Reading 28
Root Crops

"Root crops" is a convenient catch-all for a wide assortment of species scarcely less important as food plants than the groups discussed in the previous chapter. More than 500 million metric tons are produced annually for human food. The common feature of root crops is their fleshy underground storage organ, often a true root but sometimes a rhizome (tuber), corm, or bulb. Compared to cereal grains and legume seeds, food stored in fleshy roots and tubers is watery and less concentrated. Thus root crops are not generally as easily kept, transported, and marketed. Most are abundant in starch or sugar and low in protein and oil, and hence are useful "energy foods" but do not by themselves supply a balanced diet. Some consumed as fresh vegetables (such as carrots, garlic, parsnips, radish, and onions) are prized more for their flavor, vitamins, and subtle nutrient qualities than as sources of energy. Just the opposite is true of potatoes, sweetpotatoes, cassava, and sugar beets.

World gross tonnage of the major root crops is not much less than for the major cereals, although, as noted, the dry nutrient content of root crops is much less (a potato, for example, may be 80% water). Annual world production of potatoes is nearly 300 million metric tons, sweetpotatoes more than 140 million metric tons, manioc or cassava more than 100 million metric tons. Nearly 300 million metric tons of sugar beets are harvested annually. World production and consumption of fresh vegetables is difficult to ascertain, but some 18 million metric tons of onions and 7 million metric tons of carrots make up part of the total.

Numerous roots and rhizomes of wild species can be consumed for food in times of emergency, as many an early explorer learned perforce. Wildlife and primitive peoples have always made use of indigenous bulbs, roots, and tubers. Some species, changed little if at all from the ancestral form, are collected or planted in limited areas today. In the Peruvian Andes, for example, a great many root plants little known in other parts of the world (*Arracacia*, *Lepidium*, *Oxalis*, *Pachyrhizus*, *Tropaeolum*, *Ullucus*) are regularly eaten and marketed. The same is true of certain sedges (*Cyperus*), aroids (members of the family Araceae), and *Coleus* ("frafra potatoes") in Africa. In the hill country of India, soh-phlong (*Moghania vestita* of the Leguminosae) is a minor food source, in some respects more nutritious than conventional root crops (Table 1). But no other root crop promises to rival the potato as a staple food in temperate climates, or the cassava in tropical climates.

Table 1. Chemical analysis of soh-phlong, sweetpotato, and cassava.

	Approximate net weight (%)		
Constituent	Soh-phlong	Sweetpotato	Cassava
Moisture	67.9	68.5	59.4
Protein	3.0	1.2	0.7
Carbohydrate	27.0	31.0	38.7
Mineral	1.0	1.0	1.0
Calcium	0.020	0.030	0.050
Phosphorus	0.064	0.049	0.040
Iron	0.003	0.001	0.001

Potato, *Solanum tuberosum* (Solanaceae)

The Common potato is a member of another large and important plant family, the Solanaceae. Among its close relatives are eggplant and tomato, and in the same family is tobacco. The genus *Solanum* is a large one, comprising about 1700 species, many of them poorly described and incompletely understood. Various wild *Solanum* species produce small potatolike tubers, which from time immemorial have been grubbed from the ground by the Indians. One or more of these was domesticated in the Andes Mountains of Bolivia and Peru, certainly prior to 200 AD, to become the cultivated *S. tuberosum*. The diploid chromosome complement in *Solanum* is 24, with *S. tuberosum* ($2n = 48$) being an autotetraploid. Triploid and pentaploid relatives are known as well. *S. tuberosum* spp. *andigena* is hypothesized as the ancestral subspecies of the cultivated potato, itself perhaps descended (at least in part) from *S. sparsipilum* or *S. stenotomum*. In typical Indian plantings in the American tropics, many "wild" potatoes flourish about the fields and between the planted rows. Doubtless some hybridization and introgression continues to take place today, as must have occurred abundantly in the evolution of *S. tuberosum*. Archaeologists have found representations of the potato incorporated in designs on early Andean pottery. The potato is still cultivated as a staple in its Andean homeland, where, better to preserve its food value and to build reserves against a poor harvest, potatoes are made into "chuño." Chuño is prepared by trampling and drying the potato during alternate freezing and thawing.

