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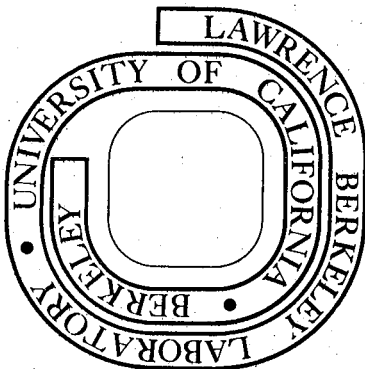
Genevieve J. Calvin and Melvin Calvin

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THE ONLY SOURCE OF ENERGY

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Several million years ago, green plants sprouted, and grew, and matured and died. And from their growth today we heat our homes, and cool our offices, and operate our industries and drive our cars, with the oil, gas and coal the plants produced.

In the last hundred years, the products of plants millions of years old have been depleted to foreseeable exhaustion. This seemingly sudden shortage has caused a disruption in human society commensurate with the profligate expenditure of years of savings. But the ultimate disruption is unnecessary, if we will use the increased understanding of the sun -- on climate (wind, hydro, ocean thermal gradients); on absorptive materials (solar cells and similar collectors); and that unparalleled factory for energy conversion, the green plant.

The least reasonable aspect of the energy shortage of 1973 was that we were a pawn of photosynthesis of millenia long past, while the source of energy (the sun) still flows and the photosynthesizing "factories" (green plants) which converted that energy, still grow. It's past due that we use the sun's energy on a current basis and that we utilize the efficiency of the green plants without the intervenor of time.

* Plant photographs by G. J. Calvin

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In the past thirty years, the mechanism of the conversion of carbon dioxide and water in the green plant to its ultimate products has been explored, mapped, and, to a degree, exposed for regulation. This knowledge is now ripe to use -- take today's allotment of energy and today's plant factories to fulfill today's needs, before completely depleting the storehouse of yesterday.

Man and all other animals have always relied on plants for sustenance. Not long past, a hundred years or so, plants also gave heat and shelter and clothing on a pay-as-you-go basis. But for more than one hundred years we have come to depend on the earth's savings accounts (coal, oil, gas) and have used them for heat, materials and energy for the machines which more and more perform tasks once done by hand or tasks unheard of one hundred (or even fifty) years ago.

Now we face an overdrawn energy bank account. Even the oil companies are materially interested in sources of fuel which are ultimately renewable. They are supporting efforts to develop energy plantations using such diverse sources as trees, carbohydrate plants (sugar cane) and hydrocarbon-producing plants (Euphorbias).

There is an immense variety of plant sources. In tropical countries such as Brazil fuel can be produced easily and effectively from carbohydrates. Sugar cane grows well in Brazil, and when fermented to alcohol it has half the volume for the same caloric value. It runs (with a small converter) a gasoline engine on the same volume of fuel, with greater efficiency and fewer pollutants. And, the cane grows again each year.

A sugar plantation can be considered to be a self-contained "energy farm" with the sunshine as the source. The sugar cane captures the sun, stores a very large fraction as fermentable sugar or cellulose residue

(both of which are used by the mill). The sugar obtained by washing and evaporation with steam is further refined. The steam is created by burning the bagasse, and it not only runs the machinery of the sugar mill, but the excess steam is run through turbines to generate electricity. The factory generates sugar from the juice, alcohol from the molasses, and electricity from the steam, thus deserving the term "energy farm". In addition to fulfilling fuel demands, the resulting alcohol can fulfill at least part of the requirement for chemicals and materials.

In the colder climates sugar cane cannot be the plant of choice, but nature is not so restrictive. Some plants produce hydrocarbons (oil) instead of carbohydrates (sugar), and these hydrocarbons can be of various kinds, one of which we have long used.

