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# Reading 34
# Fruit & Nut Crops

## FRUIT CROPS

Fruits of perennial plants have been used as food since before the dawn of civilization, and they are perhaps more popular than their nutritional quality justifies. No doubt ancestral primates gathered wild fruits as a not inconsiderable part of their food supply. (A sampling of wild fruits native to North America is given in Table 1.) Symbolic of our early admiration of fruit is the Garden of Eden scene and its tempting fruit. Five of the Biblical 7 species (Deuteronomy chapter 8, verse 8) are fruit trees. Fruit crops today, considered together and by weight, compare favorably with the world's staple agricultural crops.

In spite of their popularity, fruits in general are relatively unimportant to human sustenance (banana, coconut, and the date are exceptions). Most fruits are quite juicy (watery) and have low concentrations of nutrients, but some are excellent sources of vitamin C. Like many vegetables, however, they do add much appreciated variety and flavor to the diet. Indeed, most fruits have been selected to titillate the palate, and they commonly serve as a dessert or special treat.

A few fruits are more or less local staples. This is true of the banana and the coconut in parts of the tropics; avocados have been a prime source of nutrition in sections of the New World, and dates have been gathered in arid parts of the Old World since time immemorial. Indicative of the political importance attached to fruits, especially for sustenance in the tropics, is the voyage of the H.M.S. *Providence*, 1791–1793, under the command of the famed Captain William Bligh (whose first try with the *Bounty* resulted in failure because of the historic mutiny). Although organized principally for collecting breadfruit (*Artocarpus altilis*) from the South Pacific for planting in the British colonies of the New World, records show that the *Providence* introduced scores of exotic species and was a veritable floating plant nursery.

Most fruits are preferred eaten raw. They become quite perishable once the climacteric is reached. Thus fruits have traditionally been preserved through a variety of treatments, such as drying in the sun, cooking in sugary syrups (candied fruits and jellies), "fumigating" with sulfur dioxide (prunes, maraschino cherries), and of course by canning and freezing. Technically advanced parts of the world now enjoy rapid transportation, and increasingly fruits can be marketed fresh even though they may be grown far from the market. A few, such as the coconut and citrus, with something of a protective rind, handle and ship reasonably well. Unfortunately, many of the most delicious fruits, such as the tropical cherimoya (*Anonna cherimola*) and mangosteen (*Garcinia mangostana*), are very delicate and can hardly be transported efficiently even by air.

In the constant search for better shipping cultivars, flavor is often sacrificed, as with the banana and the avocado, of which the best-tasting tree-ripened cultivars never reach temperate-zone markets. Even within a limited market area, poor-shipping cultivars, such as 'Belle of Georgia' peach (thought by many to be the best-tasting peach ever discovered), have had to give way to more marketable ones. Unfortunately, most fruits do not adapt well to freezing; they lose their form and substance upon thawing, and consequently this modern technique for providing distant markets with tasty perishables is not of great service as far as fruits are concerned.

Since a fruit is the normal reproductive structure of flowering plants, it is no cause for wonder that an almost unlimited selection of fruits occurs in the wild, from which people have chosen do-

**Table 1**. A sampling of North American wild plants, the fruits of which can be used for food.

| Scientific name | Common name | Uses |
|---|---|---|
| *Amelanchier* spp. | juneberry; shadbush | raw, cooked, or dried |
| *Annona glabra* | pond apple | raw or made into jelly |
| *Arctostaphylos* spp. | manzanita; bearberry | raw, cooked, or dried and ground; also jelly, syrup, or cider |
| *Ardisia escallonioides* | marlberry | |
| *Asimina triloba* | papaw | raw or cooked |
| *Chiogenes hispidula* | creeping snowberry; birchberry | |
| *Chrysobalanus icaco* | cocoplum | raw or cooked |
| *Chrysobalanus pallidus* | gopher apple | |
| *Chrysophyllum oliviforme* | satinleaf | |
| *Coccoloba uvifera* | seagrape | raw or as jelly |
| *Cornus* spp. | dogwood; bunchberry | raw or cooked |
| *Crataegus* spp. | haw | raw, cooked, or dried |
| *Diospyros virginiana* | persimmon | raw, cooked, or dried and ground as meal |
| *Elaeagnus commutata* | silverberry | raw or cooked |
| *Empetrum nigrum* | crowberry | raw, cooked, or dried |
| *Ficus aurea* | wild fig | |
| *Fragaria* spp. | strawberry | raw or cooked |
| *Gaylussacia* spp. | huckleberry | raw or cooked |
| *Gleditsia triacanthos* | honey locust | fruit pulp raw; pods fermented for beer |
| *Lonicera* spp. | honeysuckle | raw, cooked, or dried |
| *Lycium* spp. | wolfberry | raw or boiled |
| *Malus* spp. | crabapple | raw, cooked, or preserved |
| *Mitchella repens* | partridgeberry | |
| *Morus rubra* | red mulberry | raw, cooked, or preserved |
| *Nyssa* spp. | Ogeechee lime; tupelo | preserved |
| *Parthenocissus quinquefolia* | Virginia creeper | |
| *Passiflora incarnata* | maypop | raw or as jelly |
| *Photinia salicifolia* | Christmasberry | raw, roasted, or dried and ground for mush |
| *Physalis* spp. | groundcherry | raw or cooked |
| *Podophyllum peltatum* | May apple | raw or cooked |
| *Prosopis* spp. | mesquite | raw, or ripe pods boiled for syrup, or dried and ground for meal, or used for beverage, fresh or fermented |
| *Prunus* spp. | cherry; plum | raw, cooked, or dried |
| *Reynosia septentrionalis* | Darling-plum | raw or cooked |
| *Rhamnus* spp. | buckthorn | some species cathartic |
| *Rhus* spp. | Red-fruited are not poisonous; avoid *R. vernix* and other species with white fruit. | |
| *Ribes* spp. | current; gooseberry | raw, cooked, or dried |
| *Rosa* spp. | rose | raw, stewed, or as jelly |
| *Roystonea elata* | royal palm | raw, boiled for juice, sweetened |
| *Rubus* spp. | blackberry; dewberry; raspberry | raw, cooked, or preserved |
| *Sambucus* spp. | elderberry | raw, cooked, dried, or made into jelly or wine |
| *Shepherdia* spp. | buffaloberry | raw, cooked, or dried |
| *Smilacina* spp. | false Solomon's-seal | |
| *Vaccinium* spp. | blueberry; cranberry; deerberry; whortleberry | raw, cooked, or dried |
| *Viburnum* spp. | black haw | raw, cooked, or dried |
| *Vitis* spp. | grape | raw, cooked, or dried |
| *Yucca* spp. | yucca; Spanish bayonet | unripe fruit cooked; ripe fruit raw, cooked, or made into paste |

mesticates. Indeed, particularly in the tropics, a wide assortment of wild species is still important to local populations. For example, the wayfarer in Brazil escapes from the beat by stopping under the umbu tree (*Spondias* sp.), not only for its shade but to refresh himself on the tart fruit. In temperate climates the collecting of wild fruits and berries, once commonplace in rural societies, has now largely given way to mass marketing of specially grown cultivars. Even so, it is surprising how relatively little most fruits have changed from the ancestral types, compared with the tremendous change that domestication has wrought on such food staples as the cereals. Over the ages new forms have arisen more from chance crossings or mutations than from genetic design. Breeding programs have dealt mostly with improving characteristics already pretty well established in earlier selections; the reasons are obvious if one considers the time necessary to undertake large-scale selective crossing with long-lived perennials.

Tropical fruits especially offer an exceedingly wide and diverse assortment. The numerically fewer temperate fruits are perhaps better known and more thoroughly investigated as horticultural crops. However, very specialized industries have developed in the temperate zone to grow and market there such tropical fruits as the banana, pineapple, and citrus. The volume of citrus and of bananas entering world commerce exceeds apple production: that of citrus is some 50 million metric tons annually, that of bananas nearly 40 million metric tons. But a temperate fruit, the grape, leads all others in total production (more than 60 million metric tons annually), largely because of its use in making wine. The coconut, at more than 30 million tons, ranks just behind grapes, citrus, and bananas, but, because it is used mainly as a source of copra, it will be discussed later in a chapter dealing with extractives. Olives, another major subtropical fruit, are grown mainly for processing to oil, and will also be left for later discussion. Pears, peaches, apricots, plums, pineapples, dates, cherries, and figs rank next, essentially in this order of importance, among the fruits in world commerce. A tremendous number of fruits are found locally in tropical markets (Table 2 and Table 3).

**Table 2.** Food fruits familiar in village markets of Central Mexico.

| Species | Common name | Family |
|---|---|---|
| *Acrocomia mexicana* | Palm fruit | Palmae |
| *Ananas comosus* | Pineapple | Bromeliaceae |
| *Annona cherimola* | Cherimoya | Annonaceae |
| *Annona reticulata* | Custard apple | Annonaceae |
| *Bumelia laetevirens* | | Sapotaceae |
| *Carica papaya* | Papaya | Caricaceae |
| *Casimiroa edulis* | White sapote | Rutaceae |
| *Citrus aurantiifolia* | Lime | Rutaceae |
| *Citrus paradisi* | Grapefruit | Rutaceae |
| *Citrus reticulata* | Mandarin | Rutaceae |
| *Citrus sinensis* | Sweet orange | Rutaceae |
| *Diospyros digyna* | Black sapote | Ebenaceae |
| *Hylocereus undatus* | Cactus fruit | Cactaceae |
| *Mangifera indica* | Mango | Anacardiaceae |
| *Manilkara zapota* | Sapodilla | Sapotaceae |
| *Musa* spp. | Banana | Musaceae |
| *Passiflora ligularis* | Passion fruit | Passifloraceae |
| *Persea americana* | Avocado | Lauraceae |
| *Physalis ixocarpa* | Tomatillo | Solanaceae |
| *Pouteria campechiana* | Yellow sapote | Sapotaceae |
| *Pouteria sapota* | Mamey sapote | Sapotaceae |
| *Psidium guajava* | Guava | Myrtaceae |
| *Punica granatum* | Pomegranate | Punicaceae |
| *Pyrus communis* | Pear | Rosaceae |
| *Malus pumila* | Apple | Rosaceae |
| *Tamarindus indica* | Tamarind | Leguminosae |

**Grape, *Vitus vinifera* (Vitaceae)**

Various species of the genus *Vitis* are known in the wild in many areas, both in the Old World and in the New World. Of chief importance today is the "bunch" or wine grape (*V. vinifera*) from the Old World, with 38 chromosomes. In many areas of the world, however, cultivars of this species must be grafted onto rootstocks of New World species to prevent devastation by the phylloxera root louse. Europe accounts for more than half of world grape production, which amounts to some 60 million metric tons annually (principally from Italy and France). As much as 90% of the European crop is used for wine. About a 10th of the crop is dried for raisins.

*Vitis vinifera* has long been domesticated. It apparently represents selection of bigger-berried, sweeter types of *V. silvestris*, a wild grape from Asia Minor and the Mediterranean basin northward along the Rhine and Danube valleys. *V. vinifera* and *V. silvestris* cross readily, and natural hybrids are often found near vineyards. Wild grapes, however, are dioecious (a trait determined by 3 alleles), a characteristic bred out of the domesticated species (which is hermaphroditic and self-fertile). Grape artifacts have been discovered with the earliest human remains in southcentral Europe and the Near East, with the earliest quite like *V. silvestris* and the later ones more like *V. vinifera*. Ancient Egyptian inscriptions indicate that the grape was widely grown by 2375 BCE. The Bible mentions the grape as having been planted by Noah; apparently it was introduced into Palestine from the north about 5000 BCE. Wine was a popular beverage in the Holy Land during Biblical times, and it is cited in practically every book of the Bible. Concoctions that include wine have also served as medicinals, pickling media (as for olives and vegetables), and even dyes for clothes. Grapes in summer and raisins in winter were familiar foods. In general the vineyard was a symbol of wealth and plenty.

The grape was equally as important in ancient Greece. Herodotus (484–425 BCE) mentions the tremendous commerce in wine sent to Egypt. During the hegemony of Rome, terraced vineyards were widely established. Preserved records include instructions for the care of vineyards—clearing away stones, hoeing, manuring, pruning, primitive disease protection, and provisions for irrigation. Today *V. vinifera* remains important throughout Greece (and nearby Turkey), where grafted cuttings of select cultivars are generally planted 2 meters (about 6 feet) apart, about 3000 vines per hectare (about 1200 vines per acre), in holes punched in the soil.

