Jack Kelly Clark

Eucalyptus (manna gum) was fastest growing of trees tested, averaging 27 feet high, 3 inches diameter, in 3 years. Tree being measured here by Dean Donaldson is 4 years old.

Trees as energy crops

Richard B. Standiford

Dean R. Donaldson

Since the 1973 Arab oil embargo and resulting rapid price increases for petroleum products, Californians have been more concerned about alternative energy sources. There is much interest in silvicultural biomass crops as renewable energy sources for direct process heat, cogeneration (production of electricity and process steam in tandem), and alcohol production. Many people are considering growing trees as a means of heating homes and as a potential commercial crop.

The Cooperative Extension office in Napa County started a biomass evaluation project in 1977 in cooperation with several local landowners. The purpose was to: (1) evaluate several tree species for potential as a biomass crop; (2) develop baseline growth and yield data for future economic feasibility studies; and (3) serve as demonstration areas to illustrate management required for silviculture biomass farming.

Study sites

Two study areas were established in 1977 and 1979 near Calistoga, California, at the north end of the Napa Valley. Areas planted are on the Napa Valley floor and receive 34 to 36 inches of rainfall per year, most of which occurs between November and March.

Area 1, Grant Street. Six species were chosen for evaluation at this site: *Eucalyptus viminalis* (manna gum), *E. camaldulensis* (river red gum), *E. dalrympleana* (mountain gum), *Pinus radiata* (Monterey pine), *Juglans regia* × *hindsii* (Paradox hybrid, a sterile

TABLE 1. Summary of data from area 1, Grant Street, Calistoga, Napa County, July 1981*

Species	1981 age (mo)	Survival	Average height† meters	(feet)	Average DBH† cm	(inches)	Average volume/area† cu. m/ha	(cu. ft/a)
Eucalyptus viminalis	39	56/70	8.3	(27.3)	7.9	(3.1)	24.7	(353.3)
Eucalyptus camaldulensis	50	88/100‡	6.7	(21.9)	7.9	(3.1)	19.1	(272.8)
Pinus radiata (5 clones)	39	62/72						
Z-6		14/15	4.4	(14.4)	5.2	(2.0)	—	—
Z-3		3/15	4.3	(13.8)	5.1	(2.0)	—	—
MM-13		10/15	3.8	(12.5)	5.0	(2.0)	—	—
MM-6		11/15	3.4	(11.2)	4.0	(1.6)	—	—
Z-5		14/15	3.0	(9.8)	2.9	(1.2)	—	—
Juglans regia × *hindsii*	50	99/100‡	2.2	(7.1)	2.1	(0.8)	—	—
Sequoia sempervirens	39	66/75	1.5	(5.0)	—	—	—	—
Eucalyptus dalrympleana	Survival less than 50%, terminated March 1978.							

*Soil: Bale Loam (Rocky Phase), irrigated by overhead sprinklers first two growing seasons. Chemical weed control. Area average annual rainfall = 36 inches. Planted 2.4 m × 2.4 m (8′×8′) square spacing.
†Means connected by bars do not differ significantly at 5 percent level.
‡Planted during a drought year (1977); first-year sprinkler irrigation could not be carried out after July.

TABLE 2. Summary of data from area 2, Bale Lane, Calistoga, Napa County, July 1981*

Species	Age (mo)	Survival	Average height meters	(feet)	Average DBH cm	(inches)
Eucalyptus camaldulensis	27	179/198	4.9	(16.1)†	5.1	(2.0)†
Eucalyptus dalrympleana	27	156/212	3.8	(12.5)	3.6	(1.4)

*Soil: Bear Creek clay-loam, irrigated with overhead sprinklers during summer. Spacing: 1.5 m × 1.5 m (5 ft × 5 ft). Chemical weed control. Average annual rainfall: 34 inches.
†Means significantly different at the 0.01 percent level.

