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Screening Douglas-fir for Rapid Early Growth in Common-Garden Tests in Spain

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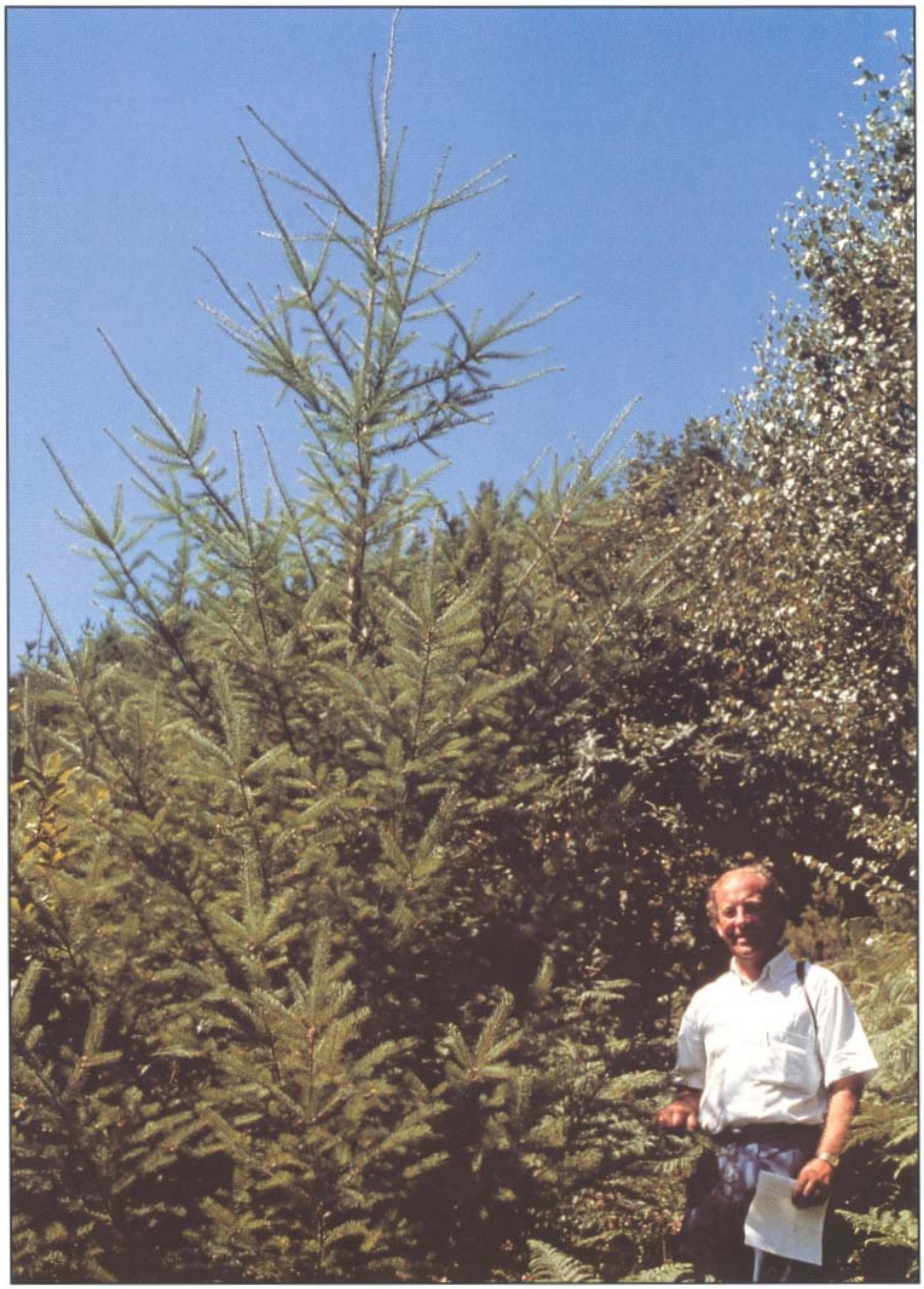

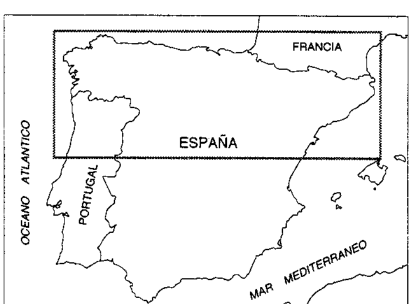

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Abstract: Douglas-firs from 91 seed sources in North America were evaluated after 5 and 6 years in 15 common-garden tests in the mountainous regions of northwest and north central Spain. Analyses of tallest trees showed that most of the sources of highest potential for reforestation in Spain are found in regions where the Pacific Ocean air mass dominates climate. Fast growers came from coastal slopes of the Coast Ranges from northwest California to the Georgia Strait of southwest British Columbia and inland slopes of the Olympic Mountains and Coast and Cascade Ranges facing the Puget Trough in western Washington and Willamette Valley in northwest Oregon. Slow growers came from latitudes south of 44° and north of 50° N, high altitudes west of the crest of the Cascade Ranges, and regions east of the crest where the continental air mass dominates climate.

Retrieval terms: climatic adaptation, genetic variation, genotype-environment interaction, species introduction, tree growth, *Pseudotsuga menziesii, P. flahaulti, P. macrolepis*

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Retrieval terms: climatic adaptation, genetic variation, genotype–environment interaction, species introduction, tree growth, *Pseudotsuga menziesii, P. flahaulti, P. macrolepis*

To locate superior Douglas-fir for reforestation in Spain, heights of Douglas-firs from 91 seed sources in North America were assessed 5 and 6 years after planting in 15 common-garden tests in the mountainous regions of northwest and north central Spain. The sources embody Douglas-fir forests in coastal and inland regions of southern British Columbia, Washington, Oregon, and northern California and natural stands of two related species in eastern Mexico. Plantations were installed on cleared planting sites from near the border with northern Portugal to near the border with southern France. Ten plantations were situated in coastal and inland regions of the Macizo Galaico Duriense of Galicia, in the Provinces of Pontevedra, Orense, and Lugo, and six plantations, in coastal and inland regions of the Cordillera Cantabrica, Montes Vascos, and Pirineos (Pyrenees), in the Provinces of Asturias, León, Guipuzcoa, and Navarra.

The test design consisted of three randomized complete blocks of seed source plots, except nine blocks in one Asturias plantation. The principal plantations received 86 and 87 sources and were situated in western and eastern Orense Province, in regions of contrasting coastal and interior climates in northwest Spain. Each had 25 seedlings per source plot and covered 6 hectares. The satellite plantations received from 4 to 31 sources and were arrayed from Portugal to France. Each had 81 seedlings per source plot, except 64 or 49 per plot for a few sources in the León plantation, and 5 per plot in the Asturias plantation with nine blocks. The plantation nearest Portugal received 22 sources, was situated in the Rio Limia watershed of southern Orense Province, and covered 4.8 hectares. That nearest France received 31 sources, was situated in the Pirineos of northern Navarra, and covered 6.8 hectares. Seedlings were spaced 3 m apart in every plantation.

Tree height was measured 5 years after planting, except 6 years in the plantations in Asturias and León. Seed source and planting site effects were assessed by analysis of variance. Analyses were run using first the mean of al l trees in each source plot and then the means of those trees most likely to dominate developing stands–the 15, 10, and 5 tallest in each plot, except 2 and 1 tallest in the Asturias plantation with nine blocks. In the principal plantations, 5 trees per plot represented 20 percent of those planted, and in the satellite plantations, 15 per plot represented 18.5 percent, except the Asturias plantation where 1 per plot represented 20 percent. Source rankings in any particular plantation were practically the same for source means based on tallest trees as for those based on all trees.

Plantation height ranged from 0.4 m on harsh sites up to 2.3 m on the better sites, based on the means of all trees in each plot. Based on means of the dominant trees, the 5 and 15 tallest in each plot in the principal and satellite plantations, respectively, height ranged from 0.6 m on the interior site in eastern Orense Province to 2.5 m on a coastal site in Asturias. The dominants averaged more than 1.4 m tall in eight plantations, including one in Lugo, the two in Asturias, the one in León, the two in Guipuzcoa, and the anchor plantations in southern Orense and northern Navarra.

Seed source effects were pronounced and highly significant ($p < 0.01$) in 12 plantations. Browsing livestock and wildfire masked the source effects in one plantation in Lugo, and soil drainage problems masked those in one in Guipuzcoa. In most plantations, trees of the best sources averaged up to three times taller than those of the poorest sources. To identify the best sources, every source was graded by the percentage of tests in which the mean of its tallest trees (18 to 20 percent of those planted) exceeded plantation height, using only those plantations where source effects were significant. Trees of 44 of the 91 sources that were graded showed good to superior growth potentials, exceeding plantation height in half or more of the tests in which the sources were assessed. Interactions of seed source and planting site were significant ($p < 0.05$ or < 0.01) in nine of the pairings of plantations that had from 5 to 85 sources in common. In each pairing, there were sources that grew well on both sites, others that grew poorly, and still others that grew well on one site and poorly on the other.

Seed origins of the 44 best sources, those that show highest promise for reforestation in Spain, are concentrated at low to middle altitudes in Pacific Slope forests where the Pacific Ocean air mass dominates climate. Forests of major interest are situated in coastal and inland regions, including maritime slopes of the North Coast Range of northwest California, the Oregon and

Washington Coast Ranges, the Olympic Peninsula, and the Georgia Strait of southwest British Columbia, and inland slopes of the Olympic Mountains and Coast and Cascade Ranges facing the Puget Trough in western Washington and Willamette Valley in northwest Oregon. Most of the fast growers came from stands at latitudes of 44° to 50° N and altitudes of 60 to 730 m (1005 m) above sea level. Most of the slow growers came from south of 44° and north of 50° N, high altitudes west of the crest of the Cascade Ranges, regions east of the Cascade crest where the continental air mass dominates climate, and eastern Mexico.

Early growth performances of Douglas-fir in common-garden tests in Spain warn that plantation success critically depends on seed source. To delimit forest regions in North America in which to collect Douglas-fir for future tree planting programs in Spain, we located origins of the fast and slow growers on maps showing established tree seed zones and plant climate zones. The resulting distributions show that most of the fast growers are found in Pacific climate types, in 27 contiguous seed zones in southwest British Columbia (4 zones), western Washington (13 zones), and northwest Oregon (10 zones). The remaining fast growers suggest three separate groups in a total of seven seed zones in coastal and inland regions of extreme southwest Oregon and northwestern California.

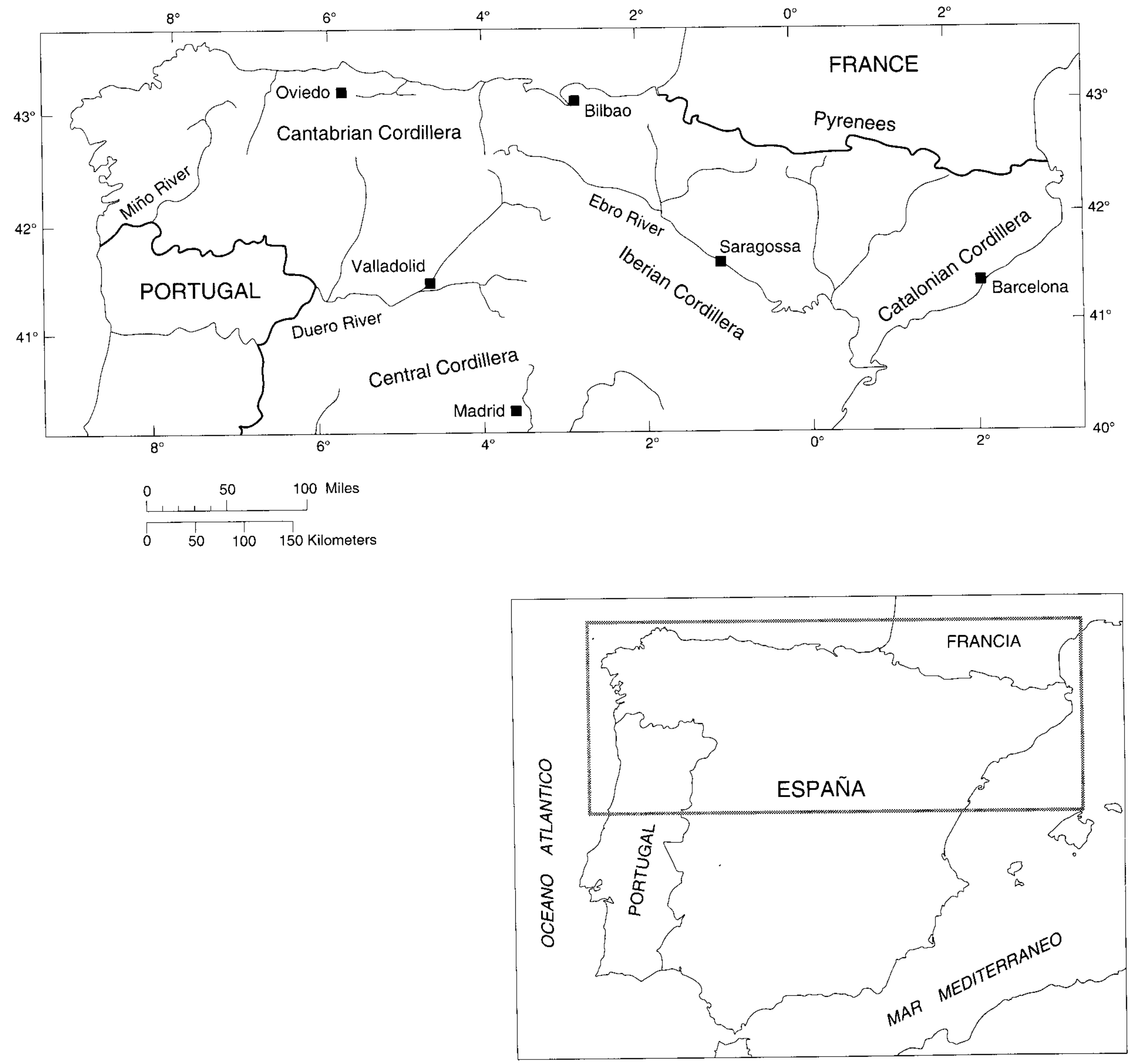


Figure 1–Major mountain ranges and river systems in northern Spain.

Introduction

Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco), the dominant timber tree in the coniferous forests of Pacific North America, is of major interest to foresters on the Iberian Peninsula. Introduced in the mountainous coastal and inland regions of northern Spain and Portugal, it grows rapidly in mixed or pure stands, consistently outperforms indigenous and introduced trees, and is a prime choice for reforestation. Unfortunately, reproductively mature stands are too small and too few to provide the genetic base and quantity of seeds needed for extensive planting programs. And like early introductions of most species, seed origins in the native range are unknown.

To identify and select best seed sources for reforestation, long-term common-garden tests of Douglas-fir from British Columbia to California and Mexico were installed on diverse forest sites in northwest and north central Spain. A definitive evaluation requires trees near midrotation age, but reforestation cannot be halted simply to await test results. Experience in western Oregon and northern California suggests that useful evaluations are possible when trees are 5 to 10 years old. On typical planting sites there, rapid early growth characterizes seed sources of high potential, even if it cannot predict those which ultimately prove best. To ensure successful reforestation in Spain, the planting stock used should be produced using known seed sources screened for rapid early growth in typical planting environments.

In this paper, we evaluate seed source effects on tree height after 5 and 6 years in the field, assess seed source−planting site interaction, and grade 91 different sources for growth performance. We describe geographic distributions of fast and slow growers with respect to tree seed zones and plant climate zones of origin and suggest the seed zones and altitudes from which to collect Douglas-fir seeds for reforestation programs in Spain. Our findings apply directly to the mountainous regions of northwest and north central Spain and may be safely extrapolated to those in adjoining northern Portugal and northeast, west central, and southern Spain.

Reforestation by Species Introduction

Spain is the second largest country in western Europe, after France, and excepting Switzerland, is the most mountainous. As in other European and Mediterranean countries, 20 centuries of woodcutting, livestock grazing, and farming of cleared timberlands and woodlands have destroyed much of Spain's original hardwood and coniferous forests. Frequent fires and cultivation have caused massive soil erosion on steep slopes and left a legacy of stony, degraded landscapes over vast regions. Residual forests are restricted in extent and, in large part, are genetically impoverished.

Professional foresters and concerned forest landowners have worked for decades to stabilize watersheds and develop anew the resources needed for wood products industries. To supply the volumes of wood and pulp that the remnant forests could not, extensive plantings of both native and introduced tree species were begun in the 1940's (Pardos and Gil 1986). The resulting plantations extended from the Atlantic Ocean to the Mediterranean Sea and blanketed large areas in the mountains of northern Spain. Plantations were established in coastal and inland regions of the Macizo Galaico Duriense in northwest Spain (Instituto Geografico Nacional 1982), along the Cordillera Cantabrica and Montes Vascos in north central Spain, and through the Pirineos (Pyrenees) to the Sierra de Montseny of Cataluña in northeast Spain (*fig. 1*).

Slow growth characterizes some extensive plantings in every region, and numerous species have been tried in a continuing search for suitably adapted and undemanding, fast growers. Prominent native pines that have been widely planted are Italian stone pine, Austrian pine, maritime pine, Aleppo pine, and Scotch pine (*Pinus pinea, P. nigra, P. pinaster, P. halepensis,* and *P. sylvestris,* respectively).

Non-native trees were first introduced at the turn of the century, and many have survived and grown well. Successful conifers include the Corsican variety of Austrian pine (*Pinus nigra* var. *corsicana*), European and Japanese larches (*Larix decidua, L. leptolepis*), Norway spruce (*Picea abies*), Atlas cedar (*Cedrus atlanticus*) from North Africa, and Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*), Port-Orford-cedar (*Chamaecyparis lawsoniana*), coast redwood (*Sequoia sempervirens*), and Monterey pine (*Pinus radiata*) from the Pacific United States. Successful hardwoods include several eucalypts from Australia (*Eucalyptus globulus, E. camaldulensis,* and others), poplars from a host of countries (*Populus* spp.), and northern red oak and pin oak (*Quercus rubra, Q. palustris*) from the Eastern United States.

The most spectacular introductions are Monterey pine (*Pinus radiata*) in Pais Vasco and blue gum (*Eucalyptus globulus*) in Galicia. First brought as curiosities by travelers, these dissimilar species now thrive in maritime regions on the Atlantic Coast and exemplify the use of introduced trees to create highly productive forests on depleted, eroded soils.

Performance of Pacific Coast Conifers

Pacific North American conifers grow well in Spain. Douglas-fir stands that were planted 30 to 70 years ago in Cantabria, Pais Vasco, and Cataluña have grown as well as those in the Oregon Coast Range, where volume growth ranges up to 21 m^3/ha/yr (Williamson and Twombly 1983). Like Monterey pine, both coast redwood and Port-Orford-cedar also thrive in Spain's Atlantic Coast regions. Coast redwoods in a stand planted near Comillas, Cantabria, ranged up to 35 m in height after 42 years, and volume growth averaged 25 m^3/ha/yr (Toval and others 1982a). Dominants in Port-Orford-cedar stands planted in La Coruña Province, Galicia, and Guipuzcoa Province, Pais Vasco, averaged 12.3 and 10.7 m in height after 20 and 16 years, and volume growth averaged 17.2 and 13.7 m^3/ha/yr (Fernandez and Michel 1982). Grand fir (*Abies grandis*) has grown the fastest in a comprehensive array of North American, European, and Mediterranean conifers planted in the Sierra de Montseny, near the Mediterranean Coast of Gerona Province, Cataluña (pers. commun., Emilio Garolera, Consorci Forestal de Catalunya, April 1987).

Douglas-fir grows well in coastal and inland regions and is a golden option for widespread reforestation. It outgrows European larch, Austrian pine, Norway spruce, and Atlas cedar in intermingled stands in Pais Vasco and Cataluña, and dominates Scotch pine in mixed plantations in the Sierra de Montseny north of Barcelona and in the eastern Sierra de Guadarrama north of Madrid. It regenerates in and overtops developing stands of native oaks in northwest and northeast Spain, in Pontevedra Province in Galicia and Gerona Province in Cataluña. Its superior tolerance of low temperature is evident in inland and upland areas where hard winter freezes have repeatedly damaged or killed Monterey pine and blue gum. Vigorous individuals and small stands are widely scattered in Galicia, and their presence suggests that Douglas-fir might grow well even on the rocky, granitic soils above 800 m of altitude, where scrub now covers 300,000 hectares. Scotch pine was planted on these harsher upland sites, but strong winds and heavy snows have shattered the surviving stands.

Methods and Materials

Common-garden tests were established in northwest and north central Spain to evaluate Douglas-fir from a total of 91 localities in southern British Columbia, Washington, Oregon, northern California (*Pseudotsuga menziesii*), and eastern Mexico (*P. flahaulti, P. macrolepis*). The tests were installed under the direction of Dr. Fernando Molina Rodríguez, Director of the Lourizán Forest Research Center, Pontevedra, Galicia, from 1953 to 1986 and Gabriel Toval Hernandez, Chief of the Center's Species Introduction Program.

Seeds of 87 sources from British Columbia to Mexico were obtained from the 1966-68 collections made by the International Union of Forestry Research Organizations (IUFRO). Seeds of four sources in central California came from 1970 collections made by the Pacific Southwest Research Station's Institute of Forest Genetics (IFG), Placerville, California (*table 1*).

Seedlings were planted in climatic and edaphic environments typical of the mountainous regions of northern Spain. The two principal plantations of IUFRO sources, La Hermida and Sierra del Eje, were installed in contrasting climates in 1978 (*table 2*). Growth and survival through 5 years in these tests have been reported (Toval 1985). Subsets of the IUFRO and IFG sources were distributed in 14 satellite plantations installed in 1978 to 1981. For this report, 20 sources were assessed in six or more plantations; 18 others, in five; another 20, in four; 22 more, in three; and 11, in two (*Appendix table 1*). Sources from northern regions were represented more often than those from southern regions. The British Columbia and Washington sources averaged 5.00 and 5.03 repeats, respectively, and the Oregon and California sources, 4.13 and 3.85 repeats.

