ECOLOGY OF NOBLE FIR

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ABSTRACT

Noble fir is the premier true fir in size of individuals, stand volumes, and appearance. Loggers recognized its value early (they called it larch) due to its high strength/weight ratio and consequent specialty uses (e.g., airplanes and ladder stock). It is a productive subalpine tree with high management potential. Available volumes exceed 1 billion ft^3*. Noble fir occurs in the Cascade Range between 44° and 47°45' north latitudes and in isolated populations in the Oregon Coast Ranges and southwestern Washington's Willapa Hills. It is found mainly in the* Abies amabilis *Zone. Noble fir is most common on habitat types characterized by herbaceous and big huckleberry-beargrass understories and is uncommon on habitat types characterized by Alaska huckleberry. It consistently plays a pioneer role because of its shade intolerance, in contrast with the other true firs. Noble fir averages medium or better cone crops 50 percent of the time over its range, although sites can go as long as six years without significant cone production. Seed quality varies greatly with cone crop size; 49 percent sound seed was the maximum observed in 54 seedtrap-based analyses. Collected seed averages 13,500 seeds/lb and 41 percent germinability. Factors responsible for poor seed quality are not completely understood. Both natural and artificial regeneration has variable success. Seedlings start slowly. Noble fir is relatively intolerant although more tolerant than Douglas-fir. Although initial growth is slow noble fir continues significant height growth into the second century; on many upper slope sites its height surpasses that of the faster-starting Douglas-fir at 50 to 75 years. Stand production can be very high with dense stands of trees of high form factor. Stand production can be very high with dense stands of trees of high form factor. Most natural noble fir is found in mixed stands but pure stands do occur. The record stand averages 329,000 board feet per acre (gross) over 10 acres; the best contiguous 2.47-acre (1-ha block) contains 407,950 board feet/acre (gross). Typical volumes in 60- to 80-year-old stands are 50 to 60 M.b.f. Noble fir attains heights and diameters in excess of 275 feet and 100 inches b.h. Noble fir is not long-lived, generally senescing at 250 to 300 years; few trees live beyond 400 years, although one has been estimated at 600 years. Noble fir is relatively free of pests and pathogens. Root rots and bear damage are most frequent.*

INTRODUCTION

In 1825 David Douglas discovered noble fir (*Abies procera* Rehd.) along the breaks of the Columbia Gorge. As individual trees, in stands of impressive volumes, and in general appearance, noble fir is outstanding in the genus (figure 1). Its present and previous Latin names describe it well—noble (*nobilis*) and tall (*procera*). Noble fir's attractive quality also extends to its wood. Loggers recognized very early that this was a valuable tree and called it larch to avoid the prejudices against true fir wood. In fact, the two Larch Mountains on both sides of the Columbia River near Portland were named for the noble fir that grows on their summits. Noble fir has the strongest wood of any true fir; in recognition of its high strength/weight ratio (similar to Sitka spruce(*Picea sitchensis* [Bong.] Carr.), noble fir has been used for specialty products such as ladder rails and airplane construction. Another interesting specialty use was as stock for venetian blinds.

Today noble fir is recognized as a manageable, productive tree for higher elevation forest sites in the Cascade Range of Oregon and Washington. There are over 1 billion cubic feet (ft^3) or 6 billion board feet (bd ft) of noble fir on commercial forest lands in the Pacific Northwest (Franklin, this symposium). Typically, it is found in mixed stands, but current management plans, which involve extensive planting, will no doubt drastically expand the proportion of this species found in the next generation of mid- and high-elevation forests. In addition to domestic uses (lumber, pulp, and plywood, for example), we can expect that noble fir will continue to bring a premium in the white wood export market. Finally, noble fir has been and will continue to be important in the Christmas tree and greenery market.

The topic of this paper is ecological characteristics of noble fir important to managers. Aspects of distribution, community relationships, regeneration behavior, productivity, pests, and genetic variability are included. Many of the data are from unpublished studies on file in the Pacific Northwest Forest and Range Experiment Station.

Franklin, Jerry F. Ecology of noble fir. In: Oliver, Chadwick Dearing; Kenady, Reid M., eds. Biology and management of true fir in the Pacific Northwest: Proceedings of the symposium; 1981 February 24-26; Seattle, WA. Contrib. 45. Seattle, WA: College of Forest Resources, University of Washington; Portland, OR: U.S. Department of Agriculture,

Figure 1. Noble fir stands are capable of prodigious growth; pictured here is the record volume noble fir stand found in the Goat Marsh Research Natural Area near Mt. St. Helens, Washington.

DISTRIBUTION

The distribution of noble fir is the most limited of all the western true firs (figure 2). Noble fir is found most commonly in the Pacific Silver Fir (*Abies amabilis* [Dougl.] Forbes) Zone of Washington and Oregon, approximately between the McKenzie River and Stevens Pass, or 44° and 48° N. latitude. Most of its range is within the Cascade Mountains, with scattered populations in the Coast Range of northern Oregon and the Willapa Hills of southwestern Washington. Despite earlier reports to the contrary, noble fir is not known from the Olympic Mountains or northern Cascades of Washington. Genetically pure noble fir is not found in southwestern Oregon, as will be discussed later in this paper.