This one is rubber, produced first in Brazil from Hevea brasiliensis (fam. Euphorbiaceae) (FIGURE 1) which fell prey to a fungus there. The seeds, transferred to the same climatic conditions in Malaysia, evaded the fungus and prospered. The Hevea trees improved with horticultural manipulation to the extent that in twenty-five years (1945-1970) the yield increased from 200 lbs of rubber per acre to 2000 lbs per acre, with experimental trees yielding 8000 lbs per acre.

The same hydrocarbon is produced by the desert shrub called Guayule argentatum (fam. Compositae) (FIGURE 2) which was grown experimentally in the United States (specifically California) during World War II and is now harvested for full pilot plant production of rubber in Saltillo, Mexico. It is anticipated that plantings of guayule will soon be made in areas of West Texas and other parts of the southwest United States where rubber companies have once more taken an interest in this most useful species.

There is a different hydrocarbon resembling crude oil instead of rubber which exists in many plants. The plants which produce this emulsion of oil and water have long been known as producers of a milky white juice (latex) but have been entirely unexploited as materials sources. They include such ornamentals as the Euphorbia poinsetta, Plumeria amarginata and the cactus-like Euphorbia lactea (FIGURE 3) and Euphorbia tirucalli (FIGURE 4) as well as the gardener's "anti-gopher" friend, Euphorbia lathyris (FIGURE 5). Milkweeds (*Asclepias*) of all kinds are another species of latex-producing plants, and there are many more waiting to be recognized.

The Euphorbia lathyris in plantation (FIGURE 6) at the South Coast Field Station of the University of California in Santa Ana in seven months, grown from seed, produces more than 10 barrels of oil/acre and is still on an upward growth curve (FIGURE 7). The oil represents only about 10% by weight of the total productivity of the plants. Therefore, in oil equivalents, there will be another five-fold caloric value in the form of cellulosic residues. The caloric value of the oil can be estimated from chemical analysis and indicates about 17,000 Btu/pound. These two factors taken together will have an enormous impact on the economics of the use of plants of this type.

