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Hardwood Species Trials in Oregon

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Survival and growth of a wide variety of native Pacific Northwest and non-native hardwood tree species were evaluated at six sites in Oregon with different climatic and soil conditions. Hybrid cottonwood performed particularly well---it had a mean survival rate of 90% and a mean height of 634 cm after 5 years. Several other species also performed well, including black cottonwood (Populus trichocarpa *Torr. & Gray), cherrybark oak* (Quercus falcata *var.* pagodifolia *Ell.), Nuttal oak* (Q. nuttallii *Palmer), water oak* (Q. nigra *L.), black cherry* (Prunus serotina *Ehrh.), black walnut* (Juglans nigra *L.), green ash* (Fraxinus pennsylvanica *Marsh.), Oregon ash* (F. latifolia *Benth.), and white ash* (F. americana *L.). Suggestions for selecting appropriate species for particular sites and for their management are included.*
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Many Oregon landowners have land that is underutilized for timber or agricultural production and could support hardwood species as a crop. In addition, there is a growing interest in tree species that can be used in agroforestry systems. Unfortunately, little information on species' site requirements and production rates is available to help these landowners select appropriate species. In an attempt to fill this information gap, a wide variety of hardwood species was planted at six locations across eastern and western Oregon in order to assess the potential for establishing these species over a range of site conditions as well as to identify the conditions in which the species grow best.

Methods

The six sites used for the species trials (table 1) were selected to represent a variety of climate and soil combinations; characteristics ranged from low precipitation (in eastern Oregon) to high precipitation (in the Coast Range) and from heavy clays to sandy loams.

Each site consisted of 3 replicate blocks of 12.2 m (40 feet) X 12.1 m plots; each square plot contained 25 trees of one of the test species, planted at 2.4-m (8-foot) spacing. The inner 9 trees of each plot were measured yearly, over a 5-year period, for basal diameter, diameter at breast height, and height. Qualitative descriptions of seedling condition were also recorded annually. Before planting the hardwoods, all vegetation was removed from the sites and the sites were treated with chemical herbicides. Subsequent site maintenance consisted of partial mechanical and chemical weed control as needed.

The hardwood species planted at each site included both natives and exotics, and they were selected on the basis of potential value at maturity, growth rate, and site suitability (table 2). All stock consisted of bareroot 1-year-old seedlings except for cottonwood and willow species. These were planted as 30.5-cm (12-inch) to 38.1-cm (15-inch) cuttings of 1year-old shoots. Seedlings were either purchased from commercial nurseries or grown from seed in the College of Forestry nursery; no effort was made to control or account for the seed-source location within a species range. Cottonwood hybrid #11 came from the joint University of Washington/ Washington State University breeding program and is a cross between *Populus trichocarpa* and *P. deltoides.* The black cottonwood cuttings planted at the Warren and Westport sites were collected along the Nisqually River in southern Washington and the Santiam River in western Oregon. The black cottonwood cuttings planted at the Corvallis and Lebanon sites were collected along the Santiam River. Black cottonwood planted at the Union site came from local cuttings.

Results and Discussion

The rate and success of seedling establishment over a 5-year period varied widely among species and sites. Several species died soon after planting and had to be replanted or replaced with other species. Others grew poorly or died within the 5-year period due to drought. Browsing by deer, rabbits, and gophers also contributed to poor growth rates, as did competing weeds. Frost damage was particularly prevalent among *Eucalyptus* species, but resprouting generally occurred during the next growing season; only red alder at the Corvallis site died from frost damage.

Table 1 -*Site characteristics for the six test sites in Oregon*

Site	Year established	Soil type	Mean monthly precipitation (cm) Winter	Mean monthly precipitation (cm) Summer	Mean monthly temperature (/C) Winter	Mean monthly temperature (/C) Summer	Level of weed control
Warren	1984	Clay loam	11.7	4.3	6.7	16.1	Good
Westport	1984	Silt loam	17.5	4.1	6.7	15.6	Excellent
Siletz	1985	Sandy loam---alluvial	29.2	6.9	11.7	15.3	Poor
Union	1985	Clay loam---high organics, seasonally flooded	3.0	3.0	3.9	15.6	Poor
Corvallis	1987	Sandy loam---river floodplain, well drained	13.5	2.8	11.1	16.7	Fair
Lebanon	1987	Clay---shallow depression, seasonally flooded	15.7	4.8	7.8	16.7	Fair

