Jojoba. I. Establishment of Commercial Plantations

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ABSTRACT

Although jojoba withstands a wide spectrum of environmental stresses, plantations should be established at first in areas where environmental factors offer a maximum likelihood of success for this crop. The two major limiting factors that will determine location of plantations appear to be temperature and soil type: flower damage occurs at temperatures lower than 22 F (-5 C), and poor growth results on heavy soils with poor water penetration. Optimum planting plan appears to consist of continuous hedge type rows spaced 15 ft (5 m) apart with plants 3 ft (90 cm) apart on the row.

Jojoba has long been known to scientists and to residents of the Southwest for its drought resistance and for the unique liquid wax extracted from its seed. As of 1974, however, jojoba is more than a botanical curiosity of the Sonoran Desert; with several hundreds of acres planted in the U.S., Mexco, and Israel, jojoba is beginning to attract considerable attention as a potentially commercial crop.

Jojoba has never been grown commercially before. Therefore, no data are available on cost of production, yields of seed and wax, market demand and price. In the absence of such basic data, no credible feasibility studies are possible; this constitutes a deterrent to establishing large commercial plantations. Preliminary production and marketing data, however, collected mostly during the last 10 years, and a better acquaintance with the agronomic aspects of this species have led to a rather optimistic attitude towards the economic potential of jojoba (1). This favorable outlook has proven to be stronger than the uncertainties surrounding the crop and has set the stage for a "getting acquainted" phase in the commercial development of jojoba. Most of the 1500 acres (600 hectars) now planted in California are in small plots ranging from 1 to 20 acres (1/2 to 8 hectars) each. If these initial small plantings bear out all the strong points that jojoba has been described as having, the acreage is expected to rise very rapidly.

High yields of jojoba seed and wax will be realized by developing both superior strains and optimum cultural practices. Breeding of improved strains with perennial crops such as jojoba is an especially long term procedure and will not be dealt with here. By contrast, the development of good cultural practices, even for perennials, is relatively easier and can often be accomplished sooner. We are very far from having answered the myriad of questions that arise in the course of domesticating a new crop. Some urgently needed basic facts relating to jojoba, however, are beginning to emerge. In this two part report, the state of the art of growing jojoba will be summarized. Part I deals with cultural aspects of establishing plantations. Part II will report data on the performance of cultivated jojoba experiments in terms of seed and wax yield and quality at the University of California in Riverside.

Deciding on the Location of Plantations

Latitude: Natural populations of jojoba occur between 23° and 35° North latitude. Jojoba responds strongly to photoperiod in terms of vegetative development (2). Greenhouse experiments have shown that seedling growth rate increases dramatically as the photoperiod approaches 24 hr of light. Until the effects of varying photoperiods on quantity and quality of jojoba seed and wax production are better known, it would seem to be safer to establish plantings within the latitude zone of the natural populations. Nevertheless, it should be pointed out that a few plants are growing in California outside this zone: in the Botanical Garden of Santa Barbara, in the La Purisima Mission by Lompoc, in the West Side Field Station of the University of California, and on a private ranch in Fresno. Seed has been harvested from all these plants indicating that the zone of adaptation of jojoba may be extended considerably farther to the north of its present distribution.

Soil type: Practically all natural jojoba populations occur on coarse, light or medium textured soils with good drainage and water penetration. Experimental plantings established on heavy soil at the West Side Field Station of the University of California bloomed much later and had a slower rate of growth than others on light soils. Jojoba nurseries have been established on soils of the Hanford, Ramona and Greenfield series at the University of California in Riverside. While growth during the first two years was not strikingly luxuriant, it accelerated progressively, and this year, on their 5th year of development, plants exhibit superior performance. Extensive pH soil measurements around jojoba populations in Mexico and the U.S. gave readings from 5 to 8, indicating that this may not be an overly critical factor.

Soil fertility: Natural populations of jojoba grow on soils of marginal soil fertility. Fertilization of field plots at UCR with nitrogen and phosphorus for three consecutive years (50 lbs of nitrogen, 50 lbs of phosphorus, or 50+50 lbs of nitrogen and phosphorus per acre annually – equivalent to 56 Kg of nitrogen, 56 Kg of phosphorus and 56+56 Kg of nitrogen and phosphorus per hectar) has not induced any obvious differences yet in terms of vegetative development. By contrast, similar fertilization treatments with potted plants, where root growth is confined, in the greenhouse indicated a dramatic, favorable response to N and P applications. Lack of response to fertilization under field conditions might be attributed to the deep, extensive root system which enables jojoba to draw nutrients from a much deeper soil profile than most other plants. Jojoba plants growing in Hoagland nutrient solution in the greenhouse for 6 months exhibited no clearcut mineral deficiency symptoms when individual nutrients were eliminated from the solution, except in the case of N. Lack of nitrogen resulted in stunted, pale, yellow plants (2).

