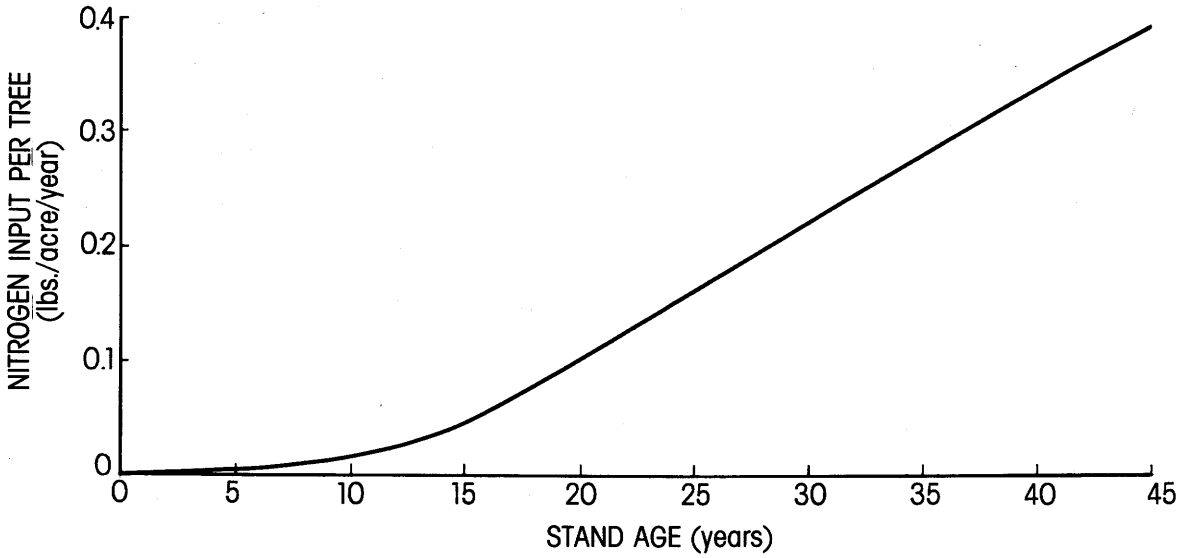


Figure 7.--Available nitrogen input by an individual red alder tree (pounds/acre per year).

Researchers feel that total annual nitrogen uptake in a fully stocked young-growth Douglas-fir stand is approximately 35 lbs per acre (*3*). The question under study, then, might be restated as: "How many red alder trees are needed to produce 35 pounds of available nitrogen each year?" Data from figure 7 can be used to answer this new question, with results in table 5. Based on this analysis, it appears that an initial planting density of 200 alder trees per acre would provide, all by itself, sufficient nitrogen for Douglas-fir after age 25. Most likely, far fewer alder trees would actually be needed as the Douglas-fir can obtain much of its nitrogen from that already in the soil.

Table 5--*Estimated number of red alder trees needed to produce 35 pounds of available nitrogen per year*

Stand age (years)	Trees needed
10	2,333
15	700
20	347
25	216
30	157
35	125
40	103
45	89

COST COMPARISON OF NITROGEN SUPPLIED BY ALDER AND BY ARTIFICIAL FERTILIZATION

Assume that 200 red alder trees are mixed into a Douglas-fir plantation. They all live until age 25, at which time alder mortality occurs at such a rate that sufficient alder trees survive to insure 35 pounds per acre per year of available nitrogen. By age 45, approximately 800 pounds per acre of available nitrogen will have been added to the system. If alder planting cost is $35 per acre (for 200 trees), then the present value of direct monetary costs of nitrogen is 35/800 = $0.044 per pound.

It is also possible to provide 800 pounds of available nitrogen through artificial fertilization. Assuming that all fertilizer nitrogen becomes available to the Douglas-fir, the required amount could be supplied by four treatments, each applying 200 pounds of nitrogen per acre. If treatments are made at stand ages 25, 30, 35 and 40, estimated present value (at 6 percent) of nitrogen fertilizer cost is $0.109 per pound, a quantity that is 2-1/2 times the cost of alder-supplied nitrogen.

One must hasten to point out that not all costs associated with using alder as a source of nitrogen are included in the previous analysis. Alder trees compete with the Douglas-fir for space, light, moisture, and nutrients. To the extent that Douglas-fir contributes more usable wood and is valued at a higher stumpage price than red alder, the pure Douglas-fir stand will be more valuable than the mixed-species stand. A consideration of such value differences leads us to the final portion of this paper, a general model for evaluating alder/Douglas-fir mixed stands.

GENERAL MODEL FOR EVALUATING RED ALDER NITROGEN INPUT TO THE FOREST SYSTEM

As alder stocking is increased, nitrogen input is probably also increased, but less room is available for the more valuable Douglas-fir. How can one define an optimal combination of alder and Douglas-fir stocking over the life of the stand? A framework for evaluating this question is proposed in figure 8. The goal is to develop a flexible system that can be used to evaluate not only various combinations of Douglas-fir and alder stocking (including alternate rotations), but also artificial fertilizer use.

The general model of figure 8 is primarily useful at this state of our knowledge in defining data needs. These can be enumerated as follows:

1. Quantify red alder's available nitrogen input, both on a unit of stocking basis, and over time.
2. Define Douglas-fir response to a continuous supply of added nitrogen. Fertilizer research is now beginning to examine repeated treatments.
3. Define the competitive interaction between red alder and Douglas-fir in mixed-species plantations. We must be able to predict future yields and sizes under various stocking alternatives.

