"Amazing" is the word for the variety and quantity of chemicals called fatty acids that are stored by plants in their seed oils. But "difficult" is the word for the task of taking these novel oil-bearing plants to commercialization. The development of a wild species into a crop may take 10-20 years of intense, broadly based research.

The four species described here have potentially bright futures as domestically produced agricultural commodities. We predict that, together, they will have a significant impact on American agriculture in the 21st century.

**Cuphea**

Oleochemical producers are actively participating in research on *Cuphea* (pronounced coo'-fee-a), a genus of the family Lythraceae with about 260 species native to the Americas. Cuphea's industrial promise lies in its unique genetic ability to produce large quantities of specific short-chain saturated fatty acids (with chain lengths of 8, 10, or 12 carbons vs. 16 or 18 in most common fats and oils). These fatty acids, combined with glycerol, are stored as triglyceride oils in the seeds.

Carbon chains are like a string of pearls, with each pearl representing a single carbon atom along the chain. Common medium-chain-length saturated fatty acids in cuphea are caprylic, capric, lauric, and myristic acids, akin to necklaces with 8, 10, 12, and 14 pearls, respectively.

Currently, coconut and palm-kernel oils are the only commercial plant sources of these types of fatty acids, primarily as 12-carbon lauric acid.
Cuphea’s industrial promise lies in its unique ability to synthesize large quantities of specific saturated fatty acids. Outlets for this oil include plasticizers for plastics, and synthetic lubricants.

The United States imports more than a billion pounds of coconut oil per year and uses more than 500 million pounds of lauric acid annually, mostly for the manufacture of soaps and detergents. Because a like amount of lauric-type raw material is supplied by petroleum, cuphea industry representatives believe that demand is assured. The high capric acid (10 carbons) content of some species of cuphea suggests other outlets for this oil in plasticizers (softening and flexibilizing agents for plastics) and in synthetic lubricants. Historically, petroleum has been the source of these materials. In addition, there may be food and medicinal uses for cuphea oils.

Industry spokespersons also point to the economic and political advantages of having a stable, domestic source of medium-chain fatty acids. Coconut oil production is centered in the Philippines, Malaysia, and Indonesia, where weather, increasing domestic consumption, aging plantations, and political instability may affect the availability and pricing of coconut oil in the United States. Scientists project that 5 to 7 million acres of cuphea would meet the worldwide demand for these types of oils.

**Domesticating Cuphea.** Rapid progress is being made toward domesticating cuphea and eliminating its wild traits. These traits relate to seed dormancy (failure to germinate), seed shatter (preharvest seed loss from the plant), and indeterminate growth (continuous and prolonged flowering, resulting in uneven maturity of seeds).
Just recently, the basis for eliminating seed shatter was discovered by Oregon State University scientists in a population of plants resulting from crosses between two cuphea species. With these good seed-retentive cultivars in hand, indeterminate growth is of less concern.

Scientists at Oregon State University also believe that they have eliminated seed dormancy as a constraint on production. This germplasm is also autofertile, eliminating the need for pollinators. Thus, it appears that the most important biological barriers to commercial production of cuphea are well on their way to being eliminated. Scientists are optimistic that these genetic advances will bring cuphea to the commercial test stage in the next few years through the cooperative efforts of academia, the private sector, and USDA’s Agricultural Research Service (ARS). While the genetic and agronomic research continues, the work on extracting the seed oil from the seed, studying the feed value of the defatted meal, and evaluating the chemical and nutritional uses of the oil must also move forward toward commercialization.

Vernonia

Every year, substantial quantities of petroleum-derived chemicals are converted to materials called “epoxies” or epoxy chemicals, which are used in high-technology applications. A familiar use is in two-tube adhesives, where the epoxy chemical in the first tube is mixed with a chemical in the second tube and the two rapidly react to form a very strong bond. Other uses for these epoxies are in the manufacture of plastics, paints, and coatings, and in embedding materials in the electronics industry.

