iometers to the wet level. The amount of water used was metered. Rows were 130 ft long; each treatment was replicated four times and each plot was 30 ft long. Plants were harvested weekly from February through June, and yield and fruit size were measured.

Irrigation time required to bring the tensiometers to the wet reading was very different among irrigation treatments. Wetting of conventional furrow-irrigated 40-inch beds could be done rapidly since it only required that the furrow be filled each irrigation. The midbed irrigated furrow on the experimental bed required from three to five hours depending upon the ambient temperatures during the preceding week. Irrigation with the two tubes or pipes on the experimental 60-inch bed, or one tube or pipe on the conventional 40-inch bed, required from five to seven hours, again depending upon the previous weeks' temperatures. The experimental 60-inch bed irrigated with the single tube or pipe required more than twice the time necessary for the double-tube or double-pipe irrigation. In fact, the difficulties encountered in wetting the 60-inch bed completely with the single lines were so great that only the double line should be considered further. The single line on the conventional 40-inch double-row bed was completely adequate. The perforated tubing on top of the bed gave more rapid and greater lateral movement than the porous pipe buried four inches. The table shows a comparison of water usage and yield over the two beds, and several irrigation systems.

Salt accumulation was not measured in these experiments because measurements during 1969 and 1970 at the same location showed no significant difference among similar treatments, and no plant injury was observed. However, salt accumulation differences were not ruled out, especially in comparing the conventional 40-inch beds under standard furrow irrigation with the perforated polyethylene tubing on the same bed. The plastic tubing required only half the water, as compared with standard furrow irrigation, and the plants yielded about 20% more.

Victor Voth is Pomologist, and Howard Bowen is Staff Research Associate, University of California, Davis—both stationed at the South Coast Field Station, Santa Ana; R. S. Bringhurst is Pomologist, University of California, Davis; and Tom Mock is Staff Research Associate, South Coast Field Station.

JOJOBA

. . . *a brief survey of*

JOJOBA, (*Simmondsia chinensis*) has been considered by many as a species which has the potential of becoming a commercial crop. Its economic value is based on the liquid wax produced in its seed which could have several industrial uses. Its special appeal lies in the fact that it is a desert species adapted to the semi-arid regions of southern California, southern Arizona, and northern Mexico —i.e., the areas in which new sources of revenue must be developed if they are going to develop economically. Furthermore, jojoba wax can be a substitute for sperm whale oil and thus it could replace a commodity obtained from an endangered species.

The hopeful attitude adopted by most jojoba enthusiasts up to now regarding its agricultural potential was based on optimistic intuition, rather than on data available regarding the possibility of producing and marketing jojoba wax at competitive prices. Because of the lack of such convincing experimental data no one ventured to invest capital in a jojoba production enterprise. It seemed clear that this climate of optimism, but also of inactivity, was destined to continue indefinitely until someone launched a research project which would prove or disprove claims made by friends or by enemies of jojoba about the possibility of producing it commercially.

OEO funds

About a year ago with funds granted by the Office of Economic Opportunity, a research project was initiated, jointly, by the Universities of California and Arizona to develop jojoba production into a source of revenue for American Indian Reservations. It will take a few years before a thorough evaluation of the potential of jojoba can be made. This report summarizes research experiences in California with jojoba during the past twelve months.

Two approaches appear possible for the commercial production of jojoba. First, harvesting the existing natural populations. Second, establishing new commercial plantations of jojoba much like almond or walnut groves. Following the first approach, in the summer of 1972 about 80,000 lbs of seed were harvested in Arizona and California from natural populations. Harvesting was done by hand and to some extent with the use of simple hand tools or pickers. Any seed that matures early and drops on the ground cannot be picked. Of the mature seed that still clings to the plant a portion drops to the ground as the fingers of the worker touch or shake these seeds during the harvest. The immature seed which is larger, easier to harvest, and heavier than the dry mature seed due to its high moisture content, presents a great temptation to the workers for harvesting, especially if they are paid by the weight of the seed they harvest, rather than by the day.

