Feature

Update:
Developing new commercial crops

In 1985, the U.S. Department of Agriculture's (USDA) Office of Critical Materials named crambe, cuphea and jojoba as crops the government considered economically advantageous for commercialization. Also included on that list were meadowfoam, winter rapeseed, Chinese tallow tree, lesquerella, lunaria, guayule and kenaf. In the following article, JAOCS *newswriter Anna Gillis looks at progress with jojoba, crambe and cuphea.*

Efforts in the U.S. to provide renewable domestic sources of lauric acid and medium chain fatty acids, high erucic acid oils and wax esters that currently are imported have included trials to develop jojoba, crambe and cuphea as crops. Of the three, jojoba is the most advanced commercially. By some projections, approximately 60,000 acres will be under cultivation in the U.S. by the end of 1988.

The goal outlined by USDA's Office of Critical Materials in 1985 was to provide industry with stable, renewable sources of raw materials by the turn of the century. USDA projected that crambe and jojoba could be developed commercially within five years of the program's outset and cuphea in five to eight years. Currently, jojoba is most likely to realize it commercial potential within USDA's timeframe. Development of cuphea and crambe, meanwhile, has been delayed by agronomic and economic factors.

Jojoba

At the beginning of the decade, the *Wall Street Digest* rated jojoba as "one of the top 10 investments in the country" and called it "the investment of the 80s." Other financial advisors made similar projections. These claims brought droves of investors looking for profit into Arizona and other growing areas.

Since that time, however, many of those would-be jojoba farmers have given up on the crop. According to Carole Ann Whittaker, a grower herself and president of Hyder Jojoba Inc. in Phoenix, Arizona, many of the early investors simply were not in the long-term financial position necessary for such a slow-growing crop.

"The industry is retrenching," Whittaker said. "There are fewer growers, but the acres that are being taken out of production are not acres that were producing well, so there is little loss in current production. Agronomic processes have improved and older plantations are becoming quite productive. Skilled growers located in favorable environments should continue to produce well. However, the industry's ability to increase production as rapidly as projected has been severely diminished."

Vicki Hubbard of the Associated Jojoba Group pointed out that even though there are fewer growers, many of the smaller stands abandoned by early growers have not been entirely lost to the industry. According to Hubbard, many of those plantations were taken over by more experienced growers who were capable of staying on until they could harvest an economic crop. "Many of these small operators were more investment-oriented than farm-oriented, and the fact remains that this is firstly an agricultural industry, and it will be those with strong agricultural capabilities who will succeed," she said.

Figures from the Arizona-based Jojoba Growers & Processors Inc. indicate the combined harvest for the U.S., Mexico and Israel in 1986 was 820 metric tons (MT) of seed, compared to 12 MT in 1976. The

TABLE 1

A History of the Jojoba Oil and Seed Market 1976–1986

Year	Metric tons seed harvested	Average seed price/lb.	Metric tons oil sold	Average oil price/gal.
1976	12	US$1.25	5	US$ 35
1977	16	1.50	7	38
1978	80	2.00	25	42
1979	80	2.10	27	45
1980	160	2.30	45	65
1981	300	4.75	90	170
1982	300	2.50	95	55
1983	400	2.05	135	48
1984	600	1.25	240	45
1985	600	1.30	260	42
1986	820	1.25	350	32
		Projections		
1987	875	1.40	400	32
1988	1,300	1.25	580	28
1989	1,800	1.20	800	27
1990	2,200	1.15	980	26

The above figures were presented at the Third International Symposium on Advances in the Cultivation of Jojoba held in Asunction, Paraguay, in September 1987. The information is from a survey of active U.S. jojoba processors conducted by James Brown, president of Jojoba Growers & Processors Inc., Apache Junction, Arizona.

1987 crop is estimated to equal or slightly exceed the 1986 crop. By 1990, the annual harvest will be 2,200 MT, according to James Brown, president of Jojoba Growers & Processors. He predicted acreage will increase, particularly in Latin America where "as much will be planted in the next year as has already been planted in the U.S."

Hubbard, disagreeing with Brown's estimate, said a 2,200 MT-harvest forecast is too low. "That (2,200 MT) is only an average of 121 pounds of seed per acre from the 40,000-plus acres now under cultivation in North America. Granted, some of that acreage is new and some unproductive, but in another three years a much greater percentage of that acreage will be reaching high productive periods in the plant life cycle," she said.