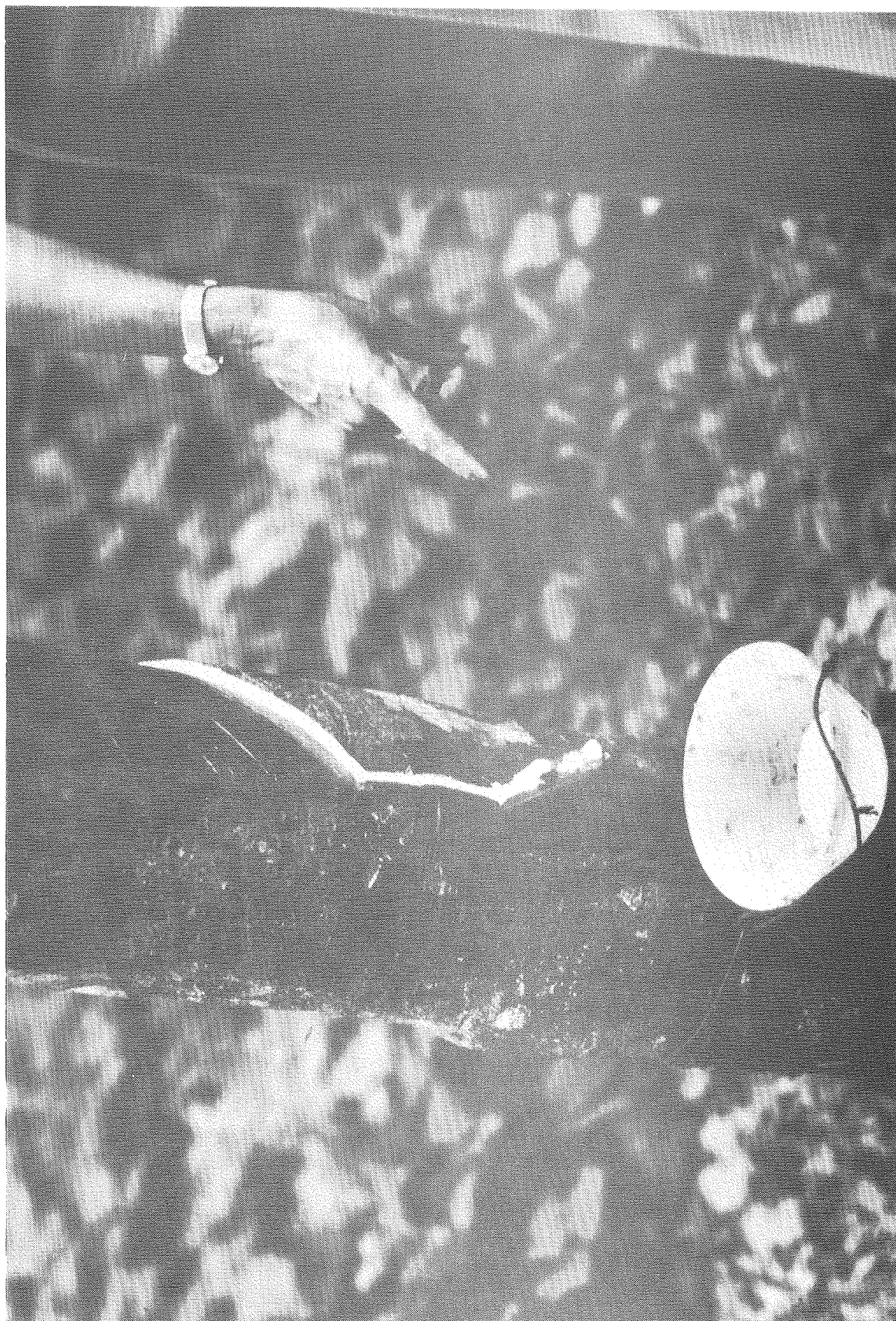
We have also made a rough calculation that it costs -- at least in the United States -- about \$100/acre to grow a commodity crop of this type. At that price, we expect that the "oil" from hydrocarbon-producing plants such as E. lathyris will cost less than \$10/barrel to grow and probably no more than \$10/barrel to process and put in the barrel, making a total cost of approximately \$20/barrel INTO the U.S. economy which can be compared with today's fossil oil price of about \$14/barrel OUT of the U.S. economy.

We feel that with the present rate of research and development a decision could be reached within two to four years as to whether or not this project could be commercially feasible. This decision will be hastened, of course, if some of the larger oil, chemical and/or paper companies undertake plantings of their own to confirm the commercial feasibility in a variety of planting situations.

As our projections are substantiated, large-scale commercial development of many thousands of acres could begin, using arid or semi-arid land, which is not now useful for food or fiber production. In the United States these "hydrocarbon" or "gasoline" tree plantations could be established in the dry areas of California, Nevada and West Texas. Worldwide there are many areas which receive sufficient sunshine and rainfall (about seven inches annual rainfall appears to be the low requirement) for the growth of these plants. It now appears also that rainfall, or irrigation, is not the limiting factor in the production of hydrocarbons from plants, but rather the amount of sunshine available to them.