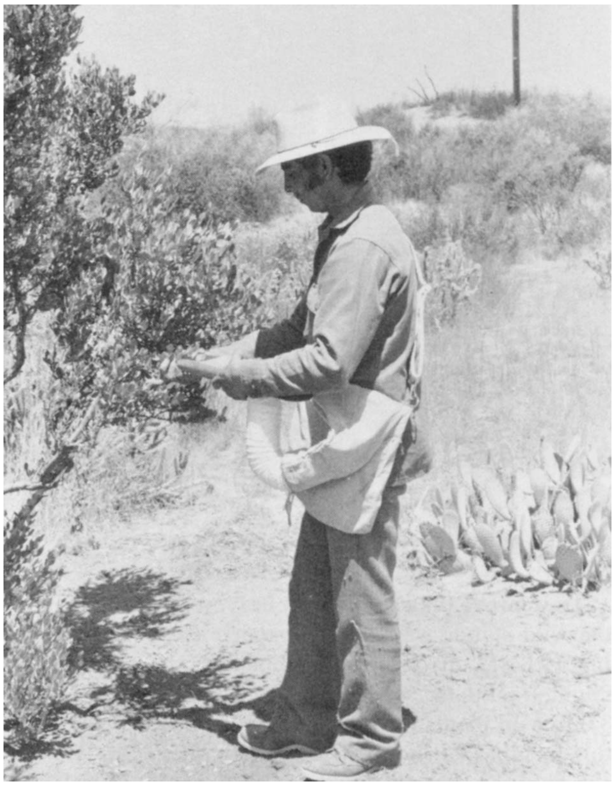
Harvest costs

It was calculated that, on the average, each worker picked 4 to 6 lbs of seed per hour. Thus, if payment was based on a minimum wage of $2.00 per hour the cost of merely harvesting the seed would be 35 to 50 cents per pound. The workers employed last summer did not have previous experience in harvesting jojoba. Thus, along with the mature seed, they often harvested immature seed with moisture content as high as 40%—also tending to include considerable quantities of leaves and stems with the seed.

After drying and cleaning it, the seed harvested last summer would have to be sold for over $1.00 per lb just to cover the harvest, drying and cleaning costs. Development of the simple picking tools shown in photos, helped raise the efficiency of harvesting. At the same time, however, they increased the percentage of leaves and stems in the seed harvested and so the net gain from their use was not significant. It should be pointed out that last year was one of the driest years on record in California and Arizona—

