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Trees and Their Economic Importance

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I. Abstract

The biological and logical meaning of trees, which are one of the important woody plants of our ecosystem, are reviewed in this article. Trees are mostly used for timber purposes, but in the present article the utility of trees with respect to their importance in restoring, reclaiming and rejuvenating denuded and disturbed soils, their ecological, ecodevelopmental and environmental use, and their educational and recreational value in gardening, landscaping and bioesthetic planning is described. In addition, the importance of trees is discussed with reference to their value as a source of sustenance: food, sugars, starches, spices and condiments, beverages, fumitories, masticatories and narcotics, medicines, essential oils, fatty oils and vegetable fats, waxes, soap substitutes, vegetable ivory, fodder, fuel, bioenergy or biofuel, fertilizers, fiber, pulp and paper, tannins, dyes, rubber and other latex products, gums, resins and cork. Lastly, the food plants of mulberry and non-mulberry silkworms, which feed on the leaves of many forest trees, are mentioned.

II. Introduction and Classification of Trees

Trees are important to humankind not only economically, environmentally and industrially but also spiritually, historically and aesthetically, for they sustain human life through direct and indirect gains by providing a wide range of products for survival and prosperity. However, it is not always easy to define "tree." A tree is a large, long-lived (i.e., perennial) woody plant that attains a height of at least 6 m (20 ft) at maturity in a given locality and usually—but not always—has a single main self-supporting stem called a "trunk" or a "bole," which gives off spreading branches, twigs and foliage to make a crown (Venkatesh, 1976; Panshin & de Zeeuw, 1980; Hawkins, 1986). Since the diameter at breast height (dbh) of trees is determined internationally at 1.35 m (4.5 ft) above the ground, a tree must be unbranched—i.e., with a single trunk—at least up to 1.5 m (5 ft) from the ground. But this definition does not cover the following (Venkatesh, 1976), which are also considered trees:

- Palms are typically unbranched trees with only one trunk (columnar stem), called the "caudex," which ends in a crown of large leaves.
- Bamboos are trees without a main trunk but with a cluster of culms arising from the underground rhizome. These culms are unbranched, with distinct nodes and internodes that give them a jointed appearance.

- The banana tree (plant) has only a thick false stem (pseudostem), which is not woody but made up of a central core of soft tissues concealed by the fibrous and sheathing bases of large leaves. Strictly speaking, the banana plant is a giant herb.
- Tree ferns like *Cyathaea* and *Alsophila* have erect rhizomes with generally unbranched trunks, topped by a crown of graceful, feathery fronds that form a rosette at the apex.
- Bonsai—i.e., tailored or humanmade miniature or dwarfed living trees that have been prevented from reaching their normal size—are grown in pots and kept in greenhouses, drawing rooms, etc. This technique was first perfected by the Japanese.

In addition to the above definitions, the scientific distinction between trees, shrubs, lianas and undershrubs or semishrubs is not always clear. For example, many species of trees—e.g. *Rhododendron* spp., which are large under normal conditions—become shrubs when growing near their altitudinal and latitudinal limits. Woody plants in which several branches arise from near the base, giving the plant a bushy appearance, are called "shrubs." Likewise, certain species of figs (*Ficus* spp.) begin their life as woody climbers called "lianas" but eventually end up as trees; i.e., they become arborescent. Similarly, *Grewia scabrophylla* at times is an undershrub, when exposed to annual fires; in other places, however, it grows into a tall shrub (Panshin & de Zeeuw, 1980). The science dealing with the study of woody plants—i.e., trees and shrubs—is called "dendrology."

Trees can be classified in several ways: Depending upon their utility or end products, they may be called "avenue," "ornamental," "shade bearing," "fragrant," "fruit bearing," "medicinal" or "drug yielding," "timber yielding," "fodder yielding," "nitrogen fixing," "venerated," "fuel yielding," "fiber yielding," "multipurpose trees," etc. Those trees that remain green in their dormant season due to persistence of leaves are called "evergreen trees." In such trees all the leaves do not fall off simultaneously, and the plants are never leafless. Those trees in which all the leaves of a plant fall at the end of one growing season one by one or simultaneously, leaving the plant leafless in the dormant season, are called "deciduous trees." All cone-being trees are called "conifers" or "coniferous trees," and all trees that are not cone bearing but are flower bearing are called "flowering trees" or "broad-leaved trees." Whereas conifers have needle-shaped leaves, flowering trees have broad or flattened leaves.

A conifer usually has a conical appearance and has an excurrent stem; i.e., its main stem is thickest at the base and gradually tapers toward the apex, with lateral branches in an acropetal succession. A flowering tree usually has a dome-shaped appearance and a deliquescent or decurrent stem in which the main trunk divides at some distance from the ground into several branches, which branch again and again, making the trunk appear to deliquese or melt away.

Ornamental trees that have showy flowers are called "ornamental flowering trees," and those with beautiful foliage and inconspicuous flowers are called "ornamental foliage trees." The former are usually deciduous; the latter, evergreen.

Those trees in which seeds are borne naked are called "gymnosperms" (from the Greek *gymnos* [naked] and *sperma* [seed]), and those trees in which seeds are enclosed within an ovary/fruit wall are called "angiosperms" (from the Greek *angeon* [vesicle] and *sperma* [seed]). The angiospermic trees are further classified into dicotyledonous or dicot trees, if they have two cotyledons in their seeds, and monocotyledonous or monocot trees, if they have only one cotyledon in their seeds. Both gymnosperms and angiosperms are sometimes placed under one division, called "spermatophyta," "siphonagama" or "phanerogams." "Spermatophytes" (from the Greek *sperma* [seed] and *phyton* [plant]) are those plants that are seed bearing. "Siphonagama" (from the Greek *siphon* [tube] and *gamous* [marriage]) are those plants in which fertilization occurs by means of a pollen tube. "Phanerogamous" (from the Greek *phaneros* [open] and *gamous* [marriage]) are those plants in which reproduction is not concealed or hidden but

open; i.e., they bear flowers and produce seeds. Trees belonging to gymnosperms and angiosperms not only constitute the dominant component of any vegetation but also add to the biodiversity or biological diversity of any particular region.

III. The Economic Importance of Trees

Trees represent one of the important components of each and every terrestrial ecosystem and are a part of nature's precious gifts. Some are deciduous; others are evergreen. Some have beautiful flowers; others have beautiful fruits or foliage. Some are scented; others are ugly but economically very important. The welfare of humankind is affected not only by their density and diversity but also by their direct and indirect values, which are beyond estimation. In fact, each letter of the plural word "TREES" has a logical meaning (Seth, 2002):

T Timber, the first and the foremost use of trees

R Restoration, reclamation and rejuvenation of denuded and disturbed soils by using trees to control soil erosion and desertification, protect watersheds, improve soil nutrient status (by growing nitrogen-fixing trees) and retain moisture in the soil

E Ecological, ecodevelopmental and environmental use of trees for effective and efficient purification of the environment because trees act as oxygen banks and eliminate air pollutants; for abating or moderating temperature, noise and wind by planting trees as environmental screens, thus affecting the microclimate; for harboring wildlife; for maintaining biodiversity; and for conserving energy

E Educational and recreational value in gardening, landscaping, bioesthetic planning, art, culture and religion

S Source of sustenance; i.e., food, fuel, fodder, fertilizer, fiber, medicine, tannin, dyes, oils, etc.

A. TREES AS A SOURCE OF TIMBER

Trees are woody perennial plants, i.e. they are capable of producing wood through the meristematic activity of the vascular cambium. The latter gives rise to secondary xylem (nontechnically called "wood") toward its inner side and to secondary phloem (nontechnically called "bark") toward its outer side. Wood produced by cycads is called "manoxylic." It is not compact—i.e., it is loose, not dense—with wide rays, pith and cortex and thus useless commercially. Wood produced by conifers, taxads, *Ginkgo biloba* and dicots is called "pycnoxylic." It is compact and dense, with narrow rays, pith and cortex and hence commercially very useful. The commercially useful woods are called "timbers," and timber that is used for building purposes is called "lumber." *Tectona grandis* (teak) and *Cedrus deodara* (deodar) are, respectively, considered the best angiospermic and gymnospermic timbers in the world.

Woods obtained from timber trees are used for construction and other miscellaneous purposes like agricultural implements, boat and ship building, carts and carriages, carving and turnery, cooperage (barrel making), electric poles, engraving and printing blocks, furniture and cabinet work, matches and match boxes, mathematical instruments, musical instruments, packing cases and boxes, pencil and pen holders, picture framing, railway carriage and wagon building, railway sleepers, rifle parts, shoe heels and boot lasts, shuttles, sports goods, tea chests, toys, etc. For examples of these one may consult Anonymous (1970–1972, 1983) and Trotter (1940, 1944).

B. TREES IN THE RESTORATION, RECLAMATION AND REJUVENATION OF DENUDED AND DISTURBED SOILS

Planting trees on denuded and waste land, along roads, railway tracks, deserted areas, watersheds, etc. protects soil from erosion by wind or water by firmly binding it with roots and by diverting runoff during rains. The sides of the roads, railway tracks and watersheds can thus be protected. Desertification can likewise be controlled by planting trees. The trees also retain moisture in the soil, and if nitrogen-fixing trees are grown, the nutrient status of the soil can be enriched tremendously.

The sap of *Cassia fistula* (amaltas) leaves contains certain chemicals that have a purgative action on the digestive organs of grazing animals like goats, cows and buffalo, and thus amaltas is well suited for planting on wastelands. Wild fruit trees like *Zizyphus jujuba* (ber) and *Morus alba* (toot) can also be propagated on wastelands in and around villages.

C. ECOLOGICAL, ECODEVELOPMENTAL AND ENVIRONMENT USES OF TREES

1. Natural Purifiers of the Environment

Plants, including shrubs and trees, act as biological filters by helping cleanse the environment. They are the best natural purifiers of environment pollution; i.e., they improve the quality of the air we breathe. First, they act as the oxygen banks on this planet. They play an important role in maintaining the oxygen cycle, which is essential for the survival of all forms of life. Second, they may help reduce pollution. Leaves can absorb gaseous pollutants on their surfaces, especially if their surfaces are waxy, spiny or hairy. In addition, stems, branches and twigs can intercept particulates. Third, they reduce oxides of carbon in the air, can also fix atmospheric nitrogen, disintegrate waste and act as sinks of pollution or pollutant scavenges by absorbing and metabolizing toxic gases and heavy metals (Chakraverty & Jain, 1984).

Different species as well as individuals within a species can vary in their tolerance to pollutants. High concentrations of pollutants can damage and even kill many tree species. Trees that are particularly sensitive could be used as early warnings of high pollution levels.

2. Environmental Screens

When properly grown in urban and rural areas, trees act as wind barriers by decreasing the force of the wind and reducing the level of noise from highways and other sources. Even individual trees, if strategically planted around a house, can provide relief from noise and annoying lights at night. Trees thus reduce stress on human beings. Ecologically they act as wind breaks and shelter belts, thus providing protection against soil erosion and a defense against encroachment by seas, floods and deserts.

3. The Physical Environment

Trees help to reduce temperature by providing shade and by intercepting, absorbing and reflecting solar radiation, especially in warmer places, where there is year-round warmth and sunshine (Schubert, 1979). Trees also function as natural air conditioners by evaporating water from their leaves through the process of transpiration. A single large, well-watered city tree can transpire about 380 liters (100 gallons) of water in one day, thus producing the cooling effect of five average room air conditioners running 20 hours a day (Schubert, 1979). Trees thus improve the microclimate; i.e., they help control and stabilize the climate of the region and of the world as a whole. A single tree standing alone may not affect the overall surrounding much, but

a belt or groups of trees or many trees scattered throughout the neighborhood can be quite effective (Schubert, 1979).

4. Wildlife

Trees, both native and ornamental, harbor wildlife. They directly feed and house the majority of world's creatures and animals like insects, birds, small mammals and reptiles, which we need in order to live. Thus they play a major role as one of the important components of natural and humanmade biodiversity.

5. Urban and Rural Afforestation Programs

Large-scale urbanization and industrialization have led to the development of severely eroded, barren and denuded areas, rocks, cliffs, etc. on which direct plantation of trees is difficult. In such cases shrubs act as the primary colonizers of denuded areas. The successful growths of shrubs create favorable conditions for tree growth by way of retaining moisture, increasing soil nutrient status and sheltering the trees from frost, wind and other biotic interferences through the process of secondary succession. The whole forest-management program can thus bring not only greenery to the Himalayas and other urban and rural regions of India but also stability to the environment by restoring the ecological balance (Maithani et al., 1991).

6. Road Safety

The presence of shrubs and trees along roadsides makes their edges and curves conspicuous, thus making a natural guide for safe driving, and for this purpose the lower portions of their stems are usually painted white (Chakraverty & Jain, 1984).

7. Protection of Road Surfaces

The semimelting of tar or bitumen in summers, cracking of road surfaces during hot weather and mechanical damage to road surfaces by heavy downpours and hailstorms can largely be prevented by growing roadside trees with thick crowns (Chakraverty & Jain, 1984).

D. THE EDUCATIONAL AND RECREATIONAL VALUE OF TREES

Increased urbanization and industrialization have resulted in isolating humans from nature. Trees can help make urban areas green, livable and beautiful. Trees with colorful flowers or foliage add extra attractiveness. They are the dominant elements of gardens and contribute substantially to the garden atmosphere.

According to Kohli (1996), the comfortable urban life needs better avenue trees and shrubs, because:

- An agricultural component is not feasible;
- Comfortable temperatures and microclimates for residents are needed;
- Pollutants that pose major problems are to be removed;
- Cool shade is needed in summer; and
- Dense populations need vegetation for gaseous exchange.

Trees are thus a source of pleasure and recreation when they are planted along roads and railway tracks and in botanical gardens, arboreta, city parks, squares, home gardens, public places, industrial areas, etc. The cultivation of trees for their aesthetic or recreational value is

known as "arboriculture." In an ornamental garden they are usually planted either as specimen trees or in groups. The educational and recreational value of trees can be studied under the following headings:

1. Shade and Shelter (or Avenue Trees)

The concept of avenue planting is as old as the vedic period. It was during the period of Ashoka (260 B.C.) and later during the reign of Kanishka (A.D. 78–101) and the Mughals, however, that the foundations of proper roadside avenues were laid.

When properly grown, the tall, fast-growing and majestic trees with thick foliage along roadsides provide not only shade for pedestrians and travelers but also shelter for stray animals from scorching heat, wind, rain, etc. Species selected for such purposes should not be thorny or prickly (Chakraverty & Jain, 1984).

The other important factors for selection of roadside trees, according to Chakraverty and Jain (1984) and Randhawa (1961, 1965–1983), are:

- The trees should be branchless up to 3–4 m above the soil surface so that vehicles can pass easily, particularly on narrow roads.
- On national highways or on very wide roads, two to three deep rows of large trees spaced 5–6 m apart should be planted. These trees should have good, dense crowns so they can provide adequate shade and protection from rain, sun and hail.
- Dwarf trees or medium-sized-to-large shrubs, preferably ever blooming in nature, should be selected for boulevards and road medians.
- The trees should not have spreading crowns that might obstruct the growth of trees in the opposite row.
- Trees on the two sides of the road should not be opposite each other; they should be planted alternately.
- Fuel-wood species and fodder species should not be chosen for the roadsides, because they are likely to be lopped, pruned and chopped by the neighboring inhabitants, thus destroying the landscaping and giving the avenue a shabby appearance.
- The root system of the trees should be neither very spreading nor very shallow. Trees with very robust and spreading root systems damage the masonry work of roads, foot paths and adjacent buildings. On the other hand, trees with shallow root system, like *Millingtonia hortensis* (mahanim), topple over in storms and obstruct traffic. Thus trees with deep root systems should be selected.
- Trees like *Ficus benghalensis* (bat or barghad) have hanging aerial roots, which would obstruct traffic and pedestrians, so they should not be selected.
- Soft-wooded and brittle trees like *Albizia lebbek, Cassia siamea, Eucalyptus* spp., *Eugenia jambolana, Ficus glomerata, Millingtonia hortensis* and *Sygyzium cumini* should not be planted along roadsides, for they tend to break in storms and block traffic.
- During summers and rainstorms, protection from sun and rain are most needed, so trees that shed their leaves during these periods should not be planted. Moreover, fallen leaves in the rainy season make the road slippery and block the drainage system.
- Various species of *Acacia, Zizyphus,* etc., which are prickly or thorny, should not be planted because the fallen prickles or thorns cause trouble for pedestrians, animals and people and may also damage the tires of cycles and vehicles.
- The trees should have the ability to withstand winter lopping, when little shade is required. These loppings can be utilized as fuel wood (Singhal & Khanna, 1991).
- Too many species should not be mixed within short distances, particularly on roads away from cities and towns.

Randhawa (1965–1983) recommended avenue trees for planting purposes: as foliage trees for outer avenues for town roads, *Albizia procera* (safed siris), *Anthocephalus cadamba* (kadam), *Averrhoea carambola* (kamrak), *Bassia latifolia* (mahua), *Callistemon lanceolatum* (lal botal brush), *Dalbergia sissoo* (shisham), *Eugenia operculata, Mangifera indica* (mango), *Melia azedarach* (drek), *Pithecolobium saman* (rain tree), *Platanus orientalis* (chinar), *Polyalthia longifolia* (ashoka), *Putranjiva roxburghii, Sterculia alata, Tamarindus indica* (imli), etc; as flowering trees for inner avenues for town roads, *Bauhinia purpurea* (gulabi kachnar), *B. variegata* (kachnar), *Cassia fistula* (amaltas), *Colvillea racemosa* (kilbili), *Gliricidia maculata* (madre tree), *Grevillea robusta, Jacaranda mimosaefolia* (nili-gul-mohur), *Lagerstroemia flos-reginae* (jarul, crepe flower), *L. thorelli* (barri sanwani), *Peltophorum ferrugineum* (ivalvagai), *Poinciana regia* (gul mohur), *Spathodea nilotica* (fountain tree), etc.