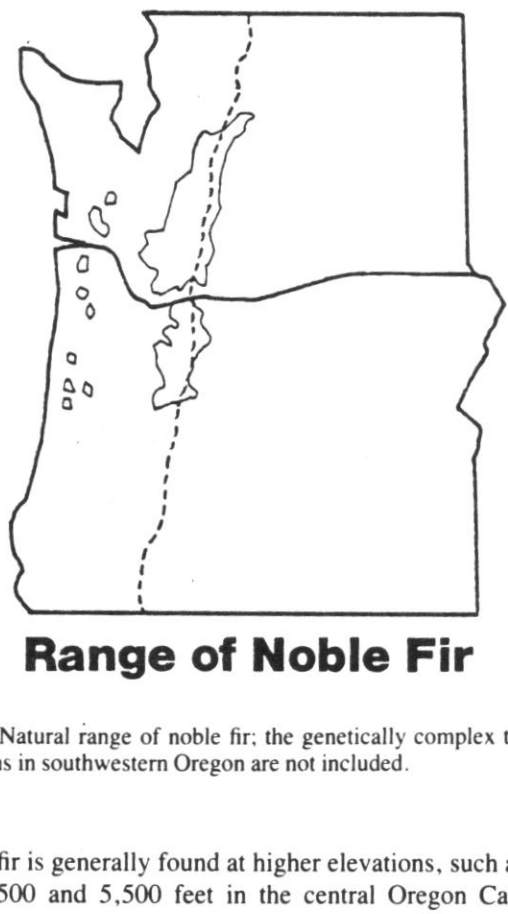

Figure 2. Natural range of noble fir; the genetically complex true fir populations in southwestern Oregon are not included.

Noble fir is generally found at higher elevations, such as between 3,500 and 5,500 feet in the central Oregon Cascade Range and 3,000 and 5,000 feet elevation in the central Washington Cascade Range. It does occur occasionally at lower elevations in both the Cascade and Coast Ranges. The excellent growth seen at lower elevations shows that it can do well there, provided it is not eliminated by early competition.

Noble fir grows in the high mountain variant of the wet maritime northwestern climate. Summers are cool. Winters are relatively mild but very wet. Precipitation is typically in excess of 100 inches annually. Much of the precipitation accumulates in winter snow packs which may reach depths of six to 10 feet. In western Oregon, noble fir has been found to occur on sites with maximum pre-dawn plant moisture stresses of 18 bars or less (Zobel *et al.* 1976). Typical temperature growth indexes (a temperature-summing procedure that has a scale of about 20 to 120 days) for noble fir sites in western Oregon are 37 to 78 days (Zobel *et al.* 1976). Noble fir does show a preference for warmer (southerly) aspects in most data sets that have been collected (Thornburgh 1969; Franklin *et al.* 1981; Dyrness *et al.* 1974).

Noble fir grows on a large variety of soils which develop most commonly in colluvium and volcanic ejecta. There are hints from soil and litter studies that it favors soils with better-than-average nutrient status. Noble fir does appear to be sensitive to soil moisture conditions. Warm, well-watered but well-drained soils are particularly favored sites for noble fir.

COMMUNITY ECOLOGY

Habitat types and plant communities in which noble fir occurs are relatively well known (e.g., Franklin 1966; Thornburgh 1969; Franklin *et al.* 1981; Dyrness *et al.* 1974; Emmingham and Hemstrom 1981). A pattern of its occurrence and importance appears to emerge in both the southern (Dyrness *et al.* 1974) and northern (Franklin *et al.* 1981) portions of its range (tables 1 and 2). Within the Mountain Hemlock (*Tsuga mertensiana* [Bong.] Carr.) Zone, noble fir is essentially confined to habitats characterized by beargrass (*Xerophyllum tenax* [Pursh] Nutt.). It is notably absent from the coldest, snowiest forest habitats, characterized by understories of shrubby ericads.

In the Pacific Silver Fir Zone, noble fir is most abundant and reaches optimum development on the herbaceous habitats characterized by species such as foamflower (*Tiarella unifoliata* Hook.), vanillaleaf (*Achlys triphylls* [Smith] DC.), and twisted stalk (*Streptopus roseus* Michx.). At Mount Rainier, noble fir is also common on some of the relatively warm and dry habitats in the Pacific Silver Fir Zone characterized by dwarf Oregon grape (*Berberis nervosa* Pursh) and beargrass.

