Chapter
1

Introduction

The land and waters of the earth sustain a vast assemblage of plants upon which all other living forms are directly or indirectly dependent. These autotrophs have the remarkable property of capturing the inexhaustible energy of the sun to synthesise organic compounds which are vital for the existence of all life on earth. Organic deposits, such as coal, lignite, peat and petroleum are evidence of the photosynthetic activity of plants in the geological past. In addition, plants stabilise soil, conserve moisture and preserve an equable climate. After violent disturbances of the earth such as volcanic eruptions and upheaval of mountains, plants cover the denuded ground with a carpet which protects the surface from being washed away.

Before man domesticated animals and learned how to cultivate plants, he was unable to form settlements because his entire time was occupied with wandering in search of food. Presumably, prehistoric man lived on berries, succulent herbage and wild game which he could catch by primitive methods. These people lived in small groups and had a fierce struggle for existence against the carnivorous animals of that time and the vagaries of nature. Undoubtedly, their life was a hard one – a life in which only the hardiest could survive.

During the earliest and longest period of human history often called the Palaeolithic or 'Old Stone Age', which began one and three quarter million years ago, the concept of farming and domestic animals as such did not exist. The people of this Age were able to use fire and chipped pieces of hard stones (flint) into rough implements (such as crude hand axes and scrapers), which were used to remove flesh from animal hides.

During this period, the population was restricted to Africa, with a density of probably only 0.00425 persons per square kilometre and a total population of about 125 000 only. At present, there are 16.4 persons per square kilometre of the earth's total land surface.

Presumably, agriculture began in the Mesolithic or 'Middle Stone Age' (12 000 –6000 BC) when man lived by the spear, the bow and the fishing net. This shift from a food gatherer to a food producer is assumed to develop independently at different times in different parts of the world. The Neolithic or 'New Stone Age' began about 6000 BC when ground and polished stone tools became the rule, and agriculture continued to develop.

With time as man's agricultural needs demanded increasingly better tools, the Stone Age passed into the Bronze Age and the latter into the Iron Age. At present, we are living in the 'Space Age'.

Cultivation of plants was a great evolutionary accomplishment that relieved some of the members of a tribe from food gathering and hunting duties. This enabled them to devote their time and thought to inventing, discovering and developing other facets of civilised life such as writing, counting, record keeping, trade, irrigation, building of roads and vehicles for transportation and industry.

In today's highly industrialised world, modern man's life still depends fundamentally on agriculture. Agriculture is the backbone of man's existence. The three basic necessities of life–food, shelter and clothing, and a host of other essentials are still derived mainly from the vegetable kingdom. It will be worthwhile to discover why the vegetable world deserves such interest, admiration and respect.

Energy-giving Foods and Flavourings

The three daily meals consist either of plant products, such as cereals, vegetables and fruits or products of animals (meat, cheese, butter, milk eggs, etc.) .

Although, man uses many lower plants in his diet, such as mushrooms, morels and puffballs the direct food value of these lower plants is small. Only a few species of green algae are utilised in Europe and America for the purpose of food as compared to China, Japan and the Pacific Islands, where algae are one of the major articles of diet. Irish moss, *Chondrus crispus* (L.) Stackh., in dried and powdered form is made into a dessert, the well-known 'sea moss farina' as well as other puddings. *Gelidium corneum* Lam., *Gracilaria lichenoides* (L.) Harv. and *Eucheuma spinosum* (L.) J. Agardh, found off the eastern coast of Asia, are sources of agar, which is used as a solidifying agent in desserts, and also in the preparation of soups, sauces, etc. Neither mosses nor liverworts contribute towards human food while, among the less complex vascular plants examples are the young 'fiddleheads' of ferns which are cooked as a vegetable in many localities. Similarly, the gymnosperms add little value to a man's food supply, although pine nuts or piñons from several species of *Pinus* and sago grains from some cycads are edible and represent important sources of food.