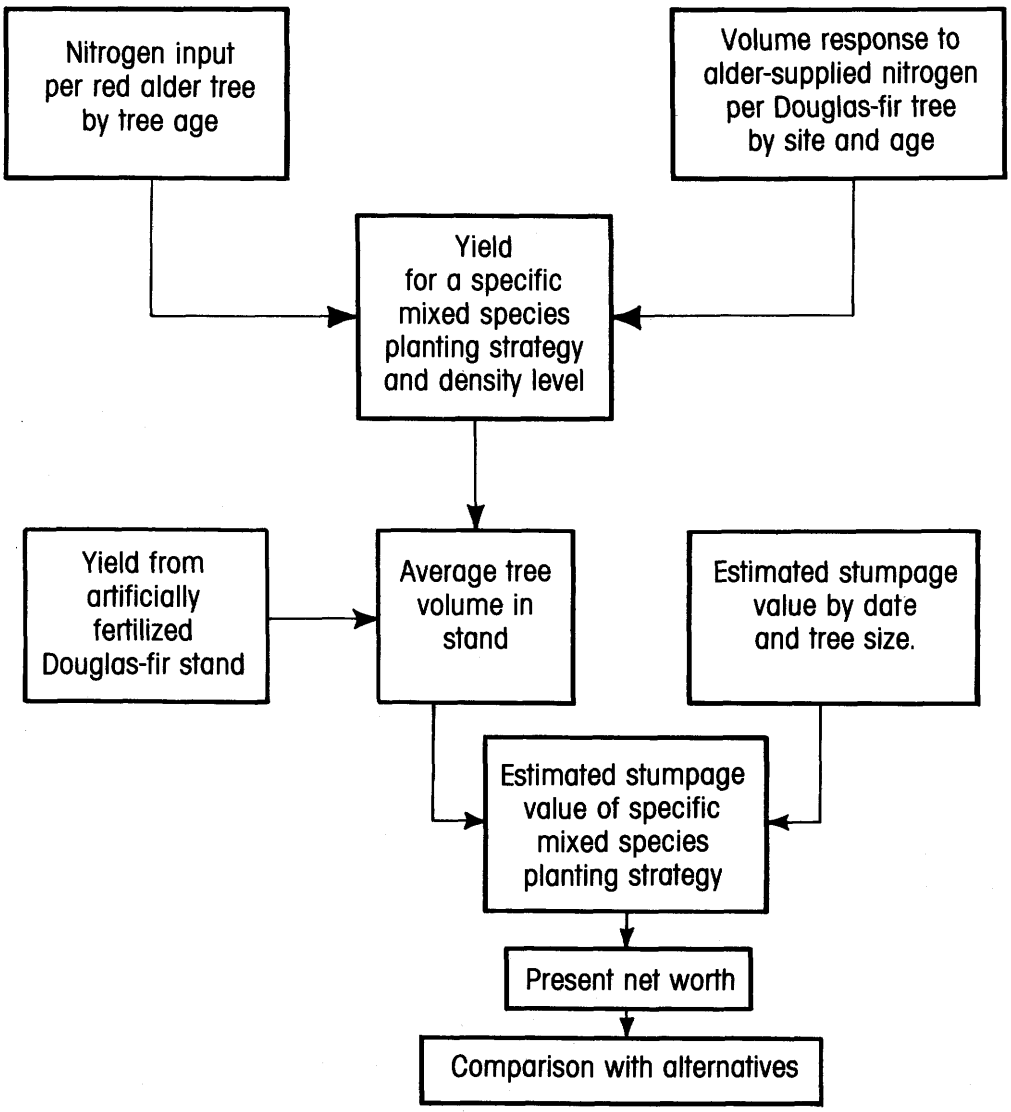


Figure 8.--General model for evaluating red alder nitrogen input to the forest system.

Conclusion

Based on what has been learned in the past few decades about the impact of nitrogen on Douglas-fir growth, it is certain that nitrogen addition will be a widely-used practice in managed stands of the future. Whether this addition will be through biological means or through the use of synthetic chemicals depends on future wood prices, as well as on future fertilizer costs. Nitrogen fertilizer is relatively inexpensive today and certainly offers the only practical avenue for increasing growth of existing stands. Its availability and cost in the years ahead, however, are uncertain. Should large cost increases occur, plantations that are currently being established may go through their entire rotation without the growth-stimulating effects of added nitrogen. Evidence already exists, as reported in this paper, that, in the absence of inexpensive chemical fertilizer, Douglas-fir plantations grown in mixture with red alder are of higher stumpage value than Douglas-fir pure species plantations. One might infer from this result that the only factor holding back current large-scale use of red alder as a nitrogen enricher is the existing low cost of urea fertilizer. This paper offers only tentative conclusions that are based on limited data, but the need for serious analysis of red alder's place in forestry should be clear to all. It is in the spirit of initiating such analysis that this paper is offered.

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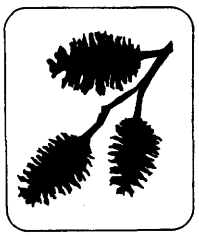
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TECHNIQUES AND COSTS OF CONVERTING HARDWOOD STANDS TO CONIFERS



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ABSTRACT

The occupation by hardwoods and brush of large areas of the most highly productive coniferous timber growing sites is a vexing problem for foresters in the Douglas-fir region. The management of red alder is at the center of this problem. In general, management decisions have tended to favor removing hardwood-brush types and replacing them with conifer stocking.

Considerable work has been carried out in converting hardwood-brush sites to coniferous timber types. The major portion of this work has been done on industry lands in Washington. Several conversion techniques have been employed with varying degrees of success. Techniques used include harvesting, scarification, chemical spraying, and burning. A study of the costs and successes of applying these techniques shows that, while conversion projects are expensive, they are generally financially feasible if adequate stocking is obtained the first time. It is when the conversion process must be repeated that financial feasibility is in question.

Introduction

In this paper I will examine the practice of converting stands of hardwoods and brush to conifer stands. The basis for this practice is that under most circumstances conifers, especially Douglas-fir, are the more desirable tree species to have occupying a site. In examining stand conversion, I will focus on (a) a review of the extent and nature of the hardwood resource, (b) a description of conversion work accomplished to date and planned for the future, (c) a description of the costs and results of conversion techniques, and finally (d) a comment on the financial feasibility of conversion projects.

The Hardwood Resource

In the Douglas-fir region a serious obstacle to increasing the productivity of forests is the presence of hardwood cover on sites that are suitable for coniferous timber production. Table 1 shows that 12.8 percent of western Oregon's and 18.5 percent of western Washington's forest lands are occupied by hardwoods. Data from a report by Fight and Gedney (*4*) show that in western Oregon 84 percent of hardwood forests were growing on conifer sites, while in western Washington the figure is 79 percent (data did not include National Forests).

Table 1--*The proportion of hardwood forest acreage to total commercial forest acreage by major ownership classes in western Oregon and western Washington*

Ownership class	Total commercial forest acreage	Hardwood acreage	Percent of total for ownership	Percent of total hardwood acreage
		WESTERN OREGON[1/]		
National Forests	4,533,600	128,400	2.8	7.3
Bureau of Land Management	2,030,020	141,300	7.0	8.0
Other public	865,720	83,090	9.6	4.7
Forest industry	4,079,000	626,000	15.3	35.6
Other private	2,210,000	781,650	35.4	44.4
Total	13,718,340	1,760,440	12.8	100.0
		WESTERN WASHINGTON[2/]		
National Forests	2,365,000	35,000	1.5	1.9
State	1,223,000	148,000	12.1	8.0
Other public	458,000	86,000	18.8	4.7
Forest industry	3,634,000	713,000	19.6	38.6
Other private	2,296,000	864,000	37.6	46.8
Total	9.976,000	1,846,000	18.5	100.0

[1/] Beuter, John H., K. Norman Johnson, and H. Lynn Scheurman, 1976. Timber for Oregon's tomorrow. An analysis of reasonably possible occurrences. Oregon State University, Forest Research Lab. Res. Bull. No. 19, 111 p., illus. Corvallis, Oregon.

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Hardwood forests are particularly extensive on industry and other private ownerships (table 1). In western Oregon 80 percent of hardwood forests are owned by industry and other private ownerships, while in western Washington the figure is 85.4 percent (total hardwood forest acreage under

all ownerships). Hardwood forests are especially prevalent on lands classified as other private. In both States these ownerships have over one-third of their lands stocked with hardwoods. National Forest lands have a relatively small component of hardwood forests. This is due partly to past cutting practices but also to lower site productivity and lesser susceptibility to hardwood invasion.

Especially vexing to foresters is the fact that hardwoods tend to occupy the more productive timber growing sites. Data from the Beuter report indicates the following distribution of hardwood forests in Oregon by Douglas-fir site indexes (*5*).

Site index (productivity)	Acres	Percent
Greater than 165 (High)	861,520	48.9
120 to 165 (Medium)	569,560	32.4
50 to 119 (Low)	329,360	18.7
20 to 49 (Very low)	--	--
	1,760,440	100.0

These figures show 81.3 percent of hardwood forests occupying medium to high growing sites. Similar figures for hardwood forests in Washington (from unpublished Forest Survey data on file at Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.) indicate approximately 85 percent are on high and medium sites.

