

PACIFIC SOUTHWEST Forest and Range Experiment Station

Response of *Eucalyptus* Species to Frost Damage at the Redwood Experimental Forest

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The genus *Eucalyptus* includes more than 500 species. These vary from vine-like shrubs to giants reported to be among the tallest trees in the world. *Eucalyptus* trees range from tropical species to those surviving sub-freezing weather and possess two unique survival adaptations. These are: a meristematic tissue at the base of buds which will grow if moderate damage to the crown destroys existing buds and leaves; a meristematic region of buds at the base of the tree called lignotubers which will produce sprouts if the crown is completely destroyed.

In warmer regions of the United States, forest industries have been experimenting with many species of eucalyptus for producing wood fiber on a short rotation. The Hudson Pulp and Paper Corporation of Palanthea, Florida, for example, had planted 2000 acres (809 ha) of eucalyptus by 1976 and expects to establish another 8000 acres (3238 ha) by 1980. Harvesting is expected to begin in the early 1980's. Horticulturists also have been using eucalyptus for ornamental and landscape purposes.

In 1961, a limited study was done to determine the feasibility of growing eucalyptus along California's north coast. Over a 3-year period, three plantations were established on the Redwood Experimental Forest about 15 miles south of Crescent City. These plantings totaled 207 trees and represented 31 species (*table 1*). Many environmental factors damaged the eucalyptus plantations but freezing—especially the freeze in December 1972—was directly responsible for 49% of the mortality and indirectly responsible for 22% of the mortality.

METHODS

Three *Eucalyptus* plantations were established in clearcut units created by the harvest of old-growth redwoods. The first, in 1961, was planted on a north aspect; the second, in 1962, on a westerly aspect; and the third, in 1963, on an easterly aspect.

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In 1961 a feasibility study was done to determine if certain *Eucalyptus* species could be grown along the California North Coast for timber or ornamental purposes. Of the 207 trees, representing 31 species, planted on the Redwood Experimental Forest, only 12 trees in 5 species were recorded in the 1976 survival examination. The single most damaging factor was frost. More than 40 percent mortality was attributed to the 1972 freeze.

Oxford: 176.1 *Eucalyptus* spp. (794):232.11:422.1.
Retrieval Terms: *Eucalyptus* species; exotic species; species trials; Redwood Experimental Forest; northern California; frost damage; mortality rate.

Table 1—Planting date, survival, and mortality of 31 species of *Eucalyptus* on the Redwood Experimental Forest, 1961–1976