Brown also predicted that of the more than 40,000 acres already planted in the U.S., approximately 25–50% will be abandoned before 1990. However, he said this doesn't mean an overall loss in area. "By the end of 1988, there will be 50,000 to 60,000 acres under cultivation," he said, adding that growers will switch to planting in areas where production costs are lower. Also, yield potential will be higher because better planting material is being used. "Fields being planted now are being planted with the benefit of a learning curve," he said.

While agreeing that some areas now in production will be abandoned, Hubbard said she doubts it will occur at the rate predicted by Brown. "Some of the acreage planted by seed in less than desirable areas will and should be abandoned," Hubbard said. She added, "It is important to point out that although there is little question that plants propagated by rooted cutting clones will be more productive and dependable in the long term, many farms established with seed should remain very viable." She noted that in 1987, Associated Jojoba's fifth-year growth, seed-planted fields yielded an average of 800.5 pounds of seed per acre, a five-fold increase over the year before.

Over the past 12 years, the jojoba industry has gained agronomic and technical knowledge, particularly in the areas of frost resistance, site selection, yield improvement, harvesting and processing. Jojoba growers lost nearly 90% of their 1985 crop due to frost; reportedly only one producer was able to make a commercial harvest. In 1986, growers did not lose nearly as much even though the crop experienced the worst frost in the growing region in nine years, according to Hal Purcell, president of the Jojoba Growers' Association.

Growers have overcome some frost problems by withholding water in the fall. This helps delay blooming until March, thus protecting female flowers and fruit which usually succumb to frost at 29–30 F. Because dormant buds can withstand temperatures below 25 F, "We've essentially lowered the frost safety level," Purcell said.

Probably the most exciting accomplishments for the relatively young industry is the development of high-yielding cloned materials, according to Purcell. "One of the problems on older seed-planted fields is that only 10% of the females produce most of the seed. Now when we plant, we use cuttings from the top one percent of producers. The potential (on an acre of these cuttings) is over 3,000 pounds at maturity."

Purcell estimated that more than 80% of the land in production is seed-planted, but more and more land is being planted with clones of higher-yielding material. "By propagating clones of plants that are successful, we will get uniformly high harvests. Conceivably, we could go from yields of 500 to 600 pounds per acre on seed-planted land to five to six times that with genetically superior plants."

Seed-planted material takes longer to mature but the anticipated yield at maturity can be 2,000 to 3,000 pounds, Whittaker said.

Previously, a successful harvest would have garnered about half of the seed produced, but Purcell said a recently designed harvest system now makes it possible to recover 90% of the seed. "The key to the system's success is proper pruning and soil preparation prior to vacuum harvesting," Purcell said. The Jojoba Vac system, developed by Arid-Oil Inc. of California, was demonstrated during a jojoba festival on Purcell's land in MacVay, Arizona, in September 1987.

"Vacuum harvesting is just coming into vogue. Growers are starting to switch from harvesting from the plant to harvesting from the ground," Purcell said. "These changes are a result of a blue-ribbon task force established by the the Jojoba Growers' Association and engineers from industry and universities."

Processing capabilities likewise are improving. The industry's first commercial solvent extraction plant is in operation, and another is scheduled to begin processing early in 1988. "With solvent extraction, we now can get 50% of the weight of the seed as oil as opposed to 40% by screw press," Purcell said.

Desert King Corp., based in Chula Vista, California, began solvent extraction at its plant near Tijuana, Mexico, late in 1986. That facility has a solvent extraction capacity of 20,000 pounds per day and a total processing capacity of 70,000 pounds per 24-hour day, according to William Watson, Desert King's executive vice president. Much of that capacity remains idle in anticipation of additional production. "The industry's current total processing capacity is at least four times greater than present jojoba production," Watson added.

Associated Jojoba Processors Inc. (AJP), a company in the Associated Jojoba Group, is expected to add to that capacity by harvest time this year. The new facility will have both mechanical and solvent extraction capabilities. According to Hubbard, the plant will be able to handle 30 tons of clean, dry seed every 24 hours. Solvent extraction capacity will be about 17 to 24 tons per day.

Before any more capacity will be required, jojoba oil markets would have to more than quadruple, Brown said. In a survey of U.S.-based jojoba processors, Brown found that 350 MT of oil were sold in 1986 at an average price of $32 per gallon. In 1987, prices remained constant. By 1990, Brown said, oil sales will total 980 MT and the price per gallon is likely to fall to

$26. Predicting demand and supply will grow at about the same rate, Whittaker said she expects prices to stay close to present levels for the next few years.