2. Ornamental Flowering Plants

Ornamental trees that have showy flowers are called "ornamental flowering trees." India has the largest number of flowering trees in the world, indigenous as well as exotic, that can be utilized for beautifying towns. Many trees bloom at a particular season and appear more effective when planted in groups.

In small and medium-sized gardens, ornamental trees should be planted only in the boundaries as foundation planting. An "arboretum" is a garden of trees. While planting a tree, beauty and utility should be combined deftly. The best time for planting trees is during the rainy season.

Dwarf ornamental flowering trees suitable for small compounds are *Acacia auriculiformis, Alangium lamarckii, Bauhinia purpurea, B. variegata, Brownea ariza, B. coccinea, Butea frondosa, Cassia fistula, C. javanica, C. marginata, Cochlospermum gossypium, Cordia sebestena, Crataeva religiosa, Erythrina blakei, E. cristagalli, Gliricidia maculata, Guaicum officinale, Holarrhena antidysentrica, Jacaranda mimosaefolia, Kleinhovia hospita, Lagerstroemia thorelli, Mesua ferrea, Milletia auriculata, Plumeria alba, P. rubra, Pongamia glabra, Saraca indica, Solanum wrightii, Spathodea nilotica, Sterculia colorata, Tecomella undulata, Thespesia populnea,* etc. (Cowen, 1950; Randhawa, 1965–1983).

For large compounds, some examples of beautiful flowering trees are *Anthocephalus indicus, Bombax malabaricum, Cassia grandis, C. nodosa, Chorisia speciosa, Colvillea racemosa, Lagerstroemia flos-reginae, Millingtonia hortensis, Peltophorum ferrugineum, Poinciana regia* and *Sterculia colorata* (Cowen, 1950; Randhawa, 1965–1983).

Trivedi (1983, 1987, 1996) recommended the following small trees for the hills: *Acacia alata* (with bright yellow flowers), *A. dealbata* (with light yellow flowers), *Bauhinia variegata* (with rose, purple and white flowers), *Magnolia grandiflora* (with white flowers), *Prunus serrulata* (with pink flowers), *Rhododendendron arboreum* (with crimson flowers) and *R. campanulatum* (with magenta flowers). Trivedi also recommends a few trees for cultivation on the plains.

3. Ornamental Foliage Plants

Ornamental trees with beautiful foliage but inconspicuous flowers are called "ornamental foliage trees." Common examples are palms, evergreen conifers, *Acacia auriculiformis, Averrhoa carambola, Callistemon lanceolatum, Citharexylum subserratum, Diospyros embryopteris, Eucalyptus spp., Ficus infectoria, F. retusa, Kigelia pinnata, Phyllanthus emblica, Polyalthia longifolia, Putranjiva roxburghii, Tamarindus indica* and *Terminalia arjuna* (Randhawa, 1961, 1965–1983).

Evergreen shrubs and trees provide a structure for the garden during winter months. Without them the garden will look bleak and dull, when the foliage of most herbaceous perennials disappears, leaving only bare stems and branches.

In temperate regions conifers constitute the most important and showy group of plants. Many varieties show symmetrical growth and are frequently used in formal gardens. They keep their ornamental effect even in winter, when most broad-leaved trees shed their leaves. Common examples of foliage trees in the hills are the species of *Araucaria, Cryptomeria* and *Cupressus* (Trivedi, 1983, 1987, 1996).

4. Ornamental Fragrance Plants

Many trees combine beauty with fragrance. Some trees that are commonly cultivated for scent or fragrance are *Acacia podalyriaefolia, Anthocephalus indicus* (kadam), *Biota orientalis, Citrus aurantifolium* (lime), *C. japonica, C. limon* (lemon), *Cymphomandra betacea, Gardenia lucida, G. latifolia, G. resinifera* (dekamali), *Galphimia gracilis, Grewia asiatica, Luculia gratissima, Magnolia grandiflora* (bara champa), *Michelia champaca* (champa or champak), *Mimusops elengi* (maulsari), *Nyctanthes arbor-tristis* (harsinghar), *Plumeria tuberculata, Rhododendron formosum* and *Sambucus nigra* (Randhawa, 1961). In home gardens these can be planted opposite windows and doors of bedrooms, so that one can enjoy their fragrance in the evening, particularly in summer months (Randhawa, 1961, 1965–1983; Trivedi, 1990).

Some examples of fragrant ornamental trees for large compounds are *Dillenia indica, Mimusops elengi* and *Pterospermum acerifolium* (Randhawa, 1965–1983).

Trees with snow-white, fragrant flowers against the background of dark green foliage are very delightful for moonlit gardens. Some common examples in this category are *Bauhinia alba, Citharexylum subserratum, Crataeva religiosa, Delonix regia, Dillenia indica, Erythrina variegata, Gardenia resinifera, Gliricidia alba, Holarrhena antidysentrica, Lagerstromia indica* (white), *Millingtonia hortensis, Mimusops elengi, M. hexandra, Plumeria acutifolia, P. alba, Prunus domestica* and *Wrightia tinctoria* (Randhawa, 1961).

5. Ornamental Fruiting Plants

Trees commonly grown for their beautiful, attractive and colorful fruits are *Citrus microcarpea, Hazara orange* and other *Citrus* spp., papaya (*Carica papaya*), peach (*Prunus persica*), pineapple (*Ananas comosus*), tree tomato (*Cymphomandra betacea*), banana (*Musa paradisiaca*), strawberry tree (*Arbutus unedo*), quince (*Cydonia oblonga*), loquat (*Eriobotrya japonica*), common spindle tree (*Euonymus europeaus*), gean (*Prunus avium*), pomegranate (*Punica granatum*) and jujube (*Zizyphus jujuba*) (Lunardi, 1987; Trivedi, 1983, 1987, 1996). Planting of trees in and around children's park can provide vitamins and nutrients to children when they eat the fruit as they play.

6. Ornamental Hedges

Hedges provide a natural background for a garden, as a frame does for a painting. The hedge may be external or internal. An external hedge—live fence—is usually tall, measuring about 1.5–2.5 m (5–9 ft) high, and it may replace the compound wall; thus it demarcates the garden from the public road. It also serves as a protective screen against wind and noise pollution. Species selected for external hedges should be tall, fast-growing and evergreen, with thick and dense foliage from the base to the top. The blooms should not clash with the general color scheme. An internal hedge that separates parts within a garden is not as tall. It is usually 30–90

cm (1–3 ft) tall. Species that are capable of growing under adverse conditions and require minimal maintenance are selected for both types of hedges.

Species of *Biota, Cupressus, Ilex, Juniperus, Thuja,* etc. are used for evergreen hedges. The following flowering trees may be used for making colorful hedges: *Bauhinia acuminata, Bougainvillaea* spp., *Erythrina indica, Hibiscus* spp., *Meyenia erecta, Plumbago capensis, Sesbania aegyptica, Strobilanthes* spp. and *Tecoma stans* (Randhawa, 1961).

7. Live Screens and Fences

In cities and towns trees can be utilized for screening the premises of adjacent houses and thus maintaining privacy. Servants' quarters and other unsightly views like manure pits, potting areas, etc. in large gardens can also be screened by growing closely spaced, small trees. Species with prickles or spines or having stiff branches or both with nonedible leaves should be preferred, according to the requirements. Ideally, the species selected for this purpose should be fast growing, of medium height, long-lived, capable of growing under adverse conditions and with minimal maintenance requirements (Singhal & Khanna, 1991).

8. Sculpture and Topiary

Topiary is an art of shaping hedges—shrubs—and trees into an ornamental form like a ball, spiral, table, cube, etc., into a figure like a bird, beast or human or into a theme such as a farmer with a pair of bullocks. A formal garden is most suitable for topiary work because it creates an Old World appearance. The most common examples used for such purposes are *Buxus sempervirens, Cupressus macropoda, Murraya exotica* and *Taxus baccata* (Randhawa, 1961, 1965–1983).

9. Education

Ornamental trees are not only a source of recreation and pleasure but also educate people, when visitors in gardens and travelers along roadsides wish to know the names and uses of such trees. If roads and gardens are named after some dominant shrub and tree species, the work of making them familiar to the public becomes easier (Chakraverty & Jain, 1984).

10. Landscaping and Bioaesthetic Planning

Shrubs and trees improve the landscape. For example, trees along roadsides are a source of beauty not only to the road but also to the length and breadth of the area through which the road runs. Along roads, fuelwood, fodder and thorny species should not be chosen. Shrubs and trees constitute two of the most important components of landscaping and bioaesthetic planning of urban cities and towns. Many species bloom at a particular season and appear more effective when planted in groups (Randhawa, 1961, 1965–1983).

As far as possible, native species should be selected, because, apart from their aesthetic value, scenic beauty and immediate utility, these trees involve reduced maintenance costs, preserve biological diversity and prevent species extinction. They are also a valuable national asset and a reserve of timber and fuel in case of emergency. It is estimated that India has the largest number of flowering trees in the world, indigenous as well as exotic, that can be utilized for beautifying cities and towns.

It may be mentioned here that bioaesthetic planning of ornamental trees has a close relationship with plant ecology. Plants must be planted only in those localities or habitats that are

similar to their natural habitats or surroundings, because the texture of the soil, the availability of water resources, the amount of rainfall, the presence of rivers, canals and tanks and the temperature play an important role in the growth and survival of the trees (Randhawa, 1965–1983).

Trees must be planted in habitats that are similar to their natural surrounding—i.e., that have approximately the same edaphic and climatic conditions—otherwise either dwarfing may occur or the species will not be able to survive. Some examples of ornamental flowering trees suited to moist localities are *Amherstia nobilis, Bauhinia purpurea, Brownea ariza, B. coccinea, Cassia javanica, C. marginata, C. nodosa, Colvillea racemosa, Guaicum officinale, Lagerstroemia flos-regine, L. thorelli, Milletia auriculata, Poinciana regia, Peltophorum ferrugineum, Pithecolobium saman, Saraca indica* and *Solanum wrightii* (Randhawa, 1965–1983).

Examples of ornamental flowering trees suited to dry localities are *Acacia auriculiformis, Butea frondosa, Cassia fistula, Cochlospermum gossypium, Cordia subestena, Erythrina blakei, E. indica, Jacaranda mimosaefolia, Melia azadirachta, Plumeria alba, Pongamia glabra, Spathodea campanulata, S. nilotica, Sterculia colorata, Tecomella undulata* and *Thespesia populnea* (Randhawa, 1965–1983).

Drought-resistant trees suitable for arid regions are *Albizia lebbek* (siris), *Butea frondosa* (dhak), *Cassia fistula* (amaltas), *Casuarina equisetifolia* (beefwood tree), *Eucalyptus citriodora* (safeda), *Melia azedarach* (Persian lilac, bakain), *Morus indica* (mulberry), *Phoenix dactylifera* (khajoor), *Prosopis juliflora* (mesquite bean), *Salvadora persica* (pilu), etc. (Randhawa, 1965–1983).

Some examples of salt-resistant trees are *Azadirachta indica* (neem), *Butea frondosa* (dhak), *Bassia latifolia* (mahua), *Eucalyptus citriodora* (safeda), *Phoenix dactylifera* (khajoor), *Phyllanthus emblica* (amla), *Psidium guava* (amrood), *Tamarix articulata* (farash) and *Thespesia populnea* (bhendi) (Randhawa, 1965–1983).

Trees for swamps and marshy areas are *Eucalyptus rostrata, Salix tetrasperma* (willow), *S. babylonica, Sapium sebiferum* (makhan), *Tamarix articulata* (farash), plantain, etc. (Randhawa, 1965–1983). *Sapium sebiferum,* known as Chinese tallow tree, is a medium-sized, deciduous tree whose leaves display lovely autumn tints. It is used for stream training in the Kangra district of Himachal Pradesh.

11. Veneration

From one end of the world to the other we can trace the extreme power of trees over the minds of humans. Christmas trees, May trees, pomegranates, *Ginkgo biloba,* bo trees, etc. can be cited as occupying a place in the religious and ceremonial activities in diveve cultures throughout the world. In India alone 99 trees are venerated (Bennet et al., 1992). In ancient times *rishis* worshiped several trees as Vrikshadevta and Vanadevta. Groves of trees and flower gardens were tended with loving care and were called “vrikshavatika” and “pushpavatika,” respectively. Several such protected forest groves or gardens, including Ashoka Vatika, Chitrakoot and Panchvatti, were known in ancient India.

12. Art and Culture

A tree laden with flowers and/or fruits is a great joy to the beholder. Native trees have a special place in Indian folk songs. Immortal poets and writers like Valmiki and Kalidasa have sung songs in praise of trees. Even folktales have celebrated the importance and beauty of trees in India (Randhawa, 1961, 1965–1983).

Indian trees have a personality of their own. The beauty of Indian trees has been sketched or painted by many artists (Randhawa, 1961, 1965–1983), like Bireshwar Sen and his wife, Lakshmi, Sarbjeet Singh, Ganga Singh, Anil Roy Chowdhry, Gopal Ghosh, Manishi Day, Madhava Menon, Devyani Kanwal Krishna, Sudhir Khastgir, Francis Brunell, Madame Sass Brunner and her daughter Elizabeth, A. K. Gohel, R. A. Eklund, E. Blatter, P. N. Sharma, A. K. Sharma, H. Smith, Margaret Thacker, G. Millard (Lady Kinnear), Sister Marychionia, Lady Douie, S. H. Prater, H. Robinson and H. N. Wandrekar. Many of their works have been included in books on Indian botany (Seth et al., 2002).

Kalidasa observed that the women of Alkapuri rubbed the dust of lodhra flowers on their cheeks, maghya flowers decorated their temples, kuruvaka flowers hung from the knots of their hair and sirisha flowers decorated their ears. Elsewhere, in the monsoon kadamba flowers glorified women's heads. The women carried pink lotuses in their hands, decorated their tress knots with white champaka, wore bracelets of jasmine around their wrists and wore garlands of jasmine and bela (Randhawa, 1961, 1965–1983).

India's vast, rich Sanskrit literature contains the names of several trees, including the ornamental trees arjuna (*Terminalia arjuna*), asoka (*Saraca indica*), champaka (*Michelia champaca*), chuta (*Mangifera indica*), devadaru (*Cedrus deodara*), gandharaja (*Gardenia florida*), kadamba (*Anthocephalus cadamba*), karnikara (*Pterospermum acerifolium*), ketaki (*Pandanus odoratissimus*), kimsuka (*Butea frondosa*), kovidara (*Bauhinia purpurea*), kunda (*Jasminum pubescens*), kuravaka (*Lawsonia alba*), lodhra (*Symplocos racemosa*), mandara (*Erythrina indica*), naga kesara (*Mesua ferrea*), narikela (*Cocos nucifera*), parijataka (*Nyctanthes arbortristis*), punnaga (*Calophyllum inophyllum*), sala (*Shorea robusta*), krishna sirish (*Albizia amara*), pitsirish (*Albizia lebbek*), tala (*Borassus flabelliformis*) and vakula (*Mimusops elengi*) (Randhawa, 1961; Anonymous, 1986; Dwivedi, 2000).

E. TREES AS A SOURCE OF SUSTENANCE

Trees are one of the major sources of sustenance: food; sugars; starches; spices and condiments; beverages; fumitories, masticatories and narcotics; medicines; essential oils; fatty oils and vegetable fats; waxes; soap substitutes; vegetable ivory; fodder; fuel, bioenergy or biofuel; fertilizers; fiber; pulp and paper; tannins; dyes; rubber and other latex products; gums; resins; and cork. These are described separately under the following headings:

1. Food

Trees as a source of food include edible fruits, vegetables and tree legumes. Botanically, a fruit is a matured or ripened ovary, along with its contents and adhering accessory structures, if any. The seeds inside the fruits are the fertilized ovules. Sometimes seeds are formed without fertilization. This phenomenon is called "agamospermy," a kind of parthenogenesis. A fruit that matures without seed formation is called "parthenocarpic fruit." Fruits are eaten raw. Vegetables are edible plants that store reserve food—mainly carbohydrates—in roots, stems, leaves or fruits and that are eaten either cooked or raw. Legumes—or pods—are the proteinaceous fruits of family Leguminosae. Some of these are edible. The important food-yielding trees are depicted in Table I.