Eucalyptus species	Planting date			Survival				Cause of mortality	
	1961	1962	1963	1965	1969	1973	1976	Frost	Other ²
	Number								
<i>E. astringens</i>			3	0				3	0
<i>E. bicostata</i>		21		20	10	6	0	9	¹ 12
<i>E. botrylides</i>		3		3	2	0	—	1	2
<i>E. camaldulensis</i>	4			4	3	3	0	4	0
<i>E. coccifera</i>			3	3	3	1	0	2	1
<i>E. cordata</i>	2			2	2	2	0	2	0
<i>E. diversicolor</i>	2			0				1	1
<i>E. diversicolor</i>		7		4	0	—	—	3	¹ 4
<i>E. dives</i>	2			1	1	1	0	1	1
<i>E. dives</i>		2		2	1	1	0	2	0
<i>E. dundasi</i>			3	0	—	—	—	3	0
<i>E. dwyeri</i>			1	0				0	1
<i>E. gigantea</i>			3	1	1	0	—	0	3
<i>E. globulus</i>		10		5	5	3	0	3	7
<i>E. grandis</i>		3		3	1	1	0	1	2
<i>E. grandis</i>			2	0				2	0
<i>E. gunnii</i> Type A	2			2	0	—	—	0	¹ 2
<i>E. gunnii</i> Type D	4			4	4	4	3	1	0
<i>E. macarthuri</i>	18			16	13	10	0	12	6
<i>E. maculosa</i>			4	4	4	1	0	1	3
<i>E. maidenii</i>		3		3	3	1	0	1	2
<i>E. marginata</i>		2		0				2	0
<i>E. megacornuta</i>		2		2	0	—	—	0	2
<i>E. melliodora</i>	4			4	2	1	0	1	¹ 3
<i>E. melliodora</i>			3	3	2	0	—	0	3
<i>E. multiflora</i>	4			1	0	—	—	4	0
<i>E. neglecta</i>	2			2	2	2	1	1	0
<i>E. neglecta</i>			3	3	3	3	1	2	0
<i>E. nicholi</i>			3	2	1	0	—	1	2
<i>E. nitens</i>	3			2	2	2	1	1	1
<i>E. nitens</i>		2		2	2	0	—	1	1
<i>E. nitens</i>			3	3	1	0	—	2	1
<i>E. perrinana</i>	2			2	2	2	2	0	0
<i>E. perrinana</i>		4		4	3	2	0	3	1
<i>E. perrinana</i>			3	3	2	1	0	1	2
<i>E. pulverulenta</i>	2			0				0	2
<i>E. robusta</i>			4	3	0	—	—	0	4
<i>E. rubida</i>		2		2	0	—	—	0	2
<i>E. rubida</i>			3	3	2	0	—	2	1
<i>E. rudis</i>	2			2	1	0	—	1	1
<i>E. saligna</i>		16		15	4	0	—	11	¹ 5
<i>E. saligna</i>			3	3	1	0	—	2	1
<i>E. viminalis</i>	4			4	2	0	—	0	4
<i>E. viminalis</i>		29		26	13	9	4	8	¹ 17

¹ Moderate frost damage recorded in prior years. Twenty-two percent mortality resulted indirectly from this freezing through loss of vigor and an increase in native plant competition.

² Includes mortality from animals, suppression from native vegetation, and a wind-thrown redwood.

Site quality is medium to good. The soil is Melbourne clay loam that has been disturbed greatly by logging so that significant sub-soil is exposed. Soil pH is from 4.8 to 5.0.

Climate at the outplanting sites is mild and humid. Rainfall averages 76 inches annually, based on an

8-year record at the Redwood Experimental Forest.² The July-August-September precipitation averages only 2.5 inches, but fog frequently reduces plant moisture stress. The frost-free period averages 8 months.

Most of the seedlings were 1 year old and potted;

however, a few, especially *E. macarthuri* and *E. globulus*, were less than 1 year and were growing in flats. Holes were dug to varying depths to accommodate the different size root systems as plants varied from ½ foot to more than 4 feet tall. Planting was done on a 10-by-10 foot spacing. The seedlings were then measured, tagged, and mapped. Animal repellent, (active ingredient Tetramethylthiuramdisulfide) was sprayed on all seedlings. This weather-resistant contact repellent protects trees against rabbits, meadow mice and, to a lesser extent, deer.

The plantations were inspected every 3 or 4 years to determine growth rate, condition, and mortality.

RESULTS

In interpreting the results of this study it should be kept in mind that most species were represented by a small number of plants. Therefore, inferences drawn from this study should be considered as tentative until corroborated by additional research.

During the first few years, animals—particularly deer—destroyed some seedlings, and repeated light frosts killed portions of crowns and some entire seedlings. All of these species died during the first 4 years, but only 1 to 3 plants of each species had been planted: *E. pulverulenta*, *E. diversicolor*, *E. marginata*, *E. grandis*, *E. Dwyeri*, *E. astringens*, and *E. Dundasi*.

In 1969, after 7, 8, or 9 growing seasons, survivors varied greatly in growth (table 2). Some species were either inherently of shrubby form or not adapted to the mild, humid climate. Many species had an extreme range in both diameter and height growth so that, even if they had not been killed by frost, they would not be recommended for timber production or landscaping. Some species looked promising after the 1969 survey, but the hard frost in December 1972 eliminated many of these survivors.