A distinctive feature of the distribution of noble fir is its relative unimportance in the very widespread Alaska Huckleberry (*Vaccinium alaskaense* Howell) Habitat Type (Franklin 1966; Franklin *et al.* 1981; Emmingham and Hemstrom 1981). This is the modal and most extensive habitat type in the Pacific Silver Fir Zone of the southern Washington Cascades; therefore, the relative sparsity of noble fir is conspicuous. Causes for this poor representation are not known. Noble fir occurs sporadically in the Western Hemlock (*Tsuga heterophylla* [Raf.] Sarg.) Zone in Mount Rainier National Park (table 2). It occurs in significant numbers only on the Western Hemlock/Vanilleaf habitat, however.

Ecology of Noble Fir

Table 1. Constancy and basal area of noble fir by habitat type in Mount Rainier National Park

Zone	Habitat types	Plots —no.—	Constancy* —%—	Basal area —m²/ha
Tsuga mertensiana	*Chamaecyparis nootkatensis/Vaccinium ovalifolium*	15	7	Tr**
	Abies amabilis/Rhododendron albiflorum	25	4	Tr
	Abies amabilis/Menziesia ferruginea	27	7	1
	Abies amabilis/Rubus lasiococcus	51	14	2
	Abies amabilis/Xerophyllum tenax	11	64	11
Abies amabilis	*Abies amabilis/Oplopanax horridum*	31	16	1
	Abies amabilis/Tiarella unifoliata	32	47	20
	Abies amabilis/Vaccinium alaskaense	87	18	3
	Abies amabilis/Berberis nervosa	38	53	6
	Abies amabilis/Xerophyllum tenax	14	50	20
	Abies amabilis/Gaultheria shallon	15	33	1
Tsuga heterophylla	*Tsuga heterophylla/Oplopanax horridum*	26	12	Tr
	Tsuga heterophylla/Polystichum munitum	22	4	Tr
	Tsuga heterophylla/Achlys triphylla	9	56	1
	Tsuga heterophylla/Gaultheria shallon	17	18	Tr

* Constancy is the percent of the plots that contain live noble fir.
** Tr indicates less than 0.5–m²/ha basal area.

(from Franklin, et al. 1981)

Successional Role

Noble fir is classed as a shade-intolerant species, a judgment confirmed by physiological measurements (Hodges 1962). It is the most intolerant of the American true firs, and noble fir seedlings are incapable of establishing themselves under a closed forest canopy. I view noble fir as slightly more tolerant than Douglas-fir, based on the persistence of occasional overtopped noble fir seedlings, saplings, and poles. Noble fir can occasionally establish in the partial shade of overmature stands with rapidly opening canopies (Franklin 1964).

Noble fir plays a seral or pioneer role successionally because of its shade intolerance. Disturbances such as wildfire, which create major stand openings, are required for its establishment, as discussed below. In natural stands noble fir is subject to replacement by its very tolerant associates, Pacific silver fir and western hemlock. This phenomenon is illustrated by size-class distributions from mature and old-growth stands in Mount Rainier National Park (figure 3).

Table 2. Constancy and coverage of noble fir by habitat type in the central western Cascade Range in Oregon

Zone	Habitat types	Plots —no.—	Constancy* —%—	Coverage —%—
Tsuga mertensiana	*Chamaecyparis nootkatensis/Oplopanax horridum*	7	14	Tr**
	Abies amabilis-Tsuga mertensiana/Xerophyllum tenax	8	62	16
Abies amabilis	*Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax*	9	100	33
	Abies amabilis/Vaccinium alaskaense/Cornus canadensis	19	37	1
Transition†	*Tsuga heterophylla-Abies amabilis/Linnaea borealis*	33	12	Tr
	Tsuga heterophylla-Abies amabilis Berberis nervosa	22	0	0

* Constancy is the percent of the plots that contain live noble fir.
** Trace indicates less than 0.5-percent cover.
† Transition between *Tsuga heterophylla* and *Abies amabilis* Zones.

(from Dyrness, et al. 1971)