**Table 3**. Fruits commonly grown in India.

| Species | Common name | Family |
|---|---|---|
| *Ananas comosus* | Pineapple | Bromeliaceae |
| *Annona squamosa* | Sweetsop | Annonaceae |
| *Carica papaya* | Papaya | Caricaceae |
| *Citrullus lanatus* | Watermelon | Cucurbitaceae |
| *Citrus paradisi* | Grapefruit | Rutaceae |
| *Citrus reticulata* | Mandarin | Rutaceae |
| *Citrus sinensis* | Sweet orange | Rutaceae |
| *Cucumis melo* | Muskmelon | Cucurbitaceae |
| *Eriobotrya japonica* | Loquat | Rosaceae |
| *Ficus carica* | Fig | Moraceae |
| *Grewia asiatica* | Phalsa | Tiliaceae |
| *Litchi chinensis* | Litchi | Sapindaceae |
| *Malus pumila* | Apple | Rosaceae |
| *Mangifera indica* | Mango | Anacardiaceae |
| *Manilkara zapota* | Sapodilla | Sapotaceae |
| *Musa* spp. | Banana | Musaceae |
| *Phoenix dactylifera* | Date | Palmae |
| *Prunus armeniaca* | Apricot | Rosaceae |
| *Prunus domestica* | Plum | Rosaceae |
| *Prunus persica* | Peach | Rosaceae |
| *Psidium guajava* | Guava | Myrtaceae |
| *Punica granatum* | Pomegranate | Punicaceae |
| *Syzygium cumini* | Jambolan | Myrtaceae |
| *Vitis vinifera* | Grape | Vitaceae |

Most of southern Greece is phylloxera-free, but New World rootstocks are generally used as a precaution in newly planted vineyards. Vines are generally pruned to remain low, and are staked rather than trellised, or sometimes simply left to trail on the ground. Since hand labor is often inexpensive, girdling (removal of a ring of bark below a grape cluster into which food from the leaves above is to be directed) or its equivalent is not uncommon. Most cultivation is still done by hand.

In North America, centuries before Columbus, Indians were gathering fruit of such species as the fox grape (*V. labrusca*), the riverbank grape (*V. riparia*), and the scuppernong (*V. rotundifolia*). The Norse name *Vinland* lends credence to the claim that North America was discovered by Norsemen. Early settlers were impressed by the profusion of wild grapes, but for 200 years attempts to introduce and grow the more select *V. vinifera* from Europe failed. During these attempts there may have been some natural crossing between *V. vinifera* stock and the native American species. In 1852, E.W. Bull of Concord, Massachusetts, exhibited a seedling grape, which he named 'Concord,' that was to remake the grape growing industry in the New World. 'Concord' came from a seed borne on a seedling of uncertain origin, but Bull speculated that it might have been a cross between a European grape gone wild and a *V. labrusca* 'Catawba' in the garden. In any event, it was far superior to cultivars then available, and even today 'Concord' is still the leading "juice" grape in the northeastern growing areas.

The greatest flowering of viticulture in America, however, awaited the settlement of California. The earliest grapes planted in California were apparently brought from Spain through Mexico by the Jesuit Fathers during the 1600s. The several California missions all had thriving vineyards before 1800. The 'Mission' grape, of obscure ancestry, was widely introduced and is still much grown in California. From 1850 on, with viticulture flourishing, many varieties of *V. vinifera* were introduced from France and other parts of Europe. During the 1960s "French hybrid" grapes (crosses of *V. vinifera* with such American species as *V. rupestris* and *V. lincecumii*, made by French hybridizers) were introduced into the midwestern United States with some success, reviving interest in grape growing there.

In the dry Central Valley of California, where phylloxera and mildew diseases do not have to be contended with, very efficient grape growing is possible on large irrigated ranches. Select varieties are planted at the rate of 1000 to 1500 vines per hectare (about 400 to 600 vines per acre) and trained to standardized trellises, with weeding and irrigation carefully controlled. Recently there has even been chemical management of fruiting: gibberellin sprays, properly timed, can substitute in large measure for tedious hand girdling to yield especially full clusters of large grapes for the fresh-fruit market. Although grapes must be hand pruned and harvested, irrigation and other growing procedures are increasingly being automated. Mechanical harvesting is past the experimental stage.

Grapes, perhaps more than many fruits, do their best only under intensive care. Although there are many varieties today, including crosses of *V. vinifera* with American species that provide suitable cultivars for most regions, the grape does require a long summer and winters mild enough—with temperatures generally above –18°C (0°F)—to avoid winterkill. Grapes reach best quality when the weather is bright and dry; the sugar content and the various subtle flavorings are then at their peak. Grapes are propagated chiefly by cuttings, and the vines perform best on well-drained soils. As has been noted, the tendency is to graft scions of *V. vinifera* onto phylloxera-resistant rootstocks of American origin. Most modern varieties are self-fertile, but some yield finer fruit when cross-pollinated with other varieties. Grapes flower and fruit on new wood (Fig. 1).

In the United States, canes are generally pruned back to 2 or 4 paired branches trained to a wire trellis, on which about 30 buds are allowed to mature into new shoots, each of which may bear 2 or 3 bunches of grapes. Depending upon cultivar, use, and market conditions, there may be thinning to provide especially select fruit.

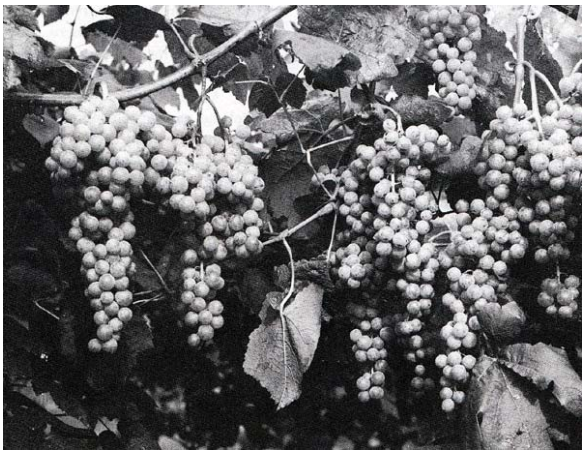

**Fig. 1.** Abundant fruiting in the grape. [Courtesy Garth Cahoon.]

Raisin production, of course, involves the drying of grapes, usually in the sun, to some 20% of fresh-fruit weight. Traditionally, raisin grapes ('Thompson Seedless' grapes are mainly used in the United States) were dipped in solutions of soda or oleate better to preserve the skins and to facilitate drying, but more recently a boiling-water bath followed by hot air dehydration has proven preferable. Nearly 1 million metric tons of raisins (equivalent to about 5 million metric tons of fresh grapes) are produced annually, mostly in Turkey, Greece, and California.

**Banana, *Musa* spp. (Musaceae)**

The taxonomy of the banana is confused. Most cultivated bananas are referred either to *Musa acuminata* (= *M. cavendishii*), or to *M. paradisiaca* (= *M. sapientium*) which is apparently a hybrid between *M. acuminata* and *M. balbisiana*. *M. acuminata* and *M. balbisiana* are diploid sources of genomes *a* and *b*, respectively, in crosses yielding triploid hybrids of genomic constitution *aab* or *abb*, such as 'French Plantain.' Triploid *M. acuminata* embraces the flavorful ladyfinger bananas and such Philippine cultivars as 'Lacatan.' A tetraploid from this source, with genomic constitution *aaaa*, is the cultivar 'Golden Beauty.' Diploid *M. acuminata* grows wild in the rain forests of Malaysia, and seems prone to production of autotriploids with bigger, more edible (parthenocarpic) fruits, which were probably the first cultivated bananas. Crosses with *M. balbisiana* occurred in India to produce *M. paradisiaca*, from which other edible selections were made that, propagated vegetatively, spread throughout the world. The *b* genome, itself not a source of flavorful raw bananas, contributes hardiness, and today's cooking bananas or plantains have various combinations of the *a* and *b* genomes. A related species, abacá (*M. textilis*), is grown for the petiole fiber rather than the fruit.

Most of the fruit marketed until recent years has been the 'Gros Michel' cultivar of *M. acuminata*, also known as the "Poya banana" (so called for its discoverer, Jean Francois Pouyat, a Jamaican planter who came upon this triploid find in 1836 while strolling through a banana farm in Martinique). The 'Gros Michel,' being reasonably flavorful, of good size, and especially durable for shipping, was long the only banana available to temperate-zone people the world over. Since 1963 new triploid cultivars of *M. acuminata*, including 'Valery' and West Indian 'Lacatan,' have gradually replaced "Big Mike" (as the 'Gros Michel' is known) in importance, because of their better resistance to the dread Panama disease. The small, thin skinned ladyfinger bananas, generally thought to be more flavorful, will not stand shipping to distant markets. The plantains are rather tasteless, large, green-skinned or red-skinned fruits that are usually baked, boiled, or fried rather than eaten raw, and they are mainly of local importance in the tropics.

As noted, the banana is believed to have been first domesticated in Southeast Asia millennia

ago, although commercial banana production has now largely gravitated to the Western Hemisphere. The banana had been introduced from the Far East into Africa by Arabian traders before historical times; it was encountered there when that continent was first explored in the 15th century. The name "banana" apparently became first applied to the fruit in Sierra Leone.

No doubt the banana was introduced into tropical America soon after Columbus' first voyage. Today Latin America accounts for more than half of the recorded world production of bananas, totaling approximately 37 million metric tons. In the Far East and Africa, some bananas are grown for export, but much of the crop is consumed locally (in some places the banana being a staple in the diet). Brazil leads the world in banana production, followed by India, Indonesia, and Central America.

Although some banana plants grow as tall as 9 meters (nearly 30 feet), botanically they are herbs rather than trees, being without woody tissue. The plant is propagated from a fleshy rhizome that produces a cluster of gigantic leaves, each nearly 3 meters (about 10 feet) long. Growth is rapid, and in less than a year a central, pendulous inflorescence forms, which, upon fruiting, terminates the plant's life (Fig. 2). About 14 months after planting, the stalk of bananas is ready for harvesting. Commercial bananas have sterile flowers, which develop unfertilized and yield fruit lacking seeds. Thus, perpetuation of the plant depends entirely upon suckers arising from the rhizome.

**Fig. 2.** The fruiting stalk of the banana consists of many clusters called hands. Each female flower of the basal end of the stem develops into a fruit—the "finger." Male flowers are produced toward the apex of the stem. [Courtesy J.C. Allen & Son.]

Most dwellings in the humid tropics have a few banana "trees" constantly in the dooryard, an aid to local subsistence. But the banana is also a remunerative cash crop in the steamy tropical lowlands. On good land it can yield more than 22 metric tons per hectare (about 10 tons per acre) annually, with reasonably little attention. Large scale growing is generally of the shifting-agriculture pattern; forest is felled, the vegetation is burned or allowed to rot, and rhizome sections are planted by hand. Efficient plantations schedule plantings to permit cutting fruit the year around. Bananas are harvested green, since they are quite perishable when ripe (yellow). Experience has indicated just the proper stage for cutting, so that the green bananas, loaded onto refrigerated steamers for transport to temperate-zone markets, ripen in just a few days when brought to room temperature in the food store. Unfortunately, the flavor of such bananas is no match for that of tree-ripened fruit in the tropics.

Early in the 20th century banana companies in the American tropics developed into very large, thoroughly organized corporate empires, with extensive plantation lands in diverse countries (often including whole villages) and privately owned railroad and

steamship lines for bringing the fruit to market. In recent years these "banana empires" have retrenched because of the growth of nationalism, and there is increasing tendency to buy fruit from native growers. Even the Indians living in isolated villages, such as in southern Panama and western Ecuador, may bring their green bananas by canoe to larger trading boats that ply the coast on regular schedules to carry produce to the larger ports.