Brown said total annual demand for jojoba oil could reach 64,000 MT as predicted by the United Nations Industrial Development Organization in its 1981 publication *The Jojoba Potential* but probably not within the 1992-1995 time-frame given by the organization. There also will not be sufficient acreage planted by 1995 to meet such demand if it were there. To reach that level of consumption, prices must drop to $4,00-$6,000 per MT from the present $9,000-$12,000, Brown said.

"The mid-1990s are too short a time horizon to expect that sufficient research will be accomplished to fully develop and quantify the benefits of jojoba oil derivatives," Brown added. "With appropriate levels of R&D investment, this industry can expect to achieve volumes in excess of the 64,000 MT projected. Industries need application data to stimulate their own internal R&D with jojoba. Thus far, there has been less than optimum efforts in this critical area. We cannot expect industries to embrace a new raw material because we walk in the door. We must bring in the data so industry can see the rationale for using jojoba. Until the jojoba industry does this, we can't hope to really expand."

Research on jojoba applications for cosmetics, pharmaceuticals, foods and lubricants has increased in recent years. The high prices in 1981—at times near $200 a gallon—drove off buyers and put a temporary damper on formulating, but increasing availabilty and stable prices have turned that around somewhat, industry representatives said.

Producers said another factor aiding jojoba commercialization is its reputation. During the early days of "jojoba fever" in the U.S., the golden liquid wax was used more often for its name rather than its chemical properties. While image remains strong in the mind of the consumers, jojoba now is used for its functional properties, Brown said.

Sources said the Japanese and Europeans generally have made more effort than Americans to use jojoba for its functional value rather than label appeal. It always has been accepted as a premium cosmetic oil in Japan and Europe but gained a reputation in the U.S. as a "snake oil" due to the wide variety of claims made by early jojoba promoters, Watson said. "This reputation is changing steadily as more and more companies discover the unique qualities of the oil." Although his company still exports nearly 75% of its production, Watson said U.S. sales have improved as formulators begin to realize the oil's potential.

Companies such as Alberto-Culver, Fabergé, Plough-Coppertone, L'Oreal, Shiseido and Crabtree & Evelyn use jojoba oil for functionality in their formulations. L'Oreal has been granted a patent on the use of jojoba oil and γ-linolenic acid in cosmetics, and Coppertone uses jojoba in two tanning products and one sunscreen. Jojoba butters are added to synthetic detergent bars in Europe to give the bars a feel similar to typical stearate soaps.

Industry needs to document jojoba's properties to encourage its use for functional rather than fad purposes, Brown said, adding, "There is a significant lack of scientific data to support theories of functionality we feel the oil and its derivatives have."

Like Brown, Frank Flider of Agro Ingredients Inc. believes more research is warranted. Flider, formerly executive director of the JMC Technologies Inc., a jojoba marketing group, said jojoba products possibly could be used in psorisis, eczema and acne products. "Jojoba limits the drying and flaking associated with psorisis and eczema, and because it represses sebum production, it may be suitable for use in acne cases. It will not support microbial growth in the skin," Flider said.

Flider said jojoba eventually might be able to compete with compounds such as mineral oil and petrolatum, which often serve as a base material for cosmetics and skin care products. "Jojoba makes up 3-10% of some formulations now. Now in this range, it begins to exert its functionality," he said. "If prices dropped to the $2 per pound range, it could replace other ingredients, even less expensive ingredients, because those products are more occlusive to the skin and just not as pleasant."

"We must bring in the data so industry can see the rationale for using jojoba."

Pharmaceutical applications for jojoba include use as a carrier for injectable drugs and as a vector for medications through the skin. Jojoba oil acts as an antifoam in the manufacture of penicillin, thereby cutting down production losses.

Jojoba oil as a low-calorie vegetable oil substitute remains an untapped market. Jojoba's chemical structure is such that only 40% of the oil's calories are absorbed, "essentially giving it the same number of calories as starch or protein," Flider said. Even though scientists at Nestle Research Center in Lausanne, Switzerland, are conducting jojoba oil consumption studies on humans and rats, Flider said it could take several years and much money to gain U.S. Food and Drug Administration (FDA) approval for jojoba in foods should such an application be proposed.

One factor that might hinder that progress is the possible presence of the cyanoglucoside

simmondsin in the oil. Simmondsin, a toxic substance, is found in the meal, and "this is enough to make the FDA want to thoroughly evaluate the oil," Flider added. Simmondsin is found principally in the press cake after oil extraction; if there were traces of the nitrogen-bearing compound left in the oil, they probably could be removed by simple refining, Brown said.