2. Sugars

Sugar is a plant product surpassed in importance only by cereals and potatoes. It is one of the most important reserve food supplies, not only for the plant in which it is found but also also because it serves as the most necessary food—source of energy—for humans. Sugar in

(Text continues on p. 337)

Table I
Trees as a source of food

Common name	Genus and species	Family	Remarks
Tree legumes			
Algaroba	*Prosopis chinensis*, *P. juliflora*	Mimosaceae	Flowers a source of honey; pods used as stock feed
Carob bean	*Ceratonia siliqua*	Caesalpiniaceae	Dried pod edible
Honey locust	*Gleditsia triacanthus*	Caesalpiniaceae	Pods eaten by animals
Tamarind or imli	*Tamarindus indica*	Caesalpiniaceae	Pods used for tart; fruits pulp used for chutney or sauce
Rain tree or vilaiti sirris	*Samanea saman*	Mimosaceae	Sweet pulp of black pods excellent food stock
Nittas	*Parkia biglobosam P. filicoidea, P. roxburghii*	Mimosaceae	Pods and seeds edible
Manila tamarind or jangal jalebi	*Pithecellobium dulce*	Mimosaceae	Aril edible
Nuts with high fat content			
Brazil nut, "neggertoes," "cream nuts"	*Bertholletia excelsa*	Lecythidaceae	Contain 65–70% fats and 17% proteins
Cashew nut or kaju	*Anacardium occidentale*	Anacardiacae	Swollen peduncle, thalamus and cotyledons edible
Coconut or nariyal	*Cocus nucifera*	Arecaceae	Endosperm edible
Filbert	*Corylus avellana*	Corylaceae	Kernels edible
Hazelnut	*Corylus americana, C. cornuta, C. colurna*	Corylaceae	Kernels edible
Hickory	*Carya ovata*	Juglandaceace	Kernels edible
Pecan nut	*Carya illinoensis*	Juglandaceae	Kernels edible
Pilinut	*Canarium ovatum*	Burseraceae	Seeds edible
Pine nut	*Pinus edulis, P. gerardiana* (*Chilgoza*), *P. kesiya,* etc.	Pinaceae	Cotyledons edible
Walnut	*Juglans nigra, J. regia*	Juglandaceae	Cotyledons edible
European beech	*Fagus sylvatica*	Fagaceae	
Jangli badam	*Terminalia catappa*	Combretaceae	
Queensland nut	*Macadamia turnifolia*	Proteaceae	
Macadamia nut	*Macadamia turnifolia, M. integrifolia*	Proteaceae	
Nuts with high protein content			
Almond	*Prunus amygdalus*	Rosaceae	Seeds edible
Beechnut	*Fagus grandifolia, F. sylvatica*	Fagaceae	Seeds edible
Pistachio nut, green almond	*Pistacia vera*	Pistaciaceae	Seeds edible

Table I, *continued*

Common name	Genus and species	Family	Remarks
Nuts with high carbohydrate content, *continued*			
Acorn	*Quercus* spp.	Fagaceae	Eaten by animals
Chestnut	*Castanea dentata*	Fagaceae	Seeds edible
Fruit vegetables			
Avocado, alligator pear	*Persea americana*	Lauraceae	Fruits edible
Breadfruit	*Artocarpus altilis*	Moraceae	Fruits edible
Jackfruit, kat-hal	*Artocarpus heterophyllus*	Moraceae	Fruits edible
Pome fruits			
Apple, vern. seb	*Malus pumila,* syn. *M. domestica*	Rosaceae	Fleshy thalamus edible
Pear, vern. nakh	*Pyrus communis*	Rosaceae	Fleshy thalamus edible
Quince	*Cydonia vulgaris*	Rosaceae	Fleshy thalamus edible
Chinese pear or sand pear, vern. nashpati	*Pyrus pyrifolia* var. *culta*	Rosaceae	Fleshy thalamus edible
Medlar	*Mespilus germanica*	Rosaceae	Fleshy thalamus edible
Stone fruits			
Apricot, vern. khurmani	*Prunus armeniaca*	Rosaceae	Seeds edible
Cherry, sweet	*Prunus avium*	Rosaceae	Seeds edible
Cherry, sour, vern. gilas	*Prunus cerasus*	Rosaceae	Seeds edible
Cherry, Himalayan	*Prunus cerasoides*	Rosaceae	Seeds edible
Cherry, Himalayan bird	*Prunus cornuta*	Rosaceae	Seeds edible
Cherry, European bird, vern. jaman	*Prunus padus*	Rosaceae	Seeds edible
Peach, vern. aru	*Prunus persica*	Rosaceae	Seeds edible
Plum, vern. alucha, alu-bukhara	*Prunus domestica*	Rosaceae	Seeds edible
Citrus fruits			
Sweet orange, musambi	*Citrus sinensis*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Sour orange, khatta	*Citrus aurantium*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Mandarin orange, santara	*Citrus reticulata*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Pomelo, grapefruit	*Citrus paradisi*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium

Lemon, bara (pahari) nimbu	*Citrus limon*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Lime, nimbu or kaghzi nimbu	*Citrus aurantifolia*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Shaddock, chakotra	*Citrus maxima*	Rutaceae	Glandular hairs arising from endocarp edible; fruit is hesperidium
Other fruits			
Emlic, amla	*Emblica officinalis*	Euphorbiaceae	Fruit rich in tannin and vitamin C; commonly pickled and used as medicine; epicarp and mesocarp of drupe edible
Pineapple, ananas	*Ananas comosus*	Bromeliaceae	
Mulberry, tut, shahtoot	*Morus alba, M. australis, M. nigra, M. rubra,* etc.	Moraceae	Succulent perianth and fleshy axis edible
Money jack, lakoocha, barhal, dahrua	*Atrocarpus lakoocha*	Moraceae	
Chinese date, jujube, ber, badara	*Zizyphus mauritiana*	Rhamnaceae	Epicarp and mesocarp of drupe edible
Limeberry, chini narangi	*Triphasia trifolia*	Rutaceae	
Cherimoya, Hanuman phal, Lakshman phal	*Annona cherimolia*	Annonaceae	Juicy mesocarps of individual berries edible
Jambolan, jamun, jambaba	*Syzygium cumini*	Myrtaceae	Epicarp and mesocarp of drupe edible
Wild jujube, jharber	*Zizyphus nummularia*	Rhamnaceae	Epicarp and mesocarp of drupe edible
Carambola, karmal	*Averrhoea carambola*	Averrhoaceae	
Bael, bilva	*Aegle marmelos*	Rutaceae	Inner fleshy layer of pericarp and placentae edible
Custard apple, sweet sop, sharifa	*Annona squamosa*	Annonaceae	Inner fleshy layer of pericarp and placentae edible
Date, pind khajur	*Phoenix dactylifera*	Arecaceae	Pericarp edible
Fig	*Ficus carica*	Moraceae	Fleshy receptacle or thalamus edible
Guava, amrood	*Psidium guajava*	Myrtaceae	Inferior (or false) berries (i.e.. pericarp is fused with thalamus); epicarp, mesocarp and endocarp edible
Jujube, ber	*Zizyphus mauritiana*	Rhamnaceae	Epicarp and mesocarp edible
Litchi	*Litchi chinensis*	Sapindaceae	Aril edible
Loquat	*Eriobotrya japonica*	Rosaceae	Fruit is a pome where thalamus is enlarged to form fleshy, edible part; pericarp is cartilaginous and encloses seed-bearing loculi

Table I, *continued*

Common name	Genus and species	Family	Remarks
Other fruits, *continued*			
Mango, aam	*Mangifera indica*	Anacardiaceae	Fleshy mesocarp edible
Olive	*Olea europaea*	Oleaceae	Epicarp and mesocarp edible; commercial olive oil is obtained from fruit pulp and seeds
Papaya, papeeta	*Carica papaya*	Caricaceae	
Pomegranate, anar	*Punica granatum*	Punicaceae	Seeds with juicy testa edible
Sapodila, sapota, chiku	*Manikara achras*	Sapotaceae	
Kumquat	*Fortunella japonica*	Rutaceae	
Wild date, khajur	*Phoenix sylvestris*	Arecaceae	Only one carpel develops into a one-seeded, edible berry
Gorgan nut, makhana (seeds)	*Euryale ferox*	Euryalaceae	Seeds edible
Phalsa	*Grewia subinaequalis*	Tiliaceae	
Durian	*Durio zibethinus*	Bombacaceae	
Granadilla, passion fruit	*Passiflora edulis, P. incarnata*, *P. laurifolia*, *P. lingularis*, *P. mollissima*, *P. quadrangularis*	Passifloraceae	
Rose apple, gulabjaman	*Syzygium jambos*	Myrtaceae	Epicarp and mesocarp of drupe edible
Japanese persimon, kaki	*Diospyros kaki*	Ebenaceae	

plants may occur in the form of sucrose (a disaccharide of glucose and fructose that, to humans, tastes sweeter than either of its constituent monosaccharides) or cane sugar, glucose or grape sugar and fructose or fruit sugar. It occurs in roots (beets, carrots, parsnips, etc.), stems (sugarcane, maize, sorghum, sugar maple), flowers (palms), bulbs (onion) and many fruits. The important trees yielding sugars of commercial interest are shown in Table II.

3. Starches

Starch, a complex carbohydrate, is a polymer of glucose units linked by alpha bonds. It exists in two forms in plants: unbranched or linear polymers called "amyloses," in which hundreds of glucose molecules form coiled molecules of starch; and branched polymers called "amylopectins," in which only 40–60 glucose molecules that form branched chains do not coil.

Soluble starch (starch grains soaked in hot water until they burst and form a thin, clear solution or paste) is used in the textile industry for strengthening fibers and cementing loose ends together, making the thread smoother and easier to weave and thus giving a finish to the goods. It is used as a mordant in calico printing and a thickener or vehicle for colors. It is also used in laundry work, in toilet powders, in medicine, as a sizing agent in the paper industry, as binding material for china clay and many derivatives or products like dextrin, glucose, industrial alcohol and nitrostarch.

Starch is one of the main reserve foods for green plants, which store it in thin-walled cells in the form of grains of different sizes, shapes and microscopic and physical characteristics. The chief sources of commercial starch are maize, potato, wheat, rice, sago, cassava and arrowroot, of which the last two are obtained from shrubs and sago is obtained from trees.

Arrowroot starch is obtained from the tubers of many tropical plants, including: *Maranta arundinacea* (Marantaceae), yielding Indian arrowroot; *Canna edulis* (Cannaceae), yielding Queensland arrowroot; *Curcuma angustifolia* (Zingiberaceae), yielding East Indian arrowroot; and *Zamia floridanda* (Cycadaceae), yielding Florida arrowroot. Only the last is a small, shrublike plant.

Sago starch is obtained from the starchy pith of the stems of *Metroxylon sagu,* of the family Arecaceae. Other important species that yield sago starch are: *Arenga saccharifera, Borassus flabellifer, Caryota urens, Metroxylon koenigii, M. leave* and *M. rumphii,* all Arecaceae; *Manihot esculenta,* of the family Euphorbiaceae; and *Cycas* species, of the family Cycadaceae, a gymnosperm. Starchy pith is removed after the trees are cut, and, after washing, the starch is freed by sedimentation. Dried, it is known as "sago flour"; it is made into a flour and then dried in the sun or in ovens to obtain shiny, granular starch, called "pearl sago." Both are used almost entirely for food purposes, like khir, kanji, payasam, kesari, uppuma, vaangibath, sago curd bhath, vadam (pappad), macaroni and spaghetti.

4. Spices and Condiments

Spices and condiments are flavoring agents obtained from plants. They are difficult to distinguish, so the terms are used interchangeably. Because they have little nutritive value, they are not classified as foods. They contain essential oils, which impart flavor and aroma to food and add greatly to the pleasure of eating. They stimulate the appetite and increase the flow of gastric juices. For these reasons they are often referred to as "food accessories" or "adjuncts." The important spice- and condiment-yielding trees are shown in Table III.

5. Nonalcoholic Beverages

Beverage plants are those plants which yield beverages or drinks—nonalcoholic or alcoholic—that are palatable and refreshing. Nonalcoholic beverages usually contain caffeine, an

Table II
Sugar-yielding trees

Common name	Genus and species	Family	Remarks
Sugar and sap from sweet sap of maples			
Sugar maple	*Acer saccharum*	Aceraceae	Incisions are made through the bark into the sapwood or large roots and sap is collected, usually in March and April, when temperatures reach 25°F at night and 55°F during the day; sugar is sucrose
Black maple	*Acer nigrum*	Aceraceae	
Sugar from unopened inflorescences of palms			
Date palm	*Phoenix dactylifera*	Aceraceae	In wild date palm sugar is obtained from tender upper portions of the stem; the tips of inflorescences or stems are cut and sweet sap that oozes out and collected is called "toddy"; its sugar content is about 14%; it is boiled and cooled to obtain hard crude sugar called "jaggary," and it can be fermented to make the beverage called "arrack"; sugar is sucrose
Wild date palm	*Phoenix sylvestris*	Aceraceae	
Palmyra palm	*Borassus flabellifer*	Aceraceae	
Coconut palm	*Cocos nucifera*	Aceraceae	
Toddy palm	*Caryota urens*	Aceraceae	
Gomuti palm	*Arenga pinnata*	Aceraceae	
Honey palm	*Jubaca chinensis*	Aceraceae	
Nipa palm	*Niga fruticans*	Aceraceae	
Glucose, dextrose or grape sugar			Present in edible fruits of many trees and shrubs
Fructose, levulose or fruit sugar			Present in edible fruits of many trees and shrubs
Manna or mannose			
Manna ash tree	*Fraxinus ornus*	Oleaceae	The juice oozes out from slits made in the bark and dries into flake-like a sweet substance called "manna," used mainly in medicine
Nectar			
Gulabi kachnar	*Bauhinia purpurea*	Caesalpinae	Secreted by attractive flowers of many species in various families; mainly sucrose, with some glucose and fructose; main food of bees, which partially digest it; it is thus converted into honey; containing 70–75% invert sugar, proteins, mineral salts and water, honey is an excellent food for humans and is used in medicine, in the tobacco industry and in the preparation of mead, a fermented beverage
Bottle brush	*Callistemon lanceolatum*	Myrtaceae	
Horse chestnut	*Aesculus indica*	Hippocastanaceae	
Jamun	*Eugenia jambolana*	Myrtaceae	
Neem	*Azadirachta indica*	Meliaceae	
Shisham	*Dalbergia sissoo*	Fabaceae	
Soapnut	*Sapindus* spp.	Sapindaceae	
Tun	*Cedrela toona*	Meliaceae	
Barna	*Crataeva religiosa*	Capparidaceae	
Chinese tallow	*Sapium sebiferum*	Euphorbiaceae	

Source: Information on nectar-yielding trees is from Randhawa, 1965–1983.

Table III
Spice- and condiment-yielding trees

Common name	Genus and species	Family	Part used
Cassia, vern. tejpat	*Cinnamomum cassia,* syn. *C. tamala*	Lauraceae	Bark
Dalchini or Ceylon cinnamon	*Cinnamomum zeylanicum*	Lauraceae	Bark
Sassafras	*Sassafras albidum*	Lauraceae	Root bark
Cloves	*Syzygium aromaticum*	Myrtaceae	Unopened flower buds
Allspice	*Pimenta dioica*	Myrtaceae	Fruits
Juniper berries	*Juniperus communis* and other species	Cupressaceae	Mature cones
Star anise or anasphal	*Illicium verum*	Apiaceae	Fruit
Nutmeg (seed or kernel) and mace (aril)	*Myristica fragrans*	Myristicaceae	Seeds
Sweet bay or laurel	*Laurus nobilis*	Lauraceae	Leaves

alkaloid, which has stimulating and refreshing qualities. Alcoholic beverages are those that contain one or more hydroxyl (–OH) groups; e.g., ethanol (CH_3–CH_2–OH). They may be fermented or distilled. Fruit juices and other beverages that contain neither caffeine nor alcohol are called "soft drinks." They have a high sugar content and thus are a good source of energy. The important nonalcoholic-beverage woody plants are shown in Table IV.

6. Fumitories, Masticatories and Narcotics

Some narcotic substances are smoked or chewed by humans for pleasure or to seek a "world full of new sensation or some flight from reality." Narcotic substances that are used for smoking purposes are called "fumitories," and those that are used for chewing purposes are called "masticatories." They have a distinct stimulating or even narcotic effect due to the presence of various alkaloids. They are also used in religious ceremonies. The important woody plants of these categories are shown in Table V.

7. Medicines

Several trees are a source of important drugs. These are obtained from the bark of *Bauhinia variegata* (kachnar), *Barringtonia acutangula* (hijjal), *Cinnamomum zeylanicum* (dalchini), *C. calisaya, C. ledgerina, C. officinalis, C. robusta, C. succirubra* (all yielding quinine), *Mimusops elengi* (maulsari), *Myrica nagi* (kaiphal), *Symplocos racemosa* (lodh), *Saraca indica* (ashok), *Terminalia arjuna* (arjun) and *Toddalia asiatica* (kanj). The stems and wood of *Acacia catechu* (katha), *Pinus roxburghii* (chir) and *Santalum album* (safed chandan) yield drugs. Drugs are also obtained from the fruit of *Aegle marmelos* (bael), *Cassia fistula* (amaltas), *Emblica officinalis* (amla), *Terminalia bellerica* (bahera) and *T. chebula* (harar). The seeds of *Croton tiglium* (jamalgota), *Pongamia pinnata* (karanja), *Ricinus communis* (arand) and *Strychnos nux-vomica* (kuchla) are also used for obtaining drugs.