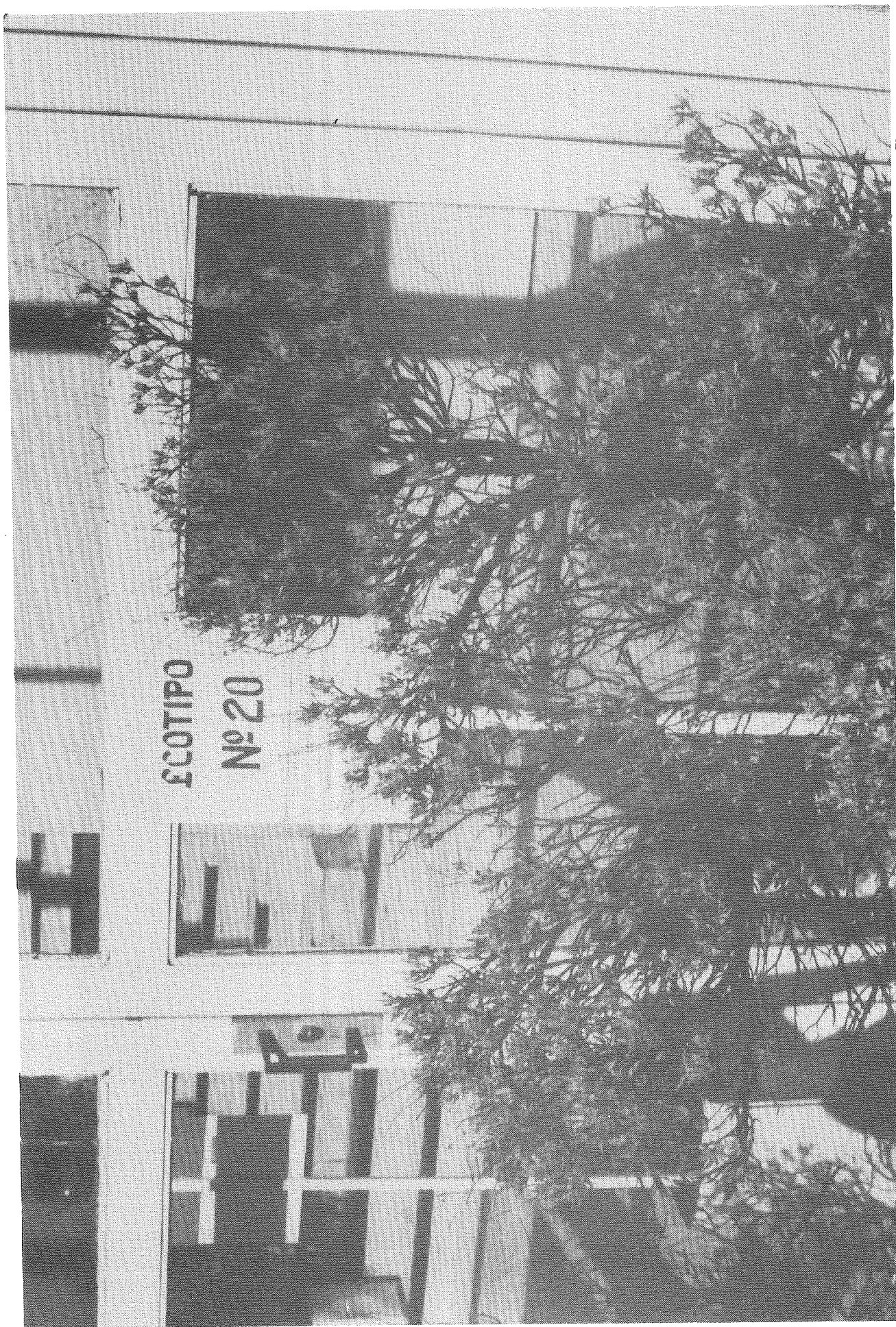
Many species of Euphorbias, some of which we have used in our first plantation, in the wild uncultivated state are actually tree-sized (Euphorbia tirucalli, FIGURE 4). On the dry banks of Puerto Rico, Euphorbia lactea (FIGURE 3) yields latex on tap as readily as Hevea rubber trees. There are milkweeds (Asclepias) in Michigan or California, whose relatives in Brazil (FIGURE 8) or Puerto Rico grow to small trees which can be tapped or harvested for regrowth.

It is time to learn to live within the income of today's sunlight which is, and always has been, the ONLY source of energy.