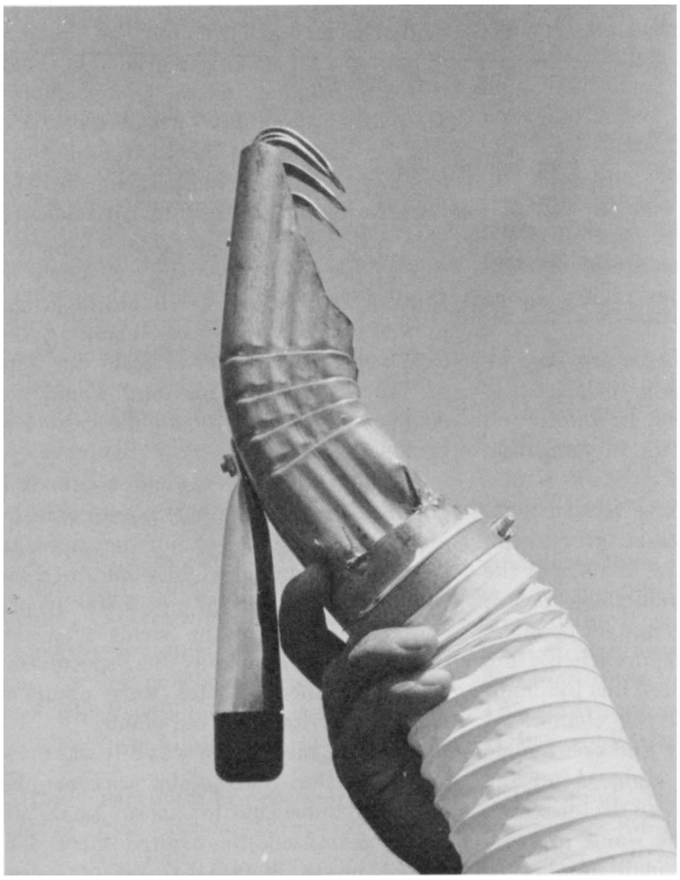
D. M. YERMANOS

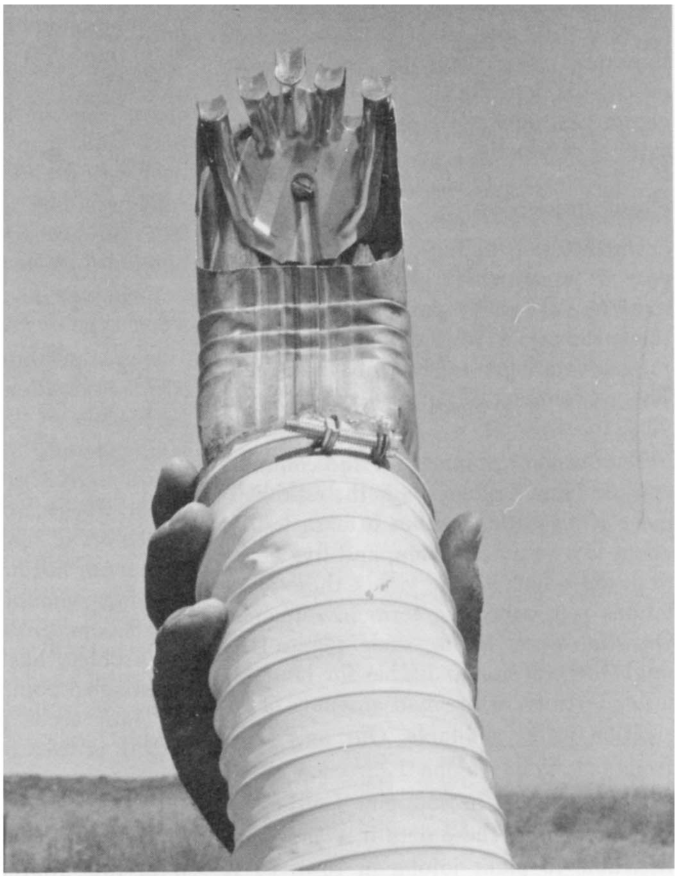
the agronomic potential

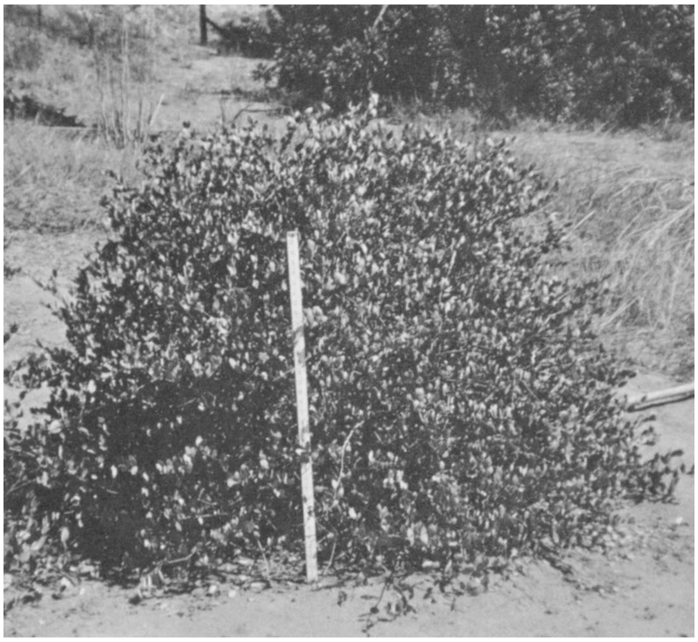


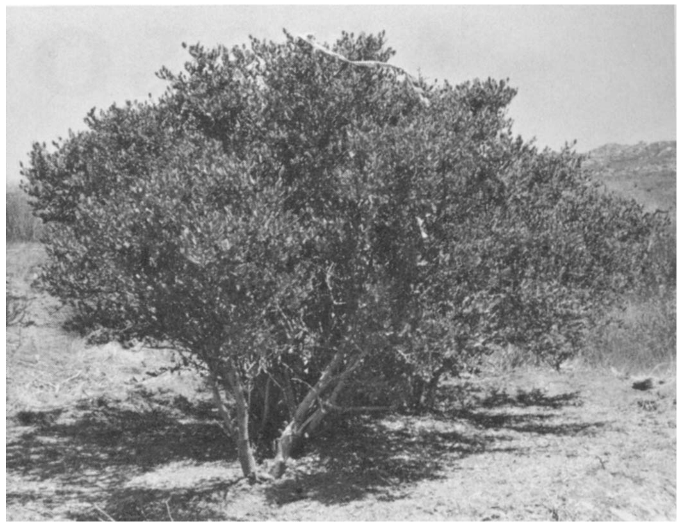
Information available now suggests that jojoba can become a viable crop for semi-arid lands. This potential, however, may be jeopardized if the implementation of a master plan for jojoba production is excessively delayed.