Irrigation

Natural jojoba plantations grow in areas receiving 3-18 in. (76-450 mm) of precipitation annually. Since a proportion of this precipitation is lost as run-off water, it would seem that jojoba can grow with less than that amount of water. The best jojoba plants observed so far, 15 ft. (5 m) in height and in diameter, were in areas with 10-15 in. (254-380 mm) of annual precipitation. Heavier applications of water, even in excess of 40 in. (1000 mm), in experimental plots with relatively good drainage stimulated more luxuriant vegetative growth. It is not known, however, whether this increased vegetative growth would result in higher seed yield. Allowing water to stand around young jojoba seedlings for several days reduces the stand very sharply.

Jojoba utilizes most of the water during late winter and spring; thus, it does not compete for water with traditional irrigated crops. In view of the fact that new flowers appear in late summer, a mid-summer irrigation in excessively dry years might insure good flower production and, thus, improve seed yield.

Jojoba appears to have considerable tolerance to soil salinity. A number of very robust jojoba plants grow as close as 10 ft (3.3 m) from the ocean water line. The above ground parts of these plants are certainly subjected to frequent sprays of ocean water, and it would be surprising if even the roots are not at times in contact with ocean water. Further verification of its salt tolerance has been offered by greenhouse experiments at UCR and by experimental irrigations of field plots elsewhere with ocean or brackhish water. While all evidence suggests that jojoba will tolerate soil salinity, there are no data on yield reductions that might be expected at higher levels of salinity. With furrow irrigation where salts are a problem, it would seem advisable to apply the water from one, always the same, side of the planted row so as to move salts away from the root system. No comparative data are available for different types of irrigation.

Temperature

Of all the environmental factors, temperature may be the most critical one in determining the geographic distribution of jojoba plantations. In Riverside, temperature drops gradually after sunset and remains at the lowest level for 3-5 hr, usually between 1-6 a.m. When temperatures reach 20-22 F (-6 to -5 C), damage occurs on flowers and on terminal portions of young branches of most jojoba plants. It should be pointed out that in the early collections of jojoba germplasm, no concerted effort was made by us to obtain seed from populations occurring in the coldest locations. Later, germplasm collections were made with cold tolerance as the primary criterion. During the early stages of seedling development, excessive cold may wipe out entire plantations. As plants grow taller, frost may not endanger their survival to the same degree, but it may curtail yields substantially in that year. In this regard, frost damage in the early flowering stages may not be as destructive as at later stages; given enough time, a new crop of flowers will replace the damaged one. Early strains of jojoba are now under observation. Flowers are more susceptible to cold than seed; thus, the development of strains that set their seed before the onset of cold may be an indirect way of introducing cold tolerance to the crop. High temperatures do not have adverse effects unless they exceed 122 F (50 C).

Propagation

Jojoba may be propagated through seed, rooted cuttings and tissue culture. The only sources of seed, at present, are the natural populations. Single plant selections from all natural populations have been made by several plant breeders and growers and are now under observation and evaluation. Selection criteria have generally been seed yield per plant and large seed size. In some cases growth habit, high wax content and fruiting pattern have been considered. Single plant variability in seed size, yield, morphology and wax content is quite striking, both within and among natural populations. Wax composition, however, is extremely uniform throughout the area of adaptation, in spite of broad botanical variability (3). Differing cultural practices do not seem to cause major departures in wax composition from what has been reported in the literature, and no mutants have been encountered as yet in that respect.

Efforts have been made to obtain planting seed from seemingly superior individual plants from natural populations. Evaluation of single plant performance in natural populations, however, cannot be expected to have a high degree of precision, especially when attempted on dioecious species. For valid comparison, plants should be of the same age and past history, of known parentage if possible, and growing on the same soil type under identical field conditions and cultural practices. Although rarely, if ever, these conditions prevail in natural populations of jojoba, selection efforts made so far were not entirely without some degree of success, at least for some of the traits used as selection criteria. It will probably take several years before cultivars with predictable performance will become widely available to growers. Germplasm with particular adaptation, and botanical features, however, will become available in the very near future.

