Eucalyptus for Low Elevation Foothill Plantations in California

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ABSTRACT. *In March 1984 we established a test plantation of selected* Eucalyptus *and poplar seedlings species and clones on a range site in the Sierra Nevada foothills. The main objectives were to evaluate survival and growth of the various species and clones and to determine a rotation age for intensively managed hardwood trees grown under low elevation foothill conditions. Seedlings and clones of six species of* Eucalyptus *and one hybrid poplar were grown with short rotation intensive culture techniques for 7 yr. Rotation age, defined as the culmination of mean annual increment, varied from 3 to 6 yr. The best producing clone produced 8 cords of fuelwood per acre per year. The potential for damage from freezing and snow at these elevations is also discussed. West. J. Appl. For. 12(4):104–107.*

Eucalyptus was promoted in the early 1900s as the "miracle tree" that would solve wood fiber supply problems in California. Early plantings were intended to be a primary source of lumber, railroad ties, and mining timbers. However, early applications showed that young growth of the species tested was largely unsuited for these applications.

The energy crisis of the mid-1970s renewed interest in *Eucalyptus* as a fuelwood species, mostly by people hoping to reduce their home heating bills with wood heat. For this purpose *Eucalyptus* excels. Its heating value rivals or surpasses that of native species, and it grows considerably faster, potentially reducing demand on the native hardwood resource. It serves as a fuel stock for biomass energy generation. In addition, *Eucalyptus* is gaining acceptance as raw material for paper pulp.

A common problem in the early *Eucalyptus* plantations was a lack of information about which species to plant, spacing, cultural methods, and expected yields. Some early unsubstantiated claims reported incredible potential yields.

In March 1984 we established a test plantation of selected *Eucalyptus* and poplar species and clones in the Yuba County foothills. The main objectives were to evaluate survival and growth of the various species and clones and to determine a rotation age for intensively managed hardwood trees grown under low elevation foothill conditions.

Methods

Procedure

Eucalyptus seedlings 6 to 10 in. tall, rooted *Eucalyptus* cuttings, and poplar cuttings were planted in Auburn-Las Posas-Argonaut rocky loam with 7% slope at a 575 ft elevation at the University of California Sierra Foothill Research and Extension Center. The soil was tested prior to planting using standard procedures. Trees were planted in a randomized complete block design with 4 replicates on a 6 by 6 ft spacing providing for 1,210 stems/ac. Table 1 identifies the species and seed source for the materials used in this study. Species were selected from commercially available stock that promised high survival, good growth and form, and resistance to frost damage (King and Krugman 1980)

Preplant weed control consisted of spraying with 1% Roundup (glyphosate) 2 wk before planting to kill annual grasses and forbs. Trees were sprinkler-irrigated during the

Table 1. Species or clones studied.

Species or clone (and common name)	Seed source	Species code
Eucalyptus camaldulensis, C-1 clone	Unknown—random selection	C-1
E. camaldulensis, C-2 clone	Improved Spanish seed	C-2
E. dalrympleana (mountain gum)	Australia, longitude unknown, latitude 35°S, 800 ft elevation	DAL
E. globulus (blue gum)	Barnback, Australia	GLO
E. camaldulensis, (river red gum)	Lake Albacutya, Australia	LAC
Populus deltoides × *nigra* (poplar)	"Giacometti" hybrid clone	POP
E. viminalis (manna gum)	South coast, New South Wales, Australia, 200 ft elevation.	VIM

first growing season beginning within 2 wk of planting and continuing until mid-September. After installation of a drip irrigation system in 1985, trees were drip-irrigated weekly from May through September at the rate of 80% of the evaporation from a Class A evaporation pan. Actual water applied ranged from 40 to 65 gal/tree/wk.

Herbicides and hand weeding were necessary weed control during the first year. Simazine at 0.5 lb ai/ac and Surflan (oryzalin) at 4 lb ai/ac were applied in late May to control summer annuals. Even at this low rate of simazine, some herbicide injury occurred, especially to *Eucalyptus viminalis* (manna gum). Subsequent hand hoeing was required two or three times on most plots. Bermuda grass and bindweed were successfully controlled by spot spraying with 1.5% glyphosate in late August and September. Surflan at 4 lb ai was applied in November 1984. In the summer of 1985, the canopy mostly closed, and no further weed control was necessary.

Grasshopper damage was limited the first summer after planting by two applications of malathion spray and Sevin (carbaryl) bait. Light deer browsing occurred on several *Eucalyptus* species, but was extensive on many of the poplars during the first season, and to a lesser extent the second year. Two commercial deer repellents were used in 1984; however, they were mostly ineffective, possibly due to the sprinkler irrigation. Although early growth may have been slowed, all of the poplars survived and outgrew deer browsing by the second season.