Red alder stands are an important component of the total hardwood resource in western Oregon and Washington. Red alder is the predominant hardwood species type in the Pacific Northwest. Metcalf (*6*) shows data indicating that red alder stands constitute 77 percent of hardwood forests in western Oregon and 87 percent of hardwood forests in western Washington.

Conversion of Hardwood Stands

As we have seen, the acreage of hardwood forests is substantial, is largely in private hands, and occupies some of the best timber growing sites in the Pacific Northwest. Because of the extensive hardwood component and the potential productivity of the lands it occupies, some landowners have decided to convert these stands into more productive conifer forests.

Table 2 is the result of a survey of hardwood and brush conversion practices in western Oregon and Washington (*3*).[1] The results are not entirely representative of hardwood conversion projects because brushland

[1]Readers interested in more information on hardwood-brush conversion and in the procedures used in obtaining the information presented in tables 2-4 of this paper should consult Dimock et al (*3*).

Table 2--*Area summary of high-site brush and hardwood lands as either converted or not yet converted to conifers for 16 ownership units in western Oregon and western Washington*

(In acres)

Ownership	Owned	Not yet converted			Converted							Hardwood not yet converted			
		Brush and hardwood	Brush	Hardwood	Total	Harvest	Tractor scarify	Multiple spray	Slash and burn	Spray and burn	High-lead scarify	To be converted	Retained in hardwoods	Retained and managed for harvest	Retained and not managed for harvest
Oregon	2,466,045	386,805	36,475	350,330	33,795	5,470	15,705	6,890	380	4,850	500	291,310	59,020	38,490	20,530
Washington	3,655,415	480,025	73,165	406,860	181,940	44,385	104,255	12,380	10,920	9,400	600	373,395	33,465	18,280	15,185
Total	6,121,460	866,830	109,640	757,190	215,735	49,855	119,960	19,270	11,300	14,250	1,100	664,705	92,485	56,770	35,715
Public	2,349,760	447,500	48,000	399,500	33,635	770	16,425	5,090	--	11,350	--	361,070	38,430	13,395	25,035
Private	3,771,700	419,330	61,640	357,690	182,100	49,085	103,535	14,180	11,300	2,900	1,100	303,635	54,055	43,375	10,680

[1/] Dimock, Edward J., II, Enoch Bell, and Robert M. Randall. 1976. Converting brush and hardwoods to conifers on high sites in western Washington and Oregon--Progress, policy, success and costs. USDA For. Serv. Res. Pap. PNW-213, 16 p., illus. Pac. Northwest Forest and Range Experiment Station, Portland, Oregon.

conversion projects were also surveyed. The hardwood conversion projects, however, were preponderant; and thus the results should provide a reasonable guide to the extent and nature of work being done.

The Federal, State, and private industry units surveyed manage 6,121,460 acres of commercial forest land in the Douglas-fir region. Of this total acreage, 12.4 percent is classified as hardwood type of which managers plan to convert 88 percent to conifers. This leaves 12 percent that will either be managed for hardwood timber production or will be retained for other purposes.

The total acreage converted in both States and all ownership classes was 215,735 acres. The preponderance of conversion work has been done in the State of Washington (84 percent) and in the private sector (84 percent). The large amount of conversion work done by private firms may reflect differing management objectives between public and private owners, and it may also reflect the much higher proportion of privately owned hardwood stands.

The survey classified conversion projects into six categories identified by the dominant site preparation technique employed. The proportion of lands converted by these techniques is as follows:

Dominant site preparation techniques	Proportion of lands converted (percent)
Harvest	23
Tractor scarify	55
Multiple spray	9
Slash and burn	5
Spray and burn	7
High-lead scarify	1

Conversion Methods and Their Costs

The general sequence of events for each conversion project can be classified into three major steps.

(1) Site preparation. Removing existing vegetation or scarifying the site to the extent that reforestation is possible.

(2) Regeneration. Planting the area with conifer seedlings.

(3) Post-regeneration treatments.

a. Animal damage control. Ranges from treating seedlings with repellants to individually caging a proportion of planted seedlings.

b. Plantation release. Typically involves spraying competing vegetation with a herbicide.

c. Replanting. Involves replanting if adequate stocking levels are not established by the first planting.

Table 3 shows the mean costs, cost ranges, and costs per established tree for the six classes of conversion treatments surveyed.[2] The costs are identified by the dominant site preparation treatment used on a project; but the costs actually represent expenditures for all activities, in all three major steps, occurring up to the establishment of a conifer stand. To better understand just where the costs do occur in a project, it is useful to look at the three conversion stages individually.

TABLE 3 -- *Costs of conversion by technique, expressed in 1975 dollars per acre based on 99 projects in western Oregon and western Washington*[1/]

Technique	Mean cost	Cost range	Cost per established conifer	Number of projects represented
Harvest	103	41-197	.39	13
Tractor scarify	140	45-487	.45	52
Multiple spray	149	39-351	1.15	19
Slash and burn	235	170-300	.52	6
Spray and burn	269	135-505	.57	8
High-lead scarify	210	--	.86	1

[1/] Dimock, Edward J. II, Enoch Bell, and Robert M. Randall. 1976. Converting brush and hardwoods to conifers on high sites in western Washington and Oregon--Progress, policy, success and costs. USDA For. Serv. Res. Pap. PNW-213, 16 p., illus. Pac. Northwest Forest and Range Experiment Station, Portland, Oregon.

Site Preparation Costs

Site preparation methods often comprised various combinations of harvesting, slashing, scarification, chemical application, and burning. For example, combinations such as harvesting and scarification often occurred on the same project. In such cases the dominant method was used to classify the project.

HARVESTING

When merchantable material is present, harvesting can reduce or eliminate site preparation costs. Harvesting was the predominant means

[2] To establish comparability of cost data occurring at different times, all data were adjusted for inflation and compared at 1975 price levels.

of site preparation in 13 projects; and except for 2 projects that used some tractor scarification ("crushing"), there was minimum use of machinery in site preparation.

TRACTOR SCARIFICATION

Scarification, in conversion projects, generally entails the uprooting, windrowing or piling, and perhaps burning of unmerchantable hardwoods and brush. The average cost of tractor scarification was $55 per acre. Of 52 scarification projects, 17 included some harvesting of merchantable timber. The median cost for scarification was $45 per acre with about 70 percent of the costs falling between $25 to $65 per acre. Tractor scarification was generally limited to lands with slopes not exceeding 30 percent.

MULTIPLE SPRAYS

Multiple spraying involves the repeated application of herbicides until unwanted vegetation is dead or at least until it represents little threat to coniferous plantings. Spraying can occur before and after planting of conifer stock. The cost of spray projects largely depends on the number of sprays applied. Sprays applied from two to four times seemed common practice. Sprays were generally applied from a year to several years apart depending on circumstances. For 19 observations the median single application spray cost was $12.77 per acre while the average cost was $13.18 per acre. Only three observations fell outside the range $12 to $14.90 per acre.

Most multiple spray projects took place on slopes ranging from 30 up to 100 percent.