Table 2- *Hardwood species tested and planting sites in Oregon*

Common name	Scientific name	Site
bigleaf maple*	*Acer macrophyllum* Pursh	War, Wes, Cor, Leb
black cherry	*Prunus serotina* Ehrh.	War, Cor
black cottonwood*	*Populus trichocarpa* Torr. & Gray	War, Uni, Wes, Cor, Leb
black locust	*Robinia pseudoacacia* L.	Uni, Leb
black walnut	*Juglans nigra* L.	War, Wes, Cor
Brazilian willow	*Salix* spp.	Leb
cherrybark oak	*Quercus falcata* var. *pagodifolia* Ell.	War, Wes, Cor, Leb
cottonwood hybrid #11	*Populus trichocarpa* X *deltoides*	War, Wes, Cor, Leb
	Eucalyptus glaucescens	War, Sil, Cor
	E. *gunnii*	War, Cor
	E. *nitens*	Sil
	E. *urnigera*	War, Sil
green ash	*Fraxinus pennsylvanica* Marsh.	War, Uni, Wes, Cor, Leb
imperial poplar	*Populus* spp.	Uni
northern red oak	*Quercus rubra* L.	War, Cor, Leb
Norway maple	*Acer plantinoides* L.	Uni, Leb
Nuttal oak	*Quercus nuttallii* Palmer	War, Wes, Cor, Leb
Oregon ash*	*Fraxinus latifolia* Benth.	War, Cor, Leb
Pauwlonia	*Pauwlonia tomentosa* (Thunb.) Sieb. & Zuch ex Steud.	War, Cor, Leb
pin oak	*Quercus palustris* Muenchh.	Uni, Cor, Leb
red alder*	*Alnus rubra* Bong.	War, Cor, Leb
red maple	*Acer rubrum* L.	Uni
silver maple	Acer *saccharinum* L.	Uni
sycamore A	*Platanus occidentalis* L.	War
sycamore B		War
sycamore C		War
yellow-poplar	*Liriodendron tulipifera* L.	Wes
water oak	*Quercus nigra* L.	War, Cor, Leb
white ash	*Fraxinus americana* L.	War, Wes, Cor
windbreak poplar	*Populus* supp.	Uni

Cor = Corvallis, Leb = Lebanon, Sil = Siletz, War = Warren, Wes = Westport, Uni = Union; see table 1 for characteristics.

*Native trees of the Pacific Northwest.

Species survival and height data (table 3) at the end of the 5-year establishment period provide a good indication of which species will grow successfully over the range of site conditions we tested. These data generally reflect the species' minimum level of performance; placing more emphasis on weed control and seed source would have improved performance in many cases. Our intent was simply to examine the interaction between species and sites to identify species that deserve further attention in specific environments. The following paragraphs summarize our findings.

Table 3 -*Hardwood mean survival and mean height (survival (%)/height(cm)) after 5 years at 6 Oregon sites*

Species	Warren	Union	Siletz	Westport	Corvallis	Lebanon	Species Average
Oak							
cherrybark	100/111	-	-	80/320	67/114	87/41	84/147
Nuttall	98/158	-	-	100/383	67/40	87/43	88/156
pin	-	4/19	-	-	55/25	84/31	48/25
northern red	92/157	-	-	-	48/36	48/25	63/73
water	93/115	-	-	-	83/92	91/44	89/117
Ash							
green	100/132	51/85	-	99/450	97/77	96/66	89/162
Oregon*	100/210	-	-	-	92/77	100/59	97/115
white	96/145	-	-	99/405	72/69	-	89/206
Maple							
bigleaf*	98/257	-	-	99/497	67/130	35/37	75/230
Norway	-	37/69	-	-	-	51/42	44/56
red	-	3/90	-	-	-	-	3/90
silver	-	13/39	-	-	-	-	13/39
Cottonwood							
cottonwood hybrid #11	100/808	-	-	91/996	76/635	91/95	90/634
black cottonwood*	95/738	0/-	-	100/982	41/255	-	59/494
imperial poplar	-	17/137	-	-	-	-	17/137
windbreak poplar	-	4/141	-	-	-	-	4/141
Other							
black walnut	97/89	-	-	77/346	73/90	-	82/175
black cherry	95/140	-	-	-	69/204	-	82/172
Brazilian willow	-	-	-	-	-	67/58	67/58
Eucalyptus umigera	12/-	-	65/194	-	-	-	39/97
Eucalyptus nitens	-	-	1 /27	-	-	-	1 /27
Eucalyptus glaucescens	11/-	-	63/154	-	80/575	-	51/243
Eucalyptus gunnii	39/265	-	-	-	80/418	-	60/342
Paulownia tomentosa	88/405	-	-	-	0/-	3/22	30/142
red alder*	100/598	-	-	-	0/-	20/74	40/224
sycamore A	96/207	-	-	97/209	-	-	97/208
sycamore B	92/173	-	-	-	-	-	92/173
sycamore C	96/104	-	-	-	-	-	96/104
yellow-poplar	-	-	-	60/474	-	-	60/474
Site average	85/241	16/73	43/125	90/506	63/167	66/49	

- =not present at site.
*Native trees of the Pacific Northwest.