The food value of angiosperms is correspondingly very high. The three main classes of food materials, namely carbohydrates, fats and proteins as well as other important nutrients such as vitamins and minerals are all obtained from the flowering plants. The bulk of the world's food supply comes from rice, wheat, maize, sorghum, barley; sugar cane and sugar beet; potato, sweet potato and cassava; beans, soya bean and groundnuts; coconut and banana. Valuable edible oils are extracted from cottonseed, olive, maize, coconut, soya bean and groundnuts. Large quantities of cottonseed and soya bean oils are also converted into solid fats by the process of hydrogenation. Other vegetable oils such as tung, linseed and castor oil are widely used in the food industry.

On the whole though vegetables and fleshy fruits contain comparatively less stored food, they are of considerable significance as they provide us with vitamins and mineral salts that are essential for the maintenance of health. A few examples of the diseases caused by vitamin deficiency are beriberi, scurvy and pellagra resulting from the lack of vitamin B (thiamine), vitamin C and vitamin PP (niacin), respectively.

Although not strictly food, all our spices are obtained from plants, of which the most familiar are paprika, pepper, ginger, cloves, cinnamon and mustard. The characteristic aromas and flavours of the spices are attributed to different essential oils. Man's chief non-alcoholic beverages – coffee, tea and cocoa, and alcoholic drinks also come from plants. Cocoa and chocolate from cacao seeds combine flavour and greater food value.

Plants and Home

Prehistoric man used many different kinds of plants for constructing his means of transport and dwellings, such as wattle and daub huts and the more elaborate Swiss lake dwellings built on piles along the borders of lakes. Even today, wood is employed as a source of structural support, as a principal constructional material for housing and transportation and as a raw material for the manufacture of paper, rayon, plastics, explosives, lacquers, cellophane and photographic films. The fuel that warms one's house and the energy which operates most of the industries comes directly or indirectly from plants. The paper industry depends largely upon wood pulp. Thus, plants are the carriers of written words, ideas and information, and have been referred to as 'the medium of thought'.

Plant Fibres and Fabrics

From the earliest times until today, man has used fabrics of many kinds for protection, warmth, personal adornment and even to display personal wealth. Besides clothing, plant fibres are used in the manufacture of ropes and strings, brushes and brooms, paper and paper products, upholstery work (filling mattresses, cushions, etc.) and life belts. Fibres of commercial importance, however, are relatively few, the most important of which are cotton and kapok (surface fibres); flax, jute, hemp, roselle and ramie (soft fibres); abacá and sisal (hard fibres). Cotton is still the world's most important natural fibre.

Plants and Health

Primitive people, the world over, have always used many different kinds of plants as cures for various ailments. Quinine obtained from the bark of several species of *Cinchona* has long been used as an antimalarial drug. The leaves of European foxglove (*Digitalis purpurea* L.) provide digitalis – a valuable heart stimulant. Opium and its derivatives, obtained from *Papaver somniferum* L., are used to relieve pain and induce sleep.

Numerous other drugs that originate from plants have been found to be useful in the treatment of various disorders. Among these are rauwolfia, belladonna, nux-vomica, ephedrine, ergot, aconite, podophyllum, ginseng, cascara and curare. Quite recently, a fungus, *Psilocybe mexicana* Heim, used by the Mexican Indians in their religious rituals, has been reported to possess psychotherapeutic properties.

Antibiotics have the property of preventing the growth and development of pathogens. Since 1928, when the first antibiotic 'penicillin' was discovered by Sir Alexander Fleming, many other antibiotics have been isolated from bacteria, actinomycetes and moulds. Many more have also been extracted from other groups of fungi, including yeast, and from algae, lichens and seed plants. The use of these antibiotics has greatly contributed to lengthening the average human lifespan.

A number of vegetable products are also used for their stimulating and narcotic effects. These include opium and its derivatives, marijuana, cola, betel nut, coca and tobacco, of which the first two especially are habit-forming drugs.

Plants as Colouring Materials

Since ancient times, vegetable tannins and dyes have been used for the purpose of colouring of fabrics, animal hides and personal adornment. Madder, *Rubia tinctorum* L., was perhaps the first camouflage to be used in a war.

Tannins are organic compounds with a bitter (astringent) taste that tend to accumulate in the physiologically inactive tissues, such as heartwood, cork and old foliage. They are extracted either from the bark (hemlock, chestnut oak, mangrove), wood (quebracho), leaves (sumac), fruits (divi-divi), or from other parts of the plant. Tannins combine with proteins in animal hides to form soft and pliable leather. They are also used for the manufacture of inks.