SLASH AND BURN

This technique involves felling all unmerchantable trees, using an herbicide or desiccant on understory vegetation, and burning. Based on only a few observations, slashing costs between $60 to $75 per acre while broadcast burning costs from $30 to $55 per acre.

SPRAY AND BURN

This technique involves the treatment with herbicides of hardwoods and brush often in conjunction with a harvest of a merchantable overstory. Broadcast burning follows. With only a few observations, costs ranged from $121 to $213 per acre with values skewed toward the lower end of the range.

HIGHLEAD SCARIFICATION

This technique involves scarification by cable yarding with heavy weights. There was only one example of this relatively experimental method. Costs were $118 per acre on a 50-percent slope.

Regeneration Costs

Hand planting is the predominant regeneration method used in the Douglas-fir region. We found a wide range in planting costs per tree. The range was from $.05 to $.22 per tree with the median cost of planting with 2-0 stock being $.11 while the median cost with 2-1 stock was $.13. One can determine per acre costs for a particular project by multiplying cost per tree by number of trees planted. For example, a project with 600 trees per acre would cost about $66 per acre for 2-0 stock and about $78 per acre for 2-1 stock.

Postregeneration Treatment Costs

Costs are often incurred after the regeneration stage. These costs may be required to protect the investment from animal damage or from competing vegetation. Likewise it may be necessary to replant all or part of a project because of the failure of planting stock to survive. Of the 99 projects reported here, 82 had incurred some additional costs after the initial regeneration.

In all, 70 projects used some form of animal damage control. Costs ranged from lows of $.50 per acre for the use of rabbit repellants on seedlings to $120 per acre for wire-caged seedlings. Of the 70 projects, 47 had costs of $1 or less per acre, 15 projects cost from $2 to $30 per acre, and 8 projects cost in excess of $30 per acre.

Release of plantations from competing vegetation was carried out on 41 projects. Six of the projects cost less than $10 per acre, 18 projects cost from $10 to $20, 11 projects from $21 to $40, and 6 projects cost over $40 per acre.

Replanting was necessary on 24 projects. Costs varied widely. The average cost was $62 per acre with 15 of the projects falling in the range $32 to $92.

Conversion projects often required combinations of the above postregeneration treatments. Costs of these combinations ranged up to $200+. Of the 39 projects combining two or more treatments, 21 cost less than $50, 9 cost between $50 and $100, 6 cost between $100 and $200, and 3 cost more than $200 per acre.

Treatment Success

At least for the short run, the success of conversion projects is measured by the level of stocking obtained. Table 4 shows the levels of stocking obtained for 99 projects. Stocking percent was based on the stock-quadrant method with 100 1/250-acre plots per project. Estimates of density were based on the measured distances from 25 sampling points to the nearest established conifer.

TABLE 4 -- *Number of projects by conversion technique achieving given stocking levels for 99 projects in western Oregon and western Washington. Numbers in parenthesis indicate projects that were replanted*

(Number of projects)

Stocking level	Harvest	Tractor scarify	Multiple spray	Slash and burn	Spray and burn	High-lead scarify	Total
Nonstocked 0- 9 percent	0	0	1	0	0	0	1
Low 10- 39 percent	1	7(2)	4	0	0	0	12(2)
Medium 40- 69 percent	9(3)	19(3)	14(2)	2(2)	2	0	46(10)
High 70-100 percent	3(2)	26(3)	0	4(1)	6(4)	1(1)	40(11)
Total projects	13(5)	52(8)	19(2)	6(3)	8(4)	1(1)	99(23)
Mean stocking percent	61	65	44	77	80	71	
Stocking range	39-79	10-95	6-69	52-93	64-91	--	
Mean density trees per acre	265	310	130	453	424	244	

Table 4 shows that out of a total of 99 projects, 86 were medium stocked or better. In 12 cases (shown in parenthesis) even replanting failed to result in high stocking. The methods, utilizing burning, produced the greatest measure of success in that 10 of 14 projects resulted in a high stocking level. Tractor scarification produced high stocking 50 percent of the time. The most disappointing results came from the use of herbicide sprays as the primary method of site preparation. Multiple spraying failed to produce stocking levels over 70 percent.

Conclusions

As we have seen, hardwood and brush conversion projects are not cheap. Complicating matters is the fact that results in the form of adequate stocking levels are far from sure. It is not reassuring to see that well over half the projects result in stands less than 70 percent stocked (table 4). Many such lightly stocked stands may not be of sufficient density to produce income opportunities through commercial thinning when they reach merchantable size. Further, the present net values of future returns from such stands may not be sufficient to offset costs.

What of stands that are over 70 percent stocked? Are the costs of conversion projects justified by future returns? From Beuter and Handy's (*1*) economic guidelines for reforestation a number of tables show expected returns for various management situations. Using table 42, representing Douglas-fir site II, we can determine expected returns for a management regime of frequent light commercial thinnings preceded by a precommercial thinning and assumptions of no taxes and constant prices. At 5-percent discount rate for a financially optimum rotation, the return would be $852 for site II. At a 7-percent discount rate, the present net worth for site II would be $581.

From table 3 we can see that the mean costs of the most expensive conversion technique was $269. The highest cost project was $505 per acre. At 5 and 7 percent, we could expect to more than break even, if we achieve high stocking levels. Of course, the financial feasibility of conversion projects will vary by the owner's situation, by site, and by factors outside the owner's control such as interest rates and stumpage prices. Nevertheless, conversion projects do look profitable on sites I and II under a wide range of ownership situations under current market conditions. What seems crucial is the level of stocking obtained and the costs required to obtain a high level of stocking. It would seem prudent for managers to put extra effort into insuring successful regeneration on the first planting.

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SHOULD ALDER BE REPLACED BY CONIFERS?



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ABSTRACT

As with most hypothetical questions, the question of whether alder should or should not be replaced with conifer must be answered ambiguously. It is assumed that this basic question will be approached from an economic or financial point of view.

Application of financial analysis to the question of site conversion requires two basic sets of information: 1) biological response data relevant to the management options to be considered, and 2) present and future values for both costs and returns for each management option, including the relevant cost of capital.

A primary consideration in the analysis of site conversion is the determination of yield responses from management. Also, projected time trends in both yield values and costs need to be carefully considered, since both management feasibility and the comparative advantage of an optimal management program can change greatly under such trends. Because of the long financial production periods, the cost of time is often a major determinant of economic feasibility.

Examples for generalized site conversion analysis are reviewed and the implications of the major management variables are discussed. The application of these approaches requires each manager to carefully assess the specifics of his forest land and the site-specific cost and value relationships.

Introduction

Recent years have shown a substantial growth in interest in the relative merits of producing red alder as a commercial species on substantial acreages of forest land in the Pacific Northwest. In part, this interest is spurred by the naturally occurring stands of alder that have simply grown in spite of any conscious management effort. These stands are frequently seen as a problem, since conventional wisdom says that conifers are preferred and that otherwise productive sites are being underutilized when occupied by alder. Hence, we are faced with the question: Should

286-657 O - 79 - 25

alder be replaced by conifers? as with most hypothetical questions, this question must be answered ambiguously: It all depends. There is simply no rational basis for prescribing management nostrums as generalized land management guidelines.