Large land-clearing and leveling machinery may be used on well-capitalized plantations to prepare planting sites. Cultivation to restrain weeds until the bananas form a tight canopy is often a hand operation. On plantations, natural rainfall may be supplemented by irrigation, and fungicidal spraying is commonly practiced. Nowadays, on managed plantations, young stems of bananas are usually covered with a blue-tinted polyethylene plastic "sleeve"; this accelerates growth, resulting in a weight gain for the stem of about 2.5 kilograms (about 5.5 pounds) more than the stem of an uncovered plant, and it also affords some protection against insect and bird damage to developing fruit. Harvesting is by hand: a worker with a knife on a long pole lops the banana plant, settling the fruit cluster onto the shoulder of a 2nd man, who is to carry it, and then severs the inflorescence from the rest of the plant. The carrier may take the bunch to a mule, small rail car, canoe, or other means of transportation for delivery to a major port. There the bananas may be washed, and are carefully loaded into air-conditioned ship holds by means of canvas conveyors or other sophisticated means to avoid bruising. There is even some individual packaging of clusters in cardboard cartons before shipping. The bananas may be treated with an antioxidant and a postharvest fungicide, too. During the long haul to market the temperature in the ship's hold is maintained at 14°C (57°F), the ideal temperature for preventing premature ripening. Where bananas are shipped in polyethylene bags, an atmosphere enriched in carbon dioxide and reduced in oxygen may be maintained, which prevents premature ripening and molding. A few days at 21°C (70°F)—or at 15.5–18.5°C (60–65°F) if ethylene is present in the atmosphere—causes the bananas to turn from green to yellow and the starch to hydrolyze to fruit sugars. Ripening with ethylene, from other fruit or from chemical sources, promotes shelf life and quality. The ripened banana is a wholesome and fairly well balanced source of nutrition, containing various minerals and vitamins, as well as a high complement of carbohydrate with some oil and a little protein.

**Citrus, *Citrus* spp. (Rutaceae)**

In the genus *Citrus* are the many familiar citrus fruits, of which the orange, tangerine, lemon, lime, and grapefruit are perhaps the most familiar. Sweet oranges are classed as *C. sinensis*; lemons, *C. limon*; limes, *C. aurantiifolia*; mandarin orange, or tangerine, *C. reticulata*; grapefruits, *C. paradisi*; citrons, *C. medica*; pomelos, pummelos, or "shaddocks" (after a Captain Shaddock), *C. maxima*; and sour oranges, *C. aurantium*. There are several other species that are seldom used for food. All except the grapefruit (which apparently arose from hybridization between the orange and the pomelo during the 1700s in the West Indies) seem native to Southeast Asia, where the more useful fruit types were selected by primitive people before historical times. Undoubtedly, a number of hybridizations are represented. All species have a diploid chromosome complement of 18, and cross with one another.

Most citrus is grown today in tropical and subtropical America, although there is considerable production in southern Europe, Japan, North Africa, and the Near East. Oranges and tangerines are the most popular of citrus fruits, totaling about 33 million metric tons annually, about twice the production of all other citrus fruits combined. The leading producing areas are the subtropical parts of the United States, Brazil, Japan, Spain, Italy, Argentina, Mexico, and Morocco. Grape-

fruits find their market almost solely in the United States. Lemons, limes, and other citrus fruits (such as sour orange) are grown mostly in Italy and the United States. Worldwide, recorded citrus production amounts to about 50 million metric tons annually.

Citrus fruits are borne on relatively small wiry trees, many of which apparently depend upon root mycorrhizae. Most are temperamental about soils, frequently suffering from trace-element deficiencies, excessive alkalinity (in Texas and California), nematode attacks, and similar afflictions. In the United States they do well on the sandy soils of south-central Florida, and in Sunny southern California and southern Texas (Fig. 3). In these areas, highly mechanized orcharding is practiced, often with irrigation, pest control, protection against winter frost, and selection of improved cultivars. Intensive growing is also practiced in Japan, where the mandarin orange, or tangerine, is much esteemed. In less advanced parts of the tropics, however, citrus growing is rather casual, with occasional trees of doubtful origin planted in the home garden. In western Africa, where citrus trees should do well, fruit may be harvested only from chance trees that get little if any attention.

The citrus fruit, technically a **hesperidium**, is an excellent source of vitamin C and various fruit acids. It is approximately 10 to 45% juice, 20 to 40% rind, and 20 to 35% pulp and seeds. Chemically it is 86 to 92% water, 5 to 8% sugars, 1 to 2% pectin, with smaller quantities of acids, protein, essential oils, and minerals. The rind is full of oil glands, and it is the rind of the sour orange that is the part esteemed for production of an essential oil, flavorings, and marmalades.

The citron was well known in the Mediterranean area before Christian times, and it may have been the earliest of the *Citrus* domesticates, spread widely by the Jewish peoples (for whom it had religious significance), thus pointing the way for later *Citrus* plantings of various species throughout the Mediterranean basin. Some authorities have speculated that the citron was native to southern Arabia rather than Southeast Asia. The Western world became acquainted with the more esteemed types of citrus fruits only during the Middle Ages, when Arabic traders brought them from the East. The Crusades acquainted the northern Europeans with citrus fruits, and the Portuguese and Spanish explorers quickly introduced them into the New World. About this same time the sweet orange was introduced to Europe, apparently from India. Citrus was brought into Florida before 1565, and a number of "wild" orange groves (of relatively unpalatable types) were growing in Florida when it became a state in 1821. These wild groves were topworked with buds of superior strains, and Florida was thus started on the road toward leadership in the citrus industry. As with the grape, citrus trees were introduced into California through the Spanish missions.

The 'Washington Navel' orange sparked the growth of the orange industry in California. In 1869 a missionary, one Reverend Schneider, discovered the navel orange in Baia, Brazil, where it probably had originated as a mutation decades earlier. Budded trees were sent to the United States Department of Agriculture in 1870, and propagations from them were sent to Riverside, California. Two trees planted in the yard of Mrs.

**Fig. 3.** Picking navel oranges from trees planted in 1913 in an orchard in Visalia, California. [Courtesy USDA.]

Luther Tibbetts started the 'Baia Navel' (later the 'Washington Navel') orange on its way.

In 1862, near Lakeland, Florida, William Hancock purchased a farm from one Mrs. Rushing, who had set out 3 seedling grapefruit trees. One of these happened to bear seedless fruit, and thus originated the 'Marsh' seedless strain of grapefruit, named after C.M. Marsh, a nurseryman who eventually purchased budwood from this cultivar. Today this variety and selections from it are widely grown in Florida, Texas, California, and in various other parts of the world. Also arising by chance in Florida were the pink-fleshed grapefruits. A bud sport was found on a 'Marsh' seedless tree near Oneco, Florida, in 1913; it became the 'Thompson Seedless' grapefruit, named after the Thompson groves where it was found. A new bud mutation from this stock was discovered at McAllen, Texas, in 1929, and became 'Ruby,' the first patented grapefruit cultivar, and the one most grown in Texas today.

Although the 'Temple' orange does not keep well, it is one of the more flavorful varieties. The 'Temple' originated in Winter Park, Florida, from trees grafted with budwood obtained in Jamaica. The cultivar may be the result of a cross between a tangerine and a sweet orange (a tangor). A "new" citrus was discovered in Puerto Rico in 1956, and was named the chironja. It is said to combine the better characteristics of the orange and the grapefruit, and to peel like a tangerine; it may have originated as a natural cross between the grapefruit and the orange, or between the orange and the tangelo (itself a cross between the tangerine and the grapefruit).

Select cultivars of citrus are usually budded on sour-orange stock that is started from seed. Trees are planted about 7.5 meters (25 feet) apart, often cover-cropped or green-manured, sprayed for insects and disease, and irrigated in an appropriate fashion. Precautions taken against soil problems and frost have already been mentioned. Occasional serious winter freezings have been disastrous in the southern growing areas of the United States.

Citrus fruits are much used for fresh consumption, since they ship rather well to distant markets. The fruit is generally allowed to ripen almost fully on the tree, except for lemons and limes, which are picked green. Many oranges are not deeply orange, and are artificially dyed or treated with ethylene before being marketed. The demand for preserved citrus juice is increasing. In the past most juice was preserved by canning, but frozen concentrate (prepared by boiling the juice in vacuum pans and then freezing the concentrate) has captured and revolutionized the industry in the United States. More than half the Florida orange and grapefruit crop is now processed. This had led to intensive study of possible uses for citrus by products.

The need for disposing of peel, pulp, and seed after juice extraction has resulted in the use of dried citrus pulp for cattle feed and for production of a molasses that can also be used in stock feed. The processing residues (about 50% of the fruit) are shredded in hammermills, limed (which precipitates and coagulates the pectin, causing cells to break down further), cured, and expressed. The expressed liquor is evaporated to yield oils and a molasses liquor (nearly 50% sugar), and the press cake is dried separately (to a moisture content of 8%) for cattle feed. The essential oils from the expressed liquor, primarily terpenes, are used for flavoring, perfumery, pharmaceuticals, and soap. It is possible also to produce alcohol by fermenting the molasses or to grow yeast (for feed) on these residues. An oil that resembles olive oil can be extracted from the seeds. Sometimes pectin is extracted from the rinds, used chiefly in jellies and confectionary products. Of course, the fruit juices themselves can be fermented to vinegars and liqueurs or be utilized as a source of acetic acid.

**Apple, *Malus pumila* (Rosaceae)**

Malus pumila (= *M. communis*, *M. domestica*, and *Pyrus malus*) embraces most of the cultivated fruit apples. Additionally there are many wild species in the genus, including *M. sylvestris*, whose name has also been applied to the cultivated apples, and which may figure in the ancestry of certain cultivars. The apple was among the first plants sought in the wild; it was gradually adapted to orchards in the northern Mesopotamian center of domestication. Apparently the ancestral apple was indigenous to the Caucasus mountains of western Asia, where wild forms still grow. In the New World the genus is represented by a confusing group of indigenous crabapples, which, along with introduced forms, serve as attractive ornamentals.

Worldwide apple production comes to about 22 million metric tons annually. Europe is the leading apple growing continent (much of the crop is consumed as a mild alcoholic cider), and North America is a rather distant 2nd. France, Italy, and Germany are the leading European apple producers; the United States, Japan, and Argentina are all about equally as important in their respective parts of the world. Other than the grape, there is no temperate-zone fruit more important than the apple,

The apple fruit lends itself quite well to handling and keeping, in spite of having a thin skin. A ripe apple is approximately 84% water, 11% sugar, 1% fiber, with fractional percentages of protein, fat, mineral, and fruit acids. It is generally harvested fully ripe, because immature apples ripen poorly after removal from the tree. On the other hand, apples left too long on the tree turn somewhat mealy because of the incipient decomposition of the pectic portions of the cell wall. Ripe fruit kept in a cool, properly ventilated storage space will keep for months. Controlled atmosphere storage permits year-round marketing of apples, which fruit only in summer. A large portion of the apple crop is converted into preserves, such as apple butter and jelly, canned apple sauce, cider, and cider vinegar.

Authorities estimate that there are nearly 2,000 named cultivars of the apple today. Not many have become important commercially; it has been estimated that in the United States only about 2 dozen cultivars have been much grown until modern times. Of the 2 dozen, only one, the 'Cortland,' is a product of directed plant breeding. Of the remaining 23, which include many of the best-liked cultivars, most originated as chance seedlings, and some from bud mutations; a few are of unknown origin. The 'Rhode Island Greening' apple, for example, is said to stem from a seedling tree raised by a Mr. Green at his tavern near Newport, Rhode Island, from which admiring travelers obtained scions after tasting the delicious fruit that this tree bore. Other well-known cultivars that seem to have been chance seedlings include 'Delicious,' 'Golden Delicious,' 'Jonathan,' and 'York Imperial.'

The apple is a long-lived, spreading tree, which may remain productive for a century, though becoming gnarled and broken. Apple trees for commercial orchards are propagated by grafting select cultivars onto seedling rootstocks or clonally propagated "dwarfing" rootstocks. Different varieties have distinctive fruiting habits, some flowering and bearing abundantly only in alternate years, and a number requiring cross-fertilization from a different cultivar to set fruit adequately. Pollination is accomplished chiefly by bees. The apple fruit is botanically a **pome** (a fruit having an inner cartilaginous core surrounded by fleshy tissue).