Meanwhile, USDA/ARS researchers at the Northern Regional Research Center continue to study jojoba oil and oil derivatives to determine their chemical and physical properties, according to Marvin Bagby, oil chemical research leader there. Work also is being done on the detoxification of defatted jojoba meal.

Although cosmetic and skin care product formulators use more than 90% of the jojoba oil produced annually, specialty lubricant applications in the industrial and automotive fields are looked at as "sleeping giants" with immeasurable possibilities. "At some point in the distant future, that first account from a major oil company will be larger than that of all the cosmetic accounts combined," according to consultant George Arndt, who previously served as technical director for Desert King.

Arndt, who developed a jojoba-based additive for use in motor oils, does not think the jojoba industry is not ready for potentially massive automotive and petrochemical accounts at this time. Several years ago, a large petroleum company approached him about a "small" project that would have required a million pounds of oil per year, Arndt said.

"Before we can do anything with a major oil company, the volume we produce would have to be 100 times larger than it is now. Big companies require that substances be available at all times in sufficient supplies," Arndt said. "The jojoba industry is too small to meet the smallest requirement of a large company's small projects."

Despite possible limitations caused by supply, sources say the industry could see greater markets for jojoba in automatic transmission fluids and differential fluids because of jojoba's stability at high temperatures. Engine benefits occur even at levels as slight as 0.1% jojoba oil in a formulation, Arndt said. According to Arndt and others, jojoba lowers wear and engine-operating temperatures caused by friction.

Wynn Oil Co., based in Fullerton, California, for the past three years has produced a patented crankcase oil additive that contains jojoba oil. Les Lugosi, manager of research at Wynn Oil, said the company chose jojoba oil as part of an additive package for its crankcase oil because it gave the "most satisfactory results." This year, the company plans to introduce a radiator stopleak made from ground jojoba meal. No one knows what kind of potential jojoba meal will have in this use, Lugosi said, adding, "So much will depend on its performance."

International Lubricants in Seattle, Washington, uses jojoba oil in its five oils and four oil supplements. According to the company's president, Frank Erickson, concentration levels of jojoba are critical to a product's ability to withstand extreme pressure applications such as automatic transmission fluid, power transmission and cutting oils.

By developing derivatives, it's possible to get the maximum potential out of limited supplies of jojoba, Erickson said. Some of International Lubricants' oil supplement formulations contain as much as 50% jojoba oil derivatives. The company has applied for a master patent to cover the use of their derivatives on applications ranging from aviation oils to textile fluids. One of International Lubricants' major research efforts involves studies on engine transmission fluids and rear axle products. This project is being carried out with a large Pacific Northwest truck manufacturing firm, Erickson said.

Although the company is still mainly in the research and test marketing stage, it sees a large potential market, Erickson said, adding, however, "The limited supply of jojoba will retard our growth."

Sources indicated another possible high temperature lubricant application for jojoba would be in weapons. Reportedly, a small California company that sells to the U.S. government is looking at jojoba oil as a lubricant for machine guns.

Balancing production capabilities, new market development and price concern Arndt and others in the industry. "Let us all in the jojoba business be glad that large-scale industrial demand isn't there yet. If we could not meet it, it might take another 20 years to draw industry back," Arndt said.

Growers like Whittaker, also closely watching the relationship between marketing and jojoba availability, noted that marketing activities may be outstripping production. Even if demand increases, Whittaker said oil prices over $50 a gallon "will ruin the market."

Whittaker believes the jojoba industry can be successful, particularly with better coordination between production and marketing. "It has cost $400 million of private sector money to get the industry where it is. A small investment—$20 to $40 million—for production by the public sector would ensure the success of the jojoba industry," she said.

Crambe

Researchers concur that economics rather than agronomics is the greater hindrance to the commercialization of crambe. "In the past, the only thing holding it up was a committed market," according to Koert Lessman.

Lessman, an agronomy professor at New Mexico State University, has studied the genetics, breeding and agronomics of crambe since 1963. Although the plant is not too far from the wild, he believes enough is known about its planting and harvesting to make it agronomically viable. "The major effort now is to find out where it could be marketed," he said.

USDA first took notice of crambe in the early 1960s when the Agricultural Research Service (ARS) carried out a screening program to identify unknown consti-

tuents or unusual amounts of constituents in plants. At that time, no rapeseed was grown in the U.S., and it was questionable how well it would do. Crambe, with its high erucic acid profile, was considered a good potential replacement for imported high erucic acid rapeseed oil.