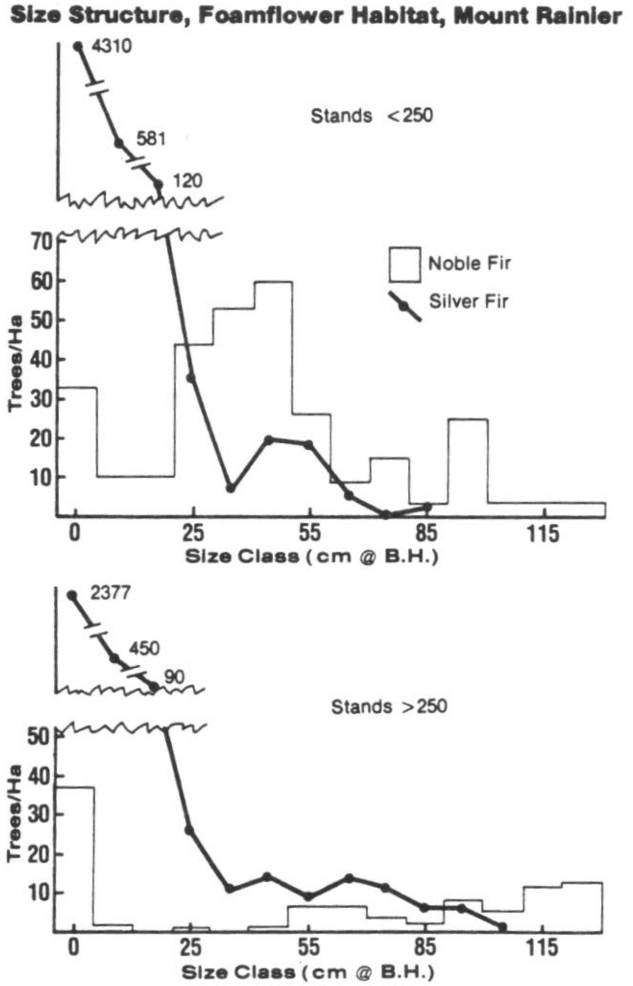

Figure 3. Size-class distributions for noble fir and Pacific silver fir in young and old stands found on the Pacific Silver Fir/Foamflower Habitat Type at Mt. Rainier National park, Washington: the seral nature of the shade-intolerant noble fir is apparent.

REGENERATION BEHAVIOR

Noble fir begins producing cones in quantity at 35 to 50 years. Older trees can produce very large quantities. The record annual production for an individual tree was estimated at 3,000 cones, which would yield over 1,500,000 seeds. Cone production has been observed in nine mature stands for periods between 1961 and 1980 (Franklin *et al.* 1974). Regionwide, excluding 1961 when only two plots were counted, noble firs produced a medium or better crop 42 percent of the time (table 3). Cone production at particular locations was sometimes much poorer, however, especially along the eastern margin of species range. Individual stands there had intervals of up to six years between medium cone crops.

Seed quality is typically poor. Seed-fall collections within natural stands totalling 54 seed years (five stands for 10 to 11 years) had a maximum sound seed percentage of 49 percent.[1]. Most of the unsound seed consisted of round but unfilled seed, with relatively small amounts of seed lost to cone and seed insects in these seed-trap collections. Others have reported substantial losses to insects, however. Seed quality is very strongly correlated with cone crop size (figure 4); cone crops must be medium size or better for sound seed to exceed 10 percent. Factors responsible for poor seed quality are not known but may include insufficient pollen in years of light cone crops.

It is possible that the primary factors responsible for the low percent of sound seed may be similar to those described for Pacific silver fir (Owens and Molder 1977). Pacific silver fir has an unspecialized pollen mechanism, long periods of pollen dormancy, and a short time after germination when pollen tubes must develop and penetrate the long nucellar tip. Also, archegonia are not numerous and abort very quickly if not fertilized. Owens and Molder(1977) concluded that these factors are responsible for the low percent of viable seed in Pacific silver fir, and I believe that this is also true for noble fir.

Noble fir seeds are not widely dispersed because of their heavy weight, averaging 13,500 seeds per pound (Schopmeyer 1974). Although Isaac (1930) showed that noble fir seeds can disperse as far as 2,000 feet from their origin, most seed actually falls much closer to the parent trees (Carkin *et al.* 1978). Thornburgh (1969) thought that the distributional pattern of noble fir was largely controlled by small seed-dispersal distance coupled with susceptibility to fire. He found that most noble fir in his study area grew in burns that were narrow in one dimension.

1. Data on file at the USDA Forest Service, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

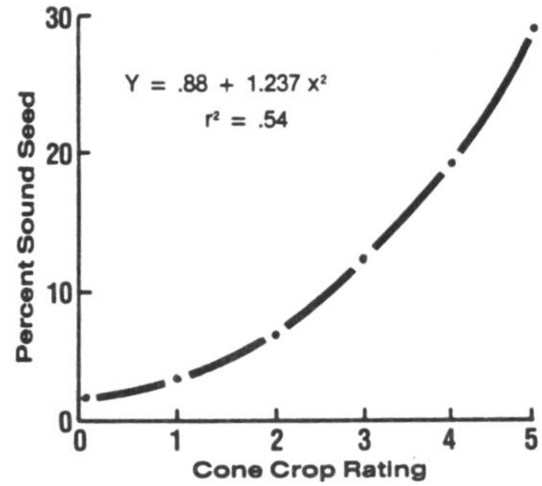

Figure 4. Relation of noble fir seed quality to cone-crop size.

Table 3. Median production by mature noble fir trees from 1961 to 1980; based on the median of annual counts of 10 to 30 individually marked trees per site.

Year	Plots —no.—	Median*† —no. cones—	Range‡ —no. cones—
1961	2	20	18-22
1962	7	50	1-280
1963	8	0.5	0-26
1964	8	1.5	0-8
1965	8	38	0-184
1966	8	6	0-40
1967	9	2	0-12
1968	9	149	40-441
1969	9	0	0
1970	9	3	0-34
1971	9	35	18-164
1972	9	0	0-3
1973	9	0	0-17
1974	9	32	8-127
1975	9	4	0-20
1976	9	12	2-50
1977	9	4	0-15
1978	9	45	18-116
1979	9	0	0-15
1980	8	18	4-64

* Median of all plots counted.