The potato was presumably first seen by a European in 1537, when the Spanish landed in what is now Columbia. New World explorers and monks became familiar with it in the decades that followed, and it was brought back to Europe by 1570. It was cultivated throughout the Continent before 1600, and in Ireland by 1663. The cultivated potato is said to have been first introduced into North America in 1621 (presumably via Bermuda), Not until 1700, however, was the potato extensively planted. One reason for its sudden prominence in Europe during the 1700s was that reigning sovereigns, recognizing its food potential, compelled the people by royal edict to plant it (Germany, 1744; Sweden, 1764). Especially in Ireland was the potato adopted as a mainstay food, and when the late-blight disease (caused by the fungus *Phytophthora infestans*) wiped out the crop two years in a row in the 1840s, famine forced large-scale emigration to America. One might speculate that the Irish introduction stemmed from one narrow genetic source, and that—had the great genetic variability of the potato in its South American homeland been available—famine might have been avoided and the course of history materially changed. Even before the Irish immigrants came to the United States, introductions of the potato into New England from Ireland had given it the appellation "Irish" potato. It is sometimes referred to as "white potato" to distinguish it from sweetpotato (a different family entirely), but the use of this adjective ignores the many colored varieties.

It may appear strange that a plant from the New World tropics should have become so important in temperate Europe. Keep in mind, however, that in the New World the potato was a highland crop, grown at elevations in the Andes that were too cold for corn. Basically it is adapted to a cool environment, and it will not yield well when temperatures average about 21°C (70ºF). However, the many freely intercrossing species related to *S. tuberosum* afford great plasticity for selection, and types adapted even to the humid lowland tropics (certainly the dry highland tropics with irrigation) have proven to give yields as high as 15 metric tons per hectare in 60 days.

Today the potato is grown chiefly in Europe, with more than 200 million metric tons being harvested annually, if Soviet production is included. China produces more than 40 million metric tons, and North America about half that. The potato's ancestral homeland, South America, altogether produces only about 9 million metrics tons per year. The Soviet Union, Poland, and China are the leading potato countries. In the United States, some 8 million metric tons of potatoes are produced annually for the table, and another 6 million metric tons are processed (mostly for potato chips, frozen French fries, dehydrated mashed potatoes, and starch). Nearly 1 million metric tons each may be utilized for animal feed and propagation.

The food value of the potato varies, depending on variety, growth conditions, storage, and handling. Analyses have indicated its composition to be 70-81% water, 8–28% starch, and 1–19% protein (most cultivars have around 5% Kjeldahl nitrogen, perhaps half of it not in protein form, and with varying amino acid composition), with traces of minerals and other food elements. There seems ample opportunity to breed new cultivars nutritionally better balanced and as productive of protein as is the soybean. In comparison with other familiar foods, the potato is fairly economical, the cost per kilocalorie being roughly in the same range as that of bread and margarine, much cheaper than meat, but half again to three times as costly as sugar. In Europe much of the potato crop is fed to livestock, and an appreciable portion is used for fermentation or for starch for industrial purposes. In the United States, cull potatoes–those not used as food because of poor appearance–are utilized for animal feed and for industrial purposes. Potato starch is nowadays less important than corn starch, but potatoes mill more easily than corn, as they do not require preliminary soakings and separations, although final concentration by centrifugation or in starch tables is similar to the handling of corn starch. Potato starch goes chiefly into sizings for textiles and paper, and to some extent into confections and adhesives.

The potato tuber is anatomically a stem, with external buds (eyes) that are able to sprout into new growth. Sections of potato with a bud (eye) are conventionally used to vegetatively propagate and maintain potato varieties, since sexual reproduction through true seed would be slower to yield and would risk changes due to genetic segregation. In China and the tropics, however, newly inaugurated systems of growing potatoes from true seed are being undertaken. Potatoes saved for propagation, some 7% of the crop, are unfortunately termed “seed” potatoes, but of course they are not true seed.

Only since 1850 have there been serious attempts to improve the potato. A century ago plantings started “running out,” gradually decreasing in yield, probably because of accumulation of tuber-transmitted virus diseases. Since then new introductions have been secured from throughout the Americas and entered into a breeding program. A large germplasm collection is maintained for breeding at the USDA Experimental Station at Sturgeon Bay, Wisconsin.