According to Kenneth Carlson, an ARS research scientist with USDA's Northern Regional Research Center in Peoria, Illinois, the erucic acid in domestic rapeseed or crambe could be converted to erucamide, ethylene brassylate, behenic acid and other erucic acid derivatives that presently are made from imported rapeseed oil. "Although not a large amount of high erucic acid oil is imported—it's in the range of 10-20 million pounds—the uses are critical," he said. Without erucamide, he noted the manufacture of polyethylene films would be more difficult and their functionality would decline.

Erucamide is an antiblock, slip-promoting additive for plastic films; ethylene brassylate is used as a fixative for fragrances. Crambe oil derivatives, like rapeseed oil products, can be used in nylons, plasticizers and lubricants. From his discussions with industry, Carlson has concluded that "uses for purified erucic acid and for totally new products and applications could push domestic requirements for high erucic acid oil to 50-100 million pounds annually. This won't happen overnight. Some of these products are currently only on the drawing board."

Crambe abyssinica, the most important of the crambe species under consideration, is a mustard family member that originated in the North African plains. The near-wild, white-flowered plants produce tan BB-sized seeds whose oil has an erucic acid content of 55-60%. It's adaptable as a spring crop in the Pacific Northwest, the Midwest and Texas; however, USDA is concentrating its efforts on developing crambe for the Midwestern corn belt, where it is thought to have greatest potential.

Researchers believe they already have proven crambe can be planted, grown and harvested successfully despite minor agronomic problems with seed shattering and drying.

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According to Lessman, three cultivars—Prophet, Indy and Meyer—developed at Purdue University have demonstrated high-yield potential. The Meyer cultivar averages 1,800—2,200 pounds of seed per acre in research trials, and in larger-scale field testing, the best yield was 2,160 pounds, Lessman said. Crambe harvests can range as low as 500 pounds per acre with poor management.

In field studies in western Kentucky, crambe production has been about 900-1,200 pounds per acre in the past few years; ideal production would be 1,700 to 2,000 pounds. Researchers at Murray State University in Kentucky produced crops close to the ideal range in 1978. "The decline in yields since then may have been caused by the recycling of diseased seeds," Durwood Beatty, an agronomist there, said.

The seeds, if diseased, were infected by the fungus *Alternaria brassicicola*. Alternaria, a disease common to all members of the mustard family, is the major potential disease problem for crambe, Beatty said, but the use of suitable fungicides might alleviate that. Noting that the disease is more common in humid areas and that crambe normally matures under drier conditions, Beatty suggested areas such as Nebraska and Wyoming might be better suited to the crop. The studies were established in Kentucky because the crop could be double-cropped with soybeans.

Nebraska and Indiana were the sites of field trials during the late 1960s. In 1972, 3,000 acres were harvested in Ohio, Illinois and Indiana, and the seed was processed in Cleveland, Ohio. Commercial-scale runs occurred in 1974 and 1975 in Culbertson, Montana; in 1978, two runs were carried out in Champaign, Illinois, Carlson said. "The oil produced in those runs was utilized by blending it with high erucic rapeseed oil with no problems."

More recently, steps were undertaken to have farmers in Iowa plant crambe for sale to Humko Chemical in Memphis, Tennessee. The growers were willing to plant 3,000 acres of crambe in 1986, but problems with seed availability caused the agreement to be scrapped. In late 1986, the company again expressed interest in contracting for the crop and was willing to pay growers seven cents per pound, but Iowa State agronomist Donald Wolley said that price would not have convinced growers to plant because break-even is 10 cents per pound. Wolley said the state of Iowa offered to help pay for the crambe seed to get the planting project started but that still would not have been enough to make the crop attractive to growers.

Humko has looked at both crambe and winter rapeseed as high erucic acid sources, but the company has decided to concentrate on rapeseed. "There's no point in our being interested in crambe now. The oil in crambe is roughly the same as high erucic rapeseed oil, which is cheaper now," Charles Leonard, Humko's General Manager, said. A large fraction of Humko's erucic acid needs in 1987 were met with rapeseed grown in Arkansas, Tennessee and Mississippi by the California-based Calgene Inc.

Although Humko has withdrawn from the crambe project, Richard Wheaton, director of USDA's Office of Critical Materials, said there still is a good possibility that crambe could be commercialized by 1990.