Plant dyestuffs were not only used by the primitive man for colouring animal skins, but their own skin during religious festivals and in war time. The use of natural dyes has diminished with the advent of synthetics such as aniline and alizarin derivatives. However, a number of natural dyes are still prized, for example, indigo, logwood, woad, safflower, saffron and annatto. They are used for dyeing textiles, leather, paints, varnishes, paper and ink, and also for colouring food, beverages and medicines.

Plants and Beauty

Plants add beauty to the earth's surface and contribute a great deal to man's pleasure. The fields and forests provide retreats where millions of people can enjoy peace and contentment. Artists and poets alike derive inspiration from the detail and beauty of plants. They are the ornaments of our gardens and houses. Through planned planting, our environment has been made still more pleasing by the efforts of florists, landscape gardeners and nurserymen. In addition, flowers are the medium through which many varying emotions such as love, worship and sorrow can be conveyed, often more effectively than through words.

Plants and Atmosphere

From the earliest times, plants have been purifying the atmosphere by assimilating carbon dioxide. By increasing the number of trees in a city its supply of oxygen can be augmented by the photosynthetic activity. Trees in the regions of low rainfall absorb water from considerable depths and release it into the atmosphere, thereby improving the climate.

Plants and Perfume

Chemically, essential oils are mostly derivatives of terpenes or benzene. Despite having an oily texture, they are not true oils, evaporating rapidly when they come into contact with the air. Essential oils were used by the early Egyptians for mummification (preserving the dead). Today, essential oils from the flowers of jasmine, carnation, lavender, champaca, rose and many other plants give a pleasant odour to perfumes, soaps, deodorants, cosmetics and incense. Oil of citronella, derived from *Cymbopogon nardus* (L.) Rendle, is a common ingredient of low-priced soaps, perfumes and insect repellents. Camphor, obtained from the distillation of wood of the camphor tree, *Cinnamomum camphora* (L.) Nees and Eberm, is used in the manufacture of celluloid, various nitrocellulose compounds, in medicines and in cosmetics. Wood turpentine derived from the softwood distillation of the conifers is used as solvents for paints.

Miscellaneous Products

A variety of other plant products that are in use today include pectins, gums, resins, latex products, waxes and insecticides.

PECTINS

Pectins are found as a cementing material in the cell wall of nearly all the plants, however, they are usually obtained from citrus rind and green apple residue (pomace). They are used in the manufacture of jellies and candies, to increase viscosity in tomato juice and in the tobacco and pharmaceutical industry.

GUMS

Gums are mostly amorphous colloids that are largely composed of the degradation products of cellulose or other carbohydrates. They are mainly hydrophilic in nature forming viscous liquids. Gums are used in industry as sizing, stiffening agents in ice cream and stabilisers and binders in medicinal pills. Many cough drops and syrups contain plant gums. The most common plant gums are: gum arabic, gum tragacanth, gum karaya and cherry gum.

RESINS

Although resins resemble gums in superficial appearance, they differ in their origin and chemical composition. Some resins are sticky, viscous liquids while others are hard, brittle solids, usually clear but sometimes opaque in appearance. They seem to be the oxidative products of essential oils, occurring as secretions in special ducts, often mixed with other substances such as latex, essential oils, or gums. Unlike gums, resins are insoluble in water but dissolve readily in alcohol and other organic solvents to form 'varnishes'. When applied in thin films, the solvent evaporates leaving behind a hard waterproof layer of resin. Commercial supplies are obtained from plant families such as the Fabaceae (Congo copal, copaiba balsam and balsam of Peru), Dipterocarpaceae (damars) and Pinaceae (Canada balsam). Amber is a fossil resin, occurring chiefly along the shores of the Baltic Sea. It is an exudate from the extinct pine, *Pinus succinifera* (Göppert) Conw. Nowadays, it is mainly used for the preparation of the mouthpieces of pipes and holders for cigars and cigarettes.

Resins are used in a variety of ways, for example, as perfume fixatives, ingredients in incense and tobacco flavourings, in the manufacture of plastics, paints, varnishes and in some pharmaceuticals. They are also used in the manufacture of linoleum, oilcloth, printer's ink, roofing compounds, soaps, adhesives and for sizing paper.