Potatoes are grown in all states of the United States, but Aroostook County, Maine, is responsible for about 3 times as much production as the next most productive counties (Kern County, California; Bingham County, Idaho; and Suffolk County, New York). Yields under irrigation in Idaho have been phenomenal—averaging some 33 metric tons per hectare (about 15 tons per acre), with some fields yielding 78 metric tons per hectare (about 35 tons per acre). (Some agronomists have predicted yields as high as 225 metric tons per hectare eventually. Few food plants can boast this productivity potential!) Winter and early-spring potatoes come from Florida and southern California, late-spring and early-summer potatoes from the southern and border states, and late-summer and fall potatoes from the northern half of the nation, where nearly three fourths of the domestic crop is grown.

Sandy, well-drained loams, and soils high in organic content, are generally best for potato growing. In Idaho, the leading producing state in the United States, vital soil moisture is generally provided by irrigation, The potato is responsive to day length; in general, long days stimulate stem elongation, and short days stimulate tuberization. Under short days with low light intensity, foliage tends to be soft and more susceptible to late blight, whereas tinder long days and higher light intensities, foliage tends to be more resistant to late blight. Thus a variety grown in Florida in winter may have considerable blight trouble, but it may be relatively immune when grown in Maine in summer.

Potatoes are planted in well cultivated land, often after plowing down a legume or green manure. Ample organic matter keeps soil crumbly, which is beneficial to potato growth, and it facilitates digging. Moderately acid soils favor scab-free tubers. More than 2 metric tons of fertilizer per hectare (about 1 ton per acre) is used in commercial potato growing, bringing the average yields per hectare to more than 22 metric tons in the United States (triple the yield of only 30 years ago).

Seed tubers certified free of disease are the preferred planting stock. Fusarium wilt, wart, corky ringspot, and powdery scab are examples of diseases that might permanently infest the soil if uncertified tubers were used. It has been shown that the geographical source of "seed," as well as storage conditions, can have an influence on yields of subsequent plantings. Moreover, varieties differ in dormancy requirements, ability to sustain repeated desprouting in storage, and response to chemical dormancy treatment. It was once common practice to disinfect tubers before sectioning for planting, but with improved seed stock this is not so critical. In some areas whole (small size) potatoes may be planted as seed, both to avoid the spread of disease (on the sectioning knife) and the cost of sectioning. In the United States, both sectioning and planting are mostly done mechanically.

Choice of spacing, depth of planting, and mode of cultivation are determined partly by variety and partly by local conditions. Spraying and dusting to control insects and diseases are common practices today, in keeping with intensified modern agriculture. Dozens of afflictions can affect tuber quality, and equally as many preventatives can be advocated. Weeds are controlled chiefly by cultivation, but pre-emergence herbicides are increasingly being used.

Potato tops must be eliminated to facilitate mechanical digging. This can be done chemically or physically. The digging machines then "sift" the soil from slightly below tuber depth, screening the tubers and depositing them on elevator lifts that carry them to adjacent vehicles for transportation from the field (Fig. 1). More than 90% of the crop is now harvested mechanically in the United States.

Fig. 1. Machine harvesting of potatoes from muck soil. [Courtesy Purdue University.]

Considerable loss can arise from bruising potatoes during harvest. Care must be taken in handling and storage to avoid this injury as much as possible. Most potatoes are washed (with spray jets) to remove soil before marketing, and this, too, may encourage injury and rot. In northern producing areas, a goodly portion of the crop is stored on the farm in such facilities as pit houses, where low temperatures discourage sprouting. In larger storage facilities, special air circulation and ventilation may be needed. Potatoes are preferably kept at about 4°C (39°F). About 10°C (50°F), sprouting is stimulated within a few months, although this can be inhibited by chemical treatment with maleic hydrazide. The processing quality of potatoes intended for french fries and potato chips is improved if they are held for some time (from a few days to a couple of weeks) at 15 to 21°C (60 to 70°F) before processing to avoid an undesirable brown discoloration caused by the formation of reducing sugars. This treatment is called reconditioning. During this period the concentration of reducing sugars (glucose and fructose) is decreased, partially by respiration and partially by conversion to starch.