Unfortunately, the apple is attacked by many insect and fungus pests, which is especially troublesome because, when this Old World species was introduced to the New World, natural predators of the pests were lacking. This may not have been of any great concern in rural areas, where most apples were probably consumed at home, or crushed for cider, applejack, and vinegar,

but for modern marketing blemished fruits become unsalable. Thus the orchardist must undertake a complicated and unceasing series of pesticide sprayings, beginning before buds first appear and ending only just before the apple is harvested. With a half dozen or more such treatments required, apple growers have had to automate lavishly to keep production costs down. Elaborate mist blowers and efficient modern pesticides are commonplace in the orchards of the United States. Not only are such familiar pests as apple scab and the codling moth controlled by spraying, but chemicals are utilized to thin fruit when it is borne too abundantly (Fig. 4) or to hold ripening fruit on the tree longer (to prevent bruising due to preharvest drop). Fortunately, promising results are now forthcoming from the breeding of apples resistant to all of the major pests. For example, such cultivars as 'Prima,' 'Priscilla,' and 'Sir Prize' are immune to apple scab and resistant to several other afflictions. Pruning of the orchard, to encourage vigorous bearing wood and to shape trees for ease in harvesting, does not lend itself well to mechanization. European growers are especially adept at training fruit trees to shapes that fit the limited area that can be accorded them. Fortunately, North American orchidists can handle pruning during winter, when the trees are dormant. If care is taken in pruning to avoid stubs and tearing of the bark, and if hygienic techniques are followed (including the painting of large wounds with a dressing), canker diseases are generally prevented.

One of the most laborious jobs in fruit production is harvesting, still done mostly by hand. Harvesting of apples for processing may eventually become mechanized. One portable harvesting machine has a special catching frame covered with foam plastic onto which apples fall as the tree is shaken by another mechanical device. Other labor-saving innovations are now used, including dwarfed trees for easier harvesting, direct field harvest into 30-bushel pallet boxes, and automatic grading and sorting devices.

The apple is adapted to cold climates, and is quite hardy even where winter temperatures are considerably below freezing. By the same token the apple requires winter-conditioning in order to fruit; it will not last in southern locations where winters are mild. The favorite apple-growing locations are to the leeward of bodies of water, or in rolling country where frost does not accumulate in low-lying pockets; thus early flowering is inhibited, and freezing that would ruin the year's crop is avoided. In the United States, Washington, Oregon, and California are the leading apple states of the West; New York, Michigan, and Virginia lead in the East. Nearly half the production is consumed as fresh fruit, and much of the remainder is processed for apple juice (sweet cider), which in turn may be fer-

**Fig. 4.** Chemical thinning is a standard practice in apple growing. The left side of the tree was thinned; the right side was not. Overbearing may cause broken limbs, small, poorly colored fruit, and may lead to alternate bearing in some cultivars. Apples are thinned by materials that burn off the blossoms or cause abortion of the embryo. [Courtesy Purdue University.]

mented to produce an alcoholic product (hard cider) or, by controlled bacterial inoculation yield acetic acid (vinegar). Pectin is an important by product from the cider mills.

**Other Fruits**

The 4 fruits that have been reviewed serve as examples of the temperate and tropical types. Quite obviously, scores more could be discussed that are of equal interest, and many of them almost as important in world commerce. Brief treatments of a few of those that are fairly important follow.

## ADDITIONAL TEMPERATE FRUITS

**Apricot, *Prunus armeniaca* (Rosaceae)**

The apricot was probably native to China, but it was early brought to the Near East, and into California during the 18th century. It is a close relative of the peach, but more tender, and is cultivated in much the same way. Southern and central Europe and California account for most of the world production, which exceeds 1 million metric tons annually. Much of the crop is preserved by sun drying.

**Blueberry, *Vaccinium* spp. (Ericaceae)**

The blueberry (Fig. 5) occurs in "low-bush" and "high-bush" species, both wild and cultivated, in cultivars ranging up to the hexaploid. Considerable wild fruit is still harvested, especially in New England and eastern Canada. Commercial plantings are mostly on acid soils from Michigan into New England, and in Washington and Oregon. Blueberries have been domesticated from wild forms mostly within the last half century. The larger, high-bush types are used in orchards, now supporting a thriving small-fruit industry. The greatest cost is the hand picking of the berries, but machine harvesting has now gained a following. Wild fruit is harvested with a specially designed rake that combs the upright stems, gathering many leaves and twigs as well as fruit. Most of the debris is removed by winnowing. Wild blueberries are generally used for processing. Total production, chiefly from the northern United States and northeastern Canada, probably does not exceed 50,000 metric tons annually.

**Fig. 5.** The blueberry has become increasingly important, transforming many formerly worthless acid soils into valuable cropland. [Courtesy J.C. Allen & Son.]

**Brambles, *Rubus* spp. (Rosaceae)**

Grouped as "brambles" are the red and black raspberries, blackberries, dewberries, loganberries, and other popular types, each of these common names embracing perhaps a dozen species and botanical varieties. The plants are prickly perennial shrubs (hence the name), but individual canes are often biennial (bearing fruit the 2nd year, then dying). The "berries" are an aggregation of separate pistils on a fleshy receptacle (aggregate fruits); in the raspberry the fruit separates readily from its core when picked (giving a "hollow" berry). As with blueberries, brambles are relatively recent domesticates, mostly since the Middle Ages. Appreciable amounts are still harvest-

ed from the wild, although cultivated forms are now widely grown, often as home-garden plants, but mainly in commercial orchards in Oregon and the northeastern states. In season, the fruit is consumed fresh locally, but most of the crop is preserved (especially for jellies and sauces), canned, or frozen. Perhaps 100,000 metric tons are processed annually in the United States. World production of raspberries is about 150,000 metric tons (mostly from central Europe).

**Cherry, *Prunus* spp. (Rosaceae)**
Most grown are the diploid sweet cherries, *P. avium*, and the tetraploid sour or tart cherries, *P. cerasus*. Both are believed native to Asia Minor, where they were well known to the ancients. Wild sweet cherry often serves as a rootstock for grafted cultivars, as does *P. mahaleb*. Cherry orchards are handled in much the same was as apples. In the United States, sweet cherries are grown in several western states, sour cherries mostly in Michigan and New York. Production of cherries exceeds 250,000 metric tons annually in the United States. The most popular sour cherry in the United States is the 'Montmorency,' which originated in the Montmorency valley of France several centuries ago. World production of cherries is a sizable 1.5 million metric tons annually, chiefly from Europe. Italy, Germany, France, the United States, and Turkey are the leading producing countries. The cherry, plum, peach, and apricot, all species of *Prunus*, constitute the so-called **stone fruits**.

**Cranberry, *Vaccinium macrocarpon* (Ericaceae)**
The cranberry is a vine like relative of the blueberry, grown in acid bogs of the northern United States. Another recent domesticate, it is still harvested from the wild in some locations, just as it was in colonial times. It is propagated from cuttings set by hand, an expensive procedure considering the difficult bog locations where these tart-fruited vines must grow. Regulated nitrogen fertilization increases yields. The fruit is gathered much like the wild blueberry, by combing with special rakes; or, where it is possible, the bogs are flooded to float the berries to the surface, where they can be churned with a mechanical beater (a large reel on the front of a motorized "garden tractor") and thus be more readily gathered. Cranberries are almost entirely a North American crop, utilized chiefly to make a tart red jelly or sauce that is consumed with fowl during the Thanksgiving and Christmas season. Production exceeds 100,000 metric tons annually.

**Currant, *Ribes sativum* and other species (Saxifragaceae)**
Currants and gooseberries are very hardy "bush fruits" grown largely in northern Europe (especially in Germany and Poland), but they are used to some extent for jellies and preserves in North America. Their planting has been discouraged in many parts of the United States because the plants are alternate hosts for the troublesome white-pine blister rust. World production is some 330,000 metric tons annually.

**Peach, *Prunus persica* (Rosaceae)**
The peach, in numerous cultivars, seems to have been first domesticated in China. It was brought to Persia before Christian times (hence the specific name), and then further spread throughout Europe during the era of Roman dominance. The peach is more tolerant of warmth and less tolerant of cold than is the apple; although it is hardly "subtropical," southern climates such as prevail in Georgia (the "peach state") are responsible for considerable production. The peach fruit, botanically a **drupe**, is much prized for its rich, "aromatic" flavor. Select cultivars are usually budded

or grafted onto unselected peach or almond rootstocks (the almond is a close relative of peach in which the seed rather than the fleshy outer part of the fruit is consumed). Only in the 19th century were useful cultivars, such as the 'Elberta,' a freestone seedling from a Chinese cling peach, introduced into the United States to make peach orcharding successful. Active breeding programs have increased adaptation by incorporating winter hardiness, low chill requirements, and an extended harvest season. The world's peach crop exceeds 7 million metric tons annually, with Europe and North America about equally represented. The United States and Italy are the leading peach-growing countries, with no little production in Japan. The **nectarine** is simply a peach without fuzz, grown especially on the Pacific coast. There are a number of cultivars.

**Pear, *Pyrus communis* (Rosaceae)**

The pear is most important in Europe, where there are many cultivars. Total world production exceeds 7 million metric tons annually, mainly from Italy. The pear is believed indigenous to western Asia, where it has long been cultivated. Selection of modern cultivars has been accomplished only fairly recently, mostly in northern Europe. Varieties important to North America, such as the 'Bartlett,' were introduced from Europe (the 'Bartlett' is known as the 'Williams' in England; it was discovered by a schoolmaster as a wilding, and brought to America about 1797). The 'Seckel' pear "originated in America," having been discovered on a tract of land just south of Philadelphia that became the property of a Mr. Seckel, but the original stock had no doubt been brought from Europe. Growing requirements for the pear are much the same as for the apple, although it is less tolerant of extremes. (The pear and apple constitute the so-called **pome** fruits.) When mature, the pear fruit is quite perishable, the stage of edible ripeness coinciding with the peak of the climacteric. In the United States there is a sizable pear-canning industry based on the 'Bartlett' cultivar, and in Europe a good portion of the crop is crushed for pear cider (perry) and wine making. A limiting factor in the United States pear industry is the bacterial disease fireblight, which is caused by *Erwinia amylovora*.

**Plum, *Prunus* spp. (Rosaceae)**

Plums (Fig. 6) are the most extensively grown stone fruits. There are a number of species, some of them wild, and many of them cross freely. It is estimated that about 2000 cultivars are grown, selected from 15 different species; but cultivars of the European plum (*P. domestica*) are most important worldwide, followed by cultivars of the Japanese plum (*P. salicina*) and various North American species. Centers of origin are the Orient, Europe, and North America. With such diversity, it is no wonder that plum cultivars can be found suited to almost any climate or soil. Growing requirements are the same as for the peach. Some cultivars are self-sterile, and must be interplanted with other cultivars for pollination. But other than that, plums are perhaps the least temperamental of

**Fig. 6.** Harvesting plums, grown with the help of irrigation, on the Adana Plain of Turkey. [Photograph by Mary H. Hill, Courtesy World Bank.]

the temperate-zone orchard fruits, seeming to give at least some yield with only scant attention. The drupe fruits are quite perishable unless refrigerated. Plums are not so much eaten fresh as preserved (jellies and jams), canned, and dried (prunes). The prune industry is especially important on the Pacific coast, where "*domestica*" plums are dried, "sweated," and "glossed" with a steamy glycerine bath of sweetened juice that produces the sterile glossy skin we associate with prunes. Europe accounts for most of the total world production of plums, about 5 million metric tons annually; Yugoslavia, Romania, and Germany are the leading producers. In the United States, plums are grown for fresh fruit in many scattered locations, but prunes are produced chiefly in California and Oregon.

**Strawberry, *Fragaria* spp. (Rosaceae)**

One of the temperate zone's favorite fruits, and probably the most popular "berry," is the strawberry (Fig. 7 and Fig. 8). Yields of 90 metric tons per hectare (about 40 tons per acre) have been achieved with well-adapted cultivars. World production amounts to about 1.3 million metric tons, mostly from the United States, Japan, Italy, and Poland. Botanically the strawberry is not a true berry, but an aggregate fruit, consisting of an assemblage of separate pistils on a fleshy receptacle. The modern octoploid cultivated strawberry has a rare genetic make-up. The male-sterile *Fragaria chiloensis*, native to the southern Andes and the Coast Ranges of western North America, and the eastern American species, *F. virginiana* (and possibly other European species) are thought to have been hybridized in Europe after introduction there, to produce the modern strawberry, often designated *F.* × *ananassa*. Cato the Elder (234–149 BCE) grew strawberries of some type (perhaps *F. vesca*) at his villa in Rome. Of all fruits discussed, the cultivars of the strawberry stand out as the result of breeding programs rather than chance selections. Breeders are still making crosses of wild *F. chiloensis*, *F. virginiana*, and *F. ovalis*, which along with the cultivated *F.* × *ananassa* constitute the 4 octoploid species of strawberry. Selections have been bred that are adaptable to subtropical climates such as prevail in southern Florida, and for northern states as well. Some cultivars now yield tremendous fruits as big as a plum. Most commercial cultivars bear but once in the spring, but especially for the home garden there are everbearing sorts that yield almost continuously if the weather remains reasonably cool and moist through the summer.