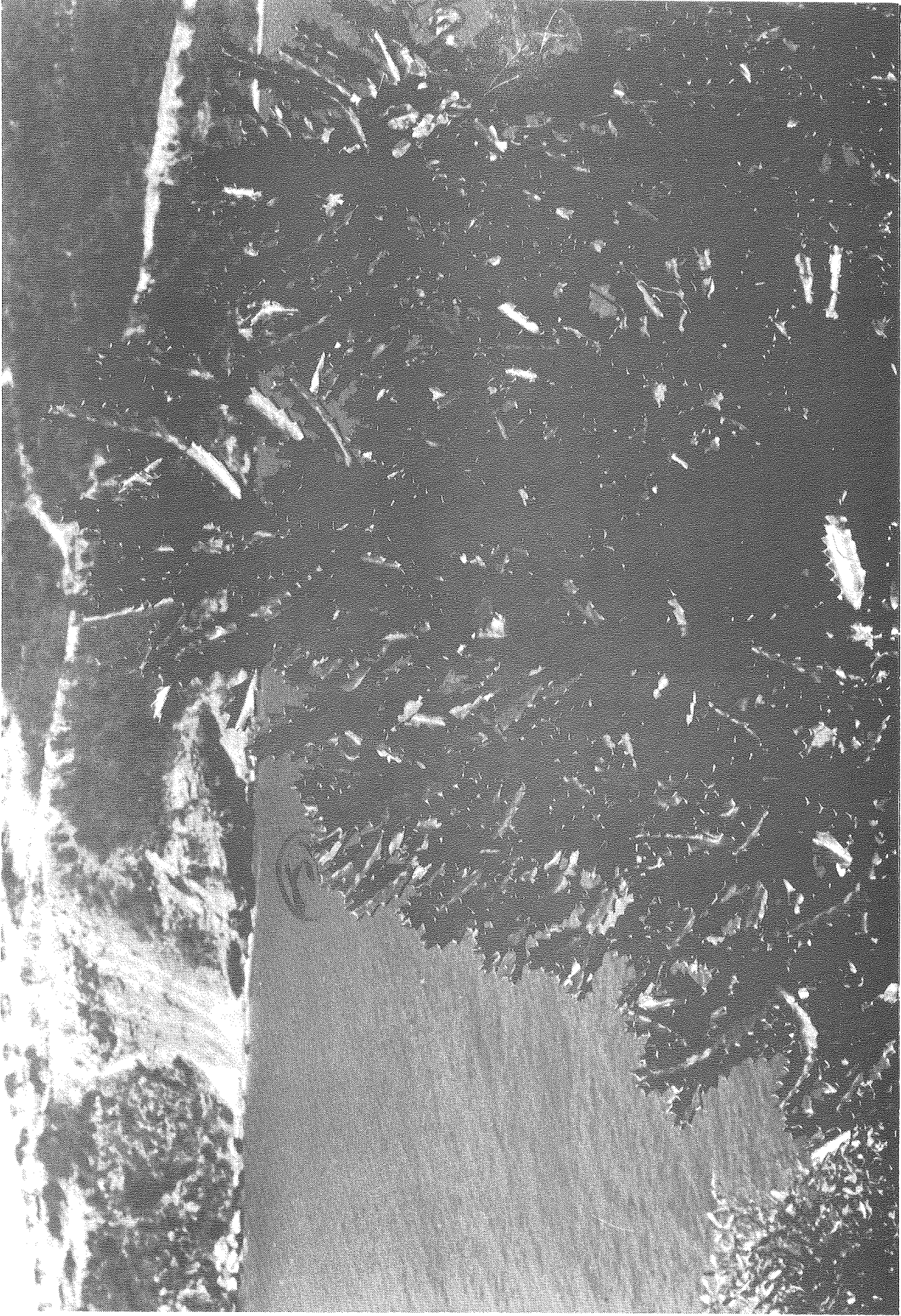
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Fig. 1 Rubber tap, Brazil



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Fig. 2 Guayule, Saltillo, Mexico



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Fig. 3 Euphorbia trigona, Puerto Rico



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Fig. 4 Euphorbia tirucalli, Brazil



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Fig. 5 Euphorbia lathyris, Northern California