Seed Sources

Douglas-fir (*Pseudotsuga menziesii*) was sampled over 14° of latitude and 9° of longitude, and at altitudes of 45 to 1600 m above sea level (*figs. 2-3, table 1*). The sources represent natural stands in mixed conifer forests ranging from latitude 38.7° N in central California to 52.7° N in southern British Columbia and extend through maritime and inland regions of the Pacific Slope to continental regions east of the crest of the Cascade Ranges in Washington and Oregon. Coastal sources reach longitude 126.1 ° W on Vancouver Island, 124.4° W in Washington, 124.2° W in Oregon, and 124.0° W in California, and inland sources, 119.2° W in British Columbia, 117.2° W in Washington, 121.4° W in Oregon, and 120.5° W in California.

Sources were chosen in 9 areas in southern British Columbia, including 4 on Vancouver Island and 5 on the mainland; 31 areas in Washington, 24 on the Pacific Slope and 7 east of the crest of the Cascade Ranges; 23 areas in Oregon, 22 on the Pacific Slope and 1 east of the crest; and 26 areas in California, 23 in the North Coast Range and Klamath Mountains and 3 in the Cascade Range–Sierra Nevada. Sources west of the crest of the Cascade Ranges–Sierra Nevada represent the green race (var. *menziesii*), and those east of the crest, the blue race (var. *glauca*). Single sources of related species (*P. flahaulti, P. macrolepis*) were collected in the Sierra Madre Oriental, eastern Mexico.

The Pacific Slope sources represent 64 tree seed zones, 6 in British Columbia (Lines 1987), 21 in Washington, 20 in Oregon, and 17 in California (Buck and others 1970, USDA Forest Service 1969, 1973). Source altitudes ranged from 45 to 730 m above sea level in British Columbia, 60 to 760 m in Washington, 75 to 1600 m in Oregon, and 60 to 1555 m in California.

Mature cones were picked from 15 trees per locality, except where noted differently (*table 1*). Dominant trees were located roughly 100 m apart in stands ranging up to 1.6 km across (Barner 1971). Cones were sun-dried, and seeds were extracted, cleaned, air-dried, mixed to form one bulk seedlot per source, and stored in freezers at -9° C.

Nursery Procedures

Seedlings were produced in the Lourizán Forest Research Center nursery. The nursery is situated on Ria de Pontevedra on the south coast of Galicia, at latitude 42.4° N and about 10 m above sea level (*fig. 4*). Here, growing seasons are long, winters are mild, and the Atlantic Ocean air mass dominates the climate as the Pacific Ocean air mass dominates climate in the coastal regions of Oregon and northwest California.

Seeds were chilled 30 days in wet sand at 4° C and germinated outdoors in the period from May to July. The chilled seeds were sown in flats filled with a standard mix of peat, sand, and granitic soil (1:1:1) that had been fumigated with vapam to control soilborne pathogens.

In their first winter, seedlings were transplanted individually into black polyethylene bags measuring 8 cm in diameter and 20 cm deep. The planting medium was a finely ground pine bark that had been amended with a balanced mineral fertilizer (N, P, K, Mg, Mn, B, Cu, and Mo). During transplanting, the medium in each container was inoculated with a handful of mycorrhizal soil dug from the conifer arboretum at Lourizán (Toval 1983).

Seedlings were planted in common-garden tests after one summer in the containers. Plantations were installed on cleared sites from May 1978 to April 1981. Planting was done in autumn, winter, or spring, depending on site location and weather conditions (*table 2*).

Planting Sites

The planting site climates and soils are typical of those found in the mountainous regions of northern Spain (Montero de Burgos and González 1974, Toval and others 1982b). The planting sites range from latitude 42° to 43.5° N, the same as southernmost Oregon (*fig. 4, table 2*). They extend eastward from longitude 8.3° W in the Macizo Galaico Duriense of southwest Galicia to 1° W in the Pirineos of northeast Navarra, and vary from 450 to 1360 m above sea level. Ten sites are located in coastal and inland regions of Galicia, northwest Spain: six in Lugo Province, three in Orense Province, and one in Pontevedra Province. Six others are distributed across north central Spain: two on coastal slopes of the Cordillera Cantabrica in Asturias, one inland in the mountains of northern León, two inland in the Montes Vascos of Guipuzcoa, and one inland in the Pirineos of Navarra. A detailed topographic map of these regions is available (Instituto Geografico Nacional 1982).

Planting sites were prepared by proven methods for the region, slope, soil type, and vegetative cover (ICONA 1975). Sites on gentle slopes, like those at Sierra del Eje and Regavel la, were tractor-plowed to a depth of 60 cm. Sites on steep slopes, like those at La Hermida, Bande, Valdemadeiro, Gamalleira, and La Vecilla, were tractor-bladed along the contour to form planting terraces. To control aggressive sprouters, improve soil drainage, and facilitate planting, as at La Vecilla, terraces were ripped to a depth of 60 cm using chisels set 50 cm apart.

Plantation Procedures

The principal plantations, La Hermida and Sierra del Eje, were situated just inside the northwest and northeast boundaries of Orense Province (*fig. 4, table 2*). Here, seedlings of 86 and 87 IUFRO seed sources were planted on sites of contrasting climate, one inland with a short growing season and cold winter and the other coastal with a longer growing season and milder winter (Toval and others 1982b). The plantation design consisted of three randomized complete blocks of seed source plots. Each plot contained 25 seedlings set 3 m apart in a 5 by 5 grid and was made large enough to carry a group of five or six trees to rotation age.

The 14 satellite plantations were arrayed from Bande in southwest Orense Province to Ochagavía in northeast Navarra. The Bande plantation was situated in the Rio Limia watershed, in sight of northwest Portugal. The Ochagavía plantation was situated near midslope in the Pirineos, very near the border with southwest France. Unlike the principal plantations, which were allocated the full set of IUFRO sources, the satellite plantations were allocated subsets of the IUFRO and IFG sources (*table 1, Appendix table 1*). Which sources and how many were allocated depended on the planting site, seedlings available, and resources of cooperators.

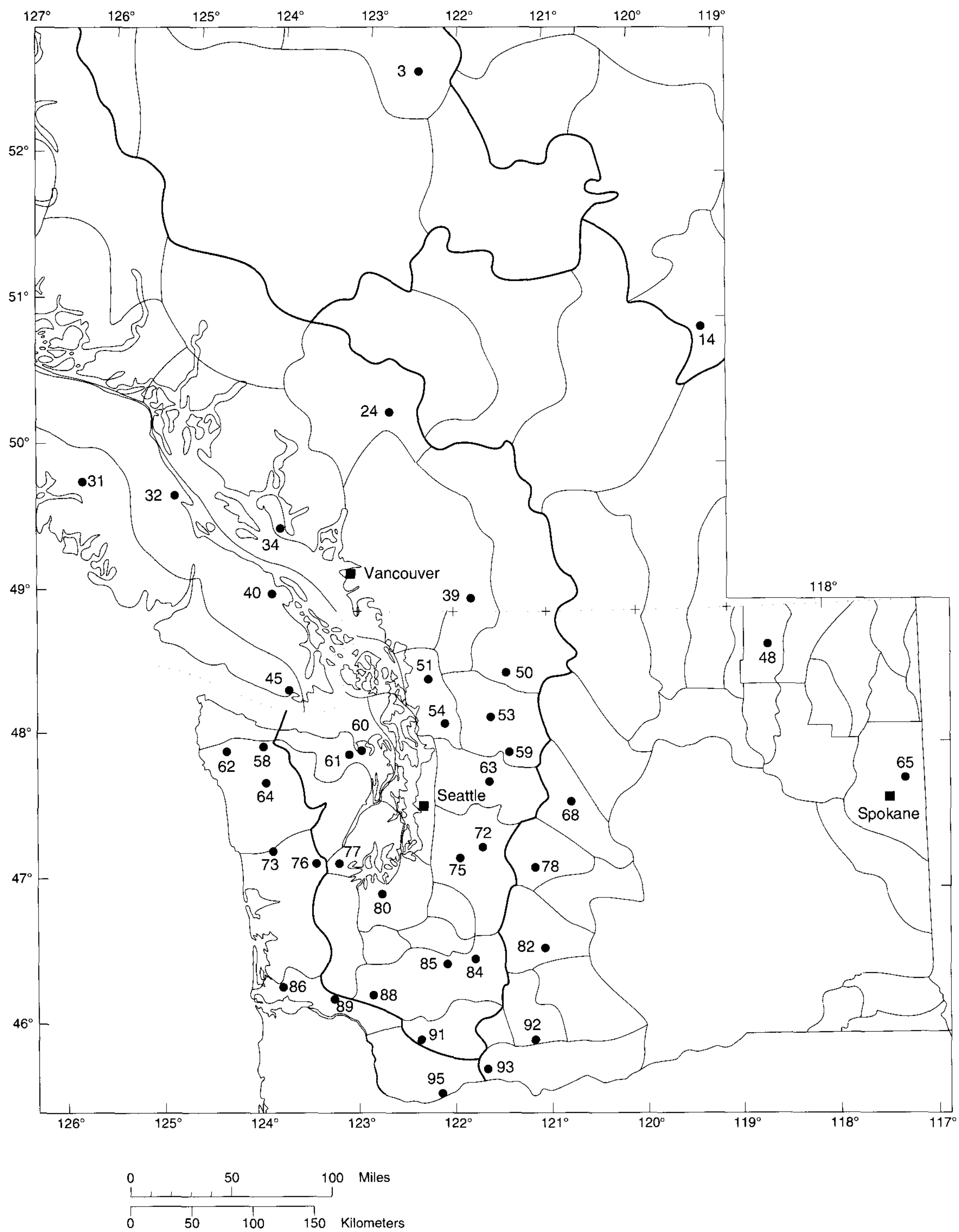
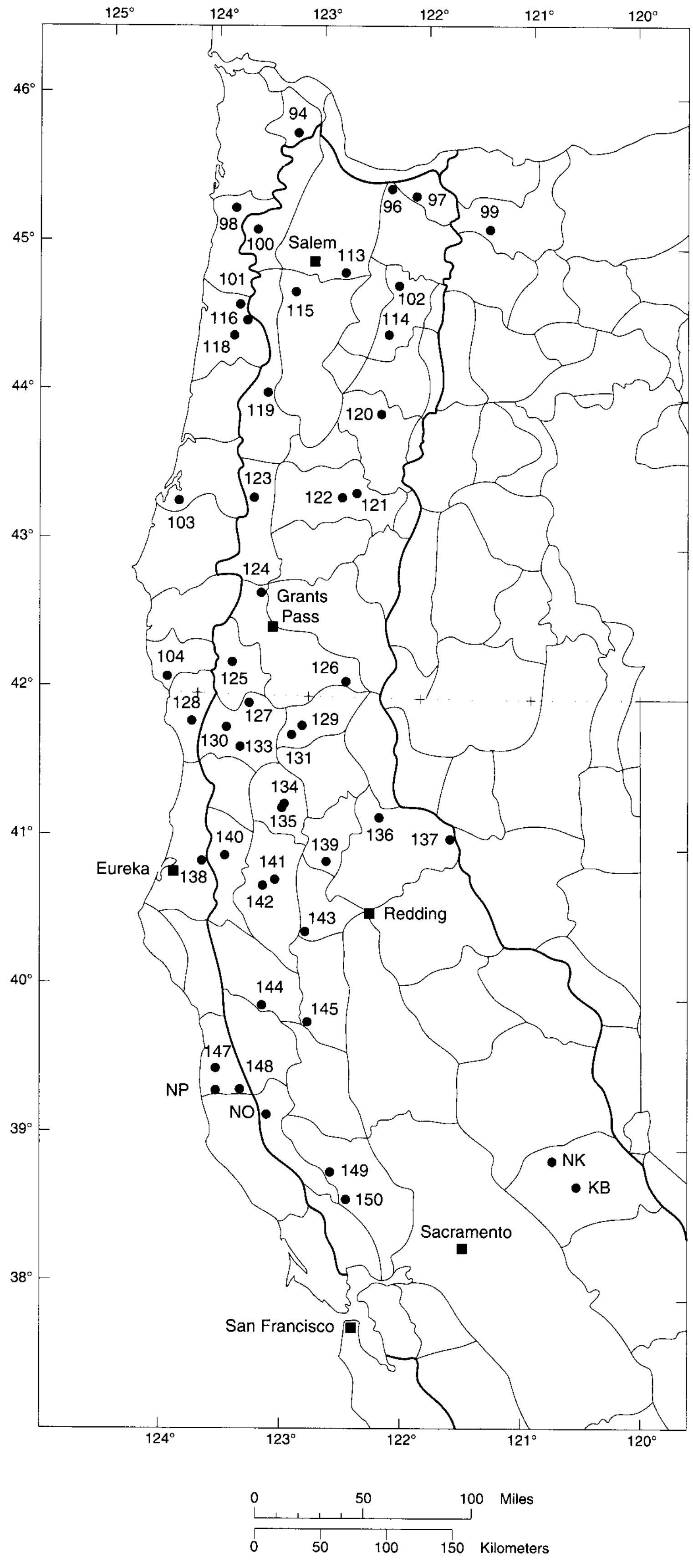


Figure 2–Douglas-fir seed sources in North America assessed for tree growth in common-garden tests in Spain. The key shows the source code number and locality of seed origin. The diamond symbol (♦) marks a source for which mean tree height exceeded plantation height in half or more of the tests in which the source was assessed. See *fig. 3* for the tree seed zones and altitudes of seed origin, and *table 1* for the Mexico sources.



Seed source ●

British Columbia
3 Alexandria
14 Eagle Bay
24 Owl Creek
31 Gold River
32 ♦ Courtenay
34 ♦ Sechelt
39 ♦ Chilliwack
40 Cassidy
45 ♦ Sooke

Washington
48 Republic
50 Marblemount
51 ♦ Sedro Woolley
53 ♦ Darrington
54 ♦ Arlington
58 Lake Crescent
59 Perry Creek
60 ♦ Sequim
61 Louella GS
62 ♦ Forks
63 ♦ Gold Bar
64 ♦ Hoh River
65 Spokane
68 Chiwaukum
72 ♦ Chester Morse
73 ♦ Humptulips
75 ♦ Enumclaw
76 ♦ Matlock
77 ♦ Shelton
78 Cle Elum
80 ♦ Yelm
82 Rimrock
84 ♦ Packwood
85 ♦ Randle
86 Naselle
88 ♦ Castle Rock
89 ♦ Cathlamet
91 ♦ Yale
92 ♦ Glenwood
93 Willard
95 ♦ Prindle

Oregon
94 ♦ Vernonia
96 ♦ Sandy
97 ♦ Cherryville
98 ♦ Hebo
99 Pine Grove
100 ♦ Grand Ronde
101 ♦ Waldport
102 Upper Soda
103 Coquille
104 ♦ Brookings
113 ♦ Mill City
114 ♦ Detroit
115 ♦ Corvallis
116 ♦ Burnt Woods
118 ♦ Marys Peak
119 ♦ Eugene
120 Oakridge
121 Steamboat 1
122 Steamboat 2
123 Roseburg
124 Wolf Creek
125 ♦ Cave Junction
126 Ashland

California
127 Happy Camp 1
128 ♦ Gasquet
129 Seiad Valley
130 Hawkinsville
131 Scott Bar
133 Happy Camp 2
134 Sawyers Bar 1
135 Sawyers Bar 2
136 ♦ Dunsmuir
137 ♦ Burney
138 Arcata 1
139 Weaverville
140 Arcata 2
141 Big Bar 1
142 Big Bar 2
143 ♦ Wildwood
144 Covelo 1
145 Covelo 2
147 Fort Bragg
148 Willits
149 ♦ Lower Lake
150 Mt St Helena
KB Fresh Pond
NK Georgetown
NO Ukiah
NP ♦ Big River

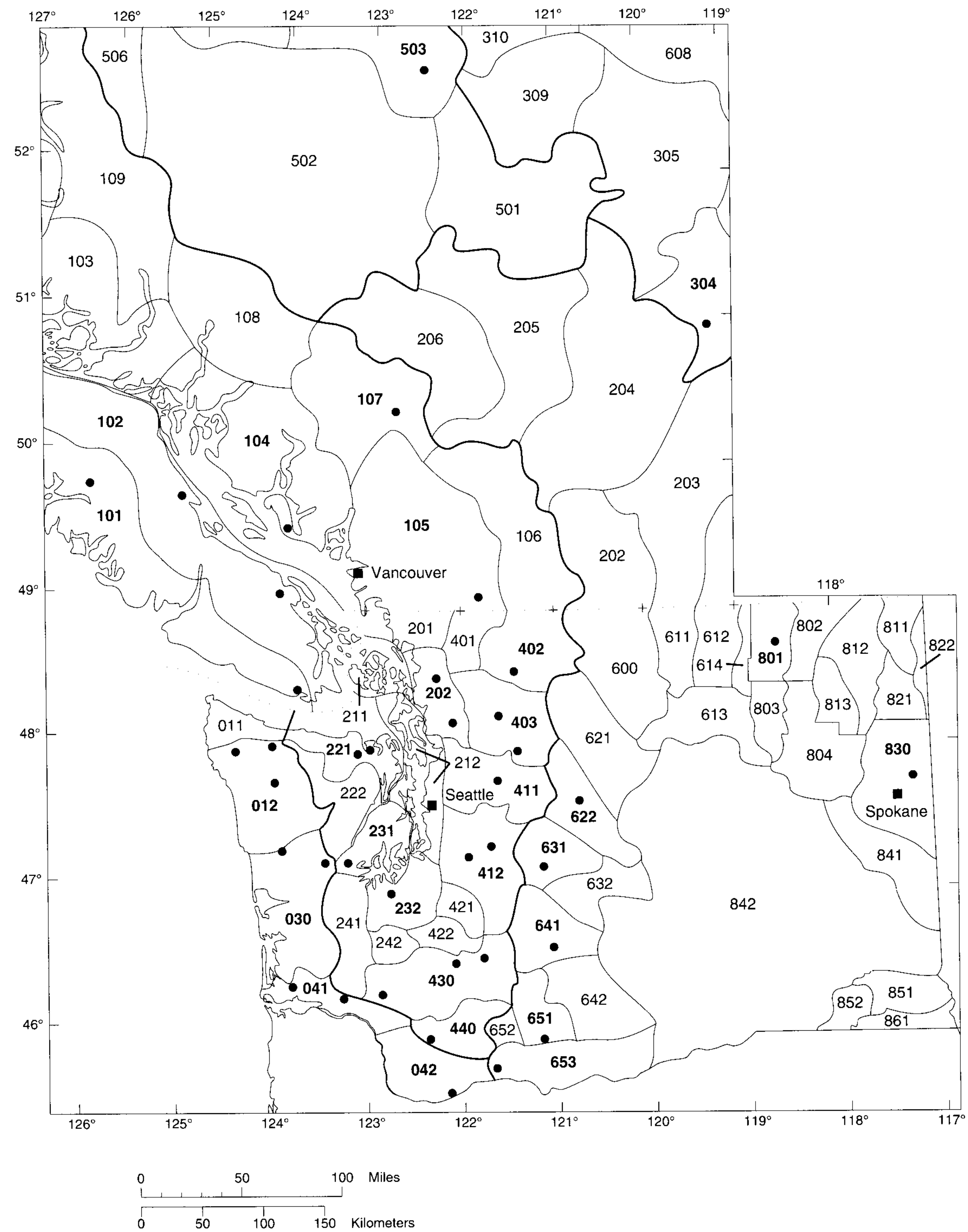
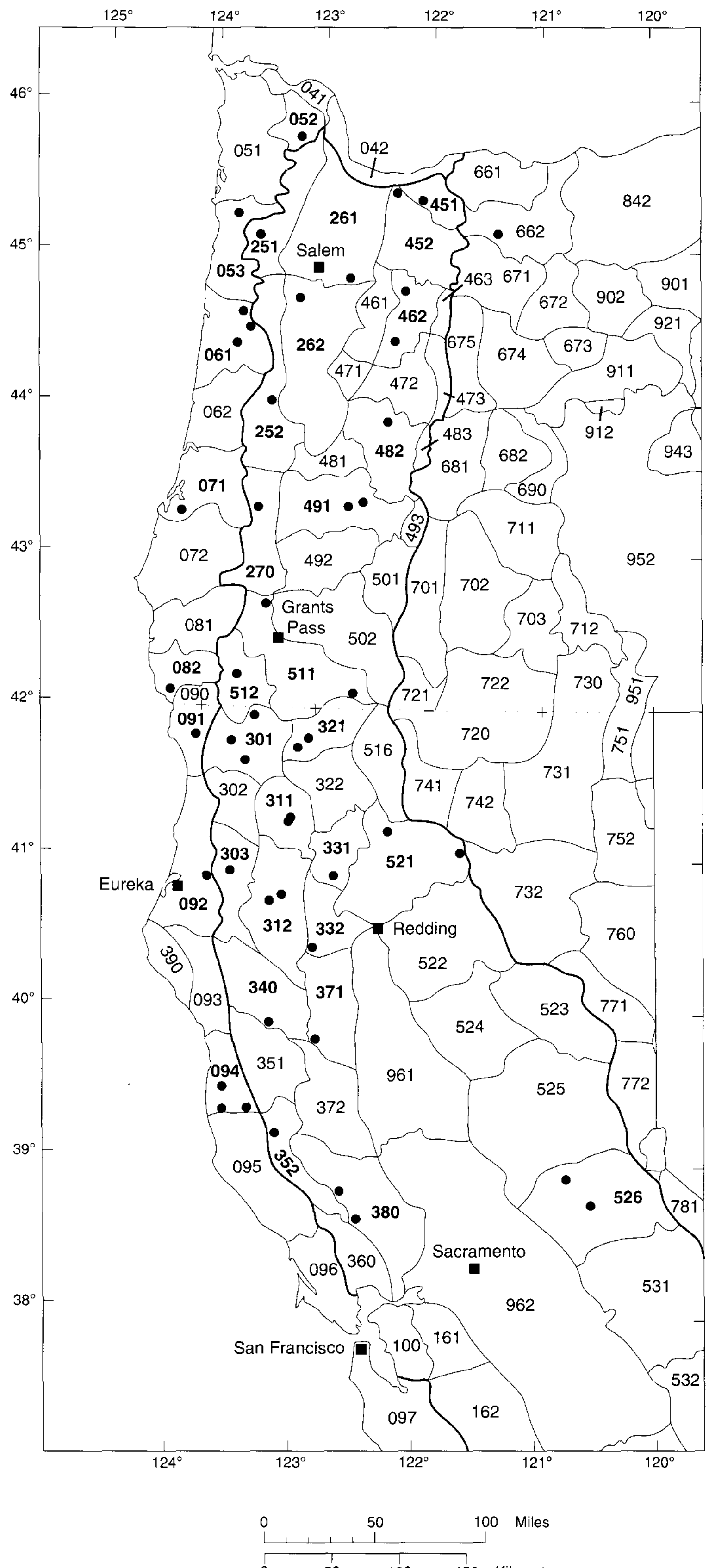


Figure 3–Douglas-fir seed sources in North America assessed for tree growth in common-garden tests in Spain. The key shows the tree seed zone, source code number, and altitude of seed origin. The diamond symbol (♦) marks a source for which mean tree height exceeded plantation height in half or more of the tests in which the source was assessed. See *fig. 2* for the localities of seed origin, and *table 1* for the Mexico sources.