Strawberries are herbaceous perennials that produce clusters of leaves from the condensed stem or crown. Under long days, trailing stems or stolons (runners) spread from the crowns, forming new plantlets. Plantings generally become too crowded after a few years, and the strawber-

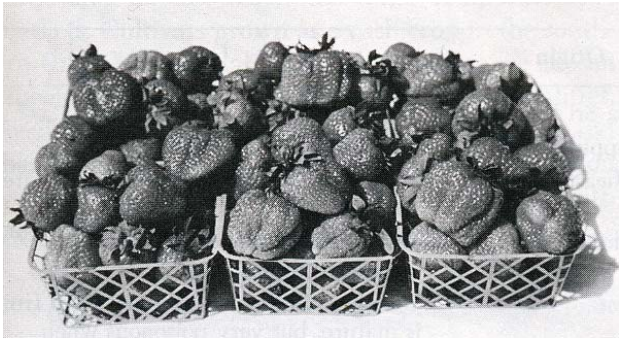

**Fig. 7.** The strawberry is one of the most widely adapted fruit crops. [Courtesy Victor Voth.]

**Fig. 8.** Plantings in California are made on fumigated soil, and production is stimulated with polyethylene mulch. [Courtesy Victor Voth.]

ries diminish in size and quality. When this happens, new daughter plants must be set in newly prepared beds, or the existing beds must be thinned and allowed to replenish by stolons from adjacent plants. Plants produced during summer will flower and bear fruit the following spring; in this sense the crop is a biennial, although the plants themselves are perennial. Many commercial plantings are replanted annually. In California, which is responsible for ¾ of the United States production, improved cultivars are started annually under polyethylene mulch on fumigated soil. The practices are regulated to provide the plants with enough chilling for good fruit yields but not enough to encourage vegetative (runner) exuberance. Trickle irrigation is increasingly practiced, allowing increases in plant population of as much as 50%. Yields can be as high as 40 metric tons per hectare (about 18 tons per acre).

Several modern herbicides have been used to help control weeds in strawberry plantings, but picking has always been a laborious process. Near urban areas many growers invite the public in for "pick your own" harvesting, the customer paying for the quantity taken. Some new cultivars are nearly determinate, so that mechanical lifters can harvest the whole plant and enough ripe berries can be sorted from the trash to make the practice economical. Strawberries are soft and quite perishable, but so prized and delectable is this fruit that international air shipment has become a sizable business in recent years. Much of the commercial crop is processed into jellies, preserves, and sauces.

## ADDITIONAL TROPICAL FRUITS

The richness of the tropical flora provides many fruits that are of direct importance to people and innumerable others that are important to the maintenance of tropical ecosystems. Many are little if at all known to inhabitants of temperate climates. Obviously, it is impossible even to list, much less discuss, the majority of these species, although a number of more major ones are touched upon in the few pages following. By way of example, Table 4 lists 23 fruits and vegetables grown in southern Florida, several of which have been discussed, but a number of which are unfamiliar to residents of the other 49 states (and even to most Floridians).

### Avocado, *Persea americana* (Lauraceae)

The avocado, alligator pear, or aguacate is a rainforest tree native to the American tropics, but it has now been introduced to many areas with suitable climate worldwide. It was among the wild plants first utilized by the early Central American civilizations; in some it was a major source of nutrition. Archaeological finds show it to have been important in Mexico 9000 years ago. The fruit was strikingly increased in size by prehistorical selection, as archaeological remains show. The avocado is still widely grown, esteemed as a nutritious food, although more a delicacy than a staple in the modern diet. The large greenish or purplish fruits contain a single large seed surrounded by rich flesh containing as much as 30% digestible fat and 4% protein. Compared to most fruits it thus packs quite a nutritional wallop. Many local selections (some of them appreciably more tasty than the commercial avocado) are thin-skinned and ship poorly; they are consumed locally, and do not reach the large temperate-zone markets. Cultivars grown as a cash crop in the southern United States (California and Florida) are chosen especially for their keeping and shipping qualities. Even so, once ripe the fruit is quickly perishable, and therefore it is expensive to market. World production well exceeds 1 million metric tons annually, with Mexico the leading producing country.

**Table 4**. Some tropical fruits and vegetables grown in Dade County, Florida.

| Scientific name | Common name | Origin | Uses |
|---|---|---|---|
| *Aegle marmelos* | Bael | India, Sri Lanka | Yellow pulp is eaten fresh. |
| *Antidesma bunius* | Bignau | Philippines | Fruit is made into jelly and wine. |
| *Artocarpus heterophyllus* | Jack-fruit | Southeast Asia | Pulp is eaten fresh or cooked; seeds are eaten cooked. |
| *Averrhoa carambola* | Carambola | Southeast Asia | Tart to sweet pulp is eaten fresh or made into preserves. |
| *Blighia sapida* | Akee | Africa | Ye1lowish-white aril is edible when fruit is mature, but very poisonous when immature. |
| *Carissa carandas* | Karanda | India | Pulp is eaten fresh or made into jellies or preserves. |
| *Carissa grandiflora* | Natal plum | South Africa | Pulp is eaten fresh or made into jellies or preserves. |
| *Citrus aurantiifolia* 'Tahiti' | Tahiti lime (Persian lime) | Unknown | Juice is used in beverages, marinades, seasonings. Oil is used as flavoring and in cosmetics. |
| *Citrus aurantiifolia* | West Indian lime (Key lime) | Southeast Asia | Same as Tahiti lime. |
| *Citrus maxima* | Pummelo (Shaddock) | Southeast Asia | Pulp is eaten fresh. |
| *Cocos nucifera* | Coconut | Tropics | Important source of food, oil, and fiber. |
| *Cucurbita moschata* | Calabaza (Cuban squash) | Asia | Fruits are boiled, baked, or used to make pie. |
| *Dioscorea alata* | Yame (yam) | West Africa | Tubers are boiled; used to manufacture flour and flakes. |
| *Diospyros diayna* | Black sapote | Central America | Sweet brown pulp is eaten fresh. |
| *Ipomoea batatas* | Boniato (Cuban sweetpotato) | American Tropics | Tubers are boiled, baked, fried, or used to make preserves. |
| *Manihot escilenta* | Cassava (yuca, manioc) | Brazil and Mexico | Roots are boiled; used to manufacture starch and other products. |
| *Manilkara zapota* | Sapodilla (nispero) | American Tropics | Pulp is eaten fresh; tree is source of chiclé. |
| *Monstera deliciosa* | Ceriman | Mexico | Soft, sweet pulp is eaten fresh. |
| *Persea americana* | Avocado | American Tropics | Oily pulp is eaten fresh, usually in salads or dips. |
| *Pouteria sapota* | Mamey sapote | American Tropics | Sweet red pulp is eaten fresh or made into ice cream or sherbet. |
| *Psidium guajava* | Guava | American Tropics | Tart to sweet pulp is eaten fresh or made into purees, jellies, and paste. |
| *Spondias cytherea* | Ambarella | South Pacific | Sweet yellow pulp is eaten fresh or made into jelly. |
| *Xanthosoma sagittifolium* | Malanga (yautia, cocoyam) | South America | Tubers are boiled, baked, fried, or added to soup. |

**Breadfruit, *Artocarpus altilis* (Moraceae)**
The breadfruit is a handsome East Indian tree, and its large fruit is recognized as an excellent source of food. The species does well in hot, humid climates and was widely dispersed by Britain during her colonial era. Captain Bligh, against whom the famed mutiny took place on the *Bounty*, was on a mission to gather young breadfruit trees in Tahiti and transport them to the West Indies. Ordinarily, the meaty aggregate fruit develops parthenocarpically, and it is about 20% starch. It is usually eaten cooked in much the same fashion as potatoes. When cultivars do set seed (then called breadnut), little edible flesh develops, but the seeds can be cooked and eaten. Propagation is by root cuttings and offshoots. A similar species, the jackfruit, *A. heterophyllus*, also yields large, edible fruits, but it is less esteemed than the breadfruit.

**Cashew, *Anacardium occidentale* (Anacardiaceae)**
This small Brazilian tree is better known for the seed (nut) than for the fleshy receptacle (pear) that bears it (Fig. 9), and is used in its homeland as a fresh or preserved fruit. The cashew is discussed further under Nuts, later in this chapter.

**Coconut, *Cocos nucifera* (Palmae)**
With world production of some 30 billion coconuts annually, this is hardly a fruit that can be overlooked. Chief sources of the coconut are the Philippines, Indonesia, Sri Lanka, Malaysia, and Mexico. Most of the crop is used to produce copra, a source of oil that will be discussed in the next chapter. Both volunteer and planted coconuts provide food and other essentials for simple maritime societies throughout the tropics.

**Custard apple, *Annona* spp. (Annonaceae)**
Several annonas, including the cherimoyas or pinhas as well as the custard apple, are flavorful tropical fruits little known in temperate countries. They are relatives of the wild papaw (*Asimina*). Delicate and quickly perishable, they ship poorly even by air. The delightfully "fruity" sweet types are consumed raw, the pulp (with seeds) being spooned from the inedible rind. Other, more acid annonas are used mostly to make drinks or flavor frozen desserts. There are relatively few selected cultivars, and often volunteer or wild trees are the source of this delicacy which is consumed locally.

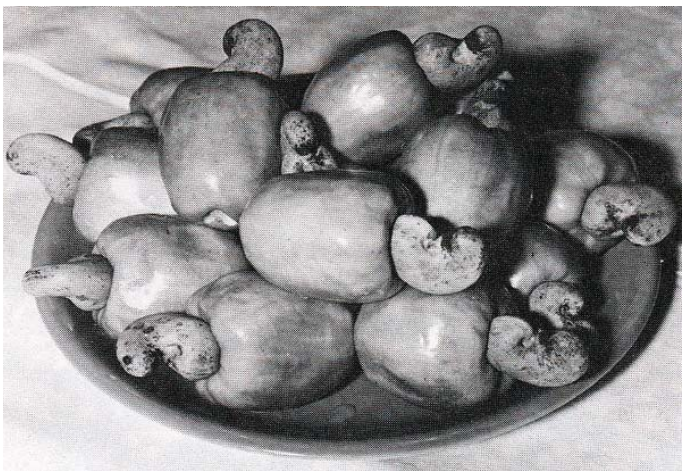

**Fig. 9.** Fresh cashews as harvested in Guatemala. The true fruit at the tip contains the cashew nut kernel; the fleshy pear-shaped pedicel and receptacle can be eaten fresh or preserved. [Courtesy USDA.]

**Date, Phoenix dactylifera (Palmae)**
Dates appear to have been in cultivation in arid parts of the Near East since 4000 BCE, and they were much utilized by the Sumerian and Assyrian civilizations. Puny-fruited wild and feral palms are still found in the area. *P. dactylifera* is interfertile with other wild species, including the east African *P. reclinata* and the northwest African *P. atlantica*, as well as with island and Indian species. Today the annual production

exceeds 2 million metric tons, most being grown in Asia Minor and northern Africa. In the Arabic world the date has long been a prime source of subsistence for nomadic tribes, being a rich source of nutrients when dried (about 70% carbohydrate, 2% protein, and 2.5% fat).

Dates may be eaten fresh, pounded into a paste, mixed with milk products (bolstering the protein content), or fermented to arrak (once described as "the strongest and most dreadful drink ever invented"). The date palm is usually propagated by "suckers" (side shoots from the base of the trunk). Flowering begins about the 4th year, and the flowers of the pistillate (female) tree are dusted by hand with inflorescences obtained from a relatively few staminate (male) trees grown apart from the female trees. In modernized date orchards the developing fruit may be protected from birds or other damage by being "bagged" in netting. Date palms require hot, dry weather for flowering, but they are ordinarily planted in oases, or where irrigation is possible, to supply necessary ground water. A single tree when mature may yield more than 45 kilograms (100 pounds) of fruit yearly, the fruit usually ripening in autumn (Fig. 10). The fruit must be hand picked, after which it is usually heated or treated chemically to aid in its preservation, and then allowed to ripen further to develop sugar content and to precipitate astringent components. Date palm fronds are widely used for thatching, braiding, and basketry, and the stems are in many places almost the only wood available.