No fertilizer was applied in 1984. Beginning in 1985, a total of 75 lb of nitrogen per acre per year was applied as urea in four equal monthly applications through the drip system from early June through early September.

Diameter at breast height (dbh) in in. and total height in ft were measured annually beginning in 1985. Diameter was measured with a diameter tape. Height was measured with a height pole to 20 ft, and with a clinometer when they exceeded 20 ft. Only the interior 9 trees of each 49 tree block were measured, producing a 2 tree buffer, to avoid any edge effect. Beginning in 1986, diameter was measured every 5 ft along the stem to calculate stem volume for three of the interior nine trees. Outside bark stem diameter and height were measured to a 2 in. top diameter.

We had planned to harvest the stand after the culmination of mean annual increment (MAI), but 2 unusual weather events in 2 yr caused us to harvest the trees. The first event was a severe freeze in February of 1989, possibly reducing the growth of the surviving eucalypts. The minimum air temperature dropped to 14°F. During 35 yr of records (1961 to 1996) at a weather station located within 985 ft of the trial plot, a minimum temperature of 14° or less occurred in only 3 other years. More importantly, perhaps, the duration of the 1989 freeze, with lows of 20° or below for 5 consecutive days, appears to be rare at this site. The only comparable cold spell on record occurred in December, 1978, when three consecutive daily lows dipped to the 10° range. We decided to wait an additional year to see if the trees would recover. But on February 16, 1990, about 6 in. of wet, heavy snow uprooted or otherwise damaged 50% of the remaining trees, again with the exception of the poplar. The sudden, heavy snowfall was unique at this location. Snow is so rare that snow depth records are not maintained at the weather station, but anecdotally, long-time Research Center staff could not recall such a fast, heavy snow fall. At that point we decided to terminate the study and the trees were harvested in April and May, 1990, 72 months after planting.

At harvest, all of the trees were felled with a chain saw, leaving a 6 in. high stump. Dbh and total height was measured for each of the surviving interior 9 trees. Dbh, total height, and stem diameter and height to a 2 in. top were measured on three of the interior nine trees. The trees and all of their branches were weighed to within the nearest 0.5 lb within moments of harvesting with an electronic crane scale. The branches and top to a 2 in. diameter were removed and the trees reweighed. One inch thick rounds were removed from the base, halfway along the stem, and from the top of each tree. These rounds were used to estimate moisture content and specific gravity.

Results and Discussion

Site Characteristics

The study site appears to be representative of a low elevation foothills range site, with the exception of higher than expected fertility. It is dominated by annual grasses, with scattered oaks, mainly blue oak *(Quercus douglasii)*, nearby. Dominant use on this and similar sites is seasonal (winter and spring) livestock grazing. Annual precipitation averages 28.5 in. falling mainly in October through May as rain. Soil organic matter at the site was substantially higher than expected (site average was 3.3%, normal is 1.0–1.5%) as was the content of the major nutrients phosphorus (site average 13.8 ppm, normal 4–5 ppm) and potassium (site average 149 ppm, normal 100–120 ppm). Both NO_3-N (average 39.3 ppm) and NH_4-N (average 23.3 ppm) were several times higher than the normal background levels of 4–7 ppm and 1–4 ppm, respectively. The unusually high fertility is probably due in large measure to supplemental feeding that concentrated cattle numbers and excretions in the area prior to initiation of the study plot.

Tree Characteristics

Average tree characteristics for all species at each measurement are summarized in Table 2. Average diameter increased throughout the life of the stand for all species and clones with the exception of *E. globulus* which decreased slightly, due to the death of some larger trees. At harvest, there was no difference statistically between species in terms of diameter; however the C-2 clone had the greatest average diameter

Height measurements for the 55 month and 67 month measurements were taken mostly with a clinometer, which are less accurate than direct measurement of felled trees. Also, only a subsample of 55 and 67 month old trees could be sampled for height.

Stand Characteristics

Yield curves by species appear in Figure 1 for cords per acre assuming 85 ft^3 of solid wood per cord. The C-2 clone had the highest volume per acre and calculated dry weight per acre, though not statistically significant from *E. dalrympleana*, *E. globulus*, or the poplar.

Volume equations were developed for each species/clone. The logarithmically transformed measures of dbh and height were linear, showed no obvious departure from normality, and had approximately equal variance. Thus linear regression for these transformed data was an appropriate statistical technique.