Seed zone	Seed source ●	Elev *m*
British Columbia		
101	31	90
101	45 ♦	45
102	32 ♦	65
102	40	200
104	34 ♦	185
105	39 ♦	170
107	24	215
304	14	490
503	3	730
Washington		
012	58	305
012	62 ♦	90
012	64 ♦	245
030	73 ♦	135
030	76 ♦	120
041	86	60
041	89 ♦	245
042	95 ♦	455
202	51 ♦	60
202	54 ♦	90
221	60 ♦	90
221	61	455
231	77 ♦	90
232	80 ♦	60
402	50	120
403	53 ♦	150
403	59	640
411	63 ♦	120
412	72 ♦	670
412	75 ♦	245
430	84 ♦	305
430	85 ♦	335
430	88 ♦	150
440	91 ♦	120
622	68	550
631	78	640
641	82	760
651	92 ♦	490
653	93	550
801	48	730
830	65	670
Oregon		
052	94 ♦	215
053	98 ♦	185
061	101 ♦	90
061	116 ♦	335
061	118 ♦	1005
071	103	120
082	104 ♦	365
251	100 ♦	215
252	119 ♦	215
261	113 ♦	170
262	115 ♦	75
270	123	305
451	97 ♦	730
452	96 ♦	275
462	102	1065
462	114 ♦	490
482	120	885
491	121	1600
491	122	520
511	124	425
511	126	1495
512	125 ♦	455
662	99	730
California		
091	128 ♦	120
092	138	520
094	147	60
094	148	550
094	NP ♦	60
301	127	975
301	130	1065
301	133	1250
303	140	885
311	134	1190
311	135	1465
312	141	1370
312	142	990
321	129	855
321	131	1035
331	139	1190
332	143 ♦	1190
340	144	915
352	NO	490
371	145	1555
380	149 ♦	945
380	150	760
521	136 ♦	1005
521	137 ♦	1020
526	KB	1250
526	NK	855

Table 1–***Douglas-fir seed sources graded for tree growth in common-garden tests in Spain***

North America Seed source[1], trees, and Locality			Tree seed zone[2]	Plant climate zone[3]	Seed source location				Seed source grade[4]	Tests used[5]
					Altitude		Lat	Long		
					ft	*m*	*°N*	*°W*	*pct*	*no.*
British Columbia										
3	15	Alexandria	503	1	2400	730	52.69	122.43	0	1
14	—	Eagle Bay	304	1	1600	490	50.93	119.22	0	4
24	15	Owl Creek	107	4	700	215	50.33	122.72	25	4
31	15	Gold River	101	5	300	90	49.75	126.07	25	4
♦32	15	Courtenay	102	5	220	65	49.70	125.06	75	4
♦34	15	Sechelt	104	5	600	185	49.51	123.88	60	5
♦39	15	Chilliwack	105	5	550	170	49.07	121.80	75	8
40	15	Cassidy	102	5	650	200	49.06	123.95	33	6
♦45	15	Sooke	101	5	150	45	48.40	123.73	67	3
Washington										
48	16	Republic	801	1	2400	730	48.60	118.73	0	3
50	15	Marblemount	402	4\1	400	120	48.58	121.40	25	4
♦51	16	Sedro Woo lley	202	4	200	60	48.53	122.32	83	6
♦53	15	Darrington	403	4\1	500	150	48.27	121.63	100	6
♦54	15	Arlington	202	4	300	90	48.22	122.07	75	4
58	15	Lake Crescent	012	4\1	1	305	48.07	124.00	33	3
59	16	Perry Creek	403	1	2100	640	48.05	121.47	33	3
♦60	16	Sequim	221	5	300	90	48.03	123.03	75	4
61	15	Louella GS	221	5	1	455	48.00	123.08	0	2
♦62	15	Forks	012	4	300	90	47.98	124.40	100	3
♦63	15	Gold Bar	411	4	400	120	47.85	121.65	100	3
♦64	15	Hoh River	012	4	800	245	47.80	123.97	80	5
65	15	Spokane	830	1	2200	670	47.78	117.20	0	4
68	16	Chiwaukum	622	1	1800	550	47.68	120.73	0	5
♦72	16	Chester Morse	412	1\4	2200	670	47.37	121.67	100	5
♦73	17	Humptulips	030	4	450	135	47.32	123.90	83	6
♦75	15	Enumclaw	412	4	800	245	47.27	121.93	67	3
♦76	16	Matlock	030	4	400	120	47.25	123.42	50	4
♦77	15	Shelton	231	4	300	90	47.25	123.20	75	4
78	15	Cle Elum	631	1\2	2100	640	47.22	*121.12*	0	6
♦80	15	Yelm	232	4	200	60	47.02	122.73	86	7
82	15	Rimrock	641	1	2500	760	46.67	121.03	0	6
♦84	16	Packwood	430	1\4	1000	305	46.57	121.70	50	2
♦85	16	Randle	430	1\4	1100	335	46.55	122.05	50	4
86	15	Naselle	041	5	200	60	46.37	123.73	20	5
♦88	15	Castle Rock	430	6	500	150	46.32	122.87	83	6
♦89	15	Cathlamet	041	5\1	800	245	46.30	123.27	88	8
♦91	16	Yale	440	6\1	400	120	46.00	122.37	100	6
♦92	16	Glenwood	651	1\3	1	490	46.00	121.17	50	4
93	15	Willard	653	3	1800	550	45.80	121.68	20	5
♦95	14	Prindle	042	6\3	1500	455	45.62	122.13	83	6
Oregon										
♦94	15	Vernonia	052	6\1	700	215	45.77	123.22	100	5
♦96	15	Sandy	452	6\1	900	275	45.38	122.30	86	7
♦97	15	Cherryville	451	1\6	2400	730	45.32	122.13	60	5
♦98	15	Hebo	053	5\1	600	185	45.22	123.85	80	5
99	15	Pine Grove	662	1	2400	730	45.10	121.38	0	5
♦100	15	Grand Ronde	251	6\1	700	215	45.10	123.60	50	2
♦101	15	Waldport	061	5\1	300	90	44.40	123.87	100	5
102	15	Upper Soda	462	1\6	3500	1065	44.38	122.20	20	5
103	15	Coquille	071	5	400	120	43.20	124.17	33	3
♦104	15	Brookings	082	5\1	1200	365	42.12	124.20	60	5

continues

Table 1–*Douglas-fir seed sources graded for tree growth in common-garden tests in Spain*

North America Seed source[1]	trees	Locality	Tree seed zone[2]	Plant climate zone[3]	Seed source location: Altitude		Lat	Long	Seed source grade[4]	Tests used[5]
					ft	*m*	*°N*	*°W*	*pct*	*no.*
Oregon										
♦113	15	Mill City	261	6	550	170	44.80	122.70	100	3
♦114	17	Detroit	462	6\1	1600	490	44.73	122.17	100	2
♦115	16	Corvallis	262	6	250	75	44.70	123.22	100	2
♦116	17	Burnt Woods	061	5\1	1100	335	44.60	123.70	100	3
♦118	15	Marys Peak	061	1\5	3300	1005	44.50	123.57	67	3
♦119	16	Eugene	252	6\1	700	215	44.02	123.38	67	3
120	17	Oakridge	482	1	2900	885	43.90	122.37	0	3
121	15	Steamboat 1	491	1	5250	1600	43.37	122.52	0	2
122	13	Steamboat 2	491	1	1700	520	43.33	122.70	0	2
123	16	Roseburg	270	6	1000	305	43.32	123.50	0	2
124	15	Wolf Creek	511	7\1	1400	425	42.68	123.38	20	5
♦125	16	Cave Junction	512	7\1	1500	455	42.18	123.67	60	5
126	15	Ashland	511	1	4900	1495	42.08	122.65	0	3
California										
127	15	Happy Camp 1	301	1\7	3200	975	41.95	123.50	0	3
♦128	17	Gasquet	091	17	400	120	41.85	123.98	50	4
129	19	Seiad Valley	321	1	2800	855	41.80	123.00	25	4
130	14	Hawkinsville	301	1\7	3500	1065	41.78	123.67	0	3
131	17	Scott Bar	321	1	3400	1035	41.73	123.10	25	4
133	16	Happy Camp 2	301	1\7	4100	1250	41.65	123.52	0	3
134	16	Sawyers Bar 1	311	1	3900	1190	41.28	123.13	0	3
135	15	Sawyers Bar 2	311	1	4800	1465	41.27	123.15	0	2
♦136	14	Dunsmuir	521	1\7	3300	1005	41.20	122.30	67	3
♦137	15	Burney	521	1\7	3350	1020	41.08	121.65	50	2
138	16	Arcata 1	092	15	1700	520	40.92	123.83	25	4
139	17	Weaverville	331	1\7	3900	1190	40.90	122.73	0	3
140	18	Arcata 2	303	15	2900	885	40.90	123.77	33	3
141	18	Big Bar 1	312	1	4500	1370	40.78	123.20	0	3
142	15	Big Bar 2	312	1\7	3250	990	40.72	123.30	25	4
♦143	16	Wildwood	332	1\7	3900	1190	40.38	123.00	50	4
144	17	Covelo 1	340	7	3000	915	39.92	123.30	0	5
145	15	Covelo 2	371	1	5100	1555	39.80	122.93	33	6
147	7	Fort Bragg	094	17	200	60	39.50	123.72	33	3
148	17	Willits	094	15	1800	550	39.38	123.42	33	3
♦149	15	Lower Lake	380	7	3100	945	38.83	122.70	100	1
150	13	Mt St Helena	380	7	2500	760	38.67	122.60	25	4
KB	4	Fresh Pond	526	1	4100	1250	38.76	120.54	0	4
NK	33	Georgetown	526	7	2800	855	38.92	120.75	0	2
NO	20	Ukiah	352	14	1600	490	39.20	123.35	40	5
♦NP	20	Big River	094	15	200	60	39.32	123.62	67	3
Mexico										
151	15	Saltillo	—	1	8250	2515	25.28	100.58	33	3
152	10	Tlaxco	—	1	8200	2500	19.60	98.05	0	2

[1] The diamond symbol (♦) marks a source for which mean tree height exceeded plantation height in half or more of the tests in which the source was assessed. Numbers are IUFRO sources, and letters, IFG sources; source 151 is *P. flahaulti,* and 152, *P. macrolepis.*

[2] Lines 1987, Buck and others 1970, USDA Forest Service 1969, 1973.

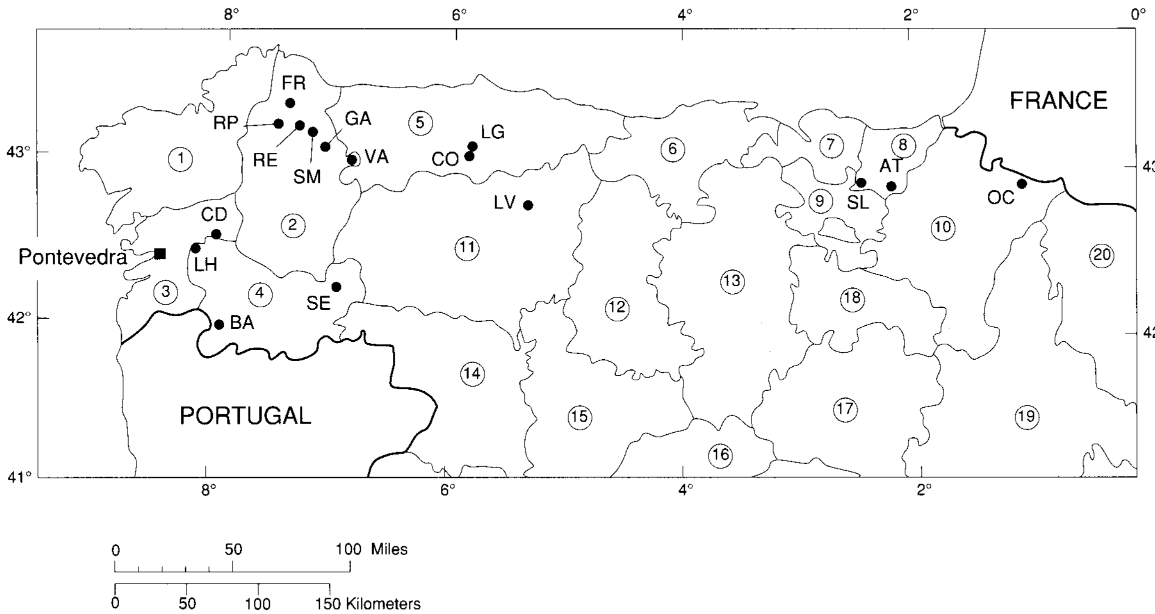
[3] Williamson and others 1987. The backslash symbol (\) shows that the source is located near the boundary with the adjoining climate zone.

[4] Grade is the percentage of tests in which the source tree height exceeded plantation height.

[5] Source was assessed in the number of tests shown. See *Appendix table 1.*

Bande and Ochagavía anchored the satellite array and were the largest plantations, receiving 22 and 31 sources, respectively (*table 2*). Various other large plantations were located in Lugo, Asturias, León, and Guipuzcoa Provinces and received from 9 to 21 sources. The smallest plantations were located in Lugo and Pontevedra Provinces and received four and five sources. The plantation design again consisted of three randomized complete blocks of seed source plots, except that at Conforcal where there were nine blocks. Each plot contained 81 seedlings set 3 m apart in a 9 by 9 grid, except at La Vecilla where a few sources had 64 or 49 seedlings per plot, and Conforcal where each plot held a single row of 5 seedlings lined upslope. Every plot was made large enough to carry a small grove of 14 to 20 trees to rotation age, except 1 tree each for those at Conforcal.

Project scientists staked out and mapped the blocks and source plots. Local forestry crews dug the planting holes and planted the seedlings. The containers were



Autonomy and Province	Map no.
Galicia	
La Coruña	1
Lugo	2
Pontevedra	3
Orense	4
Asturias	5
Cantabria	6
Pais Vasco	
Vizcaya	7
Alava	8
Guipuzcoa	9
Navarra	10
Castilla y León	
León	11
Palencia	12
Burgos	13
Zamora	14
Valladolid	15
Segovia	16
Soria	17
La Rioja	18
Aragon	
Zaragosa	19
Huesca	20

Plantation ●		Elev *m*
Principal tests		
LH ♦	La Hermida	700
SE ♦	Sierra del Eje	1360
Satellite tests		
BA ♦	Bande	900
CD ♦	Castro Dozón	750
RP	Rocha da Perdiz	520
FR ♦	Fragavella	580
RE ♦	Regavella	450
SM	Sierra de Meira	850
GA ♦	Gamalleira	660
VA ♦	Valdemadeiro	920
CO ♦	Conforcal	850
LG ♦	La Gallina	600
LV ♦	La Vecilla	1160
SL	Salinas de Léniz	900
AT ♦	Ataun	750
OC ♦	Ochagavía	900

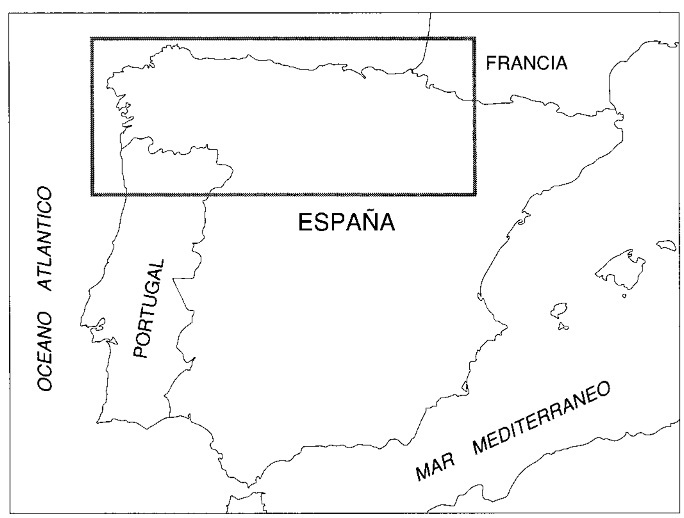


Figure 4—Douglas-fir common-garden tests in northwest and north central Spain. The keys show provinces and plantations. The diamond symbol (♦) marks a plantation in which seed source effects were significant. See *table* 2 and *fig. 5.*

cut from the roots just before planting, and every seedling was planted with yet another handful of soil from the Lourizán arboretum, to ensure mycorrhizal inoculation.

Seedling survival was scored 1 year after planting, and all survivors were cleared of vegetative competition. Tree height was measured 5 years after planting, except 6 years after planting at Conforcal, La Gallina, and La Vecilla. Within 7 to 9 years of planting, crown closure was imminent in plots of the best seed sources on good sites, but edge effects were not discernible in the perimeter rows of any plantation. Superior Douglas-firs in these common-garden tests illustrate the species potential for reforestation in Spain (*fig. 5*).

Analyses of Tree Heights

Taller trees were analyzed to assess seed sources in terms of practical plantation silviculture. Douglas-fir is intolerant of heavy shade and root competition, and rapid early height growth on the planting site is the key to seedling and stand establishment. Planted seedlings must grow fast enough to overtop and suppress the toughest competitors—including grasses, brush, and sprouting hardwoods. Saplings that fail to exceed 1 m in height in the first 5 years may never capture the site resources. On productive sites, thinning to release robust trees and improve wood yields may be done within 10 years of planting. Thinning is easier when trees are small and is prudent once the fast growers have emerged. Research on ponderosa pine (*Pinus ponderosa*)

Table 2—*Douglas-fir common-garden tests in northwest and north central Spain*[1]

Province and Plantation[2]		Seed sources tested	Planting date	Planting site[3]					
				Altitude	Slope		Area	Lat	Long
		no.		*m*		*pct*	*ha*	*°N*	*°W*
Northwest Spain									
Orense									
♦LH	La Hermida	86	Nov 78	700	N	30	6.0	42.52	8.26
♦SE	Sierra del Eje	87	May 78	1360	SW	10	6.0	42.28	6.97
♦BA	Bande	22	Dec 79	900	N	30	4.8	42.03	7.95
Pontevedra									
♦CD	Castro Dozón	5	Nov 80	750	N	5	1.1	42.55	8.05
Lugo									
RP	Rocha da Perdiz	4	Dec 78	520	NE	35	0.9	43.27	7.53
♦FR	Fragavella	20	May 79	580	NW	13	4.4	43.45	7.45
♦RE	Regavella	21	Dec 78	450	flat		4.6	43.27	7.35
SM	Sierra de Meira	14	Apr 80	850	SE	8	3.1	43.22	7.23
♦GA	Gamalleira	21	May 80	660	NE	30	4.6	43.27	7.07
♦VA	Valdemadeiro	19	Jan 80	920	SW	10	4.2	43.12	6.95
North central Spain									
Asturias									
♦CO	Conforcal	18	Apr 81	850	N	55	0.8	43.12	5.88
♦LG	La Gallina	12	Apr 81	600	N	10	2.6	43.18	5.84
León									
♦LV	La Vecilla	9	Apr 81	1160	N	30	2.0	42.82	5.36
Guipuzcoa									
SL	Salinas de Léniz	15	Mar 80	900	W	10	3.3	42.98	2.54
♦AT	Ataun	15	Mar 80	750	E	30	3.3	42.97	2.18
Navarra									
♦OC	Ochagavía	31	Mar 80	900	W	40	6.8	42.92	1.05

[1] The test design is three randomized complete blocks of seed source plots, except nine blocks in plantation CO. The principal plantations SE and LH received the IUFRO sources, and the satellite plantations BA to OC, subsets of the IUFRO and IFG sources. Plantations SE and LH had 25 seedlings per plot, and BA to OC, 81, except LV where a few sources had 64 or 49 and CO where there were 5 per plot. See *Appendix table 1.*

[2] The diamond symbol (♦) marks a test in which seed source effects were significant. See *Appendix table 2.*

[3] 1 m = 3.28 ft; 1 ha = 2.47 acres.

in California plantations ranging from 16 to 50 years of age has shown that the first trees to reach breast height (1.37 m) continue to grow as dominants and codominants in the developing stands (Oliver and Powers 1971).

Seed source effects were assessed in the 15 plantations that contained five or more sources (*table 2*). Analyses of variance were run using BMDP program P8V for a mixed model with seed sources fixed and trees and blocks random (*table 3,* Jennrich and Sampson 1985). Analyses employed first the mean of all trees in each source plot and then the 15, 10, and 5 tallest in each plot, except the 2 and 1 tallest at Conforcal (*Appendix table 2*). The tall-tree sets represented 60, 40, and 20 percent of initial stocking in the principal plantations, Sierra del Eje and La Hermida, and 18.5, 12.3, and 6.2 percent of that in the satellite plantations, except 40 and 20 percent at Conforcal. Sources with fewer trees per plot than specified were dropped from analysis. Standard errors were computed for the plantation means, and one-sided t-tests ($p = 0.05$) were used to identify those sources for which mean tree height significantly exceeded plantation height (Steel and Torrie 1960).