The question of replacing alder with conifers is essentially one of economics - or at least it will be assumed to be one of economics for the purposes of this discussion. That is, it is assumed that we are interested in using our forest lands efficiently from an economic point of view. This requires us to set two conditions as limits on our analysis. First, we want to avoid taking management actions that are not economically feasible - that is, the anticipated costs exceed the anticipated returns when properly adjusted for time. Second, when faced with mutually exclusive alternatives which are technically and economically feasible, we want to choose the alternative that contributes the most to our economic objective. When only one alternative is feasible, no choice is implied. More typically, however, we must choose the preferred course of action.

For the purposes of discussion, we will simply assume the goal of our forester-decisionmaker to be the maximization over time of anticipated net value from his timber production efforts. As such, the criterion of maximum net present value is taken as the proper decision variable. Conventional tools of financial analysis will help us outline the dimensions of our problem.

Our original question implies that we have existing stands of alder and that the issue at the moment is whether to harvest those stands (commercially or otherwise) and replace them with conifers. Basically this involves two separate but related issues: whether to harvest the alder and whether to follow up such harvesting with the establishment of conifers. Alder could be harvested and the land again planted with alder, allowed to remain fallow, or converted to a nontimber use. On the other hand, the existing stand of alder can be retained for some yet undetermined period of time. Financially, our decisionmaker will want to optimize the combined results of these two decisions To hold the existing stand delays the time at which conifers (or another alder stand, or an alternative nontimber land use) can be established. If the alternative use has a positive value (is economically feasible), such a delay will entail a cost. In return, the existing stand may result in an increased value. For operational reasons, we would simply want to hold the existing stand only so long as the increase in value more than compensates us for the costs of delay. In practice this is not as easily determined as it might appear. We need to carefully formulate our methodology so that the final results tell us what we want to know. A precise answer to the wrong question is of little value and can even be detrimental.

Methodology

The application of financial analysis to the question of timber site conversion requires two basic sets of information: a) biological response data relevant to the species and the management options to be considered,

and b) present and future values (estimates) for both costs and returns for each management option, including the relevant cost of capital.

The first priority is to determine the economic feasibility of management for both retention of red alder and potential management of the site for conifer. In effect, we want to be assured that the options we are considering are really feasible, on their own merits, before attempting to resolve the choice between the two.

Let's consider the red alder option first. It is tempting to look at the existing stand and to formulate our question of conversion around the condition of this stand. This, however, is not really our best option. Although we are constrained by the existing stand (at the moment), our real options are for future management for either alder or conifer. Needless to say, we should determine the most profitable form of management for alder (if any) as the basis for our assumed future management. It does no good to construct an analysis based on any form of management or rotation age other than the best.

Likewise, we must identify the best form of management which is likely if the site is converted to conifer. This again means that we must determine the optimal intensity of management and rotation for the particular species and site. It should be apparent that the analysis of alder and conifer requires us to specify site equivalents for the two species. Although it is not within the scope of this paper to examine the topic of site equivalents, suffice it to say that this is an area where much more specific data are needed. Unless we know the alder and conifer potential for the same piece of land, there is no way that we can formulate a meaningful economic analysis of the conversion question. More on this point later.

The above-mentioned analysis of best management for alder and conifer will lead us to the answer to site conversion - if the analysis has been properly done. The form of future management with the highest positive net present value, determined at the proper cost of capital, is our best longrun option. This does not, however, automatically tell us what to do with our existing stand. It is necessary to consider the condition of the existing stand relative to the feasibility of timing of conversion to conifer or the re-establishment of the same species. There *may* be some future period for which it is financially feasible to hold the existing stand, even at the cost of delaying future management for either alder or conifer.

The suggested economic methodology can be summarized as follows:

1) determination of site comparison and alternative production/yield functions for red alder and conifer management,

2) evaluation of the economic feasibility of management options for each species and determination of present value of optimal future management regimes,

3) analysis of present stand value and future management costs if held, and

4) analysis of the economic advantage/disadvantage of site conversion either now or some time in the future.

The mechanics of such an analysis have been described elsewhere (*2, 3*). A graphic representation of this process is reproduced as figure 1. The financial calculations for a sample analysis are contained in appendix 1.

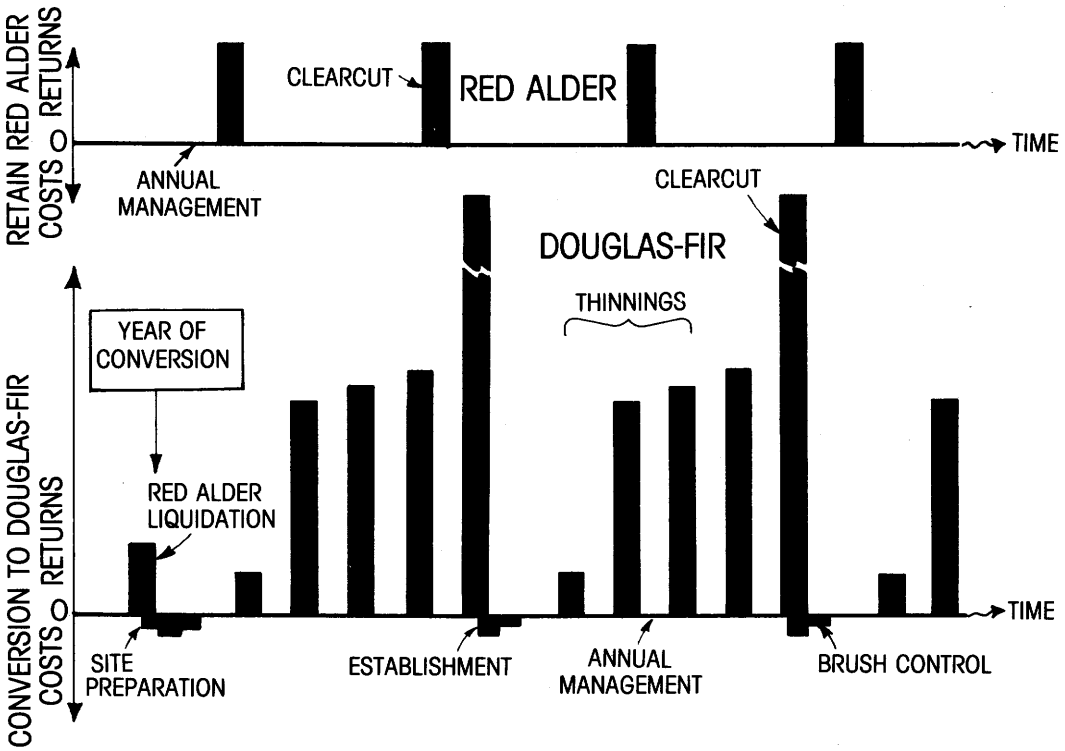


Figure 1.--Representative costs and returns to be expected from retaining red alder and from liquidating red alder and converting site to Douglas-fir, Yoho, et al. (3).

The upper portion of figure 1 illustrates the consideration of retaining red alder. Our manager is faced with determining the present value of a perpetual series of red alder yields, properly adjusted to account for the age of the present stand. This requires us to determine the present value of the existing stand, which is to be harvested at the end of the holding

period, and the present value of all subsequent stand values derived at the end of all future rotations. These combined values, then, represent the present value of total revenues to be obtained from retention of alder.

