the production of alternative crops and the construction of processing plants adaptable to several lines of output.

Successful developments of this type would imply important effects on the optimum technical organization of both field and plant organization as well as on costs. They might lead to review and modification of procedures for the coordination of the operations of processors and farmers, and these might call for new forms of contractual relations between growers and processors or even bear significantly on the possibilities and benefits of the integration of growing and processing activities under a single management.

Other illustrations of the possibilities of systems development can easily be visualized. Many of them also would suggest the possibility that systems analysis may stimulate technical developments, which, in turn, create possibilities for new forms of technical organization.

Interaction among the various operating components of agricultural systems evidently has a parallel in the relationship of analysis and development in systems studies.

Comprehensive systems in agricultural production and marketing evidently provide extremely wide possibilities for investigation and analysis and for extending the results of such work into the applied area of systems development.

Such studies embrace the subject matter of many different fields and this suggests the research team as a productive—even necessary—approach. If well organized, such teams would have the capability of deep penetration in special problem areas. They would be equipped for exhaustive search for significant interrelationships among individual system components, but also be prepared to set aside those likely to be of little significance in overall systems operation.

The growing complexity of farm production and marketing operations and the need for improved coordination of existing system organizations and for the development of new process methods and organization may provide a new role—or at least expansion of an old one—for engineering in its service to agriculture.

Machines for New Crops

Leonard G. Schoenleber

We call castorbeans, kenaf, safflower, sesame, and canaigre new crops because of the new interest farmers and industry have in them.

To produce and sell them and other new crops profitably, new or modified machines usually must be developed to produce, harvest, and process them.

Success in establishing a new crop depends also on efforts of plant scientists, who work to change characteristics of the plants to make them better suited to accommodate limitations of machines and increase efficiency. Developments in machinery likewise take into consideration the characteristics and limitations of the plants.

Such factors as the nature and potential value of the crop, climate and soil conditions, and annual use of the machine dictate which, how, and whether new machines are developed or old ones are adapted. Development of a new machine often requires years of research by agricultural engineers, individual enterprises, and manufacturers.

When the potential acreage or value of a crop does not justify the expense of developing a machine by industry, public institutions may initiate and carry on the development work.

Castorbeans contain an oil that is used in the production of more than

200 products. The potential uses of the oil seem unlimited. It is particularly valuable in the manufacture of certain plastics, protective coatings, synthetic lubricants for jet aircraft, all-purpose greases, and hydraulic fluids. It is used in making nylon-type cloth and extruded and molded parts.

The pulp that remains after the oil is extracted is useful as fertilizer. It is known as castor pomace. It contains protein and someday may be used as feed for livestock if a poisonous constituent can be economically neutralized.

Castorbeans were grown commercially, mainly in the Midwest, in the 19th century. Production was hampered by problems in harvesting, handling, and hulling. The large size of the bushy plants, the irregular ripening of the seed, and the susceptibility of ripened seed to shatter made necessary much harvesting by hand as the seed matured. Farmers therefore lost interest in the crop, and production dropped to practically nothing by 1910.

The consumption of oil from castorbeans in the United States has increased steadily since 1900. Most of it was imported. The annual consumption of the oil since 1950 has exceeded 100 million pounds.

The strategic value of castor oil in wartime emphasized the need for a domestic supply. Research was started by employees of the Federal Government to establish production but was discontinued after a while.

World conditions in the 1940's led to the classification of castor oil as a strategic material, and the Government scientists again inaugurated a research program. Intensive studies have been made to develop equipment and better, higher yielding varieties.

One of the first machines was a huller for removing the seed from the pod, or hull. A disk type of huller came into wide use by 1952. The hulling was done by large stationary huller units, usually at a central location, such as a railroad siding, or by small hulling units at the side of the field.

The hullers have a pair of rubber-covered parallel hulling disks. One is stationary and one rotates. They are spaced about three-eighths inch apart. The seeds pass through an opening at the center of the stationary disk. The hulls are removed by the scouring action of the rubber-faced disks as the seed is forced out radially between the disks. A fan separates loose hulls and other foreign material from the seed.

Development of the first experimental harvesting machine started in 1947 in Nebraska. A one-row machine, it used a pair of rotating beaters with canvas flaps for stripping the seeds from standing plants, a cleaner for removing foreign material, and an elevator for depositing the unhulled seeds in a bin mounted on a harvester. Several machines of this kind were built and used.