Mean Annual Increment is displayed in Figure 2 for cords per acre per year. All species and clones, except the poplar, were somewhat damaged in the February 1989 freeze, reducing their growth for the 67 month remeasurement. *E. viminalis* and *E. dalrympleana* were less seriously affected. The culmination of mean annual increment gives the time in which the maximum growth rate occurs. This is the age trees would be harvested if maximum biomass yields over time were the management objective.

Table 2. Sierra Field Range Experiment Station biomass trial Average dbh and height and results of Tukey's HSD multiple range test at 72 months.

	Tree characteristics					
Species	*n*	Ave. dbh (in.)	Sig. diff. (Tukey's)	*n*	Ave. height (ft)	Sig. diff. (Tukey's)
C-1	29	4.12	a	29	39.41	a
C-2	36	4.87	a	36	54.13	c
DAL	33	4.55	a	33	41.75	a
GLO	23	4.80	a	23	53.31	c
LAC	30	4.34	a	30	36.96	a
POP	36	4.42	a	36	50.71	bc
VIM	25	4.61	a	25	43.34	ab

Ignoring the effects of the 1989 freeze, it appears that *E globulus* culminated in MAI around the 43 month measurement and quickly began to lose growth rate due to competition induced mortality. The C-1 clone and the Lake Albacutya *E. camaldulensis* also appear to have leveled off in growth rate by the 43 month remeasurement. *E. dalrympleana* and the poplar clone appear to have reached culmination of MAI by the 67 month measurement. Neither C-2 nor *E. viminalis* appear to have reached culmination of MAI by the 72 month measurement.

Moisture content and specific gravity appear in Table 3 The poplar clone has a significantly lower specific gravity This is important in that poplar is not viewed as a desirable fuelwood species, thus it has potential value only for pulp production.

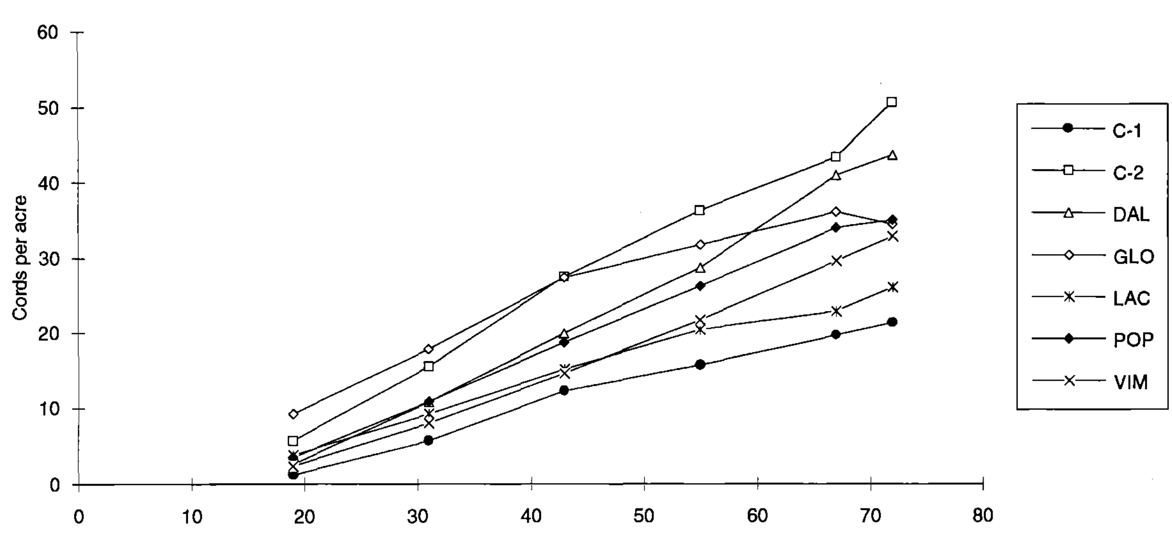

Figure 1. Volume cords per acre.