TABLE 3. Volume and energy calculations for two field-planted eucalyptus species in area 1, at Calistoga, California

Species	Age (yr)	Average volume yields m³/ha	Calculated mean annual yield m³/ha/yr	cords/a/yr	Total energy yields* million Btu/a/yr	million kcal/ha/yr
E. viminalis	3.2	24.7	7.8	1.3	32	20
E. camaldulensis	4.2	19.1	4.3	0.8	25	15

*Using specific gravity information reported by H. E. Dadswell, 1972, *The Anatomy of Eucalypt Woods*, Commonwealth Scientific and Industrial Research Organization, Australia, Forest Products Laboratory Division of Applied Chemistry Technological Paper No. 66, and wood energy values in A. J. Panshin and C. deZeeuw, 1970, *Textbook of Wood Technology*, Vol. 1, McGraw-Hill Book Co.

walnut hybrid), and *Sequoia sempervirens* (coast redwood). All trees were first-year seedlings, except Monterey pines, which were rooted cuttings from five different clones collected from the Monterey peninsula and from New Zealand. There were five individuals of each of the five clones in each Monterey pine replication.

Ground preparation included cross-ripping and disking before planting. Trees were planted by hand, except walnuts, which were planted with an auger. Each species was block-planted, 5 trees by 5 trees (25 per block), at a square spacing of 2.4 by 2.4 meters (8 by 8 feet). Replications of species were arranged in a randomized block design.

In May 1977, river red gum, mountain gum, and walnut were planted. Due to poor survival, mountain gum was discontinued and replaced by manna gum in April 1978. Coast redwood was also planted in 1978. Young trees received periodic overhead sprinkler irrigation the first two seasons, and no irrigation since. Chemical weed control has been carried out annually.

Area 2, Bale Lane. River red gum and mountain gum were evaluated at this site. The area was cultivated and hand-planted in April 1979. Two blocks of each species were planted with approximately 100 seedlings per block. Trees were planted at a square spacing of 1.5 by 1.5 meters (5 by 5 feet). The area has been irrigated with an overhead sprinkler system during the summer. Chemical weed control has been carried out annually.

All trees were measured in July 1981 (39 and 50 months after planting in area 1, 27 months after planting in area 2). Diameter at 1.4 meters (breast height [DBH]) and total height were measured. Tree measurement comparisons between outside border trees and inside trees were statistically evaluated. Wood volume per block of trees to a 5-cm (2-inch) top was calculated for the eucalyptus species in area 1 using the following volume equation derived from work reported by W. Metcalf in 1924 and J. P. King and S. L. Krugman in 1980:

Volume (cubic feet) = 0.00245 (DBH [inches]) × (height [feet])-0.3318.

Volume converted to cubic meters using 1 cubic foot = 0.02832 cubic meters.

This 5-cm small-end diameter is felt to be the approximate minimum size of a firewood product. Other species have not reached a size to allow calculation of volume using this standard.

Results

No statistical differences in tree diameters and heights among these trees were found between the interior and exterior portions of each planting. Therefore, all tree measurements were combined for volume estimation.

At area 1, eucalyptus were by far the fastest growing of the four genera evaluated. The two eucalyptus species were 1½ to 2 times taller in height, and 1½ times larger in diameter than the next fastest growing species, Monterey pine (Clone Z-6). Manna gum, *Eucalyptus viminalis*, at 39 months was already significantly taller in total height than river red gum, *E. camaldulensis*, at 50 months.

At area 2, river red gum was significantly larger than mountain gum at 27 months (table 2). The trees were still too small for volume to be calculated.

Average volume yields for the two fastest growing species in area 1 were 24.7 and 19.1 cubic meters per hectare (353.3 and 272.8 cubic feet per acre) for manna gum and river red gum, respectively, and from these figures the mean annual increment was calculated (table 3). Manna gum is producing an estimated total energy yield of 20 million kcal per hectare (32 million Btu per acre) per year, and river red gum 15 million kcal per hectare (25 million Btu per acre) per year.

Future growth will be periodically measured, and height, DBH, volume, and energy yield will be calculated. It is expected that these future measurements will show higher annual wood volume increments, because root and canopy development will allow for more complete utilization of the resources at the site. This information will be useful to landowners evaluating the potential of growing biomass crops. Similar trials should be established in other areas of the state where energy plantations are being considered.

Richard B. Standiford is Forestry Specialist, Cooperative Extension, University of California, Berkeley, and Dean R. Donaldson is Farm Advisor, Napa County.