To encourage the production of castorbeans, the Government began to support prices of the crop in 1949 and contracted with a manufacturer of combines to furnish modified machines that might be used to harvest the castorbeans. The machines had a header attached to a combine to cut the plants near the ground surface. The plants passed through a cylinder and over cleaners that removed the seed capsules, which were deposited in a bin.

A research and development program, started in 1950 by the Federal Government and the Oklahoma Agricultural Experiment Station, led to a machine that used the stripping principles employed on the Nebraska harvester but had modifications to suit the existing varieties.

During the next 2 years, about 200 one-row and two-row tractor-mounted harvesters were built under Government contract to assist in harvesting the greatly expanded castorbean acreage. The machines helped engineers in developing the basic components of effective harvesters, but they only stripped the seed capsules from the plant. Some machines built in 1952 removed foreign material from the unhulled seed, but hauling and handling the bulky unhulled castor material from the harvesters took a lot of time.

At the same time, several companies built a number of one-row harvesters, which stripped the seed capsules from the plant. One company included a huller on one of the harvesters built in 1954. All had many new features.

They made it apparent that a one-man, once-over, two-row machine, which could open a field, strip the seed from the plant, hull and clean the seed, and then place the seed in a bin, would be needed to make mechanical harvesting successful. It became clear also that castorbeans would need to be grown in sections that are relatively dry during harvest. The seed, hulls, and leaves must be dried by frost or defoliation with chemicals to accomplish satisfactory harvesting.

Those principles were taken into account in research by Government workers in 1953 and 1954. They built the first prototype machine in 1955. Machines built since then have included most of the principles they developed.

Higher-yielding varieties, better adapted for mechanical harvesting, have been bred. They are particularly well suited for growing in the Southwest under irrigation. Varieties have been developed also for nonirrigated areas.

Yields of the tall varieties range from a few hundred pounds on unfavorable dryland conditions to yields of 3,500 pounds an acre or more under good management on irrigated areas of California and Arizona.

Dwarf varieties are grown only under irrigation to obtain normal height. In 1960 they were grown in the High Plains of Texas. They normally grow 3.5 to 4 feet tall and are affected little by wind. The crop is much easier to handle than tall varieties, which are 8 to 12 feet tall. Yields of 2,500 pounds an acre of dwarf varieties are common.

Conventional row-crop planters with seed plates adapted for castor seed and regular cultivating equipment are satisfactory. At least 15 to 20 inches of rainfall, well distributed during the growing season, are needed in nonirrigated sections to obtain satisfactory yields.

Castorbeans of varieties now grown commercially need a growing season of at least 180 days for favorable yields.

Four companies were making harvesters in 1960. They were mounted on tractors or were self-propelled and were made in two- and four-row units.

Two companies are providing attachments to mount on self-propelled combines. The changes consist of a header for shaking the seed capsules from the plants with conveyors, a rubber-covered huller with either two rotating drums or one rotating drum and concave, and a bucket or auger elevator for conveying hulled seed.

The two-row machines operate best at 3 miles an hour or less and harvesting at the rate of 2 acres an hour in fields that yield 2,500 pounds an acre. A two-row machine commonly harvests 500 acres of beans a season.

KENAF is a soft-bast, long-fiber plant. In experimental plantings of jute and jutelike substitutes that can be grown in the United States, it was one of the most promising. Such materials are used to make rope, twine, bags, burlap, and similar items. We have depended on imports for them—169 million pounds of raw jute fiber and 753 million pounds of products made from jute were imported in 1956.

Kenaf is less susceptible to diseases and insects and is less exacting in growing requirements than jute. It will grow well in most parts of the South and yields up to 2 thousand pounds of fiber an acre.

It is grown as an annual on land prepared as for other drilled crops. The seed is planted easily with an ordinary grain drill. The rapid growth of the plants chokes out weeds. The stalks are .5 to .75 inch in diameter and are 8 to 12 feet tall at harvest. When seeded at the rate of 25 pounds an acre, the stalks are free of branches except at the top.

Because much hand labor is entailed in cutting, retting, separating, grading, and bundling, agricultural engineers in the Department of Agriculture and the

Florida Agricultural Experiment Station began work to develop machines.

They developed a field harvester-ribboner, which will harvest the stalks and remove the leaves and woody core, with only the bast fibrous ribbons to be taken from the field; a mechanized process of conveying the ribbons through a bacterial retting process; and washing and cleaning machinery for treating the fiber after the ret.