Claw picker developed at the University of California in Riverside as an aid to the harvest of wild jojoba plants.









Wild plant (female) of jojoba in the Aguanga area, to left. Wild plant of jojoba with the lower branches removed to facilitate harvest, in photo to right.

causing lower yields of seed per plant and low harvesting efficiency.

To improve the efficiency in harvesting the wild stands we are now experimenting with various pruning methods which might facilitate seed collection. Some 3,000 wild plants have been pruned with this in mind as shown in the photo, and the harvest next August will show whether this pruning will make a significant difference. Unless we devise methods of harvesting the wild populations considerably more efficiently and economically, it is doubtful that the natural populations of jojoba will be used for commercial production.

Plant yields

On the basis of the data collected last year, in areas where plants were five to six feet tall, yields per plant harvested ranged from 4 to 6 lbs. Seed weight ranged from 0.3 to 1.1 gms per seed. The wax content of the seed ranged from 43% to 56%.

The second approach for the commercial production of jojoba is the establishment of plantations. Since it takes jojoba about two years to bloom, and five years to produce harvestable yields, these plantations represent long term investments. On the other hand, such plantations might be especially suitable for lands of lower fertility, with small amounts of irrigation water available. Our only data from cultivated jojoba is from a small plot (0.1 acre) in southern California. On the basis of these data it would seem desirable to plant jojoba in rows 10 ft apart with plants on the row 5 ft apart, so as to have 900 plants per acre. This arrangement could be maintained for 10 to 12 years at which time the maximum diameter of the plants would be about 6 ft. If the plants continue to grow rapidly after the twelfth year, every other plant on the row might have to be removed so as to end up with a 10 by 10 ft planting.

It would seem that a ratio of one male to five or six female plants would provide adequate amounts of pollen for fertilization, thus 750 female plants would be available per acre. Seed could be planted directly in the field, or better in gallon pots, and then transplanted when the seedlings would be about one year old. All lower side branches up to 3 to 4 ft from the ground would be cut off allowing only a few (one to three) upright branches to develop, thus giving jojoba a tree type of growth.

Irrigation water would be provided by trickle irrigation, about 6 inches below the surface of the ground. In addition to saving water, this system of irrigation would restrict growth of weeds to a minimum. To be able to have a systematic repetition of male plants on every sixth or seventh hill on the row, the sex of the seedlings should be predictable before they bloom. Since this is not yet possible, the problem has to be approached from a statistical point of view. Thus by planting four seeds per hill the chances of getting at least one male and one female plant are seven out of eight. After the plants bloom the grower can decide which one of the four plants he wants to keep. With this approach a small number of hills may have to be replanted later to establish the desired one-to-five ratio of male and female plants. At maturity the nuts would be allowed to drop to the ground and would be harvested with a vacuum cleaner type of equipment.

Plantation costs

What does it cost to establish and maintain a plantation and what returns could be expected? An initial investment of $1,000 to $2,500, depending on the type of land available, will be needed to establish a plantation in the United States. Thereafter, about $100 per acre per year will be needed for the next four years to cover cultural expenses. In the fifth year the plantation should have a harvestable production of nuts; therefore, the cost of harvesting (possibly as much as $100 to $200 per acre) should be added to the cultural expenses—bringing the total expenses to $200 to $300 per acre on the fifth year. This total would not change drastically during the next few years.

In the fifth year a yield of about a pound of nuts per female plant could be expected, or 750 lbs of nuts per acre. In the twelfth year, the yield would increase to 5 lbs per female plant, or 3,750 lbs per acre. The trend of the yields after the twelfth year can only be speculated. Yields of about 30 lbs were obtained from twenty-five year old plants.

Who will buy jojoba wax? It was mentioned earlier that jojoba wax can be used as a substitute for sperm whale oil. When permitted, the United States imported up to 50,000,000 lbs of sperm whale oil annually. While the long term objective for jojoba would be to capture that market, this objective may be difficult to accomplish at first, for two reasons: (1) sperm whale oil sells for 28 cents per pound. Therefore, to enter that market, jojoba should sell for 10 cents per pound so as to make wax available at about 28 cents per pound. This appears to be impossible, if we wish to depend on the wild populations of jojoba for the seed. A price of 10 cents per pound is conceivable, however, from plantations of jojoba yielding 4,000 lbs per acre or more; (2) to produce 50,000,000 lbs of jojoba wax we must have at least 100,000,000 lbs of nuts.