Wheaton said project development work is going on with other companies interested in high-temperature lubricants and mining applications for crambe oil. "For the first five years of development, until there is substantial acreage, the crop will have to be grown on a contract-basis or with some other type of support," he said.

Crambe's economic development hinges on finding buyers, but buyers are reluctant to commit to a crop when seed is not plentiful. There are 60,000 pounds of seed presently in storage at Iowa State University. Before companies would be willing to contract for the crop, there would have to be a 10-fold increase in seed availability. "Without committed buyers, people have been very reluctant to underwrite seed development," Lessman said.

Another obstacle to crambe's commercialization is a reluctance on the part of industry to switch from a commercial crop such as rapeseed to an untried one, Wheaton said. Even though domestic production of high erucic acid rapeseed has increased and prices for rapeseed oil have declined, the Office of Critical Materials will continue to support both crambe and winter rapeseed research.

"The main reason we support both is we want a reliable supply at a constant price. U.S. industry sometimes has problems with gyrating prices and fickleness of supply," Wheaton said. "Also, by supporting both crops, we can get in a spring and a fall rotation. Crambe is planted in the spring and harvested in mid-summer, while rapeseed is planted in the fall and harvested the following summer." Crambe also contains higher erucic acid levels in the oil compared to the high erucic acid rapeseed oil currently available.

Another variable that could affect future erucic acid availability for the U.S. is the move in Europe away from high erucic acid varieties. Melvin Blase, an agricultural economist at the University of Missouri at Columbia who studies crambe's economic potential, said the world trend toward lower erucic acid rapeseed varieties for food uses could tighten supplies. This, plus a major breakthrough in uses for erucic acid for industrial purposes, could favorably influence crambe's development.

Blase also said growers may be more willing to grow crops such as crambe as 1995 approaches. "The 1985 Food Security Act specifies that by 1995, farmers are to be practicing conservation to get benefits from USDA programs. That means there will have to be a change in cropping patterns on erosive land. They could plant more wheat, but most do not have a large enough acreage base to do so. Hence, we anticipate that more people will be interested in non-erosive, alternative cash crops. This will present new potential niches for these crops," Blase said.

Blase predicted that crambe will not become a commercial crop until it is market-driven to do so. For a new crop to be developed successfully, Blase said, it must be able to fit into a production, marketing and consumption framework. "All the pieces must be in place for a new crop to succeed," he said.

"A jump can be expected in the demand for high erucic acid oils if new commercial end-products develop as expected. Expanded production of both rapeseed and crambe may be needed to satisfy that demand," Blase said. Before firms will be willing to invest in new product development based on these crops, a dependable supply is essential, he said, adding that the market for erucic acid ultimately will determine the mix of the two crops as well as their production locations.

Cuphea

"Cuphea has a market but needs a technology. Crops such as crambe and meadowfoam are the opposite. They have agronomic technologies but need market development," according to Joseph Boggs.

Boggs, associate director for research and development at Procter & Gamble's industrial chemical division, also serves as chairman of the Soap and Detergent Association's (SDA) technical subcommittee on cuphea.

That SDA technical subcommittee, Oregon State University (OSU) and USDA's ARS jointly fund an ongoing cuphea research project at OSU. SDA member companies supplied approximately $92,500 per year from 1984 through 1986 for the project; OSU and USDA have matched these funds. Last January, SDA agreed to continue funding the project through 1988. Speaking as a member of the SDA, Boggs said, "I am optimistic that in the next five to eight years, we'll know if we have a possible winner. The market is there for domestically produced lauric acid."

U.S. Department of Commerce figures show that in 1986, the U.S. imported 1.4 billion pounds of crude coconut and palm kernel oils for nonfood uses. The Office of Critical Materials would like to see cuphea someday replace or supplement these imports as a source of lauric acid and other medium-chain fatty acids. According to USDA, a domestic crop high in lauric acid would keep prices stable and provide growers with a new industrial crop that would not compete with food crops already in production.

Researchers, agreeing that farmers would be willing to grow a competitive, nonfood crop, added that the need to solve agronomic problems precede economic considerations. "Our mission is to domesticate a C-12 species," according to Steven Knapp, a researcher in OSU's crop science department and principal investigator on the university's cuphea project. There are nearly 300 species of wild cuphea; scientists have narrowed the field to four candidates for possible domestication. In the next year or two, Knapp would like to narrow the list to one or two species. "Some of the more promising cuphea species are *Cuphea lutea*, *C. laminuligera*, *C.lanceolata* and *C. viscosissima*. Each has positive attributes, but there's no clear winner," he said.