The harvester-ribboner has harvesting, crushing, and ribboning units.

The harvesting unit gathers the stalks from a 32-inch swath, separates those to be cut from those left standing, cuts the swath at the ground, removes 12 to 18 inches of the tops (which contain most of the leaves and practically no fiber), and delivers them to a feed table on the machine.

The crushing unit mashes and breaks the woody core of the stalk at 6-inch intervals. The ribboning drums, 36 inches in diameter with a 20-inch face, have 6 blades with scalping edges. The ribbons from the bast layer surrounding the woody core of the stalks are delivered at the rear of the machine free from leaf material and most of the woody part of the stalk.

Improvements in the machine have reduced field losses, increased the capacity, and reduced the number of men needed to operate it. Three men can harvest about 1 acre an hour. An acre should yield about 3 thousand pounds of dried ribbons, or half that amount of dried fiber after retting.

Ribbons may be treated in several ways. They may be dried and spun into coarse yarns without further processing at harvest. The green ribbons may be mechanically decorticated; the fiber is dried and spun without further treatment. The ribbons also may be chemically or bacterially retted before spinning. Bacterial retting produces a fiber more nearly equal in quality and spinning characteristics to the Indian jute that American manufacturers are accustomed to handling. Most manufacturers demand fiber of the quality produced by water retting.

A number of retting procedures that produce acceptable fiber have been investigated. Methods of securing uniformity and mechanization of the handling processes were being investigated in 1960.

In order to make the production of water-retted fiber feasible in this country, a completely mechanized process of large capacity must be developed. Machinery to do this has been devised and has been undergoing tests and improvements in the fiber laboratory at Belle Glade, Fla.

The process involves a series of squeezing-washing operations to remove slime and loose extraneous material. A scutching operation removes shives, bark, and such from the fiber. Subsequent squeezing removes the last traces of discoloration that may develop from the scutching operation, and the clean fiber is ready for drying and baling. Artificial driers and baling machinery developed for other fibers are suitable for handling kenaf fiber in large-scale operations.

Machinery has been developed for extracting and processing other long fibers—sansevieria for rope and marine cordage, ramie for textiles and industrial products, and lecheguilla for brushes and like products. The machinery for fiber extraction can be used with minor modification on most of the long-fiber plants. Equipment for drying, brushing, and baling can be used for all the fibers with little change.

None of these fibers was grown commercially in the United States in 1960, but the mechanical developments may make it possible to produce enough of them to meet a considerable part of our needs if an emergency occurs.

Safflower, an oilseed crop grown in India and other parts of the world for centuries, is a new crop for American farmers. Its seed may contain up to 35 percent of oil. Its drying and non-yellowing properties make it useful in paints and varnishes. The processed oil is edible. The seed pulp and hulls that remain after the oil is removed contain about 25 percent of protein, a feed supplement for livestock.

This drought-tolerant plant was introduced in this country on an experimental basis in the 1920's. More than 200 thousand acres of safflower were grown in 1959.

The crop is well adapted to parts of the Western States that have a low relative humidity. Best yields are obtained when the atmosphere is dry and hot during the flowering time and enough subsoil moisture is present throughout the growing season. Irrigation, which is controlled so as not to encourage root rot, a common disease, increases yields when rainfall is deficient.

Safflower, an annual of the thistle family, grows 1 to 5 feet tall. The average yield in California was 1,700 pounds of seed an acre in 1956. Average dryland yields of 700 to 1,200 pounds an acre are common. The seed sells for about twice the price of barley. The oil sells for about the same price as linseed oil or soybean oil.

Safflower can be planted, cultivated, and harvested with the machinery that is used for small grains. Its future as a cash crop in the United States looks bright. Disease-resistant varieties, which produce more seed of a higher oil content, are being developed.

SESAME is one of the oldest oilseed plants known to man. Its seed is used for food and feed. The seeds contain about 50 percent oil and 25 percent protein, which is highly digestible, and are used in baked goods, candies, and other food products. The oil is used in cooking and for making margarine, shortening, paints, soaps, and pharmaceutical products.

This plant, of tropical origin, produces best in places where the temperature remains high during the growing season. This includes the southern half of the United States.

The crop was first grown in this country in the 17th century, but interest in growing it on a commercial scale did not develop until about 1953. The acreage has increased steadily each year since then. About 15 thousand acres of sesame were grown in 1959.