Cassava, or manioc, *Manihot esculenta* (Euphorbiaceae)

Cassava, a member of the family Euphorbiaceae, is a species of the tropical lowlands, probably domesticated in northern Amazonia. It adapts to poor soil and casual cultivation, and has consequently become a staple food in many of the poor and developing parts of the world. Mandioca, yuca, tapioca, and sagu are other common names by which the cassava is known, and in Africa (where it was introduced by the Portuguese in 1558) more than a half dozen vernacular names prevail. The Latin name, *Manihot esculenta*, represents a huge complex of cultivars that taxonomists have from time to time tried to separate into distinctive species with but little success. Thus *M. utilissima*, *M. dulcis*, *M. aipi*, *M. palmata*, and other proposed species are generally regarded as synonyms of *M. esculenta*. Scores of wild *Manihot* species grow in eastern South America, but it is not known whether any of these are ancestral to modern cassava cultivars; indeed, with widespread abandonment under primitive slash-and-burn agriculture, it is difficult to distinguish between occasional escapes and wild plants.

Although one of the world's most important food staples, cassava is known in North America and Europe almost solely as tapioca, an occasional dessert. But in remote tropical areas, such as the Amazon valley, it may be almost the sole cultivated plant. World production is reported to be about 110 million metric tons annually, but the figure may not reflect scattered local production in remote locations. Brazil is the leading producer of cassava, with Indonesia probably second (cassava is the third most important food staple in Indonesia, after rice and corn). Cassava is not as esteemed in Indonesia as are other foods, but it is often the only crop that can be economically grown on poor, exhausted land. Cassava is also an important staple in several tropical African countries, especially in Zaire and Nigeria.

The cassava plant is a shrubby, monoecious perennial that produces several swollen roots that resemble sweetpotatoes and develop from a central trunklike stem. The palmate leaves are quite characteristic of the genus, and they have been investigated as a tropical source of protein for livestock feed (the foliage is about 30% protein). The roots contain little protein (1.2–2.7%) or oil, but are about 30% starch, found chiefly in the voluminous pith. Yielding up to 40 metric tons per hectare with little attention, cassava is one of the more remunerative crops. Its cultivars are vaguely grouped as "bitter" or "sweet," having respectively relatively high or low concentrations of a cyanogenic glycoside. The poison is found mainly in the periderm and shallow cortex. Sweet cassavas require no special treatment before consumption, but bitter varieties are shredded, squeezed, cooked, and treated in other ways to rid them of the poisonous juice or to reduce its toxicity. There is no clear cut demarcation between these two groups, as the glycoside content varies with individual plants and cultivars. There has been some speculation that low doses of cassava glycoside can be prophylactic, preventing several human ills!

Under the typical slash-and-burn agriculture of the tropics, cassava stem sections are hand planted in holes grubbed into the soil just before the rainy season. Extensive feeder roots grow quickly, making full use of the evanescent soil fertility. In most cases the crop is quite responsive to fertilizers, especially those high in potassium. If all goes well, within as little as 7 months a number of starchy roots can be harvested from each plant, although best yields are not obtained until after 16 months. If allowed to grow for too long a time, however, the roots become rather woody and less edible. Cassava is a heliophile, performing best in full sun. Otherwise it is broadly tolerant, with local selections adapted to a wide variety of soils, pH values, and moisture conditions. In agriculturally advanced parts of the tropics, such as in Jamaica and parts of Central America, cassava fits well into rotation with corn and other cultivars. In some areas the cassava crop is undersown with a ground cover, such as *Stylosanthes*, to protect and improve the soil, and to increase top growth (important for livestock feeding, especially during the dry season), In Indonesia the "mukibat system" is sometimes employed, in which especially "good eating" types of *M. esculenta* are grafted to stocks of *M. glaziovii*, which increase yield and facilitate crop growing.

Cassava is used in a number of ways. The whole root may be boiled; it has a sticky, "heavy" consistency, and of itself is rather tasteless. In Brazil it is usually shredded, then heated and dried, to make a meal known as *farinha*, eaten alone if need be, or mixed with other food and sauces. In Indonesia the roots are sectioned, dried in the sun, and later ground into meal. In the making of tapioca, an important export from Indonesia, the peeled roots are grated, the mass soaked in water for several days, kneaded, strained, dried, and then heated to partly hydrolize the starch to sugar and gel particles into "pearls" while being agitated on a grill. In Jamaica roots are ground into a mush called *bami*, or formed into cakes called *casabe*. In Africa boiled roots are often pounded into a thick paste called *fufu*. In many parts of the world cassava mush is fermented into a beer that is much like *chicha* (which is usually made from corn). The heat and pressure of grinding cassava serves to change or remove poisonous glycosides. Juices expressed from bitter cassava are usually saved for fermentation to beer, or they may be variously treated to yield meat sauces such as "West Indian pepperpot."