8. Essential Oils

Like all other necessities of humans, oils are one of the main necessities of daily life. India holds a prominent position in the world oil industry. Oils are of two types: essential, volatile or

Table IV
Important beverage-yielding woody plants

Common name	Genus and species	Family	Part used	Caffeine content (%)
Coffee	*Coffea arabica, C. canephora, C. liberica, C. robusta, C. stenophylla*	Rubiaceae	Coffee seeds called "beans"	1–1.5
Cocoa or chocolate	*Theobroma cacao*	Sterculiaceae	Seeds	
Maté or Paraguay tea	*Ilex paraguariensis*	Aquifoliaceae	Leaves	
Guarana	*Paullinia cupana*	Sapindaceae	Seeds	3–4.5
Cola	*Cola nitida*	Sterculiaceae	Seeds	2
Cassine	*Ilex vomitoria*	Aquifoliaceae	Fresh or dried leaves and shoots	
Yoco	*Paullinia yoco*	Sapindaceae	Bark	3–4
Coca and cocaine	*Erythroxylon coca*	Erythroxylaceae	Dried leaves	

Table V
Trees used as fumitories and mascatories

Common name	Genus and species	Family	Remarks
Bidi or tendu	*Diospyros melanoxylon*	Ebenaceae	Dried leaves used for wrapping the tobacco and as a fumitory
Areca, betal nut or supari	*Areca catechu*	Arecaceae	Betal nuts (drupes) chewed along with pan (leaves of *Piper betle*)
Catechu, katha, khair or khadira	*Acacia catechu*	Mimosaceae	Katha obtained from heartwood applied to pan (leaves of *Piper betle*)
Cola or kola nuts	*Cola nitida*	Sterculiaceae	Seeds of cola tree used as a masticator in tropical Africa; it contains 2% caffeine, essential oil and a glucoside, chelonian, which is a heart stimulant

Table VI
Differences between essential and fatty (fixed) oils

Essential oils	Fatty (fixed) oils
They evaporate or volatilize in contact with air and hence are called "volatile oils"	They do not evaporate or become volatile when they come into contact with air and hence are called "nonvolatile oils"
They can be readily removed from the plant tissues without any change in their composition and hence are called "distilled oils"	They cannot be distilled without being decomposed and hence are called "expressed oils"
They possess a pleasant taste, have a strong, aromatic odor and may be colored	They do not possess a strong taste or odor and are colorless
They are typically liquids	At normal (room) or high temperatures they are either liquids or fluids and are called "oils"; at normal or cold temperatures they may be solids or semisolids and are called "fats." Quite obviously, what is an oil in a warm climate may be a fat in a cold climate.
They are very complex in their chemical composition. The two principal groups are terpenes, which are hydrocarbons, and oxygenated and sulphuretted oils.	Chemically these vegetable fatty oils are close to animal fats. They consist of glycerine and fatty acid, which is an oleic acid if it is an oil but stearic or palmatic acid if it is a fat.
They have antiseptic qualities	They generally do not possess antiseptic properties
They are used for diverse purposes, but not as food	Most of them are edible and are available as food for humans
Soap is not formed when they are treated with an alkali	When a fat is boiled with an alkali, it decomposes and the fatty acid unites with an alkali to form soap. If potash or lye is used, a soft soap is obtained; if soda is used, a hard soap is obtained.
They can be obtained by distillation, expression or extraction	They can be obtained by a combination of expression and extraction, but not by distillation

distilled oils; and fatty, nonvolatile, expressed or fixed oils. These two types of oils can be distinguished in Table VI.

Essential oils are by-products of carbohydrate and fat metabolism and occur in some 60 families. The important ones are Apiaceae (= Umbellifereae), Asteraceae (= Compositae), Fabaceae (= Leguminosae), Geraniaceae, Lamiaceae (= Labiatae), Lauraceae, Myrtaceae, Poaceae (= Graminae) and Rutaceae. They occur in small concentrations, from minute traces to as much as 1–2%, or even more, in specialized cells, glands or ducts, either in one particular organ of the plant or distributed over many parts. They may be present in flowers (e.g., roses), fruits (e.g., oranges), leaves (e.g., eucalyptus), bark (e.g., cinnamomum), roots (e.g., ginger), woods (e.g., cedar) or seeds (e.g., cardamon) and many resinous exudations.

The utility of essential oils to the plant itself is obscure. The characteristic aroma and flavor they impart to flowers, fruits and seeds probably attract insects and other animals, which play an important role in pollination and/or in the dispersal of fruits and seeds. When essential oils are present in high concentrations, the unpleasant odor may serve to repel enemies like parasites, animals and insects. The essential oils may have antiseptic and bactericidal properties

and may thus act as a wound fluid. They affect transpiration and other physiological processes by minimizing the effect of heat on transpiration. They play a vital role as hydrogen donors in oxido-reduction reactions as potential sources of energy.

Because of their odor and high volatility, essential oils are also put to a variety of uses by humans. They are extensively used in the manufacture of perfumes, sachets, soaps and other toilet preparations. The perfumes are stored in closed, compactly filled containers since they deteriorate due to oxidation and polymerization when they come into contact with air. In confectionary and aerated waters they are used as flavoring materials or essences for ice creams, candies, cordials, liqueurs, nonalcoholic beverages, tobacco, etc. They are very valuable in medicine, dentistry and pharmaceuticals because of their therapeutic, antiseptic and bactericidal properties. They are used as insecticides and deodorants, as solvents in paint and varnish industries and in the manufacture of several synthetic odors and flavors, such as attars and scents. Some of the essential oils (e.g., clove oil) are used as clearing or cleaning agents in histological work. They are also used in such diversified products as chewing gum, toothpaste, dhoop, agar batis, incense, shoe polish, library paste and fish glue. The important essential oil-yielding trees are listed in Table VII.

9. Fatty Oils and Vegetable Fats

Vegetable fatty oils are called "fixed oils" or "nonvolatile oils" because they do not evaporate or become volatile like the essential oils. They are also called "nondistilled oils" because they cannot be distilled without being decomposed.

Chemically, fatty oils consist of glycerin in combination with a fatty acid. The so-called fats or tallows are solids at ordinary temperatures and contain stearic or palmitic acid. Their iodine number (the number of grams of iodine absorbed by 100 g of the fats in a medium in which it is soluble) is below 70. On the other hand, oils are liquids at ordinary temperatures and contain oleic acid.

Oils are of three types: drying, semidrying and nondrying. The drying oils are able to absorb oxygen and, on exposure, dry into thin elastic film. They are used mainly in the paint and varnish industry. Their iodine number is higher than 150. The semidrying oils absorb oxygen slowly and only in limited amounts. They form a soft film only after long exposure. Their iodine number is between 100 and 150. The nondrying oils remain liquid at ordinary temperatures and do not form a film. Their iodine number is between 70 and 100.

The fatty oils are insoluble in water but soluble in various organic solvents. When a fat is boiled with an alkali, it decomposes, and the fatty acid unites with the alkali to form soap. If soda is used, a hard soap is obtained; and if potash or lye is used, a soft soap is obtained.

When fats break down, they yield fatty acids and glycerin, of which they are composed, and usually develop a rancid odor and taste. The fatty oils are bland (balmy) and lack the strong taste, odor and antiseptic qualities of essential oils. Thus they are available as indispensable articles in human food. Important species that yield fatty oils and vegetable fats are listed in Table VIII.

10. Waxes

Waxes are quite similar to fats but are esters of monohydric alcohols rather than glycerides. They are harder than fats and have a high melting point. They are less easily hydrolyzed and do not become rancid. Waxes are usually found on the epidermis of leaves and fruits. They serve to prevent excessive loss of water through transpiration, because of their impervious character. The commercially important waxes obtained from trees are shown in Table IX. Wax is also obtained from the leaves of the raffia and licuri palms, sugarcane and esparto.

(Text continues on p. 349)

Table VII
Essential-oil-yielding trees

Common name	Genus and species	Family	Remarks
Ylang-ylang	*Cananga odorata*	Annonaceae	Oil is extracted from flower petals. Cananga oil is used in some of the finest perfumery creations in France; cheaper grades are used in soap making.
Neroli: true oil of neroli or neroli bigarade	*Citrus aurantium*	Rutaceae	Oil is extracted from flowers of the sour orange
Neroli Portugal	*Citrus sinensis*	Rutaceae	Oil is extracted from flowers of the sweet orange
Mandarin oil	*Citrus reticulata*	Rutaceae	Oil from peels is used in confectionery, toilet products and pharmaceutical preparations
Petitgrain oil	*Citrus* spp.; in India, *C. aurantium, C. limettoides*	Rutaceae	Oil extracted from leaves and twigs is used to add a pleasant bouquet to scents, cosmetics, skin creams and soaps
Orange oil	*Citrus* spp.; in India, *C. aurantifoli, C. reticulata*	Rutaceae	Oil extracted from ripe peels is used to add a pleasant bouquet to scents, cosmetics, skin creams and soaps
Bergamot	*Citrus aurantium* subsp. *bergamia*	Rutaceae	Greenish oil extracted from ripe peels has a soft, sweet odor and is used for scenting toilet soaps, in mixed perfumes and as a clearing agent
Mexican linaloe	*Bursera penicillata, B. glabrifolia*	Burseraceae	Very aromatic oil extracted from the wood is widely used in perfumes, soaps, cosmetics, etc. and for flavoring food and beverages
Mysore linaloe	*Bursera penicillata*	Burseraceae	Very aromatic oil extracted from husks of berries is widely used in perfumes, soaps, cosmetics, etc. and for flavoring food and beverages
Cayenne linaloe	*Aniba panurensis*	Lauraceae	Very aromatic oil is widely used in perfumes, soaps, cosmetics, etc. and for flavoring food and beverages
Brazilian bois de rose	*Ariba rosaeodora* var. *amazonia*	Lauraceae	Very aromatic oil extracted from the wood is widely used in perfumes, soaps, cosmetics, etc. and for flavoring food and beverages
Sandalwood oil, vern. safed chandan	*Santalum album* and related spp.	Santalaceae	Oil extracted from the wood is largely used as a perfume and in soaps, face creams and toilet powders. In medicine it has cooling, diaphoretic, diuretic and expectorant properties. An excellent fixative, it is much used in blends. The sweet-scented wood is utilized for boxes and chests.
Champaca oil	*Michelia champaca*	Magnoliaceae	One of the most famous perfumes of India, it is used for various purposes

Table VII, *continued*

Common name	Genus and species	Family	Remarks
Camphor, camphor gum, mushkapur, camphor oil	*Cinnamomum camphora*	Lauraceae	Camphor is solid with tough, white, translucent granule-like masses at ordinary temperatures. Extracted from the wood, twigs and leaves, it is used in the manufacture of celluloid, nitrocellulose compounds and expensive perfumes and in medicine for inflammations, rheumatic pains and sprains, as a cardiac stimulant and to relieve diarrhoea. The by-product is called "safrole."
Cedarwood oil	*Juniperus virginiana*	Cupressaceae	Oil extracted from the heartwood is valuable as a clearing agent in the preparation of permanent microscopic mounts and for use with oil-immersion lenses because of its high refractory index. It is also used in soaps, perfumes, liniments, deodorants and cleaning and polishing preparations and as an adulterant of geranium and sandlewood oils. Because of its insecticidal properties it is utilized as a moth repellent and in fly sprays.
Deodar oil	*Cedrus deodara, Juniperus macropoda*	Pinaceae, Cupressaceae	The variants of cedarwood oil used in India are obtained from chips, sawdust or wood of *Cedrus deodara* and from the shavings and sawdust of *Juniperus macropoda*
Clove oil, vern. loung-ka-tel	*Syzygium aromaticum*	Myrtaceae	Oil extracted from flower buds is used in perfumes, soaps, confectionery and medicine, as a stimulant, carminative and in flatulence and as a clearing agent in histological work for microscopy
Oil of turpentine, pine oil	*Pinus* spp.	Pinaceae	Oil from resins is used in the manufacture of varnishes, lacquers, disinfectants, paints, linoleum, sealing wax, oilcloth, lubricating compounds, inks, etc.
Cinnamon oil	*Cinnamomum zeylanicum*	Lauraceae	Oil from chips and waste bark is used in the preparation of cinnamon quills and as denitifrices and perfumes
Eucalyptus oil	*Eucalyptus citriodora, E. dives, E. globulus*, etc.	Myrtaceae	Oil from the leaves and terminal branchlets is a source of citronellal, citronellol and menthol. It is widely used in perfumery, as a mosquito repellent, germicide and disinfectant and in medicine in the treatment of asthma and bronchitis.
Nutmeg oil	*Myristica fragrans*	Myristicaceae	Oils from nutmeg (the aromatic kernels) and mace (the arils) of the fruits of *Myristica fragrans* (vern. jaiphal) are used externally to treat rheumatism and in soaps and perfumes. Oil obtained from the leaves is used in the preparation of chewing gum, flavoring essences and cosmetics.

Macassar oil	*Schleichera trijuga*	Sapindaceae	Extracted from seeds of the gum-lac tree (vern. gausam), the oil has a valuable stimulating and cleansing effect on the scalp, promoting hair growth. It is also used to cure skin diseases, itches, rheumatism and headaches.
Agar oil, agar attar	*Aquillaria agallocha*	Thymelaeaceae	Agar oil, from resinous portions of the wood, is pale yellow to brownish yellow or dark amber in color. It is used in perfumery and as an incense. True agar is heavier than water.
Keora oil, attar of kewda, attar keora, keora water, sandali attar, kewda or oil kewda	*Pandanus tectorius* (= *P. odoratissimus*)	Pandanaceae	Screwpine flowers are unusually large: a single flower weighs up to 150 g. The oil is used in the preparation of fragrant hair oils, perfumes, etc.
Cajeput oil	*Melaleuca leucadendron*	Myrtaceae	Oil extracted from fresh leaves and twigs is used in pharmaceuticals as throat lozenges, gargles, etc. and in medicine as a remedy for colds, throat diseases, headaches, etc.
Elengi oil	*Mimusops elengi*	Sapotaceae	The essential oil, from bulletwood flowers, is a pale yellow, mobile liquid with a very delicate, sweet and tenacious floral odor. It is used in the manufacture of perfumes.

Table VIII
Fatty-oil- and vegetable-fat-yielding trees

Common name	Genus and species	Family	Remarks
Drying oils from seeds			
Tung oil	*Aleurites fordii, A. montana*	Euphorbiaceae	Used in the paint and varnish industry; also used for waterproofing wood, paper and fabrics, and therefore valuable for outdoor paints
Kekuna, candle nut, lumbang oil	*Aleurites moluccana*	Euphorbiaceae	Used in making paint, varnish, lacquer, linoleum and soft soap
Walnut oil	*Juglans regia*	Juglandaceae	Mature and old kernels yield a drying oil. An edible oil, it is also used for white paint, artists' oil paints, printing ink and soap.
Laurelwood oil	*Calophyllum inophyllum*	Guttiferae	Used as an illuminant, for soap making and to treat rheumatism
Margosa oil	*Azadirachta indica*	Meliaceae	Used as an antiseptic and for burning purposes
Oiticia oil	*Licania rigida*	Rosaceae	Used in the paint and varnish industry; also used in making linoleum and printing inks and for improving the elasticity of rubber products
Nondrying oils from seeds			
Castor oil	*Ricinus communis*	Euphorbiaceae	Used as a purgative, a lubricant and an illuminant; also used in soaps, the textile industry, typewriter inks, perfumes, varnishes and paints
Olive oil	*Olea europaea*	Oleaceae	Used mainly as salad and cooking oil; also used in soap making, as a lubricant and in medicine
Vegetable fats			
Coconut oil	*Cocos nucifera*	Arecaceae	Dried coconut meat yields oil. Refined coconut oil is edible. Used for cooking, confectionery, making candy bars, soap, cosmetics, shaving cream, shampoo and other toilet preparations and also as an illuminant.
Palm oil, palm-kernel oil	*Elaeis guineensis*	Arecaceae	Extracted from the fibrous pulp of nuts and from kernels. Used in making soap and margarine and as a fuel for diesel engines; also used for making glycerin, shampoo, soap and candles.

Mahua oil, mowra or bassia fat; mahua or illipe butter	*Madhuca indica*	Sapotaceae	Oil obtained from seeds is used mainly in the manufacture of laundry soap and also in making candy, in the jute industry, and to treat skin diseases, rheumatism, headache, constipation, piles, etc.
Phulwara butter	*Diplokneura butyracea* (= *Madhuca butyracea*)	Sapotaceae	Oil obtained from seeds is used mainly in the manufacture of laundry soap and also in making candy, in the jute industry, and to treat skin diseases, rheumatism, headache, constipation, piles, etc.
Carapa oil	*Xylocarpus moluccensis*	Meliaceae	Oil obtained from seeds is used for soap and as an illuminant
Nutmeg butter	*Myristica fragrans*	Myristicaceae	Seeds contain about 40% of a yellow fat, used in soap, ointment, perfumes and candles and also to treat rheumatism
Pongam oil	*Pongamia pinnata*	Papilionaceae	Oil obtained from seeds is used for soap making, as an illuminant, and in the treatment of skin diseases and rheumatism
Babassu oil	*Orbignya martiana, O. oleifera*	Arecaceae	Oil obtained from nuts is used as a substitute for coconut oil and for making bullet-proof glass, explosives and lubricants
Cohune oil	*Orbignya cohune*	Arecaceae	Oil obtained from nuts is used as a substitute for coconut oil and for making bullet-proof glass, explosives and lubricants
Licuri oil	*Syagrus coronata*	Arecaceae	Oil obtained from nuts is used as a substitute for coconut oil and for making bullet-proof glass, explosives and lubricants
Murumuru oil	*Astrocaryum murumuru, A. tucuma, A. vulgare*	Arecaceae	Oil obtained from nuts is used as a substitute for coconut oil and for making bullet-proof glass, explosives and lubricants
Cocoa butter	*Theobroma cacao*	Sterculiaceae	Fat obtained from beans is used for cosmetics and perfumes, as a base for ointments and as a lubricant for massaging
Shea butter	*Butyrospermum parkii*	Sapotaceae	The fat is edible and is used as a substitute for cocoa butter and in making soap and candles
Borneo tallow	*Shorea aptera*	Dipterocarpaceae	Fat from kernels is used for soap making and as a substitute for cocoa butter
Chinese vegetable tallow	*Sapium sebiferum*	Euphorbiaceae	Obtained from a thick layer of hard, white fat on seeds, it is used in soap, cosmetics and candles. Seeds yield drying oil, used for paints, varnishes and plastics and as an illuminant.
Macassar oil	*Schleichera oleosa*	Sapindaceae	Oil from seeds is used in cooking, as a hair oil and for illumination
Ucuhuba butter, otoba butter	*Virola* spp.	Myristaceae	Used for various purposes

Table IX
Wax-yielding trees

Common name	Genus and species	Family	Remarks
Carnauba wax	*Copernicia cerifera*	Arecaceae	The most important vegetable wax from the wax palm tree (the "tree of life" in Brazil), it occurs as an exudation on leaves and is used in the manufacture of candles, soap, high-luster varnish, paint, car wax, shoe polish, carbon paper, batteries, insulation, phonograph records, salve, sound film, ointment, etc.
Wax tree	*Ceroxylon andicola*	Arecaceae	Used as a substitute for carnauba wax
Myrtle wax	*Myrica pensylvanica*, *M. cerifera*	Myricaceae	Berries are covered with thick layer of wax, used for the manufacture of soap and candles with a pleasant fragrance
Japanese wax	*Rhus succedanea*	Anacardiaceae	Berries yield wax, used in the manufacture of candles, wax matches, pencils, leather, furniture polish, soap and lipstick and in the vulcanization of rubber

Table X
Saponin-yielding trees

Common name	Genus and species	Family	Remarks
Soap nut or soap berries, vern. ritha	*Sapindus emarginatus, S. mukorossi, S. saponaria*	Sapindaceae	Used as a soap substitute for washing hair and woolen, silken and other delicate fabrics; also used in the preparation of hair tonic
Soapbark	*Quillaja saponaria*	Rosaceae	Dried inner bark contains 9% saponin, used for washing delicate fabrics, cleaning lenses and precision instruments, as an expectorant and emulsifying agent in medicine and in the manufacture of shampoo, cosmetics and hair tonic

11. Soap Substitutes

Saponins are a group of water-soluble glucosides that yield soap froth in water, form emulsions with oils and fats, and are capable of absorbing large amounts of gases such as carbon dioxide. Because of these properties they are used for cleansing and other purposes, both at home and in industry. The important saponin-containing trees are listed in Table X.