At Sierra del Eje and La Hermida, 87 and 85 sources were analyzed using the 5 tallest trees in each source plot. At Bande, Castro Dozón, Gamalleira, Valdemadeiro, Conforcal, La Gallina, La Vecilla, Salinas de Léniz, Ataun, and Ochagavía, all sources were analyzed using the 15 tallest trees in each plot, except the 2 tallest at Conforcal. Periodic flooding, browsing livestock, and wildfire caused high mortality in sources at Regavella, Fragavella, and Sierra de Meira. Tree heights for the sources and the t-test significant difference were graphed for each plantation, using first the mean of all trees in each source plot and then that of the 5 or 15 tallest in each plot, representing 20 and 18.5 percent of initial stocking in the principal and satellite plantations, respectively (*figs. 6-7*).

In each of the principal and larger satellite plantations, sources were ranked by the mean of all trees in each source plot and by the means of the 15, 10, and 5 tallest in each plot, except the 2 and 1 tallest at Conforcal. The stability of source ranking was assessed for each plantation separately by calculating coefficients of determination, r^2, between the source means based on tallest trees and those based on all trees.

Interactions of seed source and planting site were assessed in pairs of plantations that had five or more sources in common (*Appendix tables 3-5*). Analyses of variance were run using BMDP program P8V for a mixed model with seed sources and planting sites fixed and trees and blocks random (*table 3,* Jennrich and Sampson 1985). Where seed source-planting site interaction was significant ($p < 0.01$ or < 0.05), tree heights for the sources were graphed by plantation and then compared to identify differential responses between the sites (*figs. 8-9*).

Seed sources were graded for growth performance (*table 1*). The source grade was expressed as the percentage of plantations in which tree height for the source was numerically greater than plantation height, excluding Sierra de Meira and Salinas de Léniz, where seed source effects were not significant (*Appendix table 2*). Source height was the mean of the 5 or 15 tallest trees in each source plot, except the 2 tallest in each plot at Conforcal. The principal plantations were counted for sources that had 5 or more trees per plot, and the satellite plantations, for those that had 15 or more, except 2 at Conforcal.

Table 3—*Variance analyses of Douglas-fir in common-garden tests in Spain*[1]

Plantation (pair) and Source of variation	Degrees freedom	Expected mean squares
La Hermida		
[2] Seed source, S	84	[5] +5[4] +15[2]
[3] Block, B	2	[5] +425[3]
[4] SB	168	[5] +5[4]
[5] Trees, T(SB)	1020	[5]
La Hermida<>Sierra del Eje		
[2] Planting site, P	1	[7] +425[4] +1275[2]
[3] Seed source, S	84	[7] +5[6] +30[3]
[4] Block,B(P)	4	[7] +425[4]
[5] PS	84	[7] +5[6] +15[5]
[6] SB(P)	336	[7] +5[6]
[7] Trees, T(PSB)	2040	[7]

[1] The examples employ the 5 tallest trees in each seed source plot. Analyses were run using BMDP program P8V and mixed models with seed sources and planting sites fixed and trees and blocks random (Jennrich and Sampson 1985).

A. Seed source differences in tree height and survival after seven growing seasons in Ochagavía plantation, in the Rio Salazar watershed of the Pirineos in Navarra (March 1987).

B. Superior performance of trees of seed source 128—Gasquet, northwest California—in a 9 x 9 plot in Ochagavía plantation (March 1987).

Figure 5—Douglas-firs in common-garden tests in northwest and north central Spain (*pages 13-16*). See *fig. 4* for the plantation locations.

continues

C. Douglas-firs of a superior seed source after six growing seasons in La Vecilla plantation, in the Rio Curueño watershed of the Cordillera Cantabrica in León (November 1986).

D. Seed source differences in tree height and survival in the tenth growing season in Sierra del Eje plantation, in the Rio Sil watershed in Orense Province (August 1987).

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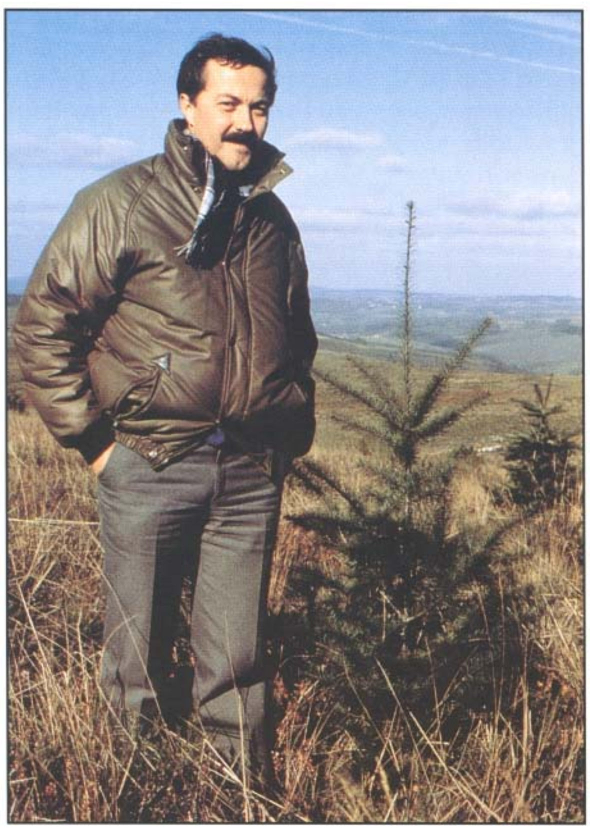
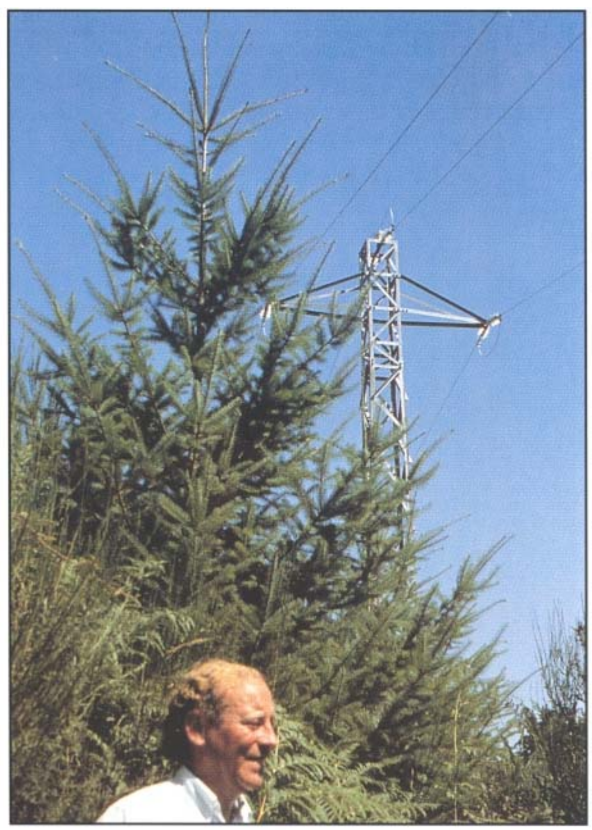
E. Seed source differences in tree height and survival after seven growing seasons in Bande plantation, in the Rio Limia watershed in Orense Province (September 1986).



F. Trees showing marked gains in leader length after six growing seasons in Castro Dozón plantation, in the Macizo Galaico Duriense in Pontevedra Province (November 1986).



G. Trees of a superior seed source in the eighth summer in Gamalleira plantation, in the Rio Eo watershed in Lugo Province (August 1987).

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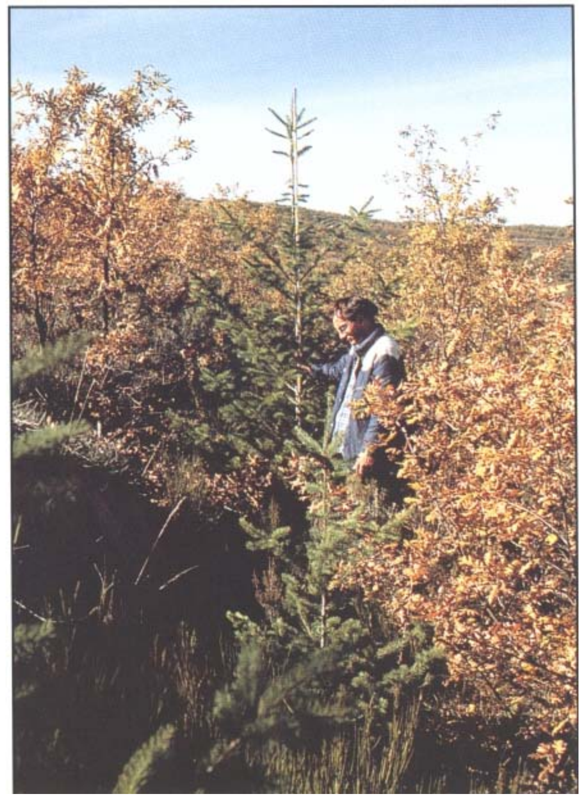
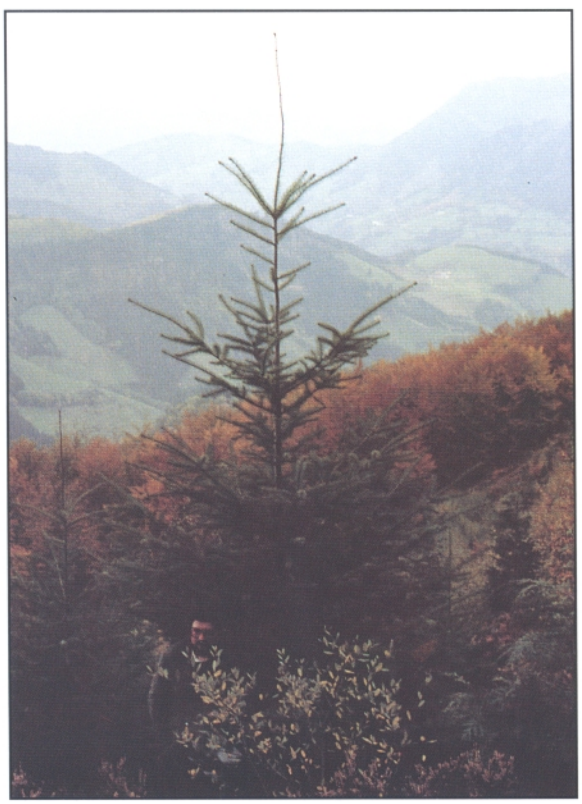
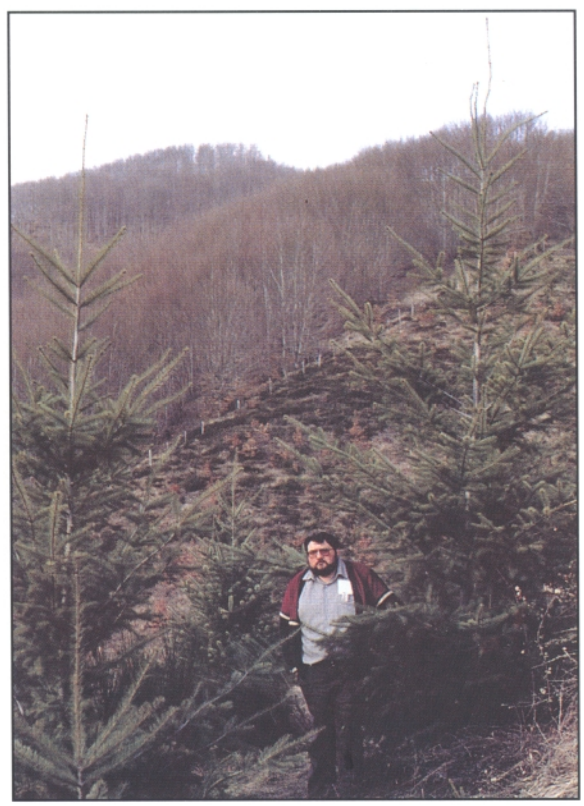
H. Trees of a superior seed source in the tenth growing season in Sierra del Eje plantation (August 1987).



I. Douglas-firs gaining on oak sprouts (*Quercus pyrenaica*) after six growing seasons in La Vecilla plantation (November 1986).



J. Superior Douglas-fir after seven growing seasons in Ataun plantation, in the Rio Oria watershed of the Montes Vascos in Guipuzcoa Province (November 1986).



K. Trees of a superior seed source after seven growing seasons in Ochagavía plantation (March 1987).

Results

Seed source effects were highly significant ($p < 0.01$) and significant ($p < 0.05$) in the principal plantations at La Hermida and Sierra del Eje, and highly significant in the satellite plantations at Bande, Castro Dozón, Fragavella, Regavella, Gamalleira, Valdemadeiro, Conforcal, La Gallina, La Vecilla, Ataun, and Ochagavía (*Appendix table 2*). Seed source effects were also highly significant in 13 plantation pairings: La Hermida against Sierra del Eje, Bande, Fragavella, Regavella, Gamalleira, Valdemadeiro, La Gallina, Ataun, and Ochagavía, and Ochagavía against Bande, Gamalleira, La Gallina, and Ataun (*Appendix tables 3-5*). Seed source-planting site interaction was significant in 8 of those 13 pairings: La Hermida against Sierra del Eje, Bande, Gamalleira, La Gallina, Ataun, and Ochagavía, and Ochagavía against Bande and La Gallina. Seed source-planting site interaction accounted for one-fifth to one-half the variance accounted for by seed source alone.

Seed Source Effects on Tree Height

In the milder coastal environment of the principal plantation at La Hermida, height growth was moderate, and seed source accounted for 38 and 27 percent of the total variance in analyses using the mean of all trees and the 5 tallest trees in each source plot, respectively (*Appendix table 2*). In the harsher interior environment of the principal plantation at Sierra del Eje, growth was slow, and seed source accounted for about 12 and 8 percent of the total variance in the respective analyses.

Growth in the satellite plantations ranged from as slow as that at Sierra del Eje up to 2.5 times that at La Hermida. Tree height at Bande and Ochagavía, the anchor plantations, was superior to that at La Hermida, and seed source accounted for larger amounts of the total variance. In analyses using the mean of all trees and the 15 tallest trees in each source plot, seed source accounted for 63 and 47 percent of the variance at Bande and for 61 and 41 percent of that at Ochagavía. Seed source in respective analyses of the other satellite plantations accounted for 72 and 41 percent of the variance at Castro Dozón, 58 and 41 percent of that at Gamalleira, 75 and 26 percent at Valdemadeiro, 35 and 29 percent at Conforcal (2 tallest trees in each plot), 51 and 33 percent at La Gallina, 50 and 36 percent at La Vecilla, and 69 and 52 percent at Ataun.

Planting Site Effects on Tree Height

Plantation height ranged from disappointing to spectacular, depending on the planting site environment. Trees in plantations on the better sites averaged up to four times the height of those in plantations on the harsher sites. Plantation height after 5 years ranged from 0.38 m at Sierra del Eje to 1.65 m at Ataun, based on the mean of all trees in each source plot (*fig. 6*), and from 0.60 to 2.31 m, based on the 5 and 15 tallest in each plot in the principal and satellite plantations, respectively (*fig. 7*). Plantation height after 6 years ranged from 0.96 m at La Vecilla to 1.83 m at Conforcal, based on the mean of all trees in each plot, and from 1.51 to 2.26 m based on the 15 tallest (2 tallest at Conforcal) in each plot. The tall-tree means exceeded breast height (1.37 m) at Bande, Gamalleira, Conforcal, La Gallina, La Vecilla, Salinas de Léniz, Ataun, and Ochagavía.

Seed Sources Ranked by Tall Trees

Within plantations, seed sources were effectively ranked by the mean heights of their taller trees. In the principal plantations, values of r^2 between means based on the 10 and 5 tallest trees in each source plot and those based on all trees, respectively, were 0.969 and 0.951 at La Hermida and 0.958 and 0.914 at Sierra del Eje. In the satellite plantations, values of r^2 between means based on the 15 and 10 tallest trees in each plot and those based on all trees were 0.959 and 0.954 at Bande, 0.958 and 0.945 at Gamalleira, 0.976 and 0.981 at La Gallina, 0.971 and 0.962 at Ataun, and 0.920 and 0.912 at Ochagavía.

Seed Source—Planting Site Interaction

Differential growth in tree height was evident in the plantation pairs in which analyses showed significant seed source-planting site interaction. The graphs show that differential responses were pronounced in pairings of the principal and satellite plantations, using source means based on the 5 and 15 tallest trees in each source plot, except the 1 tallest at Conforcal, respectively (*figs. 8-9*). In each pair, certain sources grew well on both sites, certain others grew poorly on both sites, and still others grew well on one site and poorly on the other. Tree height of from one in five to one in eight sources showed marked upward or downward shifts between sites in the pairings of La Hermida with Sierra del Eje, Bande, Gamalleira, Conforcal, La Gallina, Ataun, and

Ochagavía, and in those of Ochagavía with Bande and La Gallina. Pairings that have many sources in common illustrate the responses best:

- La Hermida<>Sierra del Eje: Sources 89 and 113 were in the top eight on both sites. Sources 51, 77, 95, and 96 were in the top eight at La Hermida, but average at Sierra del Eje. Sources 98 and 118 were in the top eight at Sierra del Eje, but below average at La Hermida. Sources 48, 65, 68, 82, 99, 130, 133, and 142 were in the bottom sixteen on both sites. Mexico sources 151 and 152 were average at La Hermida and below average at Sierra del Eje.

- La Hermida<>Bande: Sources 97, 101, and 104 were superior on both sites. Source 40 was superior at La Hermida but average at Bande, and source 98 was superior at Bande but below average at La Hermida. Sources 24, 99, 130, and 134 were poor on both sites.

- La Hermida<>Gamalleira: Source 91 was superior at La Hermida and in the top five at Gamalleira. Sources 39, 76, 98, and 101 were in the top five at Gamalleira, but average or below at La Hermida. Sources 40 and 143 were average or above at La Hermida, but ranked among the poorest at Gamalleira. Sources 78, 102, and 133 were poor on both sites.

- La Hermida<>Conforcal: Sources 91 and 96 were top performers on both sites. Source 39 was superior to sources 91 and 96 at Conforcal, but average at La Hermida. Sources 40 and 89 were among the best at La Hermida, but average at Conforcal. Sources 68, 78, 131, 139, and 141 were poor on both sites.

- La Hermida<>Ochagavía: Sources 51, 53, 72, 73, 89, 95, and 96 were top performers on both sites. Sources 77 and 91 were superior at La Hermida, but average at Ochagavía. Sources 54 and 128 were superior and sources 34, 39, 50, 85, 94, 97, and 145 were among the best at Ochagavía, but all were average or lower at La Hermida. Sources 68, 82, and 99 were the poorest on both sites.