Low-amylose starch from cassava is a minor item of commerce, being imported from the Far East into North America and Europe for foodstuffs, sizing, and adhesives. Leaf-protein extraction similar to that undertaken with alfalfa has been attempted. Regulated cassava fermentation can yield alcohol (important in Brazil as a back up for fuel from sugarcane) or butanol and acetone. Or fungal protein can be secured by inoculation with *Aspergillus fumigatus* and the addition of traces of urea, potassium phosphate, and sulfuric acid (to obtain a pH of 3.5). Starch hydrolysis is a source of glucose.

Sweetpotato, *Ipomoea batatas* (Convolvulaceae)

In many respects the sweetpotato (Fig. 2) reminds one of the cassava root. It contains about 30% solids (mostly starch, but some sugar, and not inconsiderable minerals and such vitamins as ascorbic acid), concentrated especially in the storage parenchyma of the xylem. The protein content of most cultivars is about 5–7% of the dry weight. Yields as high as 40 metric tons per hectare (about 18 tons per acre) are obtained. The sweetpotato is a trailing vine adapted to tropical lowlands, and cultivars are propagated vegetatively. The cultivated sweetpotato is a hexaploid ($2n$ = 90), and it may have been domesticated from the ill-defined *I. trifida*, a wild hexaploid species, or other tropical American entities, such as *I. tiliacea*, *I. gracilis*, and *I. trichocarpa*. *I. batatas* is a short-day plant, flowering with a photoperiod of 11 hours or less. It grows best where the average temperature is not less than 24°C (75°F).

The spread of the sweetpotato from its presumed ancestral home in Central America or South America has been gradual and unspectacular. Tubers 10,000 years old have been discovered in coastal Peru, so it has long been under cultivation. It was apparently introduced into southern Europe very early in the Colonial period, and was carried by navigators of the 16th and 17th centuries to the Far East, where it found greater favor than in its homeland or Europe (but evidence of the sweetpotato in Polynesia dated to 500 AD is an enigma still to be explained). Especially in China and Japan, the sweetpotato has become an important food plant; it is very productive on the intensively managed uplands in rotation with other crops, such as grains. In many parts of the world the sweetpotato is used more as a nourishing livestock feed than for human consumption. Whether baked or boiled, the sweetpotato is more flavorful than most root crops, especially the moist, reddish cultivars favored in the southern United States, where they are popularly called “yams” (most northerners favor the drier, light yellow cultivars).

World sweetpotato production runs about 140 million metric tons annually. China is by far the leading sweetpotato center, although the root is extensively grown in many other Asiatic countries, and in many Latin American and African ones, too. One-third of the United States’ production comes from North Carolina. Some cultivars rarely flower, and the sweetpotato has proven temperamental in breeding programs. It is often self-incompatible due to 3 separate genes. Both incompatibility and sterility are influenced by environment. Commercially the sweetpotato is vegetatively propagated from numerous sprouts that originate at the head of a root when it is kept moist and warm. A certain percentage of the crop is saved to produce new planting “slips”. Although the plant is a perennial, slips grow fast enough to yield roots on an annual basis. Slips are generally planted into hills or rows by hand. In the Far East, whatever cultivation and weeding is needed is done by hand, as is digging of the roots at about the time of killing frost. In the southern United States the same type of mechanization as was developed for harvesting the potato is increasingly being used. Throughout much of the world the sweetpotato is a home-garden plant that never goes to market. Roots are generally dried for several days (to form a protective periderm) and then stored in a cool place. Because sweetpotatoes do not keep as well as potatoes, they are sometimes cut into slices and dried, especially when they are to be used for industrial purposes. In Japan and Korea the dried sweet potatoes may be ground into a meal, which in turn can be cooked for human consumption or fermented for alcohol.

Fig. 2. The edible portion of the sweetpotato is the tuberous root. [Courtesy J.C. Allen & Son.]