LATEX PRODUCTS

Latex is a milky, viscous, colloidal secretion, occurring in specialised laticiferous ducts. Some of the more important products derived from latex are rubber, gutta-percha, balata and chicle. Of these rubber is the most familiar and the most valuable product, chiefly obtained from the Para-rubber tree, *Hevea brasiliensis* (Willd. ex A. Juss.) Müll.-Arg.) of the family Euphorbiaceae. Because of its elasticity, pliability and resilience, rubber is used in hundreds of products, such as tyres, tubes, hoses, etc. On the other hand, gutta-percha is a non-elastic product possessing the properties of resilience and

pliability. Hence, it finds wider application in the manufacture of marine cables, golf balls, telephone receivers, waterproofing, adhesives, surgical apparatus and in dentistry for temporary fillings. Balata is also used in much the same way as gutta-percha, but particularly well suited for machine beltings. Chicle is the basis of the chewing gum industry.

WAXES

They are usually fatty acid esters of monohydroxy alcohols such as cetyl alcohol, ceryl alcohol and myricyl alcohol, and are mostly found as protective coverings on the epidermis of leaves, stems and fruits to retard water loss. Carnauba, *Copernicia cerifera* Mart. of the family Arecaceae, is the world's most important wax plant. The wax derived from the leaves is widely used in the manufacture of candles and polishes. Candelilla wax, obtained from the stem of *Euphorbia antisyphilitica* Zucc. (family Euphorbiaceae) is often mixed with the paraffin wax to make candles.

INSECTICIDES

Many species of plants seem to possess insecticidal properties. Two of the most potent insecticides of plant origin are rotenone and pyrethrum. Rotenone is mainly extracted from the roots of *Derris elliptica* (Roxb.) Benth. and *Lonchocarpus nicou* (Aubl.) DC. of the family Fabaceae. Pyrethrum is obtained from the unopened flower heads of several species of *Chrysanthemum* (family Asteraceae), particularly *C. cinerariifolium* (Trev.) Bip. Schultz and *C. coccineum* Willd. Tobacco dust and crude extract of tobacco, byproducts of the tobacco industry, are also effective natural insecticides. Unlike synthetic insecticides such as dichlorodiphenyltrichloroethane (DDT), chlordane, arsenic and copper compounds, natural insecticides are relatively harmless to man and higher animals and are thus safer to use.

OTHER MISCELLANEOUS PRODUCTS

Besides the various uses of plants and their products, the non-green plants are also of great economic importance to the mankind. The manufacture of vinegar, butter, cheese, sauerkraut; the tanning of leather; the curing of tea, coffee, cacao beans and vanilla pods; the production of silage; and the extraction of fibres from flax, hemp and jute, are all examples of the beneficial activities of bacteria. Yeasts are used in the baking and the fermentation process involved in the manufacture of beer, wine, whisky, and other liquors. They are also an important source of vitamins of the B and D groups. Bacteria and fungi act as natural scavengers, decomposing the dead bodies and organic waste of plants and animals into simpler units that can be readily taken up by plants, thereby maintaining soil fertility.

From the preceding discussion, it is quite evident that plants, in the past, have played an important role in human nutrition and in providing other necessities of life. Today, they are equally important and will no doubt remain intimately connected with our lives in the times to come.

Almost all the food and fibre plants that we value today were known to the early agriculturists in the Old or New World. Although, the modern man has added a little to this list of plants despite his increased knowledge of Botany, he has improved the yield potentials of crop plants. Economic botany is, therefore, largely an inheritance from our untutored ancestors who obtained their information over the centuries by trial and error. During man's evolution, he experimented with at least 3000 species for food, of which about 200 have become more or less domesticated and only 24 of these are of major importance (Figure 1.1).