Although soybean and linseed oils can be chemically converted into epoxidized oils, naturally occurring epoxy fatty acids have been found in a limited number of plant species worldwide. One of these, vernonia (Vernonia galamensis, family Asteraceae), grows over a wide area of tropical and subtropical Africa. Its seeds have high quantities of a novel oil containing a unique epoxy fatty acid called vemolic acid. Two other species with seed oils containing epoxy acids are Stokes’ aster (Stokesia laevis), a biennial native to the Southeastern United States, and euphorbia
(Euphorbia lagascae), a native of Spain. Stokes’ aster has received attention in the United States as an oilseed and a horticultural specimen. Euphorbia is being researched in Europe as a source of epoxy oil for industry, but it has problems of severe seed shatter and a milky, irritating sap.

**Why Vernonia?** ARS scientists are determining the feasibility of making vernonia a new industrial crop. Vernonia oil is not seen as a substitute or replacement for the traditional industrial applications of epoxidized soybean or linseed oils, from which it is chemically distinct. One important physical difference that can be exploited is vernonia oil’s relatively low viscosity and its pourability, even below 32 °F, compared with epoxidized soybean and linseed oils.

An exciting possible new use for vernonia oil is in reformulating oil-based or alkyd-resin paints. About 325 million gallons of this type of paint are produced annually in the United States. Organic solvents (diluents) evaporate from these paints during their manufacture and use and react with other chemicals in the air, contributing to the smog that plagues many urban areas and industrial sites. It is estimated, for instance, that 22 tons per day of volatile organic compounds are released into the air from paints and varnishes in California’s Los Angeles Basin alone. The Clean Air Act amendments of 1990 will require the reduction of this kind of air pollution.

Vernonia oil can replace substantial quantities of these volatile solvents...
and function as a “reactive diluent” in these products. Since vernonia oil functions both as a solvent and a reactant in the paint formulation, it becomes an integral part of the dry paint surface and does not evaporate to pollute the air. One pound of vernonia oil in each gallon of paint would reduce volatiles by as much as 160 million pounds per year across the Nation. Such usage alone would require at least 365,000 acres of vernonia production.

Other uses for vernonia oil may include the manufacture of new types of tough, rubbery plastics called interpenetrating polymer networks. Vernonia oil also is known to form clear, tough, yet flexible baked coatings on metals. Other new products are expected to be developed when vernonia oil becomes readily available.

**Vernonia’s Characteristics.** There is no U.S. commercial production of vernonia, but limited acreages are being grown in tropical Africa and Central America. Many companies have received samples of the seed or oil to evaluate.

Until 1990, varieties of vernonia that would flower and produce mature seed within the United States were merely botanical curiosities. Most vernonia varieties require daylight exposures of about 12 hours to initiate flowering. In most of the United States, these plants grow during the spring, summer, and early fall months, but do not flower. Since these plants are from the Tropics, they are easily killed by even light frosts.

ARS scientists are evaluating an array of vernonia varieties collected from the wild in various parts of Africa. They have found one, given the name petitiana, that flowers readily under the long-day growing conditions in the United States. They also found that, except for flowering, petitiana and other varieties of vernonia grow well in many areas of the United States. But petitiana lacks several important agronomic characteristics needed for successful growth in a farmer’s field. Plants mature unevenly, which makes mechanical harvesting difficult. Also, maturing seeds resemble dandelion seeds and are easily lost to the wind.

Scientists are now busy crossing petitiana material with other types of vernonia to combine as many desirable characteristics as possible into one new variety. These new materials are being distributed for the first time in 1992 to cooperating Federal, State, and private-sector scientists for evaluation and selection under a wide array of climatic and geographic conditions. These scientists are optimistic that new adapted varieties will be selected and tested for broad adaptation in the United States within the next 6 to 10 years.

Vernonia seed has been processed by traditional prepress solvent extraction without significant problems. Newer techniques of extrusion processing and solvent extraction are expected to work equally well for recovering oil from vernonia seed. However, further research is needed on preparing the seed for oil extraction and also on using the remaining
Vernonia’s rise to the status of a potential crop offers an excellent example of the importance of individual champions who move ideas (whether about a new crop or a new technology) from the stage of “impossible dream and not needed” to that of “possible, useful, and accomplished.”