Beets, *Beta vulgaris* (Chenopodiaceae)

There are 2 major groups of beet cultivars, the gross sugar beets and the delicate table beets, best adapted to temperate climates. The former are used somewhat as livestock feed, but have been selected principally for the extraction of their high sugar content. Both are biennial, although they are planted and harvested as annuals. Table beets are generally consumed when young, a few weeks after planting, when the swollen roots are sweet and tender. More than 0.5 million metric tons are grown annually in the United States. They are about 8% carbohydrate and 2% protein. Cultivated beets are presumed to be derived from the wild beet of northern Europe, *Beta maritima*. Close relatives are chard and the white-fleshed mangel-wurzels. The leaf of chard is eaten as a green, which seems to have been the case also with the original cultivated beet in pre-Christian times. In northern India, foliage of the annual *B. vulgaris* var. *orientalis*, the *palang* or *palanki* of the marketplace, is likewise consumed. The modern table beet was apparently not developed as a garden plant until about the 16th century.

Sugar beets have much more commercial value than table beets. Through selection and breeding, their sugar content has been increased from the 2–4% that is normal for table beets to as much as 20%. The annual harvest of sugar beets is about 300 million metric tons, and yields average about 50 metric tons per hectare (a little more than 22 tons per acre). Most of the world crop is grown in Europe. The USSR is the leading producer, followed by the United States, France, Germany, Poland, and Italy.

The sugar beet received its greatest impetus after 1747, when the German chemist Andreas Sigismund Marggraf proved that sugar from beets was identical with that from sugarcane. The King of Prussia became interested, and in 1802 financed the first beet-sugar factory. A few years later, Napoleon also became interested, for naval blockades had cut off the supply of imported sugar, and he hoped to supply his armies with sugar produced domestically. The French people never became enthusiastic about growing sugar beets, however, and after Waterloo the industry collapsed in France as the importation of cane sugar was resumed. In the United States, sugar beets were first grown in the Philadelphia area in 1830, and shortly thereafter in Massachusetts, Michigan, and finally, with most success, in California. California, Minnesota, Idaho, and North Dakota are prominent sugar beet producing states today.

Sugar beets are well adapted to a diversity of soil and climatic conditions, and today are grown in many states, drill planted in early spring. New, better yielding cultivars, and new monogerm seed (which produces a single plant rather than clusters and thus saves thinning) have given substantial boosts to the industry. Machines similar to potato lifters have mechanized harvesting, and the use of byproducts (tops, pulp, and molasses for cattle feed) has given the crop further impetus.

Harvested sugar beets, weighing as much as 2.25 kilograms (about 5 pounds) each, are washed at the factory, cut with revolving knives into thin strips (cossettes), and soaked in hot water for diffusion of the sugar. Soluble contaminants are precipitated from the sugary solution with carbon dioxide and lime (clarification) and filtered out. The solution is then evaporated to a syrup, from which the sugar is crystallized by boiling under vacuum. The crystallized sugar is separated by centrifugation and further refined to make table sugar. The pulp may either be dried for stock feed or treated with dilute acid to yield commercial pectin.

Edible aroids (Araceae)

A number of genera of the family Araceae yield edible corms or tubers–food basic to many tropical areas. Cocoyam, dasheen, eddoe, tannia, taro, and yautia are a few of the more familiar common names. The 2 most prominent genera are *Colocasia*, the taros and dasheens; and *Xanthosoma*, the cocoyams, yautias, and tannias. Some species of these genera also serve as house plants ("elephant ears”) in summer garden pools and greenhouses.

Colocasia esculenta, adapted to the rainy tropics, with some strains adapted even to subaquatic habitats, was apparently domesticated in southeastern Asia. It had been spread throughout the Pacific and as far east as the Mediterranean in prehistoric times. The corms, the source for the famed *poi* of Hawaii, are low in protein. *Xanthosoma sagittifolium* probably embraces most of the edible cocoyams, yautias, and tannias. They are 5–9% protein on a dry weight basis, and yields can run as high as 60 metric tons per hectare (nearly 27 tons per acre). The species is native to tropical America, but it was distributed worldwide in post-Columbian times. *Alocasia*, *Amorphophallus*, and *Cyrtosperma* are other genera prominently used for food, as are a number of others under emergency conditions.

The food value of aroid corms is similar to that of the potato, being about 20% starch with little protein and oil. Most of the corms are boiled like potatoes, and then crushed to make “cakes.” Corms can also be roasted, steamed, or fried in oil to make “chips.” In the making of *poi*, the crushed corm is allowed to undergo a natural fermentation before final table preparation.