It may be added here that leaves of a familiar garden plant, bouncing bet or soapwort (*Saponaria officinalis,* family Caryophyllaceae), when placed in water, produce a lather that is utilized for washing and imparting luster to silk and woolen fabrics. Similarly, bulbs of the Californian soaproot (*Chlorogalum pomeridianum,* family Liliaceae) yield a good lather, which is utilized for washing fabrics.

12. Vegetable Ivory

The seeds of *Phytelephas macrocarpa,* in the family Arecaceae, commonly called "ivory nut" or "tagua palm tree," is the chief source of vegetable ivory. It is extensively used as a substitute for true ivory. It can be carved and used in the manufacture of buttons, chess pieces, poker chips, dice, knobs, inlays, billiard balls, toys, etc. *Metroxylon amicarum,* in the Arecaceae family, can likewise be used for these purposes.

13. Fodder

The leaves of trees and shrubs are rich in calcium and phosphorus. Although considered inferior to grasses, trees in different parts of India are lopped for fodder, especially when grasses are scarce. The important fodder-yielding trees are *Acacia nilotica* (= *A. arabica*), *A. catechu, Acer* spp., *Aegle marmelos, Bauhinia variegata, Celtis australis, Dendrocalamus strictus, Ficus glomerata, F. religiosa, Grewia* spp., *Helicteres isora, Kydia calycina, Leucaena leucocephala, Melia azedarach, Millettia auriculata, Morus australis, M. serrata, Ougeinia oojeinsis, Populus ciliata, Quercus glauca, Q. incana, Zizyphus mauritiana* and *Z. nummularia* (Singh, 1982; Anonymous, 1983).

14. Fuel, Bioenergy or Biofuel

Bioenergy is the energy available from biological sources, both living and immediate remains. Fuel is any material that burns readily in air. Biofuels are materials of biological origin that are used for producing heat and other forms of energy. Fuel is a great necessity of modern life. Wood, peat and coal, which represent three stages in the carbonization of the original woody plant tissue, are important fuel substances.

Because their moisture content is lower than that of green wood, seasoned or oven-dried wood makes excellent fuel: 99% of it is combustible, so it leaves only a small amount of ash. Hardwoods, such as ash, beech, hickory, maple and oak, which burn for a longer time and provide more uniform heat than does gymnospermic wood, are excellent fuelwoods. The mean calorific value of oven-dried Indian hardwoods is about 9000 btu. The different forms of energy that can be obtained from wood are shown in Table XI.

The qualities needed for fuelwood are physical properties of the wood as well as environmental and silvicultural properties of the species. Small-diameter, thornless shrubs and trees, which are easy to cut with primitive tools and easy to transport, are generally preferred. Likewise, fuelwood that is easy to split and either has a low moisture content or dries rapidly is preferred over other wood, because considerable heat is lost in burning moist wood. Such wood is also nontoxic and produces less smoke. For health reasons, too, these are important

Table XI
Forms of energy obtained from wood

Process	Form of energy
Direct burning	Heat, fire
Gasification	Producer gas
Carbonization (the process of heating wood and converting it into carbon)	Charcoal (has twice as much heating power as wood and burns without flame or smoke)
Pyrolysis	Charcoal, gas, oil
Hydrolysis, fermentation	Ethanol
Gasification, synthesis	Methanol

fuelwoods: ventilation is poor in village houses. While burning, wood should neither split nor spark. Wood density is positively correlated with the calorific value of fuelwood. A negative correlation also exists between wood density and growth rate, so fast-growing species generally have inferior burning properties. The best fuelwood species burn slowly and produce good heat from glowing charcoals. *Acacia* and *Casuarina* spp. are regarded as the best fuelwood species (Singhal & Khanna, 1991).

Some common fuelwood species of India are *Acacia catechu, A. leucocephala, A. nilotica* var. c*upressiformis, A. nilotica* var. *indica, Albizia amara, A. lebbek, Anogeissus latifolia, Azadirachta indica, Borassus flabellifer, Carrissa spinarum, Dalbergia sissoo, Delonix elata, Eucalyptus* spp., *Euphorbia* spp., *Leucaena leucocephala, Mangifera indica, Melia azedarach, Moringa tinctoria, Morus serrata, Pithecellobium dulce, Prosopis juliflora, P. spicigera, Psidium guajava, Sesbania sesban, Syzygium cuminii, Tamarix indica, Thespesia populnea, Zizyphus mauritiana,* etc. (Singhal & Khanna, 1991).

15. Fertilizers

Several species of nitrogen-fixing bacteria of *Rhizobium,* including *R. leguminosarum, R. lupini, R. meliloti* and *R. phaseoli,* live inside the root nodules of leguminous trees. Similarly, *Frankia,* a nitrogen-fixing mycelial bacterium, is associated symbiotically with the root nodules of several nonlegume plants, including *Alnus, Casuarina, Coriaria, Myrica* and *Rubus.* Both *Rhizobium* and *Frankia* are capable of fixing atmospheric nitrogen. When the roots of these plants decay, they enrich the soil with nitrogen salts.

16. Fibers

Botanically, a fiber is a special type of cell (sclerenchymatous) that has thick walls, a narrow lumen and tapering ends. Chemically, it is made up of cellulose and lignin. Commercially, a plant fiber is a strand consisting of one or hundreds of cells that varies in length from a fraction of a millimeter to 2 meters or more. Depending on how fibers are used, they can be classed as textile fibers (for fabrics, netting, cordage), brush fibers, plaiting and rough weaving fibers (for hats, sandals, baskets, chairs, etc.), filling fibers, natural fabrics and papermaking fibers.

The important fiber-yielding woody plants, including trees and shrubs, are *Abroma angusta, Abutilon* spp., *Acacia leucocephala, Ananas comosus, Antiaris toxicaria, Boehmeria nivea, Borassus flabellifer, Butea monosperma, Caryota urens* (leaves), *Cordia dichotoma, C. rothii, Ficus bengalensis, F. cunia, F. religiosa, Grewia glabra, G. elastica, G. optiva, G. tiliaefolia, G. vestita, Hardwickia binata, Hibiscus* spp., *Malachra capitata, Marsdenia volubilis, Pandanus* spp. (leaves), *Sterculia foetida, S. urens, S. villosa, Trema orientalis* and *Urena lobata.*

Most fibers are obtained from the bark of these plants. Silky flosses produced in the fruits of *Bombax ceiba, Ceiba pentandra* and *Cochlospermum religiosum* are also used as fibers for filling purposes. The well-known coir fiber is obtained from the fibrous mesocarp of the coconut palm, *Cocos nucifera*. It is coarse, stiff, buoyant and elastic and is therefore used for ship ropes, mats, brushes, ropes, etc. (Watt, 1889–1893; Anonymous, 1983; Maithani et al., 1991).

17. Pulp and Paper

An important use of fibers is in the manufacture of paper, which is playing an increasingly important role in modern civilized society. It can be divided into two categories: cultural paper (printing and writing paper) and industrial paper (packing and wrapping papers and boards).

The word "paper" comes from the Latin *papyrus* (the name of *Cyperus papyrus* of the family Cyperaceae), a sedge plant, the pith of which was used for paper in Egypt as early as 2400 B.C. The Chinese, however, were the first to actually make the paper. In 1799 Louis Robert of France invented the papermaking machine, which was improved by Henry and Sealy Fourdrinier of London in 1803.

The important and major raw materials of the pulp and paper industry are wood fibers (furnishing more than 90% of all the paper produced in the world), cotton and linen rags (yielding fine grades of paper, because of their high cellulose content), agricultural residues (bamboo, bagasse, straw, etc.) and waste paper (for recycled paper). Raw materials of minor importance are esparto grass (*Stipa tebnacissima,* family Poaccae), textile fibers (jute, hemp, coir, ramie, sisal hemp, sunn hemp, etc.), bast fibers of paper mulberry (*Broussonetia papyrifera,* family Moraceae) and fibers of papyrus (*Cyperus papyrus*), baobab (*Adansonia digitata*) and *Daphne cannabina*. Chinese and Japanese rice paper is made from *Tetrapanax papyriferum, Edgeworthia tomentosa* and *Wickstroemia canescens*.

Generally, softwood tracheids are preferred over hardwood fibers for papermaking because the tracheids of conifers are longer (about 2–4 mm) than are hardwood fibers (0.5–1.5 mm). Spruce wood is the most important raw material for pulp. Its fibers are long and strong, with a maximum content of cellulose. Almost free of resins, gums and tannins, it is light colored, sound and usually free of defects. The important species used are *Picea rubens* (red spruce), *P. glauca* (white spruce), *P. sitchensis* (sitka spruce), etc.

The other important raw materials for pulp are pines, other conifers and hardwoods, like *Pinus australis* (yellow pine), *P. banksiana* (jack pine), *Tsuga canadensis* (eastern hemlock), *T. heterophylla* (western hemlock), *Abies balsamea* (balsam fir), *A. concolor* (white fir), *Larix laricina* (tamarack), *Populus tremuloides* and *P. grandidentata* (aspens), *Fagus grandifolia* (beech), *Acer saccharum* (sugar maple) and *Betula lutea* (birch).

Although ancient Indian written records are on the leaves of the tree called "bhojpatra" (*Betula alnoides,* family Betulaceae), the art of papermaking in India started with the installation of first papermaking machine at Serampore in West Bengal in 1830. The main fibrous raw materials for papermaking are *Bambusa arundinacea, Boswellia serrata, Dendrocalamus strictus, Eulaliopsis binata* (Sabai grass) and *Pinus roxburghii*. These are followed by *Abies pindrow, Adansonia digitata, Agave americana, Arundo donax, Bambusa polymorpha, B. tulda, Broussonetia papyrifera, Daphne papyracea, Dendrocalamus giganteus, D. hamiltonii, Eucalyptus citriodora, E. globulus, Ochlandra travancorica* and *Populus ciliata*. The following Indian hardwood species are used for making bleachable pulp: *Albizia lebbeck, Anogeissus latifolia, Chloroxylon swietenia, Gmelina arborea, Lannea coromandelica, Prosopis chilensis, Pterocarpus marsupium, Sesbania grandiflora, Sterculia urens, Tectona grandis* and *Terminalia bellerica*.

18. Tannins

Tannins are soluble, astringent, bitter and complex phenolic substances of plant origin. These are glycosidal in nature and acidic in reactions. They may be hydrolizable or condensed in nature. Whereas hydrolyzable tannins are easily split into alcohols and acids by water, condensed tannins are not, for they are made up of polymers of cyclic compounds. Tannins may be present in individual cells or in special containers known as "tannin sacs." In individual cells, tannins are found in the cell sap or are impregnated in the cell's walls, often accumulating in large quantities in dead tissues such as cork or present in bark, wood, leaves, roots, fruits and galls.

The biological functions of tannins are not very clear. It is thought that tannins protect the protoplast against desiccation, decay and injury by animals. It may be concerned with the formation of cork or with protection of the plant. Economically, tannins are important in various ways. They have the ability to unite with certain types of proteins, such as those in animal skins (hides), to form a strong, flexible, resistant and insoluble substance known as "leather." The process and art of converting raw hides and skins of animals into leather, usually through the use of certain chemicals, is called "tanning." Tannins react with salts of iron to form dark blue, blue-black or greenish black compounds, which are the basis of tannin or writing inks. Tannins are also useful in medicine, because of their astringent nature. Tanning materials are often utilized in oil drilling to reduce the viscosity of the drill without reducing the specific gravity. Tannins may be obtained from the different parts of the trees, as shown in Table XII.

19. Dyes

Dyes are colored compounds (pigments) that are capable of being fixed to fabrics permanently; i.e., they neither fade on exposure to light nor wash out with soap. Therefore, a colored organic substance is not necessarily a dye. For example, trinitrotoluene, which is yellow in color, cannot fix to a cloth and therefore is not a dye. On the other hand, picric acid, which is also yellow in color, can fix to a cloth and therefore is a dye. A large number of plants secrete or contain pigments, but only about 150 are commercially important. In addition, synthetic or aniline dyes are now obtained from coal-tar products. These are cheaper, brighter, more permanent and easier to use, and they offer a wider range of colors. Among the chief uses of dyes is in coloring fabrics in the textile industry, where they are used with weak salt solutions of various metals like iron, chromium, aluminum or tin. A fine layer of metallic oxide, which forms an insoluble compound with the dye, is deposited on the cloth. Such salts of metals that increase the adherence of various dyes to the fabrics are called "mordants." These actually form a chemical bridge between the fiber molecules and the dye. Dyes are also used for coloring paints, varnishes, leather, ink, paper, wood, furs, food, cosmetics and medicines. A partial list of important dye-yielding trees in given in Table XIII.

20. Rubber and Other Latex Products

Rubber is obtained from the milky juice or latex of various tropical or subtropical woody plants. Latex is a gummy white liquid full of minute globules, a mixture of water, hydrocarbons, resins, oils, proteins, acids, salts, sugars and caoutchoue, a substance used as a source of rubber. Rubber is a polyterpene consisting of a long chain of thousands of isoprene (hydrocarbon) units. The tissue containing latex is called "laticiferous tissue." It consists of latex cells or latex coenocytes and latex vessels, the latter being formed by the fusion of many latex cells. Laticifers occur in bark, leaves and other softer parts of trees.

(Text continues on p. 357)

Table XII
Tannin-yielding trees

Common name	Genus and species	Family	Remarks
Tannins obtained from bark			
Mangrove	*Aegiceras corniculatum, Bruguiera conjugata, B. cylindrica, B. parviflora, Rhizophora candelaria*	Rhizophoraceae	Bark is very hard and heavy and contains 22–33% tannin; extract is the cheapest source of tanning material
Wattle	*Acacia dealbata, A. decurrens, A. leucocephala, A. mearnsii, A. mollis, A. nilotica, A. polyacantha*	Mimosaceae	Wattles contain 40–50% tannin. Bark, removed when trees are 5–15 years old, is ground to a powder. Pods also contain tannin. Wattles yield a very firm, pink leather, used for soles.
Avaram	*Cassia auriculata*	Caesalpiniaceae	Contains 18–23% tannin; used for tanning
Konnai bark	*Cassia fistula*	Caesalpiniaceae	Contains 10–12% tannin; used for tanning
Sumac	*Rhus mysurensis*	Anacardiaceae	Used for tanning
Arjun	*Terminalia arjuna*	Combretaceae	Contains 20–24% tannin; used for tanning
Indian almond	*Terminalia catappa*	Combretaceae	Used for tanning
Jujube	*Zizyphus mauritiana, Z. nummularia, Z. oenophlia*	Rhamnaceae	Used for tanning
Ceriops	*Ceriops roxburghiana*	Rhizophoraceae	Bark contains 20–37% tannin; leaves, 9–15%
Cuddaph almond	*Buchanania lanzan*	Anacardiaceae	Used for tanning
Casuarina	*Casuarina equisetifolia, C. suberosa*	Casuarinaceae	Used for tanning
Sal	*Shorea robusta*	Dipterocarpaceae	Bark contains 3–9% tannin; used for tanning
Pomegranate	*Punica granatum*	Punicaceae	Bark and fruit used for tanning
Hog plum	*Spondias pinnata*	Anacardiaceae	Used for tanning
Oak	*Lithocarpus densiflora, Quercus alba, Q. borealis, Q. infectorea, Q. leucotrichophora, Q. montana, Q. velutina*	Fagaceae	Bark contains 6–30% tannin; used for tanning
Mallet	*Eucalyptus occidentalis*	Myrtaceae	Bark contains 35–50% tannin
Hemlock	*Tsuga canadensis, T. heterophylla*	Pinaceae	Bark contain 8–30% tannin; used for tanning
European larch	*Larix decidua*	Pinaceae	
Norway spruce	*Picea abies*	Pinaceae	
Tanekaha bark	*Phyllocladus trichomanoides*	Podocarpaceae	