Likewise, the upper portion of figure 1 indicates certain annual management costs, which must be paid during both the holding period for the existing stand as well as during future rotations, assuming retention of alder. When both revenues and costs are discounted, we have the present value of retaining alder. It should be noted that figure 1 assumes that both the existing stand and future stands will be harvested at a predetermined rotation. In practice, we would want to carefully determine the future rotation and the proper year of harvest of the existing stand (holding).

The lower portion of figure 1 illustrates the more complex case of site conversion to conifer. In considering revenues, we first see that the liquidation of the existing alder stand will result in an immediate receipt at the time of conversion. Second, for the conifer regime illustrated, there are receipts from both thinnings and final harvest, which reoccur at regular intervals for all future conifer rotations. Finally, conversion involves a one-time site preparation cost at the time of conversion, as well as future stand establishment, brush control, and annual management costs. All but the site preparation cost are assumed to repeat at regular intervals for all future rotations.

Illustrative Analysis

The particular numbers and assumptions used in an illustrative example are not as important as a logical and consistent approach for the analysis. Each landowner clearly faces a different set of management options and market conditions, and it would be foolish to attempt to present site-specific findings. Nevertheless, the results presented by Yoho, et al. (*3*), can be instructive with respect to the methodology used. Specifically, it is useful to examine the consequences of possible misspecification of site equivalents between red alder and conifer. This comparison is reproduced as table 1.

The upper portion of table 1 represents the situation where we have mistakenly equated the alder site with too low a conifer site equivalent. We have thus understated the relative productivity of the site for conifer. The original (faulty) analysis indicated that alder should be retained under certain conditions. Thus, at a 3-percent discount rate, alder would be retained only where conversion costs were high. At 6 percent, alder would be retained for both high and medium conversion costs, and for low conversion costs for stands 55 years of age or older. At 9 percent, alder would be retained for both high and medium conversion costs, and again for 55-year-old stands (or older) with low conversion costs.

With correct site equivalence, however, we see that at 3 percent our finding of retention of alder under high conversion costs is reversed. Likewise, the retention of alder at 6 percent for stands 55 years of age and

Table 1--*Conversion recommendations that would be changed if the estimated productivity of Douglas-fir on a given red alder site were changed*[1/]

(Number of years to wait[2/])

Red alder/ Douglas-fir site class	Present age (years) of red alder stand	Guiding rate of return								
		3 percent			6 percent			9 percent		
		High conversion costs	Medium conversion costs	Low conversion costs	High conversion costs	Medium conversion costs	Low conversion costs	High conversion costs	Medium conversion costs	Low conversion costs
		If a red alder site 70 is actually a Douglas-fir site III rather than IV, the shaded R's should be numbers--convert to Douglas-fir								
70/IV	15	R	20	0	R	R	20	R	R	20
	25	R	10	0	R	R	10	R	R	10
	35	R	0	0	R	R	0	R	R	0
	45	R	0	0	R	R	0	R	R	0
	55	R	0	0	R	R	R	R	R	R
	65	R	0	0	R	R	R	R	R	R
		If a red alder site 90 is actually a Douglas-fir site IV rather than III, the shaded numbers should be R's--do not convert to Douglas-fir								
90/III	15	20	0	0	R	20	10	R	R	20
	25	10	10	0	R	10	0	R	R	10
	35	0	0	0	R	0	0	R	R	0
	45	0	0	0	R	R	0	R	R	0
	55	0	0	0	R	R	0	R	R	R

NOTE: Shaded recommendations would be reversed if an error were made in estimation of Douglas-fir site productivity.

[1/] Table entries were extracted from table 7; conversion cost levels are defined in table 4; the high management costs and low prices are defined in table 6 of (3).

[2/] Before conversion of red alder to Douglas-fir. An "R" means that red alder should be managed in perpetuity.

Source: Yoho, Chappelle, and Schweitzer, 1969, table 10, p. 18.

older is also reversed. Our site misspecification would result in overretention of alder.

One could err, of course, in the other direction. The lower portion of table 1 illustrates the consequences of overstating the conifer productivity relative to alder. Without detailing the results, it is apparent that conversion would be recommended too frequently. As is evident in both portions of table 1, conversion becomes increasingly less desirable at higher interest rates, particularly when conversion costs are medium to high. This is in part attributable to the longer rotation for conifer (hence longer investment period) as well as the fact that conifer management is assumed to require both stand establishment and brush control costs which must also be carried over time. Needless to say, conversion doesn't necessarily always pay.

Factors Affecting Site Conversion Decisions

A primary consideration in the anlaysis of site conversion is the determination of yield responses from management. This includes dimensions of both quality and quantity. From the quality standpoint, stumpage prices can and do vary greatly based on log size and quality. One should be wary of analyses utilizing average stumpage prices without due recognition of quality differentials. The importance of yield volume is partly revealed in the previous discussion of site comparison. A higher site generally means a greater recoverable volume and/or higher quality logs at a given age. More volume means a greater economic yield. Economic feasibility is quite sensitive to yield volumes and the per-unit values attached to future yields. Since yield values are also sensitive to quality measures, accurate quality-yield relationships are critical.

In addition to volume yields, projected time trends in both yield values and costs need to be carefully considered, since both management feasibilty and the comparative advantage of an optimal management program can change greatly in response to such trends. Finally, a careful consideration of the cost of capital is required. Because of the long financial production periods, the cost of time is often a major determinant of economic feasibility. The use of artificially low discount rates to justify otherwise unprofitable management regimes is questionable at best.

Examples of Hardwood and Conifer Stand Analysis

Does hardwood management pay? Does conifer management pay? Should we convert? When? These are all good questions asked daily by forest managers. Unfortunately, few pertinent answers can be given. Nevertheless, it can be useful to examine some recent indicators of economic feasibility for both conifer and hardwood production and draw some inferences about the potential for conversion. The examples which follow are taken from the recent study by the Washington Department of Natural Resources analysis of timber productivity (*1*). Following our earlier suggested methodology, we will summarize

first the findings with regard to the economics of hardwood production, then look at the feasibility of conifer production, and finally make some comparisons between the relative feasibility of the two.

HARDWOODS

The Department of Natural Resources examined potential management of hardwoods on the approximate 1.8 million acres currently occupied by hardwoods in western Washington. About 1.4 million acres were considered "hardwoods on conifer site" with the remaining 0.4 million acres classed as "hardwoods on hardwood site." The distinction in site was based on both the hardwood index as well as assumptions about conifer productivity. Hardwood site index 70 to 90 was considered "hardwood on conifer" while hardwood site index 100 to 120 was considered "hardwood on hardwood site." Assuming natural management yields, average 1976 costs, 1976 hardwood log values, and a range of interest rates (real rates after taxes), the study concluded that economic management opportunities for hardwoods (i.e. red alder) were extremely limited.

For "hardwood on conifer sites" (the lower alder sites), natural management resulted in negative land values for all hardwood rotations at both 5- and 7-percent discount rates with constant costs and price assumptions. Similarly, if both costs and prices were allowed to increase at an annual rate of 2 percent, all land values remained negative. When costs were held constant, while prices were increased by 2 percent per year, management of forest industry lands on site 90 became marginally feasible at a 5-percent discount rate; all other options continued to show negative returns.

The situation was slightly better for "hardwood on hardwood sites" - but not much better. No management showed positive returns under the assumption of constant prices and costs. With a 2-percent increase in both prices and costs, management of publicly owned site 90 lands became feasible only at a 5-percent discount rate as did all "hardwood on hardwood sites" in forest industry ownership. Nonindustrial private ownership continued to show negative returns under this price-cost assumption.