Most edible aroids are simply cultivated in small patches by peasant farmers. They grow best in moist, lowland, frost free locations, under light shade. Propagation is accomplished typically by means of satellite cormels or by sectioning of a corm. Yields as high as 45 metric tons per hectare (20 tons per acre) have been obtained experimentally, and under favorable conditions a crop can be harvested in as little as 6 months. Harvested corms can be stored for a few months if they are kept dry and ventilated. Cropping is mostly by hand in those tropical lands where aroids are an important crop. Accurate statistics on world production are not available, but several millions of metric tons of edible aroids are probably produced annually, which qualifies them as one of the world’s basic food resources.

Other Important Root Crops

Arracacha, *Arracacia esculenta* (Umbelliferae)

Also known as the Peruvian carrot, *Arracacia* is an herbaceous perennial of the Andes, mostly used locally because of short storage life. The starchy tubers (10–25% starch) are only half as costly as potatoes in many places, and the stems and foliage are eaten as well. Propagation is from offset tubers.

Carrot, *Daucus carota* (Umbelliferae)

The species is a wild weed of the family Umbelliferae. The cultivated variety (*D. carota* var. *sativus*) is believed to have been selected in the Near East long ago, but the root was generally accepted as human food only in recent centuries. Recorded world production is about 7 million metric tons, mostly from western Europe, China, and North America.

Horseradish, *Armoracia rusticana* (Cruciferae)

A crucifer native to Europe, this member of the mustard family has a white, carrot-shaped root that contains a pungent glucoside used mostly for flavoring.

Jerusalem artichoke, or sunchoke, *Helianthus tuberosus* (Compositae)

This rank sunflower has a potatolike rhizome (Fig. 3) that can be eaten boiled, pickled, or raw. The crisp flesh often substitutes for water chestnut in oriental dishes, and is gaining favor in the United States.

Onion, *Allium cepa* (Liliaceae)
Along with its relatives–garlic, leeks, shallots, and chives, all members of the genus *Allium*—the onion is an important flavoring and food plant throughout the world (Fig. 4). The onion is a true bulb, consisting of condensed food storage leaves that are rich in sugar and in the pungent compound allyl sulfide. It is a major crop in central and southern Europe and in the mucklands of the Great Lakes area of the United States (Fig. 5). Recorded world production is a sizable 18 million metric tons, mostly from China, India, the United States, Spain, and Japan. Shallots, surprisingly, are a fairly important crop on the sandy soils of Ghana, in tropical Africa.

Parsnip, *Pastinaca sativa* (Umbelliferae)
Another relative of the carrot, the biennial parsnip has edible roots that turn quite sweetish after exposure to cold. A vigorous species mostly grown in Europe, the parsnip was presumably domesticated in the Mediterranean area; wild and escaped plants are common in many parts of the world.

Radish, *Raphanus sativus* (Cruciferae)
The radish, presumably native to China, is used chiefly in the Orient, where gigantic roots are grown and often pickled in brine.

Rutabaga, *Brassica napus*, Napobrassica group (Cruciferae)
Another of the cabbages, the rutabaga is also known as swede, or swede turnip, and seems to be a cross between the turnip and the cabbage in Europe during the Middle Ages.

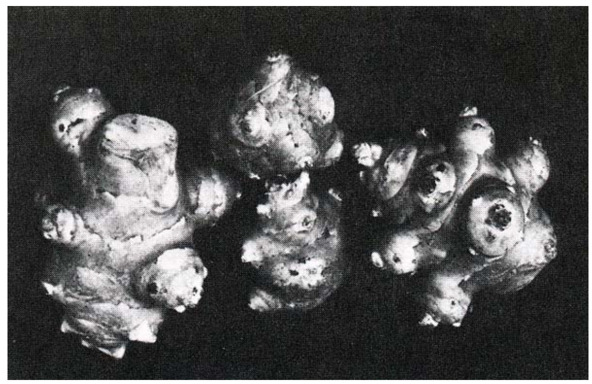

Fig. 3. Rhizome of the Jerusalem artichoke, or sunchoke, Helianthus tuberosus, Indians and now becoming more generally popular. These rhizomes have been washed free of soil. [Courtesy USDA.]