Table XII, *continued*

Common name	Genus and species	Family	Remarks
Tannins obtained from wood			
Chestnut	*Castanea dentata, C. sativa*	Fagaceae	Wood contains 30–40% tannin
Quebracho	*Schinopsis balansae, S. lorentzii*	Anacardiaceae	Wood, known as "axe breaker," is one of the hardest known woods; its specific gravity is 1.30–1.40. Wood contains 40–60% tannin; used for tanning.
Tannins obtained from leaves			
Sumac	*Rhus copallina, R. glabra, R. mysurensis, R. punjabensis, R. succedanea, R. typhina*	Anacardiaceae	10–25% tannin in leaves / leaf galls; used for tanning
Smoke tree, Indian sumac	*Cotinus coggyria*	Anacardcaceae	Used for tanning
Gumghatti, dhawa sumac	*Anogeissus latifolia*	Combretaceae	Leaves contain 32–39% tannin; used for tanning
Sicilian sumac	*Rhus coriaria*	Anacardiaceae	Leaves contain 20–35% tannin
Tannins obtained from fruits			
Myrobalan	*Terminalia bellerica, T. catappa, T. chebula, T. citrina, T. tomentosa*	Combretaceae	Nuts contain 30–40% tannin; used for tanning
Emblic myrobalan	*Emblica officinalis*	Euphorbiaceae	Tannin content 28% in fruit, 21% in twigs, 8–9% in stems, 22% in leaves
Divi divi	*Caesalpinia coriaria, C. digyna*	Caesalpiniaceae	Pods contain 40–50% tannin; used for tanning
Wild jujube	*Zizyphus xylocarpa*	Rhamnaceae	Used for tanning
Pomegranate	*Punica granatum*	Punicaceae	Fruit shells and bark used for tanning
Tora	*Caesalpinia spinosa*	Caesalpiniaceae	Fruits contain 43–51% tannin; used for tanning and making ink and as a black dye
Algarobilla	*Caesalpinia brevifolia*	Caesalpiniaceae	Used for tanning
Valonia	*Quercus macrolepsis*	Fagaceae	Sun-dried acorn cups contain 45% tannin; used for tanning
Tannins obtained from roots			
Palmetto	*Sabal palmetto*	Arecaceae	Tannin content in roots is low (10%)

Table XIII
Dye-yielding trees

Common name	Genus and species	Family	Remarks
Dyes obtained from wood			
Logwood	*Haematoxylon campechianum*	Caesalpiniaceae	Heartwood contains purplish red dye; with iron salts it becomes black; used for making inks and in histological work as a stain; also used for dyeing
Cutch	*Acacia catechu, A. catechuoides, A. sundra*	Mimosaceae	Heartwood contains 44–69% catechin; used as a dyeing stuff, as a masticatory and in medicine; cutch is the by-product
Sappan wood, Brazil wood, Braziline	*Caesalpinia echinata, C. sappan*	Caesalpiniaceae	Heartwood yields a red dye; used for dyeing cotton and wool and for preparing red ink
Red sandalwood, red sanderswood, santaline	*Pterocarpus santalinus*	Papilionaceae	Heartwood yields a red dye; used for dyeing cotton and wool and for preparing red ink
Fustic	*Chlorophora tinctoria*	Moraceae	Natural yellow, brown and olive dyes obtained from heartwood are used for dyeing
Osage orange	*Maclura pomifera*	Moraceae	Bright orange wood yields orange-yellow, gold and green dyes
Camwood	*Baphia nitida*	Fabaceae	Redwood dye is obtained
Barwood	*Pterocarpus erinaceous, P. soyauxii*	Papilionaceae	Yields shades of brown, red and violet dyes
Artocarpus	*Artocarpus heterophyllus, A. lakoocha*	Moraceae	Yields bright yellow dye; used by Buddhist monks
Dyes obtained from leaves			
Lodh	*Symplocos crataegoides*	Symplocaceae	Yellow dye is obtained
Chlorophyll a ($C_{55}H_{72}O_5N_4Mg$), Chlorophyll b ($C_{55}H_{70}O_6N_4Mg$); all green plants			Used for coloring food, soap and similar products
Dyes obtained from roots and tubers			
Indian mulberry	*Morinda angustifolia, M. bracteata, M. citrifolia, M. tinctoria*	Rubiaceae	Roots yield red and yellow dyes

Table XIII, *continued*

Common name	Genus and species	Family	Remarks
Dyes obtained from bark			
Bishopwood	*Bischofia javanica*	Euphorbiaceae	Red and tan dyes are obtained
Teak	*Tectona grandis*	Verbenaceae	Yields yellow dye for coloring baskets
Quercitron	*Quercus velutina*	Fagaceae	Yields bright yellow dye used for dyeing
Lokao, buckthorn	*Rhamnus globosa, R. utilis*	Rhamnaceae	Yields green dye used for dyeing silks and cottons
Dyes obtained from flowers			
Flame of the forest, dhak	*Butea monosperma*	Papilionaceae	Yields yellow dye used in Holi festivals
Tree of sorrow	*Nyctanthes arbor-tristis*	Oleaceae	Yields orange dye used for coloring silk and cotton
Sweet indrajao	*Wrightia tinctoria*	Apocyanaceae	Yields blue dye
Red cedar	*Toona ciliata*	Meliaceae	Yields yellowish red dye used for dyeing cotton
Dyes obtained from fruits			
Kamla, kamela	*Mallotus philippinensis*	Euphorbiaceae	Yields red dye used for dyeing silk
Dyes obtained from seeds			
Annatto	*Bixa orellana*	Bixaceae	Used for coloring foodstuffs as well as wools, paints, varnishes and soaps
Dharauli	*Wrightia tomentosa*	Apocyanaceae	Yields yellow dye
Dyes obtained from different parts			
Gum resin, gamboge	*Garcinia cambogia, G. cowa, G. hanburyi, G. morella, G. xanthochymus*	Guttiferae	Pith, flowers, leaves and fruits yield a yellow emulsion used for making watercolors and gold-colored spirit varnishes for metals

Laticifers are not known in gymnosperms. They are present in a large number of species and genera belonging to about 20 families, mostly dicotyledonous. Important rubber plants belong to Apocyanaceae, Euphorbiaceae and Moraceae.

Latex performs five functions in plants: healing of wounds; protection (warding off the attack of animals) because of the presence of bitter or poisonous alkaloids; storage of food reserve (for nutrition); formation and storage of excretory products; and transport of materials (conduction or translocation or as a fluid reservoir).

Joseph Priestley, the discoverer of oxygen, coined the term "rubber," owing to the fact that it could be used for removing pencil marks. In 1839 Charles Goodyear discovered the vulcanization process, in which sulphur is added to rubber to cross-link the molecules of isoprene chains. This process makes the latex impervious to weather conditions and improves its elasticity. Rubber is one of the best insulating and dielectric materials available. The important rubber-yielding woody plants are shown in Table XIV.

21. Gums

Gums contain large amounts of sugars and are closely allied to pectins. They are colloidal in nature and have the ability to dissolve in water and form a viscid solution (viscous liquids) or to absorb water and swell to form a gelatinous paste. On exposure to air these pastes dry to hard, clear, glassy masses by losing their water. Gums are insoluble in alcohol and ether.

Gums exude naturally or in response to wounding from the stems and are formed by disintegration of internal tissues, mostly from the decomposition of cellulose through a process known as "gummosis." They are mostly obtained from bark or secondary phloem.

Gums are used in a variety of ways. The finer grades are utilized in finishing silk, clarifying liqueurs and preparing high-quality watercolors. The intermediate grades are used in printing inks, in sizing, finishing and dyeing textile fabrics, in confectionery and in the pharmaceutical industry. The cheaper grades are used as adhesives, in calico printing, in sizing of paper and in the paint industry. In the cosmetic and pharmaceutical industries gums act as emollients or demulcents or serve to bind or emulsify mixtures in lotions, ointments and creams. They may add body and bulk to foodstuffs like commercial ice creams.

Commercial gums are dried exudations of dry-region plants belonging to the Anacardiaceae, Combretaceae, Fabaceae, Meliaceae, Rosaceae and Rutaceae. One hundred or more species of *Acacia* alone are known to yield gum. The important gum-yielding trees are shown in Table XV.

22. Resins

Although resins resemble gum in superficial appearance, they differ in origin and chemical composition. Some resins are sticky, viscous liquids; others are hard, brittle, amorphous solids, generally clear or transparent but sometimes opaque. Important resin-yielding families, differences among three main types of resins and resin-yielding trees are presented in Tables XVI, XVII and XVIII, respectively.

Resins represent oxidation products of various essential oils. They are complex and varied in their chemical composition. Chemically, they are polymerized terpenes that are usually mixed with volatile oils. Unlike gums, resins are insoluble in water but soluble in alcohol, ether, turpentine, spirit, carbon disulphide and other solvents. The latter property is utilized to form varnishes; when applied in thin films, the solvent evaporates, leaving behind a hard, waterproof layer of resin. Resins are fusible; that is, when heated they first soften and then melt to a more or less clear, sticky fluid. They are resistant to most reagents and to decay but, when ignited, burn with a smoky flame.

(Text continues on p. 370)

Table XIV
Rubber-yielding trees

Common name	Genus and species	Family	Remarks
Elastic rubber			
Hevea or Pará rubber	*Hevea brasiliensis*	Euphorbiaceae	98% of the world's rubber comes from this tree, which is native to Amazonia; in India it is a plantation crop in Kerala, Tamil Nadu and Karnataka
Castilla or Panama rubber	*Castilla elastica*	Moraceae	Native to Mexico and Central America
Caucho rubber	*Castilla ulei*	Moraceae	Native to Amazonia
Ceará or Manicoba rubber	*Manihot glaziovii*	Euphorbiaceae	Native to Brazil; also grown in India
Assam or India rubber	*Ficus elastica*	Moraceae	Native to northern India and Malaysia; of low grade and little commercial value
Mangabeira	*Hancornia speciosa*	Apocyanaceae	Native to Bolivia, Brazil and Paraguay
Chilte rubber	*Cnidosceolus* spp.	Euphorbiaceae	
Nonelastic rubber			
Gutta-percha	*Pelaquium ellipticum, P. gutta, P. polyanthum*	Sapotaceae	Obtained from grayish white latex of this Malaysian tree; latex, present in sacs that occur in the cortex, phloem, pith and leaves, is used for insulation, submarine cables, golf balls, waterproofing and adhesives and as a substitute for chicle
Balata	*Manilkara bidentata*	Sapotaceae	Native to Trinidad and South America; used for insulation, submarine cables, golf balls, waterproofing and adhesives and as a substitute for chicle
Jelutong	*Dyera costulata*	Apocyanaceae	A Malayasian tree; used as a substitute for chicle
Chicle, sapodilla, naseberry	*Manilkara achras*	Sapotaceae	Native to the Yucatán Peninsula, cultivated in India; latex contains 20–25% gutta-percha–like gum called "chicle," which is the basis of the chewing gum industry; also used in making surgical tape and dental supplies
Sorva, leche caspe	*Couma macrocarpa*	Apocyanaeae	A large Amazonian tree; used as a substitute for chicle

Table XV
Gum-yielding trees

Common name	Genus and species	Family	Remarks
Gum arabic, kumta	*Acacia senegal*	Mimosaceae	Gum obtained from bark; used for all purposes mentioned in the text
Khair	*Acacia catechu*	Mimosaceae	Gum obtained from bark; used for all purposes mentioned in the text
Babul, acacia, kikar	*Acacia nilotica*	Mimosaceae	Gum obtained from bark; used in confectionery
Acacia	*Acacia modesta*	Mimosaceae	Used in medicine and in printing calico
Son khair, kaiger	*Acacia ferruginea*	Mimosaceae	Gum obtained from bark; used for all purposes mentioned in the text
Karaya, kandya, katira, kuteera, katillo, kullo, India or sterculia gum	*Sterculia urens, S. villosa*	Sterculiaceae	Gum obtained from heartwood; used as a substitute for gum tragacanth, also in the cosmetic and cigar industries in several emulsions, lotions, pastes and as a laxative; forms a strong adhesive gel with a little water
Gum ghatti	*Anogeissus latifolia*	Combretaceae	Used as a substitute for gum arabic; also used in ceramics, foods and the petroleum industry, as a drilling mud conditioner, and in the explosives industry
Gum locust, carob	*Ceratonia siliqua*	Caesalpiniaceae	Not a true gum because it is obtained not from wounded woody tissues but from the endosperm of seeds; was used by Egyptians as an adhesive for binding mummies, now used in the food industry and for other purposes mentioned in the text
Cellulose gum, caboxymethyl cellulose gum; green plants			Prepared by mixing purified cellulose with sodium monochloroacetate in an alkaline medium; extra whitening and brightening of detergents is due to this gum; also used in the paper, textile, food and paint industries
—	*Limonia acidissima*	Rutaceae	Substitute for gum arabic
Hog gum	*Cochlospermum religiosum*	Cohlospermaceae	Substitute for gum arabic; is edible
Cycas gum	*Cycas circinalis*	Cycadaceae	
Larch gum	*Larix occidentalis*	Pinaceae	Gum obtained from wood chips; used as a substitute for gum arabic
Mesquite gum, kabuli kikar	*Prosopis chilensis, P glandulosa, P. juliflora*	Mimosaceae	Gum obtained from stems; used for printing calico
Cherry gum	*Prunus cerasoides, P. cerasus*	Rosaceae	Used as a substitute for gum arabic

Table XV, *continued*

Common name	Genus and species	Family	Remarks
East Indian copal	*Canarium bengalense*	Burseraceae	Gum obtained from stems; used as a hard-drying varnish
Gum benzoin, benjamin	*Styrax benzoin*	Styracaceae	Source of benzoic acid
Jhingan gum	*Lannea coromandelica*	Anacardiaceae	Used in printing calico and as sizing in the paper and textile industries
Malabar kino gum	*Pterocarpus marsupium*	Papilionaceae	Valuable medicine in diarrhea and dysentery
Bengal kino	*Butea monosperma*	Papilionaceae	Valuable medicine in diarrhea and dysentery
—	*Astragalus prolixus*	Papilionaceae	Gum obtained from stems; used in cosmetics, printing calico and confectionery
Garmezu	*Astragalus strobiliferus*	Papilionaceae	Gum obtained from stems; used in confectionery
Gum neem	*Azadirachta indica*	Meliaceae	
Wood apple, kut bel	*Feronia limonia*	Rutaceae	Gum obtained from trunk and branches; used as a substitute for gum arabic
Bialam	*Anisoptera scaphula*	Dipterocarpaceae	
Cowa	*Garcinia cowa*	Guttiferae	Gum obtained from trunk and branches; used for preparing yellow varnish
Semla gond	*Bauhinia retusa*	Mimosaceae	Substitute for gum arabic; used for sizing cloth and paper and for waterproofing terraced roofs
Albizia gums	*Albizia chinensis, A. lebbek, A. odoratissima, A. procera*	Mimosaceae	Used for various purposes
Bauhinia gums	*Bauhinia purpurea, B. racemosa, B. variegata*	Mimosaceae	
—	*Chloroxylon swietenia*	Rutaceae	Yields amber or reddish brown gum
Mango	*Mangifera indica*	Anacardiaceae	Substitute for gum arabic
—	*Terminalia bellerica*	Combretaceae	Contains crystals of calcium carbonate
—	*Terminalia tomentosa*	Combretaceae	Used as incense

Table XVI
Resin-yielding families

Family	Resin
	Gymnosperms
Pinaceae	Calophony, balsam, Canada balsam, kauri-resin, manil copal, oleo-resin, sandarac
Fossil conifers	Amber (from *Pinus succinifera*)
	Angiosperms
Anacardiaceae	Mastic
Apiaceae	Ammoniacum, asafoetida, galbanum
Berberidaceae	Podophyllum
Burseraceae	Elemi, frankincense, myrrh
Caesalpiniaceae	Copal
Convolvulaceae	Jalap, seamony
Dipterocarpaceae	Dammars
Guttiferae	Gamboge
Hamamelidaceae	Storax
Liliaceae	Acaroid resin, aloes, dragons blood
Leguminosae (Fabaceae)	Balsam of perum, Congo copal, copaiba balsam, Peru balsam, tolu balsam
Styracaceae	Benzoin
Zygophyllaceae	Guiacum

Table XVII
Differences among three main types of resins

Hard resins	Oleo resins	Gum resins
Little, if any, essential oil	Considerable essential oils as well as resinous materials	Mixture of both true gums and resins, thus contain small amounts of essential oils and traces of coloring matter
Usually solid, more or less transparent, brittle substances	More or less liquid in nature	Occur naturally as milky exudations, collected as tears or irregular masses
No particular odor or taste	Distinct aroma and flavor	May have an aroma and flavor
Nonvolatile and very poor conductors of electricity but become negatively electrified when friction is applied; readily fusible and burn in air with a smoky flame	Volatile essential oil component	
Common examples: copals, damars	Common examples: balsams, elemis, turpentines	Common examples: anmoniacum, asafoetida, galbanum

Table XVIII
Resin-yielding trees

Common name	Genus and species	Family	Remarks
Hard resins			
Zanzibar copal, Madagascar copal, Mozambique copal	*Trachylobium verrucosum*	Fabaceae	Hardest of all copals except amber; living, semifossil or fossil in nature; yellowish to brownish red
Inhambane copal	*Copaifera conjugata*	Fabaceae	
Congo copal, Angola copal	*Copaifera aemeusii, C. mopane*	Fabaceae	Living as well as fossil in nature; light yellow
Sierra Leone copal	*Copaifera copallifera, C. salikounda*	Fabaceae	Light yellow
Accra copal, Benin copal	*Daniella ogea*	Fabaceae	Locally called "ogea gum" in Liberia, Ghana and Nigeria
South American copal, Demerara copal, Pará copal	*Hymenaea courbaril*	Fabaceae	Softest of all copals
Manila copal	*Agathis alba*	Araucariaceae	Living, semifossil or fossil in nature; yellow
Kauri copal, kauri gum	*Agathis australis*	Araucariaceae	Living, semifossil or fossil in nature; yellow
Damar mata kuching	*Hopea micrantha*	Dipterocarpaceae	
Damar penak	*Balanocarpus heimii*	Dipterocarpaceae	
Damar temak	*Shorea hypochra*	Dipterocarpaceae	
Sal damar, guggal dhuma, ral dhuma, lal dhuma	*Shorea robusta*	Dipterocarpaceae	Used as an ingredient of "samagri," which is burned in religious ceremonies
Kala damar	*Shorea tumbuggaia*	Dipterocarpaceae	Used as an incense and in marine yards as a substitute for pitch
White damar, piney resin, Indian copal, dhupa	*Vateria indica*	Dipterocarpaceae	Used in medicine to treat chronic bronchitis, diarrhea and rheumatism
Black damar	*Canarium strictum*	Burseraceae	Used as a substitute for burgundy pitch in medical plasters
Batavian damar	*Shorea wiesneri*	Dipterocarpaceae	
Rock damar	*Hopea odorata*	Dipterocarpaceae	Used in varnishes