† Median cone counts are related to cone crop size as follows (Franklin et al. 1974):

Cone Median count/Tree	Crop rating
0	Failure
1-4	Very light
5-9	Light
10-19	Medium
20-49	Heavy
50+	Very heavy

‡ Range in median count on individual plots.

Natural regeneration of noble fir appears to have variable success. In one early study, regeneration was so rapid and abundant that the investigator concluded that it was unquestionably the result of seed stored in the duff (Hoffman 1917), a hypothesis later disproved by Isaac (1943). Noble fir regeneration was actually quite abundant on many of the late 19th- and early 20th-century burns, based on Hoffman's (1917) data and on the stands that exist today. Thornburgh (1969) found noble fir disproportionately successful at regenerating some small high-elevation burns; in one case, however, it failed to regenerate a small burn where it consisted of 24 percent of the potential seed source. Data on noble fir regeneration following cutting are limited. Noble fir seedlings were very successful on one clearcut, especially away from the stand border (Thornburgh 1969). In an artificial seeding, however, noble fir seedlings had the poorest survival of any of the true firs (Thornburgh 1969). Sullivan (1978) found noble fir stocking on clearcuts superior to that of Douglas-fir on three of five upper-slope habitat types studied on the central Willamette National Forest in Oregon. This was believed to be due to better survival of noble fir and not to seed source differences. The 15- to 17-year-old clearcuts had 114 to 720 noble fir seedlings per acre depending upon habitat type. Seedling growth was slow, with noble fir heights of 12 to 20 inches at seven years. Competing vegetation as well as frosts may deter noble fir regeneration (Fowells 1965). Shelterwood cutting would seem well suited to establishment of noble fir regeneration, but no data are currently available. In summary, although development of good natural noble fir regeneration is possible, it is not yet predictable on a given, specific site and for a specific cutting regime.

PRODUCTIVITY

Growth of individual noble fir trees can be characterized by slow initial growth and height growth that is sustained into the second and even third centuries. Noble fir is typically a slow starter. Although Williams' (1968) noble firs averaged 7.3 years to grow to breast height (b.h.) (versus 6.9 for Douglas-fir), Hanzlik (1925) reports 11 years; and Sullivan's (1978) data (cited in the previous paragraph) certainly suggest a slower initial growth. In Great Britain, noble fir had the slowest initial growth rate of any species examined (Aldhous and Low 1974); noble fir heights at six years were two to three feet in test plantations. Slow initial growth was a major factor in the conclusion that "there appears to be no case for any large scale planting of this species [in Great Britain]. . . ."

The height growth patterns of noble fir have been described for young stands (Murray 1973; Harrington and Murray, this symposium), for British plantations (Hamilton and Christie 1971), and for trees up to 300 years (Herman *et al.* 1978). Young trees on good sites are capable of annual height increment of nearly four feet (Harrington and Murray, this volume). Height growth curves by Herman *et al.* (1978) (figure 5) show that undamaged trees can maintain height growth to 200 to 250 years. Maximum heights are in excess of 260 feet on the best sites and heights at an age of 100 years range from 60 to 160 feet in the Pacific Silver Fir Zone. Even greater heights at b.h. age 100 can be expected at low elevations (Harrington and Murray, this volume).

Noble fir is only moderately long-lived. Stands generally reach a stage of senescence at 250 to 300 years. At Mount Rainier National Park, relatively few noble firs older than 400 years were encountered, although one specimen was estimated to be 600 years old (Hemstrom 1979). In the 32 plots taken on Pacific Silver Fir/Foamflower Habitat Type at Mount Rainier National Park, noble fir occurred in 60 percent of the stands under 400 years, in 25 percent of those over 400 years, and in no stand over 475 years old (Franklin *et al.* 1981).

Noble fir occurs most frequently mixed with other species such as Douglas-fir, western hemlock, and Pacific silver fir. In such stands it is typically found in dominant or superdominant

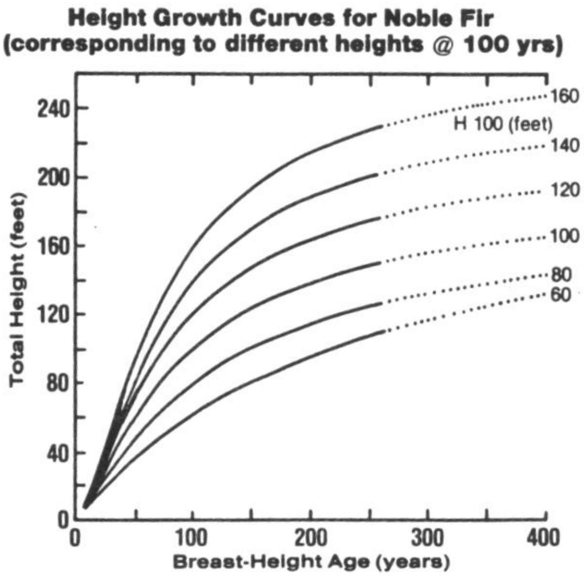

Figure 5. Height-growth curves for noble fir on a range of site qualities (from Herman et al. 1978).