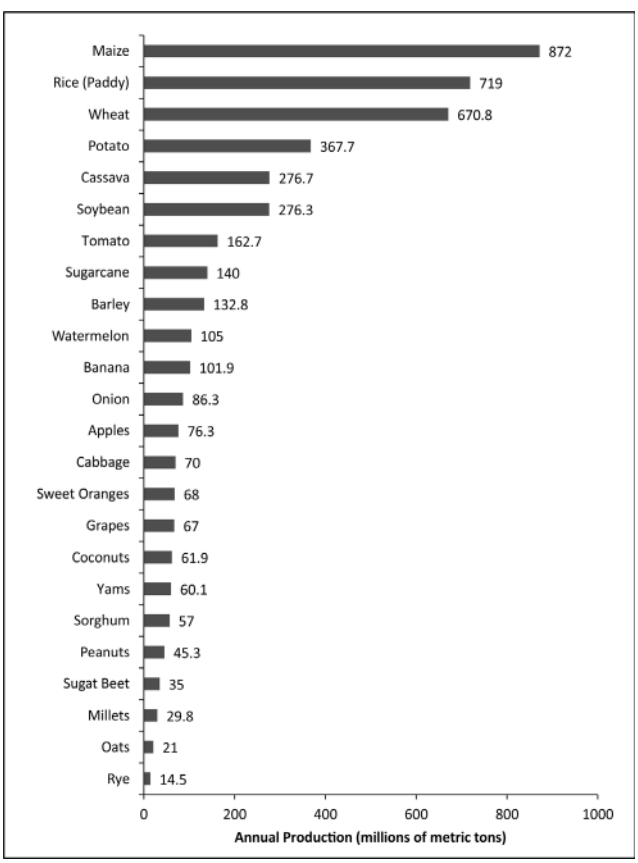

Figure 1.1 Annual production of the 24 most important crops that provide the bulk of the world's food supply. The total tonnage of the top seven crops is more than double the tonnage of the remaining 17. Sugar cane and sugar beet refers to the sugar produced and not the crop production which is about 1 832 and 269 million tonnes, respectively. Today, most of the people in the world are subsisting on about 16 crops – cereals such as wheat, rice, maize, millets and sorghum; root crops such as potato, sweet potato, cassava; legumes such as peas, beans, peanuts (groundnuts) and soybeans; sugar cane, sugar beet, coconuts and banana. These 24 crops are the main bulwark between the mankind and the starvation. Source: FAO statistics.

Origin of Cultivated Plants[1]

Cultivation of plants is one of the man's oldest occupations and probably began when he discovered that certain seeds when spilled on disturbed ground[2] grew in some mysterious way into new plants. It

[1] On the basis of recent studies, plant domestication is known to have originated independently and almost simultaneously 6000 to 9000 years ago in America, Africa, southwestern and southeastern Asia. The first successful domestication of plants has been suggested to have occurred in Thailand where remnants of rice and broad beans or soya bean from 10 000 years ago were excavated (Flannery, 1973).

[2] In 'dump-heap hypothesis', Edgar Anderson, the famous American Ethnobotanist of the Missouri Botanical Garden, has reasoned that as man started living a sedentary mode of life, the cultivation of plants was a

now appears certain that early domestications were made more or less concurrently and independently on the lower slopes of the Zagros Mountains, the 'fertile crescent' of the Tigris and Euphrates valleys in northern Iraq (Old World), and in the Tehuacán Valley of Mexico (New World). Ancient settlements were surprisingly abundant in both these regions. The earliest evidence of genuinely cultivated forms so far discovered, dates from about 7000 BC in both the hemispheres. Every important species of plants which we value today is a living tribute to our prehistoric ancestors who, long before the dawn of recorded history, discovered the virtues of certain plants, selected the most useful wild species and profoundly altered them. Many of them have been changed so much that their wild ancestors cannot be traced with certainty. In fact, early man was a plant breeder, without any knowledge of genetics, and displayed a noteworthy wisdom in domesticating plants and preparing them for food.

For the discovery of many of these economic plants, their migrations from one continent to another and knowledge of their properties and cultivation, we are indebted to the scholars of antiquity, the ancient conquerors, the medieval merchant princes, the Spanish conquistadores and the mariners and explorers of many lands. They all took with them the seeds of their native plants and in return, brought home for transplantation whatever they found fit.