Amber	*Pinus* (= *Pinites*) *succinifera* (principal source)	Pinaceae	Fossilized terpenoid resin occurring on the shores of the Baltic Sea, it is the only jewel of plant origin. It is exceedingly hard, brittle, yellow to brown or even black, transparent or opaque with a characteristic aromatic odor; when rubbed, it takes a high polish and becomes negatively charged. Used for beads, ornaments, mouthpieces of pipes and holders for cigars and cigarettes, etc. Sometimes organisms of the past are embedded in it.
Amber	*Hymenaea* spp., *Copaifera* spp. (other sources)	Fabaceae	Fossilized terpenoid resin occurring on the shores of the Baltic Sea, it is the only jewel of plant origin. It is exceedingly hard, brittle, yellow to brown or even black, transparent or opaque with a characteristic aromatic odor; when rubbed, it takes a high polish and becomes negatively charged. Used for beads, ornaments, mouthpieces of pipes and holders for cigars and cigarettes, etc. Sometimes organisms of the past are embedded in it.
Lacquer	*Rhus verniciflua, R. succedanea*	Anacardiaceae	Natural varnish exuded from Asiatic trees, it affords protection because it remains unchanged by acids, alkalis, alcohol or heat up to 160°F *Rhus succedanea* yields liquid resin from the mesocarp of fruits, which is used in ointments, wax varnishes, etc.
Burmese lacquer, thitsi	*Melanorrhoea usitata*	Anacardiaceae	Affords protection because it remains unchanged by acids, alkalis, alcohol or heat up to 160°F
Shellac	*Butea monosperma, Cajanus cajan*	Papilionaceae	Not strictly a plant product but a resinous substance secreted on the twigs of many trees by the sap-feeding stick lac insect *Tachardia lacca* ("lacca" is derived from the Sanskrit word *laksha,* meaning "lakh"). Used in the manufacture of phonograph records, high-grade insulators, spirit varnish, sealing wax, drawing ink, watercolors, nitrocellulose lacquers and as sizing in paper and stiffening in felt hats.
Shellac	*Schleichera oleosa*	Sapindaceae	Not strictly a plant product but a resinous substance secreted on the twigs of many trees by the sap-feeding stick lac insect *Tachardia lacca* ("lacca" is derived from the Sanskrit word *laksha,* meaning "lakh"). Used in the manufacture of phonograph records, high-grade insulators, spirit varnish, sealing wax, drawing ink, watercolors, nitrocellulose lacquers and as sizing in paper and stiffening in felt hats.

Table XVIII, *continued*

Common name	Genus and species	Family	Remarks
Hard resins, *continued*			
Shellac	*Zizyphus xylopyrus*	Rhamnaceae	Not strictly a plant product but a resinous substance secreted on the twigs of many trees by the sap-feeding stick lac insect *Tachardia lacca* ("lacca" is derived from the Sanskrit word *laksha,* meaning "lakh"). Used in the manufacture of phonograph records, high-grade insulators, spirit varnish, sealing wax, drawing ink, watercolors, nitrocellulose lacquers and as sizing in paper and stiffening in felt hats.
Shellac	*Ficus religiosa*	Moraceae	Not strictly a plant product but a resinous substance secreted on the twigs of many trees by the sap-feeding stick lac insect *Tachardia lacca* ("lacca" is derived from the Sanskrit word *laksha,* meaning "lakh"). Used in the manufacture of phonograph records, high-grade insulators, spirit varnish, sealing wax, drawing ink, watercolors, nitrocellulose lacquers and as sizing in paper and stiffening in felt hats.
Shellac	*Acacia nilotica*	Mimosaceae	Not strictly a plant product but a resinous substance secreted on the twigs of many trees by the sap-feeding stick lac insect *Tachardia lacca* ("lacca" is derived from the Sanskrit word *laksha,* meaning "lakh"). Used in the manufacture of phonograph records, high-grade insulators, spirit varnish, sealing wax, drawing ink, watercolors, nitrocellulose lacquers and as sizing in paper and stiffening in felt hats.
Acaroid or grass-tree resins	*Xanthorrhoea hastilis, X. tateana, X. australis*	Liliaceae	Resin collected around the bases of old leaves is yellow from the first species and red from the other species. Used in making sealing wax and spirit varnishes and as a substitute for rosin in paper sizing and ink; also as a source of picric acid and in medicine.
Sandarac	*Tetraclinis articulata, Callitris quadrivalvis*	Cupressaceae	Secreted in the form of small tears on the bark, it is hard, white and rather brittle. Used for coating labels, negatives, cardboard leather and metal and in dental cement, incense and fumigating powder.

Chios mastic	*Pistacia lentiscus*	Pistaciaceae	Excreted from the bark in the form of long, ovoid, pale yellow, brittle tears. Used for coating metals and both oil and watercolor pictures; in the preparation of transparent varnishes and in chewing gum; also used in perfumery, medicine, lithographic work and as a cement for dental work.
Bombay mastic	*Pistacia cabulica*	Pistaciaceae	Dull, milk-colored resin. Used for coating metals and both oil and watercolor pictures; in the preparation of transparent varnishes and in chewing gum; also used in perfumery, medicine, lithographic work and as a cement for dental work.
Malbar, gum or Indian kino	*Pterocarpus marsupium*	Fabaceae	Used in medicine for throat troubles and in tanning
West African kino	*Pterocarpus erinaceus*	Fabaceae	Red resin, used in medicine for throat troubles and in tanning
Bengal kino	*Butea monosperma*	Fabaceae	Used in medicine for throat troubles and in tanning
Gum kino	*Eucalyptus camaldulensis*	Myrtaceae	Secreted between the wood and the bark
Gum kino	*Dipteryx odorata, Coccoloba uvifera*	Polygonaceae	Secreted between the wood and the bark
Lesch	*Antiaris toxicaria*	Moraceae	White resin, used for poisoning arrows and in medicine
Oleoresins			
Turpentine, birja, biroja, lisha, lassa	*Pinus australis, P. caribaea, P. ponderosa* (in America); *P. roxburghii, P. wallichiana, P. merkusii, P. insularis, P. kesiya* (in India); *P. pinaster, P. maritima* (in France); *P. pinaster, P. halepensis, P. nigra, P. pinea* (in Spain); *P. pinaster, P. pinea* (in Portugal); *P. halepensis* (in Greece); *P. sylvestris* (in Russia, Poland and Germany)	Pinaceae	Exuded from coniferous trees as a viscous, honey-like liquid or a soft, sticky substance called "pitch." On distillation it yields essential oil (called "oil" or "spirit of turpentine") and rosin (the residue). The oil is used in the paint and varnish industry, in printing cotton and wool, as a solvent for rubber and gutta-percha, in medicine and in the manufacture of pine oil, terpineol, camphor, pine tar, vormeol, voneol acetate and other chemicals. The rosin, or colophony, is a brittle, friable, faintly aromatic, solid used in the manufacture of soap, varnish, paint, oilcloth, linoleum, sealing wax, adhesives, printers' ink, floor and roof coverings, rubbers, drugs, plastics, etc. and as a sizing material for paper. Rosin oil is used as grease, a lubricant and a solvent.

Table XVIII, *continued*

Common name	Genus and species	Family	Remarks
Oleoresins, *continued*			
Venetian turpentine	*Larix decidua*	Pinaceae	Used in histology, lithographic work, varnishes and veterinary medicine; yellowish or greenish liquid with a characteristic taste and odor
Bordeaux turpentine	*Pinus pinaster*	Pinaceae	The residue, called "Burgundy pitch," is a stimulant and counterirritant and is used in plastics, ointments and pharmaceuticals
Strasbourg turpentine	*Abies alba*	Pinaceae	The residue, called "Burgundy pitch," is a stimulant and counterirritant and is used in plastics, ointments and pharmaceuticals
Jura turpentine	*Picea abies*	Pinaceae	
Canada balsam	*Abies balsamea*	Pinaceae	True turpentine (oleoresin) from the balsam fir, it is a viscid, yellowish or greenish substance used as a mounting medium for microscopic work and a cement for optical lenses; also used as an irritant, stimulant and antiseptic, as a component in collodion and many plasters and as a fixative for soap and perfumes. Technically, balsams are aromatic oleoresins that contain benzoic or cinnamic acid and are less viscous and contain less oil than turpentines. On distillation balsams yield essential oils that are used in medicine and as fixatives in the perfume industry.
Oregon balsam	*Pseudotsuga taxifolia*	Pinaceae	A viscid, yellowish or greenish substance used as a mounting medium for microscopic work and a cement for optical lenses; also used as an irritant, stimulant and antiseptic, as a component in collodion and many plasters and as a fixative for soap and perfumes
Spruce gum	*Picea rubens*	Pinaceae	Obtained from wood and bark, the oleoresin is thin, clean, bitter and sticky, hardens on exposure to air and has a pleasing, resinous taste. Used as a masticatory because it softens in the mouth and becomes reddish.

Balsam of Peru	*Myroxylon pereirae*	Fabaceae	A dark, reddish brown, thick, viscous, syrupy liquid obtained by wounding the tree. Used in medicine for treating slow-healing wounds and skin diseases (especially during World War II) and, because of its stimulating and antiseptic effect on mucous membranes, for treating coughs, bronchitis, etc.; also used as a substitute for vanilla, as a fixative in perfumes and in the soap industry. The common name is a misnomer because the tree grows in Central America, not in Peru.
Balsam of Tolu	*Myroxylon balsamum*	Papilionaceae	A brown or yellowish brown, plastic substance with a pleasant aromatic taste and odor; used for almost the same purposes as balsam of Peru
Levant styrax or storax	*Liquidamber orientalis*	Hamamelidaceae	A semiliquid, sticky, grayish brown, opaque, aromatic substance obtained from inner bark by wounding the tree; used in cosmetics, soap, adhesives, lacquers and incense as a fixative, in perfumes and in medicine for the treatment of coughs and scabies
American styrax	*Liquidamber styraciflua*	Hamamelidaceae	A clear, thick, brownish yellow semisolid or solid substance obtained from inner bark by wounding the tree; used in cosmetics, soap, adhesives, lacquers and incense; as a fixative in perfumes; and in medicine for the treatment of coughs and scabies. India imports it from France.
Siam benzoin, balsamic resin	*Styrax benzoides, S. tankinense*	Styraceae	Yellowish or brownish, pebble-like hard and brittle tears with a milky white center and a strong, vanilla-like aroma; used as incense and in medicine as a stimulant, diuretic, carminative and expectorant; in the manufacture of perfume, soap, toilet water, lotion, tooth powder and fumigating materials; a source of benzoic acid
Sumatra benzoin	*Styrax benzoin*	Styraceae	Reddish or grayish brown tears that aggregate to form blocks or lumps; used as incense and in medicine as a stimulant, diuretic, carminative and expectorant; in the manufacture of perfume, soap, toilet water, lotion, tooth powder and fumigating materials; a source of benzoic acid

Table XVIII, *continued*

Common name	Genus and species	Family	Remarks
Oleoresins, *continued*			
Copaiba, Copaiba balsam, capaiva	*Copaifera* spp., especially *C. officinalis, C. reticulata*	Fabaceae	Obtained by boring holes into heartwood, it is a thin, clear, colorless liquid that turns yellow and viscid with age, is aromatic and has a bitter taste; used in making lacquer, varnish and tracing paper, as a fixative in perfume and soap; in photography for half-tones and shadows and in medicine as a laxative, disinfectant, diuretic and mild stimulant
Gurjan balsam	*Dipterocarpus alatus, D. indicus, D. turbintus*	Dipterocarpaceae	Thick, opaque and grayish, it is used in medicine and for caulking and varnishing boats
Illurin balsam, African copaiba, Sierra Leone frankincense	*Daniella oliveri, D. thurifera*	Fabaceae	Thick, very fragrant, pungent, pepper-like oleoresin
Manila elemi	*Canarium luzonicum*	Burseraceae	Oozes from trunk bark in fragrant, white masses on tree trunks; used locally for torches, for caulking boats, in lithographic work, in the manufacture of cements, adhesives and ink, in perfume, in medicine, in plastics and ointments, and in the varnish industry to make products tough and elastic
African elemi	*Boswellia frereana*	Burseraceae	
Mexican elemi	*Amyris balsamifera, A. elemifera*	Rutaceae	
Brazilian elemi	*Bursera gummifera, Protium heptaphyllum*	Burseraceae	
Mecca balsam	*Commiphora opabalsamum*	Burseraceae	A greenish, turbid oleoresin with an odor of rosemary; used in incense, perfumes and medicine
Mexican linaloe	*Bursera penicillata*	Burseraceae	Obtained from the aromatic fruits; used in perfume
Salai gum, Indian olibanum	*Boswellia serrata:*	Burseraceae	Used as an incense, in medicine for rheumatism, nervous diseases and ointments and as a fire lighter

Gum resins			
Ammoniacum	*Dorema ammoniacum*	Apiaceae	Exudes from stems and flowering branches as a milky juice that hardens on exposure to form brittle, brownish yellow tears, which occur singly or in masses; used in perfumery and in medicine as a circulatory stimulant
Herabol myrrh	*Commiphora myrrha*	Burseraceae	Oozes from stems as a pale yellow liquid that hardens to form brown or black tears; used in perfumery, as a constituent of mouthwash and dentifrices and in medicine as a tonic, stimulant and antiseptic
Bisabol, sweet myrrh	*Commiphora erythraea*	Burseraceae	Used in incense, perfumes and embalming and as a constituent of Chinese joss sticks
Gum resin	*Commiphora caudata*	Burseraceae	A pale yellow liquid that gradually solidifies and turns brown or black; used in medicine, as incense and for embalming
Frankincense of olibanum	*Boswellia carteri*	Burseraceae	Exudes from bark as a clear, yellow resin that hardens into small yellow grains; used in incense and perfumes and as a fixative for face powders, pastilles and fumigating powders
Indian frankincense, luban	*Boswellia serrata*	Burseraceae	Obtained from bark, the oleo-gum-resin contains: oily, turpentinic liquid, used as a substitute for turpentine oil; a rosin-like resin, used in the soap industry; and gum, used in printing calico
Opopanax	*Commiphora kataf*	Burseraceae	Used in perfumery and in medicine
Opopanax	*Opopanax chironium*	Apiaceae	An herb used in perfumery and in medicine
Ceylon gambose, Indian gamboge	*Garcinia hanburyi, G. morella*	Guttiferae	Yellow emulsion obtained from the pith, leaves, flowers and fruits; used in preparing watercolors and gold-colored spirit varnishes and in medicine as a violent cathartic
Madar	*Calotropis gigantea, C. hamiltonii*	Asclepiadaceae	Used as a substitute for gutta-percha

Resins are very important in industry. Two types are used in manufacturing varnishes and lacquers. The first type comprises resins that, after melting, can be combined with linseed oil or turpentine and utilized for forming amber, copal and other oil varnishes. Oil varnishes are superior but costly.

The word "copal" is of Mexican origin. In England many of the harder copals are known as "animes." The copals are resins of recent semifossil or fossil tropical and subtropical tree species. They contain almost no oil and yield a hard, elastic varnish, which is much used for outdoor work.

The second type of resins comprises those that dissolve in alcohol, turpentine or other volatile solvents. They are utilized for forming spirit varnishes, such as rosin, damar, sandarac, mastic and elemis. Spirit varnishes are less expensive and more easily prepared and applied. They produce brilliant, transparent finishes. All damars are used chiefly in spirit varnishes and in the manufacture of nitrocellulose lacquers. Damar varnishes are softer, less durable and adhere better. They are used mainly for varnishing paper because of their luster and light color. They are also used for indoor work and in histology. "Elemi" is a collective name for several oleoresins of different origin that exude as clear, pale liquids. Most tend to harden on exposure, but some may remain soft.

Resinous substances have been used for waterproof coatings and also for decorative coatings for ages. The ancient Egyptians varnished their mummy cases, and the Incas utilized resins in their embalming mixtures. Resins are also used in the preparation of soap—they dissolve in alkali to form soap—and in medicine, for sizing paper, as a stiffening material for mats, in the preparation of fixatives, incenses, perfumes, tobacco flavorings, sealing wax, plastics, linoleum, oilcloth, printers' ink, adhesives, etc. Their combustible properties are utilized for making torches; their waterproofing qualities, for making boats.

Resins tend to lessen the amount of water lost from the tissues of plants. Because of their antiseptic properties, resins prevent decay, and, when present in wood, add strength and durability.

Resin is secreted in plant tissues in specialized canals or cavities called "resin ducts," which are lined with a special layer of secretory cells, called the "epithelial layer," that secrete resin into the cavity through a thin cuticular layer. Resin ducts may be present in leaves, wood and bark of stems. They normally ooze out through the bark and harden on exposure to air. Commercial resins, however, are extracted from artificial wounds or fossil materials.

23. Cork

Commercial cork is obtained from the outer bark (phellem) of cork oak, Q*uercus suber,* an evergreen tree of the family Fagaceae. It is native to the western Mediterranean region: about 70% of the world's commercial cork comes from Portugal alone. Cork is nothing more than thin-walled but strong cellulosic cell walls, which are heavily coated with suberin, a substance that is impervious to water. Cell lumens, which represent nearly 53% of the total cork volume, are filled with air, thus making cork very light—its specific gravity is 0.15–0.25.