**Fig, *Ficus carica* (Moraceae)**

The fig's relationship with people has been long and involved. *F. carica* is native to the eastern Mediterranean region, and either wildings or escapes are found scattered throughout the Near East, as are many native species of *Ficus*. Certainly the fig has been cultivated in the Holy Land for more than 5000 years, and escapes are found in rocky crevices all along the Jordan River and around the Dead Sea. The fig is cited in Egyptian documents of the 4th dynasty (about 2700 BCE), and it is mentioned repeatedly in both the Old and New Testaments of the Bible. Most figs are self pollinated and parthenogenetic, producing a nearly continuous sequence of fruits. But the larger, more luscious Smyrna figs (*F. carica* var. *smyrniaca*) bear only pistillate flowers, and so are dependent for fertilization upon the pollen of other figs. For this the male forms of the wild or semicultivated caprifigs (*F. carica* var. *sylvestris*), possibly ancestral to many of the select cultivars, are used as a source of pollen. The caprifigs are the host for a small fig wasp that carries the pollen from the caprifig to the Smyrna; the process is known as caprification. Caprification seems to have been discovered in Greece, several centuries BCE. In ancient Greece the biological facts of caprification were not clear, but it was realized that to assure good yields caprifig stems had to be hung in the elite fig trees, often with suitable ritual and tribute to

**Fig. 10.** The fruit of the date palm. [Courtesy J.C. Allen & Son.]

the gods. In California the Smyrna figs, termed 'Calimyrna' there, were not a commercial success until caprifigs and fig wasps were introduced in 1899. Most of today's fig cultivars develop fruit parthenocarpically, so they do not require caprification.

The fig fruit is a curious structure called a **syconium**, in which unisexual flowers are borne inside a pear shaped, nearly closed receptacle. In figs that bear only pistillate flowers and require pollination, the fig wasp enters the syconium, pollinates the fruit, lays its eggs, and dies. Wasp and eggs are absorbed by the fig. The early fruits are usually larger and are consumed fresh, subsequent "2nd crop" figs often being dried or preserved. Fig trees vary widely in size and shape, ranging from frail climbers to sturdy orchard trees about the size and shape of an apple tree. The latter, propagated by cuttings, are planted commercially. The fruit is generally gathered by hand when fully ripe and is often sun-dried (figs are typically grown in semiarid climates, where orchards must be irrigated). World production of fresh figs totals about 1.5 million metric tons, with about 200,000 metric tons dried. Portugal, Italy, and Turkey are the major fig producing countries. In the United States, production is chiefly in California, with some importation from the Near East. In the Near East figs are utilized for stock feed as well as for human food. The sycamore figs of the Nile Valley, *F. sycomorus*, have long been important in Egypt, where both the fruits and the timber have been extensively used.

**Guava, *Psidium guajava* (Myrtaceae)**
Now widely distributed and naturalized, the guava is believed native to tropical Brazil, domesticated more than 2000 years ago. The fruits are somewhat gritty, and are more often used to make a dessert paste or jelly than eaten fresh. The fruit is a rich source of minerals and vitamins. Most of the harvesting is done casually and by hand from relatively unselected dooryard trees, although some modern orcharding is practiced, especially in Florida. A smaller tree, *P. littora1e*, the strawberry guava, is cultivated on a small scale in the West Indies.

**Litchi, *Litchi chinensis* (Sapindaceae)**
Well known in the Far East, the litchi has been in cultivation since time immemorial. It is a favorite fruit in China, where the species is believed to be indigenous.

**Maracujá, *Passiflora* spp. (Passifloraceae)**
Known also as the passion flower, or granadilla, species of *Passiflora* yield tart, aromatic fruits about the shape of a small gourd; the fruit is usually used to make drinks or sherbetlike desserts.

**Mango, *Mangifera indica* (Anacardiaceae)**
The mango is a large, handsome tropical tree that bears an oblique, 1 seeded drupe with a distinctively aromatic outer pulp. It is apparently native to Southeast Asia, where it has been cultivated for thousands of years. Wild forms are found from the Malay Archipelago to northeast India (it is mentioned in ancient Hindu mythology). There are about 40 species in the genus *Mangifera*, and more than a 1000 cultivars. Many are delectable, tasting like something between a peach and a pineapple; others are quite rich, and have a turpentine taste that must be cultivated to be enjoyed. The diploid chromosome number is 40, and some cultivars are apparently polyploid. Today the mango grows throughout southern Asia, the Pacific islands, and the lowlands of Central America and South America. The Portuguese brought the mango from India to Brazil, and it is said that Captain Cook found the fruit abundant in Rio de Janeiro in 1768. Seeds reportedly brought from

Rio de Janeiro introduced the mango into the West Indies in 1742. Introductions into Florida, both from Mexico and from India, occurred early in the 19th century. An unusually diversified mango germplasm bank has been assembled in southern Florida, where better cultivars yield 30 metric tons per hectare (about 13 tons per acre) on a regular basis (unselected mangos tend to bear heavily in alternate years, and in irregular cycles). World production of mangos exceeds 13 million metric tons annually, two-thirds of the crop coming from India.

The mango thrives best in climates having a humid rainy season alternating with a dry season (during which the plant flowers and fruits). The species adapts well to a wide variety of soils, but it should have adequate drainage. Most mango trees are seedlings, and, although apomixis often occurs, variability is high. Inflorescences produce voluminous flowers, but often as few as 1% are hermaphroditic (the remainder being staminate), depending upon cultivar and conditions. Selections having superior fruit, made mostly in India, are vegetatively propagated by grafting, budding, marcottage (stem layering), or inarch grafting (bringing into contact partially debarked stock and scion until they grow together–a method widely practiced in India). Plantations are fertilized, often planted to a cover crop or an intercrop until the mango trees are of bearing age, and provided with irrigation when necessary (especially for young trees being established). Harvesting generally involves shaking the fruit from the trees; the fruit is then put into baskets and taken to the market. The fruits are quite astringent until fully ripe; eating mangos gives many people a rash on the lips, much like that caused by poison ivy (to which the mango is related). Where modern facilities are available, mangos keep well for many days in cold storage. Unfortunately, up to this time the mango has not been sufficiently important in technologically advanced markets to have been accorded the necessary experimentation on how best to keep and ripen the fruit (such as has been given the banana); consequently, much of the market fruit is inferior in taste to tree-ripened mangos locally consumed. The fruit contains as much as 20% sugar, plus fruit acids, minerals, and a slight bit of fat and protein. As with other fruits, surplus mangos can be fermented to vinegar or wines and brandy.

**Mangosteen, *Garcinia mangostana* (Guttiferae)**

This small tree from Southeast Asia yields a fruit of exquisite flavor, often termed the "queen of tropical fruits." Production in the Far East is mostly from dooryard plants, and transplantings to the New World have seldom succeeded. The mangosteen is a lowland species of the humid tropics, and quite susceptible to cold. Protective shade is helpful to young trees.

**Olive, *Olea europaea* (Oleaceae)**

Like the fig, the olive was intimately involved in early civilizations in the Mediterranean area, and it is frequently mentioned in the Bible. Carbonized remains of olives that are 5700 years old have been unearthed in archaeological diggings near the Dead Sea. Wild olives (frequently considered *O. europaea* var. *oleaster*) are found throughout the Mediterranean basin, and they cross readily with *O. europaea*. The wild and cultivated forms together probably represent 1 complex species. World production exceeds 8 million metric tons annually, mainly from the Mediterranean area (Spain, Italy, Greece, Tunisia, and Turkey). Perhaps 90% of these olives are crushed to yield oil. Olives for table use were 1st introduced into California through the San Diego Mission in 1769, and the 'Mission' cultivar is still a leading one. The olives are carefully handpicked–when straw-colored for green olives, and when black for ripe olives. The fruit is kept for several months in a weak salt solution, where a lactic acid fermentation takes place. The pickled fruit is then treated

with sodium hydroxide, washed, and stored in dilute brine. The lactic acid fermentation is omitted for green olives.

There are hundreds of cultivars of the olive tree, a small evergreen native to western Asia. The species has rather exacting climatic requirements, since it is killed outright at temperatures below –9°C (15°F), though a certain amount of winter chilling is required for floral induction. Olives, typically grown in semiarid regions, are apparently tolerant of alkaline soils. For steady and certain production irrigation is required. Propagation is vegetative, in the Near East mainly from knobs ("ovuli") developing at the base of the trunk, which root easily. Select cultivars are budded onto seedling olive trees or propagated from cuttings or by layering. In California, softwood cuttings are made under mist, and hardwood cuttings may be set vertically in the nursery row rather than as layers. Several decades are required for olive trees to reach full productivity. Well-established trees in Spain are estimated to yield nearly 750 kilograms of olives per hectare (about 670 pounds of olives per acre). In California, olives are more intensively fertilized, and yields are better. Olives, like mangos and many other fruits, are prone to **alternate bearing**—a heavy fruit set 1 year so exhausts the tree that only a light crop is borne the next. In California, this tendency is overcome to some extent by hormonal thinning. Harvesting is increasingly being done by mechanical shakers, especially for olives from which oil is to be extracted.

**Papaya, *Carica papaya* (Caricaceae)**

The papaya or mamão is a fast-growing, short-lived dioecious tree native to tropical America (Fig. 11). It was introduced into India before the 17th century, and it now grows throughout the Pacific islands, where it is more highly esteemed than in its homeland (many Americans think of it as a Hawaiian fruit). Recorded world production is well over 1 million metric tons annually, mostly from India and Brazil. The tree propagates readily from seed, and it may bear ripe fruit resembling the honeydew melon in as little as a year. The fruit is not very tasty unless it is eaten at just the proper stage of ripeness, one of the factors contributing to its limited usefulness outside of the area of its immediate production. It is usually consumed fresh in the same fashion as a cantaloupe, but it can be squeezed for juices or be pickled, candied, made into jellies, or even cooked like squash. The fruit is 90% water, but it is rich in vitamins A and C, and it contains some carbohydrates and minerals.

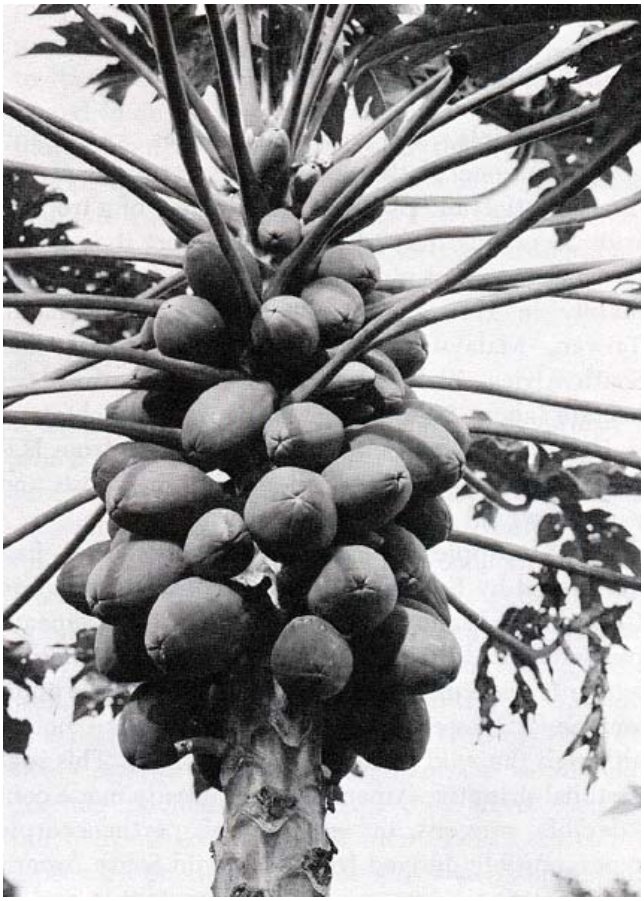

**Fig. 11.** Papaya is a popular tropical fruit and the source of the enzyme papain, which is used as a meat tenderizer. [Courtesy J.C. Allen & Son.]

A constituent called papain, which acts as a proteolytic enzyme, is sometimes used in meat tenderizers; consumption of the fruit is believed to be an aid to digestion and perhaps

also a vermicide. Papain is extracted commercially by scratching the green, immature fruits, from which a latex exudes and drips to a collecting platform. Most papain is produced in Tanzania, with imports to the United States chiefly for use in "chill-proof" beer (to prevent cloudiness due to precipitation of proteins). The papaya tree volunteers readily in warm, humid climates, performing best in full sunlight. It is weak, subject to damage where not protected from strong winds, but it tolerates a wide variety of soils. Plantations are established by clearing the land of all vegetation, planting seeds in a nursery, transplanting the young plants to the field, and keeping weeds in check (usually by hand labor, in the tropics). As with dioecious cultivars, all but a few staminate (male) trees are destroyed; some cultivars have perfect (hermaphroditic) flowers and sometimes sex reversal occurs (male to female, but never the reverse). Since the life of the papaya tree is only a few years, rotation planting is often practiced to ensure a continuous supply of bearing trees. Fertilizing and mulching are well rewarded by increased yields.