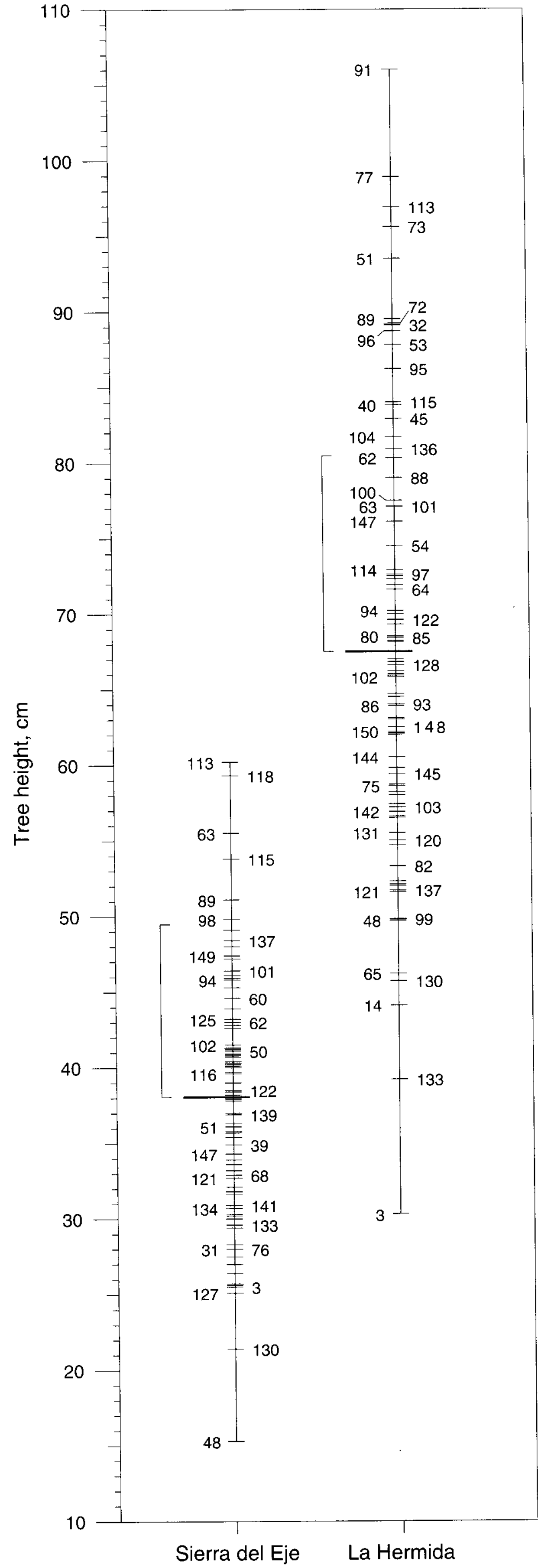
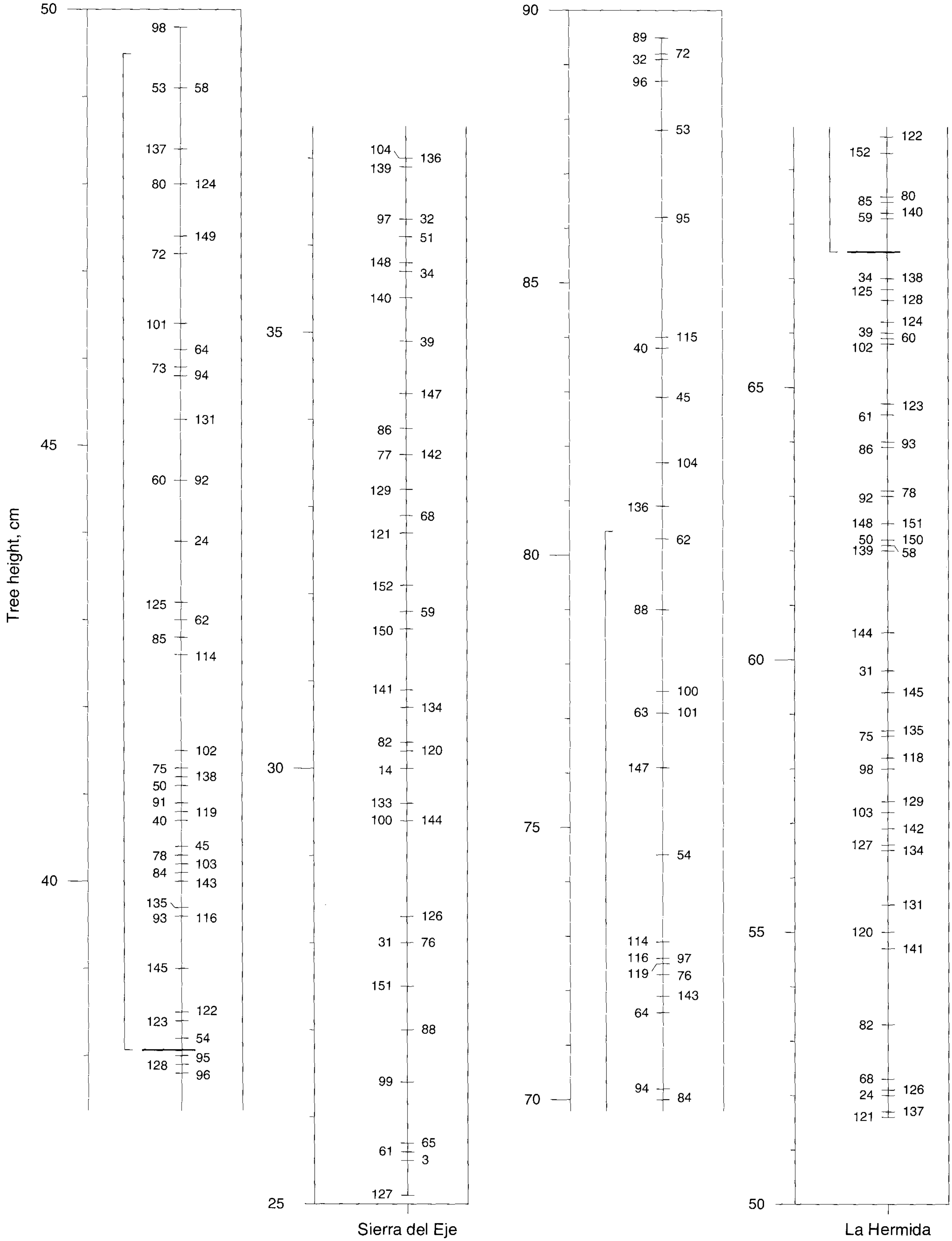
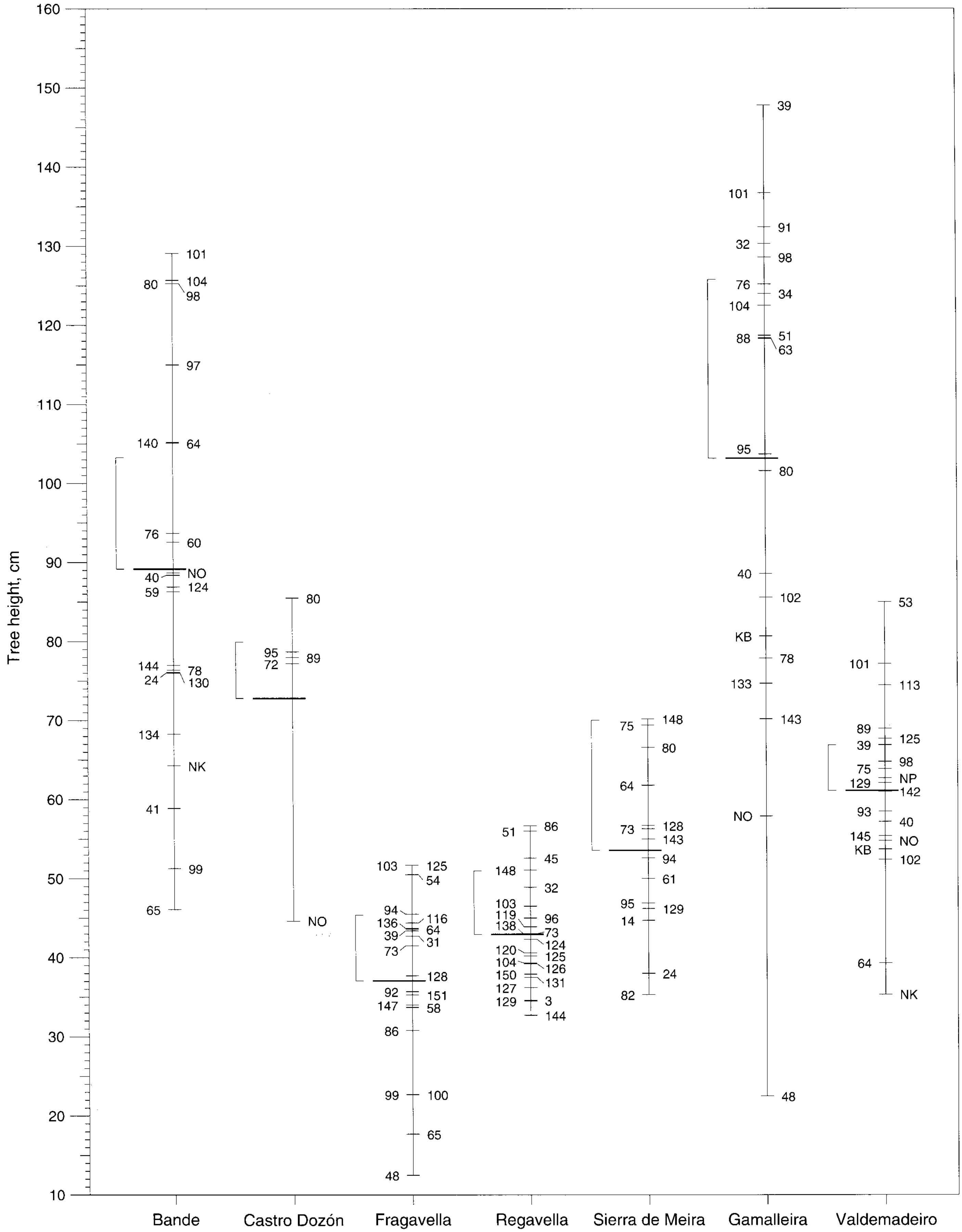
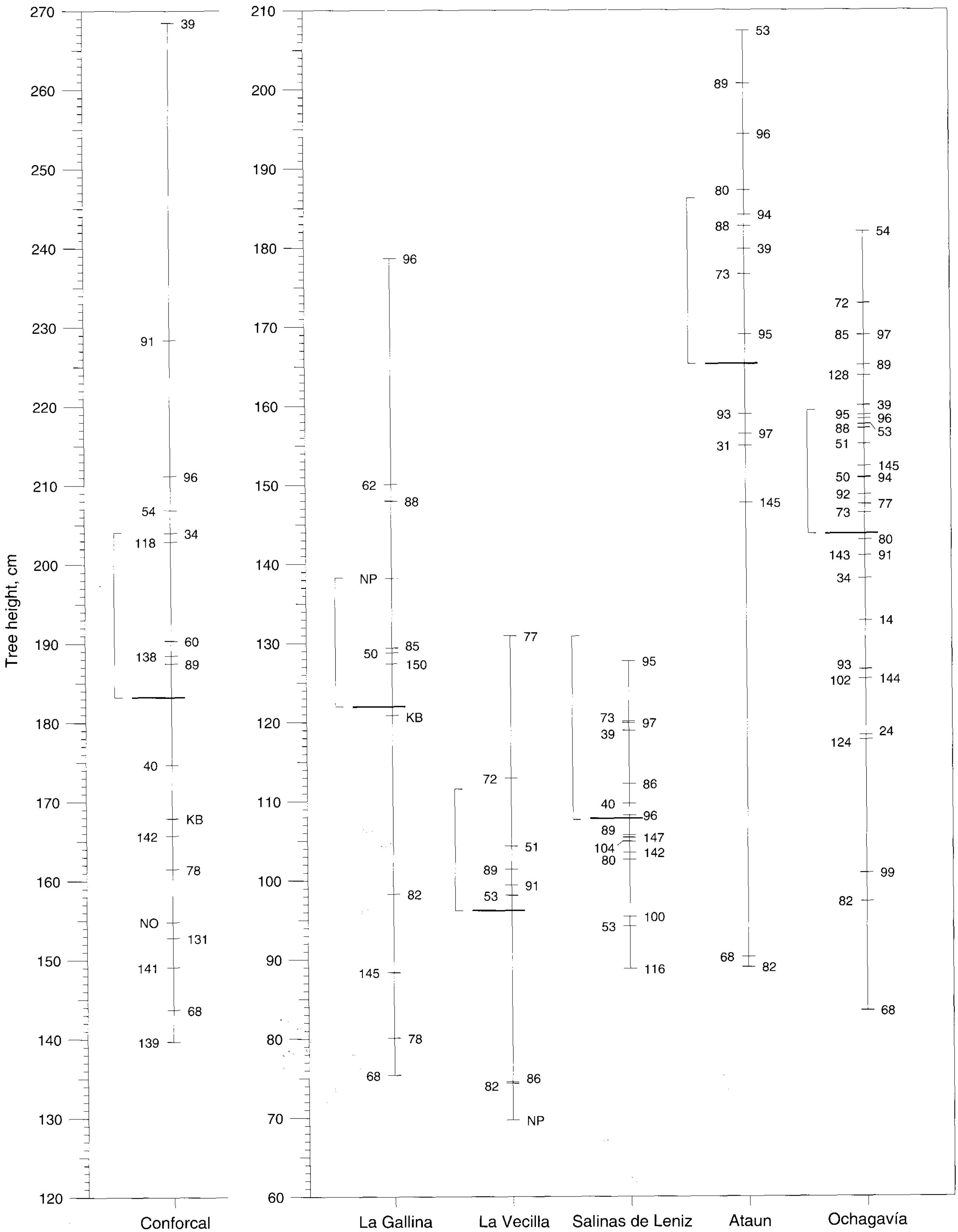


Figure 6—Seed source effects on Douglas-fir height after 5 and 6 years in common-garden tests in Spain (*pages 18-21*). Source tree height is shown as the mean of all trees in each source plot. Centers of the graphs for Sierra del Eje and La Hermida, the principal plantations, are expanded to show every source. The graphs for Bande to Ochagavía, the satellite plantations, are arrayed from Portugal to France. The side bar shows plantation height, and the bracket, significant difference (p = 0.05).


Tree height, cm
Sierra del Eje
La Hermida


Tree height, cm
Bande
Castro Dozón
Fragavella
Regavella
Sierra de Meira
Gamalleira
Valdemadeiro


Tree height, cm
Conforcal
La Gallina
La Vecilla
Salinas de Leniz
Ataun
Ochagavía

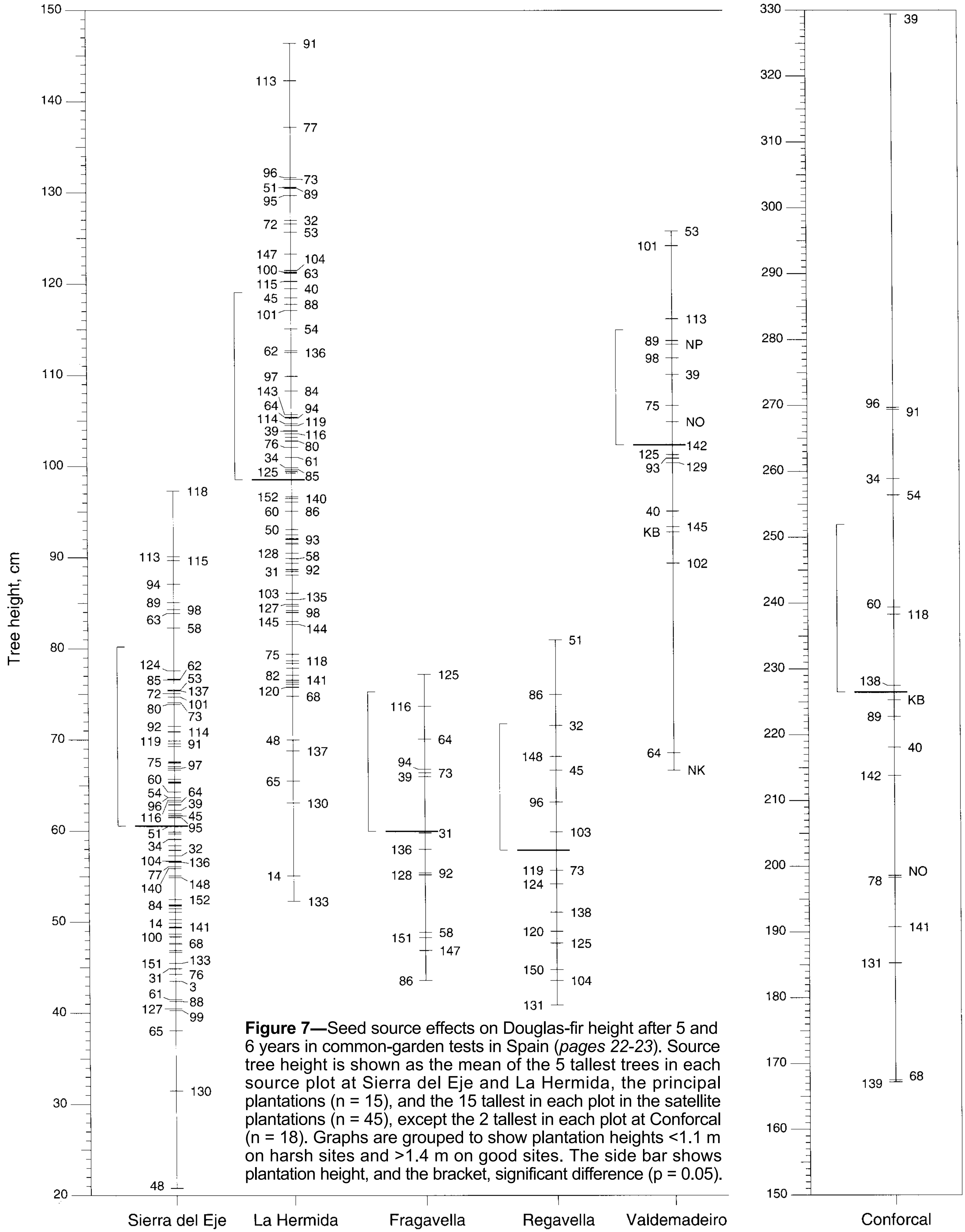
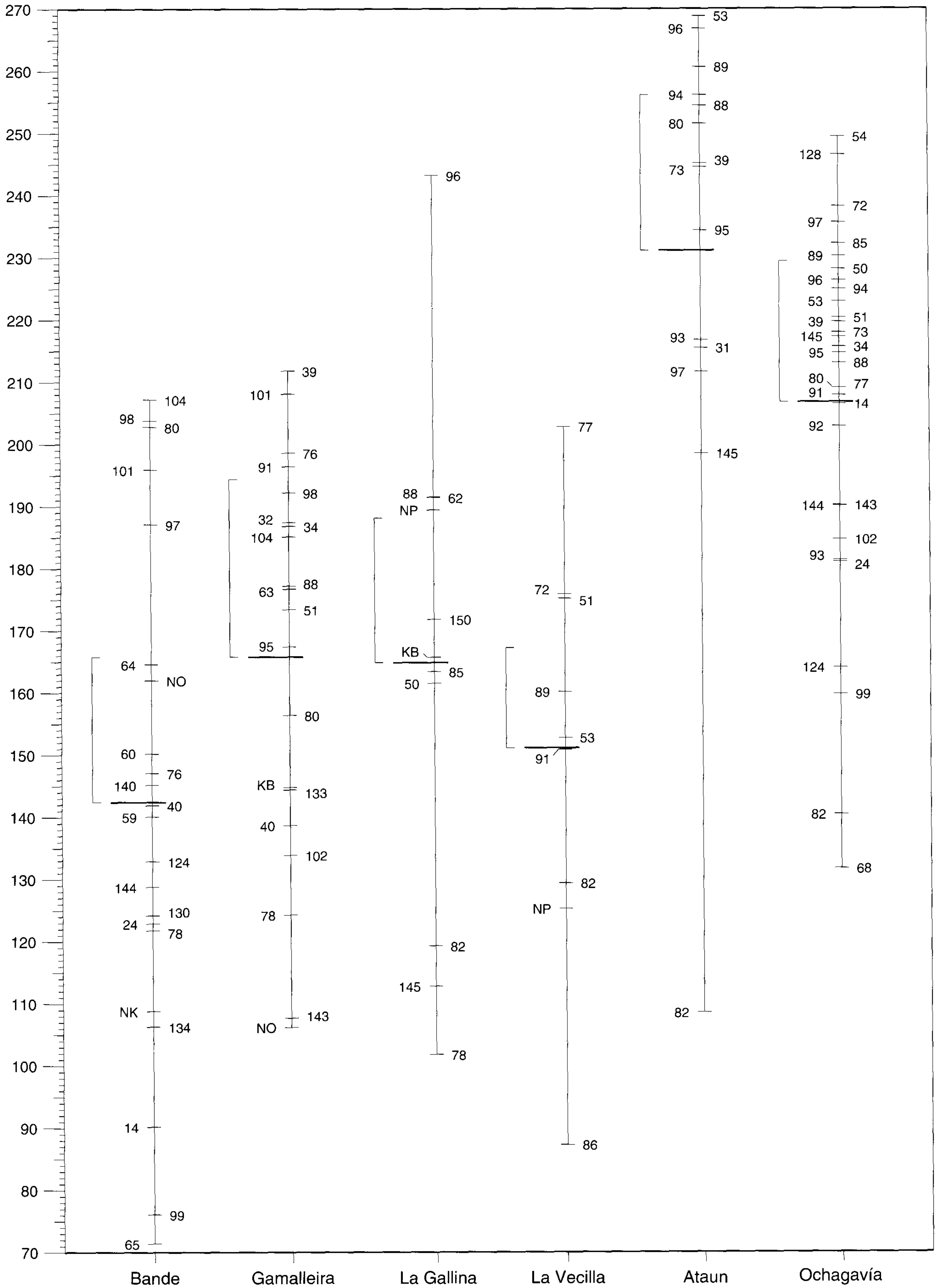


Figure 7—Seed source effects on Douglas-fir height after 5 and 6 years in common-garden tests in Spain (*pages 22-23*). Source tree height is shown as the mean of the 5 tallest trees in each source plot at Sierra del Eje and La Hermida, the principal plantations (n = 15), and the 15 tallest in each plot in the satellite plantations (n = 45), except the 2 tallest in each plot at Conforcal (n = 18). Graphs are grouped to show plantation heights <1.1 m on harsh sites and >1.4 m on good sites. The side bar shows plantation height, and the bracket, significant difference (p = 0.05).



Bande
Gamalleira
La Gallina
La Vecilla
Ataun
Ochagavía

Seed Source Grades and Climate Zones

Forty-four of the 91 seed sources graded from 50 to 100 percent, that is, had mean tree heights greater than plantation height on half or more of the sites on which they were assessed (*table 1*). Twenty-one of these came from stands in regions where the Pacific Ocean air mass dominates climate, plant climate zones 4, 5, and 6 (Williamson and others 1987). Another 18 came from inland stands that receive maritime influence, stands situated in the watersheds of rivers that flow westward to the Pacific Ocean through plant climate zones 4, 5, and 6. The 18 are listed in climate zones 4\1 or 1 \4, 5\1 or 1 \5, and 6\1 or 1 \6, depending on whether their map coordinates place them just west or east of the boundary of plant climate zone 1, which covers those regions where the continental air mass prevails. The remaining five sources came from stands in areas of interior-valley climate, plant climate zone 7.

Of the 47 sources that graded below 50 percent, 25 graded zero, that is, consistently had mean tree heights less than plantation height. Sixteen of these came from stands in regions of continental climate, plant climate zone 1, and four, from stands in climate zone 1 \7. The other five came from stands in areas of interior-valley or Pacific Ocean influence, plant climate zone 7 or climate zones 5, 6, and 15. In the next-to-lowest category, 12 sources graded 20 to 25 percent, and almost all of them came from stands in regions of continental influence, plant climate zone 1.

In general, slow growth characterized seed sources from latitudes north of 50° N, interior British Columbia, regions east of the crest of the Cascade Ranges in Washington and Oregon (var. *glauca*), latitudes south of 44° N, high altitudes west of the crest of the Cascade Ranges and the Sierra Nevada (*var. menziesii*), and eastern Mexico (*P. flahaulti, P. macrolepis*). Physiographic distributions of the best and poorest sources, as judged by source grade, may be summarized as follows (see *table 1*):

- British Columbia: The best four sources are situated in Pacific coastal regions south of latitude 50° N, at altitudes of 45 to 185 m above sea level on Vancouver Island and the mainland. Three of the four poorest sources are situated at altitudes of 215 to 730 m in coastal and inland regions north of latitude 50° N.