Cuphea viscosissima, which contains nearly 80% capric acid, is the only one of the four indigenous to the U.S. and is extremely promising for this reason. According to Knapp, the disadvantage with this species is that it is predominantly a C-10 species. *C. laminuligera*, a C-12 species, and *C. lanceolota*, a C10 species, require insect pollination. According to Knapp, the

problem with these species is that suitable, manageable pollinators have not been identified, thus limiting seed yield.

C. lutea, with 35–40% lauric content, is considered an excellent candidate for domestication. However, the species has problems with seed dormancy. Knapp said researchers are continuing selection work to reduce seed dormancy so that freshly harvested seeds may be germinated immediately.

According to Robert Kleiman, the lead scientist for USDA's new crop utilization program at the Northern Regional Research Center, plant vigor is the most important trait to aim for at this point. "Instead of trying to develop cuphea for its fatty acid profile, we're developing ways to make it agronomically viable. Breeding for other traits will come later," he said.

William Roath, one of four scientists working full-time on cuphea, maintains the project's germplasm collection at USDA's Regional Plant Introduction Station in Ames, Iowa. The collection includes germplasm for 40–50 species and contains 290 accessions which must be studied. This is to provide the genetic variability necessary to manipulate cuphea into a viable crop. In November 1988, a group of scientists plan to go to Brazil for four months to gather more accessions.

Among the agronomic problems Roath is studying are indeterminance, dormancy and seed shattering. Cuphea grows as a bushy plant and flowers intermittently. "This trait makes capturing the yield difficult because seeds develop at different rates," Roath said.

Researchers are trying to overcome this by creating a cuphea plant in which all seeds would be produced on a monoculm, a plant with a single stem. Knapp said German researchers Frank Hirsinger and Gerhard Röbbelen have produced a single stem mutant. Now, researchers at OSU have made crosses using the mutant and are studying the mutant's genetics. Knapp has suggested that the monoculm mutant be used to develop uniform cultivars with determinate fruit production.

Seed shattering remains the largest barrier to cuphea's domestication, sources say. All cuphea species characteristically express a seed-holding trait. "We've made minimal progress at overcoming seed shatter," Roath said. Shattering occurs when the seed pod opens and the seed detaches from it. The seeds then are easily dispersed by wind or rain. While this is a desirable trait in wild plants, it is not suitable for domestic crops, Roath said. "We're looking at selecting plants with closed pods so that we can harvest mature seeds prior to their shattering."

Knapp reports that researchers also are using chemical mutagens to generate mutants that might hold onto their seeds. "It's a matter of time and numbers; we don't know how soon we might find a non-shattering plant," he said. By limiting seed shatter, the recoverable seed yield will greatly increase, Knapp said. "We have collected up to 1,500 pounds of seed per acre in some species, but that was with more than one pass through the field. To be profitable, a grower would have to be able to make that kind of harvest with only one pass with conventional harvesting equipment." Solving the seed-shattering problem and producing plants with determinate flowers would be ways to guarantee harvesting a larger crop with more mature seeds.

Seed shattering remains the largest barrier to cuphea's domestication.

Anson Thompson at the USDA/ARS Water Conservation Laboratory in Phoenix, Arizona, is using interspecific hybridization as a means of overcoming seed shattering, interdeterminance and seed dormancy. He and Dennis Ray at the University of Arizona in Tucson have been making crosses among eight cuphea species.

One cross that has been shown to be vigorous and self-pollinated is the cross between *C. leptopoda*, a C10 species, and *C. laminuligera*, a C12 species, Thompson said. The hybrid, the first between fatty acid groups, was sterile, but treatment with colchicine to double the chromosome number restored fertility.

The fertile hybrid has produced abundant, large-sized seed by natural self-pollination in Arizona, and rooted cuttings have been propagated and sent to Oregon, Iowa and Georgia for agronomic evaluation. "The vigor and the possibility of producing seed without insect pollination may well elevate this hybrid into a primary candidate for production and commercialization," Thompson said. The seed is being analyzed by Kleiman to determine the fatty acid profile of the cross.

Thompson also has crossed *C. procumbens*, a herbaceous annual, and *C. llavea*, a semiwoody perennial. While the cross between the C10 species has proven to be fertile, none of the selections for seed retention have proven to be fully effective.