With an assumed 2-percent increase in prices, at constant costs, hardwood management on these better sites (site index 100-120) became feasible for all ownerships but only at the modest 5-percent discount rate. At 7 percent, management was again uniformly submarginal.

We should remember that these conclusions are conditional on the assumed yields, prices, and costs. Nevertheless, the pattern of results indicate that even under the most favorable circumstances of increasing prices and constant costs, hardwood management is questionable on all but the better hardwood sites even at modest interest rates.

CONIFERS

Does the above view of hardwood management necessarily mean that conifer management should prevail? Obviously not. Our methodology specified that we

must also examine the economic feasibility of conifer management before making any relative comparisons. Table 2, reproduced below from the DNR study,

Table 2--*Conifer investment recommendation summary based on the L.E.V. solutions, by owner group, price and cost combination, site, and interest rate*

Owner	Price and cost combination	Site					
		High		Medium		Low	
		Real interest rate (percent)		Real interest rate (percent)		Real interest rate (percent)	
		5	7	5	7	5	7
Public	Constant prices and costs	X[1]	0[2]	X	0	0	0
	Two percent rate of increase in prices and costs	X	X	X	X	X	0
	Two percent rate of increase in prices with constant costs	X	X	X	X	X	X[3]
Forest Industry	Constant prices and costs	X	0	X	0	0	0
	Two percent rate of increase in prices and costs	X	X	X	X	X	0
	Two percent rate of increase in prices with constant costs	X	X	X	X	X	X
Other Private	Constant prices and costs	X	0	X	0	0	0
	Two percent rate of increase in prices and costs	X	X	X	X	X	0
	Two percent rate of increase in prices with constant costs	X	X	X	X	X	X[3]

[1] The symbol "X" indicates a positive Land Expectation Value.

[2] The symbol "0" indicates a zero or negative Land Expectation Value.

[3] These only include 90 percent of the acres. Ten percent of the acres were considered for regimes without thinning, but all the L.E.V.'s were negative.

Source: Washington Department of Natural Resources. Forest Productivity Study, Phase II.

summarizes the findings with respect to conifer management. The X designation in the table represents management options where positive land values were obtained, indicating economic feasibility under the stated conditions. The 0 designation indicates that no management was economically feasible under the stated conditions. Examination of table 2 shows an interesting pattern. For example, conifer management for all ownerships and all cost-price assumptions show positive returns for high and medium sites with the sole exception of the constant cost/price assumption at a 7-percent discount rate. The situation is less favorable, however, for low site lands. Perhaps not surprisingly, no ownership shows positive value for any management regime for low sites under constant price/cost assumptions at either 5- or 7-percent real discount rates. With an assumed 2-percent trend in both costs and prices, management pays its way at 5-percent discount rate but not at 7 percent. Finally, with constant costs but an increasing price trend, conifer management shows positive returns at both 5 percent and 7 percent.

The Relative Comparison of Conifer Conversion

The results summarized above indicate certain conditions where both hardwood management and conifer management may be financially feasible, given the assumptions about management regimes and yields, costs, prices, and discount rates. Given these findings, we can expect future growth of hardwoods under three conditions:

1) active management (natural regime) on hardwood sites. This represents conscious management of the better hardwood sites where management is demonstrated to be economically feasible and where conifer management is submarginal.

2) natural, unmanaged stands on sites which are uneconomical for either hardwood or conifer management but currently support hardwood stands. These might be called "default" stands since they do not occur as a result from a specific management decision to produce hardwood but rather are the result of natural conditions in the absence of alternative management activity.

3) natural stands on sites which may be either economical or uneconomical for future hardwood management and which currently support conifer stands, but are submarginal for continued conifer production. Assuming that uneconomic conifer production will not persist beyond harvesting of the current stand, these lands may revert to hardwood.

It is extremely difficult to generalize about the potential of these different possibilities. As we have seen, cases 1 and 2 currently include an estimated 400,000 acres (hardwood on hardwood site). Low site conifer currently occupy an estimated 2.7 million acres which potentially fall in case 3, although it is doubtful that a substantial percentage of this land would naturally revert to hardwood. We simply lack good data on lands in this category at the moment.

In addition, we still need to consider the 1.4 million acres carried as "hardwood on conifer site." How much of this acreage can we economically convert to conifer - if any? This is really the essence of our management problem. Two conditions hold. First, future conifer management must be economically justified, and second, the future management must more than compensate for the additional costs of stand conversion.

Following the Department of Natural Resources analysis a step further, we can gain some insights into the feasibility of conversion on these sites (*1* - appendix B). Our first task is to recognize the impact of a one-time additional cost for site conversion on the financial feasibility of conifer production. The results tabulated in table 2 simply assumed bare land. Conversion of existing hardwood stands, however, requires an additional assumed expenditure of $225 per acre. The results of such an analysis are presented in table 3 in appendix I. The findings can be easily stated: Low and medium sites have negative conversion values at a 7-percent discount rate when conversion costs of $225 per acre are considered. Conversion of these sites at a 5-percent discount rate is feasible if intensive conifer management is adopted. For high site lands, conversion is generally feasible for all ownerships and management regimes at a 5-percent discount rate and only marginally feasible at 7 percent. All these findings assume increases in prices of 2 percent per year under both constant and increasing costs. Evaluation of site conversion under a constant price and cost situation is not reported, although by inference we can conclude that conversion of low sites would be unprofitable at both 5 and 7 percent, and that conversion of medium sites will become marginal even at 5 percent, as would high site conversion at 7 percent.

Conclusion

We should remain cautious about overinterpretation of the case study results summarized in the foregoing discussion. The important point is the recognition of the patterns revealed in these results, and the apparent sensitivity of our results to the necessary assumptions which we are required to make. Our conclusions are obviously conditioned by anticipated yields and assumed site equivalents between hardwood and conifer. This probably remains one of the weakest points in our analysis. Further, we can see that both the levels of costs and prices assumed, as well as the potential trends in these factors over time, are highly critical to our conversion analysis. Finally, the choice of an appropriate discount rate is significant. The difference between results using a real rate of 5 percent and 7 percent illustrate the sharp impact of interest rates on economic feasibility.

Needless to say, the application of economic analysis requires that each land manager carefully assess the specifics of his forest land and the site-specific yield, costs, and value relationships. Generalized results such as those discussed here can only illustrate basic principles. Management decisions require much more detailed analysis of the actual on-the-ground conditions faced by each landowner or manager. Should we convert? It all depends!

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Appendix I

CALCULATION OF A SAMPLE PROBLEM

The following sample calculation illustrates the analysis of the choice of converting a red alder stand immediately at age 15 to conifer. The assumed rotation for red alder is 45 years (for both the present stand and future stands) and 70 years for conifer. The discount rate is 9 percent. All costs and returns are as shown in the sample calculations. The present value of retaining red alder, with the present stand held to age 45, is $17.47. The present value of immediate conversion to Douglas-fir on a 70-year rotation is -$26.05. All assumed costs and revenues are only illustrative (3).