Cork is buoyant, light and highly compressible, but it is resilient, chemically inert to moisture and common liquids, resistant to deterioration, an excellent insulator, a nonconductor of electricity, a low thermal conductor and impervious to water and other liquids. It imparts no flavor or odor to substances, is slow to catch fire, absorbs sound and vibrations and has a high coefficient of friction. All of these properties render commercial cork invaluable in the world market, and it is used either as natural cork or as composition cork, the latter as linoleum, linotiles, binder-coated cork and cork (insulation) boards. Cork is used in the preparation of stoppers, hats and helmets, tips for cigarettes, carburetor floats, fishing-net floats, golf-club handles, penholders, fishing rods, life preservers, floats and life jackets, surf balls, seals for

jars, sealing liners, shoe insoles, sporting goods, picture frames, small cork balls in referees' whistles, etc.

24. Food for Silkworms

Mulberry silk accounts for 95% of the world's silk production. It is produced by *Bombyx mori* L., which feeds on the leaves of mulberry plants. *Morus* is the Latin word for "mulberry" (French: *muries;* Italian: *gelso;* Japanese: *lewwa*). It belongs to the family Moraceae, of the order Unisexuales or Urticales. The following species of *Morus* are known in the world: *acidosa, arabica, atropurpurea, australis, bombycis, boninensis, cathayama, celtidifolia, cordatifelia, indica, glabrata, insignis, japonica, kagayamae, laevigata, latifolia, lhou, macroura, microphylla, miyabean, mizuho, mollis, mongolica, mosozygia, multicaulis, nigra, nigriformis, notabilis, pabularia, philippinensis, rotundifolia, rubra, serrata, sinensis, tiliaefolia* and *yoshimurai* (Seth & Lal, 2002).

Tasar silk is the product of the secretion from the silk glands of *Antheraea proylei* and *A. mylitta,* the temperate and tropical tasar silkworms, respectively. Although *Antheraea* species are polyphagous in nature, the food plants of first choice are known as "primary" and others, as "secondary." The three main food plants of tropical tasar silkworms are: *Terminalia alata,* syn. *T. tomentosa,* vern. asan; *Terminatia arjuna,* vern. arjun; and *Shorea robusta,* vern. sal. In addition to the three main food plants, the tasar silkworm may feed on the following (Seth, 2000a):

- *Anogeissus latifolia;* axlewood, vern. dhawa, dhaura, dhaunta; family Combretaceae, order Myrtales
- *Bauhinia variegata;* vern. kachnar; family Caesalpiniaceae, order Rosales
- *Bombax ceiba,* syn. *Salmalia malabarica, Bombax malabaricum, Gossampinus malabarica;* silk cotton tree, vern. semul, shembal, raket-senbal, kaanti sembal, pagun; family Bombacaceae, order Malvales
- *Canthium dicoccum,* syn. *C. didymum, Plectronia didyma;* vern. rangruri; family Rubiaceae, order Rubiales
- *Capadessa fruiticosa:* vern. nalbali; family Meliaceae, order Geraniales
- *Careya arborea;* kumbi, vern. kumbi; family Lecythidaceae, order Myrtales
- *Carissa carundus;* karunda, vern. karumcha, karaunda; family Apocynaceae, order Gentianales
- *Celastrus paniculatus;* vern. malkangni; family Celastraceae, order Celastrales
- *Chloroxylon swietenia;* East Indian satinwood, vern. bhirra, girya; family Rutaceae, order Geraniales
- *Dodonaea viscosa;* vern. aliar, sinatha; family Sapindaceae, order Sapindales
- *Ficus benjamina;* family Moraceae, order Unisexuales or Urticales
- *Ficus religiosa;* peepal, vern. pipal, pipli; family Moraceae, order Unisexuales or Urticales
- *Ficus retusa;* vern. kamrup, chilkan; family Moraceae, order Unisexuales or Urticales
- *Ficus tsiela;* vern. jari; family Moraceae, order Unisexuales or Urticales
- *Ficus tsjakela;* family Moraceae, order Unisexuales or Urticales
- *Hardwickia binata;* anjan, vern. anjan; family Caesalpiniaceae, order Rosales
- *Lagerstroemia indica;* common crape myrtle, vern. saoni; family Lythraceae, order Myrtales
- *Lagerstroemia parviflora;* landau, vern. Sida, dhaura, Bali, Sidi; family Lythraceae, order Myrtales
- *Madhuca indica,* syn. *M. latifolia, Bassia latifolia;* mahua, mowra, illipe, butter tree, vern. mahua, mohwa, mauwa; family Sapotaceae, order Sapindales

- *Melastoma malabathricum;* vern. phutki; family Melastomataceae, order Myrtales
- *Ricinus communis;* castor, castor seed, vern. erandi, bharenda; family Euphorbiaceae, order Euphorbiales
- *Shorea roxburghii,* syn. *S. talura;* lac tree of South India; family Dipterocarpaceae, order Parietales
- *Syzygium cuminii,* syn. *Eugenia jambolana, E. cuminii;* jaman, jambolan, blackplum, java plum, vern. jamun, jam; family Myrtaceae, order Myrtales
- *Tectona grandis;* teak, vern. sagun, sagwan; family Verbenaceae, order Lamiales
- *Terminalia bellerica;* belleric myrobalan, bahera, vern. bahera; family Combretaceae, order Myrtales
- *Terminalia catappa;* Indian almond tree, vern. deshibadam; family Combretaceae, order Myrtales
- *Terminalia chebula;* chebulic myrobalan, vern. haritaki, harar; family Combretaceae, order Myrtales
- *Terminalia coriacea,* syn. *T. tomentosa* var. *coriacea;* leathery murdah, vern. tani; family Combretaceae, order Myrtales
- *Terminalia crenulata,* syn. *T. tomentosa* var. *crenulata;* vern. karu maruthu, tehmbava; family Combretaceae, order Myrtales
- *Terminalia paniculata;* flowering murdah, kindal, vern. kinjal; family Combretaceae, order Myrtales
- *Zizyphus jujuba,* syn. *Z. sativa, Z. vulgaris;* vern. pitni ber, ban ber, beri; family Rhamnaceae, order Celastrales
- *Zizyphus mauritiana,* syn. *Z. jujuba;* Indian jujube, common jujube, vern. ber, hevi; family Rhamnaceae, order Celastrales
- *Zizyphus rugosa,* vern. bhand, churna; family Rhamnaceae, order Celastrales
- *Zizyphus xylopyra,* including *Z. glaberrima santapau;* katber, kathber, ghont; family Rhamnaceae, order Celastrales

The introduction of two oak tasar silkworms, *Antheraea proylei* and *A. pernyi,* has enabled India to produce oak tasar silk. The main food plants of oak tasar silkworms belong to *Quercus* species, the oaks of the family Fagaceae, order Fagales. The other food plants of temperate tasar belong to genera like *Castanopsis* and *Lithocarpus,* of the family Fagaceae, order Fagales, and *Salix,* of the family Salicaceae, order Salicales. The different species of these food plants are (Seth, 2000b):

- *Castanopsis hystrix,* syn. *C. rufescens;* vern. katus, hingori
- *Castanopsis indica;* Indian chestnut, vern. bank katus, serang
- *Lithocarpus dealbatus,* syn. *Quercus dealbata*
- *Quercus aegilops;* valonia oak
- *Quercus acutissima,* syn. *Q. serrata*
- *Quercus borealis;* American red oak
- *Quercus castaneaefolia;* chestnut-leaved oak
- *Quercus cerris;* turkey oak
- *Quercus coccinea;* scarlet oak
- *Quercus crispula*
- *Quercus dentata*
- *Quercus dilatata;* green oak, moru oak, vern. moru, tilonj
- *Quercus floribunda*
- *Quercus frainetto;* Hungarian oak
- *Quercus glauca;* blue Japanese oak, vern. bran, siri, inai

- *Quercus griffithii;* vern. dingim
- *Quercus hispanica* var. *lucombeana;* lucombe oak
- *Quercus ilex;* evergreen oak, holly or holm oak, vern. bechur, iri
- *Quercus infectoria;* gall oak, Dyer's oak, vern. majuphal, mazu, muphal
- *Quercus lamellosa;* vern. buk, shalshi
- *Quercus lanata,* syn. *Q. lanuginosa;* woolly oak, vern. ranj, kiani
- *Quercus lanceaefolia,* syn. *Castanopsis lanceaefolia;* vern. siri, shingra
- *Quercus leucotrichophora,* syn. *Q. incana;* ban oak, gray oak, vern. ban, rin, vari, iri
- *Quercus libani;* Lebanon oak
- *Quercus lineata;* vern. phalut
- *Quercus lusitanica;* Lusitanian oak
- *Quercus mongolica*
- *Quercus myrsinaefolia*
- *Quercus palustris;* pin oak
- *Quercus petraea;* sessile oak
- *Quercus prinus*
- *Quercus reticulatum;* net leaf oak
- *Quercus robur;* English oak
- *Quercus rubra*
- *Quercus semecarpifolia;* brown oak of Himalaya, kharsu oak, vern. karshu, kharshu
- *Quercus semiserrata;* vern. schop
- *Quercus suber;* cork oak
- *Quercus undulata*
- *Salix viminalis;* English willow, osier, basket willow, vern. bibsu, kumanta

Eri silk, also known as "errandi" or "endi," is produced by the eri silkworm *Samia ricini,* syn. *Philosamia ricini, Attacus ricini*. It belongs to the family Saturniidae, order Lepidoptera. Being polyphagous, it may feed on the leaves of a large number of plants (Seth, 2000c):

- *Ricinus communis;* castor, castor seed, vern. erandi; family Euphorbiaceae, order Euphorbiales
- *Ailanthus altissima,* syn. *A. glandulosa;* ailanto, tree of Heaven, vern. barkessuru, barpat; family Simaroubaceae, order Geraniales
- *Ailanthus excelsa;* vern. maharuk, barkessuru; family Simaroubaceae, order Geraniales
- *Ailanthus grandis;* family Simaroubaceae, order Geraniales
- *Ailanthus triphysa,* syn. *A. malabarica;* vern. guggal dhup, family Simaroubaceae, order Geraniales
- *Carica papaya;* papaya, papaw tree, vern. papeeta; family Caricaceae, order Geraniales
- *Cinnamomum cecidodaphne;* family Lauraceae, order Laurales
- *Coriaria nepalensis;* vern. masuri, makola; family Coriariaceae, order Sapindales
- *Evodia fraxinifolia;* vern. payam; family Rutaceae, order Geraniales
- *Gmelina arborea;* gumhar, vern. gambhar, gumbhar, kambhari; family Verbenaceae, order Lamiales
- *Heteropanax fragrans;* vern. kesseru, tarla; family Araliaceae, order Umbellales
- *Hodgsonia heteroclita;* vern. thebow; family Cucurbitaceae, order Passiflorales
- *Jatropha curcas;* physic nut, purging nut, vern. botera, bagbherenda, jangliarandi, safedarand; family Euphorbiaceae, order Euphorbiales
- *Jatropha multifida;* coral plant, vern. bhotera; family Euphorbiaceae, order Euphorbiales
- *Manihot esculenta,* syn. *M. utilissima, M. aipi, M. dulcis, M. palmata;* cassava, manioc, tapioca, vern. simul-alu; family Euphorbiaceae, order Euphorbiales

- *Ricinus virdia;* family Euphorbiaceae, order Euphorbiales
- *Sapium eugeniifolium;* vern. korha, family Euphorbiaceae, order Euphorbiales
- *Sapium sebiferum;* Chinese tallow tree, vern. pippal-yang, vilayati-shisham, pahari-shisham; family Euphorbiaceae, order Euphorbiales
- *Zanthoxylum armatum,* syn. *Z. alatum;* vern. darmar, Nepali dhaniya, tejphal, tumru; family Rutaceae, order Geraniales
- *Zanthoxylum limonella,* syn. *Z. budrunga, Z. rhetsa;* vern. bazramani; family Rutaceae, order Geraniales
- *Zizyphus mauritiana,* syn. *Z. jujuba;* Indian jujube, common jujube, vern. baer, ber; family Rhamnaceae, order Rhamnales

Muga silk is produced by the muga silkworm *Antheraea assama* Westwood, syn. *A. asamensis* Helf., *A. mejankari* Moore. It belongs to the phylum Arthropoda, class Insecta, order Lepidoptera and family Saturniidae. The muga silkworm is polyphagous (Seth, 2000d). Its primary food plants are:

- *Machilus bombycina;* vern. som; family Lauraceae, order Laurales
- *Litsaea monopetala,* syn. *L. polyantha;* vern. soalu, meda, ketmarra, patoia, kakuri; family Lauraceae, order Laurales

Its secondary food plants are:

- *Actinodaphne angustifolia,* syn. *A. hookeri;* pisa, vern. petarichawa; family Lauraceae, order Laurales
- *Cinnamomum glanduliferum;* cinnamon, vern. dieng-puin-waith, dieng-sing, gonhorai, gonhorai-arong, gonsalu, gonsarai, malligiri, marisgiri; family Lauraceae, order Laurales
- *Cinnamomum obtusifolium,* syn. *Actinodaphne obovata;* vern. patichanda, patihanda; family Lauraceae, order Laurales
- *Gmelina arboraea;* gumhar, vern. bambari; family Verbenaceae, order Lamiales
- *Litsaea cubeba,* syn. *L. citrata;* vern. mezankari, sittimbar; family Lauraceae, order Laurales
- *Litsaea nitida,* vern. kothalua; family Lauraceae, order Laurales
- *Litsaea salicifolia;* vern. dighleti, digloti; family Lauraceae, order Laurales
- *Magnolia pterocarpa,* syn. *M. sphenocarpa;* vern. panchapa; family Magnoliaceae, order Magnoliales
- *Michelia champaca;* champak; family Magnoliaceae, order Magnoliales
- *Michelia oblonga;* family Magnoliaceae, order Magnoliales
- *Machilus odoratissima;* machilus, vern. kawala; family Lauraceae, order Laurales
- *Symplocos grandiflora;* family Symplocaceae, order Ebenales
- *Symplocus paniculata,* syn. *S. crataegoides;* sapphire berry, sweet leaf, vern. ludh; family Symplocaceae, order Ebenales
- *Symplocos ramosissima;* vern. lodh; family Symplocaceae, order Ebenales
- *Zanthoxylum armatum,* syn. *Z. alatum* and its var. *planispinum, Z. planispinum;* vern. darmar, Nepali dhaniya, tejphal, tumru; family Rutaceae, order Geraniales
- *Zanthoxylum limonella,* syn. *Z. budrunga, Z. rhetsa;* vern. bazramani; family Rutaceae, order Geraniales
- *Zizyphus jujuba,* syn. *Z. sativa, Z. vulgaris;* vern. ber, pitni ber; family Rhamnaceae, order Rhamnales
- *Zizyphus mauritiana,* syn. *Z. jujuba;* Indian jujube, common jujube, vern. bear, ber; family Rhamnaceae, order Rhamnales

A large number of wild silkworms are known in nature. They, too, produce silk by feeding on the leaves of a number of plants. However, the silk they produce is not of good quality. The

food plants of these wild silkworms are: *Acer campbellii, A. caudatum, Actinodaphne sikkimensis, Anacardium occidentale, Ardisia species, Artemisia vulgaris, Bischofia javanica, Careya arborea, Cedrella serrata, C. toona, Clerodendron infortunatum, Coriaria nepalensis, Cydonia oblonga* syn. *C. vulgaris, Dalbergia sissoo, Dillenia indica, D. pentagyna* syn. *D. pentagynia, Emblica officinalis* syn. *Phyllanthus emblica, Eugenia fruiticosa, Glochidion hohenackeri* syn. *G. lanceolarium, G. velutinum, Juglans rigia, Lagerstroemia speciosa* syn. *L. flos reginae, Lannea coromandelica* syn. *Odina wodier, Leucosceptrum canum, Litsaea glutinosa* syn. *L. sebifera, Lyonia ovalifolia* syn. *Pieris ovalifolia, Machilus odoratissima, Mangifera indica, Melastoma malabathricum, Meyna laxiflora* syn. *Vangueria spinosa, Microcos paniculata* syn. *Grewia microcos, Mimusops elengi, Mitragyna rotundifolia* syn. *Stephegyne diversifolia, Ocimum* spp., *Phyllanthus lanceolaria, Prunus cerasoides* syn. *P. puddum, Pterospermum semisagittatum, Pyrus communis, P. pashia, Salix babylonica, S. tetrasperma, Sapium insigne, Schleichera oleosa,* syn. *S. trijuga, Symplocos paniculata,* syn. *S. crataegoides, S. racemosa, Syzygium cuminii* syn. *Eugenia jambolana, Terminalia alata* syn. *T. tomentosa, Turpinia nepalensis, T. pomifera, Wendlandia thyrsoidea* syn. *W. notonia, Zanthoxylum acanthopodium* and *Z. armatum* syn. *Z. alatum* (Seth, 2000e).

IV. Conclusions

As discussed above, trees are of great importance to people, not only economically and ecologically but also ornamentally and bioaesthetically. Because trees meet the needs of humans, the primary objective of any afforestation, biodiversity, ecodevelopment, bioaesthetic or landscape plan must be both to protect native tree–growing areas from further destruction and to plant trees in large areas. For any society, planting and care of trees serve as important endeavors and symbolize hope for the future. Multipurpose trees and shrubs have the capacity to provide for a variety of end uses while reversing the process of land degradation.

Most of our environmental problems can be solved to a great extent if we grow more trees, especially in urbanized localities and cities. Because people in different parts of the world have become aware of the needs of trees and forests, many countries have started celebrating annual "Forest Festivals" or "Tree Festivals" or "Greening Weeks" or "Arbor Days." In India, too, tree planting has been adopted as a national policy. The first successful tree-planting week was celebrated in Delhi in July 1947, with the participation of national leaders like Jawaharlal Nehru, Rajendra Prasad and Abdul Kalam Azad, among many others (Randhawa, 1961, 1965–1983). In 1950 the celebration was renamed "Vana Mahotsava" (Grand Festival of Forests [or Trees]) (Seth et al., 1962).

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