In 1957, a small group of scientists, inspired and led by USDA botanist Dr. Robert E. Perdue, Jr., dreamed that Vernonia galamensis could be a useful new crop with important industrial applications. Dr. Perdue collected the original, and much of the subsequent, vernonia germplasm that is available to scientists today. Now retired from USDA, Dr. Perdue still devotes nearly full-time attention to his dream of commercializing vernonia as a natural source of epoxy oil. With steady funding, continuing support from the private sector, and continued dedication of vernonia scientists, Dr. Perdue’s dream will likely come true.

defatted meal. This research should proceed simultaneously with the breeding, agronomic, and product development studies to move vernonia smoothly toward commercialization.

Jojoba
Jojoba (pronounced ho-hó-ba) is another example of the importance of crop champions and stubborn determination to move a wild plant to crop status. The jojoba industry was started in 1971 when Native American communities in California and Arizona, in collaboration with scientists at the Universities of California and Arizona and with support from the Federal Government, collected and processed jojoba seed from wild jojoba plants. The research investment at the time was small, but it was enough to convince a few entrepreneurs of the potential of jojoba oil for use in industrial materials.

Many investors joined the “jojoba rush” to the Southwest after the sperm whale was placed on the endangered species list, the importation of sperm whale oil was banned, and scientific evidence pointed to jojoba oil as its potential replacement in many applications. At one time, as many as 40,000 acres of jojoba were under cultivation, most planted with wild, unimproved germplasm. In the ensuing years, only a few producers of jojoba have survived. They are working to improve jojoba’s germplasm, plantation management, and production practices and to develop additional markets for the oil. The existing jojoba industry has relied extensively on continuing private-sector investments.

Jojoba (Simmondsia chinensis) is a slow-growing perennial native to the Sonoran Desert of Arizona, California, and Mexico. Commercial seed harvest usually begins when the plants are 4 to 5 years old. Unlike other seed oils composed of triglycerides, jojoba oil is composed of liquid wax esters. These are chemicals that result from the union of long-chain alcohols and long-chain fatty acids, each having predominantly 20 or 22 carbon atoms in their chains. Oil is recovered primarily by cold pressing, and additional
oil can be recovered from the press cake by solvent extraction. Although the residual jojoba meal cannot be used in feeds unless its antinutritional compounds are removed or destroyed, ARS scientists have researched a fermentation process that does this, and such meal appears to be acceptable to cattle. Its use in cattle feed, however, will require approval by the responsible State or Federal regulatory agencies.

**Jojoba Production.** The private sector is reported to have invested over $200 million in jojoba plantations over the past 12 years and to have established about 15 million jojoba shrubs that will produce for many years. Jojoba has been commercially harvested in the United States since 1982. Active commercial plantations also exist in South America, Mexico, and Israel, and additional plantations are being established in India, Australia, South Africa, and the Middle East. In 1990, five major U.S. processors crushed 3.5 million pounds of seed from nearly 16,000 acres of actively managed U.S. jojoba plantations. Producers received an average of $3.35 per pound for the seed, which contains about 50 percent oil. Jojoba oil prices were $56-$70 per gallon in large quantities. Over the past 15 years, jojoba has grown to be an $11 million industry at the farm gate, and about $14 million out the processor’s door, with at least 70 percent of these revenues derived from export trade.

**Jojoba Markets.** The cosmetics industry uses more than 90 percent of the jojoba oil produced and will likely continue as the major industrial consumer over the next decade. According to Jojoba Growers and Processors, Inc., this trend of increased consumption is partly due to the industry’s removal of products of animal origin and their replacement by materials of botanical origin. The specialty lubricants market would consume more jojoba oil if its cost were lower. Chemically, jojoba oil is closely related to sperm whale oil, which formerly provided high-performance, high-temperature, and extreme-pressure lubricating properties to automatic transmission fluids. The use of natural, biodegradable oils for lubricants and other applications may increase as this industry also moves.
toward environmentally friendly products.

**Jojoba’s Future.** Once established, jojoba has deep roots and requires only about 2 acre-feet of water per year. As an alternative crop, it can help to relieve pressure on water resources in arid and semiarid regions of the world. But additional jojoba research and development are needed to develop ways of effectively and profitably using the residual meal after oil extraction and to develop new derivatives, chemicals, and products from jojoba oil to increase its markets. Agronomic and genetic research are also required to improve production yields. A strong Jojoba Grower’s Association has served the industry for a decade by helping to establish industry standards for quality control of oil and seed, pesticide registration, irrigation and fertilizer research, plantation management practices, harvesting technology, and germplasm development.