It is still not possible to distinguish male from female seedlings prior to flowering. This would seem to create a problem in following a given planting plan in terms of position and frequency of male and female plants. This difficulty, however, can easily be circumvented by overplanting, especially when seed rather than seedlings is planted. A grower can afford to rogue out of his field extra male and a large number of inferior female plants soon after blooming. Thus, in addition to adjusting the number of male plants, he can also excercise selection for high productivity under the specific environmental conditions of his own land.

The use of rooted cuttings has not yet spread widely in the establishment of commercial fields. One reason for this is the lack of long term performance records from plants verifying their superiority to be used as sources of cuttings. In addition the production of cuttings proceeds slowly and requires considerable greenhouse facilities. It is expected that as soon as superior genetic material is available for propagation, tissue culture will be the most popular method of vegetative propagation. In addition to providing genetic uniformity, vegetative propagation will enable growers to plant in accordance with predesigned planting plans in terms of frequency and position of male and female plants in the field.

Planting Plan

Until recently there was no published information on the cultural requirements of jojoba, and little was known in terms of plant development or the performance components that are traditionally used as guidelines in arriving at an optimum number and arrangement of plants per acre. The planting plan that we are now recommending is based on the following observations. (a) During the first 10 years and under favorable soil and climatological conditions in California, jojoba grows 1/2 to one ft (15-30) cm) per year in diameter and in height. Under optimum conditions, such as those prevailing in Sonora and B.C. in Mexico, this growth rate may double. (b) The seed is born on new growth, and most of it is found on the outer periphery of the plant. (c) The ratio of male to female plants that should be expected in commercial plantings is about 1:1 or slightly in favor of males by about 5% (4). (d) Crowding of plants does not seem to depress plant growth and production substantially. (3) When several seeds are planted per hill, it is very time consuming to rogue out extra male plants. (f) Male plants flower several months earlier than female plants. (g) Jojoba pollen travels distances in excess of 45 ft (15 m) with relatively mild breezes.

With these observations in mind, the following planting plan is now being tried at UCR. Individual seeds or seedlings are planted 1-1½ ft (30-45 cm) apart. As soon as the male plants flower, they are thinned out to one male every 40 ft (13 m) on the row. As soon as the female plants flower, usually on the 3rd year, any slow growing, obviously late and unproductive plants are rogued out leaving a female plant at every 2-3 ft (60-90 cm) on the row. Spacing between rows depends on the type of harvesters to be used and on the expected rate of growth at a particular location. With hand harvesting and cultivation, rows could be as close as 10 ft (3.3 m) apart without creating major management problems during the first decade. In mechanized farms, however, sufficient space should be allowed between rows for vehicular traffic; optimum row spacing in that case would be closer to 14-16 ft (4-5 m). If these planting patterns prove to be excessively dense after the 10th year or so, every other row could be taken out, and, in addition a few plants could be removed from each row. For optimum pollen distribution, male plants are thinned so as to develop a rombic rather than a square distribution pattern over the entire field.

Plants are allowed to grow naturally for about 3 years. After thinning is completed, the rows are pruned vertically with a cane cutter such as that used for vineyards. The vertical sickle bar cutter moves parallel to the planted row and is adjusted to cut one foot away from the center of the row on each side. This gives the planted row the shape of a continuous rectangular hedgerow, ca. 2 ft wide and 3 ft tall (60x90 cm); branches which are initiated 4 ft (1.2 m) or higher from the ground are allowed to develop sideways, and as the plants continue to grow in height, the cross section of the hedgerow starts to resemble a center cross section of a tree.

It may be unnecessary to allow plants to grow any taller or wider than 10-15 (3-5 m). This decision, however, will have to wait until data from various types of 10-20-year-old hedgerows are available for yield comparisons. What we anticipate now is that hedgerows will be pruned back to a uniform height and width and then sprayed with one of the growth regulators that has been found to stimulate new and profuse branching on jojoba (2). Since flowers and seeds occur on new growth, a balanced system of pruning and spraying will hopefully both maximize and stabilize yields in time and will promote uniformity in seed maturity, size, wax quantity and quality.