Although man domesticated plants at an early date, he did not study them seriously for a long time, but for the occasional plant sketches made by the Palaeolithic man. The real foundation of the scientific study of plants, however, was laid by the Greek and Roman physician-botanists such as Theophrastus (often known as 'the father of botany'), Dioscorides, Pliny the Elder, Galen and others. Dioscorides' *De Materia Medica* is perhaps one of the most important ancient writings. For the next fourteen centuries, in botany as in other sciences, almost nothing was accomplished. The earlier works of Aristotle and Theophrastus were considered so complete and authoritative that there was little else to learn and certainly nothing to question. However, the revival of learning in the 'Renaissance' had a great impact on agriculture.

One of the old beliefs regarding the origin of cultivated plants was that they came to man as gifts from God. In addition, there was a belief that the process of cultivation itself improved the heredity of plants. However, people started questioning these suggestions by the end of the eighteenth century. In 1807, Alexander von Humboldt said 'we know nothing of the original sources of our most useful plants, their origin is an impenetrable secret'.

Darwin (1868) considered that the cultivated plants arose by the profound modifications in the wild plants which were under cultivation. Mendel's work, first published in 1865, remained obscure until 1900. He formulated the laws of inheritance and attributed the origin of cultivated plants to natural selection and hybridisation.

Alphonse de Candolle (1883) in his book *Origin of Cultivated Plants*, studied 247 species of cultivated plants and attempted to solve the mystery about the ancestral form, region of domestication and history of most of our important cultivated plants (Figure 1.2). He based his conclusions on a variety of disciplines, such as the works of ancient historians like Theophrastus, Dioscorides, etc.; Chinese writings; travellers accounts; archaeological and ethnological findings, such as Egyptian

consequence of the human practice of dumping refuse as a heap near their place of dwellings. Humans might have dropped the seeds or grains of some plants which he gathered from the wild over such refuse heap that are rich in nutrients. These seeds or grains might have sprung up and given rise to vigorous plants, resulting in a primitive type of vegetable garden, thus, assuring a dependable source of edible plant products close to home.

monuments, the remains of Pompeii[3], the relics of Swiss lake dwellers and the ruins of the Inca civilisation in South America; philological evidence from the names of crops in ancient languages such as Hebrew and Sanskrit; and botanical conclusions based on geographical distribution and variation, etc. In determining the place of origin of cultivated plants, de Candolle attached great importance to the presence of wild relatives.

Figure 1.2 Alphonse de Candolle (1806–93), a Swiss botanist, who first attempted to solve the mystery about the ancestral form, region of domestication and history of our important cultivated plants.

He classified the plants of economic importance into six classes. A few examples from each of the classes are as follows:

Plants of Old World origin		
1. Plants cultivated for at least 4000 years and possibly longer		
almond	fig	peach
apple	flax	pear
apricot	grape	rice
banana	hemp	sorghum
barley	mango	soyabean

[3] Pompeii, the ancient Roman city, was destroyed in AD 79 by a cataclysmic eruption of Mount Vesuvius that killed thousands of people and buried the city under 20 feet of volcanic ash. Hence, Pompeii was preserved for 1 600 years and provided precious information on what life was like in the ancient world.

cabbage	millet	tea
date	olive	watermelon
eggplant	onion	wheat
2. Plants cultivated for at least 2000 years and probably longer		
alfalfa	oats	radish
asparagus	breadfruit	cherry
beet	carrot	chestnut
cotton (some types)	celery	citrus fruits
	pea	rye
lettuce	pepper (black)	sugarcane
mustard	plum	walnut
nutmeg	poppy	yam
3. Plants cultivated for less than 2000 years		
artichoke	muskmelon	rhubarb
buckwheat	okra	strawberry (some types)
coffee	parsley	
currant	parsnip	
gooseberry	raspberry	
Plants of New World origin		
4. Plants cultivated certainly over 2000 years and probably more than 4000 years		
cacao	maize	sweet potato
kidney bean	mate	tobacco
5. Plants cultivated before the time of Columbus, but whose antiquity is not known		
avocado	Jerusalem artichoke	quinoa
cotton (some species)	pineapple	pepper (red)
		squash
groundnut	potato	tomato
guava	pumpkin	vanilla
6. Plants cultivated since the time of Columbus		
allspice	cinchona	pecan
blackberry	cranberry	plum
black walnut	dewberry	rubber
blueberry	gooseberry	strawberry