**Meadowfoam**

Meadowfoam is the common name for species of the genus *Limnanthes* in the small North American family Limnanthaceae, which means marsh-flower. Meadowfoam is a herbaceous winter-spring annual wildflower native to northern California, southern Oregon, and Vancouver Island, British Columbia. One species, *L. douglasii*, was carried to England in about 1833 and later distributed widely as an ornamental in northwestern Europe and throughout North America. This suggests high adaptability for cultivation.

Meadowfoam seeds contain 25-35 percent oil. The oil is novel because over 95 percent of its fatty acids have extralong (20- and 22-carbon) chain lengths. These fatty acids are unique in having very high levels of monounsaturation (a single site of reactivity) at the number 5 and 6 carbon atoms and very little polyunsaturation. These characteristics make meadowfoam oil especially stable, even when heated or exposed to air.

The name meadowfoam derives from the appearance of a field of *Limnanthes* in full bloom, a beautiful canopy of creamy white flowers. Marvin Ringsdorf, a meadowfoam grower, tells of flying at dusk and momentarily mistaking a distant field of meadowfoam for the lighted end of an airport runway, because of the field’s brilliant white appearance from the air.

**Production and Markets.**

Meadowfoam has been grown commercially on only a small scale (less than 300 tons of seed), in the Willamette Valley of Oregon, but this production provided valuable experience in cultivation, harvesting, processing of the seed, and refining and marketing of the oil. Most of the oil was exported to Japan for use in cosmetics, personal-care items, and other high-value-added products.

Several other types of products are under investigation, including dimer acids (similar to commercial products used in coatings and adhesives) and estolides (chemicals resulting from the union of two different types of fatty acids). Potential applications for these...
Meadowfoam seeds contain 25-35 percent oil. The fatty acids in meadowfoam oil have very high levels of monounsaturation and very little polyunsaturation. These characteristics make meadowfoam oil especially stable when exposed to air and heat, and one of the most stable vegetable oils known.

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novel products are being explored with the private sector. Liquid wax esters, similar to those occurring naturally in jojoba and sperm whale oils, were synthesized and performed well in lubricant tests. Overall, meadowfoam oil still seeks a large market.

As with any new oilseed crop, the produce-the-oil-first versus develop-the-market-first dilemma is exacerbated by meadowfoam oil’s relatively high cost. This cost results at least partly from inefficient seed production, but more broadly from an immature framework of production (breeding, agronomy, crop management, harvesting), processing (oil extraction and meal use), and market-
products. Plant breeders at Oregon State University have developed a new, more productive cultivar that yields at least one-third more oil, and cross-pollinated experimental genetic lines have yielded more than 800 pounds of oil per acre.

In another approach, the Oregon scientists are researching the development of self-pollinating cultivars, which could revolutionize meadowfoam production if high oil yields can be obtained. This approach, if successful, could lead to the elimination of extra production and management costs associated with the current need for honeybee pollination of meadowfoam in commercial fields. Scientists agree that important biological barriers to the economical production of meadowfoam oil are being conquered, and that these advances are reducing the risks of commercialization. A competitively priced meadowfoam oil could create additional market interest and spur product development by the private sector.

The Evolution of New Crops
Forty years ago, the drive to diversify American agriculture and to develop new crops from wild species began at USDA’s National Center for Agricultural Utilization Research (then the Northern Regional Research Center-ARS) with a chemical screening program on seeds from around the world. Today, the fruits of this investment are being used by many scientists worldwide. The four species discussed here, and those presented in other chapters, are but a few of the species identified in the original research that are currently wending their way to the marketplace. Dedicated scientists have persisted, and thereby ensured that 21st-century agriculture will have new crops.

Recognizing the potential regional and national impact of alternative crops, Congress authorized Alternative Agricultural Research and Commercialization (AARC) Centers in the 1990 farm bill. The goal of the AARC legislation is to foster the commercialization of new nonfood and nonfeed industrial products from American agriculture. It aims to develop an institutional mechanism that can foster technology transfer and thus help overcome barriers to commercialization. □