The Present Net Worth of Retaining Red Alder

$$\left[\begin{array}{c}\text{Present value of perpetual series of red alder yields}\end{array}\right] = (299.23)\left[\frac{(1.09)^{45}}{[(1.09)^{45}-1]\,(1.09)^{45-15}}\right]$$

$$= \$23.03$$

$$\left[\begin{array}{c}\text{Present value of annual red alder management costs}\end{array}\right] = (0.50)\left[\frac{1}{0.09}\right]$$

$$= \$5.56$$

$$\left[\begin{array}{c}\text{Present net worth of retaining red alder}\end{array}\right] = \$23.03 - \$5.56 = \boxed{\$17.47}$$

The Present Net Worth of Replacing Red Alder With Douglas-Fir

$$\left[\begin{array}{c}\text{Present value of}\\ \text{existing red}\\ \text{alder stand}\end{array}\right] = (66.01)\left[\frac{1}{(1.09)^{0}}\right]$$

$$= \$66.01$$

$$\left[\begin{array}{c}\text{Present value of}\\ \text{annual red alder}\\ \text{management costs}\end{array}\right] = (0.50)\left[\frac{(1.09)^{0}-1}{0.09(1.09)^{0}}\right]$$

$$= \$0.00$$

$$\left[\begin{array}{c}\text{Present net worth}\\ \text{of existing red}\\ \text{alder stand}\\ \text{BEFORE CONVERSION}\end{array}\right] = \$66.01 - \$0.00 = \$66.01$$

$$\left[\begin{array}{c}\text{Present net worth}\\ \text{of site preparation}\\ \text{costs at CONVERSION}\end{array}\right] = (70.00)\left[\frac{1}{(1.09)^{0}}\right]$$

$$= \$70.00$$

$$\left[\begin{array}{c}\text{Present value of}\\ \text{cost of periodically}\\ \text{establishing Douglas-fir}\end{array}\right] = (80.00)\left[\frac{(1.09)^{70}}{[(1.09)^{70}-1](1.09)^{0}}\right]$$

$$= \$80.19$$

$$\left[\begin{array}{c}\text{Present value of}\\ \text{cost of periodic}\\ \text{brush control}\end{array}\right] = (40.00)\left[\frac{(1.09)^{70}}{[(1.09)^{70}-1](1.09)^{0+5}}\right]$$

$$= \$26.06$$

$$\left[\begin{array}{c}\text{Present value of}\\ \text{annual Douglas-fir}\\ \text{management costs}\end{array}\right] = (0.60)\left[\frac{1}{0.09(1.09)^{0}}\right]$$

$$= \$6.67$$

$$\left[\begin{array}{c}\text{Present value of}\\ \text{perpetual series of}\\ \text{Douglas-fir yields}\end{array}\right] = \left[\frac{(1.09)^{70}}{[(1.09)^{70}-1](1.09)^{0}}\right]\left\{\left[\frac{436.50}{(1.09)^{25}}\right] + \left[\frac{769.50}{(1.09)^{40}}\right] + \left[\frac{922.50}{(1.09)^{55}}\right] + \left[\frac{3,180.00}{(1.09)^{70}}\right]\right\}$$

$$= \$90.86$$

$$\left[\begin{array}{c}\text{Present net worth of}\\ \text{perpetual Douglas-}\\ \text{fir management}\\ \text{AFTER CONVERSION}\end{array}\right] = \$90.86 - \$80.19 - \$26.06 - \$6.67 = -\$22.06$$

$$\left[\begin{array}{c}\text{Present net worth}\\ \text{of converting red}\\ \text{alder to Douglas-fir}\end{array}\right] = \$66.01 - \$70.00 - \$22.06 = \boxed{-\$26.05}$$

Table 3--*Conifer reclamation or hardwood*

Regime	Rotation (Years)	Forest Industry ownership							
		Site							
		High		Medium		Low		High	
		Real interest rate (Percent)		Real interest rate (Percent)		Real interest rate (Percent)		Real interest rate (Percent)	
		5	7	5	7	5	7	5	7
		- - -Two percent rate of increase in prices and costs- - -						- - - - - - - - -	
Stand Establishment	50	113	(97)[1/]	(39)	(146)	(112)	(168)	241	(63)[1/]
	60	162	(104)	40	(135)	(88)	(169)	317	(71)
Thinning	50	418	15	186	(69)	(13)	(138)	643	78
	60	388	(21)	187	(88)	12	(144)	585	21
Intensive (No CT)	50	330	(36)	118	(106)	(39)	(157)	542	17
	60	333	(70)	126	(127)	(14)	(164)	553	(31)
Intensive	50	465[2/]	27[2/]	225[2/]	(60)	15[2/]	(136)	684[2/]	83[2/]
	60	474[2/]	4	220	(81)	39[2/]	(141)	686[2/]	46
		Two percent rate of increase in prices with constant costs						- - - - - - - - -	
Stand Establishment	50	153	(67)	(2)	(118)	(77)	(142)	289	(29)
	60	204	(74)	79	(107)	(52)	(143)	368	(36)
Thinning	50	461	47	226	(40)	25	(110)	698	116
	60	433	11	229	(58)	52	(115)	642	60
Intensive (No CT)	50	388	4	173	(67)	15	(120)	623	70
	60	393	(30)	182	(88)	40	(127)	635	23
Intensive	50	523[2/]	67[2/]	280	(21)	68[2/]	(99)	765[2/]	136[2/]
	60	534[2/]	45	277	(42)	94[2/]	(103)	768[2/]	100

[1/] Parentheses denote negative values.

[2/] Highest positive Land Expectation Values for each price and cost combination and interest rate.

Source: Washington Department of Natural Resources. Forest Productivity Study, Phase II.

conversion. Land expectation values per acre

Public ownership				Other private ownership					
Site				Site					
Medium		Low		High		Medium		Low	
Real interest rate (Percent)		Real interest rate (Percent)		Real interest rate (Percent)		Real interest rate (Percent)		Real interest rate (Percent)	
5	7	5	7	5	7	5	7	5	7
-Two percent rate of increase in prices and costs-									
7	(143)	(107)	(183)	149	(99)[1/]	(36)	(158)	(122)	(184)
128	(125)	(70)	(183)	212	(107)	65	(144)	(91)	(184)
318	(41)	32	(142)	500	25	232	(69)	(3)	(149)
310	(72)	67	(151)	452	(24)	226	(95)	27	(156)
221	(94)	(16)	(175)	408	(30)	148	(115)	(42)	(176)
237	(122)	24	(184)	415	(72)	161	(140)	(8)	(184)
340[2/]	(44)	51[2/]	(150)	539[2/]	31[2/]	256[2/]	(69)	17[2/]	(154)
323	(79)	68[2/]	(163)	542[2/]	0	244	(98)	35[2/]	(163)
-Two percent rate of increase in prices with constant costs-									
56	(110)	(59)	(149)	202	(63)	13	(124)	(77)	(152)
178	(91)	(20)	(148)	268	(69)	117	(109)	(44)	(152)
373	(3)	87	(104)	558	65	286	(32)	48	(113)
367	(33)	124	(112)	513	17	283	(57)	80	(120)
302	(41)	65	(122)	488	22	224	(65)	30	(128)
320	(68)	107	(130)	498	(18)	239	(89)	65	(135)
421[2/]	9[2/]	132[2/]	(97)	619[2/]	83[2/]	332[2/]	(19)	89[2/]	(106)
406	(25)	150[2/]	(109)	624[2/]	53	321	(47)	108[2/]	(115)

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