Assuming a yield of 4,000 lbs per acre it would take 25,000 acres of jojoba to produce the quantity of nuts needed. Even if 25,000 acres of jojoba were planted today it would take 10 to 12 years before the potential production of 100,000,000 lbs of jojoba nuts would be realized.

While jojoba production at present cannot satisfy the large sperm whale oil market it can satisfy other specialty markets such as cosmetics, candles, floor waxes, specialty lubricants, etc. These markets are smaller but pay higher prices than 28 cents per pound for raw materials like jojoba wax.

Conclusions based on the information available today would indicate that: (1) jojoba wax has a good marketing potential; (2) large scale, profitable production of cultivated jojoba is possible; (3) jojoba nut production could be based on the wild stands for a few years, preferably with a government subsidy. Jojoba plantations should be established in the meantime so that jojoba production could eventually be based on these plantations. These three statements are valid now. If action is not taken now to go ahead with a large scale production project—initially based on the wild populations and eventually on cultivated jojoba—and if time is lost, two things may happen: (1) industries using sperm whale oil may reformulate their products or redesign their equipment so as to make the use of sperm whale oil unnecessary or essentially so; and (2) synthetic substitutes for sperm whale oil may be developed which will take the market hoped for away from jojoba.

D. M. Yermanos is Professor, Department of Plant Sciences, University of California, Riverside.

EUCALYPTUS

Fuel Dynamics, and Fire Hazard in the Oakland Hills

J. K. AGEE · R. H. WAKIMOTO
E. F. DARLEY · H. H. BISWELL

This study reports the results of two years of fuel studies in blue gum eucalyptus stands. Fuel weights are related to stand densities, and the dynamics of fuel accumulation are investigated. Techniques for managing fuel loads in eucalyptus stands are discussed. Results of this study indicate that fuel buildup occurs very rapidly in unmanaged eucalyptus stands, and that to maintain low fuel levels, a fuel reduction program is essential. If prescribed fire is used, burning techniques that minimize air pollution must be used.

EUCALYPTUS HAS BEEN a scenic and aromatic addition to the California landscape for over a century. The rapid growth of early plantations caught the eye of timber speculators around 1900 and millions of eucalyptus seedlings, predominately blue gum (*Eucalyptus globulus*) were planted. They soon covered the crest of the Berkeley-Oakland Hills, and have created a serious fire hazard since that time at the urban-wildland interface. This study reports the results of two years of fuel studies in the Berkeley-Oakland Hills.

The stand basal area and existing fuel weights in Sibley Regional Park were measured in 1971. Fine fuels, segregated as undecomposed (litter) and partially to predominately decomposed (duff) fuels were measured by collecting randomly placed $0.1m^2$ quadrat samples into bags, and oven drying them. Heavy fuels were measured by the line-intersect technique.

More detailed methods were used the following year to investigate fine fuel dynamics. Litter trays were distributed to collect fine fuels, and each of ten $1\text{-}m^2$ frames was randomly placed in the Sibley study area. The trays were sampled for bark, capsule, branch and twig, and leaf fall every two weeks, from September, 1971 to March, 1973. Decomposition packets containing 25 to 50 gm of each fine fuel component replicated five times were placed in the field in October, 1972 and removed after six months.

The study was terminated soon after the massive freeze of December, 1972, because the eucalyptus tree crowns were severely damaged or killed and the area was cleared to reduce fire hazards.

TABLE 1. ACCESSION, DECOMPOSITION, AND HEAT OF COMBUSTION OF FUEL COMPONENTS IN EUCALYPTUS

	Yearly Accession		Decomposition		Heat of Combustic Kcal/gm
	lbs/ ac	g/m^2	% 6 mos.	Adj. % 12 mos.	
Leaves	2557	287	34.12	42.23	5.732
Bark	2660	291	13.56	16.79	4.616
Capsules	1813	203	14.94	18.49	5.052
Branch & twig	2580	289	9.50	11.76	4.591
Duff			11.43	14.15	5.454