**Pineapple, *Ananas comosus* (= *A. sativus*) (Bromeliaceae)**

The pineapple, also known as ananas, piña, and abacaxí, is one of the outstanding examples of the domestication and plantation production of a tropical fruit. So popular has it become that more than 6 million metric tons of pineapples are produced annually mainly in Hawaii, but also in Brazil, Thailand, Taiwan, Malaysia, Mexico, the Philippines, and South Africa. Yields as high as 67 metric tons per hectare (about 30 tons per acre) have been obtained in Hawaii. However, production is shifting from Hawaii to other locations because of the high costs and expensive land capitalization.

The pineapple is a native American species, first discovered by Europeans when Columbus landed on Guadaloupe Island in 1493. At that time the pineapple had spread throughout most of tropical America, where it was cultivated here and there by the Indians. Several essentially seedless types were noted, although the wild forms were quite seedy. This suggest that primitive Americans had already made considerable progress in selection of parthenocarpic types, possibly derived from such wild South American species as *A. ananassoides*, *A. bracteatus*, and *A. erectifolius*.

Early introductions to Europe were grown in the greenhouse, mostly as a curiosity and the plaything of monarchs. But some selection and improvement was achieved, although it is not clear how much of this was transferred back to the pineapple-growing regions. The pineapple was taken by the Portuguese to India in 1548, and it was grown in the East Indies soon after. Breeding work was undertaken in southern Florida about 1900, and shortly after in Hawaii. Little came of this, however; most commercially produced cultivars, bearing such varietal names as 'Cayenne,' 'Queen,' 'Spanish,' and 'Pernambuco,' have been obtained in various other parts of the world. Pigeon-holing of cultivars has never been very satisfactory, but the more recent studies suggest these groupings:

- 'Spanish'—A spicy-acid flavor, very good for shipping, worldwide.
- 'Queen'—Sweeter, less acid, rather small fruits, mainly African and Australian.
- 'Abacaxi'—Sweet, tender, juicy, best suited to local use, mostly South American.
- 'Cayenne'—Large, tender, low fiber, excellent for canning (most of the Hawaiian crop), worldwide.
- 'Maipure'—A newer spineless form, sweeter than Cayenne but more fibrous, mainly northern South American.

The pineapple fruit grows on a central stalk from a rosette of leaves, which are usually prickly.

The fruit is multiple, consisting of fused individual flowers. Strains are self-incompatible, but cultivars will cross and set seed, as will crosses with wild types. The fruit contains up to 16% sugar, various acids, vitamins, and minerals, and a supposed digestive enzyme (bromelin). Plants are propagated by basal suckers or "slips" that arise from beneath the fruit (Fig. 12). Under the careful, automated culture accorded plantation growing in Hawaii, a sucker will bear a new pineapple head in about 1 year. After the 1st fruit is cut, the plant branches to yield a 2nd crop of 2 fruits, and when these are cut, a further branching yields 4 small pineapples, which are used for cut pineapple or for juice. After the 3rd crop, the field is replanted to avoid any further reduction in fruit size. Planting is typically through a paper or plastic mulch to conserve water and to control weeds. In Hawaii, extensive research has determined just what fertilization, trace elements, and pesticide schedules are needed to give the highest yields of high-quality fruit. The whole operation, including field harvesting, is almost completely automated. Although the individual pineapple heads are generally still cut by hand, portable conveyor belts carry the fruits to central loading facilities,

The pineapple has been suggested as an efficient source of biomass production, being about as productive as sugarcane or cassava on far less water. Pineapple has crassulacean acid metabolism, providing good carbon dioxide assimilation with maximum water conservation. One study has indicated that pineapple, sugarcane, and cassava can yield enough sugar to produce 964, 921, and 611 liters of ethanol per hectare per month, respectively with pineapple requiring less than half the water of sugarcane and only a little more than half that of cassava. The crop is suggested for seasonally dry regions, such as central and northeastern Brazil.

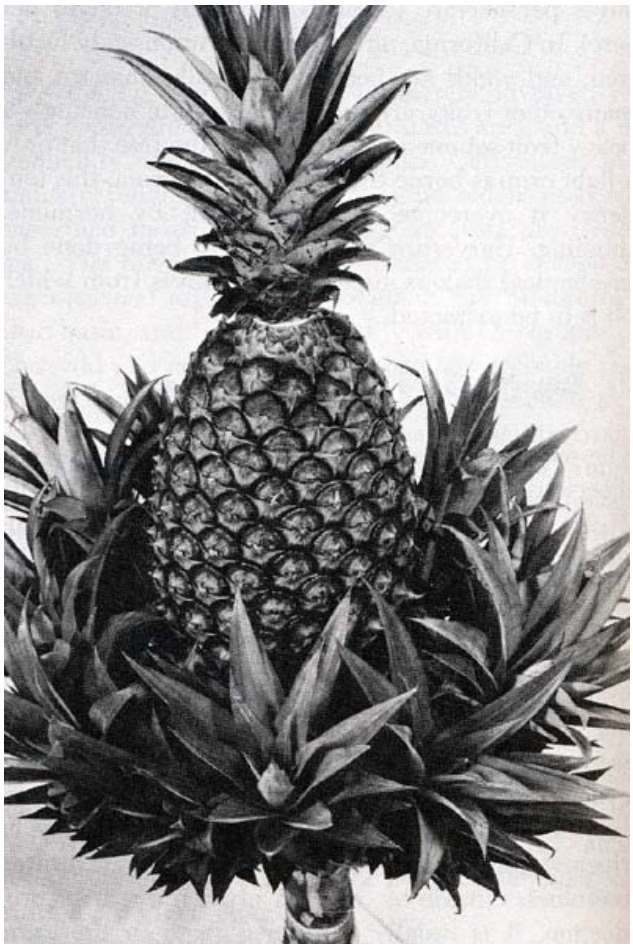

**Fig. 12.** Pineapple may be propagated from slips (leafy shoots originating from axillary buds borne on the base of the fruit stalk), from the crown of the fruit, or from suckers lower down on the stem. [Courtesy Dole Corporation.]

**Pomegranate, *Punica granatum* (Punicaccae)**

The pomegranate is a small shrubby tree found wild in northeastern Turkey and the Caspian region. The fruit contains many pulpy seeds, each with a red, juicy aril—an additional covering surrounding the seed. Pomegranate domestication goes back at least to the Bronze Age, and the species is often represented in ancient Egyptian tombs. Pomegranates are more eaten in the Old World than in the New World, but they are grown somewhat in California and Latin America. There are few select cultivars. Plants can be propagated from seed or cuttings, or by layering.

**NUTS**

A number of woody plants (trees and shrubs) of which the seed is the important food con-

stituent are grouped here as "nuts." Nuts are not of great commercial importance, although nutritionally they are quite a concentrated source of food. Unlike most fruits of the previous section, they are generally rich in oil and fat, and contain moderate amounts of carbohydrate and protein. They ship and keep rather well, and they can be used in much the same fashion as cereal grains and seed legumes. Nuts provide relatively little of the food needed for the world's burgeoning populations. Perhaps they have been too much overlooked and will increase in importance, especially on those tropical soils that cannot stand continuous tillage and annual cropping. Tropical forestlands, yielding little in the way of food directly, would seem to be a logical habitat for more extensive nut cropping. Certainly one would suppose that the seeds of trees could be as important a source of food in their adapted habitat as are the seeds of grasses and annual legumes.

Most nuts are something of a luxury; they are expensive, and mostly consumed in small amounts as sweetmeats or delicacies. But in certain times and places, nuts have been used as staple foods, as the piñon nut was by the American Indian in sections of the Southwest. Indeed, the piñon nut crop is still collected from wild stands of the piñon pine rather than from cultivated orchards. In fact, nuts are more often gathered from the wild than any of the foods discussed in this chapter. Wild trees are the source of most Brazil nuts, cashews, black walnuts, certain hickory nuts and pecans, and of course coconuts, if you prefer to consider it here rather than with fruits or oil sources. Fortunately, others, such as the almond, filbert (hazelnut), and domesticated pecans have been brought into cultivation, and cultivars have been selected that yield vastly improved nuts. Usually these are grown in well-tended orchards with the aid of many of the techniques employed in fruit orchards. There would still seem to be tremendous opportunities ahead for domestication and improvement of nut crops; a handicap, of course, is the long generation time, a problem encountered with all perennial tree crops.

**Almond, *Prunus dulcis* (Rosaceae)**

The almond, *Prunus dulcis* (= *P. amygdalus* and *P. communis*), is a species closely related to *P. persica*, the peach. In the almond, however, the seed of the drupe is utilized and the flesh is discarded. The outer flesh is astringent and tough, unlike that of its near relative the peach. The 2 species may have had a common Near Eastern ancestor, and some believe that the peach was developed from an almondlike progenitor through selection of types having edible flesh. The almond has been under cultivation for thousands of years in the eastern Mediterranean region, and it is repeatedly referred to in the Bible. There are 2 varieties of almond, the sweet (*P. dulcis* var. *dulcis*), and the bitter (*P. dulcis* var. *amara*). The former is the source of edible almond nuts used in confectionery; the latter (poisonous to eat because it contains prussic acid) is grown chiefly for the extraction of bitter almond oil. Almonds contain 18–20% protein; the "skin" surrounding the nutmeat is rich in minerals and should be consumed with the nut for its food value.

The cultivation of almond trees is similar to that of peaches. They require a subtropical climate that is nearly frost free, similar to that of their native Mediterranean region. In the United States the center of almond production is in semiarid California, where almonds were introduced in 1843 by Franciscan Fathers; the orchards are irrigated, and harvesting is mechanized. The trees begin bearing within 7 years. Planted 7.5 to 9 meters (about 25 to 30 feet) apart, they yield slightly more than 1 metric ton of nuts per hectare (about 0.5 ton per acre) at maturity. The pit or seed separates readily from the split flesh as the fruit ripens and cracks. The pit is mechanically cracked, freeing the seed, which may be bleached, but is more commonly roasted for consumption in candy, mixed nuts, and confectionery.

Almond production in the United States (mainly California) runs more than 200,000 metric tons annually. World production approaches 1 million metric tons in some years, with Italy and Spain almost as productive as the United States.

**Brazil nut, *Bertholletia excelsa* (Lecythidaceae)**

Known also as the cream nut, or castanha do Pará, the Brazil nut is an important indigenous food plant of northern South America. Closely related is the Brazilian sapucaia, or paradise nut, *Lecythis* spp. Both are magnificent forest trees that grow in the Amazon Valley and bear clusters of seeds (nuts) in horny, urnlike fruits. The tip end of the fruit dehisces, and within it, clustered much like segments of an orange, are the individual Brazil nuts that have become so familiar a component of mixed nuts at temperate-zone cocktail parties. The nuts contain as much as 70% oil. Most nuts are still collected from fallen pods in the forest. Production amounts to approximately 30,000 metric tons annually, most of which is exported to the United States and to Europe.

**Cashew, *Anacardium occidentale* (Anacardiaceae)**

The cashew, known also as the marañón, or cajuil (Spanish), cajou (French), and cajú (Portuguese), is a remarkable plant of many uses (see Fig. 9). In a previous section it was noted that the fleshy, pear-shaped stalk or receptacle, which bears the single-seeded fruit, is often utilized fresh or preserved, especially in South America (in India, the chief commercial source of the cashew, the receptacle is usually discarded). In addition to the receptacle and the nut, the species yields a phenolic nut-shell "oil," cardol (90% anacardic acid) that is used as a medicinal, an irritant, a wood protectant, and a source of resin; the young leaves are sometimes used as a flavoring and as a medicinal; a yellow gum obtained as an exudate from incisions made in the bark is used mainly as an adhesive; the wood is utilized in several ways; and the bark is used to some extent for tanning and to make a yellow dye.