positions and invariably contributes volume far out of proportion to its numbers. In one Larch Mountain stand in Oregon, noble fir numbered only 20 percent of the trees but contributed 46 percent of the volume (Hanzlik 1925). Noble fir does occur in nearly pure stands, however; and data from 12 such stands ranging widely in age and site quality illustrate prodigious growth (table 4). Yields of about 100,000 bd ft/acre occur on site class II lands (e.g., site index 125 b.h. age 100 years (Herman *et al.* 1978). A grove at Goat Marsh Research Natural Area on the southwestern slopes of Mount St. Helens contains the record volume. The best contiguous 2.47 acre (1-ha block) contains 407,950 bd ft/acre, a value that significantly exceeds the highest gross volume for an acre of Douglas-fir. The British yield tables for noble fir plantations (table 5) also indicate that managed-stand yields are high.

Culmination of mean annual increment (m.a.i.) appears to be relatively late in normally stocked stands of noble fir. Volume growth and to a lesser extent m.a.i., increase rapidly in stands from 70 to 100 years (table 4). Culmination of m.a.i. for site class II (site index of 110–130 feet at b.h. age 100 years (Herman *et al.* 1978) appears to be between 115 and 130 years.

Noble fir can also be very productive of biomass as well as of wood volumes (Fujimori *et al.* 1976). Above-ground and leaf biomass values in a 100- to 130-year-old stand were 393 and 7.8 tons/acre, respectively. The leaf biomass was particularly high relative to temperate forest types of the same age and reflects retention of some needles for as long as 20 years.

A comparison of Douglas-fir and noble fir productivity is probably useful because there is widespread familiarity with the former species. Murray (1973) made an exhaustive comparison of youthful noble fir and Douglas-fir after constructing noble fir site-index curves with an index age of 25 years (b.h. age). A comparison on 56 sites found Douglas-fir exceeded noble fir site index on 25 sites, no difference on 30 sites, and noble fir exceeded Douglas-fir on one site. The performance of noble fir in this instance is quite good, since most stands were young and growing at relatively low elevation, and the site-index age was young—all circumstances being disadvantageous to noble fir. Douglas-fir site index did not exceed noble fir on any site where the stand was greater than 25 years old. Harrington and Murray (this volume) continued the comparative growth studies and found that noble fir typically performed

Table 4. Preliminary stand data for natural noble fir-dominated stands in the southern Washington and northern Oregon Cascade Range; based on four or five systematically located 0.247-acre plots per stand except as noted for Goat Marsh.

Location	*Stand age*	*Site* index*	*Noble** fir*	*Density†*	*Mean d.b.h.*	*Basal area*	*Volume/ acre‡*
	yr	*ft*	*%*	*no./acre*	*in*	*ft**/acre*	*bd ft*
Huffman	68	113	82	746	8.3	363	51,000
Yacolt	68	113	98	576	10.5	348	51,500
Carpenter	70	122	93	500	9.8	306	59,000
Sunrise	100	125	89	315	11.4	380	104,800
Wildcat	130	143	92	114	20.5	355	161,600
Yarder	136	73	87	232	13.5	181	50,600
Marys	161	134	99	105	20.9	341	151,400
Wahtum	218	68	50	156	18.7	338	85,000
Wilson	256	98	82	125	23.6	380	134,900
Goat Marsh	290	155	70	108	23.2	552	333,200
Cushman	313	105	79	188	14.5	478	207,500
Blue Lake	331	122	87	81	31.6	583	304,900

* Height at b.h. age of 100 years.

** Noble fir percent by volume.

† Trees 2 in d.b.h. and over except in Goat Marsh where density is for trees 6 in d.b.h. and over.

‡ Gross volume.

Table 5. Yield of normal noble fir stands in Great Britain at 80 years for three yield classes.

Yield class*	Trees			Current stand		Total yield**
	No.	Height	Diameter	Basal area	Volume**	Volume**
	no./acre	ft	in	ft^2/acre	ft^3/acre	ft^3/acre
22	132	110	18.8	254	12,178	24,781
18	169	99	15.9	233	10,476	20,322
14	226	86	13.2	216	8,646	15,892

* Yield class is based upon the maximum mean annual increment possible in cubic meters per hectare (m^3/ha). For example, yield class 22 means that on a site so designated noble fir has a possible mean annual increment of about 22 m^3/ha.