Yields of more than 2 thousand pounds an acre have been had. Average yields of 600 to 1,500 pounds are commoner.

Sesame, an annual plant, tolerates drought, but responds well to proper irrigation. Plants that stand in water only a few hours are damaged or killed, however.

Sesame can be planted and cultivated with equipment used on other row crops. Seed boxes used for small vegetable seeds can be used satisfactorily for planting the seed of sesame.

Harvesting has been a major problem. The two types of seed—the dehiscent (shattering) and the indehiscent (nonshattering) varieties, both adapted for growing in this country—are difficult to harvest. The dehiscent varieties lose seed readily because the seed pods open during the maturing process and scatter seed. The seed pods of the indehiscent varieties are very tough and hard to open.

Injury to the seed reduces its viability. Seeds even slightly cracked produce objectionable free fatty acids in a short time and become unfit for human food. The dehiscent varieties mostly are grown in the United States.

A common method of harvesting is to cut the crop with grain or row-crop binders and place it in shocks as soon as the plants reach maturity, when most of the leaves drop. The shocks are made compact by tying with twine to prevent loss of seed as the shocks cure. After 10 to 14 days of normal curing weather, the shocks are ready to thresh. Grain combines are used for this purpose.

A platform at the front of the combine helps cut seed losses. The combine is driven to each shock; the whole shock is pushed onto the platform to avoid excessive handling. Bundles are fed from the platform into the machine one at a time. Loose seed that falls on the platform is saved by dumping into the combine. Proper adjustment and speed of the threshing unit is essential; otherwise, seed damage will be excessive.

Research on another type of harvester has been undertaken in California. It picks up windrowed sesame, chops the stalks, knocks out of the pods the seed that has not already shattered, runs the seed over a cleaner, and conveys the seed to a bin on the machine. Four rows of plants are cut with a windrower and placed into an irrigation furrow, which should be wide and shallow. Slicking the furrow with a sled fills the cracks and smooths the surface to provide a suitable area for drying the stalks. Dehisced seed, which falls to the bottom of the furrow, is picked up easily by the gathering arms and air equipment on the harvester.

Sesame can be grown in many sections. Further research is needed to develop higher yielding varieties that are easy to thresh but less subject to shatter than existing varieties, so that direct combining may be done from standing plants. New methods of harvesting may have to be developed also.

CANAIGRE has roots that are rich in tannin, which is important in the manufacture of leather goods and in other uses. Nearly all our tannin has been imported.

This perennial herb, native to the United States, grows from seed, crowns, or root. It tolerates drought and is well adapted to the Southwestern States, but for good yields the crop should be irrigated. Production yields of 15 tons of roots to the acre may be expected under good growing conditions. Yields exceeding 25 tons have been obtained in trials with improved varieties. The freshly harvested mature roots contain about 70 percent of water. The remaining dry matter contains about 35 percent of tannin.

Canaigre roots were used by Indians and early settlers for tanning hides and as a dye and medicine. Now they are used mainly in the manufacture of leather goods. Attempts were made to commercialize canaigre as a source of tannin during the 19th century. The roots were dug by hand from wild stands.

Experimental plantings of canaigre in Arizona have demonstrated that the crop can be handled with ordinary planting and cultivating equipment. The crop is ready for harvest usually by July 1, when the tops die back to the crown.

An experimental digger, built by men in the Department of Agriculture, embodies the main mechanical features of a potato digger but permits deeper penetration of the digger blade to get under the roots. Long shaker chains and a special clod crushing roller aid in the cleaning of the roots. Present commercial potato harvesters with certain modifications should make them adaptable for harvesting canaigre. Bulk methods of handling root crops during harvest and storage can be applied to canaigre.

Roots processed immediately after drying may require further cleaning to remove all remaining soil. Vegetable washers can be used when the agitation of the roots and the rate of cleaning are controlled.

Roots held for later processing require proper storage. The cheapest and best method is to pile the freshly dug, unwashed roots on the ground and cover them with straw to protect them from the hot sun. Undamaged roots stored in this manner should remain in good condition for a year. Good yielding varieties and suitable equipment make possible the production of canaigre on a commercial scale.

THE NEW technology that is accumulating in agriculture and in other industries will have an even greater impact on development of equipment for new crops than experienced in the past. These fascinating new machines and new crops that cast their shadows on the countryside are attracting the attention of farmers and are making possible avenues for new income with efficient farming and better life for the farm families.