The planting plan and management described involves overplanting initially: as much as 7-9 lbs of seeds per acre (6-8 Kg per hectar) may be needed. It is recommended, however, because it enables a grower to adjust the density and pattern of males in his field to eliminate low producing females and to maximize yield per acre during the first critical 10-year period. If future data will indicate that higher yields may be obtained by lower population densities, these can easily be adjusted downward by removing plants or entire rows at the appropriate stage of development. An additional advantage of this plan is that it does away with tying, wrapping and staking of individual plants which, although necessary for research plantings where individual plant performance needs to be evaluated, is time consuming and expensive for commercial enterprises.

Stand Establishment

Direct seeding: In most of the direct-seeded commercial jojoba fields, planting was done with commercially available planters on raised beds. With two planters mounted on a tool bar, one tractor operator can easily plant in excess of 50 acres a day. Large seed is easier to harvest and usually has a higher wax content; therefore, large seed is preferred as planting seed with the expectation that it will produce large seeded plants. Large seed (1 g or more per seed) produces more vigorous seedlings than small seed during the first 2-3 month period of growth; this superiority, however, disappears later. After planting on dry beds, seed is irrigated up. For faster emergence plantings should be made during the warm months of the year, and depth of planting should not exceed 1½ in. (2-3 cm). With soil temperatures of 70 F (21 C) or over, germination occurs within a week; the tap roots develop rapidly at first at the rate of about 1 in. (2.5 cm) a day. Emergence occurs in about 20 days. Low soil temperature may delay emergence by 2-3 months. Irrigation should be applied as needed during the first 2-3 months to maintain adequate moisture close to the top of the raised bed to insure good germination and root establishment. Later, irrigations may be applied at monthly intervals between September and June so as to supply the field with a total of about 1½ acre ft (45 hectar cm) of water. Overwatering jojoba seedlings or planting the seed inside the irrigation furrow may have disastrous effects on seedling emergence and survival.

No jojoba cultivars are in existence yet and, therefore, no varietal recommendations can be made; it cannot be overemphasized, however, that one should avoid using seed harvested from natural stands in warm climates if plantings are to be made in areas where frost is not uncommon.

Production and transplanting of seedlings: Planting seedlings speeds up the establishment of plantations and gives jojoba a head start over weeds. The method of seedling production used at UCR is the following: seeds are pregerminated in large containers filled with vermiculite, sand or similar material at about 80 F (27 C). As soon as germination starts and before a radicle starts to grow (usually in 2 days), single seeds are transplanted 1 in. deep (2.5 cm) in 2x2x5 in. (5x5x12.5 cm) square paper containers that are open at both ends and filled with a potting mix. The paper containers are placed in plastic 16x16 in. (40x40 cm) flats, with large holes at the bottom, 64 per flat. Jojoba does not seem to require a particular potting mix; a mix of 30%-40% organic matter with a medium or light loamy soil has given satisfactory results. With such a mix, watering is needed only every 4-5 days. Emergence occurs in about 15-20 days, and the seedlings are ready for transplanting when they are 6 in. (15 cm) tall, usually in 8-10 weeks. At that time the paper container is partly disintegrated and may be left undisturbed or may be peeled off as seedlings are transplanted.

As soon as the jojoba tap root outgrows the 5 in. (12.5 cm) deep container and gets outside the soil column, it self prunes. This triggers the initiation of many fibrous side roots. Side roots do not develop when containers that are closed at the bottom are used; instead, the tap root continues to grow in a somewhat abnormal coiled pattern which persists unchanged in the later life of the plant.

Instead of paper containers, styrofoam blocks with 128 pyramidal performations each, 2x2 in. at the top and 1/2 x 1/2 in. (5x5 cm and 1x1 cm, respectively) at the bottom, have also been used successfully for seedling production. When seedlings are 6-8 in. in height (15-20 cm) in about 8-10 weeks, they are pulled off the styrofoam blocks and are transplanted. To avoid damaging the seedlings as they are detached from the styrofoam blocks, and to produce firm seedlings the following technique is utilized: on the 6th week after planting, a grain of barley or wheat is planted next to each seedling in the block. The dense, fibrous, grain root system binds the soil around each jojoba seedling and contributes to lower transplanting losses. The grain stalk may be nipped off at transplanting. Equipment is now available for mechanical transplanting of such seedlings.

To insure fibrous rather than tap root development, the flats or styrofoam blocks should not be resting on the soil. If they do, the tap root is not air pruned, but it penetrates and continues to grow into the soil, and few if any side roots develop.