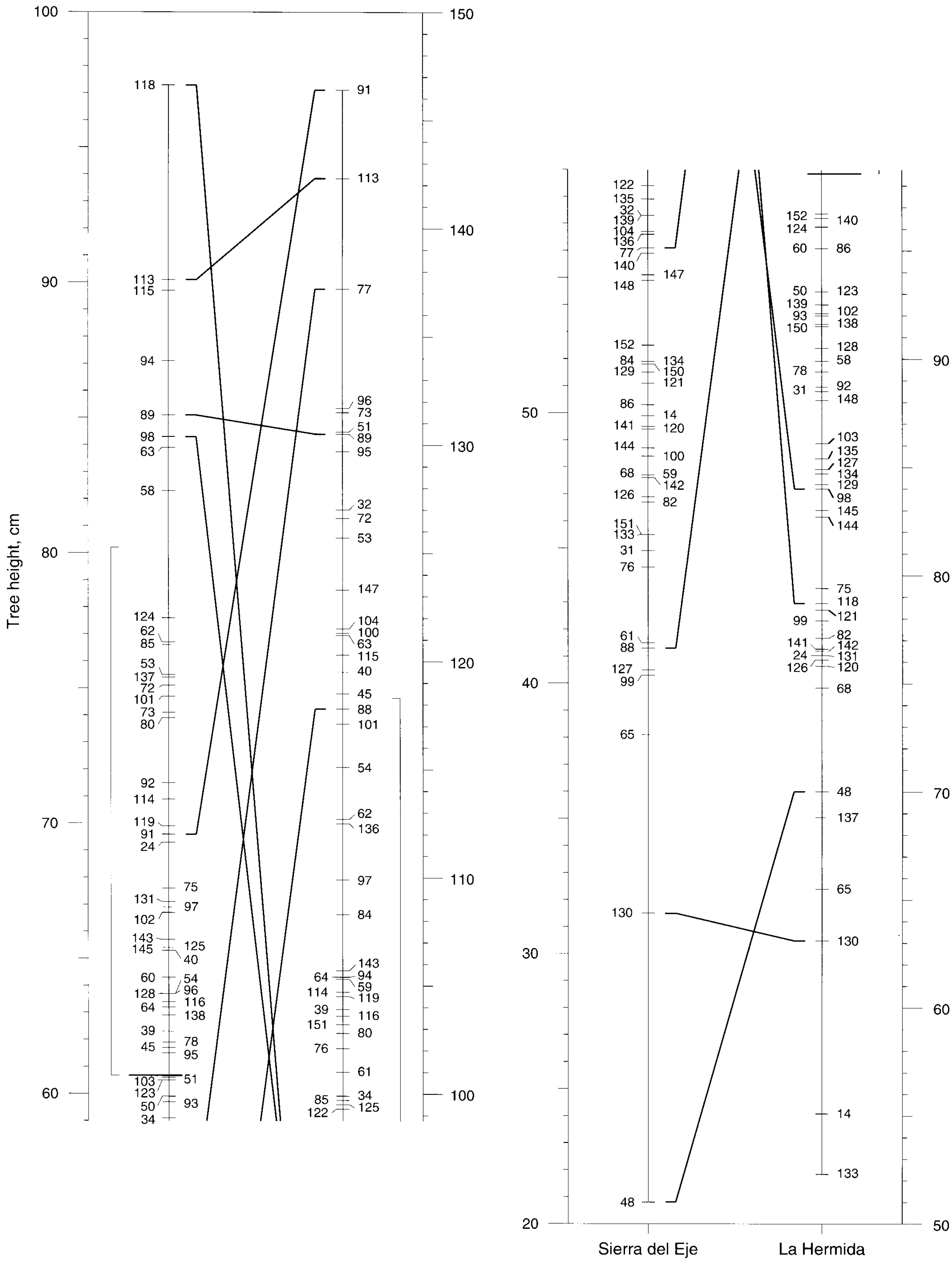
- Washington: The best 20 sources are situated in regions of Pacific Ocean influence, including source 53 in the Sauk River watershed, source 72 in the Cedar watershed, sources 84 and 85 in the Cowlitz, source 89 in the Elochoman, source 91 in the Lewis, and source 92 in the Klickitat on the east slope of the Cascade Range just north of the Columbia River. The 20 range in altitude from 60 to 455 m, except source 92 at 490 m. Five of the six poorest sources are situated at altitudes of 550 to 760 m in continental regions east of the crest of the Cascade Range.

- Oregon: Thirteen of the best 14 sources are situated in regions of Pacific Ocean influence, including source 94 in the Nehalem River watershed, sources 96 and 97 in the Clackamas and Sandy watersheds, source 98 in the Nestuca, source 100 in the South Yamhill, source 101 in the Alsea, source 104 in the Chetco, source 114 in the Santiam, source 116 in the Yaquina, source 118 in the North Fork Alsea, and source 119 in the Long Tom. Only one is situated in an area of interior-valley influence, source 125 in the Illinois River watershed in the Klamath Mountains. The 14 range in altitude from 75 to 730 m, except source 118 at 1005 m on the coastal side of the Oregon Coast Range. The six poorest sources are situated in areas of continental influence, five at altitudes of 520 to 1600 m in the Cascade Range and one at 1495 m in the Klamath Mountains.

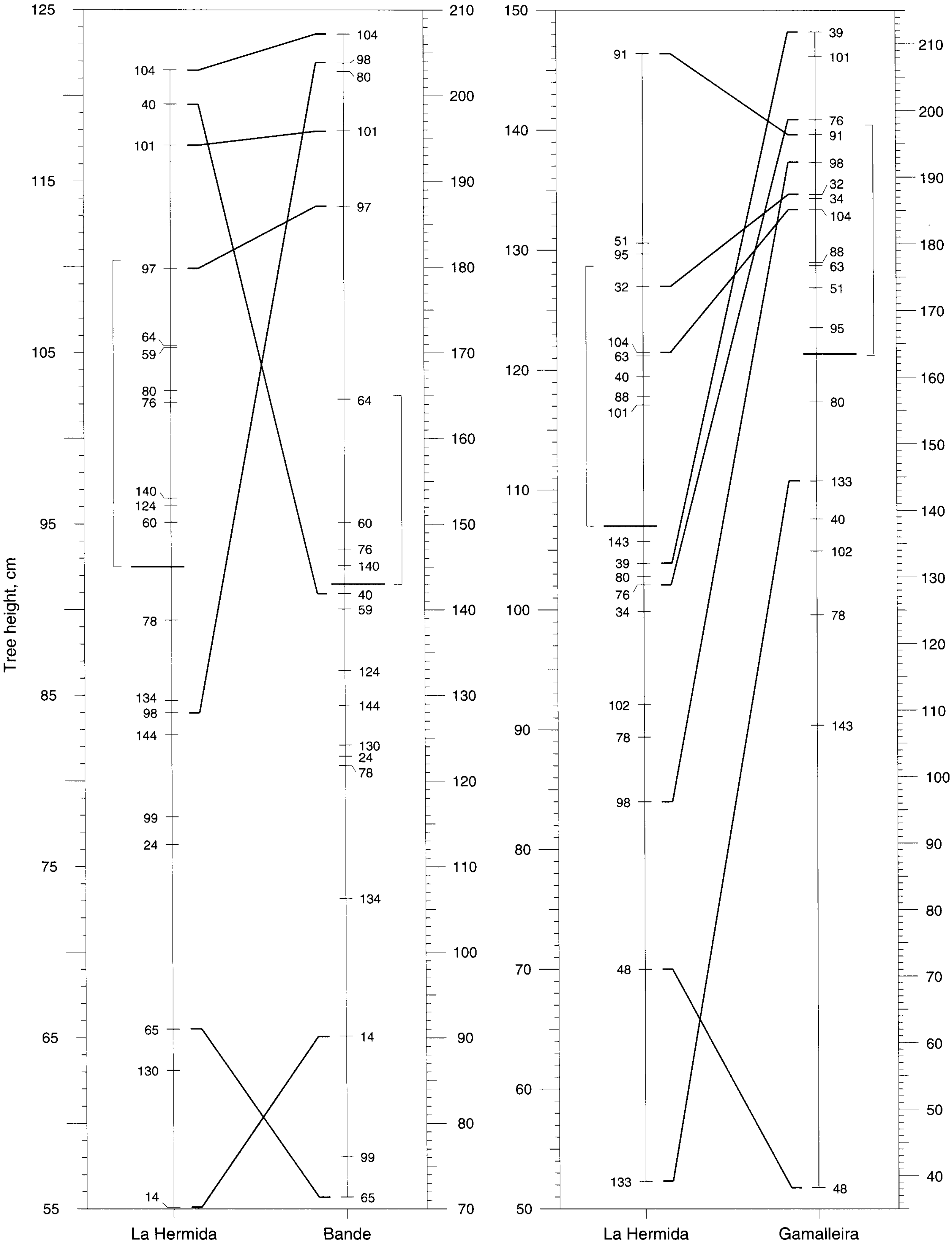
- California: Two of the best six sources are situated in the coastal North Coast Range, and three others, in areas of interior-valley influence in the Cascade Range and Klamath Mountains—sources 136,137, and 143 in the watersheds of the Sacramento, Pit, and South Fork Trinity Rivers, respectively. The coastal sources are at altitudes of 60 and 120 m, and the inland sources, at 1005 to 1 190 m. Eight of the 10 poorest sources are situated in areas of continental influence—seven at altitudes of 975 to 1465 m in the Klamath Mountains and one at 1250 m in the Sierra Nevada. The other two are situated in areas of Pacific Ocean and interior-valley influence, at 915 m in the North Coast Range and 855 m in the Sierra Nevada.

Figure 8—Seed source-planting site interaction effects on Douglas-fir height after 5 years in the principal plantations at Sierra del Eje and La Hermida, northwest Spain (*page 25*). Source tree height is shown as the mean of the 5 tallest trees in each source plot (n = 15). Lines between the arrays show that certain sources grew better on one site than on the other. The side bar shows plantation height, and the bracket, significant difference (p = 0.05).

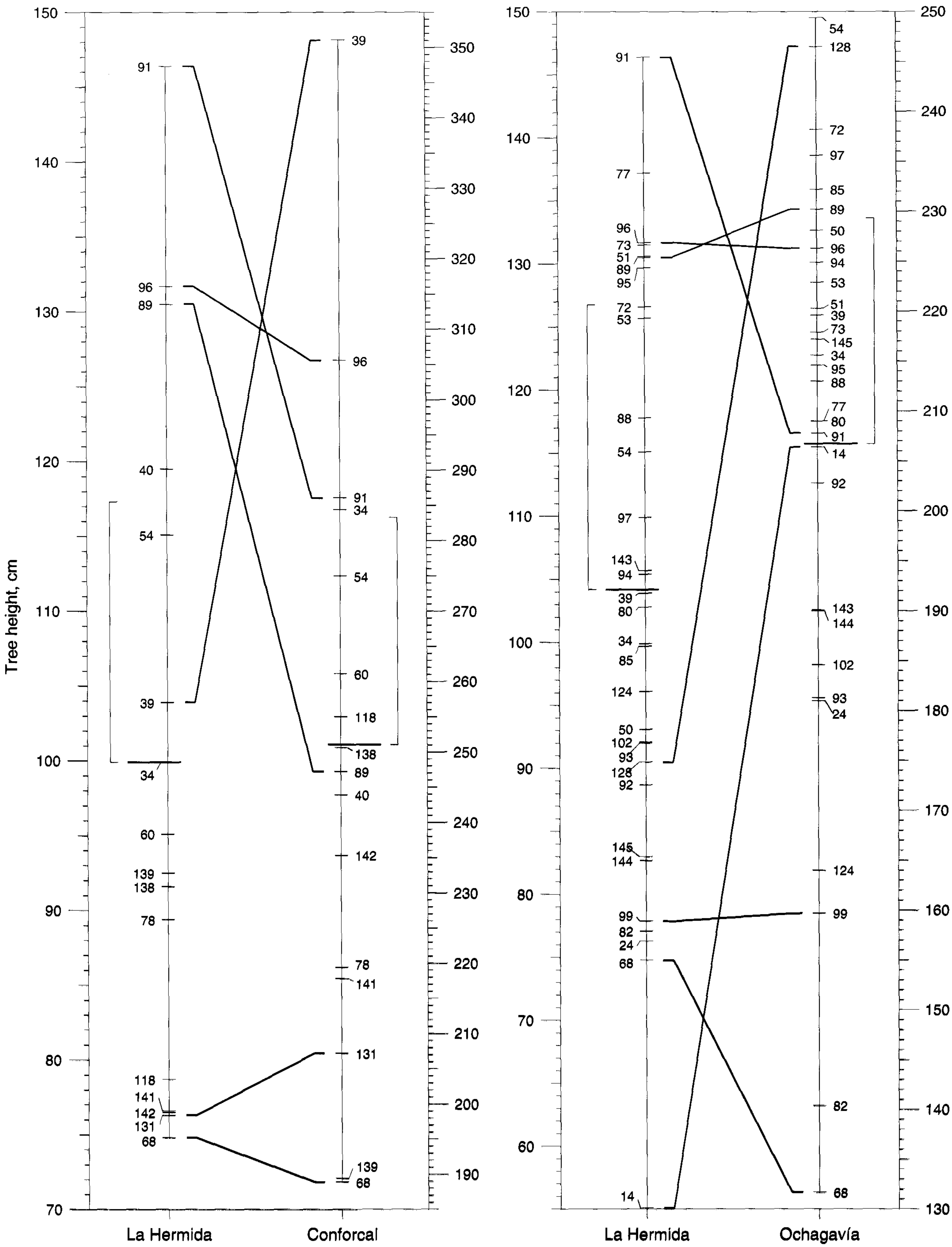
Figure 9—Seed source-planting site interaction effects on Douglas-fir height after 5 and 6 years in the principal plantation at La Hermida and satellite plantations on better sites, northwest and north central Spain (*pages 26-27*). Source tree height is shown as the mean of the 5 tallest trees in each source plot at La Hermida (n = 15), the 15 tallest in each plot at Bande, Gamalleira, and Ochagavía (n = 45), and the 1 tallest in each plot at Conforcal (n = 9). Lines between the arrays show that certain sources grew better on one site than on the other. The side bar shows plantation height, and the bracket, significant difference (p = 0.05).



Tree height, cm
Sierra del Eje
La Hermida



Tree height, cm
La Hermida
Bande
La Hermida
Gamalleira



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Discussion

Early height growth in common-garden tests of Douglas-fir shows that Pacific Slope seed sources promise rapid plantation establishment in coastal and inland regions of northwest and north central Spain. Superior sources for Spain are clustered in regions where climate is dominated by the Pacific Ocean air mass. Pacific climate types characterize maritime slopes along the Georgia Strait in southwest British Columbia, the Olympic Peninsula, and the Coast Ranges of Washington, Oregon, and northwest California. Inland, they characterize lower slopes of the Olympic Mountains and the Coast and Cascade Ranges facing the Puget Trough in western Washington and Willamette Valley in northwest Oregon.

Best Seed Sources Defined

Promising seed sources are those that graded 50 to 100 percent (*table 1, fig. 10*). These sources span 11 ° of latitude in coastal forests—from 39° N in the North Coast Range of northwest California to 50° N along the Georgia Strait of southwest British Columbia—and 8° in inland forests—from 41 ° N in the Klamath Mountains of northwest California to just above 49° N near the lower Fraser River in southwest British Columbia. They represent altitudes of 45 to 365 m (1005 m) along the Pacific Coast, 75 to 730 m in the Olympic Mountains and Coast and Cascade Ranges facing the Puget Trough of western Washington and Willamette Valley of northwest Oregon, and 455 to 1190 m in the Klamath Mountains and Cascade Ranges of southwest Oregon and northwest California.

Thirty-one of the 36 sources that graded 60 to 100 percent are found in Pacific Slope forests north of latitude 44° N and at altitudes of 45 to 1005 m above sea level. The other five are found south of 42.5° N, in the Oregon Coast Range at 365 m, the North Coast Range at 60 and 945 m, and the Klamath Mountains at 455 and 1005 m. Twenty-five of the 26 sources that graded 75 to 100 percent are found north of 44° N and at altitudes of 60 to 670 m.

Seed Source Climates Typed

The most promising seed sources are situated in habitats characterized by long growing seasons, favorable water regimes, soils of good drainage, and cold but not harsh winters (Franklin and Dyrness 1973, Williamson and others 1987). Pacific Ocean influence typifies climates at seed origin and largely explains the broad latitudinal and low altitudinal distributions of superior sources in the common-garden tests. Taken together, the extent of Pacific climate types and the distribution of seed zones of known superior sources allow us to delimit forest regions within which we may collect Douglas-fir of high potential for reforestation in Spain.

Climates at seed origin of the sources tested in Spain fall into six distinct climate types. These types relate plant climate zones (Williamson and others 1987) to Douglas-fir forests in a north-south, coast-inland, and altitudinal format. Pacific climate types A through C characterize the fast growers, and Pacific type D, interior-valley type E, and continental type F, the average and slow growers. Pacific types A—C have long growing seasons and beneficially cold winters. The winters are normally colder in types A—C and E than in type D and are longest and coldest in type F. The types may be summarized as follows (parentheses show related plant climate zones):

- A (zone 5): Pacific Ocean air brings relatively warm winters to coastal regions from southwest British Columbia to northwest California and effectively enhances forest growth. Growing seasons extend up to 250 days and longer in areas near salt water, including the southern end of Vancouver Island and coastal slopes of the Olympic Peninsula and Oregon Coast Range. Winter lows in these regions range from —2° to —18° C.

- B (zone 4): Inland regions west of the Washington Cascades are influenced primarily by the Pacific Ocean and Puget Sound, and at times by high altitudes and the continental air mass. These regions differ from neighboring coastal regions in having shorter growing seasons, greater rainfall, and colder winters. Winter lows range from —7° to —22° C.

- C (zones 6, 3): Uplands adjoining the Puget Trough in western Washington and the Willamette Valley in northwest Oregon get maritime influence much of the year. Pacific Ocean air spills inland along the Columbia River and low passes through the Coast Ranges and penetrates eastward to middle slopes of the Cascade Ranges. Growing seasons are longer and warmer in these regions than around Puget Sound, but rainfall is as great and winters are as cold. Winter lows range from —7° to —22° C.

- D (zones 17, 15, 14): California's coastal North Coast Range is dominated almost totally by Pacific Ocean air. Growing seasons are long, summers are cool and foggy, and winters are wet and cool. Record lows range from –1 ° to –7° C. Away from the coast, Pacific Ocean influence still prevails 85 percent of the time. Winters in the North Coast Range are coldest on the ridgetops and in the valley and canyon bottoms. Record lows inland range from–7° to –12° C.

- E (zone 7): Inland regions west of the Cascade Range–Sierra Nevada in southern Oregon and northern California, in watersheds of the Rogue, Klamath, Trinity, and Sacramento Rivers, have interior-valley climates. The growing seasons are long, summers are hot and dry, and winters are pronounced. Record lows here range from –9° to –18° C.

- F (zones 1, 2): At high altitudes to the west and in regions east of the crest of the Cascade Range–Sierra Nevada, the continental air mass dominates supremely. Growing seasons are mostly short, ranging from 90 days or less up to 150 days. Winters are severe and snowpacks are the rule. Record lows range from –19° to –37° C.

Cold winters and hard freezes at seed origins explain the freeze-hardy growth of even the most coastal sources of Douglas-fir on cold inland sites in Spain, including those at Sierra del Eje, La Vecilla, and Ochagavía (*fig. 3, table 2*). The Pacific and interior-valley climates of western Washington, western Oregon, and northern California match those of the Iberian Peninsula so closely that Douglas-fir may have greater potential in Spain and Portugal than in the rest of western Europe.

European Findings Compared

Douglas-fir is the most successful North American tree in Europe, with vigorous stands in 24 countries (Hermann 1987). Douglas-fir plantations in France, Germany, and Great Britain already cover 220,000, 80,000, and 46,000 hectares, respectively (Hermann 1987, Lines 1987). Current planting rates suggest that France could have 500,000 hectares in Douglas-fir by the year 2020. West Germany may plant Douglas-fir on up to 20 percent of its forested area, where it yields double the volume of Scotch pine and 30 percent more volume than Norway spruce (Hermann 1987). Greater timber values and growth rates will promote a wider use of Douglas-fir in Britain, too, as emphasis shifts from forestation to replanting of the sheltered valley sites that now carry Scotch pine and European larch (Lines 1987).

The successes of Douglas-fir in Britain, Germany, and France have been shown to depend on seed source, and Spain's common-garden tests have largely confirmed the findings in those countries. In the common-garden tests of IUFRO seed sources in Scotland, mean tree height and stem diameter after 10 years showed that the fastest growers came from coastal slopes and foothills of the Olympic Mountains and western Cascade Ranges in Washington and a few areas at low altitudes in western Oregon. Growth was moderate for sources from Vancouver Island and poor for sources from latitudes north of 50° and south of 44° N. Seed sources advocated for Britain are those situated below 800 m in seed zones 012, 041, 222, 240, 202, 403, 411, and 412 in western Washington, seed zone 072 in south coastal Oregon, and seed zone 103 on the north end of Vancouver Island (Lines 1987).

Findings in Britain differ little from those in Germany or France. The results in 12 trials that were begun in Germany in the period from 1910 to 1978 showed that the fastest growers came from seed sources in the coastal forests of Washington and southwest British Columbia and inland forests at low altitudes in the western Washington Cascades (Kleinschmit 1984, cited in Hermann 1987). After 13 years in the tests of 131 IUFRO sources in France, the best 63 sources (48 percent) had mean tree heights of 7.2 to 8.4 m. All 63 of them came from Pacific Slope forests, counting 16 in British Columbia, 37 in Washington, and 10 in Oregon. Sixty-two of the best came from stands at altitudes below 600 m, and 59 of them, from coastal and inland regions between latitudes 44° and 50° N (Roman-Amat 1987).

Findings in Spain differ from those in Britain, Germany, and France in terms of substantial southward shifts and appreciable altitudinal extensions of promising seed origins. Of Spain's best 44 sources (48 percent), British Columbia yielded 4; Washington, 20; Oregon, 14; and California, 6 (*table 1*). Seven of the best sources came from regions south of 43° N, three from the Oregon Coast and North Coast Ranges and four from the Klamath Mountains and California Cascades. Six of the best came from altitudes higher than 600 m: one from 670 m in Washington, two from 730 and 1005 m in Oregon, and three from 945 to 1190 m in California.