Other research by Thompson and Kleiman indicated seed maturity may have little effect on seed oil quantity or quality. This led them to conclude that harvesting seed at varying stages of development "does not present a major constraint to the development of cuphea as a new, alternative source of laurics and other medium chain fatty acids. The ultimate significance of these minor changes will depend upon relative yields, demands and values of the various seed components."

"Breeding any crop is scale-dependent," Thompson said. "Given that there are only four full-time scientists devoting their time to the breeding and development of cuphea, 15 to 20 years is not an unrealistic time-frame in which to

produce a new crop." Noting that it takes five to ten years to develop a new variety of corn (already a domesticated crop), Thompson said five to eight years might be overly optimistic for commercializing a crop like cuphea that isn't even domesticated.

The economics of jojoba

Potential Utilization of Agricultural Resources: The Case of Jojoba, a study by the U.S. Department of Agriculture's Economic Research Service (ERS), indicates that in a "best case" scenario, the payback period for jojoba would be eight years. The payback period is the minimum number of operating years needed for a grower to recover the initial investment and the annual costs incurred until that time.

The economic analysis published in August 1987 looked at jojoba's potential performance in a number of situations. The project's objective was to estimate the cost of production and to assess jojoba's economic viability in southwestern U.S. It was part of a larger study examining the feasibility of substituting industrial crops for excess food and fiber crops.

The project's researchers based their findings on a number of assumptions. These included the following:

- Jojoba would be planted on previously developed cotton land. The farm's infrastructure would already be in place.
- The plantation would be 1,000 acres in the lower California desert or in frost-free regions of the Southwest.
- Commercial yields of 400 pounds per acre could be harvested in the fourth year. By the tenth year, harvest average would be 2,000 pounds per acre.
- Processing and marketing costs are 40 cents per pound.
- Ninety-five percent of the yield would be harvested.
- The expected initial price for jojoba oil would be $30 per gallon; the minimum price would be $15 per gallon.
- The analysis period would be 25 years.

Under the base-run analysis where oil prices declined from $30 to $15 a gallon and yields increased from 400 to 2,500 pounds per acre, the study reported, "Jojoba is likely to be a profitable venture with an internal rate of return of about 11%. However, the payback period, at 13 years, is relatively long. Such a long payback period can present a serious financial problem and a need to rely on outside or other special financing arrangement. The long payback period will result in a cumulative maximum negative cash balance of about $3.8 million for the 1,000-acre jojoba plantation."

In the base-run analysis, the average break-even yield was 817 pounds per acre but the actual average harvested yield was expected to be 1,360 pounds per acre. The break-even price for oil based on average yields was $10.28 per gallon; the actual average price was $18 per gallon.

However, in the "worst case" situation in which prices and yields were forecast 30% lower than figures for the base-run, jojoba was not deemed profitable. When prices were reduced and yields were kept at base level, the payback period was expected to take longer than 25 years. When yields were increased 30% and prices were reduced, jojoba was considered marginally profitable, but payback was 17 years. The payback period was reduced to 10 years when yields stayed at base level and prices increased by 30%. In the "best-case" situation in which both prices and yields increased by 30%, the payback period was eight years and the return rate was 23.7%. The study noted that "this outcome is not likely to take place since higher yields tend to increase supply, which is likely to force market prices down."

Meanwhile, some people in the jojoba industry do not believe jojoba will reach its maximum commercial potential until the price drops well below its present level. Soraya Rohde, secretary/treasurer of Desert Whale Jojoba Co. Inc., believes lower prices will only be obtained through greater development outside the U.S. "Getting oil prices down to $10 per gallon or less is the key to success for jojoba as a commercial crop. We're not sure U.S. growers will be able to do that."

However, she added, Latin American growers are able to produce the crop for approximately $10 per gallon and still make a profit. In her estimation, jojoba has enormous potential as a commercial crop in Paraguay, Brazil and Argentina. Figures from her company indicate Brazil and Paraguay each has 4,000 acres planted; Argentina's jojoba area is 3,000 acres. Bolivia and Colombia also are interested in developing the crop, but have much smaller plantations.

"The trend toward developing jojoba in Latin America really began about four years ago," Rohde said, adding, "Several factors make Latin America an ideal jojoba area."

Factors that favor jojoba are low land and labor costs, adequate technology, an active growers' association, and ideal growing conditions, particularly in Paraguay, Argentina and Brazil. Rohde said Latin America also offers a favorable investment climate, especially for Europeans. Among the economic incentives available to jojoba investors are deferred taxes in some countries.