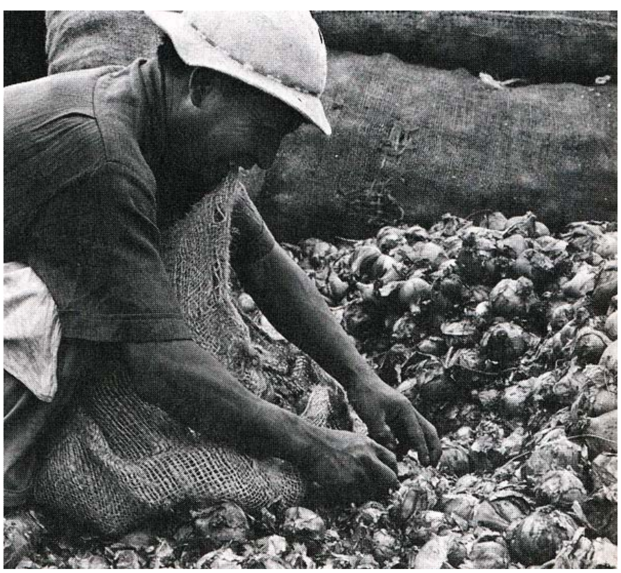

Fig. 4. Sacking onion bulbs in Ecuador. [Photograph by Larry Daughters, courtesy World Bank.]

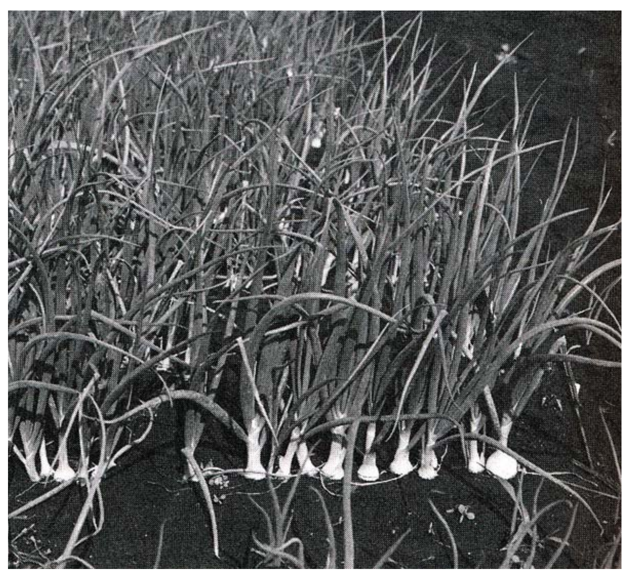

Fig. 5. Hybrid onions growing on muck soil.

Salsify, *Tragopogon porrifolius* (Compositae)
Also known as oyster plant, salsify has fleshy, parsniplike roots that are usually consumed boiled.

Turnip, *Brassica rapa* Rapifera group (Cruciferae)
Another biennial of the cabbage clan, the turnip has been long in cultivation and is probably native to Europe and central Asia. It is easily grown and is often used as stock feed.

Yam, *Dioscorea* (Dioscoreaceae)
Yams comprise several species of the genus *Dioscorea*, principally *D. cayenensis* and *D. rotundata*, which were domesticated in tropical Africa perhaps 5000 years ago, and *D. alata*, which is indigenous to southeast Asia. The true yam is not to be confused with the sweetpotato, sometimes popularly termed "yam." Mostly tropical vines with worldwide distribution, adapted to climates with abundant rainfall, yams can produce tremendous roots weighing as much as 40 kilograms each and yields of as much as 40 metric tons per hectare (nearly 18 tons per acre). Many yams resemble potatoes and are consumed in the same fashion; in western Africa, yams are pounded to make the prized dish *fufu*. Wild yams, of which there are more than 500 species, were much sought as a source of steroidal sapogenins in the development of cortisone, and yams have been the source of diosgenin for the manufacture of birthcontrol pills, the industry in Mexico first utilizing wild sources. Several species are cultivated in China and Africa for food (they contain about the same amount of starch as does the potato). Propagation is chiefly by replanting the top of a harvested root, and trellises are usually provided for the trailing vine. A growing season of 8 to 10 months is required to mature a crop, making yams unsuitable for any but tropical climates. World production must exceed 20 million metric tons, with Nigeria a major center for cultivation. Breeding of new cultivars has been undertaken there, and an assemblage of species and cultivars has been made at Mayaguez, Puerto Rico.