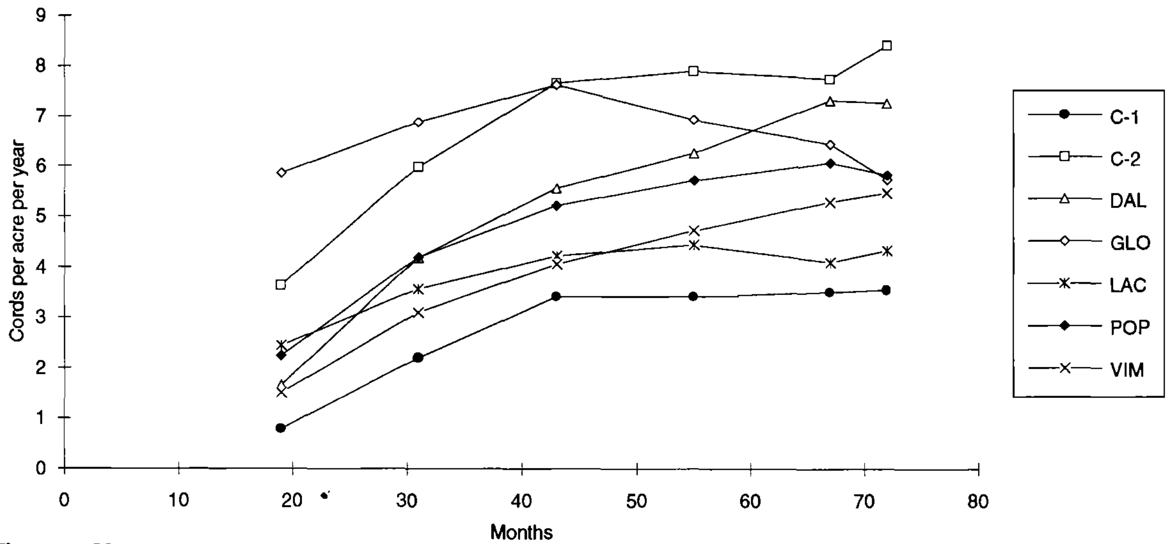

Figure 2. Mean Annual Increment —cords per acre per year.

Conclusions

From these data, it appears that *Eucalyptus* has excellent potential for the production of fuelwood and pulpwood in Sierra Nevada foothill locations using short rotation, intensive culture techniques. To put these yields into context, redwood (*Sequoia sempervirens*) mean annual increment on high quality sites, which represent some of the most productive forest ecosystems known, can produce 5.9 cords/ac/yr at a culmination of 75 yr (Lindquist and Palley 1963). The C-2 clone in this trial exceeded 8 cords/ac/yr at the culmination of 6 yr. Genetic selection has the potential to increase these yields substantially. Appropriate species/clones are selected based on their fiber production and also their tolerance of extreme weather conditions.

The C-2 clone was the species of choice from a volume production and materials handling standpoint. Individual stems were tall, straight, and uniform in appearance. This is especially important for those sites that will be machine-harvested. C-2 produced the greatest volume of any of the species evaluated. In contrast, C-1 clones were short, crooked, and branched profusely.

Table 3. Sierra Field Range Experiment Station biomass trial. Wood characteristics—moisture content and specific gravity.

Species code	Moisture content	Tukey HSD	Specific gravity	Tukey HSD
C-1	1.63	b	0.42	ab
C-2	1.44	b	0.43	b
DAL	1.41	b	0.44	b
GLO	1.19	ab	0.48	b
LAC	1.41	b	0.43	b
POP	0.87	a	0.35	a
VIM	1.40	b	0.47	b

From an economic standpoint, *E. globulus* might be a more desirable species. Because it reached culmination of MAI in about 43 months, almost 2 complete rotations could be produced in the same time as it would take to produce 1 rotation for any of the other species/clones evaluated. The shorter rotation would also make the damage from extreme weather conditions less of a problem in that less time would be invested in each stand. The downside of a shorter rotation is that individual trees would be smaller in terms of diameter and height, increasing handling costs.

Being deciduous, the poplar clone was able to survive both the freeze and snowfall , but it has little value for fuelwood. The low specific gravity indicates a fast burning species with little heat value per cord when compared to *Eucalyptus* or oak, a common fuelwood in this area. In fact, the fuelwood dealer that bought the *Eucalyptus* from this trial would not take the poplar. Poplar does have some value for pulp; however, this market, in California, is poorly developed at this time.

This study demonstrated the feasibility of growing *Eucalyptus* in short rotation, intensively cultured management systems. Coppice sprout culture and appropriate density and spacing are questions yet to be resolved. Concerns about off-site spread of these exotics also need to be addressed.

Literature Cited

KING, J.P., AND S.L KRUGMAN. 1980. Tests of 36 *Eucalyptus* species in northern California. USDA For. Serv. Res. Paper PSW-152. 6 p.

LINDQUIST, J.L., AND M.N. PALLEY. 1963. Empirical yield tables for young growth redwood. Calif. Agric. Exp. Sta. Bull. 796. 47 p.