Oak species. Across all sites and all oak species we tested, mean survival was 76% and mean height was 103 cm. Cherrybark, Nuttall, and water oak all had higher than average survival and growth rates at all sites on which they were established: Mean survival across all sites was 87%, and mean height was 133 cm. The lowest single-site mean survival rate for the three species (67%) occurred at the Corvallis site, possibly because of the site's sandy soil and relatively low precipitation compared to the other sites. Summer precipitation, in particular, was as much as 2.0 cm (0.8 inch) per month less at the Corvallis site than at the other western Oregon sites. Only cherrybark and water oak maintained their growth on this site.

The two remaining oak species we tested, red oak and pin oak, performed poorly at almost all sites. Even at sites where their survival was above average, their height was usually low. No oak species did well in the wet clay of the Lebanon site.

Ash species. With the exception of green ash at the Union site and white ash at the Corvallis site, survival of the three ash species we tested was among the highest in the species trials, typically well above 90%. For the three species combined, mean survival across sites was 91%.
All of the ash species had greater height growth on the Warren and Westport sites; height at other sites averaged approximately half that of these two sites after 5 years. Combine mean height for all ash species across all sites was 161 cm.

Maple species. Except on sites that were both moist and fertile, the four maple species we tested performed poorly. For example, mean survival was

only 18% for the maple species planted at the dry Union site and only 43% for those planted at the wet, clay-soiled Lebanon site. Across all sites and maple species, mean survival was 50% and mean height was 145 cm. With a mean survival rate of 75% and mean height of 230 cm across all sites, bigleaf maple performed the best of the maple species and grew especially well at the Warren and Westport sites.

Cottonwood species. Of the cottonwood species we tested, hybrid #11 showed excellent survival and height growth. Hybrid #11 was perhaps the best-performing entry in the trials. Across the four sites at which it was planted, mean survival was 90% and mean height was 634 cm. In fact, even with a relatively low survival rate at the Corvallis site (76%) and a low height measurement at the Lebanon site (95 cm), hybrid #11 still outperformed all other species at these sites. Black cottonwood also clearly outperformed other species at the Warren and Westport sites. Survival was low at the Corvallis site although height growth was exceptional. The three cottonwood species planted at the Union site (black cottonwood, imperial poplar, and windbreak poplar) had poor survival rates and height growth.

Other species. Black cherry and black walnut were inconsistent in survival and height growth. Both species had an 82% mean survival rate across sites and had similar mean heights after 5 years (172 and 175 cm, respectively). On sites where both were planted, black cherry outgrew black walnut in height. Black cherry generally had a branchy form, whereas first-year dieback was common for black walnut.

Native versus exotic species. It is difficult to make any generalizations about the relative performance of native Pacific Northwest species versus non-native species. Some exotics, such as the southern oaks (cherrybark, Nuttall, and water oaks), performed quite well; the eucalyptus species, however, which froze to the ground and resprouted at least once, must be considered failures. Among the native Pacific Northwest species, establishment was best on sites with climate and soil conditions similar to those where the species are found naturally.

Conclusions

Success of species was considered a function of survival and growth. The minimum acceptable survival rate for successful species was 70%. A 5-year height greater than 75% of a species' average 5-year height in its native habitat was considered successful growth. In addition to these criteria, there are several others that could be used to characterize successful species. Site adaptability, stress tolerance, and sensitivity to competition are all characteristics that may be important to landowners. It would be difficult to assess success of individual species based on these characteristics, however, without knowing a landowner's values and needs. Nonetheless, the information presented in this paper should assist landowners in selecting potentially successful species given their situation.

Figure 1 shows the successful hardwood species (according to the success criteria cited in the preceding paragraph) at each experimental site. Only the five topperforming species for survival or growth category are listed for each site. In most cases, less than 5 species were successful in one or both categories. At Union and Siletz, no species were successful. In examining this table for potential crop species, the following points should be considered. First, the importance of a site's soil and climate characteristics in determining which hardwood species will grow successfully should not be underestimated. Although most of the species used in these trials were successful on sites with ample moisture and fertile soil, only cottonwoods were successful across the full range of sites, and only with good site preparation, weed control, and animal fencing. Second, performance of some species differed dramatically among sites. On sites where the environment approaches the edge of a species' natural tolerance, stress due to animal browsing and weed competition is magnified, and the importance of protecting against these factors increases. If a good site maintenance program is established from the beginning, many of the successful species (as identified in these trials) will be large enough in 3 to 4 years to withstand pressure from animals and other plants. Tilling between trees several times during the growing season is a successful and efficient method of weed control. Chemical herbicides are also effective for weed control, but only if directed toward a broad range of weed species. Because some hardwood species are very sensitive to chemical herbicides, care must be taken to apply the smallest possible amount of chemical that provides adequate weed control, and seedlings must be protected during herbicide application.