Differences aside, three-fourths of the best sources for Spain are the same as those for France. Most of the fast growers are concentrated between latitudes 44° and 50° N and at altitudes of 60 to 730 m on the Pacific Slope, in regions where the Pacific Ocean air mass dominates climate.

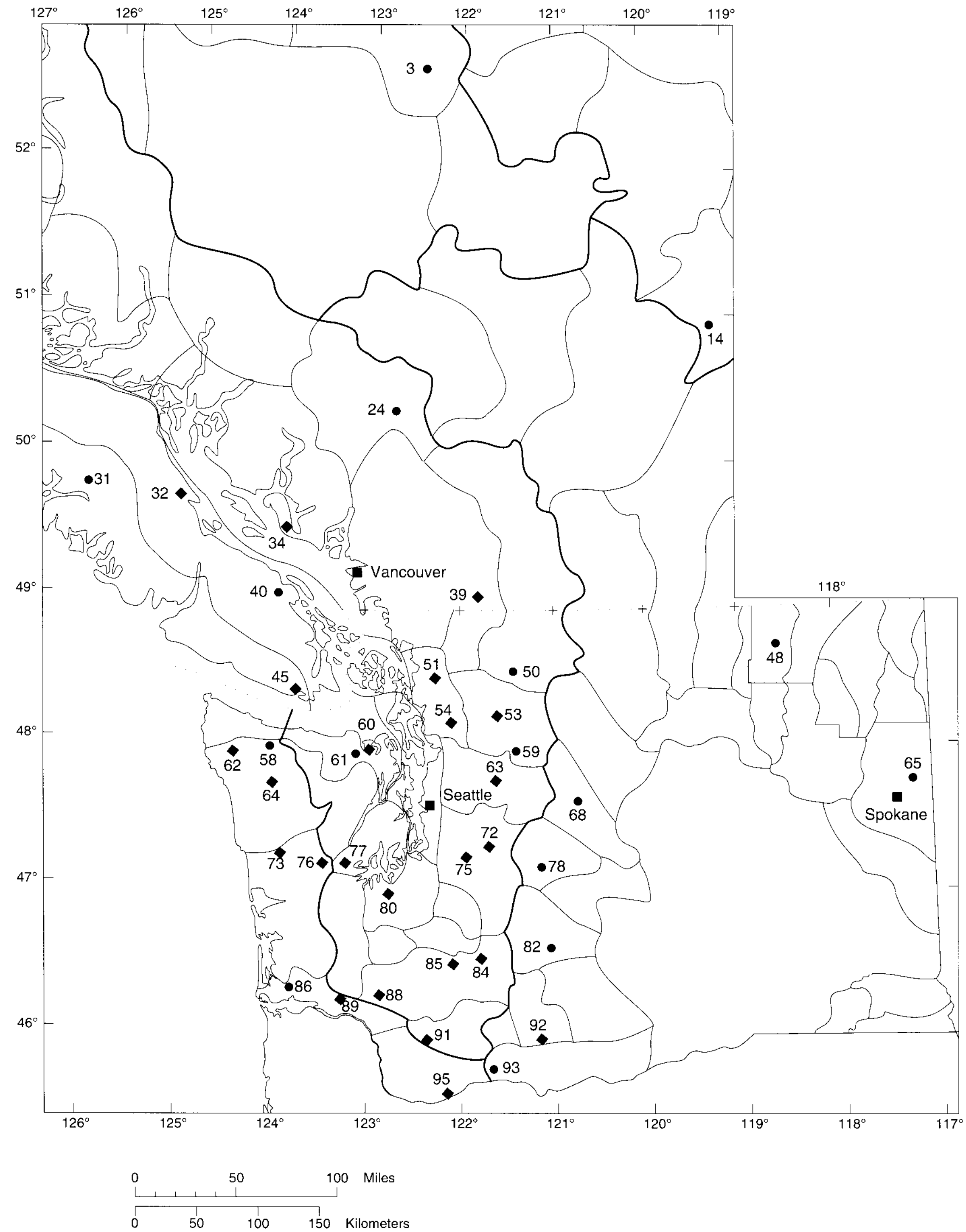
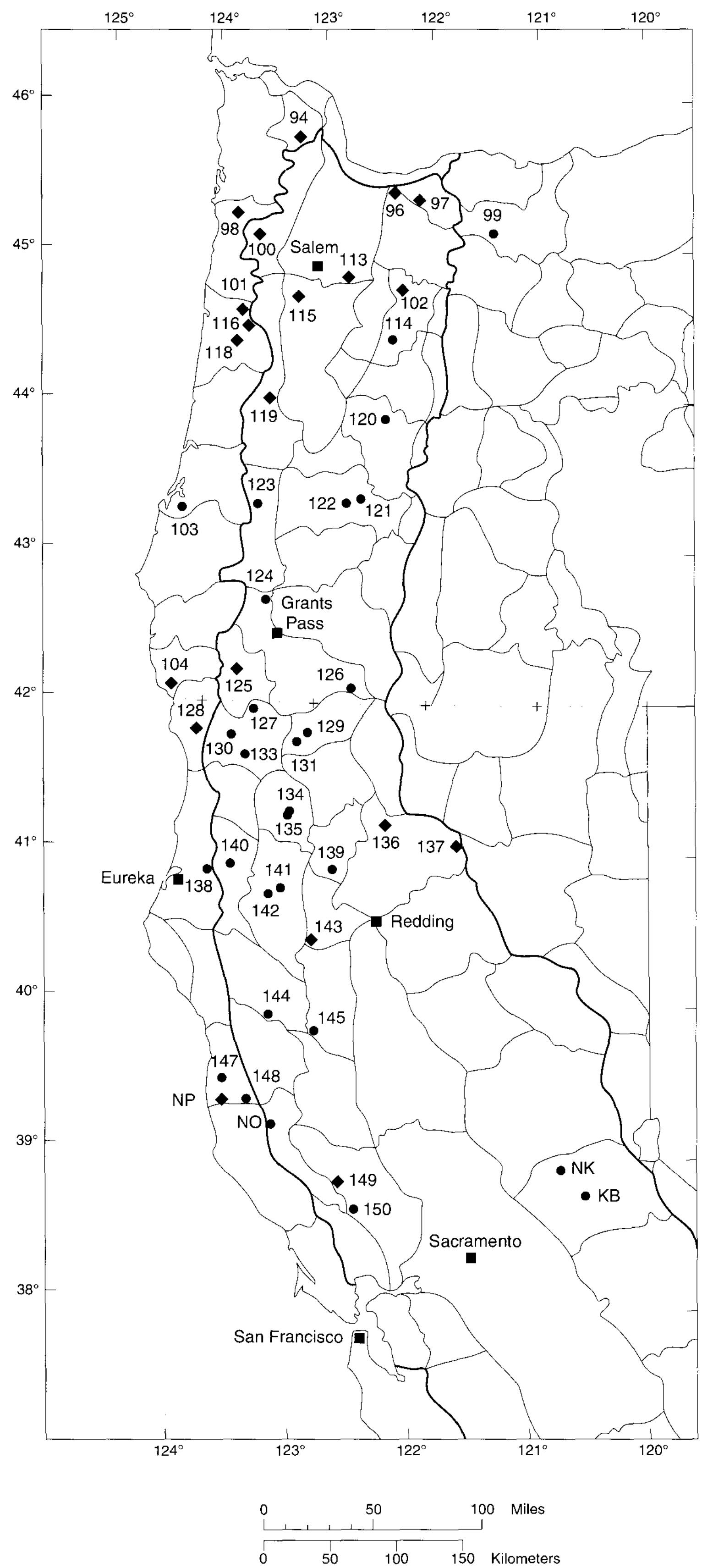


Figure 10—Douglas-fir seed sources in Pacific North America suggested for use in tree planting programs in Spain (♦). The key lists sources by physiographic region, tree seed zone, and altitude. Fast growers are found in the coastal forests from northwest California to the Georgia Strait in southwest British Columbia, and in the inland forests on lower slopes of the Olympic Mountains and the Coast and Cascade Ranges facing the Puget Trough in western Washington and Willamette Valley in northwest Oregon, regions where the Pacific Ocean air mass dominates climate.



Seed source ●	Seed zone	Elev *m*
Continental BC–OR		
3	503	730
14	304	490
48	801	730
65	830	670
68	622	550
78	631	640
82	641	760
92 ◆	651	490
93	653	550
99	662	730
Georgia Strait, BC		
31	101	90
45 ◆	101	45
32 ◆	102	65
40	102	200
34 ◆	104	185
39 ◆	105	170
24	107	215
Pacific Coast WA–CA		
58	012	305
62 ◆	012	90
64 ◆	012	245
73 ◆	030	135
76 ◆	030	120
86	041	60
89 ◆	041	245
94 ◆	052	215
98 ◆	053	185
101 ◆	061	90
116 ◆	061	335
118 ◆	061	1005
103	071	120
104 ◆	082	365
128 ◆	091	120
138	092	520
147	094	60
148	094	550
NP ◆	094	60
Puget Trough, W WA		
51 ◆	202	60
54 ◆	202	90
60 ◆	221	90
61	221	455
77 ◆	231	90
80 ◆	232	60
50	402	120
53 ◆	403	150
59	403	640
63 ◆	411	120
72 ◆	412	670
75 ◆	412	245
84 ◆	430	305
85 ◆	430	335
88 ◆	430	150
91 ◆	440	120
95 ◆	042	455
Willamette V, NW OR		
100 ◆	251	215
119 ◆	252	215
113 ◆	261	170
115 ◆	262	75
97 ◆	451	730
96 ◆	452	275
102	462	1065
114 ◆	462	490
120	482	885
Inland SW OR–N CA		
123	270	305
121	491	1600
122	491	520
124	511	425
126	511	1495
125 ◆	512	455
127	301	975
130	301	1065
133	301	1250
140	303	885
134	311	1190
135	311	1465
141	312	1370
142	312	990
129	321	855
131	321	1035
136 ◆	521	1005
137 ◆	521	1020
139	331	1190
143 ◆	332	1190
144	340	915
145	371	1555
NO	352	490
149 ◆	380	945
150	380	760
NK	526	855
KB	526	1250

Implications for Reforestation in Spain

To ensure Douglas-fir of high growth potential for reforestation in the coastal and inland regions of northern Spain, seed sources should be selected in Pacific Slope forests in Pacific climate types A—C. Spain's common-garden tests show that most of the best sources for Spain are situated at latitudes of 44° to 50° N and altitudes of 60 to 700 m in coastal and inland regions west of the crest of the Cascade Ranges. The best coastal sources are found along the southern Georgia Strait of southwest British Columbia and on lower slopes of the Olympic Peninsula and Coast Ranges of Washington, Oregon, and northwest California. The best inland sources are found on lower slopes of the Olympic Mountains and Coast and Cascade Ranges facing the Puget Trough in western Washington and Willamette Valley in northwest Oregon, except the few in southwest Oregon and northwest California.

To identify seed zones for future Douglas-fir collections, we marked the origins of the 44 best seed sources (♦) determined in the common-garden tests (*fig. 10, table 1*). The resulting map distributions show that most of the best sources are located in contiguous regional sets of neighboring seed zones. Known source performances recommend seed collections from stands in southwest British Columbia, western Washington, and northwest Oregon, in the seed zones and altitudes listed below:

- Southwest British Columbia: seed zones 101, 102, 104, and 105 at altitudes of 45 to 185 m

- Western Washington: seed zones 012, 030, 041, 042, 202, 221, 231, 232, 403, 411, 412, 430, and 440 at altitudes of 60 to 455 m, even 670 m in zone 412

- Northwest Oregon: seed zones 052, 053, 061, 251, 252, 261, 262, 451, 452, and 462 at altitudes of 90 to 490 m, even 1005 m in zone 061

Certain seed zones in southwest Oregon and northwest California should also be targeted, to produce seedlings for planting on sites that are similar to those of plantations in which trees of the particular sources grew well. Known source performances recommend seed collections from stands at altitudes of 60 to 365 m in coastal seed zones 082, 091, and 094, and at 455 to 1190 m in inland seed zones 512, 332, and 521.

Trees of many of the best seed sources grew well on diverse planting sites (*figs. 8-9*). Sources 32, 39, 51, 53, 54, 60, 62, 63, 64, 72, 73, 77, 80, 88, 89, 91, 94, 95, 96, 98, 101, 113, 114, 115, and 116, for example, are characterized by broad adaptability. Their consistently good growth shows that they may be safely used on almost any planting site. Trees of some of the other best sources, however, grew well on one site and poorly on another. Best sources that show differential growth performance, such as sources 34, 40, 58, 98, 100, 118, 128, and 145, may be considered safe to plant wherever the soils and climates are similar to those in which trees of the particular source grew well.

Whenever possible, Douglas-fir stands in Spain's target seed zones—and any stands to be collected in adjacent zones—should be located at altitudes close to those of the known seed sources (*table 1*). Seed collections should represent 20 or more trees that are near planned harvest age, spaced about 185 m apart, and chosen for health, form, vigor, and abundance of cones in the top third of the live crown. Mature cones should be picked in years when the crops are moderate to heavy, in order to enhance seed quality, obtain large seed lots of broad genetic base, and supply selection differentials for the improvement of timber traits (Kitzmiller 1976).

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Appendix Tables

Table 1—*Allocation of Douglas-fir seed sources among common-garden tests in Spain*[1]

North America Seed source[2] and Locality		Tree seed zone[3]	Spain region and plantation[4]														
			Northwest										*North central*				
			SE	LH	BA	CD	FR	RE	SM	GA	VA	CO	LG	LV	SL	AT	OC
British Columbia																	
3	Alexandria	503	+	+	—	—	—	+	—	—	—	—	—	—	—	—	—
14	Eagle Bay	304	+	+	+	—	—	—	+	—	—	—	—	—	—	—	+
24	Owl Creek	107	†	+	+	—	—	—	+	—	—	—	—	—	—	—	+
31	Gold River	101	+	+	—	—	†	—	—	—	—	—	—	—	—	+	—
♦32	Courtenay	102	+	†	—	—	—	†	—	†	—	—	—	—	—	—	—
♦34	Sechelt	104	+	+	—	—	—	—	—	†	—	†	—	—	—	—	†
♦39	Chilliwack	105	+	+	—	—	†	—	—	†	†	†	—	—	+	†	†
40	Cassidy	102	†	†	+	—	—	—	—	+	+	+	—	—	+	—	—
♦45	Sooke	101	+	†	—	—	—	†	—	—	—	—	—	—	—	—	—
Washington																	
48	Republic	801	+	+	—	—	+	—	—	+	—	—	—	—	—	—	—
50	Marblemount	402	+	+	—	—	—	—	—	—	—	—	+	—	—	—	†
♦51	Sedro Wooley	202	+	†	—	—	—	†	—	†	—	—	—	†	—	—	†
♦53	Darrington	403	†	†	—	—	—	—	—	—	†	—	—	†	+	†	†
♦54	Arlington	202	+	†	—	—	+	—	—	—	—	†	—	—	—	—	†
58	Lake Crescent	012	†	+	—	—	+	—	—	—	—	—	—	—	—	—	—
59	Perry Creek	403	+	†	+	—	—	—	—	—	—	—	—	—	—	—	—
♦60	Sequim	221	†	+	†	—	—	—	—	—	—	†	—	—	—	—	—
61	Louella GS	221	+	+	—	—	—	—	+	—	—	—	—	—	—	—	—
♦62	Forks	012	†	†	—	—	—	—	—	—	—	—	†	—	—	—	—
♦63	Gold Bar	411	†	†	—	—	—	—	—	†	—	—	—	—	—	—	—
♦64	Hoh River	012	†	†	†	—	†	—	+	—	+	—	—	—	—	—	—
65	Spokane	830	+	+	+	—	+	—	—	—	—	—	—	—	—	—	—
68	Chiwaukum	622	+	+	—	—	—	—	—	—	—	+	+	—	—	+	+
♦72	Chester Morse	412	†	†	—	†	—	—	—	—	—	—	—	†	—	—	†
♦73	Humptulips	030	†	†	—	—	†	+	+	—	—	—	—	—	+	†	†
♦75	Enumclaw	412	†	+	—	—	—	—	+	—	†	—	—	—	—	—	—
♦76	Matlock	030	+	+	†	—	—	—	—	†	—	—	—	—	—	—	—
♦77	Shelton	231	+	†	—	—	—	—	—	—	—	—	—	†	—	—	†
78	Cle Elum	631	+	+	+	—	—	—	—	+	—	+	+	—	—	—	—
♦80	Yelm	232	†	†	†	†	—	—	+	†	—	—	—	—	+	†	+
82	Rimrock	641	+	+	—	—	—	—	+	—	—	—	+	+	—	+	+
♦84	Packwood	430	+	†	—	—	—	—	—	—	—	—	—	—	—	—	—
♦85	Randle	430	†	+	—	—	—	—	—	—	—	—	+	—	—	—	†
86	Naselle	041	+	+	—	—	+	†	—	—	—	—	—	+	+	—	—
♦88	Castle Rock	430	+	†	—	—	—	—	—	†	—	—	†	—	—	†	†
♦89	Cathlamet	041	†	†	—	†	—	—	—	—	†	+	—	†	+	†	†
♦91	Yale	440	†	†	—	—	—	—	—	†	—	†	—	†	—	—	†
♦92	Glenwood	651	†	+	—	—	†	—	—	—	—	—	—	—	—	—	+
93	Willard	653	+	+	—	—	—	—	—	—	†	—	—	—	—	+	+
♦95	Prindle	042	+	†	—	†	—	—	+	†	—	—	—	—	+	†	†
Oregon																	
♦94	Vernonia	052	†	†	—	—	†	—	+	—	—	—	—	—	—	†	†
♦96	Sandy	452	+	†	—	—	—	†	—	—	—	†	†	—	+	†	†
♦97	Cherryville	451	†	†	†	—	—	—	—	—	—	—	—	—	+	+	†
♦98	Hebo	053	†	+	†	—	—	—	—	†	†	—	—	—	—	—	—
99	Pine Grove	662	+	+	+	—	+	—	—	—	—	—	—	—	—	—	+
♦100	Grand Ronde	251	+	†	—	—	+	—	—	—	—	—	—	—	+	—	—

continues

Table 1—*Allocation of Douglas-fir seed sources among common-garden tests in Spain*[1]

North America Seed source[2] and Locality		Tree seed zone[3]	Spain region and plantation[4]														
			Northwest									*North central*					
			SE	LH	BA	CD	FR	RE	SM	GA	VA	CO	LG	LV	SL	AT	OC
Oregon																	
♦101	Waldport	061	†	†	†	—	—	—	—	†	†	—	—	—	—	—	—
102	Upper Soda	462	†	+	—	—	—	—	—	+	+	—	—	—	—	—	+
103	Coquille	071	+	+	—	—	+	†	—	—	—	—	—	—	—	—	—
♦104	Brookings	082	+	†	†	—	—	+	—	†	—	—	—	—	+	—	—
♦113	Mill City	261	†	†	—	—	—	—	—	—	†	—	—	—	—	—	—
♦114	Detroit	462	†	†	—	—	—	—	—	—	—	—	—	—	—	—	—
♦115	Corvallis	262	†	†	—	—	—	—	—	—	—	—	—	—	—	—	—
♦116	Burnt Woods	061	†	†	—	—	†	—	—	—	—	—	—	—	+	—	—
♦118	Marys Peak	061	†	+	—	—	—	—	—	—	—	†	—	—	—	—	—
♦119	Eugene	252	†	†	—	—	—	+	—	—	—	—	—	—	—	—	—
120	Oakridge	482	+	+	—	—	—	+	—	—	—	—	—	—	—	—	—
121	Steamboat 1	491	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—
122	Steamboat 2	491	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—
123	Roseburg	270	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—
124	Wolf Creek	511	†	+	+	—	—	+	—	—	—	—	—	—	—	—	+
♦125	Cave Junction	512	†	+	—	—	†	+	—	—	†	—	—	—	—	—	—
126	Ashland	511	+	+	—	—	—	+	—	—	—	—	—	—	—	—	—
California																	
127	Happy Camp 1	301	+	+	—	—	—	+	—	—	—	—	—	—	—	—	—
♦128	Gasquet	091	+	+	—	—	†	—	+	—	—	—	—	—	—	—	†
129	Seiad Valley	321	+	+	—	—	—	+	+	—	†	—	—	—	—	—	—
130	Hawkinsville	301	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—
131	Scott Bar	321	†	+	—	—	—	+	—	—	—	+	—	—	—	—	—
133	Happy Camp 2	301	+	+	—	—	—	—	—	+	—	—	—	—	—	—	—
134	Sawyers Bar 1	311	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—
135	Sawyers Bar 2	311	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—
♦136	Dunsmuir	521	+	†	—	—	†	—	—	—	—	—	—	—	—	—	—
♦137	Burney	521	†	+	—	—	—	—	—	—	—	—	—	—	—	—	—
138	Arcata 1	092	†	+	—	—	—	+	—	—	—	+	—	—	—	—	—
139	Weaverville	331	+	+	—	—	—	—	—	—	—	+	—	—	—	—	—
140	Arcata 2	303	+	+	†	—	—	—	—	—	—	—	—	—	—	—	—
141	Big Bar 1	312	+	+	—	—	—	—	—	—	—	+	—	—	—	—	—
142	Big Bar 2	312	+	+	—	—	—	—	—	—	†	+	—	—	+	—	—
♦143	Wildwood	332	†	†	—	—	—	—	+	+	—	—	—	—	—	—	+
144	Covelo 1	340	+	+	+	—	—	+	—	—	—	—	—	—	—	—	+
145	Covelo 2	371	†	+	—	—	—	—	—	—	+	—	+	—	—	+	†
147	Fort Bragg	094	+	†	—	—	+	—	—	—	—	—	—	—	+	—	—
148	Willits	094	+	+	—	—	—	†	+	—	—	—	—	—	—	—	—
♦149	Lower Lake	380	†	—	—	—	—	—	—	—	—	—	—	—	—	—	—
150	Mt St Helena	380	+	+	—	—	—	+	—	—	—	—	†	—	—	—	—
KB	Fresh Pond	526	—	—	—	—	—	—	+	+	+	+	—	—	—	—	—
NK	Georgetown	526	—	—	+	—	—	—	—	—	+	—	—	—	—	—	—
NO	Ukiah	352	—	—	†	+	—	—	—	+	†	+	—	—	—	—	—
♦NP	Big River	094	—	—	—	—	—	—	—	—	†	—	†	+	—	—	—
Mexico																	
151	Saltillo	—	+	†	—	—	+	—	—	—	—	—	—	—	—	—	—
152	Tlaxco	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] The symbols (+, †) show where each source was assessed, and (†), where mean tree height for the source exceeded plantation height. See *figs. 2-3* and *table 1.*

[2] The diamond symbol (♦) marks a source for which mean tree height exceeded plantation height in half or more of the tests in which the source was assessed. See *Appendix table 2.*

[3] Lines 1987, Buck and others 1970, USDA Forest Service 1969, 1973.