** Total yield is the current stand plus volume removed in thinnings.

from Hamilton and Christie 1972.

better than Douglas-fir on low Douglas-fir site qualities.

A comparison of site indexes using the site curves with index age 100 (Herman *et al.* 1978; McArdle *et al.* 1930) shows a noble fir advantage over Douglas-fir on most habitat types in the Pacific Silver Fir Zone of southern Washington (table 6). It must be remembered that Douglas-fir height growth typically exceeds that of noble fir for several decades, even when noble fir has superior height at 100 years. It is this "sprinting ability" of Douglas-fir that sometimes makes it look better than noble fir in young stand mixtures. Despite a slower start, the subsequent height increments of noble fir typically keep pace with those of Douglas-fir (Harrington and Murray, this volume). Furthermore, noble fir continues to grow at or near its maximum rate for a much longer period than Douglas-fir and other associates.

At a common site-index value, the volume growth of a noble fir stand is clearly superior to that of Douglas-fir at ages in excess of 60 years, based upon the normal yield tables for Douglas-fir (table 7). The superiority appears partially due to higher stand densities and basal areas as well as to the much superior

Table 6. Comparison of noble fir and Douglas-fir site index on nine habitat types in the southern Washington Cascade Range

Habitat type	Site index	
	Douglas-fir	Noble fir
Pacific Silver Fir/Devilsclub	140	131
Pacific Silver Fir/Foamflower**	137	138
Pacific Silver Fir/Vine Maple/Salal	124	126
Pacific Silver Fir/Vine Maple/Vanillaleaf**	115	126
Pacific Silver Fir/Alaska Huckleberry	106	122
Pacific Silver Fir/Rustyleaf	103	106
Pacific Silver Fir/Vine Maple/Oregongrape**	98	108
Pacific Silver Fir/Rustyleaf/Clintonia**	97	111
Pacific Silver Fir/Cascades Azalea/Clintonia	97	100

(from U.S. Dept. Agr. Forest Service Region 6, 1980)*

* Douglas-fir site curves are from McArdle et al. (1930) and are indexed at 100 years, total age; noble fir site curves are from Herman et al. (1978) and are indexed at 100 years, breast height.

** Habitat type with especially abundant noble fir.

form class of noble fir. The columnar form of the noble fir is frequently noted, as by the British, who found its form the best of any species with which they had worked (Christie and Lewis 1961). There are higher stand densities in all four of the younger noble fir stands than for comparable, counterpart Douglas-fir stands (table 7). Stands over 100 years do not necessarily show the same contrast in either density or basal area, however. Noble fir appears to show a superiority in board-foot volume of from 10 percent to more than 25 percent, and up to twice as much in cubic-foot volume.

In summary, the long-term productivity of noble fir is often superior to Douglas-fir despite noble fir's slow early start. Where the two species occur on the same upper-slope sites, noble fir appears to be superior in site index to Douglas-fir. Even where site indexes are equal, noble fir stands appear to produce significantly greater volumes.

PESTS AND PATHOGENS

Noble fir is relatively free of insects and diseases when compared with most tree species. Reportedly (Fowells 1965), the noble fir bark beetle (*Pseudohylesinum nobilies* Swaine) commonly kills the tree; extensive personal observations have not confirmed this, however. Borers and weevils are apparently minor problems. Balsam woolly aphid (*Adelges piceae* (Ratz.), which is very destructive to Pacific silver fir and subalpine fir in the Pacific Northwest, is not a problem on noble fir. It is known to attack noble fir in the greenhouse and in arboreta but does not significantly infect trees in forest situations.

Information from personal observations of noble fir stands suggests that root rots are among the most important diseases affecting noble fir. There are also several trunk rot fungi that are known to infect noble fir (Hepting 1971). In the southern part of its range, noble fir is attacked by dwarf mistletoe (apparently *Arceuthobium tsugense* (Rosendahl) G.N. Jones and not *abietum* Engelm. ex Munz (Filip *et al.* 1979)). On the northern Willamette National Forest, mistletoe infections have been associated with extensive branch mortality; this may be caused partially by fungal infections of *Cystospora abietis* Sacc., *Cryptosporium pinicola* Linder, and *Cylindrocarpon cylindroides* Wollen. associated with the mistletoe (Filip *et al.* 1978 and 1979).

Bear damage can be a significant factor in younger stands. In one 68-year-old stand at Huffman Peak, Washington, over half of the dominant noble fir had identifiable bear scars at the base. The effects of such damage are not known, but may result in future losses to wind and heart rot.

Other damaging agents can be snow (which breaks the crown), browsing animals, and grouse (which destroy buds). Noble fir is very resistant to damage from chronic wind exposure such as that which occurs along the breaks of the Columbia Gorge. It is often difficult to determine causes of mortality in mature and overmature noble fir. Much of the mortality may be a consequence of physiological stresses which the short-crowned noble fir are not able to withstand. The gradual decline of older noble fir left along cutting boundaries may be one example of a stress phenomenon, with death occurring after several decades.