December	<u>Low</u>	°F	<u>High</u>
7	26		40
8	17		36
9	16		31
10	19		40
11	19		41
12	28		39

Data recorded between the 1969 and 1973 measurements showed that 49 percent of the mortality was directly attributable to the 1972 frost and 22 percent of the mortality which occurred between the 1973 and 1976 measurements was mostly the result

of severe damage from frost. During the 1973 measurement, the cambium was sampled at ground level. If the cambium was still succulent, the tree was classed as alive with a possible chance of sprouting even though the tree crown appeared dead. Many of these trees never recovered.

Of the 31 species planted, only 5 survived by 1976. Two of these species were from the 1962 plantation on a westerly aspect. Both were top-killed and had sprouted at the base but the sprouts were suppressed by native vegetation and were not doing well. These two species were *E. viminalis* (4 survived out of 29) and *E. neglecta* (1 survived out of 3). The other three species *E. gunnii* Type D, *E. nitens*, and *E. perriniana* plus *E. neglecta*—all planted on a north slope in 1961—survived and had sufficient growth to be considered promising.

Species:	<u>Diameter¹</u> <u>(Inches)</u>	<u>Height</u> <u>(Feet)</u>
<i>E. gunnii</i> Type D	9.0	46
<i>E. gunnii</i> Type D	4.5	55
<i>E. gunnii</i> Type D	2.8	32
<i>E. neglecta</i>	2.5	23
<i>E. nitens</i>	12.0	101 ²
<i>E. perriniana</i>	4.1	38
<i>E. perriniana</i>	2.5	18

¹ Diameter Breast Height (DBH) measured at 4.5 feet above the ground.

² Top of live crown is at 78 feet.

Only one individual of one species, *E. nitens*, had a straight bole for good timber quality and also a certain amount of frost resistance. During the 1972 frost, this tree was more than 100 feet tall. Because of frost damage, which killed most of the live crown and the ability of this species to sprout at the base of the dead buds, the live crown in the 1976 measurement was 78 feet. The tree had a D.B.H. of 12 inches.

The Wattle Research Institute³ study on frost resistant Eucalyptus included four species (*E. macarthuri*, *E. saligna*, *E. nitens*, and *E. grandis*) that were in our study. *E. macarthuri*, according to the Wattle research, was the only species not affected by severe frost. However, on the Redwood Experimental Forest, there was 100 percent mortality by the time of the 1976 measurement.

E. gunnii Type D showed the best frost resistance with no apparent damage. However, all of this species were leaning or were of undesirable form for producing lumber.

Frost-resistance observations on *Eucalyptus* that would survive temperatures below 15°F were made in