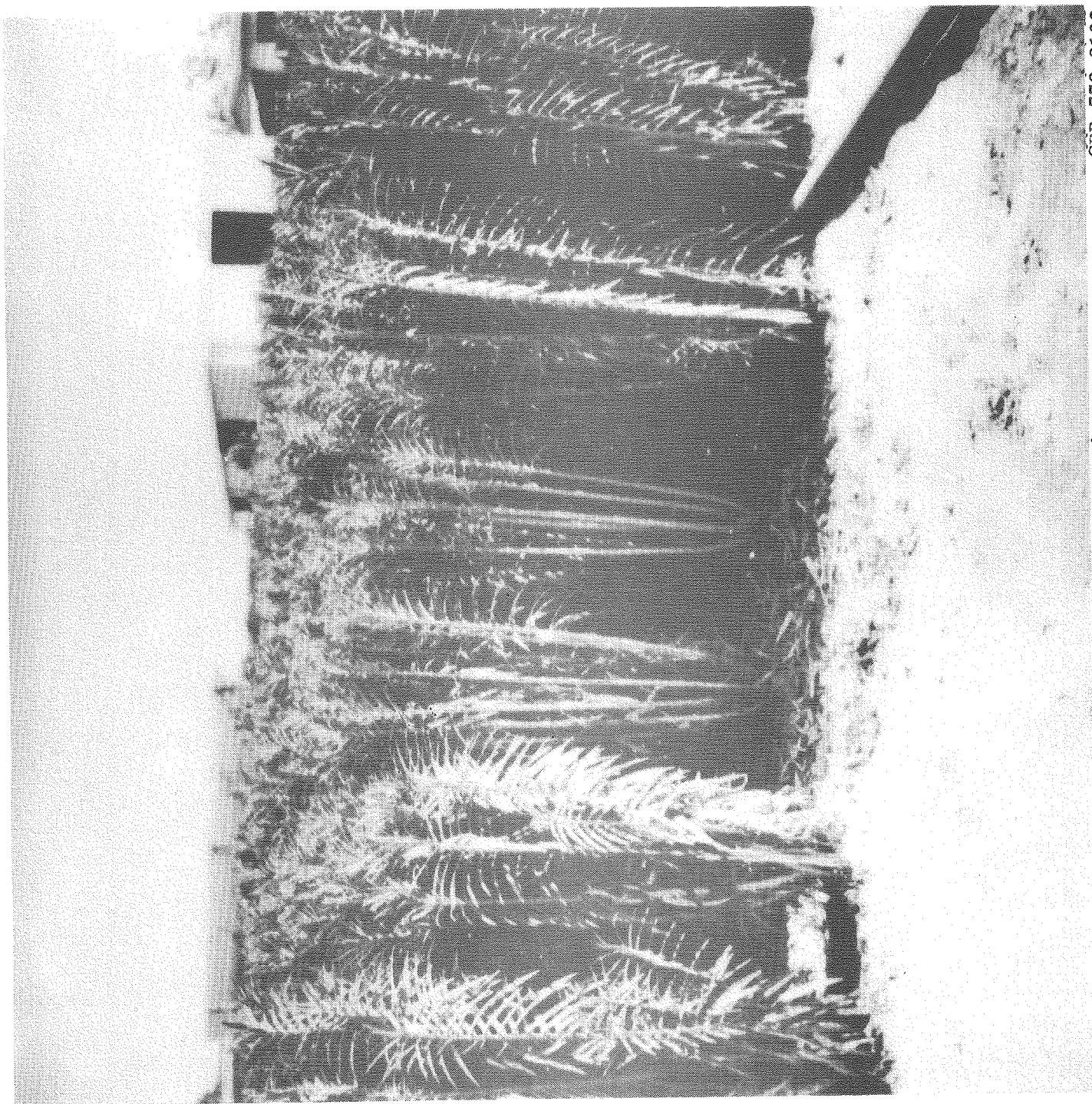
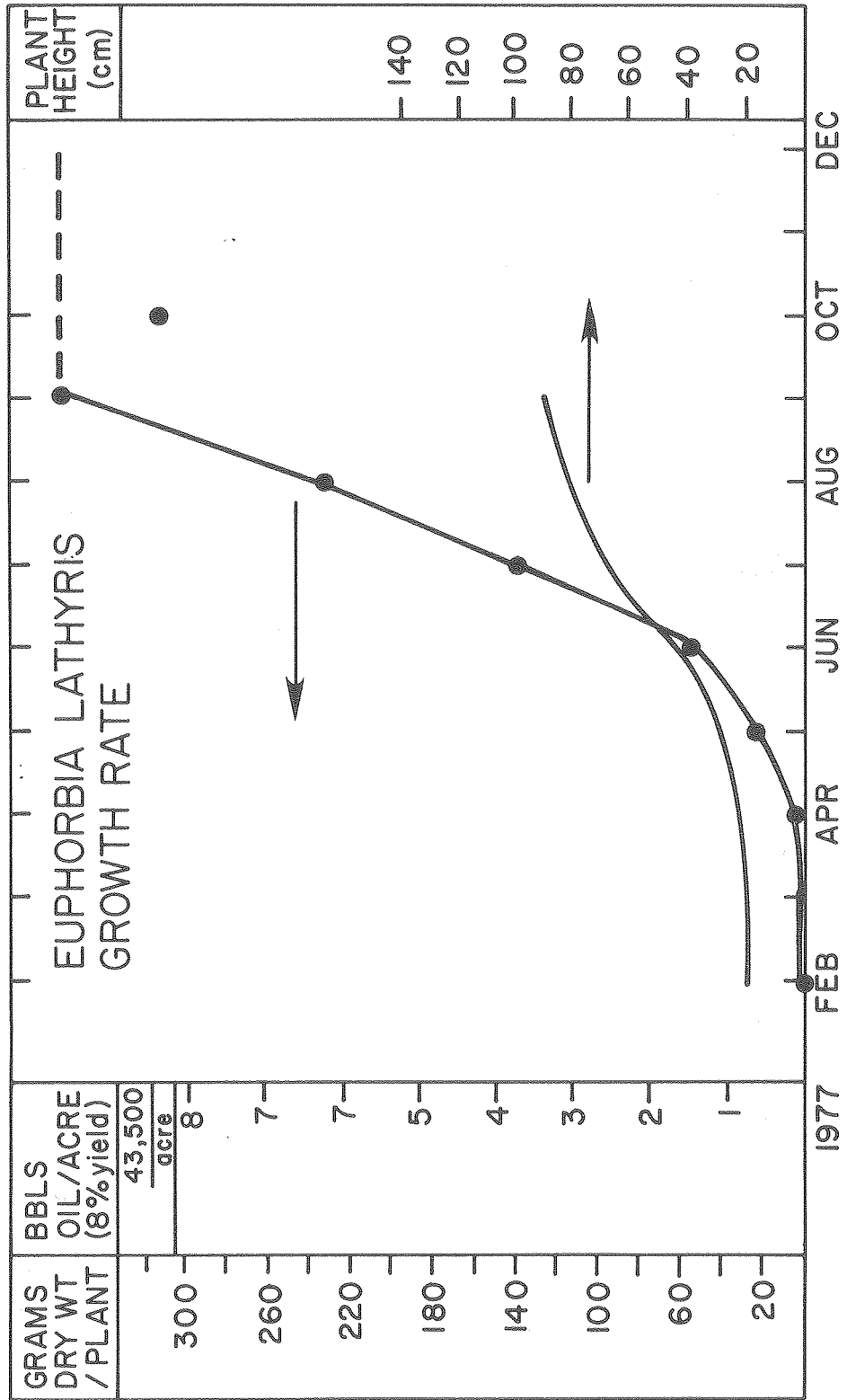


Fig. 6 Euphorbia lathyris, South Coast Field
Station, Santa Ana, California

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Fig. 8 Asclepias, Brazil