Third, many of the tested species had growth rates that were slow initially but that later improved. Thus, the 5-year height data reported in table 3 may not reflect a given species' full poten-

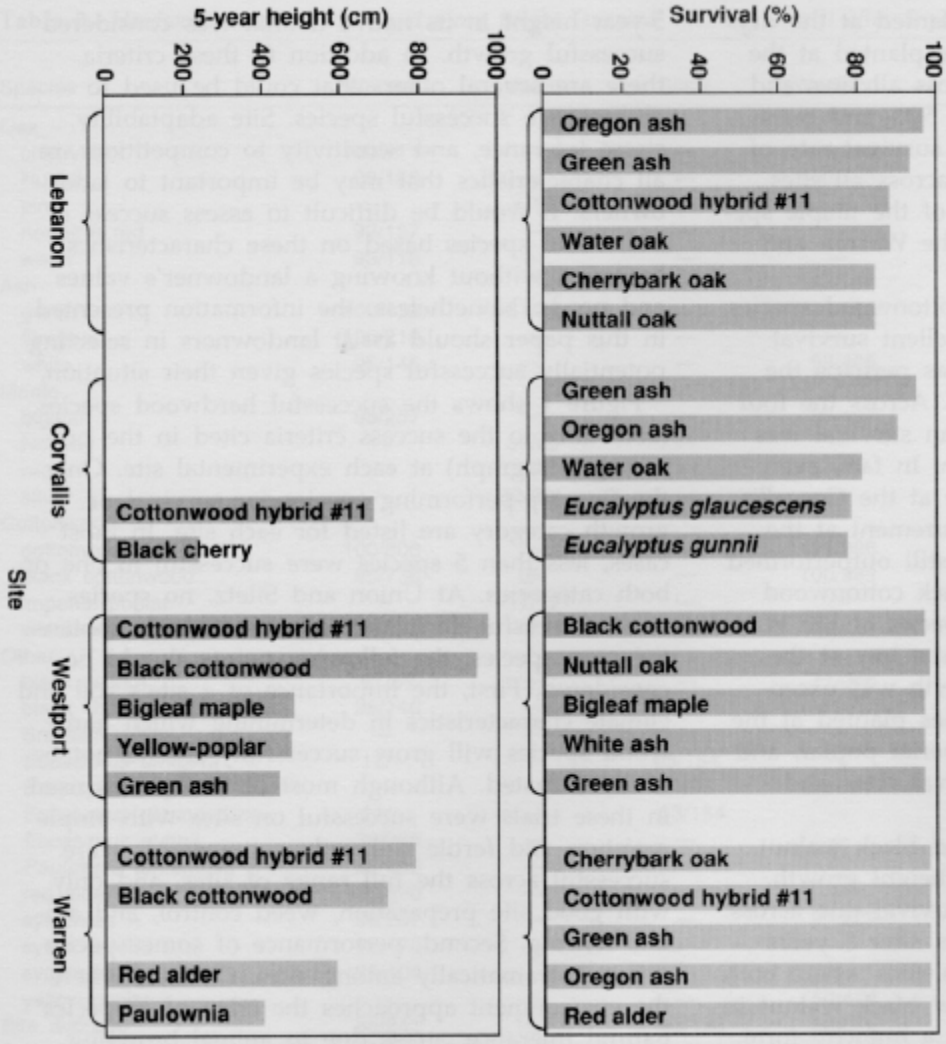

Figure 1—*Successful hardwood species by site. According to this study's success criteria for survival and growth (see text), no species were successful in either category at Union or Siletz.*

tial. The period of slow growth might be shortened by more complete elimination of competing vegetation. Proper seed-source selection could also improve performance of some of the species.

And finally, the trial results that appear in table 3 should be interpreted cautiously for species that performed poorly. Seedling establishment is closely related to the level of competing vegetation present on a site, so that a greater degree of weed control might have led to greater success in establishing some of the species that performed poorly in this study. In addition, the long-term growth potential of any of the tested species has yet to be determined; long-term survival does not necessarily follow from successful initial establishment.

Nevertheless, these species trials have provided some basic information for use in identifying hard wood species with high management potential in Oregon. The trials have also demonstrated that hardwood establishment is often difficult and re quires a well-planned maintenance program. The high growth rates and value of hardwood species may compensate for the effort required to establish these trees.

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