Table 2—Growth of *Eucalyptus* at the Redwood Experimental Forest, 1961-1969

Eucalyptus Species	Aspect ²	Growth period	Trees	Height range	Diameter range ¹
		—Years—		—Feet—	—Inches—
<i>E. bicostata</i>	West	8	10	3.7 to 27.4	0 to 3.8
<i>E. botryoides</i>	West	8	2	0.5 to 0.5	0
<i>E. camaldulensis</i>	North	9	3	7.5 to 11.2	0.2 to 0.9
<i>E. coccifera</i>	East	7	3	5.3 to 27.6	2.4 to 4.8
<i>E. cordata</i>	North	9	2	10.7 to 37.5	0.4 to 4.4
<i>E. dives</i>	West	8	1	19.2	2.4
<i>E. dives</i>	North	9	1	34.8	6.8
<i>E. gigantea</i>	East	7	1	5.7	0.1
<i>E. globulus</i>	West	8	5	2.0 to 12.5	0 to 0.6
<i>E. grandis</i>	West	8	1	33.5	6.2
<i>E. gunnii</i> Type D	North	9	4	14.0 to 36.3	1.5 to 6.7
<i>E. macarthurii</i>	North	9	13	0.3 to 30.6	0 to 5.3
<i>E. maculosa</i>	East	7	4	1.1 to 30.6	0 to 5.1
<i>E. maidenii</i>	West	8	3	0.4 to 23.2	0 to 2.3
<i>E. melliodora</i>	North	9	2	2.4 to 12.6	0 to 1.3
<i>E. melliodora</i>	East	7	2	0.4 to 2.2	0
<i>E. neglecta</i>	North	9	2	16.8 to 19.8	1.2 to 1.6
<i>E. neglecta</i>	East	7	3	12.2 to 18.4	1.7 to 7.9
<i>E. nicholi</i>	East	7	1	21.0	4.0
<i>E. nitens</i>	West	8	2	12.8 to 19.7	0.7 to 1.4
<i>E. nitens</i>	North	9	2	68.0 to 71.5	7.8 to 12.5
<i>E. nitens</i>	East	7	1	4.9	0.1
<i>E. perriniana</i>	East	7	2	3.6 to 10.6	0 to 0.9
<i>E. perriniana</i>	West	8	3	6.6 to 11.8	0.3 to 0.6
<i>E. perriniana</i>	North	9	2	11.8 to 14.0	0.9 to 2.7
<i>E. rubida</i>	East	7	2	27.0 to 35.0	3.4 to 4.9
<i>E. rudis</i>	North	9	1	0.7	0
<i>E. saligna</i>	West	8	4	6.4 to 39.5	0.1 to 5.5
<i>E. saligna</i>	East	7	1	1.2	0
<i>E. viminalis</i>	West	8	13	1.4 to 27.7	0 to 3.0
<i>E. viminalis</i>	North	9	2	29.5 to 36.0	4.2 to 4.3

¹ Diameter measured at D.B.H. 4.5 feet above ground level. A zero starting entry means that the smallest tree was less than this height.

² North planted in 1961. West planted in 1962. East planted in 1963.

South Africa.⁴ Four of the species that survived in the South African research were included in our study. Of these four, *E. gunnii* and *E. perriniana* survived and are doing well. The other two, *E. rubida*, and *E. gigantea*, were both dead before the hard frost of 1972, mostly from other causes.

In March 1962 a 4°F temperature—the coldest since 1890—was reported at plantations on the lower Rio Grande. This freeze killed to the ground all but three species of *Eucalyptus* regardless of age or size,⁵ however, some were starting to sprout at the base. Of the three surviving species—*E. gunnii*, *E. neglecta*, and *E. pulverulenta*—*E. gunnii* and *E. neglecta* also survived on the Redwood Experimental Forest. *E. pul-*

verulenta did not survive in our study, but this was attributed to factors other than low temperatures.

Major cold spells were responsible for much of the mortality in our study on the California north coast, as well as in those conducted in South Africa and Texas. Several of the species tried on the Redwood Experimental Forest showed promise for horticultural or landscaping purposes in this temperature zone. Continued testing of the species that died of other than frost damage should provide further data on cold-resistant species. Before planting *Eucalyptus*, the species' native climate should be matched to the lowest temperature recorded in the area to be planted.

NOTES

¹Selmer C. Uhr. 1976. *Eucalypt—The wonder tree*. Am. Forests 82(10):42-43, 59-63.

²Boe, Kenneth N. 1970. *Temperature, humidity, and precipitation at the Redwood Experimental Forest*. USDA Forest Serv. Res. Note PSW-222, 11 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

³Wattle Research Institute. Oct. 1974. *Cold resistance Eucalypt report for 1973-74*, p. 42-44.

Wattle Research Institute. Oct. 1975. *Cold resistance Eucalypt report for 1974-75*, p. 38-39.

⁴Halliwell, Brian. Feb. 1974. *Eucalyptus*. Aboricultural Assoc. J. 2(6):197-204.

⁵Stephens, Earl. 1962. Letter (dated March 15, 1962) to Woodbridge Metcalf, emeritus professor of forestry, University of California, Berkeley. Copy on file at Pacific Southwest Forest and Range Experiment Station, Arcata, Calif.

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