[4] The letter codes SE and LH represent the principal plantations, and BA through OC, the satellite plantations. See *fig. 4* and *table 2.*

Table 2—*Variance analyses of 5- and 6-year height of Douglas-fir in common-garden tests in Spain*

Plantation, height, Seed sources, and source of variation	Variance components[1] and p values							
	All trees		15 tallest		10 tallest		5 tallest	
Northwest Spain								
La Hermida[2]								
5-yr ht, SE, *cm*	67.5, 3.52		82.0, 5.14		86.7, 4.90		98.6, 5.45	
Seed sources, *no.*	86		63		81		85	
Seed source, S	38.13	.000**	11.20	.001**	21.82	.000**	26.52	.000**
Block, B	9.75	.—	7.29	.000	6.89	.000	8.26	.000
SB	51.94	.—	31.34	.000	33.11	.000	37.06	.000
Trees, T(SB)	.—		50.17		38.18		28.16	
mean square[3]	186.98		506.80		373.70		286.54	
Sierra del Eje[2]								
5-yr ht, SE, *cm*	38.1, 2.72		44.7, 3.69		50.4, 3.79		60.5, 4.23	
Seed sources, *no.*	87		56		80		87	
Seed source, S	11.62	.020*	5.55	.063	6.82	.037*	7.64	.046*
Block, B	10.92	.—	6.44	.000	6.73	.000	7.19	.000
SB	77.46	.—	36.88	.000	46.62	.000	58.52	.000
Trees, T(SB)	.—		51.13		39.82		26.65	
mean square[3]	145.57		292.12		233.11		180.28	
Bande								
5-yr ht, SE, *cm*	89.2, 6.08		142.3, 13.32		152.9, 13.86		168.6, 14.55	
Seed sources, *no.*	22		22		22		22	
Seed source, S	62.9	.000**	46.65	.000**	48.72	.000**	51.34	.000**
Block, B	10.8	.—	16.79	.000	17.45	.000	18.18	.000
SB	26.3	.—	16.72	.000	17.75	.000	18.93	.000
Trees, T(SB)	.—		19.84		16.08		11.55	
mean square[3]	221.81		599.75		505.48		383.37	
Castro Dozón								
5-yr ht, SE, *cm*	72.8, 4.14		99.5, 7.25		106.7, 8.07		117.8, 8.83	
Seed sources, *no.*	5		5		5		5	
Seed source, S	71.49	.001**	40.59	.006**	38.86	.013*	38.35	.034*
Block, B	12.03	.—	13.25	.000	14.79	.000	13.58	.000
SB	16.48	.—	14.20	.000	18.96	.000	29.12	.000
Trees, T(SB)	.—		31.96		27.39		18.95	
mean square[3]	55.42		304.98		280.04		220.00	
Fragavella[4]								
5-yr ht, SE, *cm*	37.1, 2.69		59.7, 5.75		61.6, 5.83		73.4, 7.31	
Seed sources, *no.*	20		14		16		17	
Seed source, S	50.90	.000**	3.49	.299	25.03	.004**	21.34	.016*
Block, B	9.17	.—	12.23	.000	9.95	.000	13.25	.000
SB	39.92	.—	37.71	.000	33.01	.000	39.89	.000
Trees, T(SB)	.—		46.57		32.01		25.52	
mean square[3]	77.37		305.50		267.58		257.30	
Regavella								
5-yr ht, SE, *cm*	42.9, 2.98		58.0, 5.43		60.6, 5.94		68.5, 6.71	
Seed sources, *no.*	21		16		19		20	
Seed source, S	20.11	.031*	13.24	.046*	19.11	.010**	21.67	.008**
Block, B	19.45	.—	13.61	.000	14.39	.000	15.92	.000
SB	60.43	.—	35.35	.000	36.21	.000	38.85	.000
Trees, T(SB)	.—		37.80		30.29		23.57	
mean square[3]	72.04		209.37		194.57		176.00	

continues

Table 2—*Variance analyses of 5- and 6-year height of Douglas-fir in common-garden tests in Spain*

Plantation, height, Seed sources, and source of variation	Variance components[1] and p values			
	All trees	15 tallest	10 tallest	5 tallest
Sierra de Meira				
5-yr ht, SE, cm	53.5, 3.97	—	64.4, 3.36	76.7, 4.10
Seed sources, no.	14	—	11	12
Seed source, S	11.12 .334	.— .—	5.75 .357	4.09 .422
Block, B	7.88 .—	.— .—	0.00 .441	0.00 .671
SB	81.00 .—	.— .—	36.99 .000	54.81 .000
Trees, T(SB)	.—	.—	57.26	41.10
mean square[3]	187.27	.—	352.39	294.06
Gamalleira				
5-yr ht, SE, cm	103.2, 3.09	159.8, 5.23	169.8, 5.44	185.7, 5.89
Seed sources, no.	21	21	21	21
Seed source, S	57.78 .000**	40.75 .000**	39.72 .000**	36.64 .001**
Block, B	0.10 .—	0.58 .000	0.57 .000	0.64 .004
SB	42.11 .—	40.13 .000	42.86 .000	48.59 .000
Trees, T(SB)	.—	18.54	16.85	14.14
mean square[3]	571.12	596.87	555.49	476.59
Valdemadeiro				
5-yr ht, SE, cm	61.1, 1.68	102.0, 3.09	109.5, 3.36	121 .2, 3.75
Seed sources, no.	19	19	19	19
Seed source, S	74.84 .000**	26.29 .000**	24.00 .002**	18.81 .027*
Block, B	3.77 .—	2.66 .000	2.96 .000	3.14 .000
S13	21.38 .—	23.23 .000	29.93 .000	43.09 .000
Trees, T(SB)	.—	47.82	43.11	34.97
mean square[3]	36.79	337.52	305.58	255.18
North central Spain				
Conforcal				
6-yr ht, SE, cm	183.2, 5.08	—	226.5, 5.78	250.3, 6.82
Seed sources, no.	18	—	18	18
Seed source, S	34.68 .000**	.— .—	29.35 .000**	28.56 .000**
Block, B	5.76 .—	.— .—	3.62 .000	4.98 .—
SB	59.55 .—	.— .—	26.76 .000	66.46 .—
Trees, T(SB)	.—	.—	40.27	.—
mean square[3]	1525.3	.—	1943.2	3211.1
La Gallina				
6-yr ht, SE, cm	122.0, 13.87	164.6, 19.47	181.2, 20.31	196.1, 21.88
Seed sources, no.	12	11	11	12
Seed source, S	50.65 .000**	33.00 .000**	35.91 .000**	44.72 .000**
Block, B	32.06 .—	23.87 .000	25.55 .000	25.04 .000
SB	17.29 .—	11.45 .000	12.81 .000	11.22 .000
Trees, T(SB)	.—	31.68	25.73	19.01
mean square[3]	297.89	1434.4	1181.8	1038.3

continues

*, ** Significant at p <0.05, <0.01

[1] Variance components are expressed as a percentage of the total variance in analyses using the mean of all trees and the 15, 10, and 5 tallest in each plot, except the 2 and 1 tallest at Conforcal. See *tables 2-3.*

[2] Includes *P. flahaulti* and *P. macrolepis.* See *Appendix table 1.*

[3] Actual estimate of SB mean square using the mean of all trees in each plot, except the 1 tallest tree at Conforcal, and T(SB) mean square using the 15, 10, and 5 tallest trees in each plot, except the 2 tallest at Conforcal.

[4] Includes *P. flahaulti.* See *Appendix table 1.*

Table 2—*Variance analyses of 5- and 6-year height of Douglas-fir in common-garden tests in Spain*

Plantation, height, Seed sources, and source of variation	Variance components[1] and p values							
	All trees		15 tallest		10 tallest		5 tallest	
La Vecilla								
6-yr ht, SE, *cm*	96.2, 5.51		151.0, 8.34		168.6, 7.63		193.4, 6.80	
Seed sources, *no.*	9		9		9		9	
Seed source, S	49.58	.004**	35.88	.000**	38.78	.000**	45.96	.000**
Block, B	9.73	.—	6.03	.000	5.39	.000	3.83	.000
SB	40.70	.—	6.55	.000	8.34	.000	12.19	.000
Trees, T(SB)	.—		51.54		47.48		38.12	
mean square[3]	260.56		1503.7		1211.1		875.16	
Salinas de Léniz								
5-yr ht, SE, *cm*	107.8, 12.91		155.0, 18.75		163.3, 19.90		178.0, 20.55	
Seed sources, *no.*	15		14		15		15	
Seed source, S	0.00	.857	0.00	.842	0.00	.868	0.00	.908
Block, B	43.85	.—	34.23	.000	36.55	.000	37.60	.000
SB	56.15	.—	47.17	.000	48.96	.000	51.55	.000
Trees, T(SB)	.—		18.61		14.48		10.85	
mean square[3]	590.06		520.47		430.96		333.94	
Ataun								
5-yr ht, SE, *cm*	165.3, 3.48		230.9, 5.46		242.5, 6.36		258.9, 7.84	
Seed sources, *no.*	15		14		14		14	
Seed source, S	68.73	.000**	52.17	.000**	51.04	.000**	51.42	.000**
Block, B	0.24	.—	1.36	.000	2.59	.000	5.28	.000
SB	31.03	.—	22.94	.000	25.85	.000	27.34	.000
Trees, T(SB)	.—		23.54		20.53		15.96	
mean square[3]	486.01		677.65		543.29		394.45	
Ochagavía								
5-yr ht, SE, cm	143.8, 2.38		206.8, 3.19		215.4, 3.01		227.6, 2.90	
Seed sources, *no.*	31		31		31		31	
Seed source, S	61.34	.000**	40.67	.000**	41.23	.000**	41.09	.000**
Block, B	1.15	.—	0.77	.000	0.56	.000	0.29	.000
SB	37.51	.—	33.89	.000	36.71	.000	41.61	.000
Trees, T(SB)	.—		24.67		21.50		17.02	
mean square[3]	269.82		392.71		322.11		245.56	

*, ** Significant at p <0.05, <0.01

[1] Variance components are expressed as a percentage of the total variance in analyses using the mean of all trees and the 15, 10, and 5 tallest in each plot, except the 2 and 1 tallest at Conforcal. See *tables 2-3.*

[2] Includes *P. flahaulti* and *P. macrolepis.* See *Appendix table 1.*

[3] Actual estimate of SB mean square using the mean of all trees in each plot, except the 1 tallest tree at Conforcal, and T(SB) mean square using the 15, 10, and 5 tallest trees in each plot, except the 2 tallest at Conforcal.

[4] Includes *P. flahaulti.* See *Appendix table 1.*

Table 3—*Variance analyses of 5-year height of Douglas-fir in pairings of the principal common-garden tests in Spain*

Plantation pair, Seed sources, and source of variation	Variance components[1] and p values					
	All trees		10 tallest		5 tallest	
La Hermida<>Sierra del Eje[2]						
Seed sources, *no.*	86		76		85	
Planting site, P	59.74	.002**	43.37	.004**	44.57	.004**
Seed source, S	9.13	.000**	7.16	.000**	8.86	.000**
Block, B(P)	3.88	.—	3.92	.000	4.13	.000
PS	3.90	.006**	3.31	.020*	2.96	.045*
SB(P)	23.35	.—	21.14	.000	24.65	.000
Trees, T(PSB)	.—		21.10		14.82	
mean square[3]	166.92		301.12		231.64	

*, ** Significant at p <0.05, <0.01

[1] Variance components are expressed as a percentage of the total variance in analyses using the mean of all trees in each plot and the 10 and 5 tallest in each plot. See *tables 2-3.*

[2] Includes *P. flahaulti* and *P. macrolepis.* See *Appendix table 1.*

[3] Actual estimate of SB(P) mean square using the mean of all trees in each plot and T(PSB) mean square using the 10 and 5 tallest in each plot.

Table 4—*Variance analyses of 5- and 6-year height of Douglas-fir in pairings of the principal and satellite common-garden tests in Spain*

Plantation pair, Seed sources, and source of variation	Variance components[1] and p values					
	All trees		10\15 tallest		5\15 tallest	
La Hermida<>Bande						
Seed sources, *no.*	20		18		20	
Planting site, P	34.30	.020*	58.37	.009**	40.28	.021*
Seed source, S	27.49	.000**	13.75	.000**	24.18	.000**
Block, B(P)	7.78	.—	8.37	.—	9.53	.—
PS	11.19	.001**	8.13	.000**	10.68	.000**
SB(P)	19.23		11.38		15.32	
mean square[2]	187.82		415.07		450.21	
La Hermida<>Fragavella[3]						
Seed sources, *no.*	20		14		14	
Planting site, P	62.85	.002**	48.14	.013*	65.27	.005**
Seed source, S	11.12	.000**	2.36	.218	1.27	.255
B(P)	4.18	.—	8.46	.—	6.21	.—
PS	4.11	.056	0.00	.571	0.00	.535
SB(P)	17.74		41.04		27.25	
mean square[2]	120.64		339.20		377.29	
La Hermida<>Regavella						
Seed sources, *no*	21		16		16	
Planting site, P	49.87	.005**	46.56	.013*	62.29	.005**
Seed source, S	14.83	.000**	12.35	.000**	7.86	.000**
B(P)	5.18	.—	8.00	.—	6.21	.—
PS	9.03	.005**	5.33	.108	2.90	.168
SB(P)	21.09		27.76		20.74	
mean square[2]	123.31		295.72		342.28	
La Hermida<>Gamalleira						
Seed sources, *no.*	19		18		19	
Planting site, P	35.37	.002**	66.98	.000**	44.44	.000**
Seed source, S	22.60	.000**	6.21	.002**	18.55	.000**
B(P)	2.15	.—	1.10	.—	1.18	.—
PS	13.19	.003**	3.78	.115	10.02	.011*
SB(P)	26.70		21.92		25.80	
mean square[2]	409.95		918.56		916.17	
La Hermida<>Valdemadeiro						
Seed sources, *no*	15		15		15	
Planting site, P	6.80	.084	17.31	.009**	0.00	.713
Seed source, S	29.04	.000**	21.83	.000**	24.38	.000**
B(P)	4.83	.—	2.48	.—	4.32	.—
PS	12.60	.060	11.30	.077	12.14	.103
SB(P)	46.73		47.10		59.16	
mean square[2]	135.41		306.07		372.16	

continues

Table 4—*Variance analyses of 5- and 6-year height of Douglas-fir in pairings of the principal and satellite common garden tests in Spain*

Plantation pair, Seed sources, and source of variation	Variance components[1] and p values					
	All trees		10\15 tallest		5\1 5 tallest	
La Hermida<>La Gallina						
Seed sources, *no.*	10		9		9	
Planting site, P	54.15	.014*	56.21	.014*	45.56	.027*
Seed source, S	18.86	.000**	17.23	.000**	22.76	.000**
B(P)	9.73	.––	10.43	.––	12.94	.––
PS	8.47	.002**	7.38	.005**	7.88	.009**
SB(P)	8.78		8.76		10.86	
mean square[2]	219.51		422.29		421.47	
La Hermida<>La Vecilla						
Seed sources, *no.*	8		8		8	
Planting site, P	9.46	.148	41.08	.016*	22.99	.058
Seed source, S	33.04	.000**	24.94	.000*	30.07	.000**
B(P)	12.82	.––	8.01	.––	11.71	.––
PS	0.00	.747	5.74	.116	5.35	.196
SB(P)	44.67		20.23		29.88	
mean square[2]	329.60		495.23		606.89	
La Hermida<>Ataun						
Seed sources, *no.*	15		14		14	
Planting site, P	78.99	.000**	84.35	.000**	80.66	.000**
Seed source, S	8.88	.000**	6.22	.000**	7.59	.000**
B(P)	0.64	.––	0.76	.––	1.09	.––
PS	3.71	.010**	2.42	.025*	2.23	.069
SB(P)	7.78		6.25		8.43	
mean square[2]	419.67		673.79		770.01	
La Hermida<>Ochagavía						
Seed sources, *no.*	31		30		31	
Planting site, P	80.00	.000**	85.61	.000**	81.69	.000**
Seed source, S	7.83	.000**	5.13	.000**	6.34	.000**
B(P)	0.77	.––	0.69	.––	0.88	.––
PS	3.16	.002**	1.75	.018*	2.26	.016*
SB(P)	8.25		6.83		8.82	
mean square[2]	264.51		519.61		566.25	

, Significant at p <0.05, <0.01

[1] Variance components are expressed as a percentage of the total variance in analyses using the mean of all trees in each plot and the means of the 10\15 and 5\1 5 tallest in each plot. See *tables 2-3.*

[2] Actual estimate of SB(P) mean square.

[3] Includes *P. flahaulti.* See *Appendix table 1.*

Table 5—*Variance analyses of 5- and 6-year height of Douglas-fir in pairings of the anchor and other satellite common-garden tests in Spain*

Plantation pair, Seed sources, and source of variation	Variance components[1] and p values							
	All trees		15 tallest		10 tallest		5 tallest	
Bande<>Ochagavía								
Seed sources, *no.*	7		7		7		7	
Planting site, P	53.09	.002**	36.79	.011*	34.65	.015*	30.47	.022*
Seed source, S	25.51	.000**	23.57	.000**	24.19	.000**	25.91	.000**
B(P)	2.83	.—	5.58	.000	6.45	.000	7.29	.000
PS	3.30	.177	9.49	.030*	11.07	.022*	12.35	.025*
SB(P)	15.27	.—	14.50	.000	15.00	.000	17.14	.000
Trees, T(PSB)	.—		10.08		8.65		6.83	
mean square[2]	289.03		435.88		368.90		280.65	
Bande<>Gamalleira								
Seed sources, *no.*	8		8		8		8	
Planting site, P	0.00	.795	0.00	.566	0.00	.474	0.00	.416
Seed source, S	44.38	.000**	24.82	.001**	25.50	.002**	26.79	.003**
Block, B(P)	5.44	.—	9.93	.000	10.37	.000	11.74	.000
PS	1.61	.391	4.79 .26	22.57	.35	10.00	.501	
SB(P)	48.58	.—	38.93	.000	43.72	.000	49.46	.000
Trees, T(PSB)	.—		21.53		17.84		12.02	
mean square[2]	498.40		677.00		570.45		395.36	
Gamalleira<>Ochagavía								
Seed sources, *no.*	9		9		9		9	
Planting site, P	43.54	.006**	30.31	.007**	28.43	.008**	23.08	.016*
Seed source, S	11.75	.015*	11.47	.017*	12.24	.017*	11.75	.033*
B(P)	4.63	.—	3.45	.000	3.51	.000	4.15	.000
PS	3.23	.297	0.00	.600	0.00	.675	0.00	.758
SB(P)	36.84	.—	36.16	.000	38.47	.000	44.75	.000
Trees, T(PSB)	.—		18.61		17.35		16.26	
mean square[2]	507.21		481.22		441.92		406.06	
La Gallina<>Ataun								
Seed sources, *no.*	5		4		4		4	
Planting site, P	5.25	.176	6.51	.164	4.87	.211	3.38	.251
Seed source, S	60.38	.000**	47.04	.000**	49.50	.000**	51.96	.000**
B(P)	9.33	.—	10.01	.000	11.79	.000	12.26	.000
PS	2.97	.277	5.18	.191	2.99	.282	0.35	.409
SB(P)	22.06	.—	17.19	.000	19.72	.000	22.90	.000
Trees, T(PSB)	.—		14.08		11.14		9.14	
mean square[2]	699.77		1150.7		886.38		716.29	

continues

Table 5—*Variance analyses of 5- and 6-year height of Douglas-fir in pairings of the anchor and other satellite common-garden tests in Spain*

Plantation pair, Seed sources, and source of variation	Variance components and p values							
	All trees		15 tallest		10 tallest		5 tallest	
La Gallina<>Ochagavía								
Seed sources, *no.*	7		6		6		7	
Planting site, P	3.82	.239	16.25	.080	10.27	.146	3.49	.260
Seed source, S	51.97	.000**	23.66	.000**	25.84	.000**	43.10	.000**
B(P)	12.61	.—	10.74	.000	13.41	.000	14.13	.000
PS	14.93	.010**	14.49	.011 *	15.64	.016*	11.16	.022*
SB(P)	16.68	.—	12.82	.000	15.53	.000	13.03	.000
Trees, T(PSB)	.—		22.05		19.31		15.10	
mean square[2]	311.58		1090.0		868.12		748.75	
Ataun<>Ochagavía								
Seed sources, *no.*	14		13		13		13	
Planting site, P	15.13	.000**	7.72	.014*	10.01	.019*	13.45	.029*
Seed source, S	54.78	.000**	37.85	.000**	35.29	.000**	32.24	.000**
B(P)	0.09	.—	1.32	.000	2.05	.000	3.80	.000
PS	4.76	.126	5.62	.115	6.08	.118	6.96	.109
SB(P)	25.23	.—	25.38	.000	27.62	.000	29.28	.000
Trees, T(PSB)	.—		22.12		18.94		14.27	
mean square[2]	378.61		555.45		441.30		318.32	

*,** Significant at p <0.05, <0.01

[1] Variance components are expressed as a percentage of the total variance in analyses using the mean of all trees in each plot and the 15, 10, and 5 tallest in each plot. See *tables 2-3.*

[2] Actual estimate of SB(P) mean square using the mean of all trees in each plot and T(PSB) mean square using the 15, 10, and 5 tallest in each plot.

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