Planting in large containers, e.g., gallon pots, appears to be unnecessary unless the plants are to be kept in them for 5-6 months prior to transplanting. Jojoba is susceptible to root rot *(Phytophthora parasitica)* in the very early seedling stage. Therefore, the soil should be sterilized before it is used in the potting mix. Overwatering and high temperature increase the severity of this disease.

In summary, the establishment of commercial plantations of jojoba does not present any problem in terms of agricultural methodology or specialized equipment. Of particular significance may be the choice of locations for the first commercial plantations. Although jojoba is not very demanding in terms of soil fertility, water quality and altitude, it might be a mistake to start plantations in locations where environmental stresses often reach extreme levels. It may be wiser to locate plantations where environmental factors offer the best chances of success and then explore progressively the ability of jojoba to produce, not merely survive, under more extreme environmental stresses.

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Four Corners

Chairman, International Relations – Eugene Marshack • Corresponding Secretary – R.F. Kohlman

Brazil . . . . R.F. Kohlman

XI International Nutrition Congress

Aug. 27 to Sept. 1, 1976

This International Congress took place for the first time in Brazil, in the city of Rio de Janeiro. The premeeting estimate of 3,000 participants was surpassed by 100%, and the huge number of last minute registrants, besides causing some organizational difficulties, contributed to the success of the event.

Oil and derivatives in Brazil

Brazil has long been self-sufficient in oilseeds, and has become a very important exporter in this field. The main raw materials are peanut, cottonseed and soybean. The figures for 1978 and projected for 1980 look as follows:

	1,000 Tons	
Crop Estimates	1978	1980
Peanuts	300	520
Cotton seed	880	1,200
Soybeans	8,100	15,000

The really important seed is soybean. The 1978 crop yield was small due to adverse weather conditions, but the growth of the crops will continue without interruption, increasing to about 15 million tons in 1980. Babassu has made no significant progress. Palm plantations continue in their infancy, peanuts remain steady, with some renewed growth for cottonseed.

Local crushing may be estimated at 7.4 million tons in 1978 and around 9.6 million tons in 1980, leaving an important bean export surplus.

The total crushing capacity installed in Brazil is estimated at approximately 18 million tons per year, thus exceeding by far the available raw material. This fact is leading to the closing down of small and uneconomic factories in favor of 1,000 ton and larger plants, which operate more efficiently. These factories are extremely modern, with some equipment of either European or American origin, and most made in Brazil. Many plants are also complemented by a refinery.

Incidentally, Brazil is following the same trend as the USA, where the number of plants is decreasing, while their individual crushing capacity is growing.

The local market absorbs presently around 1 million tons of refined oils, (roughly 2% of the oil world production) of which 800,000 are sold as edible oils, 200,000 as margarine and 90,000 as shortening. In other words, total per capita consumption of vegetable oils in all forms is around 8.5 Kg. Furthermore, the local market still absorbs most other derivatives and by-products such as stearic acid, glycerine, lecithin, isolated and concentrated protein, textured protein, soybean milk powder, etc., and, of course, part of the soybean extractions.

Interestingly, all edible oils sold in the country are filled in metal cans, while shortening and margarines are packaged in all sorts of containers, like metal, paper and plastics. All packaging material is produced in Brazil. Into the export market go, in order: soybeans, soybean extractions, some peanut oil, or soybean oil, lecithin and proteins.

But not only products are being exported. Brazil is also now an exporter of equipment like dryers, expeller presses, soybean cleaning and preparation machines, grain extruders and many others. And in the past years technology has also been sold. Thailand's most important oil factory and refinery, commissioned early this year, was planned, built and started with Brazilian technology from the Sanbra firm.

While basic research in the edible oil field is unimportant in Brazil, most R&D effort goes into applied technology, mainly for developing new products and inproving the existing ones. Official institutes devote sporadically some works to this field, but none of them with exclusive dedication.

The Ministry of Industry and Trade maintains the National Institute of Technology in Rio de Janeiro, the Ministry of Agriculture operates the Institute of Food Technology in Rio de Janeiro, while the State Government of São Paulo runs the Institute of Food Technology in Campinas, which is by far the most important of all institutes. In the same city we must mention the State Faculty of Food Technology and also a related foundation, which occasionally are used by the oil industries for complementing research or analytical jobs. •