GENETIC VARIABILITY

Noble fir appears to be closely related to California red fir (*Abies magnifica* Murr.) and its highly variable variety, Shasta red fir (*A. magnifica* Murr. var. *shastensis* Lemm.), and there have been several studies of relationships in this complex. Artificial reciprocal crossings of noble and California red fir have shown that the two species are highly interfertile and, with particular parent trees, may produce as high a percentage of sound seed as intraspecies pollinations. The most complex populations, which have been referred to as both noble and Shasta red fir, occur in southern Oregon and northern California. The classical taxonomic characteristics (leaf and cone morphology) of these populations suggest a close relation to noble fir. Studies of chemical constituents (Zavarin *et al.* 1978) and seedling characteristics (Franklin and Greathouse 1968a, 1968b) indicate, however, that the noble fir populations north of the McKenzie River are distinct from those found in southern Oregon and California; there is strong evidence for a sharp discontinuity at the McKenzie River. The fir populations found in southern Oregon appear to be highly variable; distinct from noble fir; and perhaps clinally related, with a strong latitudinal gradation in characteristics, to the California red fir found farther south in the Sierra Nevada. The southwestern Oregon populations are probably not hybrid swarms resulting from crossing of California red and noble firs (Zavarin *et al.* 1978).

Noble fir does exhibit substantial variability in characteristics such as seedling growth, but is quite uniform in other characteristics such as cone and leaf morphology. The variation determined from both morphological and cold-frame studies does not appear to be related simply to latitude. Variation exists between families within a locale and between locales in at least some characteristics. One interesting characteristics of noble fir is a relatively high self-fertility which does not appear to affect germination but can depress height growth (Sorenson *et al.* 1976).

MANAGEMENT IMPLICATIONS

Management inferences can be drawn from the ecological features of noble fir. Some of the most important of these are as follows:

1. Noble fir is a very productive tree that probably deserves wider use than it currently receives. Better information needs to be developed on how to establish and stimulate early growth. A slow early growth relative to its

Table 7. Comparative stand data for natural noble fir stands and for normal natural Douglas-fir stands of the same site index and age

Stand and Species	*Site index**	*Stand age*	*Trees*	*Average d.b.h.*	*Basal area*	*Volume*
	ft	*yr*	*no./acre*	*in*	*ft²/acre*	*bd ft/acre*
Huffman						
Noble fir	113	68	746	8.3	363	51,000
Douglas-fir	110	68	424	9.5	208	36,100
Yacolt						
Noble fir	113	68	576	10.5	348	51,500
Douglas-fir	110	68	424	9.5	208	36,100
Carpenter						
Noble fir	122	70	500	9.8	306	59,000
Douglas-fir	119	70	357	10.7	225	46,270
Sunrise						
Noble fir	125	100	315	11.4	380	104,800
Douglas-fir	119	100	246	14.1	258	69,400
Wildcat						
Noble fir	143	130	114	20.5	355	161,600
Douglas-fir	145	130	132	20.9	314	118,400
Yarder						
Noble fir	73	136	232	13.5	181	50,600
Douglas-fir	80	136	296	11.6	216	38,300
Mary's Peak						
Noble fir	134	161	105	20.9	341	151,400
Douglas-fir	149	160	105	24.5	339	137,500

* Noble fir site index is based on height at 100-year breast height age while Douglas-fir site index is based on height at 100-year total stand age. Douglas-fir site indexes have been selected to compensate for this difference in index age.

Source of Douglas-fir data is McArdle et al. (1930).

associates should be a consideration in early stand treatments such as precommercial thinning. Selection for faster initial growth could also be an objective of breeding programs.

2. Since early competition is apparently an important factor in limiting the natural range of noble fir, its range can probably be extended artificially to lower elevations if managers are willing to favor it in early thinnings.

3. The range of noble fir can be extended north of its current limits, but it should probably be confined primarily to relatively warm and well-watered sites until long-term experimental plots show it is suitable for other habitats. Its distribution within its main range strongly suggests that cold environments are in some way unfavorable for the species. If the problem appears to be one of tree establishment rather than growth of established trees, it may be possible to use noble fir on these colder habitats.

4. Shelterwood seems an appropriate silvicultural system for the establishment of noble fir regeneration, since the heavy seeds have a limited dispersal capability and seedling establishment is probably best with at least some level of overstory protection. Shelterwood can also provide for advance establishment of regeneration. Establishment of trees prior to the final overstory removal may help overcome the problem of slow early growth.

5. Noble fir can clearly produce more timber than other species on many upper slope sites; but to capture its full potential, longer rotations will have to be used than are normally considered with Douglas-fir.

ACKNOWLEDGMENTS

Special acknowledgment is due Richard Carkin of the Siuslaw National Forest and Jack Booth, who installed most of the noble fir yield plots, and to Ted Thomas and Mark Klopsch, who did most of the stand-yield calculations.

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