The cashew is native to coastal parts of northeastern Brazil, but for 400 years has been grown in many parts of the world. It is a sprawling broad leafed evergreen, well adapted to poor soils and dry, sandy locations. Various parts of the tree are quite astringent and toxic, especially the shell that surrounds the nut, which may cause painful blistering, especially before the nut is fully ripe. The tree was first introduced by the Portuguese into India as a shore tree to bind the soil; it flourished, and it now grows as an escape throughout India, Sri Lanka, and Southeast Asia. The Portuguese also introduced the cashew into Africa, where there is considerable nut production (the unshelled nuts are generally shipped to India for processing). Nut production in India may reach 150,000 metric tons annually, with an additional 350,000 metric tons from Africa (mostly Mozambique) and lesser amounts from South America and various oceanic islands.

The cashew has been propagated chiefly by seed. Typically, 3 nuts are planted into holes spaced 6 meters (about 20 feet) apart; only 1 of the 3 seedlings (the most vigorous) is allowed to persist. In recent years cultivars have been selected in India that are propagated by inarching, budding, and other vegetative techniques. The trees may begin bearing in as little as 3 years, but they seldom yield profitably until they are 7 years old. Some mature trees have been reported to yield as much as 90 kilograms (about 200 pounds) of nuts. Adapted as the cashew is to the sterile, sandy *taboleiros* of Brazil, the trees seldom receive the benefits of any fertilizer.

Nuts are generally harvested from the ground, where they fall with the receptacle when ripe. They are dried in the sun briefly until their moisture content is reduced to about 7% (marked by a rattling sound when the nut is shaken). At this stage they may be stored for prolonged intervals.

Occasionally in India the kernels are eaten in this state, but more frequently the nut is roasted. In India this is customarily done in a shallow, open pan. The shell oil that is exuded by the roasting nuts must be absorbed by shaking the nuts in sand to avoid blistering the hands of handlers and shellers. A few factories in India have mechanized the roasting of cashew nuts and specialized in the recovery of by product cashew shell oil. The actual shelling is done by hand, typically by women utilizing a mallet. In Africa a machine was developed for cutting into the shell to allow its easy separation, giving a more perfect, undamaged nut. The nuts are chiefly exported to North America and Europe, where they are consumed as table nuts and in confectionery. The kernel is nearly half oil (of which about 74% is the oleic type) and about 18% protein.

**Hazelnut, Filbert, or Cobnut, *Corylus* spp. (Betulaceae)**

Species of *Corylus* are sometimes also called Turkish nuts or Barcelona nuts, with good reason; Turkey produces as much as 300,000 metric tons annually, and Spain about 30,000 metric tons. Italy, too, is a major producer, with the crop often approaching 100,000 metric tons per year (compared with 10,000 metric tons per year in the United States, mostly from Oregon).

There are native species of *Corylus* in North America and in Eurasia. They make an excellent understory in open woodlands in temperate climates. *C. americana* furnished wild hazelnuts to many a school boy when America was still rural, and several cultivars have been domesticated. But of greater economic importance is the larger European tree, *C. avellana*, a vegetational dominant bordering peat bogs in northern Europe that enjoys climates with mild winters and cool summers. Select varieties are propagated vegetatively, often by budding or grafting onto seedlings, which are then transplanted to the orchards. Trees 1st bear when about 4 years old, and they eventually provide nut yields of about 1 metric ton per hectare (nearly 0.5 ton per acre). Nuts contain about 60% oil and 13% protein. The species bears biennially, and cultivars are self-incompatible (so about 10% of the trees in an orchard must be pollinator trees of a different cultivar).

**Macadamia, *Macadamia ternifolia* (Proteaceae)**

The macadamia nut, also known as the Queensland, Australian, gympie, bush, or bopple nut, is native to Australia, whence it was introduced into Hawaii less than a century ago. In Hawaii it has gained favor so rapidly that it has become one of the most important orchard crops of the islands. Cultivars have been selected both in Australia and in Hawaii. Of little consequence in the world food picture, macadamia nonetheless serves as an interesting example of a tropical nut industry in the making.

Macadamia trees are large, broad-leafed evergreens that reach heights of 18 meters (about 60 feet) or more. The fruit is a follicle with a fleshy husk that splits to reveal a spherical seed about an inch in diameter. This seed, or nut, consists of a meaty kernel in a relatively thin enclosing shell that must be cracked to get at the kernel. Machines have been devised to remove the outer husk, after which the unshelled nuts can be kept satisfactorily for several months in dry storage. For final processing, the unshelled nuts are dried to approximately 2% moisture in a warm draft of air. The shell is difficult to crack by hand, but, in commercial production, powered nut-cracking machines are used quite effectively. The shelled nuts are “french fried” in oil for several minutes, and after being drained are salted and vacuum-sealed in glass containers for export.

Best yields of macadamia are obtained on well-drained lands where rainfall is generous, Harvesting consists of gathering nuts as they fall, a chore that lasts for several months. Annual yields of 45 kilograms (100 pounds) or more per tree are obtained after the trees are 15 years of age.

**Pecan, *Carya illinoensis* (Juglandaceae)**

The pecan was highly regarded as a wild nut tree by settlers in what are now the border states and the upper South of the United States. Several species of hickory (the genus *Carya*) yield edible nuts, but *C. illinoensis* is responsible for those pecan cultivars that today support a sizable orchard industry. These thin-shelled ("paper shell") varieties account for about half the domestic production (which in most years well exceeds 100,000 metric tons), and are grown chiefly in Georgia and Alabama. The harvest from wild and seedling trees exceeds that from select cultivars in Louisiana, Texas, and Oklahoma. There is little growing of the pecan outside of the United States, although successful introductions have been made into Australia and China.

Typical of hickory fruits, the pecan has an outer leathery husk that splits open when mature to reveal an inner shell that surrounds the 2 kernels. Harvest is by picking the nuts from fallen fruits. Sometimes the fruits are knocked from the trees with long poles, but, since a mature pecan tree is of large forest stature, mechanical harvesting aids are not frequently feasible. The nuts are dried, or "cured," for a few weeks, and they are then ready for eating without roasting or other treatment. Cracking and shelling machines handle most of today's crop, which is usually marketed shelled.

**Pistachio, *Pistacia vera* (Anacardiaceae)**

The pistachio (or pistache), native to Western Asia, has been widely cultivated since ancient times in the Middle East. It is in the same family as the mango, the cashew, and poison ivy. There are a dozen or more species of *Pistacia*, some serving as rootstock for grafted *P. vera*, but only *P. vera* has the dehiscent fruit that yields commercially acceptable edible nuts. In India and Afghanistan, nuts are still obtained from wild trees. In general, the orchard cultivars of Iran, Turkey, and Italy differ little from wild pistachios, having been selected mainly for larger nut size. An increasing number of pistachio orchards have been established in the interior valleys of California, where the locally developed 'Kerman' cultivar yields larger, better-flavored nuts than can be imported. Also, modern California technique, free the nut from their outer hulls quickly, thus preventing the "moldy" discoloration that traditionally required imported shells to be dyed red. Most commercial production comes from Iran and Turkey, but California production is exceeding 5000 metric tons. World production approaches 70,000 metric tons annually.

Since *P. vera* does not root readily from cuttings, most cultivars are propagated by budding onto seedling rootstocks. Choice of a suitable species as rootstock can result in a dwarf tree more easily reached for harvesting. Budded seedlings should be planted to the field very early, since they tend to develop a taproot that suffers in transplanting. Transplanting is usually accomplished during the dormant season (December–January). Mature trees are usually spaced about 9 meters (30 feet) apart; trees planted closer together for earlier yield can be thinned. The trees seem to prefer well-drained soils having adequate calcium; the tree thrives on sandy loams, and is quite tolerant of drought. The pistachio is relatively slow-growing and needs little pruning, at least with budded stock. It is one of the few dicotyledonous trees known to attain an age of more than 1000 years.

The species is dioecious. As low a ratio as 1 staminate (male) tree to 20 pistillate (female) trees is considered adequate in some orchards. The diploid chromosome number for *P. vera* has been reported both as 30 and as 32. Fruit buds are initiated by winter conditioning. Like the apple, the pistachio tends to bear heavily in alternate years. Fruiting begins about the 5th year, but it is not really remunerative until the tree is at least 10 years old. Trees 20 years old are reported to yield 68 kilograms (about 150 pounds) or more of marketable nuts per tree. The fruit is a small drupe that

matures in autumn, at which time the outer "pulp" slips easily from the inner shell. The latter splits longitudinally, making it relatively easy to free the edible seed within. In the Near East, picking is done largely by hand. The husks are laid out on a cloth spread under the tree, and the nuts are removed from the husks by hand. These are dried in the sun. In Turkey the dried nuts are often soaked in water, then hulled on stone rollers, accompanied by winnowing.

The nuts are typically consumed roasted and salted, or they are absorbed by the confectionery trade. When harvested, the nuts contain about 40% moisture. Dried kernels are approximately 20% protein and nearly 60% oil. The oil is approximately 70% oleic, 20% linoleic, and 8% palmitic.

**Walnuts, *Juglans* spp. (Juglandaceae)**

There are a number of kinds of walnuts, ranging from the wild black walnut (*J. nigra*) and the butternut or white walnut (*J. cineria*) of the United States, of which there has been only limited domestication, to the English or Persian walnut (*J. regia*), which is extensively orcharded throughout southern Europe, in China, and more recently on the Pacific coast of the United States.

The black walnut is one of the outstanding timber trees of the eastern deciduous hardwood belts in the United States. It has been much decimated for timber and veneer, but some nuts are still collected from wild trees for home consumption and, in certain rural areas, for commercial sale. Walnut fruits are drupes. The husk of the black walnut does not readily separate from the shell; it is usually allowed to rot away. Moreover, the husk strongly stains hands and clothing. Add to this the hard-to-crack inner shell, and it is no wonder that the black walnut nut industry has not made great commercial strides. Production of the meat is usually a sideline activity in rural areas for "pin money." The nut fragments are mostly used as confectionery flavoring, for it is difficult to remove the kernels entire.

**Fig. 13.** Fruit of the English walnut, showing the outer husk and the shell-covered nut. [Courtesy USDA.]

World production of the English walnut, however, comes to nearly 1 million metric tons annually. California and Oregon produce 200,000 metric tons, Italy more than 60,000 metric tons, and Europe as a whole about 250,000 metric tons. Significant additional production occurs in Turkey and China. *J. regia* is native to Persia. It is a handsome ornamental tree in warmer climates. In California orchards it is customarily grafted onto American walnut rootstocks. The husks fall away much more readily than those of the black walnut, leaving an attractive shell in which the English walnut is customarily marketed (Fig. 13). Harvesting is by collection of the fallen nuts under the trees in

the orchard. Walnut meats contain about 15% protein as well as abundant oil.

**Other Nuts**

The 8 kinds of nuts reviewed so far by no means exhaust the possibilities. These are the chief nuts in commerce today, and they serve to exemplify this group of food plants, but others, such as the chestnuts (of the family *Fagaceae*) are equally significant. Chestnuts—*Castanea sativa* of southern Europe, *C. mollissima* of China, and *C. crenata* of Japan–are all much appreciated for their edible seeds, world production of which exceeds 500,000 metric tons (about 170,000 metric tons in Europe, 165,000 in China, and 67,000 in Japan). Many other nuts are of local interest only, especially those harvested from the wild in agriculturally less advanced parts of the world. One of the few temperate-zone nuts that still comes largely from wild trees is the piñon, *Pinus edulis* and related species of the family Pinaceae, of the American Southwest. An October ritual with the New Mexican Indians was the gathering of the "Pinones," mostly picked up from the ground (but occasionally gained by robbing rodent caches, or shaking the seeds from their cones into a box or onto a blanket, if collecting has been timed to coincide with the few days of nut drop). Bumper crops occur in a given locality erratically over a period of years, so the market supply is generally opportunistic. Piñon nuts will store for years, and they are generally roasted before consumption.

As noted in the opening paragraphs, a number of nuts would seem to have great potential as food plants for the future, especially in tropical climates. Some of the nuts that are well known and were used at least in earlier days are: acorns (fruit of the oak tree, *Quercus*); African locust beans (*Parkia*); beechnuts (*Fagus*); sal-nuts (*Ginkgo*); hackberry (*Celtis*); several hickories (*Carya*); oysternut (*Telfairia*); pignolia (seeds of certain European pines, *Pinus*); pili (*Canarium*, of the Far East); souari (*Caryocar*, of South America, also known as butter, paradise, or guiana-nut); *Terminalia*, and wingnut (*Pterocarya*).